WQ2000 SALINITY MODEL: ENHANCEMENT, TECHNOLOGY TRANSFER AND IMPLEMENTATION OF USER SUPPORT FOR THE VAAL SYSTEM

CE Herold • PJ le Roux • WR Nyabeze • A Gerber

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Water Research Commission

WQ2000 SALINITY MODEL: ENHANCEMENT, TECHNOLOGY TRANSFER AND IMPLEMENTATION OF USER SUPPORT FOR THE VAAL SYSTEM

REPORT

to the

WATER RESEARCH COMMISSION

by

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DISCLAIMER

TABLE OF CONTENTS

OBTAINING THE WQ2000 MODEL

WQ2000 is available from the Department of Water Affairs and Forestry's User Support System Administrator and can be obtained as follows:

- Register on the User Support System at: www.usersupport.co.za for issue of the CD. Once the CD has been issued follow the steps below to receive a licence code:

  1. Enter your user name
  2. Call / mail the User Support Administrator
  3. Specify your exact user name and user code
  4. Enter the product Licence Code provided by the Administrator
  5. Click on "Save Licence"

  - E-mail: icm@dwaf.gov.za
  - Telephone: (012) 336-7090

- Install the setup CD (see page A.2 of Appendix A)

The copy of the WQ2000 salinity model loaded on your PC is now unlocked for use. A tutorial aimed at familiarisation with the model is given in Appendix A.3.

The WQ2000 software and database is free of charge. The registration process is required to identify users to facilitate the distribution of future updates and to provide adequate user support. It is strongly recommended that users attend a one-day training workshop prior to using the system.

LIST OF FIGURES

ACKNOWLEDGEMENTS

The research in this report emanated from a project funded by the Water Research Commission, entitled: "WQ2000: Enhancement, technology transfer and implementation of a user support system".

The Steering Committee responsible for this project consisted of:

Mr HM du Plessis	Water Research Commission (Chairman)
Mr R Dube	Water Research Commission
Mr G Grobler	Department of Water Affairs and Forestry
Prof S Lorentz	University of KwaZulu-Natal
Ms J Moolman	Department of Water Affairs and Forestry
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Mr P Viljoen	Department of Water Affairs and Forestry
Mr MD Watson	Department of Water Affairs and Forestry

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

This project was only possible with the co-operation of many individuals and institutions. Special thanks are due to the Department of Water Affairs and Forestry for their support of training initiatives and incorporation of WQ2000 into their user-support system.

ABBREVIATIONS AND ACRONYMS

CMA	Catchment Management Agency
DWAF	Department of Water Affairs and Forestry
GIS	Geographic Information System
RDP	Reconstruction and Development Programme
TDS	Total Dissolved Salts (mg/l)
USS	User Support System
VRSAU	DWAF Vaal River System Analysis Update study
WMA	Water Management Area
WMS	Water Management System. DWAF model and database
WQ2000	Water Quality 2000 model. The modelling system that is the subject of this report
WQT	Hydro-salinity water quality model (RB Allen and CE Herold, 1988)
WR90	Water Resources 90 database and manuals (Midgley *et. al.*, 1994)
WR2005	Water Resources of South Africa, 2005. Water Research Commission study K5/1491.
WSAM	Water Situation Assessment Model (Schultz, 2000)

EXECUTIVE SUMMARY

INTRODUCTION

Much of South Africa is water stressed and is subject to increasing population and industrial growth pressures, leading to increasing concentration of intractable soluble salts. Hence salinity is a pivotal consideration in the planning and development of water resources. However, many smaller schemes have to be implemented rapidly to meet the burgeoning demands of rural communities. Time and funding constraints often result in scant attention being paid to water quality implications. WQ2000, which was developed in a preceding WRC study, is aimed at rectifying this situation.

WQ2000 facilitates integration of salinity modelling from the earliest stages of water resource planning, thereby assisting in the identification of optimal solutions and avoiding costly inappropriate developments. This monthly time step interactive salinity modelling system was successfully developed for the Vaal River catchment. It provides a means of rapidly and cheaply, but credibly, assessing salinity at a quaternary catchment level.

WQ2000 is a powerful evaluation tool to:

- Rapidly assess the salinity implications of development scenarios
- Overview the present and anticipated regional water resource quality
- Provide support for more detailed assessments

The ability to change default values to reflect planned developments represents a particularly powerful analysis tool. A wide range of options can be rapidly tested, including changes in effluent flow and quality, introduction of new dams or modification of existing dam capacity and full storage area, changes to the area of opportunistic irrigation and that supplied from farm or major dams, water importation and abstraction.

The primary aims of the study were to:

- Enhance the WQ2000 salinity assessment system
- Transfer the WQ2000 technology to Government and private sector users
- Establish a working and sustainable User Support System.

OVERVIEW OF WQ2000

The WQ2000 model structure is shown in Figure 1.

This model incorporates a simple to use but versatile interface that links the user to an extensive database for each quaternary catchment of the Vaal River system, the advanced WQT monthly time step hydro-salinity model, the Department of Water Affairs' GIS Viewer and a suite of display graphics modules

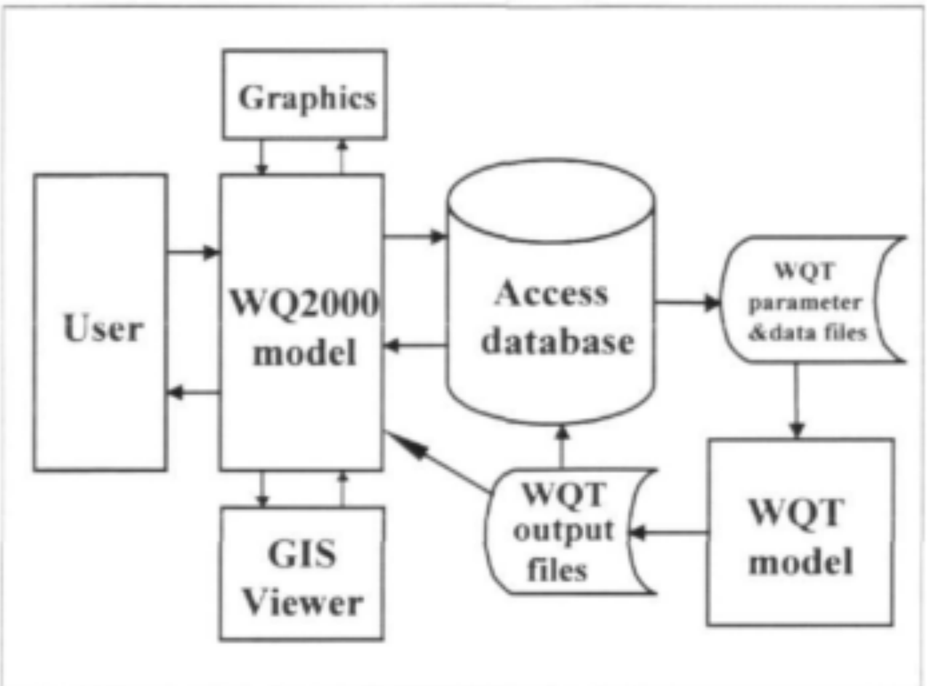

Figure 1: WQ2000 model structure

WQ2000 database

For each of the 192 quaternary catchments of the three Water Management Areas of the Vaal River system, the default database contains linkages to adjacent quaternary catchments, naturalised and present day development data, mean monthly evaporation and irrigation data, 70-year monthly time series of rainfall, naturalised pervious and unit urban catchment runoff, calibrated WQT model parameter values and input data files for each model node.

One or more user-defined project databases are built up from the default database to reflect known changes in development and define options to be evaluated.

WQT hydro-salinity model

The WQT hydro-salinity model represents the catchment system by means of user-defined sub-system elements connected by flow routes. The selected quaternary catchment is represented by two catchments, namely the quaternary catchment itself and the accumulated upstream quaternary catchments.

The following five discrete WQT sub-model elements are used in WQ2000:

- Catchment salt washoff sub-model
- Channel reach sub-model
- Irrigation sub-model
- Junction sub-model
- Reservoir sub-model.

The run option prompts simulation of a 70-year sequence of monthly hydrology for four different conditions:

- Virgin conditions for the specified quaternary catchment
- Virgin conditions for the entire cumulative system

- Developed conditions for the specified quaternary catchment
- Developed conditions for the entire cumulative system.

GIS Viewer

WQ2000 uses the GIS Viewer to present plots of regional simulation results or WQT model parameter values for user selected quaternaries. The results are presented by shading each quaternary according to the magnitude of the selected value. Small Pie Charts can also be plotted in each quaternary to represent the magnitudes for up to three more selected variables.

Graphics utilities

Graphics utilities have been included to generate plots of:

- Time series of monthly flow and TDS concentration
- TDS duration curves
- TDS seasonal distributions
- TDS percentile values for selected quaternary catchments.

Model use

The user can elect to use default present day values, or to modify them via the user-friendly screen interface.

WQ2000 includes screens for quaternary selection, rapid adjustment of default development characteristics and assessment of the salinity impact of proposed options including:

- Introduction of new dams or changes to existing ones
- Alteration or introduction of new mine or effluent inputs
- Change of quantity or quality of the water imported to the catchment
- Revision of water abstraction or minimum release from dams
- Growth in urban area
- Change in irrigated areas supported and unsupported by farm dams or with their supply regulated by the main stem river system as well as the proportions of catchment runoff entering upstream of each category
- Change in wetland area or channel bed loss.

Skill requirements

A particular strength of WQ2000 is that in-depth knowledge of the underlying WQT model is not required to rapidly simulate development changes.

MODEL ENHANCEMENTS

Enhancements have been implemented to:

- Update the installation set-up CD
- Hide the salt washoff model calibration parameter update screens
- Implement the latest GIS Viewer
- Correct the calculation of average TDS concentration in the quaternary major dam
- Include the data period in the Summary Report title
- Include a start up screen describing the model and its development
- Include an option to specify a time series file of downstream water release
- Include a default metadata, metadata entry, editing and export dialogs
- Include time series, duration curve, seasonal distribution and quaternary percentile graphical display options

- Include an option to output the results file to a spreadsheet
- Display a legend for the Quaternary Hierarchy Diagram
- Store WQT model data files for all cases
- Improve the results sheet, including statistics for the driest month and driest year and flag changed variables.

TECHNOLOGY TRANSFER

A number of presentations have been carried out to sensitise potential users to the advantages of WQ2000.

Mentoring of project personnel included background into the theory of the model and hands-on experience in the development of model enhancements, user training and handling user queries.

Three training workshops were held during 2005, with participants drawn from a wide range of state, industrial and consulting organisations located both within and outside the Vaal catchment area. Those from outside the area expressed a strong desire for the model to be extended to their geographical regions.

The DWAF's User Support System will facilitate future training. An upsurge in demand for training is expected once WQ2000 is set up for major catchments other than the Vaal River catchment.

USER SUPPORT SYSTEM

WQ2000 has been included in the DWAF Water Resource Planning System Directorate's User Support System (USS). This system has been set up to:

- Inform users of the model availability and potential
- Update software and the database
- Register trained users
- Deal with user queries
- Receive, assess and rectify errors
- Facilitate ongoing training
- Distribute software, database and documentation revisions
- Provide a Discussion Forum.

Until the end of September 2005 the WRC project team provided specialist support. Thereafter, DWAF took over this responsibility.

BENEFITS AND LIMITATIONS

WQ2000 provides the following benefits:

- Rapid Testing of options
- Ease of use
- Credible modelling platform
- Versatile presentation of results
- Regional salinity overview
- Documentation of assumptions
- User Support
- Stepping-stone for detailed evaluation

- Low cost .

The following limitations apply:

- WQ200 is not designed for complex multi-dam systems
- It is at quaternary catchment scale
- It is not designed to handle feedback loops
- It does not allow for direct supply to irrigated areas
- Water importation and effluent input flow and quality are specified as constant
- At present the model database is confined to the Vaal River catchment
- Modelling is confined to salinity (i.e. TDS).

CONCLUSIONS

Attainment of project aims: The aims of the project have been attained. These include incorporation of the originally identified model enhancements plus a number of other beneficial model enhancements that were identified during the study. The technology has been successfully transferred to the Department of Water Affairs and Forestry and to a number of other organisations by means of a series of demonstrations and training workshops. WQ2000 has been included in DWAF's User Support System to facilitate ongoing training, model improvement and dissemination of news.

The WQ2000 salinity model offers the following features:

- **Evaluation tool:** WQ2000 is a powerful tool for rapidly and credibly evaluating the salinity implications of a wide variety of development options.
- **Catchment overview:** WQ2000 provides a means to overview regional catchment water quality for both natural and present day conditions for the off-channel or cumulative cases.
- **Reporting:** A number of features are available to graphically display, tabulate and export the simulation results.
- **Ease of use:** WQ2000 has been designed for ease of use.
- **Export WQT model files:** A feature is available to export WQT model files for use in a more complex modelling system.
- **Database progression:** WQ2000 facilitates the build up of project databases, reflecting development changes.
- **Online help and metadata:** Online help and metadata options are provided.
- **User support:** WQ2000 has been incorporated in the DWAF's User Support System.
- **Influence on other developments:** WQ2000 served as a model for the development of evaluation and reporting features being incorporated in the WR2005 national water resources update.

Limitations: WQ2000 is designed to simulate monthly salinity at a quaternary catchment scale. It is not intended for use in highly regulated multiple reservoir river reaches. Under such circumstances more detailed or system wide modelling is required.

RECOMMENDATIONS

Implementation of products

- **Application of WQ2000:** The WQ2000 model should be put to use by DWAF, future CMAs, consultants, research organisations, Water Boards and tertiary institution practitioners as soon as possible. This will permit taking account of water quality for even the smallest schemes and at the very earliest stages of project development.

- **Ongoing training and user support:** Continued training and user support is required, as is the need to expand the user base.

Future research

- **Extend to other parts of South Africa:** WRC project K5/950 brought the initial development phase of WQ2000 for the Vaal River catchment to a successful conclusion. The current project concludes the primary model enhancement, technology transfer and incorporation in DWAF's User Support System. Commencement of the third phase involving extension to other geographical regions is now recommended.

  This can best be achieved by first including those catchments to which the WQT model has already been applied. Such regions represent a pre-selection of areas of recognised importance where salinity plays a significant role. Moreover, WQT model calibrations are already available for these areas. Coarse scale model calibration could be carried out for the remainder of the country.

  Extension to other catchments could be co-ordinated with the WR2005 national water resources revision. The benefit stemming from this would be the lengthened and improved hydrological record, which would permit use of the latest water quality data to the end of September 2005.

  It is anticipated that this would require 2 to 3 years.

- **Extend to other water quality variables:** Ultimately, WQ2000 could be expanded to provide a rapid evaluation tool for other variables. This could be considered after the salinity modelling has been extended to the other Water Management Areas.

- **Revise after re-calibration:** Continuing studies in key areas would result in revision of the WQT model calibrations. When this occurs, the WQ2000 database should be revised to include the model calibration and development information ensuing from such studies.

- **Model improvements:** Implementation of a few other identified potential model improvements could be considered. If necessary, some of these could be included as a part of one of the preceding proposals.

1. INTRODUCTION

1.1 Background and motivation

WQ2000 was initially developed as part of the Water Research Commission study entitled: *"WQ2000: Development of an interactive surface water quality information and evaluation system for South Africa"* (Herold and le Roux, 2004). This monthly time step interactive system was successfully developed for the Vaal River catchment. It provides a means of rapidly assessing salinity at a quaternary catchment level.

Much of South Africa can be described as being water stressed, in terms of both quantity and quality. Increasing population and industrial growth continues to make demands on the limited resource. Increasing development directly contributes to the pollutant load on our rivers. Further indirect pressure is exerted by the reduction in river flow resulting from water consumption, evaporative loss from the required storage dams and the cascading reuse of water along river systems. This has led to increasing concentration of intractable soluble salts, which are not reduced by in-stream decay processes.

Against this background it is clear that water quality, in particular salinity, is a pivotal consideration in the planning and development of water resources. However, many smaller schemes have to be implemented rapidly to meet the burgeoning demands of rural communities. Time and funding constraints often result in scant attention being paid to water quality implications. WQ2000 can facilitate much better integration of salinity from the earliest stages of water resource planning. This should reduce the cost of the planning process and assist in the identification of optimal solutions, thereby avoiding costly inappropriate developments.

The WQ2000 salinity model has been set up for the Vaal River catchment. It runs the advanced WQT monthly time step hydro-salinity model (Allen and Herold, 1988) in the background. A particular strength is that the user need not be a proficient modeller to use WQ2000. Physical characteristics, land use information, mean monthly evaporation and irrigation data, monthly time series of rainfall and catchment runoff and calibrated WQT model parameters for the 192 quaternary catchments of the Vaal River catchment are stored in the model database. This information is provided for natural and present day development conditions for both the incremental catchment condition (analogous to the off-channel case) and for the cumulative case (taking account of inflows from upstream catchments).

The ability to change default values to reflect planned developments represents a particularly powerful analysis tool. A wide range of options can be rapidly tested, including changes in effluent flow and quality, introduction of new dams or modification of existing dam capacity and full storage area, changes to the area of opportunistic irrigation and that supplied from farm or major dams, water importation and abstraction.

The need to disseminate this valuable system among state, industrial, water board, university and consultant users has been identified as a high priority. This required the preparation of suitable training material and the presentation of a training course.

A number of beneficial enhancements were also identified. These included incorporation of metadata to indicate where the default data was obtained and the changes introduced by users, an option for specifying time series releases and inclusion of graphical results presentation.

A sustainable User Support System to deal with user queries, rectify identified problems, provide ongoing training and distribute revisions was also recognised as a high priority.

The transfer of intellectual property is viewed as a priority. Prior to this study Dr Herold was the only person conversant with the workings of WQ2000. This left the water resources management community vulnerable. This raised the need for mentoring to augment South Africa's capacity in this field.

This study is aimed at addressing the above issues.

1.2 Aims

The primary aims of the study are outlined below.

- Transfer the WQ2000 technology (WRC Project 950) to Government and private sector users.
- Enhance and test the WQ2000 salinity assessment system and resolve problems identified by users.
- Establish a working and sustainable User Support System.

1.3 Approach

1.3.1 Methodology

The following methodology was used to achieve the aims of the study:

- **Enhancements and testing** (Chapter 3)

  The following model enhancements were identified from the outset:

  (a) Include options for specifying time series of downstream water release.

  (b) Include metadata to indicate where and when the default data was obtained and any major assumptions.

  (c) Include change lists to record what alterations were made by the user and the reasons for such changes.

  (d) Include options to display time series and duration curves of the simulated monthly results.

  (e) Include an option to output the results to a spreadsheet.

  Further enhancements were identified and implemented during the course of the study.

- **Technology transfer** (Chapter 5)

  The first stage involved raising awareness of the value of the system. This was achieved by means of a series of demonstrations of the existing WQ2000 system. The second stage of technology transfer was achieved by means of a training course based on the enhanced WQ2000 system. Technology transfer was also built into the project itself, which included mentoring of members of the project team.

- **User Support System** (Chapter 6)

  Continuity of the modelling system was achieved by incorporation in the DWAF's User Support System (USS) that was first developed for WSAM. The main features of the USS include:

  (a) Registration of software and documentation distribution and the training of individuals.

  (b) Dealing with user queries.

  (c) Receipt and rectification of errors.

  (d) Ongoing training.

  (e) Distribution of software and documentation revisions.

1.3.2 Products

The project was aimed at benefiting the DWAF, CMAs, Water Boards, university researchers and consultants. The products consisted of the following:

- **Enhanced and tested WQ2000 system**

  This includes a setup CD containing the model executable code and a database for the Vaal River system and a user manual.

- **Established User Support System**

  WQ2000 has been included in the DWAF's User Support System.

- **Guideline on the way forward**

  WQ2000 has been set up only for the Vaal River catchment. Recommendations for extending WQ2000 to other portions of South Africa have been made.

- **Informed and trained core of practitioners**

  A core of trained practitioners has been established and will grow as more courses are presented.

1.3.3 Applications

The enhanced WQ2000 system provides a means for rapid assessment of the salinity impact of a wide range of developments, including urbanisation, dam construction and irrigation, changes in effluent discharge, water importation and abstraction. It also allows overview of regional quaternary catchment salinity and WQT water quality model parameter values.

The User Support System managed by DWAF provides a centralised source for software and manual updates, user queries, error rectification, ongoing training and a registry of competence. This should lead to further growth in the core of trained practitioners, thereby increasing the degree to which salinity assessment becomes integrated into future studies. This would be further enhanced by extension of the dataset to cover other regions.

1.3.4 Benefits and limitations

The benefits and limitations of WQ2000 are discussed in Chapter 7.

2. OVERVIEW OF WQ2000

A detailed description of much of WQ2000 and its components is covered by the original WRC report 950/1/04 entitled: *"WQ2000: Development of an interactive surface water quality information and evaluation system for South Africa"* (Herold and le Roux, 2004). Consequently the main emphasis has been placed on the refinements introduced by the current study. However, the contents of parts of the previous study have been summarised to provide a sensible overview.

2.1 Model components

2.1.1 WQ2000

WQ2000 is an interactive computer system for rapidly assessing quaternary catchment salinity for naturalised and developed conditions. It can also be used to provide a regional overview of salinity conditions. WQ2000 incorporates powerful and flexible "What if?" capabilities for assessing the impact of proposed new developments.

It incorporates a simple to use but versatile interface that links the user to an extensive database, the advanced WQT monthly time step hydro-salinity model and the Department of Water Affairs' (DWAF) GIS Viewer (Wolff-Pigott and Olivier, 2001). The enhanced model layout is shown in Figure 2.1.

The initial implementation is for the 192 quaternary catchments of the Vaal River covering three Water Management Areas (WMAs). These range from undeveloped areas to some of the most developed catchments in South Africa. The intention is to extend this coverage to the remainder of the country.

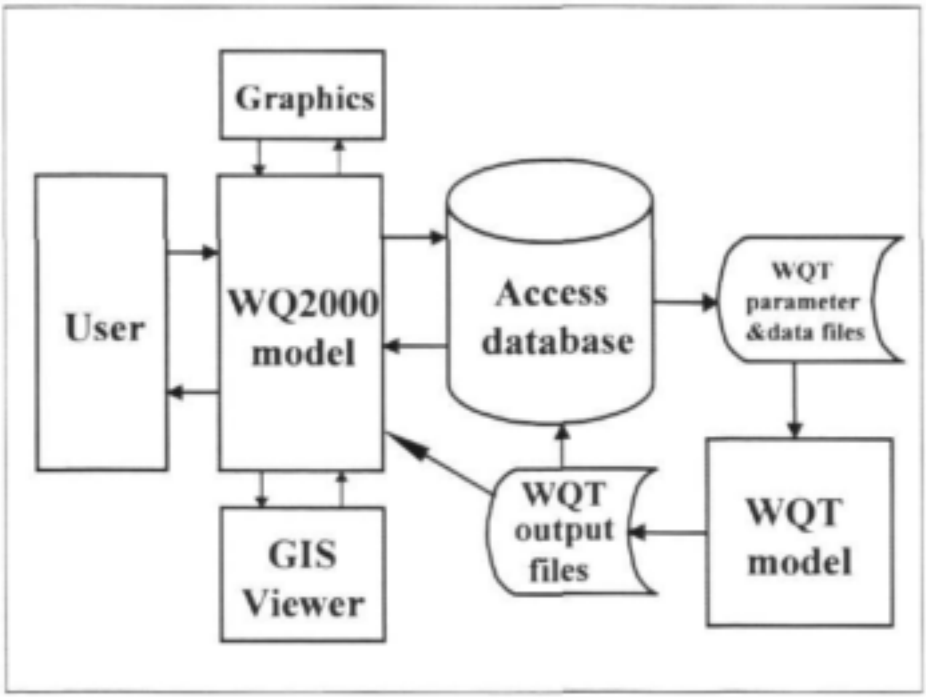

Figure 2.1: WQ2000 model structure

2.1.2 *Base database and files*

The database contains seventy-year monthly time series of rainfall, naturalised pervious and urban catchment runoff and calibrated WQT hydro-salinity model parameter values. The intrinsic characteristics of each quaternary catchment are stored, including catchment area, mean annual precipitation, mean monthly evaporation, mean annual runoff, Symons Pan and lake evaporation factors, catchment crop factors and the linkage to adjacent quaternary catchments.

The database includes default information on present day development, including urbanisation, irrigation, wetlands, bed loss, major and minor dams, mine and effluent discharge, water importation and abstraction. Altogether the database contains over 1300 fields (excluding monthly time series data) of information to describe each of the 192 quaternary catchments comprising the Vaal River catchment.

Much of the information contained in the database was obtained from the results of the DWAF's Vaal River System Analysis Update (VRSAU) study (Herold, 1999; Herold and Cardin, 1999; Herold and Taviv, 1998; Ninham Shand, 1999). More recent water use information was derived from the DWAF's Water Situation Assessment Model (WSAM) database (Schultz, 2002).

The WQT model calibration data and hydrology corresponds to 1995 conditions derived from the VRSAU study. The base year for the present day development, which was derived from the WSAM database, also coincides with 1995. However, infrastructure data was as recent as 2000. For example, in 1995 the Lesotho Highlands Water Project (LHPW) had not yet been commissioned, whereas the WSAM infrastructure data includes the LHWP transfer (to quaternary C83A). Similarly, the Grootvlei Gold Mine dewatering discharge to the Blesbokspruit (quaternary C21E) was zero in 1995, while the WQ2000 default data uses a discharge rate of 100 Ml/d to reflect the situation after Grootvlei Gold Mine resumed pumping.

2.1.3 *WQT hydro-salinity model*

WQT is a modular monthly time step hydro-salinity model. A system network is defined linking model nodes (sub-modules) by means of flow routes. The order in which upstream reservoirs are called on to meet downstream water demands is controlled by penalties assigned to each flow route and reservoir storage zone. A simplified version of the system network used in WQ2000 is given in Appendix C.

The following six types of model node are included in WQT:

<u>Salt Washoff module</u>
The catchment salt washoff module simulates the gradual accumulation of soluble solids within a catchment, their storage and subsequent release during runoff events. Account is taken of both pervious and paved urban catchment surfaces. For pervious surfaces the model simulates the movement of salt via direct surface runoff, infiltration, interflow, sub-surface storage and groundwater flow. Provision is made for the growth of paved urban surfaces and diffuse source salt recharge.

Channel Reach module
The channel reach sub-model simulates the movement of water and salt through a river reach. The upstream end of the river reach may accept input from up to five source routes. It can also accept a portion of the catchment runoff and salt washoff from an associated catchment salt washoff module. Files of monthly discharges and salt concentrations from mine de-watering may also be specified. Account is taken of riverbed loss and evapotranspiration loss from wetlands. Allowance is made for growth in wetland area, with linear or exponential growth interpolation between break point years for which areas are specified. The accumulation of salt in wetlands during periods when the potential net evaporation loss exceeds the upstream inflow is also accounted for, with the release of such salts during subsequent flood events. Each channel reach has one downstream outflow route.

An irrigation module may also be associated with the channel reach, to represent riparian irrigation. The irrigation demand is abstracted from the channel and the return seepage discharged to the channel sub-model outflow route.

Irrigation module
The irrigation sub-model simulates the accumulation of salt within irrigated lands and its release via return seepage. The irrigated land is modelled as a two layered system. Allowance is made for additional flushing during wet periods. The following processes are simulated:

- Canal transmission losses
- Annual maximum permissible water allocation and its growth or reduction
- Multiple crops (up to 20 may be specified)
- Additional return flow during wet periods
- Losses to relatively inaccessible deep-seated ground water.
- Addition of salts via agricultural lime, gypsum or fertiliser
- Growth or reduction of irrigated area with time
- Variable effective rainfall reduction factors (as function of rainfall intensity)
- Return seepage from two sub-surface zones and via surface spillage from canal ends.

The irrigation module is associated with a catchment salt washoff module. As the irrigated area increases, land (and the salt it contains) is transferred to the irrigation model. As irrigated land is taken out of service, the land (and its associated salt) is transferred back to the catchment salt washoff model. Linear or exponential interpolation can be used to calculate irrigation areas for years between break point years for which areas are specified. When the water supply is curtailed the assumption is that the area of land under irrigation is temporarily reduced, with part of the land lying fallow. Normal catchment soil evapotranspiration is assumed to apply to fallow areas, until such time as the water availability allows irrigation of the full area to resume. The salt balance is maintained.

The irrigation model can be defined as dependent on a channel reach, or as an independent node with its own water supply and return seepage routes.

Reservoir module
The reservoir sub-model simulates the monthly water and salt balance of a dam. Account is taken of evaporation loss, rainfall, abstraction and release and spillage driven by inflows to the reservoir. Complete mixing within the reservoir is

assumed. This is a reasonable assumption for most reservoirs and the relatively long monthly computational time step.

The water and salt balance equations have been set up in such a manner that a reservoir can be included as part of a dependent salt feedback loop. This facilitates the recycling of salt when water abstracted from the dependent reservoir is supplied to a demand centre, which in turn returns part or all of its salt-enriched effluent to tributaries draining back into the reservoir. This feature is not used in WQ2000.

Junction node
The junction module simply mixes together the inflows from up to five upstream routes and distributes the outflow to up to five downstream routes. A later enhancement allows for blending, whereby the inflow through preferential routes is adjusted to prevent the outflow TDS concentration from exceeding a defined blending target. Constraints on the capacity of flow routes can also be set. This feature is not required in WQ2000.

Demand Centre module
The demand centre sub-model simulates the supply of water to meet specified monthly gross water demands and the return of effluent, enriched with salt added during use. The effect of monthly climatic variation on the percentage return flow is simulated. Provision is made for the direct recycling of effluent, with or without desalination. The demand centre may form part of a larger dependent feedback cycle that spans a number of system elements including one dependent reservoir. Each demand centre may accept inputs from up to five source routes, each of which may be independent, or part of the dependent feedback cycle. The simulated monthly effluent discharge and salt load is apportioned to up to five return flow routes.

The standard WQ2000 model system layout does not include any demand centre nodes.

2.1.4 GIS viewer

The DWAF's GIS viewer was first used in the Water Situation Assessment Model (Wolff-Piggott and Olivier, 2001). WQ2000 provides access the GIS Viewer to present plots of simulation results or WQT model parameter values for user selected quaternaries. The results are presented by shading each quaternary according to the magnitude of the selected value. Small Pie Charts can also be plotted in each quaternary to represent the magnitudes for up to three more selected variables.

Appendix A provides an example of a typical application of the GIS Viewer. This is sufficient to allow the user to display model results and model parameter values. The GIS Viewer has many more features, which allow the user to (for example) change the colour gradients used in the plots. Details of these features are not provided in this report. The user is referred to dedicated literature sources for a detailed description of the more advanced features of the GIS Viewer (Wolff-Piggott and Olivier, 2001).

2.1.5 Graphics utilities

Graphic utilities have been included to generate plots of:
- Time series of monthly flow and TDS concentration

- TDS duration curves
- TDS seasonal distributions
- TDS percentile values for selected quaternary catchments.

2.2 Model uses

WQ2000 facilitates rapid initial assessment of the impact of proposed development options including:

- Introduction of new dams or changes to existing ones
- Alteration or introduction of new mine or effluent inputs
- Alteration of quantity or quality of the water imported to the catchment
- Change to water abstraction or minimum release from dams
- Growth in urban area or the density of the paved portion of urban area
- Change in irrigated areas supported and unsupported by farm dams or with their supply regulated by the main stem river system as well as the proportions of catchment runoff entering upstream of each category
- Change in wetland area or channel bed loss.

An overview showing the state of the quaternaries within a defined catchment can also be generated using the DWAF's GIS Viewer.

2.3 Actions performed

After selecting a quaternary catchment and, if desired, changing default development data to reflect the option to be examined, the model simulation is performed. The WQT hydro-salinity model then simulates seventy years of monthly hydrology for the following four scenarios:

- Natural conditions for the quaternary itself (off-channel with no influence from upstream catchments)
- Natural conditions with dilution (or pollution) from upstream catchment inflow
- Present day development state for the quaternary catchment alone
- Present day development state with cumulative inflow from upstream catchments.

Menu options are provided to tabulate or display the results or to depict a catchment overview.

2.4 Skill requirements

A particular strength of WQ2000 is that in-depth knowledge of the underlying WQT model is not required to rapidly simulate development changes. (Such specialised skills are required only for the initial model calibrations and population of the database, which has already been done for the Vaal River catchment.) The main requirement is that the user should be conversant with water resources systems and be able to interpret the flow and water quality results.

3. MODEL ENHANCEMENTS

Five enhancements were identified when this follow-on project was conceptualised. Further potential enhancements were identified during its execution. Some of the identified improvements represent substantial changes to the original scope of work. Consequently a cut-off had to be made for changes that could be implemented within the time and budget restraints of the project.

After prioritisation, taking due account of budget constraints, the 14 enhancements discussed below were included and tested.

3.1 Update installation set-up CD

The installation CD has been revised to simplify the installation procedure. Compatibility problems found with one of the versions of Windows XP were also resolved.

3.2 Hide salt washoff model calibration parameters

The initial version of WQ2000 showed two pages for editing the WQT model's catchment salt washoff module calibration parameters. However, this posed the danger that inexperienced users might change some of the calibration parameters, thereby producing invalid answers. This editing feature was therefore made less accessible to prevent inadvertent corruption of the parameter values.

3.3 Implement latest GIS Viewer

The most recent version of the GIS Viewer available at the time that the enhancements were made was implemented.

3.4 Correct calculation of average TDS concentration in the quaternary major dam

It is impossible to calculate the reservoir TDS concentration when the major dam has zero capacity, or during periods when the dam storage is zero. Under such circumstances the WQT model shows the dam TDS concentration as zero. This has no effect on the model simulation since the dam storage and its outflow are zero. However, the presence of the zeros in the monthly dam concentration time series file led to under-estimation of the average long-term TDS concentration reflected in the results report. This problem has been corrected by treating the data as missing during such periods, rather than using zero TDS concentrations.

3.5 Include data period in the Summary Report title

The Summary Report is designed as a stand-alone sheet showing the modelling assumptions and results. However, it did not reflect the hydrological period simulated. The processing data period is now reflected in the Summary Report title. The simulation period is also reflected in the graphical output. The program version number is also now displayed on the program start-up screen.

3.6 Include start up screen

When WQ200 is initiated, it now first displays a start up screen that contains a brief outline of the model and gives details of the User Support System and the origin and funding of the research.

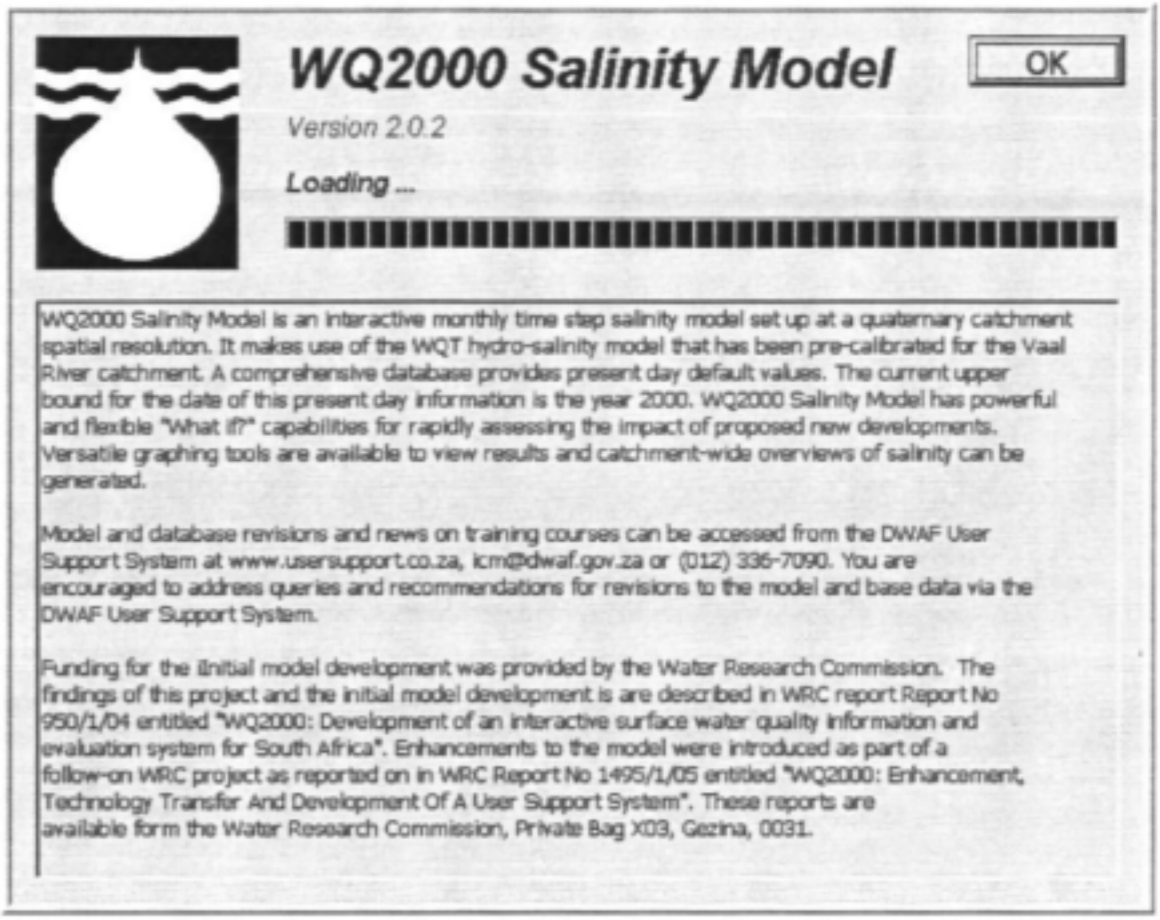

Figure 3.1: WQ2000 start-up screen

3.7 Include option to specify time series of downstream water release

The original version of WQ2000 only allowed the user to specify a fixed constant minimum major dam outflow rate. This can result in an inappropriate release pattern. For example, releases are made from Sterkfontein Dam to support shortfalls at Vaal Dam. WQ2000 has been modified to allow the user the alternative of specifying a file containing a time series of monthly dam releases that are synchronised with the hydrology.

This option permits more representative simulation of system behaviour for river reaches where flows are regulated by multiple dams.

3.8 Include metadata

Metadata is required to document the source of the original base data default values. The following enhancements have been made:

- Metadata has been included for the base dataset on the installation CD.

- The user is required to enter metadata to document all subsequent changes saved in the user-defined projects. This discipline has been introduced to ensure that changes are documented as they are made so that that this crucial information is preserved.

- Historical metadata can be displayed for any of the accessible fields.

- Options have been included to permit restricted editing of metadata. This is required to allow users to correct descriptions and remove metadata for redundant intermediate steps:

  - The text of user-generated metadata can be edited
  - However, changes to the base data metadata are not permitted
  - Older versions of user-generated metadata can be deleted
  - However, the metadata for the current (i.e. latest) values cannot be deleted.

- A facility has been introduced allowing the creation of a file of all changes made to the base data default values. This allows easy identification of changes that may be relayed to the User Support System for inclusion in future updates to the base data.

The metadata can be viewed for any field simply by hovering the cursor above a field:

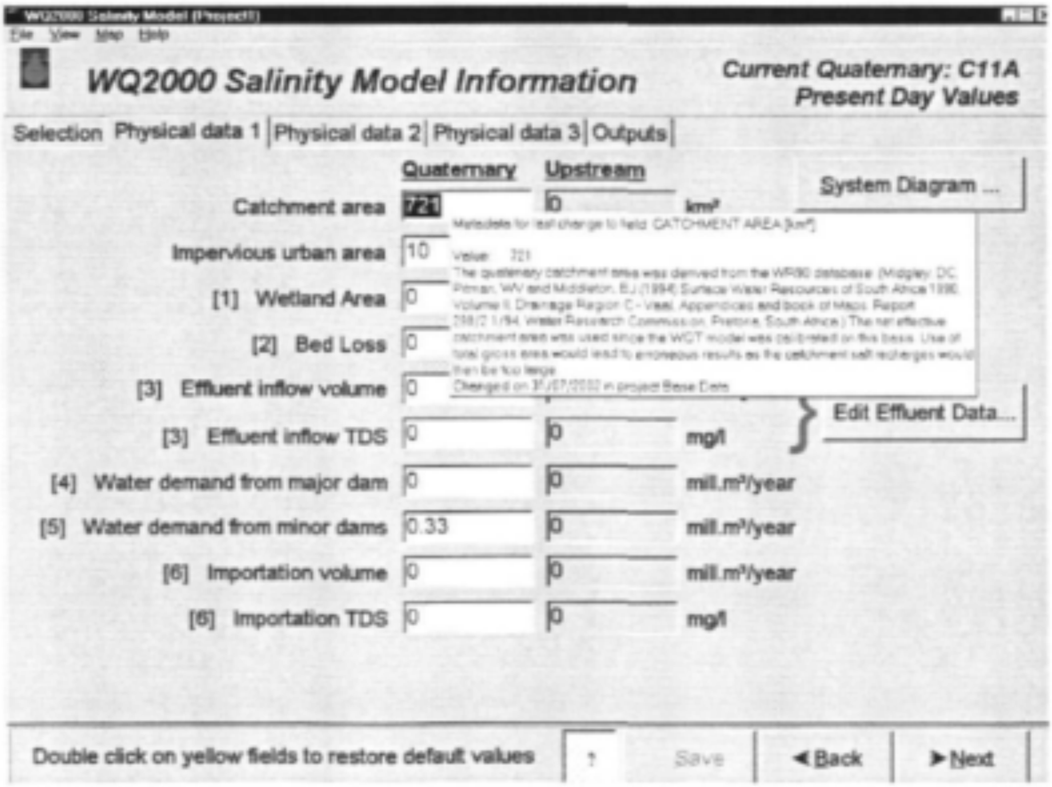

Figure 3.2: Example of metadata display

Figure 3.3 shows the dialog requiring the entry of appropriate metadata that pops up the moment the cursor leaves a changed field, e.g. when tabbing to another field after a change was made.

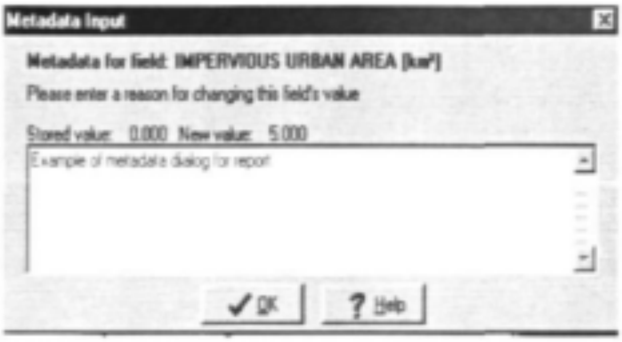

Figure 3.3: Example of metadata entry dialog

The following is an example of an editable file summarising all changes made to the original base data.

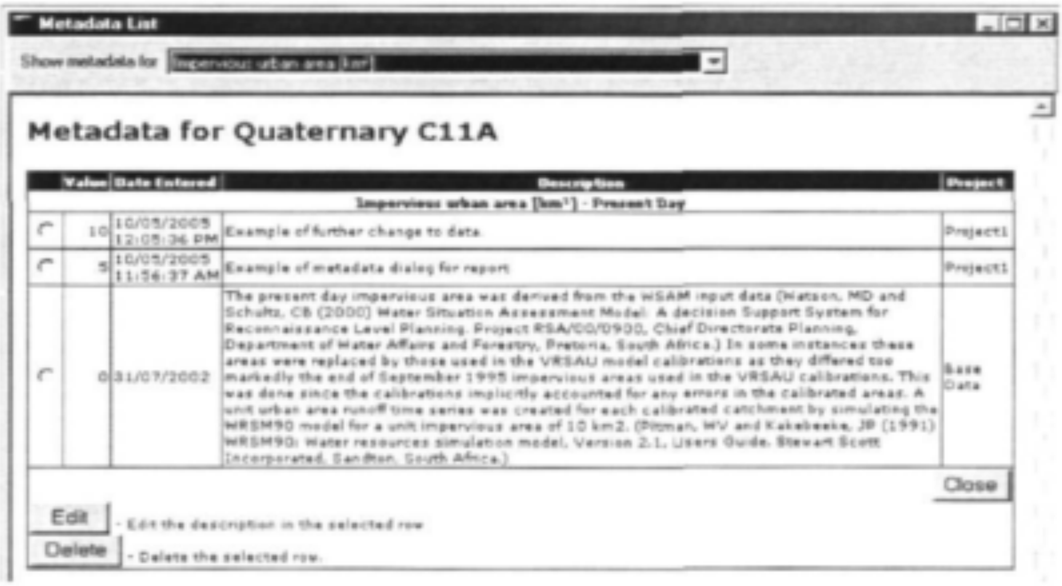

Figure 3.4: Example of editable metadata summary file

An option has been included to export a file showing all changes made to the default values along with the metadata entered by the user. Identified corrections (such as revised urban or irrigation areas, etc.) and their motivations can then easily be transmitted to the User Support System.

WQ2000 Metadata for project Project1 as on 10/05/2005 12:14:31 PM

The following is a list of the most recent changes from the initial base data.

Natural or Present Day	Value	Date Entered	Description	Project
Quaternary C11A				
Impervious urban area [km²]				
P	10	10/05/2005 12:05:36 PM	Example of further change to data.	Project1
Quaternary C21B				
Impervious urban area [km²]				
P	10	14/03/2005 07:20:37 PM	demo	Project1
[2] Effluent inflow volume [m³/day]				
P	6301	14/03/2005 07:26:15 PM	demo	Project1
[3] Effluent inflow TDS [mg/l]				
P	1395	14/03/2005 07:26:16 PM	demo	Project1

Figure 3.5 Example of metadata export file

3.9 Include graphical display options

Effective visualisation and reporting was limited in the original version of WQ2000. A new option "Display Graphs" has been added to the Outputs sheet. When invoked, this brings up a window allowing the user to choose four types of plot:

- Time series graph
- TDS duration curve
- Seasonal distribution
- Quaternary percentile plot.

If any of the first three options are selected before the model has been executed for the selected quaternary, the "Run WQT Model" option is executed automatically, as happens for the "Display Summary Information" option. In the case of a quaternary percentile plot WQ2000 will first run the model for all of the selected quaternary catchments with the latest physical parameter changes before producing the plot, as happens when the GIS Viewer option is invoked.

3.9.1 Time series graph

On requesting a time series plot, a series of dialogs are presented allowing the user to select one or more time series lines to plot, natural or logarithmic scales and the time period. The following is an example of a generated time series chart.

Up to two vertical axes are plotted, one for flow in 10^6 m^3, the other for TDS in mg/l.

Experienced users can use the standard Delphi graphing tool bars to access a number of options for changing line colour, thickness and type. Selections can also be made to alter key descriptions and opt for a 3-D display. The user can also zoom in on part of the plot, print the graph or save it to file. Hence special requirements for reporting can be satisfied.

The standard title includes the quaternary code, project name and the date and time that the plot was generated. If so required, the standard Delphi graphing tool allows the user to alter the graph title.

The field descriptions in the key also reflect whether the line is cumulative or incremental and for natural or present day conditions.

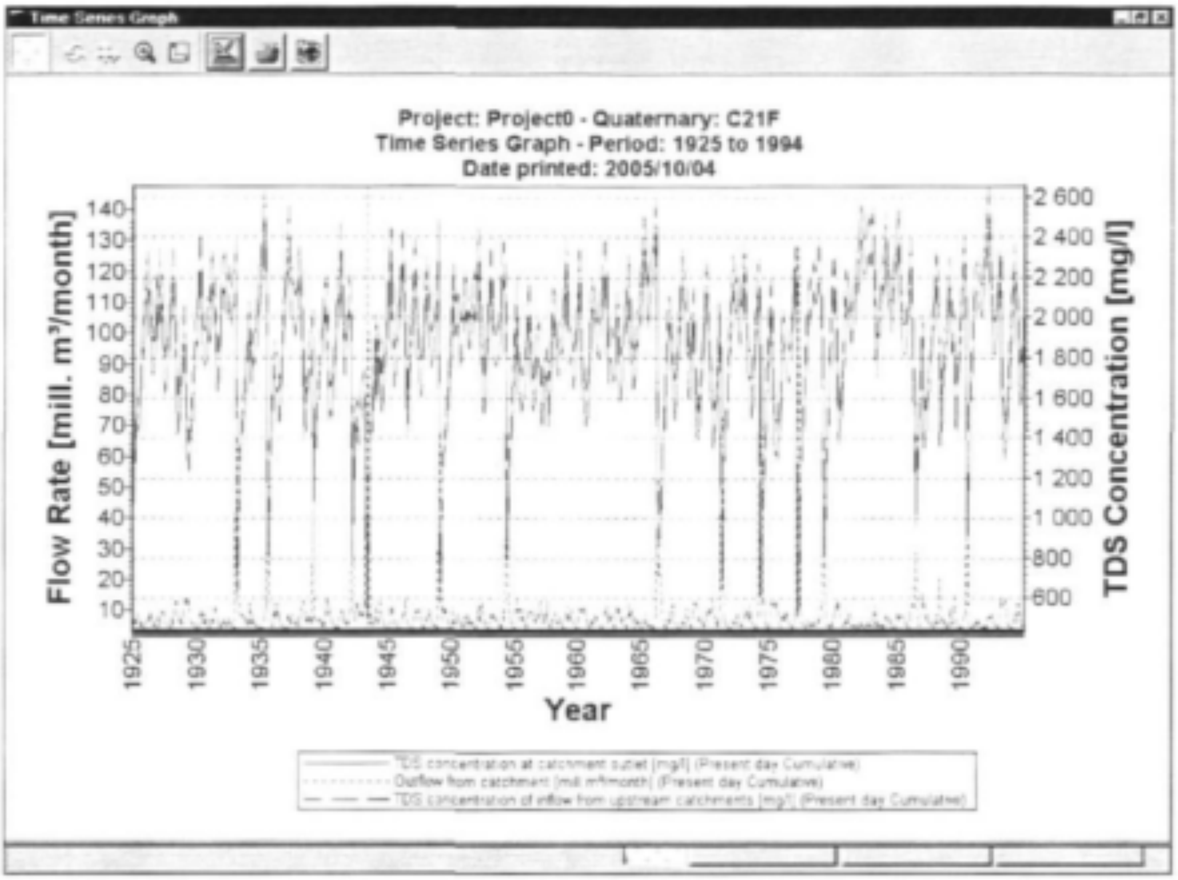

Figure 3.6: Time series plot

The graphing tool pre-selects default solid line types of different colours. Line types can be adjusted by selecting the **Edit** menu option at the top of the screen (third button from the right). Then highlight the line to be edited and select the **Series** tab, followed by the **Format** tab and the **Border** button. Finally, select the radio button next to the desired line type (i.e. solid, dashed, dotted, etc.) The standard graphing tool also allows many other options for editing line colour, thickness and other attributes.

3.9.2 TDS Duration Curve

The user can select the following fields for TDS duration curves:

- Quaternary outlet TDS concentration
- Upstream inflow TDS
- Catchment TDS
- TDS in major dam.

An example of a generated TDS duration curve plot is given in Figure 3.7.

As for the time series plot, dialogs are displayed allowing selection of the fields to plot, including choices for incremental or cumulative and natural or present day conditions, and the time period.

The standard plot title includes the quaternary code, project name and date and time stamp. The standard Delphi graphing tool provides the user with a great deal of flexibility to customise the plot for special presentation purposes.

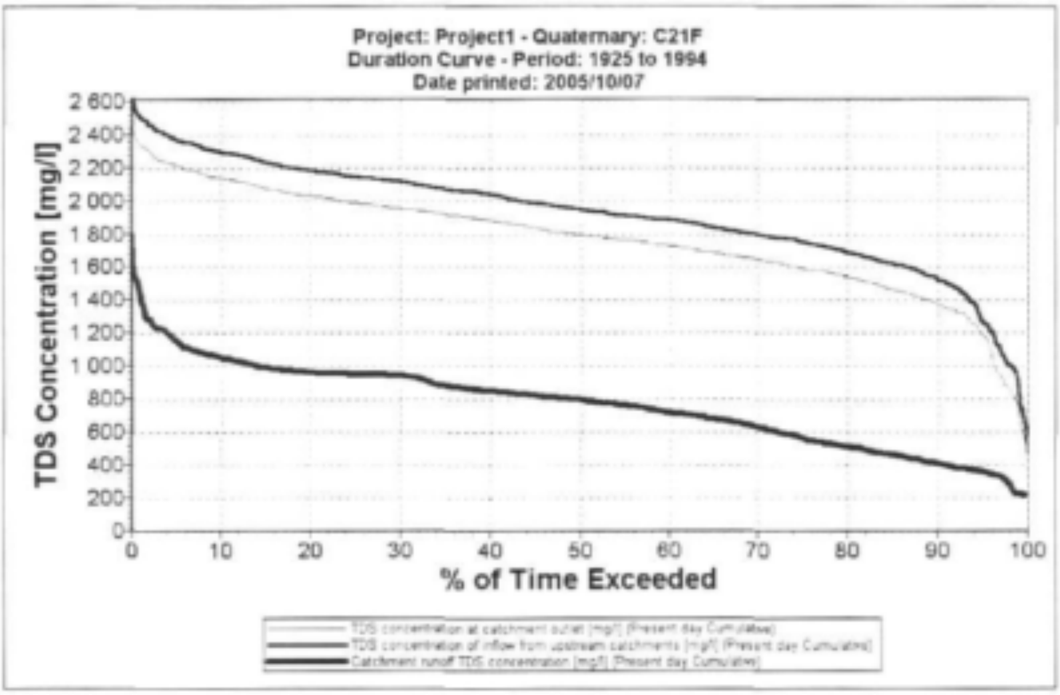

Figure 3.7: ***TDS duration curve***

3.9.3 Seasonal distribution

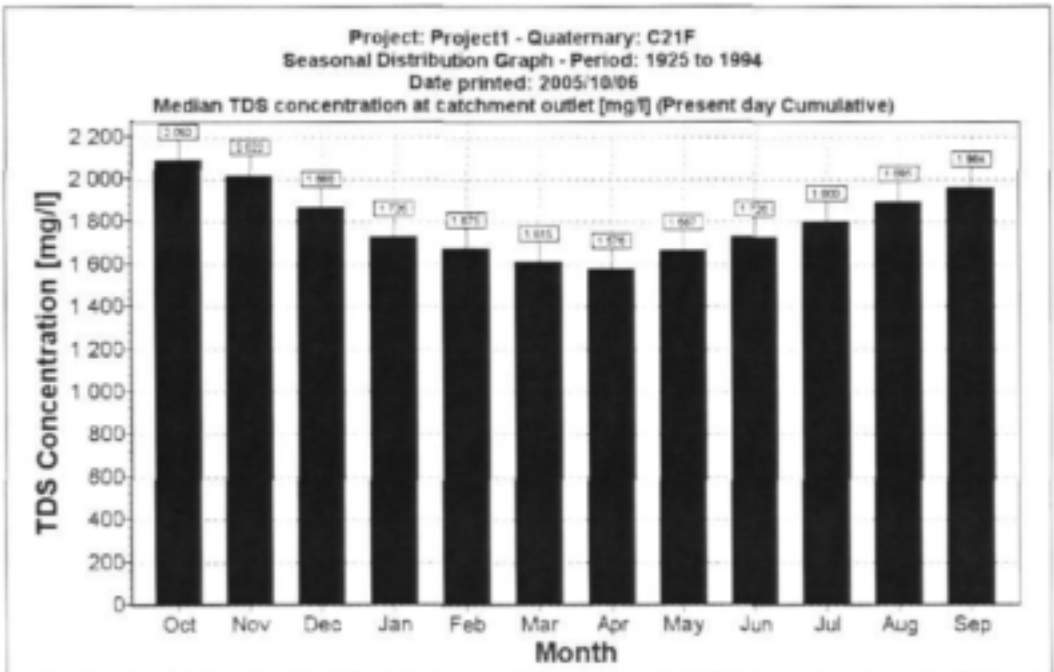

Figure 3.8 TDS seasonal distribution

Provision has been made to generate a seasonal distribution plot in the form of a bar chart (one bar per month) for the catchment outlet TDS concentration. The user is required to select one combination of incremental or cumulative case and natural or present day condition and to show either the median or average monthly TDS concentrations.

3.9.4 Quaternary percentile chart

This option allows the user to plot the 95 percentile, median and average TDS concentrations for selected quaternary catchments in the form of stacked bars.

The user first selects the quaternary catchments to be included in the plot. One combination of incremental or cumulative case and natural or present day condition is then selected.

A generated quaternary percentile plot for the Suikerbosrand River catchment is shown in Figure 3.9.

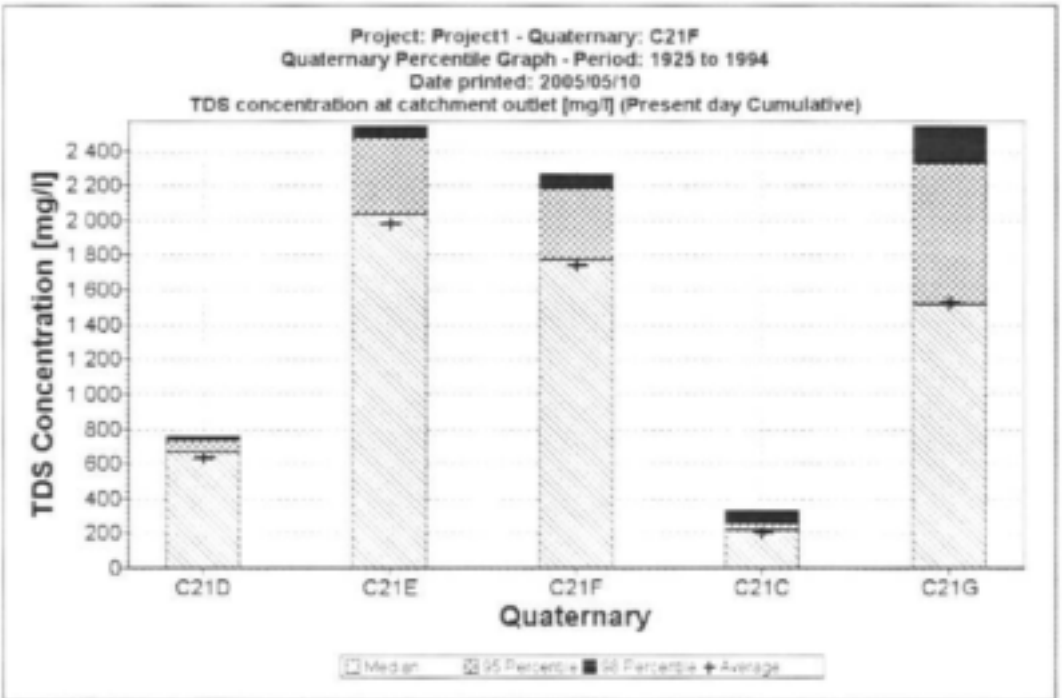

Figure 3.9: Quaternary percentile plot

3.10 Include an option to output the results file to a spreadsheet

An option to save the results sheet to a variety of different file types has been implemented.

3.11 Display legend for Quaternary Hierarchy Diagram

Previously some difficulties were experienced in interpreting the quaternary hierarchy diagram. This problem was overcome by including a legend when this diagram is displayed.

3.12 WQT model data files for all cases

The original version did not store all of the cumulative case WQT model data files. This meant that when a user chose to save the WQT model input files they were only completely valid for the incremental case. A few minor manual adjustments had to be made to set the model parameter files to run for the cumulative case. Both sets of data files are now stored and transferred to separate directories, where they are available for use by more advanced users.

3.13 Changes to the results sheet

A few cosmetic changes were made to improve the readability of the results sheet. More substantial enhancements involved introducing three new lines of statistical information to satisfy the requirements of environmental practitioners.

- The 95-percentile TDS concentration for the driest month at the catchment outlet
- The average TDS concentration for the driest year
- The TDS load leaving the catchment

These additional entries are shown in the 5th, 6th and last lines of the following excerpt from the results sheet.

Results	Quaternary Present day	Quaternary Natural	Cumulative Present day	Cumulative Natural
Average TDS concentration (mg/ℓ) [14]	94.6	206.5	1 530.3	327.8
Median TDS concentration (mg/ℓ) [14]	77.2	226.8	1 519.8	339.2
95 percentile TDS concentration (mg/ℓ) [14]	174.2	234.7	2 337.4	451.9
98 percentile TDS concentration (mg/ℓ) [14]	373.1	237.0	2 563.7	466.5
95 percentile TDS concentration for driest month (Aug) (mg/ℓ) [14]	132.8	235.3	2 255.7	458.4
Average TDS concentration for driest year (1991) (mg/ℓ) [14]	68.7	228.2	2 157.0	433.2
Flow-weighted average TDS concentration (mg/ℓ) [14]	104.3	157.6	1 014.8	212.4
Average upstream inflow volume (mil.m³/year) [16]	-	-	43.15	46.04
Flow-weighted average upstream inflow TDS concentration (mg/ℓ) [16]	-	-	150.5	150.6
Average catchment runoff volume (mil.m³/year) [13]	6.56	8.47	53.78	54.50
Average catchment runoff TDS concentration (mg/ℓ) [13]	211.5	206.5	202.0	197.8
Average TDS concentration in major dam (mg/ℓ) [8]	18.2	0.0	1 422.9	43.5
Flow-weighted average TDS con. of spillage from major dam (mg/ℓ) [8]	158.3	160.0	1 111.2	215.1
Mean annual outflow from catchment (MAR) (mil.m³) [14]	6.07	8.47	127.60	95.01
Mean annual TDS load (t) [14]	633	1 336	129 486	20 177

Figure 3.10: Excerpt from results sheet

3.14 Identification of changed variables

The Summary Information Report provides a record of the simulation results and the assumptions used to generate them. However, it was still difficult to identify just which default values had been changed in arriving at the result. An additional feature has been added to the results sheet to highlight in bold all variable values that have been changed since a user-defined date.

Pressing the "Options" button on the "Outputs" sheet brings the following dialogue, which allows the user to set the date after which any changes to the parameter values will be highlighted. In this case, all changes made since 01/08/2002 (the base database date) will be highlighted in the results sheet.

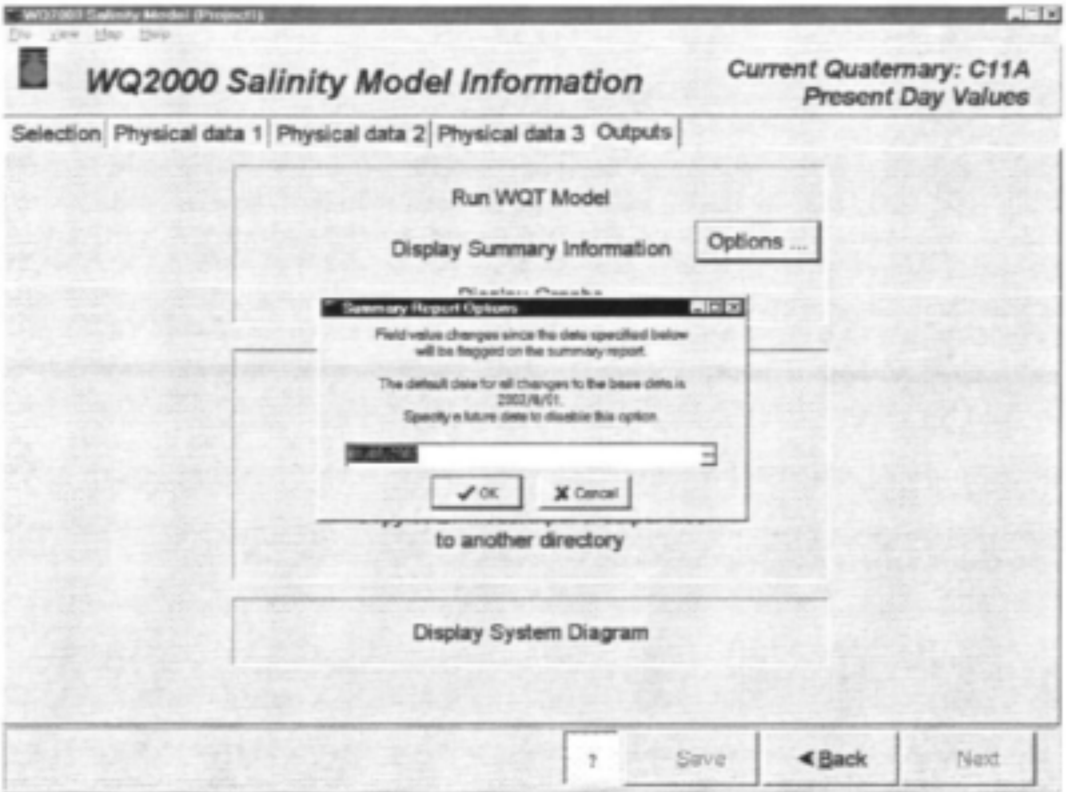

Figure 3.11: Dialog to set date after which changes are highlighted

In this example the urban area for quaternary C11A had been changed from its default value of 0 km^2 to 10 km^2. The following excerpt from the results sheet shows that this value has been highlighted in bold, since the change occurred after 01/08/2002 (the specified reference date).

WQ2000 Salinity Model

Project: Project1

Summary Information Report: Quaternary C11A

Page 1

Date: 06/10/2006

Hydrology period: October 1925 to September 1995

Description	Quaternary Present day	Quaternary Natural	Upstream Present day	Upstream Natural
Physical Data (Inputs)				
Catchment area (km^2)	721	721	0	0
Impervious paved area (km^2)	**10**	-	0	-
Wetland Area (km^2) [1]	0	0	0	0
Bed Loss (mil m^3/year) [1]	0	0	0	0

Figure 3.12: Highlighted change since reference date

4. POSSIBLE FUTURE CHANGES

Not all of the potential model enhancements that were identified could be included in the current project, since they would have required substantial changes to the original scope of work.

Those potential enhancements that were not addressed in this project (see Chapter 3) are discussed below.

4.1 Define importation source quaternary

The option of defining the quaternary catchment from which a water importation is received was considered. The simulated monthly source quaternary major dam TDS values would then define a time series of TDS concentrations for the imported water. (The current version of WQ2000 uses a fixed importation water quality.) The proviso here is that the source quaternary catchment would have to be run first.

This could be a useful enhancement, but was not implemented due to budget and time constraints.

4.2 Define other point source time series

This would involve allowing the user to choose a time series of monthly inflow volumes and TDS concentrations, instead of the present default of a fixed flow rate and quality.

In principle this could have been implemented. However, it was felt that the increased complexity of the model (adding more options for the user to learn) might inhibit the model's use. Moreover, in order to use this feature the user would have to first obtain the relevant time series input files. Since this would be beyond the reach of many users, this feature would be seldom used.

4.3 Allow direct water supply to irrigated areas

This option is aimed primarily at major irrigation schemes, such as Vaalharts. At present the water supply to large schemes that span more than one quaternary catchment has to be treated as a fixed annual supply at constant TDS concentration. Alternatively the water supply is not specified and instead the irrigation return flow can be specified as a constant rate and quality effluent inflow. Since it is difficult to obtain irrigation return flow and TDS concentration time series, it is preferable to rather provide water supply time series data and use the WQT model to simulate the salt balance of the irrigated land and the return flow.

WQ2000 operates at a quaternary scale. This means that if an irrigated area spans more than one quaternary catchment, or (as is the case with Vaalharts) the water is supplied from one quaternary catchment and used in another, the recipient quaternary catchment needs a time series of flow and salt concentration. However, this cannot be pre-simulated at the source catchment in isolation, since the irrigation and climatic factors of the recipient catchment are required to determine the monthly water demands.

Overcoming all the complexities introduced by the constraint of the quaternary spatial resolution would require demanding modifications, which were beyond the resources of the current project. It is doubtful if the relatively limited application would justify the cost. For larger scale cases, such as Vaalharts it is considered more appropriate to set up an *ad hoc* system spanning a bigger region that encloses both the water supply elements and the irrigation recipient areas within a single WQT model layout. This is well within the modelling capability and normal application of the WQT model. The WQT model parameters and data files contained in WQ2000 would provide an excellent starting point for such an application.

5. TECHNOLOGY TRANSFER

5.1 Presentations

A number of presentations of WQ2000 have been carried out to sensitise potential users to the advantages of WQ2000. These have been aimed at relevant DWAF, Water Board, industrial, university and consultant personnel. Five presentations of the original WQ2000 model were made prior to the commencement of the study and a further four were made during the tenure of the project. A further two presentations were made after the model enhancements had been carried out.

5.1.1 Initial system

Presentations that took place prior to the commencement of the project include the following:

- As early as 4 October 2002 a prototype version of WQ2000 was presented to the DWAF's old Directorate: Pollution Control.

- On 14 October 2002 the prototype version of WQ2000 was used to make an interactive presentation for a proposed dam on the Klip River to supply water to Sasol 2 and 3 and various Eskom power stations. This was more than a presentation of the model; it was the first practical application. The presentation was to East Vaal Consultants, DWAF, Eskom and Sasol officials.

- A presentation was made to Mr Pieter Viljoen and some of his staff on 27 June 2003. At that stage he had just been transferred to the DWAF Directorate: Water Resource Planning Systems, but was still operating from the old Directorate: Pollution Control.

- On 5 August 2003 the model was demonstrated to the WR2005 project submission planning team. This was a turning point in convincing the team to adopt a similar approach for the new Water Resources of South Africa. WR2005 will now also comprise an interactive system using an enhanced version of the WRSM2000 water resources simulation model.

- A lecture on WQ2000 was presented at the DWAF Sub-Directorate: Systems Analysis' 2nd Integrated Water Resource Planning Systems User Forum meeting held at Roodeplaat Dam on 6 August 2003.

Since the inception of the study WQ2000 has been presented at four other venues:

- A poster paper presentation was made at the WISA 2004 conference held in Cape Town on 3-5 May 2004.

- An interactive demonstration of the model was presented at the WR2005 Water Quality workshop held on 27 September 2004. This workshop was held as part of the inception phase of the WRC's WR2005 project.

- On 18 October 2004 an interactive presentation of WQ2000 was made to DWAF Directorate: Integrated Water Resource Planning personnel.

- An interactive model demonstration was made at a WISA meeting in held in Cape Town on 11 November 2004.

Valuable feedback was gained from these meetings, leading to the identification of further desired enhancements of the model.

5.1.2 Enhanced system

Since then a further two presentations were made of the enhanced model. These included:

- A presentation was made to the Water Quality Planning sub-directorate of the DWAF's Water Resources Planning Systems Directorate on 2 February 2005.

- On 6 September 2005 a paper entitled: *"WQ2000: Water quality modelling assessment system"* was presented at the 12[th] SANCIAHS symposium.

5.2 Training

5.2.1 Project team

A concerted effort was made to mentor personnel by involvement in the key technical tasks. Mentoring included background into the theory of the model and hands on experience in the development of model enhancements, user training and handling user queries.

5.2.2 User training

The project initially allowed for one training day, which was held in March 2005. Exceptional demand prompted a second training day in the same month. This was followed by a third training day in September 2005. All places at the third session were taken, resulting in a waiting list. Hence there is still demand for further training.

Participants were drawn from a wide range of state, industrial and consulting organisations. These were located both within and outside the Vaal catchment area. Those from outside the area expressed a strong desire for the model to be extended to their geographical regions.

5.2.3 Future training

Future training will be carried out via the DWAF's User Support System. An upsurge in demand for training is expected once WQ2000 is set up for major catchments other than the Vaal River catchment.

6. USER SUPPORT SYSTEM

6.1 Requirements

User support is considered essential to:

(a) Inform users of the model availability and potential
(b) Update software and the database
(c) Register trained users
(d) Deal with user queries
(e) Receive and rectify errors
(f) Provide ongoing training
(g) Distribute software and documentation revisions.

Such a system needs to be centralised and sustainable. As such the DWAF was identified as being in the best position to manage it.

6.2 DWAF User Support System

WQ2000 has been included in the DWAF Water Resource Planning System directorate's User Support System (USS).

As such an icon for WQ2000 has been included in the USS and Information on WQ2000 has been posted on the web site. The USS Support Administrator has a CD of the WQ2000 set-up, model executable code and base dataset. The training manuals and training course Power Point presentations are also lodged with the DSS.

The details of the participants in the training sessions have been stored in the USS system.

The USS contacts database was used to distribute advertising for the three training courses held so far. Advertisements for future courses will be posted on the Website, together with relevant news.

The USS also hosts a Forum where users can discuss issues of interest.

6.3 Support provided

The user support that is available comprises:

- Notification and provision of software and database updates
- Arrangement and notification of training courses
- Registration of trained users
- Assistance in using the software
- Assessment of queries and making appropriate updates
- Discussion Forum

6.4 Model revisions

By September 2005 a key generator had been included in the WQ2000 software and setup CD-ROM that was made available to users at the third training session. Authorised users can activate the software after loading it onto their PC and obtaining a key code from the USS Support Administrator. Those who have undergone training are regarded as registered users.

Users who were trained at the first two workshops can obtain the latest software from the USS Support Administrator, who can be contacted at:

Website:	www.usersupport.co.za
E-mail:	icm@dwaf.gov.za
Telephone:	012 336 7090

The intention is that verified corrections will be entered into new versions of the base dataset, which will also be released periodically, along with enhanced versions of the WQ2000 software. Users can either download model revisions from the Website or order a CD from the USS administrator. The choice between the two options will be at the discretion of the USS Support Administrator, depending on the size of the files.

6.5 User support

The USS serves as a receptacle for queries received from users. These can be forwarded to the DWAF Support Administrator either telephonically or electronically. The Support Administrator will then forward the queries or comments on to a designated specialist for further attention. Those received electronically will be forwarded by e-mail. Those received telephonically will be noted by the administrator and transmitted to the specialist, who will make direct contact with the user.

One or more of the following actions will be taken, depending on the nature of the request:

- Contact the user to deal with the query
- Accumulate modifications to the base dataset (arising either from new developments or errors in the data that have been uncovered)
- Set about rectifying errors in the model coding or base dataset (those that can be fixed in the short-term as part of the ongoing project support)
- Accumulate requests for "nice to have" changes that will be prioritised and considered for implementation at a later date
- The user will be notified accordingly.

Until the end of September 2005 the project team provided specialist support as part of the WRC contract, where after, DWAF took over this responsibility.

7. BENEFITS AND LIMITATIONS

The benefits and limitations of WQ2000 are discussed in the following sections.

7.1 Benefits

7.1.1 Rapid Testing of options

A key objective was to deliver a product that permits rapid, but valid evaluation of the salinity ensuing from options at a quaternary scale. Rapidity of evaluation has been achieved to an outstanding degree. The model permits fast assessment of the salinity impacts of a wide range of options. Computation time is fast enough to be irrelevant to the user. Much more important is the telescoping of weeks or months of intensive modelling preparation, calibration, simulation and results presentation work into the scale of days, hours or even minutes for simpler coarse evaluations.

7.1.2 Ease of use

Ease of use is a key project objective. This is one of the outstanding strengths of WQ2000. This contention is supported by the short time required for users drawn from a wide range of backgrounds to assimilate the training. More notable is the fact that preparation of the training exercises did not require any preceding extensive data collection and preparation. The requisite default data is readily available in the database, requiring only rapid adjustment to reflect development changes or the changes needed to represent the option to be evaluated. Much more significantly, the numerous model input files, time series files and the all important model calibration parameters are already prepared for instant use.

User-friendliness is assisted by a number of useful pop-up descriptors, as well as a comprehensive help menu.

7.1.3 Credible modelling

The third major requirement was for validity of the modelling. This is achieved by using the proven WQT hydro-salinity model as the simulation engine. This allows the delivery of a high degree of credibility for those options that fall within the limitations of the methodology.

7.1.4 Versatile presentation of results

Attention has been paid to meaningful presentation of results. This is achieved by means of a result sheet that reflects not only results, but also the assumptions made in delivering them. A range of graphical output modes supplements the tabular output.

7.1.5 Regional overview

The GIS Viewer permits rapid generation of map overviews of the regional salinity status. This feature can also be used to review a variety of other values, such as flow percentiles and WQT hydro-salinity model calibration parameters.

7.1.6 Documentation of assumptions

Extensive use of metadata permits documentation of changes made to the base default data. Project databases provide a ready means of storing and retrieving user changes. Files containing data changes and the associated metadata can easily be generated, edited and transmitted to the User Support System.

7.1.7 User Support

The DWAF's User Support System provides a ready medium for ongoing training, model and database revision and distribution, dealing with user queries, notification of changes and training opportunities and sharing with other users.

7.1.8 Stepping stone for detailed evaluation

The reservoir of accessible information contained in the database provides a valuable stepping-stone for building up more complex WQT model systems.

7.1.9 Low cost

All of these benefits are made available to practitioners at zero direct cost. Indirect costs to users are confined to the cost of making personnel available to attend a one-day training course.

7.2 Limitations

7.2.1 Complex multi-dam systems

WQ2000 is ideal for rapidly assessing the impacts of developments in relatively uncomplicated regions. However, it was never intended to cater for large multi-dam systems.

Provided the system comprises no more than two major dams, with the lower dam calling for water from the upstream dam, it can be handled with reasonable confidence. For example, the entire C1 region (upper Vaal River) should yield valid results, since the Grootdraai Dam operation is still largely independent of Vaal Dam.

The facility to specify a time series file of monthly outflows from a major dam does partially permit simulation of more complex systems, but not interactively, since calls for water to meet requirements downstream of the quaternary catchment under examination would remain invisible to the model.

Hence it is important to appreciate that WQ2000 is not intended as a multi-reservoir simulation model. Hence it will not deliver valid cumulative results for the highly regulated main stem of the Vaal River downstream of Vaal Dam. However, it could still give reasonable results for the off-channel case for such affected quaternary catchments.

7.2.2 Quaternary scale

WQ2000 has been set up to simulate salinity at the downstream end of quaternary scale sub-catchments. Hence this will not necessarily represent the salinity in smaller portions of the quaternary catchment. However, the facility does exist to change the quaternary area to represent a proposed dam upstream of the quaternary outlet.

7.2.3 Feedback loops

WQ2000 is not designed to simulate feedback loops. This is because most such loops span more than one quaternary catchment. For example, Rand Water used to abstract much of its raw water from Vaal Barrage, to which nearly a third was returned as treated sewage effluent, giving rise to a salt feedback loop. However, the effluent was returned to a number of quaternary catchments that lie outside the Vaal Barrage quaternary catchment. Simulation of such a loop therefore requires the *ad hoc* construction of a specially designed system network that incorporates all of the important elements. WQ2000 was not designed to simulate such complex options. However, while it is unsuitable for simulation of water quality in Vaal Barrage, it can still be used effectively to simulate salinity in the sub-systems draining into Vaal Barrage, such as the Klip, Suikerbosrand and Rietspruit catchments.

7.2.4 Direct supply to irrigated areas

WQ2000 does not facilitate simulation of the direct supply of water from one quaternary directly to an irrigated area located in another quaternary catchment. As discussed in Section 4.3, in the Vaal River catchment this limitation applies mainly to the Vaalharts irrigation scheme.

7.2.5 Importation and effluent quality time series

Specification of a time series of monthly water quality for importations or other water inputs is not catered for. However, use of a fixed water quality does not appear to be a major issue in most instances and holds the advantage of facilitating ease of use.

7.2.6 Geographical location

At present WQ2000's database has been set up only for the three Water Management Areas of the Vaal River catchment. While this represents one of the most economically significant and highly developed regions of South Africa, it still excludes many important areas with pressing salinity challenges.

7.2.7 Salinity only

WQ2000 has been implemented only for salinity (in particular TDS). This choice of variable was dictated by the propensity for salinity to be a persistent and economically important pollutant problem. It is also amenable to modelling and has been well studied in the Vaal River catchment as well as in other areas. However, suitable techniques to rapidly assess other pollutants need to be addressed.

8. CONCLUSIONS

8.1 Attainment of project aims

All of the project aims have been attained:

8.1.1 Model enhancement

Fourteen model enhancements were implemented and tested. This is well in excess of the five that were identified when this follow-on project was conceptualised. The enhancements include:

- Update and simplify the installation set-up CD and resolve problems encountered with one version of Windows XP.
- Hide access to the WQT salt washoff model calibration parameters to reduce the risk of the user accidentally upsetting the pre-calibrated values.
- Implement latest GIS Viewer.
- Correct calculation of the average TDS concentration in the quaternary major dam when there is no outflow or the dam storage is zero.
- Inclusion of the data period in the Summary Report title.
- A start-up screen was included to briefly describe the model, the DWA User Support System and acknowledge the funding source.
- An option to specify a monthly time series of reservoir downstream water release was included.
- Metadata was included for all of the base database default values. Provision was also made to add metadata for all new values entered by the user. Options to edit and view user-defined metadata and export data changes and their associated metadata have also been included.
- Options have been included to display, edit and print time series, duration curve and seasonal distribution plots, as well as TDS concentration percentile values for selected quaternary catchments. Time series graph
- Options to export the results sheet to a variety of different file types have been implemented.
- A legend has been included for the quaternary hierarchy diagram.
- The option to export WQT model input files has been re-structured to ensure that the data for all modelled scenarios is stored.
- Additional statistical information for the driest month and the driest year and for the salt load leaving the catchments was included in the results sheet.
- A facility was included to highlight all changes to the default data that have been made since a user-defined date.

8.1.2 Technology transfer

Technology transfer has been attained through a number of presentations, training sessions and mentoring of project team members.

Eight interactive demonstrations of the model were made to various parties within the Department of Water Affairs and Forestry, WISA and the team carrying out the WRC's WR2005 national water resources update. The model was also used to evaluate a potential new dam on the Klip River to supply water to Grootdraai Dam. A poster presentation was made at the WISA 2004 conference and a paper was delivered at the 12th SANCIAHS symposium.

Mentoring of project personnel was achieved during the study.

Three successful one-day training workshops were held. This facilitated technology transfer to a variety of state and private sector personnel.

8.1.3 User Support

The WQ2000 salinity model has been posted on the DWAF's User Support System, which has already been of great assistance in facilitating training sessions. The USS is expected to contribute considerably to the sustainability and improvement of WQ2000. It is also viewed as an important vehicle to promote further application.

8.2 Benefits of WQ2000

The WQ2000 salinity model offers the following benefits:

8.2.1 Evaluation tool

One of the most powerful features of WQ2000 is its use as an evaluation tool to rapidly and credibly test the salinity impact of a wide variety of development options, including:

- Changes in urban, irrigated and wetland area
- Introduction of new dams, changes to the size of existing dams and abstractions and releases from them
- Changes to mine pumpage and effluent flow rate and TDS concentration
- Alteration of water importation flow rate and salinity
- Changes to or introduction of new channel bed loss
- Changes to proportions of catchment runoff upstream of key features.
- Rapidly test a wide variety of development options.

This range of choices allows for the testing of a large variety of catchment development and management options.

8.2.2 Catchment overview

WQ2000 provides a means to overview regional catchment salinity for both natural and present-day conditions for the off-channel case or taking into account the inflow from upstream catchments.

8.2.3 Reporting

A number of features are available to graphically display, tabulate and export the simulation results.

8.2.4 Ease of use

WQ2000 has been designed for ease of use. This ranges from user-friendly features to create and modify user projects, select catchments, alter default values, run the model, view and report results.

8.2.5 Export WQT model files

Users who are familiar with the WQT hydro-salinity model can use the appropriate model features to export WQT model parameter and time series files for use in a more complex modelling system.

8.2.6 Database progression

The user may build up a project database incorporating the development changes affecting the region of concern that have occurred since the default database was last updated. This would enable a Catchment Management Agency, or a pollution control officer responsible for a smaller sub-unit, to develop a dynamically changing project database reflecting the current development conditions.

8.2.7 Online help and metadata

WQ2000 provides a number of help screens. Metadata is also provided for the default database and user-defined updates.

8.3 User support

WQ2000 has been incorporated in the DWAF's User Support System (USS). As well as providing support for answering queries, the USS allows for dissemination of updates and news, facilitation of training and the assimilation of information updates received from users.

8.4 Influence on other developments

Demonstration of WQ2000 has led to the adoption of similar evaluation and reporting features in the WR2005 model that is under development. This is viewed as a major leap in the progression of the development of the valuable series of South African water resources manuals through to the last 1990 version (Midgley *et al*, 1994).

8.5 Limitations

WQ2000 was designed to deliver rapid evaluation of the salinity implications of options at a quaternary catchment scale based on monthly time step modelling. At this stage the model has been implemented only for the three Water Management Areas comprising the Vaal River catchment.

While valid results can be expected for most systems, it was never intended for use in highly regulated multiple reservoir river reaches. The model does not handle salt feedback loops either. Under either of these circumstances more detailed or system-wide modelling is required.

In its present form WQ2000 does not cater for direct supply of imported water to an irrigation scheme. It also assumes a fixed salinity for effluent inflows and water importations. However, these limitations are significant only for a few applications, which, in any event, warrant more detailed modelling.

9. RECOMMENDATIONS

Two broad types of recommendations have been made. In the first instance, recommendations are made regarding the implementation of the products. Secondly, recommendations are made for future research.

9.1 Implementation of products

9.1.1 Application of WQ2000

The WQ2000 salinity model provides a powerful means of rapidly, but credibly assessing salinity. Since salinity is already a pressing problem in the Vaal River catchment, it follows that it should be put to use as soon as possible by the following organisations:

- Department of Water Affairs and Forestry
- Catchment Management Agencies (once established)
- Consulting firms
- Water Boards
- Research organisations
- Tertiary institutions

It is particularly important that those involved in the planning of water resources take account of water quality at all levels of scheme development. The speed and ease of use of WQ2000 makes it feasible to carry out water quality assessments for even the smallest schemes and at the very earliest stages of project development.

9.1.2 Ongoing training and user support

Continued training and user support is seen as a high priority, as is the need to expand the user base.

9.2 Future research

9.2.1 Extend to other parts of South Africa

WQ2000 was conceived in three phases (Herold and le Roux, 2004):

- Phase 1: Initial development
- Phase 2: Testing and model refinement
- Phase 3: Extension to rest of South Africa and possible extension to other water quality variables.

WRC project K5/950 brought Phase 1 to a successful conclusion. The current project concludes the second phase.

Commencement of Phase 3 is now recommended. This would be opportune for the following reasons:

- The training workshops have revealed a strong desire for the system to be made available in other areas.

- The WR2005 project, which will result in calibration of the modified WRSM2000 hydrological model for all of South Africa to the end of September 2005, is well underway. This will provide a wealth of up-to-date input data. Moreover, WR2000 will include database functions that will facilitate extraction of the hydrological and development data in a form that can be used directly in WQ2000.

This can best be achieved by first including those catchments to which the WQT model has already been applied. This is desirable for the following reasons:

- WQT model calibrations are already available for such areas.
- These represent a pre-selection of areas of recognised importance where salinity plays a significant role.

Extension of WQ2000 to other catchments could be co-ordinated with the WR2005 national water resources revision. The benefit stemming from this would be the lengthened and improved hydrological record, which would permit use of the latest water quality data to the end of September 2005.

Based on the above considerations, the following prioritisation is recommended:

- Upper Crocodile (West) River catchment
- Olifants River catchment (this is currently subject to the DWAF water allocation study, which should result in calibration of the WQT model).
- Fish-Sundays River catchment
- Berg River catchment
- Breede River catchment
- Olifants-Doring River catchment
- Orange River catchment
- Amatole River catchment
- Vaal River catchment (this is desirable to fully utilise the latest water use information that will be yielded by WR2005).

In the above instances the WQT model calibrations can be derived largely from earlier studies. Current development and water use information would be obtained from the WR2005 study.

Coarse calibrations of the WQT model would then be made for the remaining portions of the country, supported by the revised hydrological and development database provided by the WR2005 study.

It is anticipated that extension of WQ2000 to other key Water Management Areas (WMAs) would require two to three years. Use would be made of expertise available in different key parts of the country, especially those familiar with previous water quality studies. Key personnel for the current project team would liase with, and support the local teams.

9.2.2 Extend to other water quality variables

WR2005 includes an overview of some other water quality variables. However, this overview is confined to the cumulative case for sites located near the quaternary catchment outlet. As such it will not include any capacity to evaluate options for these constituents. The variables (other than TDS) being included in the WR2005 overview are pH, nitrates, total ammonia, fluoride, ortho-phosphate and sulphate. This will suffice for a coarse overview.

Ultimately, WQ2000 could be expanded to provide a rapid evaluation tool for these variables. However, it is recommended that this not be attempted until after the salinity modelling has been extended to other key South African catchments. This is desirable since attempting to do too much at once could over-extend the available expertise.

9.2.3 Revise after re-calibration

It is expected that critical areas will be subjected to ongoing scrutiny. Such studies are expected to include further calibration of the WQT model to take advantage of the expanding hydrological and water quality database and adequately track the effects of continuing development changes. When this occurs, the WQ2000 database should be revised to include the model calibration and development information yielded by such studies.

9.2.4 Model improvements

The model improvements discussed in Chapter 4 could be considered. These include:

- Derive importation water quality time series from previously simulated quaternary catchments
- Define time series files for point source inputs
- Allow direct water supply to an irrigated area from a previously simulated quaternary catchment.

Other possible beneficial improvements include:

- Comparison with water quality targets
- Simulation of future time horizons, with the inclusion in the database of expected development levels at selected future break-point years.

More beneficial improvements may come to light as use of the model expands.

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APPENDIX A

USER MANUAL

WQ2000 User Manual Contents

WQ2000 Help Contents

New users should read

The general operation of WQ2000 is described under

More information is available under the following topics:

Introduction

WQ2000 was developed under WRC Project K5/950 - WQ90: Development of an Interactive Surface Water Quality Information and Evaluation System for South Africa.

WQ2000 serves as a user interface for viewing quaternary parameters from the WQ90 database, for running the WQT model, displaying the results in a summary report, and for representing the data on a map using the DWAF GISViewer.

System Requirements

Also see: Installation

The minimum system requirements for installing and running WQ2000 are:

- A personal computer with Windows NT Version 4 Service Pack 3, Windows 95/98/2000/XP or compatible version.

- 70MB hard disk space for program and initial data files

* 100MB free hard disk space for temporary files while running the applications
* Super VGA screen, minimum 800 x 600 resolution.
* 64MB RAM.
* CD-ROM (only required for drive for installation)

Installation

Also see: System Requirements

Read the ReadMe.txt file on the WQ2000 Setup CD for last minute changes not applied to the Help file or manual.

To install the WQ2000 software and data files:

1. Insert the WQ2000 Setup CD-ROM into the CD drive. The CD AutoRun Index screen should appear automatically.
2. Select *Setup WQ2000*, and follow the prompts on the screen.
3. Should the DWAF GISViewer not already be installed on your PC, select *Setup DWAF GISViewer* from the CD AutoRun screen, and follow the setup prompts on the screen. The GIS Viewer is part of the WSAM application (Water Situation Assessment Model). Refer to the GISViewer User Manual should you need more information.
4. The previous step installs the GIS Viewer Version 3.0, as well as all supporting files. When starting WQ2000, it will automatically attempt to upgrade the GISViewer to Version 3.01.
5. Continue to Tutorial in Using WQ2000 for instructions on creating your first WQ2000 project.

Should you experience any problems executing WQ2000, please see the Troubleshooting and Support sections in the Help file. More detail about the installation is available under the Program Technical Information section in the Help file.

Note: WQ2000 interfaces with the DWAF GISViewer. The development of the GISViewer however is not part of this project. The GISViewer is supplied on the WQ2000 Setup CD courtesy of DWAF. For upgrades and support contact DWAF directly.

UNINSTALLING WQ2000

Refer to the instructions in the ReadMe file to remove a WQ2000 installation from the computer.

Tutorial in Using WQ2000

This tutorial should help the user to get acquainted with all the important features of WQ2000. In this tutorial we wish to see what the effect of introducing an upstream mine discharge would be on the average TDS concentration of quaternary C11E, and to display the data graphically on a map.

Startup up WQ2000

If not already installed, refer to the installation instructions

To start the WQ2000 program, select the WQ2000 icon from the desktop. A splash screen will appear describing WQ2000. Select *OK* to continue.

When WQ2000 starts up, it displays the *Open WQ2000* dialog, where a project to work with should be selected. By default the previous project used will be selected. Immediately after installation no project exists, and only the *Create a new project* option will be available. Click *OK* after selecting an option.

The Create New Project dialog appears. Enter a new project name, e.g. MyTest. Leave the default source project as Base Data, and click OK.

The new project is now created and opened. The current project name is shown in the WQ2000 title bar. The Quaternary Selection page will be shown.

Selecting a quaternary

On the Quaternary Selection page we need to specify the quaternary to work with. As we want to introduce a mining discharge to a quaternary upstream of C11E, we need to know which quaternaries supported by WQ2000 are upstream of it. To find out, select menu option *Map | Quaternary Hierarchy Diagram*.

Enter C11E as the root node, and click *Update*.

A message will be displayed mentioning the number of quaternaries found. Click OK.

The hierarchical diagram displays the logical structure upstream of C11E. Let's say we want to introduce the mine discharge to C11B.

Close the dialog to return to the Quaternary Selection page.

For our exercise we want to compare the status quo with the altered condition for C11B (the quaternary where the change takes place) and further downstream at quaternary C11E.

One can either enter the quaternary number in the Quaternary field, or select it from the map. For interest sake, click *Select Quaternary from Map*.
A map displaying all the CMA's is displayed.

Click on Upper Vaal. Always click close to the centre of the area of interest. The centre closest to the clicked point will be selected, regardless of the boundaries displayed.

The quaternary map for the Upper Vaal will be displayed. Click the *Zoom In* button and click on the map to enlarge it.

Click the *Select* button, and click on C11B (just below C11A). The selected quaternary's name is displayed in the field on top of the screen.

Click OK. The Quaternary Selection page is displayed again, and the parameters for C11B are loaded.

Displaying status quo results

Click the Next button at the bottom of the screen until the *Outputs* page is displayed.

Click *Display Summary Information*. The WQT model will be executed, and after which the Summary Information Report will be displayed. An example of such a report is given in Appendix A.

For the present day case the summary results report shows the cumulative average TDS concentration to be 230 mg/l, with a concentration of 670 mg/l being exceeded for 95% of the time.

Select the *Close* button to close the Summary Information Report screen. Now click on the Selection tab and enter quaternary C11E. Click the *Outputs* tab. Click *Display Summary Information* to execute the WQT model and display the results for quaternary C11E.

The default cumulative average TDS concentration for C11E is 116 mg/l and the value exceeded 95% of the time is 127 mg/l.

Editing parameter values

Again select quaternary C11B by clicking on the *Selection* tab and entering C11B.

Click the *Physical Data 2* tab to display the second page containing values for the quaternary. The left-hand column displays values for the selected quaternary. The right hand column displays the calculated sum for all upstream quaternaries. These values are not editable, and appear in grey.

Notice that the quaternary name and the data value set, Present Day or Naturalised, is displayed above the page tabs. Click on *Present Day*. Naturalised data will now be displayed.

Notice that some fields in the left-hand column are now also disabled (greyed). This is because these fields are not applicable for naturalised conditions.

Click *Naturalised Values* to return the display to present day values again.

Move the mouse pointer to one of the field descriptions, and keep it there for a moment. A description for the field will pop up. To disable this feature, click the question mark button at the bottom of the screen.

The same descriptions are also available in the help screens. The relevant help text for the displayed screen is called up by pressing F1.

A number appears to the left of some field captions. This number relates to a position on the system diagram. Click the *System Diagram* button to display this diagram. (Click the + button to enlarge the image.) Close the diagram screen.

Move the mouse pointer to one of the data fields (i.e. one of the white rectangles). Metadata for the data value is displayed. To disable this feature, click the question mark button at the bottom of the screen.

We want to introduce a mine discharge to this quaternary. Change the 1st field from the top of the screen from 0 to 10000, representing a flow rate of 10000 m3/day (equivalent to 10 Ml/day). Change the 2nd field from the top of the screen from 0 to 4000 mg/l.

When moving the cursor from the changed field a dialog box is displayed requesting metadata for the changed value. This must be entered before proceeding. Enter: "*Demonstration*" (or any other desired text).

Notice that the fields turn yellow. This is to indicate that this field's value is different form the stored value. To reset to the stored value, double click the field.

Press the *Save* button at the bottom of the screen to preserve the changes.

Displaying new results

The other tab pages display more parameters for the current quaternary. Click on the Outputs tab to display the *Outputs* page.

Click *Display Summary Information*. The WQT model will be executed for quaternary C11B, and after which the Summary Information Report will be displayed.

Notice that the new mine discharge data is reflected in the first column. The reported average TDS concentration for quaternary C11B has now increased to 992 mg/l and the 95% exceedance level to 2585 mg/l. This is not our final answer yet, as we want to see the effect on C11E.

Click the print button on top of the screen should you wish to print the report.

Click the close button to close the Summary Information Report screen.

You may now repeat the above steps to edit more data, and display the summary report to see the effect.

Once all changes are made, click the Save button at the bottom of the screen.

Select the Selection page again, select quaternary C11E, go to the Output page, and click *Display Summary Information*. This will display the answer we were looking for.

Notice that the new mine discharge data for quaternary C11B is now reflected in the 3rd column, as it is now in the upstream catchment. The reported average TDS concentration for quaternary C11E has now increased to 173 mg/l and the 95% exceedance level to 196 mg/l. These increases are much smaller than at C11B. This is due to considerable dilution from the water imported to quaternary C11C (from Heyshope Dam) and quaternary C11E (from Zaaihoek Dam).

Close the Summary Information Report screen.

Displaying the map

We now intend to display a map representing the new TDS values graphically.

Only saved data is displayed on the map. If there are any changed values that should be rendered, click the *Save* button before proceeding.

Select menu option *Map | GIS Viewer*. The *Map Selection* dialog will be displayed.

Indicate the quaternaries to be displayed: Click *Select all quaternaries upstream of...* and enter C11E.

Select *Average TDS Concentration* in the cumulative case ("C" column) in the next field. Select any other two or three fields to display on bar or pie charts on the map.

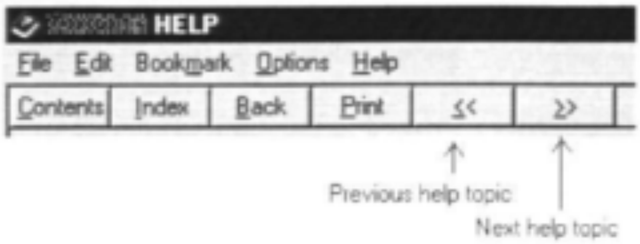
Press the down arrow in the next field. This will display all your chosen field descriptions.
Select *C; Average TDS concentration (TDS)* to use for colouring the quaternary catchments. Select the last field to include this field in the pie charts plotted in each quaternary.
Finally click OK.

The WQT model will be executed for quaternaries affected by changes since their previous calculation only.

Once all calculations are done, the GISViewer map will be displayed.

Always close the GISViewer before activating it again from WQ2000.

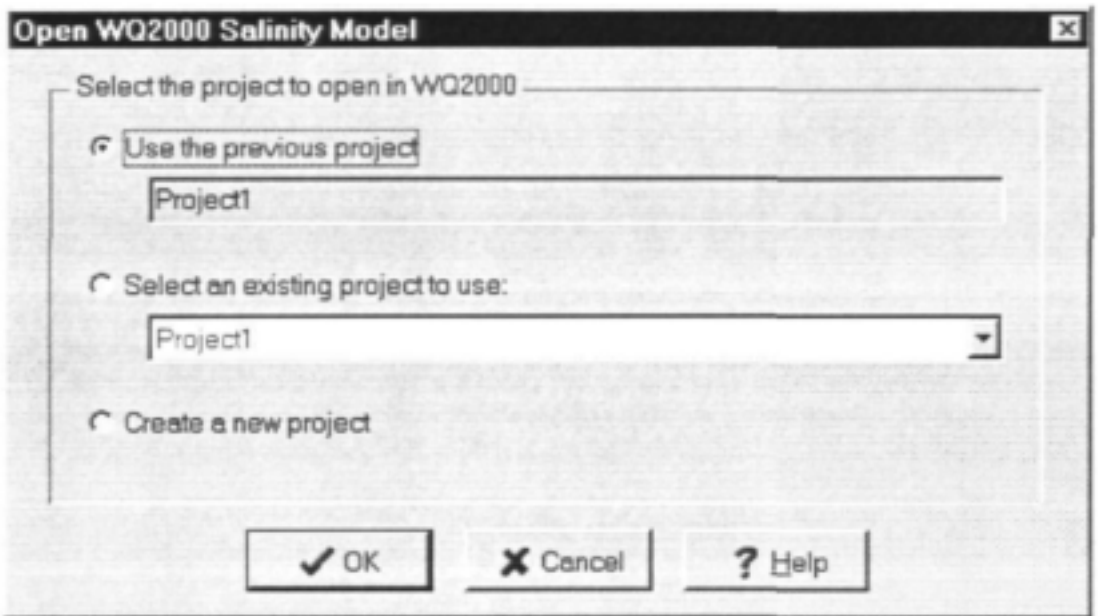
One last note:



Use the browse buttons on the help screen to display help topics sequentially. (Sorry for mentioning this - but many users don't know how to turn a page in a help file.)

About WQ2000 Projects

Also see: Creating a new WQ2000 Project
Opening an existing project



The WQ2000 Setup includes data for the available quaternaries for up to September 1995. Normally you would like to make changes to this data to reflect known changes since 1995 to the network. You may also want to make changes to the data in order to run the WQT model for different scenarios in what-if analysis.

WQ2000 isolates the initial base data as supplied with the Setup CD from any changes, by copying all the base data files to a project directory on the hard disk. Changes made are then stored in the user's project directory. Different projects (i.e. project directories) can be created for different scenarios. Each project is stored in a separate directory on the computer's hard disk.

No changes are allowed to the 1995 base data directly - this only serves as a source for new projects. It is however recommended that a present day base data project be created. The user should apply all known changes to the network since 1995 to this project. When creating a new project for what-if analysis, the user should then clone the present day base data instead of the original 1995 base data.

A project is created by selecting the *File | New* menu option in WQ2000. When creating a new project, the user can select to clone any existing project. The default will be to copy the 1995 base data supplied with the Setup CD to the new user specified project directory.

The current project name is shown in the WQ2000 title bar.

To rename a project, exit WQ2000, and use Windows Explorer to rename the project directory.

To delete a project, select menu option File | Delete Project.

To archive a project, or to copy a project from one computer to another, one simply need to copy the directory

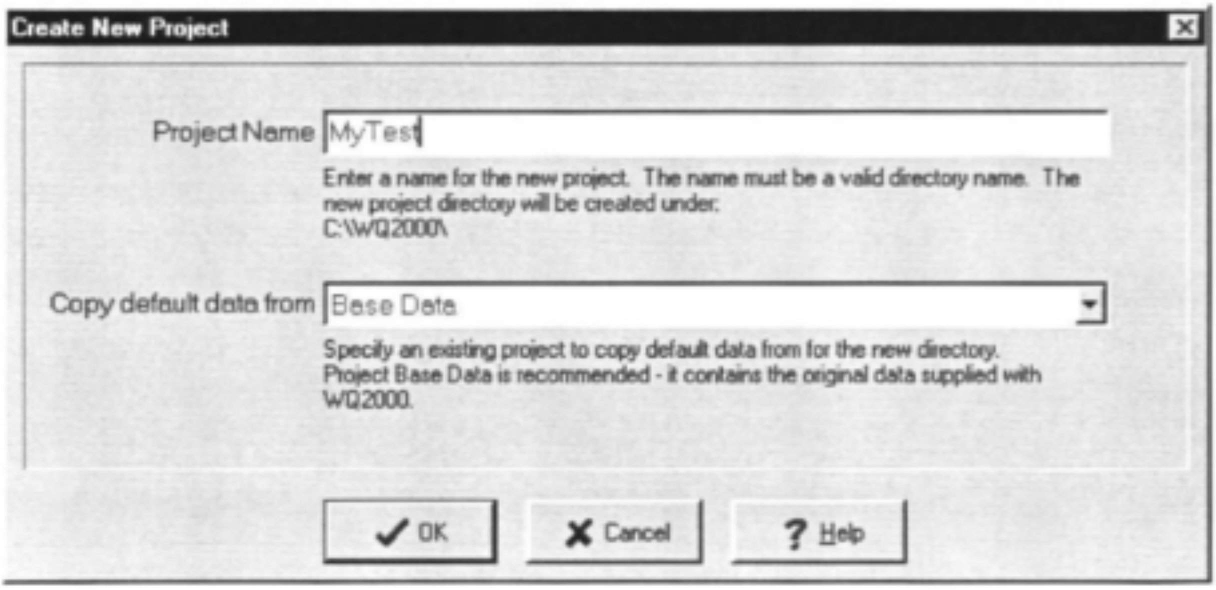
.

Creating a New WQ2000 Project

Also see: About WQ2000 Projects
Opening an existing project

To create a new WQ2000 project, select menu option *File* | *New Project*.

The *Create New Project* dialog will appear.



Enter a name to identify the new project in the *Project Name* field. This name will be used as a directory name ("folder name") on the hard disk; hence it should only contain valid directory name characters. The path for the new directory, which is the WQ2000 program directory, is shown underneath the field for reference.

Specify an existing source project in the *Copy default data from* field. The default is the Base Data project, which contains the 1995 data supplied with Setup. To include data changes from a previous project, select the previous project as source.

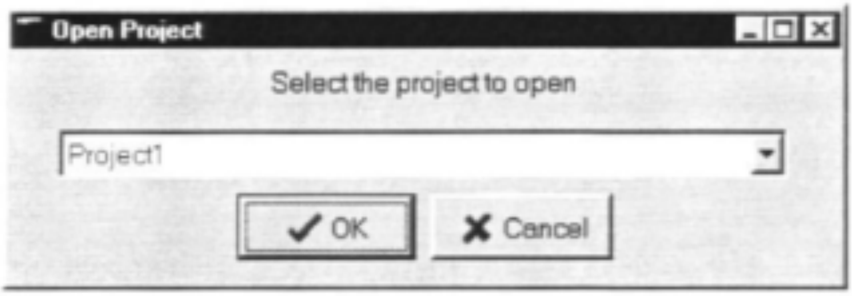
Click OK to create the new project directory and to copy the data files to it. The new project will automatically be selected as the new working project in WQ2000, i.e. the previous project will be closed.

Opening An Existing WQ2000 Project

Also see: About WQ2000 Projects
Creating a new WQ2000 Project

To open an existing project, select menu option *File | Open Project*.

Select a project name from the list of available projects, and click OK.



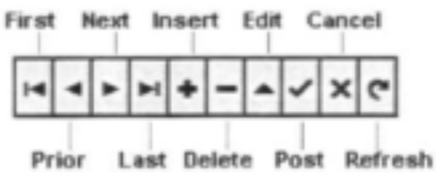
The current project will be closed, and the new project will be opened. The new project will be the default project the next time WQ2000 is started.

Using the database Navigator

The database Navigator is activated when the user selects the *Edit Effluent Data* button in the *Physical Data 1* page.

The Navigator component (a database navigator) is used to move through the data in a database table, and perform operations on the data, such as inserting a blank record or posting (saving) a new or changed record. It is used in conjunction with the data controls, such as the edit fields or the data grid, which gives the user access to the data, either for editing the data, or for simply displaying it.

The database navigator consists of multiple buttons.



When the user chooses one of the navigator buttons, the appropriate action occurs on the table the navigator is linked to. For example, if the user clicks the Insert button, a blank record is inserted in the dataset.

This table describes the buttons on the navigator:

Button	Purpose
First	Sets the current record to the first record
Prior	Sets the current record to the previous record
Next	Sets the current record to the next record
Last	Sets the current record to the last record
Insert	Inserts a new record, and sets the dataset into Edit state, and enable the Cancel and

	Post buttons
Delete	Deletes the current record and makes the next record the current record
Edit	Puts the dataset into Edit state so that the current record can be modified, and enable the Cancel and Post buttons
Post	Writes changes in the current record to the database
Cancel	Cancels edits to the current record, restores the record display to its condition prior to editing, and turns off Insert and Edit states if they are active
Refresh	Redisplays the current record from the dataset, thereby updating the display of the record on the screen

Metadata

The Metadata feature in WQ2000 allows for describing the source of each input value displayed on the screen.

If the [?] button at the bottom of the Physical Data pages is depressed, and mouse cursor is idle above a data field, a message pops up displaying the most recent metadata entry for that field. If the cursor idles above the field's description to the left of the field, the pop-up message gives a general description for the field. The same description is also available in the help screens and manual.

Whenever a value is changed, a dialog pops up requesting a description about the new value. This description is stored together with the new value, the date of the change and the project name.

Select menu option *View; List Metadata* to display a dialog with more metadata information.

By default all metadata history for the currently selected field will be displayed. The metadata for any other field can be selected from the combo-field at the top of the dialog. The first entry in the combo-field will cause the most recent metadata entry for all fields to be displayed.

Metadata entries can also be edited or deleted using this dialog: click the radio button to the left of the entry, and click the *Edit* or *Delete* button at the bottom of the list. The most recent description and the Base Data description cannot be deleted.

To export metadata comments of changes made to the initial base data values, select menu option *File; Export Metadata Changes*. The most recent change for all fields for all quaternaries will be exported to a file. This file can be printed as a report for record purposes, and can also be forwarded to Support for including changed values in future releases of the software. The exported file will be in .html format. This file can be edited in most editing applications, e.g. Open Office, MS Word, MS Excel or even NotePad.

File Maintenance

This option is accessed by selecting *File | File Maintenance* from the menu.

It is recommended to execute File Maintenance after manual manipulation of the data files.

The data used by the WQT model is stored in a database, together with a number of external data files. The experienced user can add and remove external data files, but then needs to update the database accordingly. The File Maintenance option assists in checking for missing or unknown files.

When activated, File Maintenance will prompt if it should check for outflow files (generic file names OUT2.Q & OUT2.TDS) for each quaternary. Quaternary outflow files are always stored as sets of four files: a .Q and a .TDS file for each of Natural and Present day conditions. If one of these files is missing, the remaining files will be deleted, and the flag in the database indicating their existence will be cleared. If a set of four files is found, the flag will be set in the database.

The next prompt asks if it should check for missing monthly data files. All missing files (files mentioned in the database but that do not appear on the project directory) will be reported. Similarly all files found on the project directory that are not mentioned in the database are reported. No files are created or deleted.

Rebuilding Upstream Quaternary Data

This option is activated by selecting menu option *File | Rebuild Upstream Data*.

Upstream data for all quaternaries will be recalculated. These calculations may take a few hours, depending on the processor speed.

User changes are only allowed to quaternary data. Upstream data for a quaternary is calculated automatically by WQ2000, and should not be edited. Due to the time required for calculations, the results of upstream calculations are stored, and the calculations are only repeated after changes for affected quaternaries.

When changes to a quaternary are saved, WQ2000 flags the downstream quaternaries as outdated. Before running the WQT model, WQ2000 first recalculates all outdated upstream data for each of the quaternaries of the current quaternary, and then clears the flag(s).

When advanced users make changes without using WQ2000, the flags indicating the upstream data is outdated might not be set correctly. The Rebuild Upstream Data should always be called after manual changes to the database.

This option is unavailable if there are any unsaved changes.

Quaternary Information - Help Summary

WQ2000 presents water quality parameter data at quaternary level. The WQ2000 database contains more than a thousand parameters for each quaternary. 36 of the most important parameters that can be edited by the user are displayed on the quaternary information screen. This screen is divided into seven pages, each accessible by either clicking the page's tab at the top of the screen, or by clicking the *Next* and *Back* buttons at the bottom of the screen.

The pages are:

- Quaternary Selection page - for selecting the quaternary of interest
- Physical Data page 1, page 2 and page 3 - physical network data
- Parameter page 1 and page 2 - salt washoff model parameters
- Outputs - Options to run the WQT model and to report summary information for the quaternary and display graphs.

Parameters page 1 and *Parameters page 2* are hidden by default, as the values on these pages should normally not be changed. To display these pages, select *Show additional parameter pages* from the *File* menu.

The data displayed on these pages are from the current project file. The project name is displayed in the title bar on top of the screen. See About WQ2000 Projects for more detail.

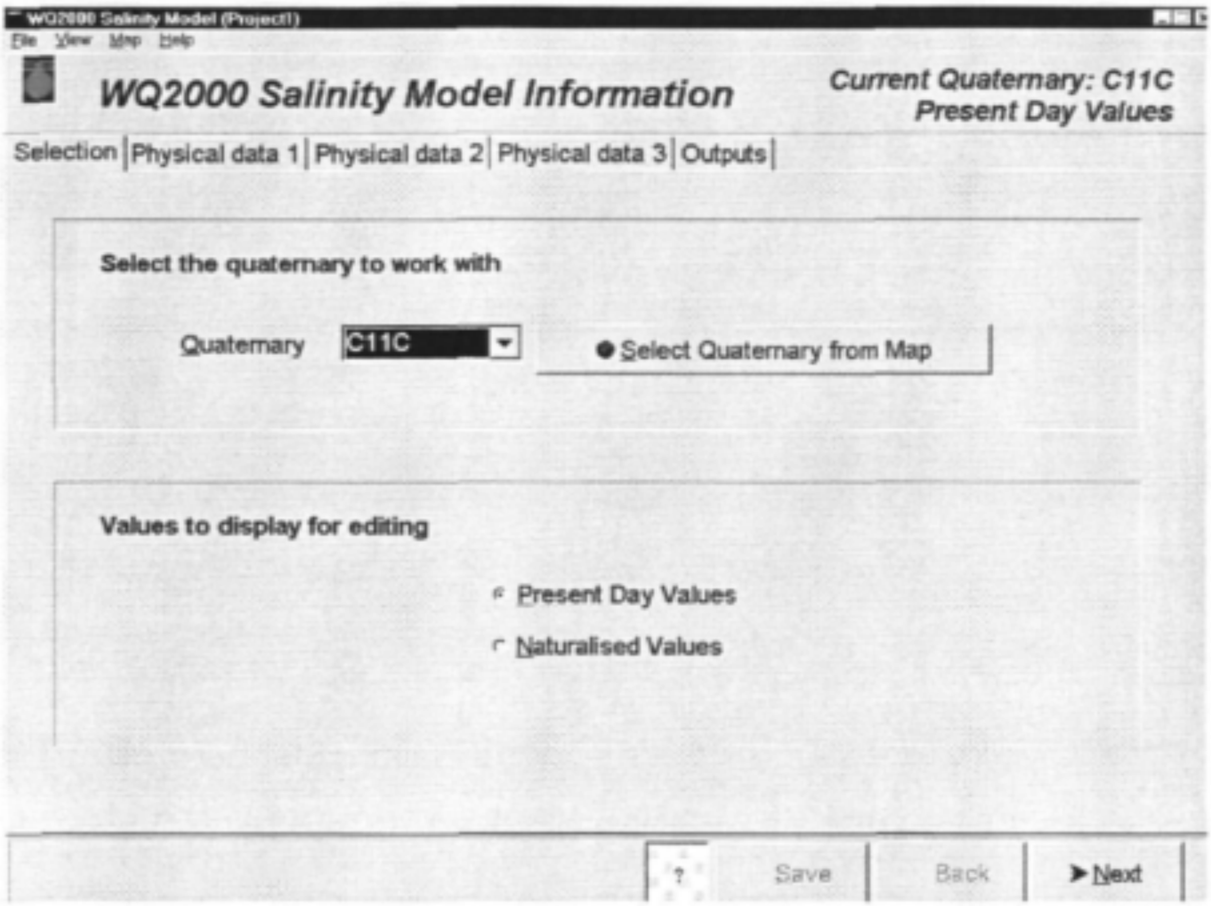
Most of the fields displayed on the physical data pages are numbered. These numbers refer to the numbers on the system diagram, which indicates the position in the network diagram each parameter applies to. See System Diagram for more detail.

Values for the quaternary can be edited on the physical data and parameter pages - see Editing Field Values for mode detail.

Also see Effluent Discharge Values and Minimum outflow from major dam

Quaternary Selection

Also see: Quaternary Information Summary



The Quaternary Selection page is the first page on the WQ2000 screen. Click the *Selection* tab to call up this page. It is used to select the quaternary of interest.

There are four ways of specifying the quaternary:

- Enter the quaternary number directly in the Quaternary field.
- Select it from the list displayed when the arrow button in the field is pressed.
- To select the quaternary from a CMA map, click the *Select Quaternary from Map* button. See Quaternary Selection Map for more detail.
- The selected quaternary number is displayed next to Current Quaternary. If this number is clicked, the quaternary selection map is also displayed.

It is not always clear from the map which quaternary is downstream from which. The Quaternary Hierarchy Diagram can be used to identify the upstream position quaternaries for each quaternary. The WQ2000 database contains data for each quaternary in the Vaal River catchment. Further extensions are expected to provide coverage for the entire the country. This diagram can also be used to identify which quaternaries are available.

Quaternary Selection Map

The quaternary of interest needs to be specified on the Quaternary Selection page. To assist in selecting the quaternary, the *Select Quaternary from Map* button can be clicked to display the selection map.

Initially a map displaying all the Water Management Areas (WMA's) is displayed.

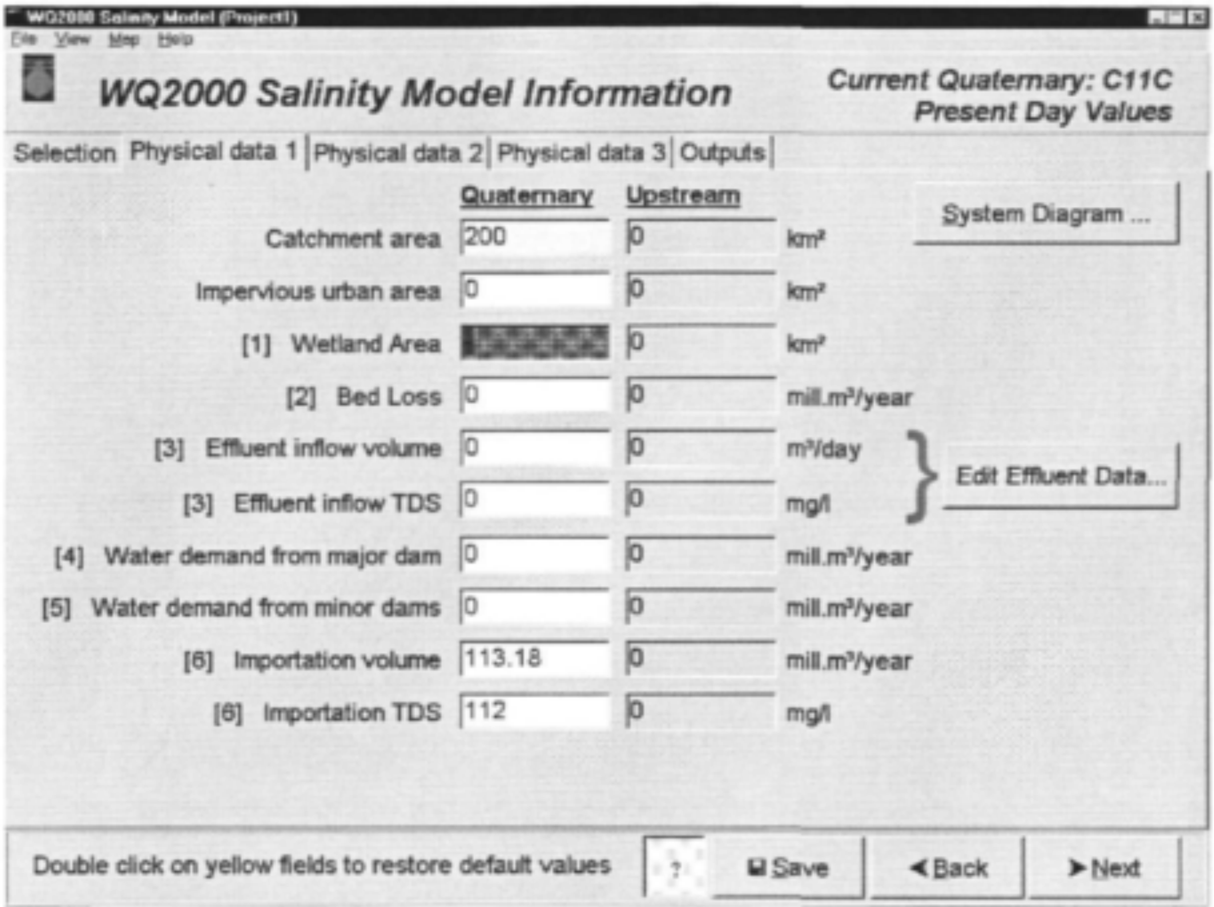
The general procedure is (a) to select a WMA. A map of all the quaternaries in the WMA is then displayed. (b) Select a quaternary in the WMA, and (c) click OK. The data for the quaternary will then be loaded, and the quaternary number will be displayed on the quaternary selection page.

Selecting an area: A WMA or quaternary can be selected by either selecting it from the combo field above the map, or by clicking on its name on the map. Always click close to the centre of the area of interest. The centre closest to the clicked point will be selected, regardless of the boundaries displayed. The name of the clicked area will appear in the combo field. The *Select* button must always be depressed to be able to select an area.

Zooming: The zoom option can be used to enlarge or reduce the image scale. Zooming has no effect on the amount of detail displayed. The image can only be enlarged three levels, and it can only be reduced to its original size. When zooming out from a quaternary map already at it default scale, the CMA map will be displayed. To zoom in or out, click the appropriate button, click on the area of interest the required number of times, and click the Select button to select an area.

Editing Field Values

Also see: Quaternary Information Summary



The detail described here applies to the Physical Data and Parameter pages. These screens display values for the selected quaternary. The left-hand column displays values for the quaternary itself, and the right hand column displays the calculated sum for all upstream quaternaries. The upstream values are not editable, and appear in grey.

The quaternary name and the data value set, Present Day or Naturalised, are displayed above the page tabs. By clicking on the quaternary name another quaternary can be selected. By clicking on the data set name the displayed values alternates between Present Day and Naturalised.

When naturalised data is displayed, some fields in the left-hand column are also disabled (greyed). This is because these fields are not applicable to naturalised conditions.

To display descriptions for the fields displayed, either (a) press F1 to display the help text for the current page, or (b) enable the pop-up help. To enable pop-up help, click the "?" button at the bottom of the screen. It is pressed by default. Move the mouse pointer to one of the data fields, and keep it there for a moment. A description for the field will pop up. The same descriptions are also available in the help screens.

A number appears to the left of some field captions. This number relates to a position on the system diagram. Click the *System Diagram* button to display this diagram.

Whenever a value is changed, a dialog pops up requesting a description about the new value. This description is stored together with the new value, the date of the change and the project name. Refer to the Metadata description for more detail.

When data in any of the fields is edited, it will be validated. A warning message will be displayed if the value is outside a specified range for the specific field. A warning can be ignored, but if a field is displayed in red, either a valid value has to be entered, or the Escape key has to be pressed to restore the original value.

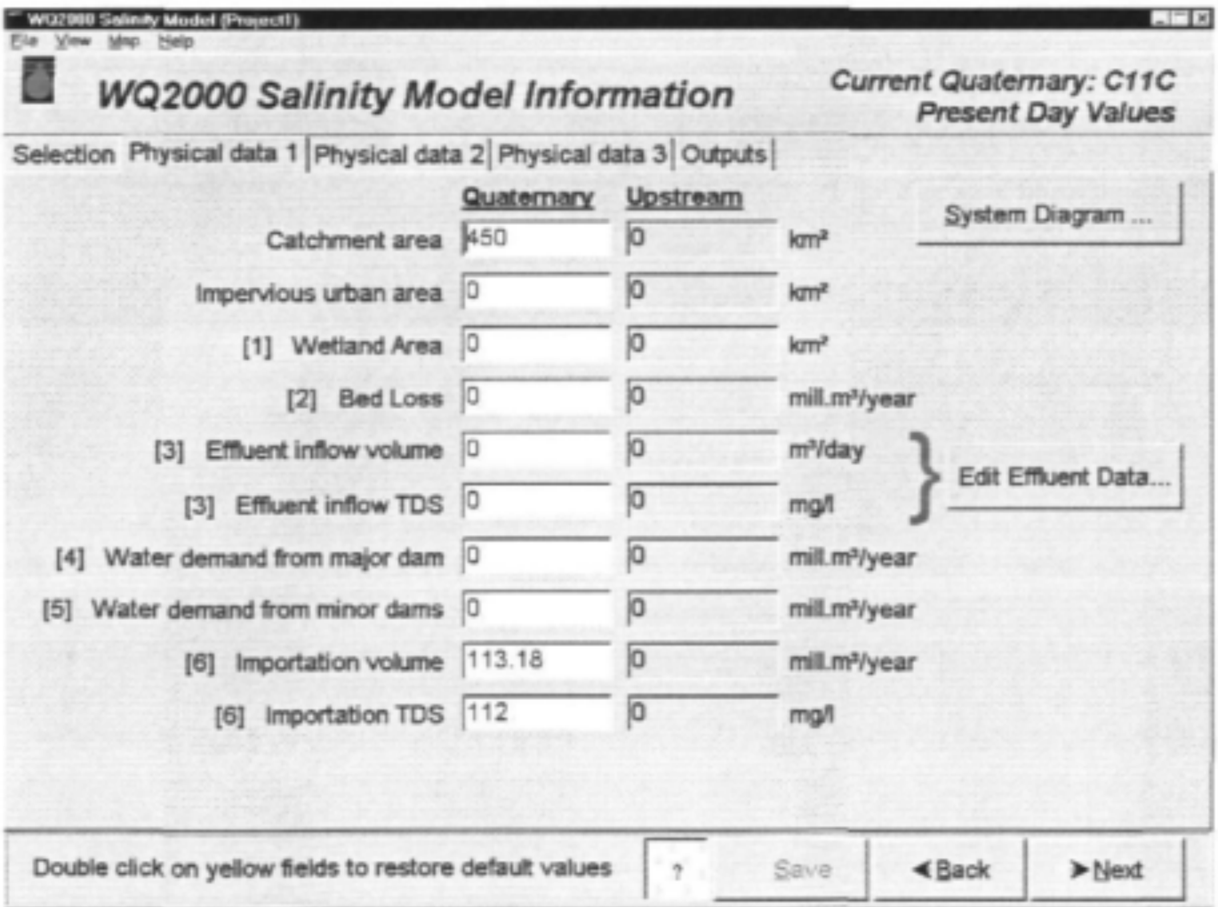
The background of a field turns yellow when it is edited. This is to indicate that this field's value is different form the stored value. To reset to the stored value, double click the field.

To save changes, click the *Save* button at the bottom of the screen. The values for all yellow fields will be written to the project's database, and the fields will be reset to white.

Changed values don't have to be saved before the model can run. The model will use the changed values even if they are not saved.

Physical Data Page 1

Also see: Quaternary Information Summary



The Physical Data page 1 is the second page on the WQ2000 screen. Click the *Physical Data 1* tab to call up this page. It is used to display and edit physical data values used to run the WQT model for the selected quaternary of interest.

Numbers in front of the field titles refer to the position on the system diagram.

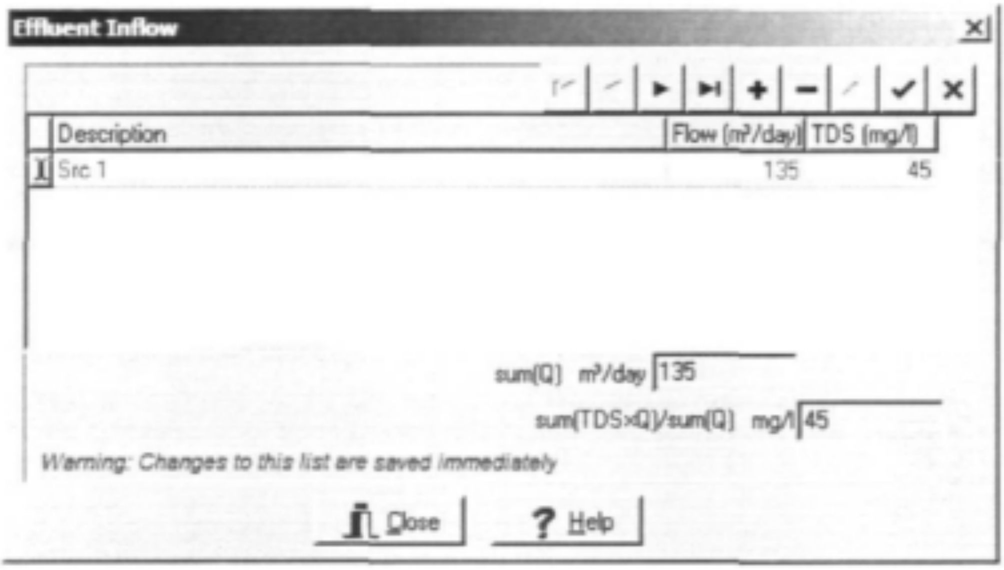
The following fields are displayed on the page:

Quaternary	-	The quaternary of interest selected via the previous screen.
Upstream	-	The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been specified. These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries.
Catchment area	km^2	Effective catchment area of the quaternary or portion thereof to be modelled.
Impervious urban area	km^2	The catchment area that is impervious. This represents the paved portion of urbanised areas that is effectively connected to the surface water drainage system. Aside from interception losses, the rainfall on this portion of the catchment contributes to direct surface runoff, with no infiltration into the soil.
[1] Wetland area	km^2	The surface area of wetlands (vleis) within the catchment.
[2] Bed loss	10^6m^3/year	The estimated annual loss of water into the bed of channels. This excludes the net evaporation loss from channel surfaces, which is calculated separately by the model.
[3] Effluent inflow volume	m^3/day	Average daily flow of all effluent discharge to the catchment. This effluent is assumed to enter the major reservoir (as per the system diagram).
[3] Effluent inflow TDS	mg/l	Flow-weighted average TDS concentration of effluent discharged to the catchment
[4] Major dam water demand	10^6m^3/year	Annual water abstraction requirement from the major dam (as per the system diagram).
[5] Minor dam water demand	10^6m^3/year	Annual water abstraction requirement from the minor dam (as per the system diagram).
[6] Importation volume	10^6m^3/year	Annual inter-basin transfer of water to the catchment.
[6] Importation TDS	mg/l	TDS concentration of water imported to the catchment.

The Effluent Inflow fields cannot be edited on this screen directly. Click the *Edit Effluent Data* button to display the Effluent Discharge Values dialog for entering these values. Unlike other user editable fields, effluent inflow values are immediately saved after being edited, and the field will not become yellow. The displayed value cannot be restored to the original saved value.

Editing Effluent Discharge Values

Also see: Quaternary Information Summary



The Effluent Inflow fields cannot be edited on Physical Data page 1. Click the Edit Effluent Data button to display the Effluent Discharge Values dialog for entering these values.

This dialog allows for entering effluent inflow from different sources. Refer to Navigator for instructions on using the database navigator for data manipulation.

The fields on this dialog are:

Description Description of effluent point source.

Inflow volume m^3/day Average daily flow of all effluent discharge to the point source. This effluent is assumed to enter the major reservoir (as per the system diagram).

Inflow TDS mg/l Flow-weighted average TDS concentration of effluent point source.

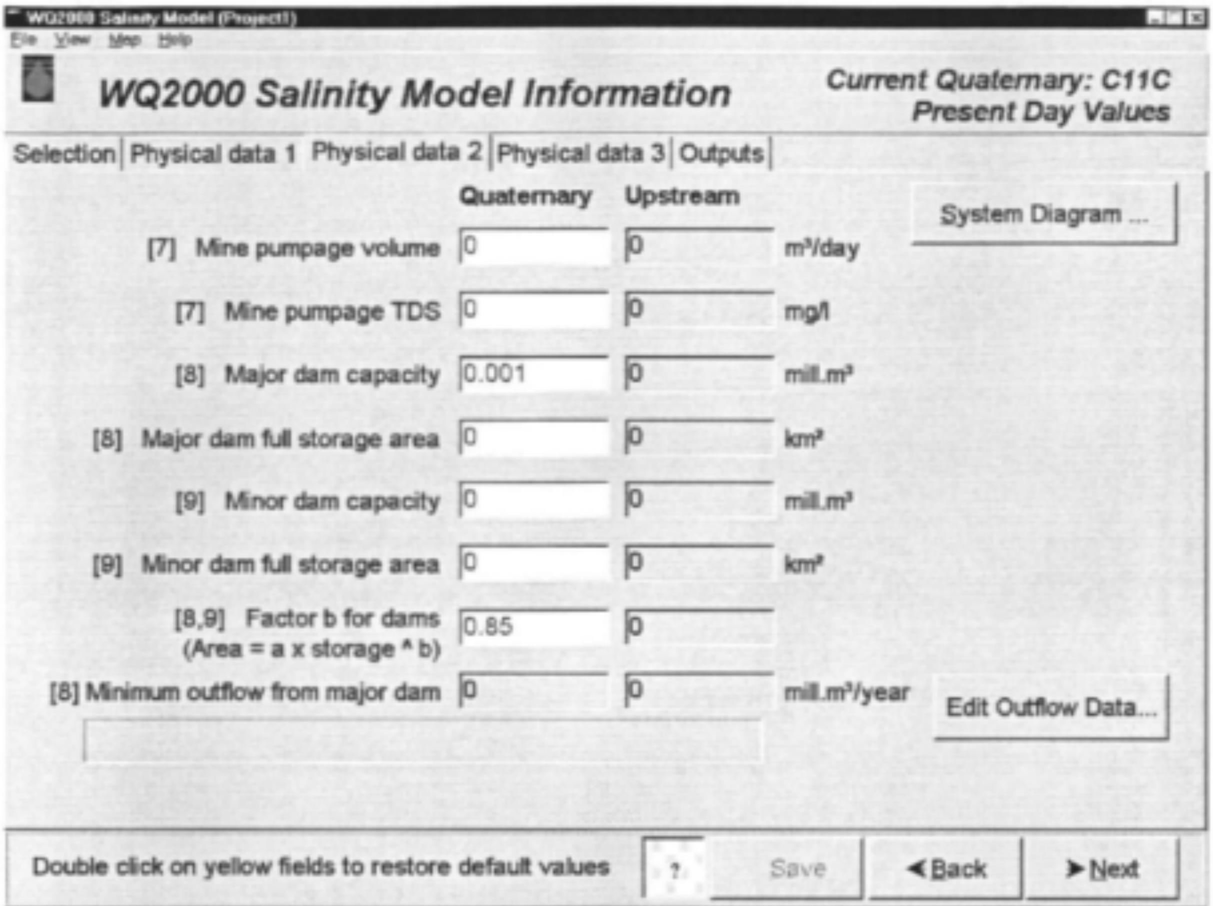
The total flow (Q) and flow-weighted average TDS concentration (TDS x Q)/(Q) for the quaternary will be calculated from all the entered point sources and written to the database and Physical Data page 1.

Unlike other user editable fields, effluent inflow values are immediately saved after being edited, and the field on the Physical Data page will not become yellow, as is the case with other fields that can be reset to their original value.

When user entered data is deleted, the total effluent inflow and concentration will be adjusted to represent the remaining entered values. *If all records are deleted, the total will be zero.*

Physical Data Page 2

Also see: Quaternary Information Summary



The Physical Data page 2 is the third page on the WQ2000 screen. Click the *Physical Data 2* tab to call up this page. It is used to display and edit physical data values used to run the WQT model for the selected quaternary of interest.

Numbers in front of the field titles refer to the position on the system diagram.

The following fields are displayed on the page:

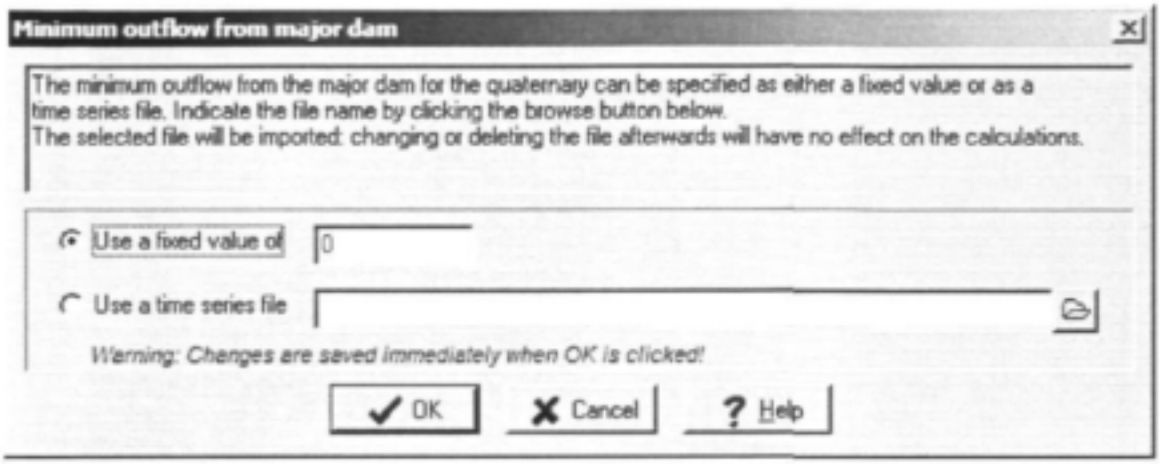
Quaternary	-	The quaternary of interest selected via the previous screen.
Upstream	-	The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been specified. These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries.
[7] Mine pumpage volume	m^3/day	Mine water discharge to the catchment. The salinity of this water is independent of the water supply from surface water, since this water is assumed to be pumped from underground.
[7] Mine pumpage TDS	mg/l	Average TDS concentration of mine pumpage water discharge.

[8] Major dam capacity	10^6m^3	Full storage capacity of the major dam. The major dam is taken as being on the main stem of the river and supported from upstream major dams (see the system diagram). Minor dams do not support this dam.
[8] Major dam full storage area	km^2	Surface area of major dam when 100% full.
[9] Minor dam capacity	10^6m^3	Full storage capacity of the combined minor dams. Minor dams are taken as being off the main stem of the river and are not supported by any other dams. Nor do they support downstream dams. These dams mostly comprise farm dams and small dams used to supply water to towns and industries. Minor dams have been aggregated into one effective "minor dam". This is an accepted hydrological modelling practice that has been adopted since many such dams are typically dispersed through each quaternary catchment. Modelling them as a single effective dam provides a reasonable representation of the cumulative effect of such dams on catchment runoff.
[9] Minor dam full storage area	km^2	Combined surface area of minor dams when 100% full.
[8,9] Factor b for dams: (Area = a x storage^b)	-	Factor used to estimate the dam surface area for any storage state. Factor a is calculated *internally from the specified full* storage capacity (FSC) and full storage area (FSA) specified above as: a = FSA x FSC^{-b} Initially the factor for the major dam is displayed, which may differ from the minor dams. The edited value is however used for both major and minor dams.
[8] Minimum outflow from major dam	mill.m³/year	Minimum monthly release from the major dam. This is typically the dam compensation release. It can also represent the flow need to meet downstream water requirements. This is only an approximation, since the downstream system requirement will change from month to month in response to climatic variation and dam storage state. When this effect is important it is strongly recommended that a more detailed system analysis is undertaken.

The Minimum outflow from major dam fields cannot be edited on this screen directly. Click the *Edit Outflow Data* button to display the *Minimum outflow from major dam* dialog for entering these values. Unlike other user editable fields, these values are immediately saved after being edited, and the field will not become yellow. The displayed value cannot be restored to the original saved value.

Minimum volume outflow from the major dam

The *Minimum volume outflow from the major dam* fields cannot be edited on Physical Data page 2. Click the *Edit Outflow Data* button to display the *Minimum outflow from major dam* dialog for entering these values.



Either a constant value or a time series file can be specified for *Minimum outflow from major dam*. If a time series file is specified, the source file's name will be displayed below the field on *Physical Data Page 2*.

Unlike other user editable fields, these values are immediately saved after being edited, and the field will not become yellow. The displayed value cannot be restored to the original saved value.

Enter the constant value or file name on the dialog, and click OK to save the input.

The selected file will be imported into the WQ2000 database: changing or deleting the source file afterwards will have no effect on the calculations. To apply changes to this file, call up this dialog again, browse for the file and click OK.

The file must be a text file in the following format:

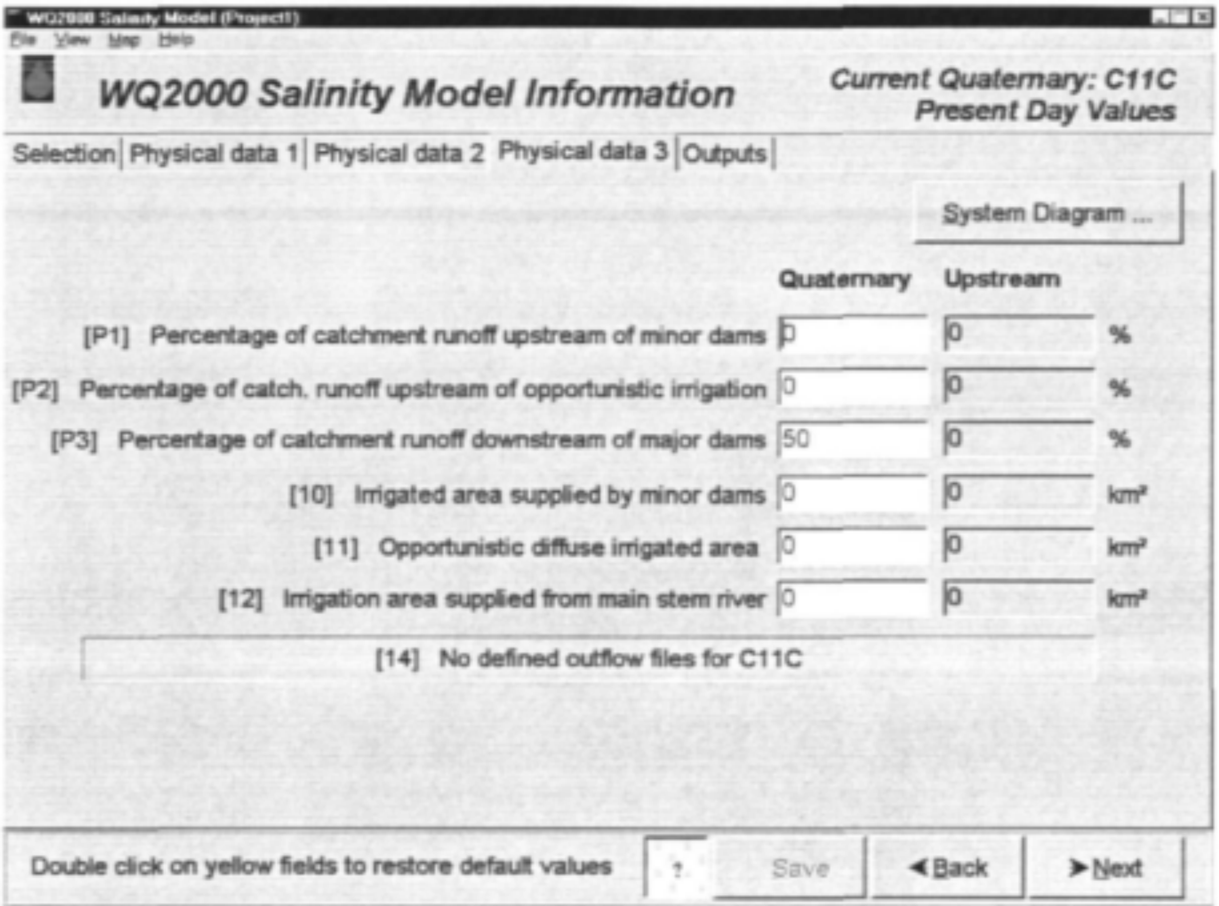
- One or more separator characters separate all values. A separator character is a comma, space or tab.
- The first column is the year, including the century, e.g. 1990, optionally prefixed by separator characters.
- This is followed by 12 monthly values. Any text after the 12th value is ignored.
- The first monthly value in each row represents October for the specified year, and the 12th value represents the value for September the following year.
- Monthly values are real or integer values in the range 0 to 9999999.
- No thousand-separators are allowed. The decimal separator must be a point (.).
- Data must start at 1925, and must be without any gaps up to 1994. Any data after 1994 will be ignored.
- Header rows are allowed, providing they are not blank and the first non-separator character in each header row is a letter and not a number.
- Some standard formats, which include an annual total column, and totals or averages at the bottom, are acceptable.

Before the file is imported, its format will first be verified, and errors will be reported.

For an example of an acceptable file see \WQ2000\Base Data\B10.URB.

Physical Data Page 3

Also see: Quaternary Information Summary



The Physical Data page 3 is the fourth page on the WQ2000 screen. Click the *Physical Data 3* tab to call up this page. It is used to display and edit physical data values used to run the WQT model for the selected quaternary of interest.

Numbers in front of the field titles refer to the position on the system diagram.

The following fields are displayed on the page:

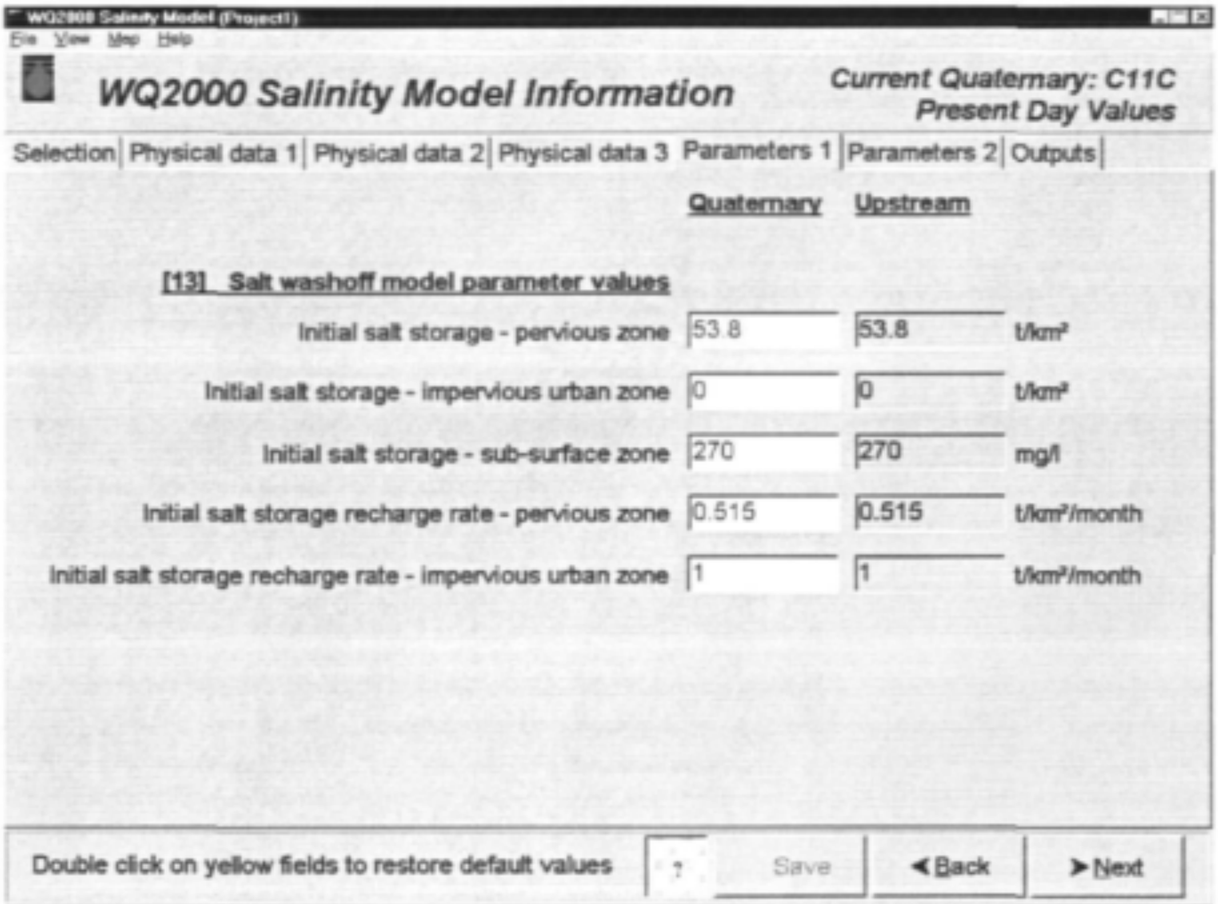
Quaternary	-	The quaternary of interest selected via the previous screen.
Upstream	-	The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been specified. These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries.
[P1] Percentage of catchment runoff upstream of minor dams	%	The percentage of the catchment runoff that is assumed to enter upstream of minor dams (see system diagram). This is an estimated average for all the aggregated minor dams.

[P2] Percentage of catchment runoff upstream of opportunistic irrigation	%	The percentage of the catchment runoff that is assumed to enter upstream of diffuse irrigation areas that are not supplied by minor dams (see system diagram). Such irrigation areas are not supplied from the main stem channel, and hence cannot be supported from upstream major dams.
[P3] Percentage of catchment runoff downstream of major dams	%	The percentage of the catchment runoff remaining after interception of minor dams and diffuse irrigation that enters the system below the major dam (see system diagram).
[10] Irrigated area supplied by minor dams	km^2	Irrigation area located directly below minor dams and is supplied from them (see system diagram).
[11] Opportunistic diffuse irrigation area	km^2	Diffuse catchment irrigation direct from local streams that is not supplied by minor dams (see system diagram). These irrigation areas are not adjacent to the main stem river and are not supplied by major dams.
[I2] Irrigation area supplied from main stem river	km^2	Irrigation area adjacent to the main stem river that can be supported from upstream major dams (see system diagram). This irrigation is assumed to be located downstream of the major dam.

Parameters Page 1

Warning! Only users skilled in the use of the WQT model (Allen and Herold, 1988) should attempt to change the model calibration parameters. Calibration requires attention to a number of important factors. Failure to follow the procedures properly will lead to a unbalanced calibration, which will lead to misleading results. Further information is given in Department of Water Affairs report P C000/00/9490 (Stewart Svirdov & Oliver, 1990).

Parameters page 1 and *Parameters page 2* are hidden by default. To display these pages, select *Show additional parameter pages* from the *File* menu.



The Parameter Data page 1 is the fifth page on the WQ2000 screen. Click the *Parameters 1* tab to call up this page. It is used to display and edit salt washoff values used to run the WQT model for the selected quaternary of interest. A description of these values is given by Herold and Allen in DWAF report P C000/00/7086: Vaal River System Analysis, Water quality modelling, Volume A: Water quality calibration model, Pretoria, 1988.

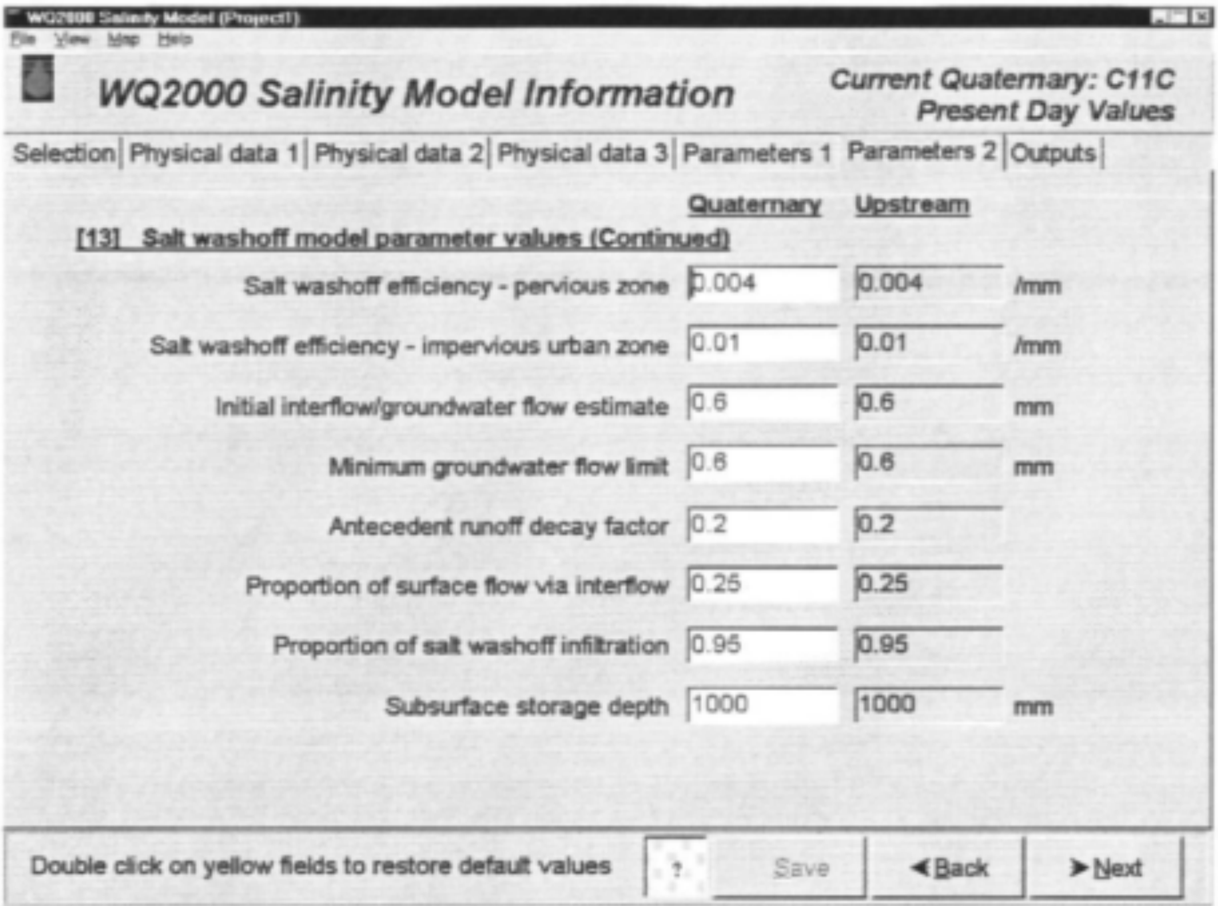
The following fields are displayed on the page:

Quaternary - The quaternary of interest selected via the previous screen.

Upstream - The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been specified.

		These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries.
Initial salt storage - pervious zone	t/km^2	Calibrated WQT model parameter defining the starting salt storage per unit area for the pervious portion of the catchment. (Parameter SWSSP in the WQT model.)
Initial salt storage - impervious urban zone	t/km^2	Calibrated WQT model parameter defining the starting salt storage per unit area for the impervious portion of the catchment. (Parameter SWSSU in the WQT model.)
Initial salt storage - sub-surface zone	mg/l	Calibrated WQT model parameter defining the starting salt storage concentration in the hydrologically active portion of the soil. (Parameter SWSSG in the WQT model.)
Initial salt storage recharge rate - pervious zone	$t/km^2/month$	Calibrated WQT model parameter defining the initial rate at which the salt storage in the pervious portion of the catchment is replenished. (Parameter SWSSRP in the WQT model.) The pervious area catchment store is increased by this amount each month. A portion of the salt is washed from the store by rainfall, part of which enters direct surface runoff, the remainder infiltrating to the sub-surface salt storage.
Initial salt storage recharge rate - urban zone	$t/km^2/month$	Calibrated WQT model parameter defining the initial rate at which the salt storage in the impervious portion of the catchment is replenished. (Parameter SWSSRU in the WQT model.) The impervious area catchment store is increased by this amount each month. A portion of the salt is washed from the store by rainfall, all of which enters direct surface runoff.

Parameters Page 2



The Parameter Data page 2 is the sixth page on the WQ2000 screen. Click the *Parameters 2* tab to call up this page. It is used to display and edit salt washoff values used to run the WQT model for the selected quaternary of interest. A description of these values is given by Herold and Allen in DWAF report P C000/00/7086: Vaal River System Analysis, Water quality modelling, Volume A: Water quality calibration model, Pretoria, 1988.

Note: *Parameters page 1* and *Parameters page 2* are hidden by default. To display these pages, select *Show additional parameter pages* from the *File* menu.

The following fields are displayed on the page:

Quaternary	-	The quaternary of interest selected via the previous screen.
Upstream	-	The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been specified. These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries.
Salt washoff efficiency - pervious zone	mm^{-1}	Calibrated WQT model parameter defining the efficiency with which salts are washed from the pervious area salt store in response to rainfall. (Parameter SWEP in the WQT model.) The amount of the stored salt washed out each month follows the

decay equation:

$$Wper = Sper \times (1 - e^{-SWEP*R})$$

Where:

Wper =	salt load washed from pervious storage (t/km^2)
Sper =	salt load in pervious storage (t/km^2)
R =	rainfall (mm)

Salt washoff efficiency - impervious urban zone	mm^{-1}	Calibrated WQT model parameter defining the efficiency with which salts are washed from the impervious area salt store in response to rainfall. (Parameter SWEU in the WQT model.) The amount of the stored salt washed out each month follows the decay equation:

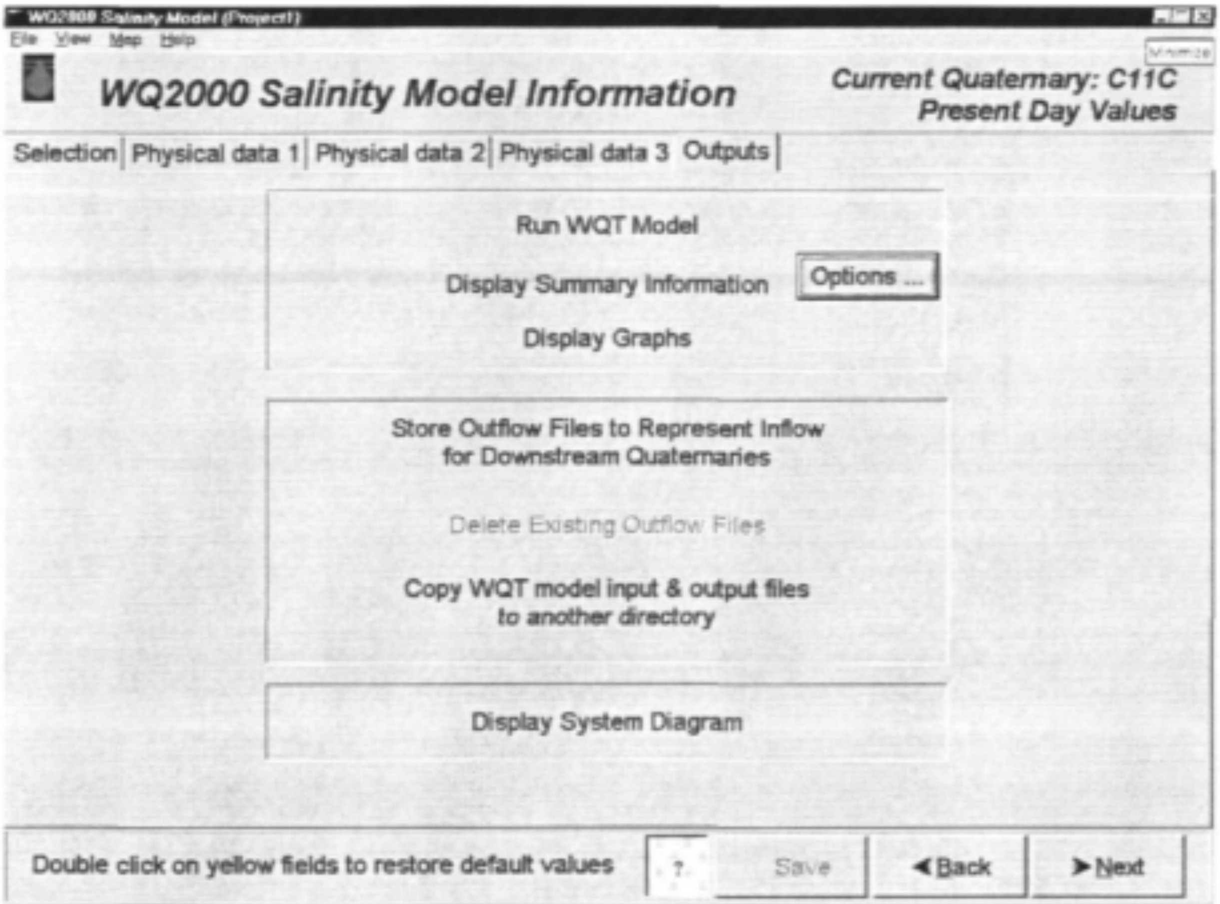
$$Wurb = Surb \times (1 - e^{-SWEU*R})$$

Where:

Wurb =	salt load washed from impervious storage (t/km^2)
Surb =	salt load in impervious storage (t/km^2)
R =	rainfall (mm)

	mm	Calibrated WQT model parameter giving the initial estimate of the surface runoff derived from sub-surface flow from groundwater and interflow. (Parameter SWEQG in the WQT model.)
Minimum groundwater flow limit	mm	Calibrated WQT model parameter defining the minimum subsurface flow. (Parameter SWEQG in the WQT model.) Hence if the monthly catchment runoff is less than SWEQG, then the entire flow is assumed to be surface flow.
Antecedent runoff decay factor	-	Calibrated WQT model parameter defining the proportion of the previous month's sub-surface flow that is carried forward to the current month. (Parameter SWRDF in the WQT model.)
Proportion of surface flow via interflow	-	Calibrated WQT model parameter defining the proportion of the current month's surface runoff (after subtracting the subsurface flow carried forward from the previous month) attributed to sub-surface flow. (Parameter SWPAF in the WQT model.)
Proportion of salt washoff infiltration	-	Calibrated WQT model parameter defining the proportion of the salt washed out of the pervious surface salt store that infiltrates to the subsurface storage zone. (Parameter SWPAF in the WQT model.)
Subsurface storage depth	mm	Calibrated WQT model parameter defining the water depth of the catchment subsurface storage zone. (Parameter SWHGW in the WQT model.) This is an empirical model parameter used to simulate the slow lagged response of the combined vadoze zone and the hydrologically significant active portion of the groundwater.

Model Outputs



The Model Outputs page is the last page on the WQ2000 screen. Click the *Outputs* tab to call up this page. It is used to run the model and use the processed results as described below.

The options on this page are the following:

- **Run WQT Model:** This option simply runs the WQT model for the selected quaternary, using the changes made on the previous pages. The changes do not have to be saved before the model will use them. No output is displayed.

  WQ2000 first processes all upstream quaternaries if necessary. It then creates the parameter files for this quaternary, and then runs the model. The model is actually executed six times for different sections and phases of the network.

  On completion a message will display "Done". If an error occurs, an error message will be displayed, and processing will terminate. All model parameter input and output files are left as is until they are recreated for another run of the model.

- **Display Summary Information:** The Summary Information report is displayed. An example of a Summary Information Report is given in Appendix A. If the WQT model has not already run, the above procedure will be executed automatically. In most cases this will be the only option the user will need to select on this page.

- **Display Graphs:** A menu for selecting a graph output option is displayed. Depending on the selected option, the WQT model will be executed automatically for the selected quaternaries.

- **Store Outflow Files:** Stores the result of the previous run of the WQT model. OUT2.Q and

OUT2.TDS represent these files on the advanced system diagram.

Outflow files represent inflow into the downstream quaternary, from the current quaternary and all quaternaries above it. When processing the downstream quaternary, WQ2000 does not have to process any quaternaries above the point where it finds an outflow file. This can save a considerable amount of processing time.

For some quaternaries more accurate measured results are available than those simulated by the model. If these files are copied as outflow files to the project directory, they will automatically be detected by the File Maintenance option, and will then be used by WQ2000 to produce more accurate results.

If data for a quaternary with a saved outflow file, or a quaternary upstream of it, is changed, the saved outflow files downstream of it will automatically be replaced by the new calculated files.

The **Quaternary Hierarchy Diagram** option can be used to see which quaternaries have saved outflow files. All these quaternary names are preceded by "<<<".

- **Delete existing outflow files:** This option deletes saved outflow files for the selected quaternary. This option is only available if there are saved files for the quaternary.

- **Copy WQT Model files:** This option is used to copy model input and output files to another directory for future use. Every time the model is run, existing files in the model directory are replaced with new files for the selected quaternary, including it's changes (edited values).

  Model directories should not be confused with project directories. Project directories contains the WQ2000 database and files for all quaternaries. A model directory only contains parameter files for the current quaternary, and WQT model program files.

  There are two model directories: one for present day values, and another for naturalised values. This option only copies one of these two at a time. Select this option again to copy the other set of files as well.

  The default destination directory is
  <WQ2000_Program_Directory>\User\QQQQ_PPPP
  where QQQQ will be the quaternary number
  and PPPP will either be Natural or Pday, depending on the data set selected,
  e.g. C:\WQ2000\Data\C11A_PDay.

  Data from the present day and naturalised directories should not be copied to the same destination, as some files will be overwritten.

  Refer to Running the model manually for more information about the model.

- **Display System Diagram:** The System Diagram is displayed. This option has the same function as the *System Diagram* buttons on the previous screen pages.

Summary Information

The *Summary Information* report option is available from the Model Output page on the WQ2000 screen, and applies to the current selected quaternary.

The report presents results from the WQT model, as well as some of the input parameters used to get these results. All changes made by the user are shown on the report, even if they were not saved at the time the report was produced. This allows the user to easily identify what assumptions were made to produce the results.

The parameters presented on the report are the following:

Quaternary Present day	Results from simulation for present day catchment development conditions. The results in this column are for those portions of the catchment that are not influenced by inflow from upstream quaternary catchments. Represented by the bottom half of the system diagram with no inflow from upstream quaternary catchments [15] or major dams [16]. Water importation direct to the quaternary [6] is included.
Quaternary Natural	Results from simulation for natural (virgin) undeveloped catchment. The results in this column are for those portions of the catchment that are not influenced by inflow from upstream quaternary catchments. Represented by the bottom half of the system diagram with no inflow from upstream quaternary catchments [15] or major dams [16]. Water importation direct to the quaternary [6] is included.
Cumulative Present day	Results from simulation for present day catchment development conditions. The results in this column are for the entire system, including the influence of inflows from upstream quaternary catchments.
Cumulative Natural	Results from simulation for natural (virgin) undeveloped catchment. The results in this column are for the entire system, including the influence of inflows from upstream quaternary catchments.

Physical Data (Inputs)	These values are the same as on Physical Data pages 1 to 3 on the input screen.
Catchment area (km²)	*Effective catchment area of the quaternary or portion thereof to be modelled.*
Impervious paved area (km²)	The catchment area that is impervious. This represents the paved portion of urbanised areas that is effectively connected to the surface water drainage system. Aside from interception losses, the rainfall on this portion of the catchment contributes to direct surface runoff, with no infiltration into the soil.
[1] Wetland Area (km²)	The surface area of wetlands (vleis) within the catchment.
[1] Bed Loss (10^6m^3/year)	Specified annual loss of water into the bed of channels and wetlands. This excludes the net evaporation loss from channel or wetland surfaces, which is calculated separately by the model.
[3] Average effluent inflow volume (10^6m^3/year)	Specified average daily flow of all effluent discharge to the catchment. This effluent is assumed to enter the major reservoir (as per the system diagram).
[3] Average effluent inflow TDS concentration (mg/l)	Flow-weighted average TDS concentration of effluent discharged to the catchment
[4] Water demand from major dam (10^6m^3/year)	Annual water abstraction requirement from the major dam (as per the system diagram).
[5] Water demand from minor dams (10^6m^3/year)	Annual water abstraction requirement from the minor dam (as per the system diagram).
[6] Importation (10^6m^3/year)	Specified annual inter-basin transfer of water to the catchment.
[6] Average water importation TDS concentration (mg/l)	Specified average TDS concentration of water imported to the quaternary catchment (route [6] of system diagram).
[7] Mine pumpage (10^6m^3/year)	Specified mine water discharge to the catchment. The salinity of this water is independent of the water supply from surface water, since this water is assumed to be pumped from underground.
[7] Mine Pumpage TDS concentration (mg/l)	Average TDS concentration of mine pumpage water discharge.
[8] Major dam storage capacity (10^6m^3)	Full storage capacity of the major dam. The major dam is taken as being on the main stem of the river and supported from upstream major dams (see the system diagram). Minor dams do not support this

	dam.
[8] Major dam surface area (km²)	Surface area of major dam when 100% full.
[9] Minor dams storage capacity (10^6m^3)	Full storage capacity of the combined minor dams. Minor dams are as taken being off the main stem of the river and are not supported by any other dams. Nor do they support downstream dams. These dams mostly comprise farm dams and small dams used to supply water to towns and industries. Minor dams have been aggregated into one effective "minor dam". This is an accepted hydrological modelling practice that has been adopted since many such dams are typically dispersed through each quaternary catchment. Modelling them as a single effective dam provides a reasonable representation of the cumulative effect of such dams on catchment runoff.
[9] Minor dams surface area (km²)	Combined surface area of minor dams when 100% full.
[8,9] Factor b for dams: (AREA = a x STORAGE^b)	Factor used to estimate the dam surface area for any storage state. Factor a is calculated internally from the specified full storage capacity (FSC) and full storage area (FSA) specified above as: a = FSA x FSC^{-b}
[8] Minimum outflow from major dam (10^6m^3/year)	Minimum rate at which water is released from the major dam. A constant discharge rate is assumed.
[P1] Proportion of catchment runoff upstream of minor dams	The proportion of the catchment runoff that is assumed to enter upstream of minor dams (see system diagram). This is an estimated average for all the aggregated minor dams.
[P2] Proportion of catchment upstream of *unregulated irrigation*	The proportion of the catchment runoff that is assumed to enter upstream of diffuse irrigation areas that are not supported by minor *dams (see system diagram). Such irrigation areas are not supplied* from the main stem channel, and hence cannot be supported from upstream major dams.
[P3] Proportion of catchment downstream of major dams	The proportion of the catchment runoff remaining after interception of minor dams and diffuse irrigation that enters the system below the major dam (see system diagram).
[10] Irrigated area supplied by minor dams (km²)	Irrigation area located directly below minor dams and is supplied from them (see system diagram).
[11] Unsupported diffuse irrigated area (km²)	Diffuse catchment irrigation direct from local streams that is not supported by minor dams (see system diagram). These irrigation areas are not adjacent to the main stem river and are not supported by major dams.
[12] Irrigation area supplied from main stem river (km²)	Irrigation area adjacent to the main stem river that can be supported from upstream major dams (see system diagram). This irrigation is assumed to be located downstream of the major dam.
SW module parameters (Inputs) [13]	WQT model Salt Washoff module parameter values used in the simulation.
Initial salt storage – pervious zone (t/km²)	Calibrated WQT model parameter defining the starting salt storage per unit area for the pervious portion of the catchment. (Parameter SWSSP in the WQT model.)
Initial salt storage - impervious urban zone (t/km²)	Calibrated WQT model parameter defining the starting salt storage per unit area for the impervious portion of the catchment. (Parameter SWSSU in the WQT model.)
Initial salt storage sub-surface zone (mg/l)	Calibrated WQT model parameter defining the starting salt storage concentration in the hydrologically active portion of the soil. (Parameter SWSSG in the WQT model.)
Initial salt storage recharge rate - pervious zone (t/km²/month)	Calibrated WQT model parameter defining the initial rate at which the salt storage in the pervious portion of the catchment is replenished. (Parameter SWSSRP in the WQT model.) The pervious area catchment store is increased by this amount each month. A portion of the salt is washed from the store by rainfall, part of which enters direct surface runoff, the remainder infiltrating to the sub-surface salt storage.

Initial salt storage recharge rate - urban zone (t/km²/month)	Calibrated WQT model parameter defining the initial rate at which the salt storage in the impervious portion of the catchment is replenished. (Parameter SWSSRU in the WQT model.) The impervious area catchment store is increased by this amount each month. A portion of the salt is washed from the store by rainfall, all of which enters direct surface runoff.
Salt washoff efficiency – pervious zone (1/mm)	Calibrated WQT model parameter defining the efficiency with which salts are washed from the pervious area salt store in response to rainfall. (Parameter SWEP in the WQT model.) The amount of the stored salt washed out each month follows the decay equation: $Wper = Sper \times (1 - e^{-SWEP*R})$ Where: Wper = salt load washed from pervious storage (t/km^2) Sper = salt load in pervious storage (t/km^2) R = rainfall (mm)
Salt washoff efficiency – urban impervious zone (1/mm)	Calibrated WQT model parameter defining the efficiency with which salts are washed from the impervious area salt store in response to rainfall. (Parameter SWEU in the WQT model.) The amount of the stored salt washed out each month follows the decay equation: $Wurb = Surb \times (1 - e^{-SWEU*R})$ Where: Wurb = salt load washed from impervious storage (t/km^2) Surb = salt load in impervious storage (t/km^2) R = rainfall (mm)
Initial interflow/groundwater flow estimate (mm)	Calibrated WQT model parameter giving the initial estimate of the surface runoff derived from sub-surface flow from groundwater and interflow. (Parameter SWEQG in the WQT model.)
Minimum groundwater flow limit (mm)	Calibrated WQT model parameter defining the minimum subsurface flow. (Parameter SWEQG in the WQT model.) Hence if the monthly catchment runoff is less than SWEQG, then the entire flow is assumed to be surface flow.
Antecedent runoff decay factor	Calibrated WQT model parameter defining the proportion of the previous month's sub-surface flow that is carried forward to the current month. (Parameter SWRDF in the WQT model.)
Proportion of surface flow via interflow	Calibrated WQT model parameter defining the proportion of the current month's surface runoff (after subtracting the subsurface flow carried forward from the previous month) attributed to sub-surface flow. (Parameter SWPAF in the WQT model.)
Proportion of salt washoff infiltration	Calibrated WQT model parameter defining the proportion of the salt washed out of the pervious surface salt store that infiltrates to the subsurface storage zone. (Parameter SWPAF in the WQT model.)
Subsurface storage depth (mm)	Calibrated WQT model parameter defining the water depth of the catchment subsurface storage zone. (Parameter SWHGW in the WQT model.) This is an empirical model parameter used to simulate the slow lagged response of the combined vadoze zone and the hydrologically significant active portion of the groundwater.;

Upstream inflow

[15] Number of defined inflows	Number of upstream inflows to the selected quaternary catchment for which time series files of simulated monthly flow and TDS concentration have been stored.
[15] Defined upstream inflow volume	Mean annual inflow from upstream quaternaries. This is the average of the defined monthly flows that have been stored from previous model

($10^6 m^3$/year)	runs.
[15] Defined upstream inflow TDS concentration (mg/l)	Flow-weighted mean TDS concentration calculated from file of defined monthly values.

Results

[14] Average TDS concentration (mg/l)	Simulated average TDS concentration outflow from the catchment (via route [14] in system diagram).
[14] Median TDS concentration (mg/l)	Median TDS concentration of simulated monthly outflow from catchment via route [14] in system diagram. Monthly TDS concentration exceeded for 50% of the time.
[14] 95 percentile TDS concentration (mg/l)	Simulated monthly TDS concentration in catchment outflow via route [14] exceeded for 5% of the time.
[14] 98 percentile TDS concentration (mg/l)	Simulated monthly TDS concentration in catchment outflow via route [14] exceeded for 2% of the time.
[14] 95 percentile TDS concentration of driest month (Aug) (mg/l)	Simulated TDS concentration in catchment outflow via route [14] for the driest month (in this case August) exceeded for 5% of the time.
[14] Average TDS concentration in driest year (1991) (mg/l)	Simulated average TDS concentration in catchment outflow via route [14] for the driest year (in this case 1991).
[14] Flow-weighted average TDS concentration (mg/l)	Simulated flow-weighted average TDS concentration of outflow from the catchment (via route [14] in system diagram). Calculated as Sum (Q*C)/Sum (Q), where Q = monthly flows and C = monthly TDS concentrations.
[13] Average catchment runoff volume ($10^6 m^3$)	Average annual runoff from the selected quaternary catchment. This includes urban runoff, but excludes the effects of irrigation, dams, mine pumpage and effluent discharge, abstractions, wetlands, bed loss and water importation.
[13] Average catchment runoff TDS concentration (mg/l)	Simulated average TDS concentration of the washoff from the selected quaternary catchment (i.e. WQT model Salt Washoff module [13] salt export concentration.)
[8] Average TDS concentration in major dam (mg/l)	Average simulated TDS concentration in the quaternary major dam. (I.e. arithmetic average of simulated monthly TDS concentrations in dam.) This value represents the concentration experienced by a user drawing water from the dam at a constant rate.
[8] Flow-weighted average TDS concentration of spillage from major dam (mg/l)	Flow-weighted average simulated TDS concentration of the water spilled from the dam. This is generally lower than the arithmetic average concentration, since during flood events large volumes of water are spilled from the dam at diluted concentrations.
[14] MAR ($10^6 m^3$)	Simulated mean annual outflow from catchment (via route [14] in system diagram).
[14] Mean annual TDS load (t)	Simulated mean annual TDS load in the outflow from the catchment (via route [14] in the system diagram).

Graphical Output

The *Display Graphs* option is available from the Model Output page on the WQ2000 screen, and applies to the current selected quaternary.

When a graph option is selected from the Outputs page, a dialog is displayed for specifying mode detail before the graph is generated.

Buttons on the toolbar above the graph allow further customisation to the graph's view properties. Some of the important options are described below:

Printing: Click the Print button to display the print preview dialog from where the printer and graph placement on the page can be adjusted.

Clipboard: Click Copy to copy the graph as a bitmap to the Windows clipboard for pasting in another application/document.

Graph Title: To edit the graph title or font, select Edit, Chart, Titles.

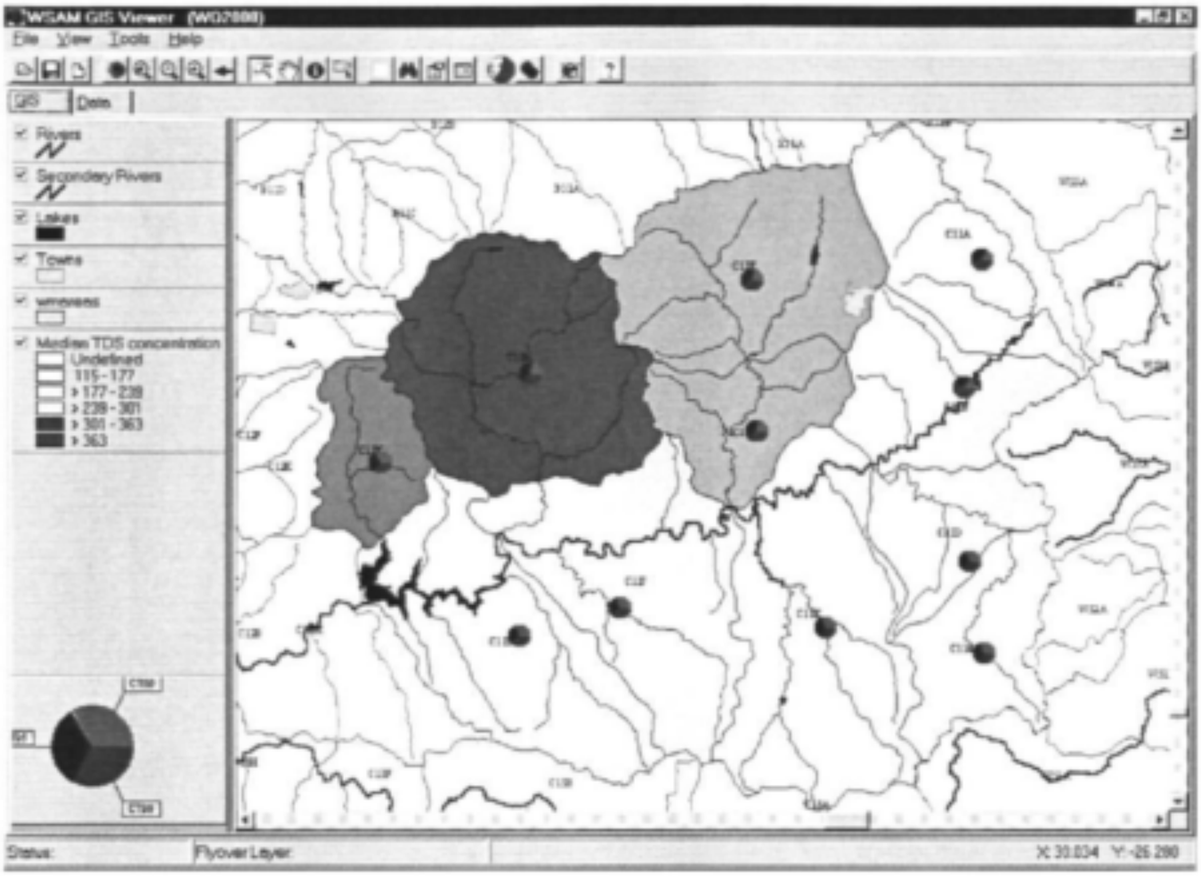
System Diagram

The system diagram provides a schematic presentation of the network.

This screen is displayed by clicking System Diagram on any page on the WQ2000 screen, except on the Selection page. The diagram is also presented in Appendix A in the user manual.

Most of the fields displayed on the physical data pages are numbered. These numbers refer to the numbers on the system diagram, which indicates the position in the network diagram each parameter applies to.

GIS Viewer



The GISViewer is used to display quaternary maps, presenting up to four numerical values per quaternary for comparison between the quaternaries. The first value is used to shade the quaternaries, while the next two or three values are used to display a pie or bar chart per quaternary.

To use the GISViewer, select WQ2000 menu option *Map | GIS Viewer*. The *GIS Map Selection* dialog is displayed, where the quaternaries and fields to display are selected. From this dialog the GIS Viewer is activated to display the required result. Quaternaries must be entered as a comma or space separated list. The *Select all quaternaries upstream of...* button can be used for automatic entering of the quaternaries for a part of the network.

To select fields to represent on the map, double click in the Q or C column next to the field to select.

If no quaternaries are displayed, refer to the WQ2000 Setup instructions for loading a default layout in GISViewer for WQ2000.

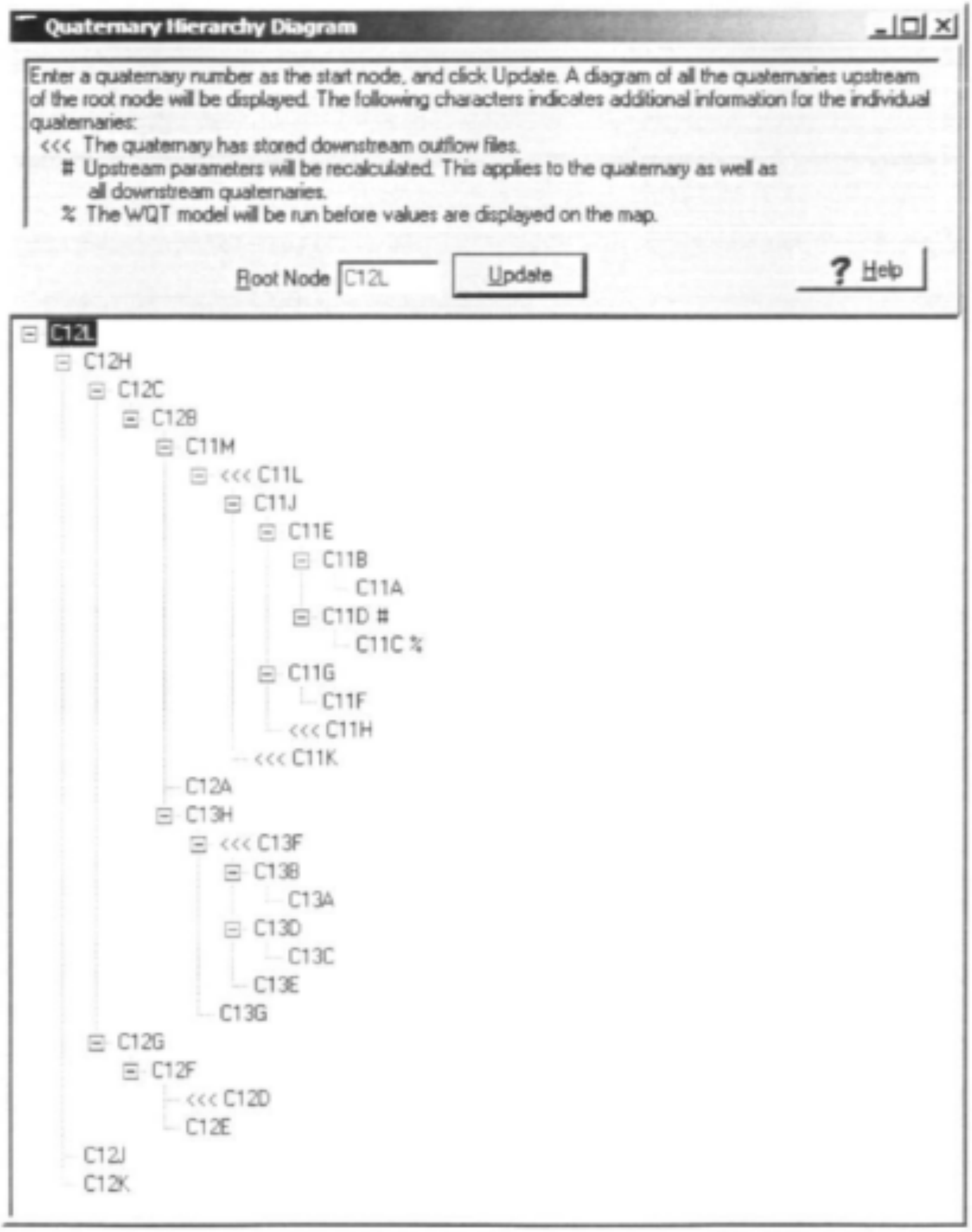
The GIS Viewer is a standalone application developed by DWAF and is used in the WSAM application (Water Situation Assessment Model). Refer to the GISViewer User Manual should you need more information.

WQ2000 communicates with the GISViewer through the Windows Clipboard. Any data already in the clipboard will be replaced when activating the GISViewer. The user is free to use the clipboard for whatever purpose after the GISViewer is displayed.

NOTE: It is important to exit the GIS Viewer before activating it again from WQ2000.

GISViewer is provided with a number of maps (layers), including a Quaternary, CMA, Primary River, Secondary River and Provinces layers. To start GISViewer manually select Windows *Start | Programs | DWAF GisViewer | GisViewer*. When starting GISViewer this way there is no link between WQ2000 and GISViewer.

Quaternary Hierarchy Diagram



Select menu option *Map* | *Quaternary Hierarchy Diagram* to display the screen.

This option has the following purposes:

1. It is not always clear from a less detailed map, as is provided with WQ2000 for quaternary selection, which quaternary is upstream of which. This can be clearly determined from this screen.

2. The WQ2000 database does not contain data for each quaternary in the country. This diagram can also be used to identify which quaternaries are available.

3. This option can be used to see which quaternaries have saved outflow files. All these quaternary names are preceded by "<<<".

4. "#" indicates quaternaries where upstream parameters will be recalculated before the quaternary will be displayed, either on screen or the map. Although not shown for the downstream quaternaries, it also applies to the downstream quaternaries.

5. "%" indicates quaternaries where the WQT model will be run before values are displayed on the map. Once run, the parameters used on the map are stored, and the model will not be executed again unless the parameters for the quaternary or any upstream quaternary are changed.

Enter the most downstream quaternary for the area of interest, in the Root Node fields, and click *Update*.

A message will be displayed mentioning the number of quaternaries found. Click OK.

The hierarchical diagram of the logical structure upstream of root node will then be displayed.

Running the WQT Model Manually

It is not the intention to describe the use of the WQT model in this manual. This section however describes how the model is run in the context of WQ2000.

WQ2000 uses a specially prepared version of WQT called WQT1. The version is set to execute without interrogating the user via the normal WQT model interactive dialog. Instead WQT1 reads the user instructions from prepared text files.

To run the WQT model outside WQ2000:

- Two similar directories on the hard disk are used for running the WQT model: one for naturalised data, and the other for present day data. The files in these directories are identical, except for the parameters in these files.

- The option: "Copy WQT model input & output files to another directory" can be used to copy the files to another directory to protect them against being overwritten when the model is run again from within WQ2000. This option can only be used after the model has run, because the input files are only created when the model is run.

- The input and output parameter files are described in the WQT model documentation.

- The second and third lines in the .CMD files indicates the directories where the files are stored, and should be changed as applicable.

- The WQT model creates/replaces all .ANS files.

- Run the model from the MS DOS command prompt. When running the WQT model, a .KR5 network configuration input file must be specified as command line parameter, e.g. C:\>WQT1 WQ1.KR5.

- To run the model to include upstream influences:
  Run WQT1 with WQ1.KR5
  Edit file WQRV15.DAT and change line 5 (Line 5(a)) to:
  15 '' ''

Run WQT1 with WQ2.KR5

- To run the model to exclude upstream influences:
  Run WQT1 with WQ1.KR5
  Edit file WQRV15.DAT and change line 5 (Line 5(a)) to:
  15 'dummy.q' 'dummy.q'
  Run WQT1 with WQ3.KR5

- When running the WQT model with WQ3.KR5, it overwrites the output created by WQ2.KR5. To overcome this, the WQ3.KR5 output files will be written to a NoUsOut ("NO UpStream influence OUTput") subdirectory of the current directory, e.g. to C:\WQ2000\NATURAL\NOUSOUT. The input files are all taken from the current directory (NATURAL in the previous example). This is accomplished by setting the 3rd line in WQ3.CMD to the NoUsOut directory.

- All of the data files that are created by WQ2000 are fully compatible with the original WQT model. Hence an advanced user who has the executable code for the original WQT model can simply use the data files as input as normal. The original WQT model executable code and detailed instructions on its use are not included on the WQ2000 distribution CD-ROM.

Troubleshooting

Unable to run WQ2000 after Setup?

WQ2000 requires ADO for access to the database. ADO is part of Microsoft Data Access Components (MDAC). MDAC is part of Windows 2000 and Windows XP, but needs to be installed separately for Windows 95 and 98. MDAC is also installed by various other applications. If WQ2000 gives an error message during start-up, it probably means that MDAC is not installed on the PC.

MDAC Version 2.1 can be found on the \Extras\ADO directory on the Setup CD. Refer to ReadMe_MDAC.doc on the CD for mode detail.

Support

For support in using WQ2000, or for reporting any problems or comments, please contact the SD: Systems Analysis User Support Team at DWAF:

Web page: www.usersupport.co.za

Danielle Strydom
Telephone: icm@dwaf.gov.za
E-mail: 012-336 7090

Jodie Botha
Telephone: 012-336 7090
E-mail: icm@dwaf.gov.za

Glossary

Allen, RB and Herold, CE (1988) *Vaal River System Analysis, Water Quality Modelling, Volume A: Water Quality Calibration Model.* Report P C000/00/7086, Department of Water Affairs and Forestry, Pretoria, South Africa.

Stewart Sviridov & Oliver (1991) *Vaal River Water Quality Management Study, Calibration procedures for the monthly time step hydro-salinity model.* Report P C00/00/9490, Department of Water Affairs and Forestry, Pretoria, South Africa.

Herold, CE and le Roux PJ (2004) *WQ2000: Development of an interactive surface water quality information and evaluation system for South Africa.* Report No. 950/1/04, Water Research Commission, Pretoria, South Africa.

Tips

Backup!: Remember to make regular backups of the data. If the database gets corrupted, EVERYTHING can be lost, and often nothing can be recovered!

Feedback: Users' comments on this program will be highly appreciated. Please let us know about any problems, defects or advice. See the Support section for contact numbers.

File Maintenance: Menu option *File | File Maintenance* should be executed regularly to refresh some tables.

Print Screen: To print a screen dump from Windows is not as simple as just pressing the *Print Screen* key as in DOS. Press *Print Screen* to copy a bitmap image of the entire screen to the clipboard, or press *Alt - Print Screen* to copy a bitmap image of the active window to the clipboard. Then call up any word processor, e.g. Word Perfect or Word. Position the cursor where the image should be inserted, and press *Ctrl-V* or select menu option *Edit | Paste*, to load the image into the document. The image can then be printed from that application.

Program Technical Information

WQ2000 is a 32-bit program that will run on Windows NT Version 4 and Windows 95 or later.

The WQ2000 database is in MS Access 97 format. Monthly data files are ASCII files in the format described for the WQT model.

Refer to *System Requirements* for installation requirements.

Program Directories involved:

The following programs and files are installed in the default directories indicated:

C:\WQ2000	WQ2000 program files
C:\WQ2000\Base Data	Default project data files
C:\WQ2000\Current	WQT Model with present day data

C:\WQ2000\Natural WQT Model with naturalised data

Other directories can be specified for C:\WQ2000 during installation.

While running WQ2000, mode directories may be created as specified by the user.

APPENDIX B

SUMMARY INFORMATION REPORT

WQ2000 Salinity Model

Project: Project1

Summary Information Report: Quaternary C11C

Date: 07/10/2005

Hydrology period: October 1925 to September 1995

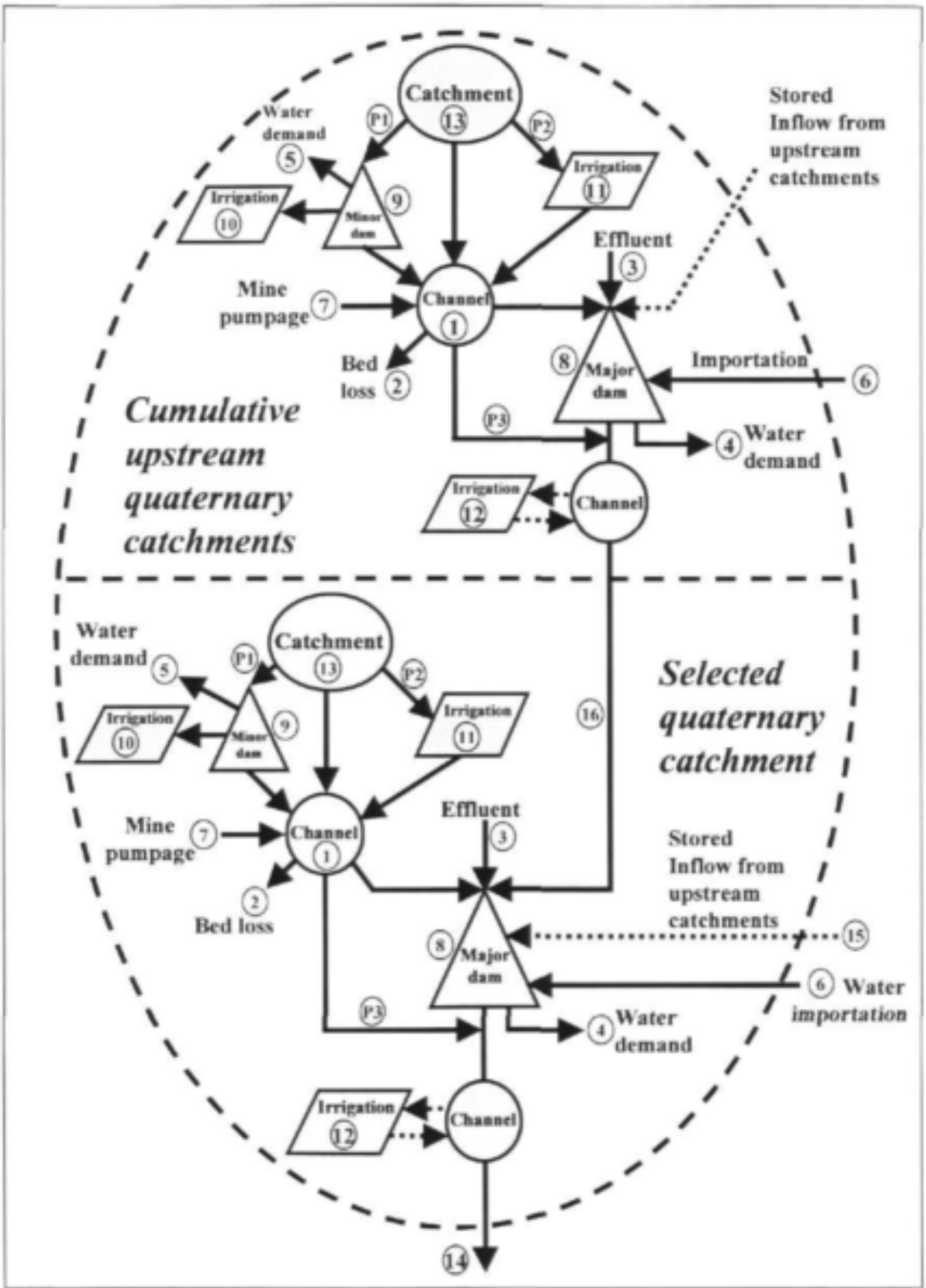
Description	Quaternary Present day	Quaternary Natural	Upstream Present day	Upstream Natural
Physical Data (Inputs)				
Catchment area (km²)	450	450	0	0
Impervious paved area (km²)	0	-	0	-
Wetland Area (km²) [1]	0	0	0	0
Bed Loss (mil m³/year) [1]	0	0	0	0
Average effluent inflow volume (mil.m³/year) [3]	0	-	0	-
Average effluent inflow TDS concentration (mg/l) [3]	0	-	0	-
Water Demand from major dam (mil.m³/year) [4]	0	-	0	-
Water Demand from minor dams (mil.m³/year) [5]	0	-	0	-
Average water importation volume (mil.m³/year) [6]	113.18	-	0	-
Average water importation TDS concentration (mg/l) [6]	112	-	0	-
Mine pumpage (mil.m³/year) [7]	0	-	0	-
Mine pumpage TDS concentration (mg/l) [7]	0	-	0	-
Major dam storage capacity (mil.m³) [8]	0.001	-	0	-
Major dam surface area (km²) [8]	0	-	0	-
Minor dams storage capacity (mil.m³) [9]	0	-	0	-
Minor dams surface area (km²) [9]	0	-	0	-
Factor b for dams (AREA = a * STORAGE^b) [8,9]	0.85	-	0	-
Minimum volume outflow from major dam (mil.m³/year) [8]	0	-	0	-
Proportion of catchment runoff upstream of minor dams [P1]	0	0	0	0
Proportion of catchment runoff upstream of opportunistic irrigation [P2]	0	0	0	0
Proportion of catchment runoff downstream of major dams [P3]	0.5	0.5	0	0
Irrigated area supported by minor dams (km²) [10]	0	-	0	-
Opportunistic diffuse irrigated area (km²) [11]	0	-	0	-
Irrigated area supplied from main stem river (km²) [12]	0	-	0	-
Salt Washoff Module Parameters (Inputs) [13]				
Initial salt storage - pervious zone (t/km²)	53.8	57.9	53.8	57.9
Initial salt storage - impervious urban zone (t/km²)	0	0	0	0
Initial salt storage - sub-surface zone (mg/l)	270	273	270	273
Initial salt storage recharge rate - pervious zone (t/km²/month)	0.515	0.52	0.515	0.52
Initial salt storage recharge rate - impervious urban zone (t/km²/month)	1	1	1	1
Salt washoff efficiency - pervious zone (/mm)	0.004	0.004	0.004	0.004
Salt washoff efficiency - impervious urban zone (/mm)	0.01	0.01	0.01	0.01
Initial interflow/groundwater flow estimate (mm)	0.6	0.6	0.6	0.6
Minimum groundwater flow limit (mm)	0.6	0.6	0.6	0.6
Antecedent runoff decay factor	0.2	0.2	0.2	0.2
Proportion of surface flow via interflow	0.25	0.25	0.25	0.25
Proportion of salt washoff infiltration	0.95	0.95	0.95	0.95
Subsurface storage depth (mm)	1 000	1 000	1 000	1 000
Upstream Inflows				
Number of defined inflows [15]	-	-	0	0
Average defined upstream inflow volume (mil.m³/year) [15]	-	-	0	0
Average defined upstream inflow TDS concentration (mg/l) [15]	-	-	0	0

Results	Quaternary Present day	Quaternary Natural	Cumulative Present day	Cumulative Natural
Average TDS concentration (mg/l) [14]	113.0	181.7	113.0	181.7
Median TDS concentration (mg/l) [14]	115.1	172.3	115.1	172.3
95 percentile TDS concentration (mg/l) [14]	119.7	278.3	119.7	278.3
98 percentile TDS concentration (mg/l) [14]	123.4	281.3	123.4	281.3
95 percentile TDS concentration for driest month (Aug) (mg/l) [14]	116.7	280.5	116.7	280.5
Average TDS concentration for driest year (1982) (mg/l) [14]	115.6	226.2	115.6	226.2
Flow-weighted average TDS concentration (mg/l) [14]	110.3	106.9	110.3	106.9
Average upstream inflow volume (mil.m³/year) [16]	-	-	0.00	0.00
Flow-weighted average upstream inflow TDS concentration (mg/l) [16]	-	-	-	-
Average catchment runoff volume (mil.m³/year) [13]	37.14	37.14	37.14	37.14
Average catchment runoff TDS concentration (mg/l) [13]	175.1	177.6	175.1	177.6
Average TDS concentration in major dam (mg/l) [8]	112.2	0.0	112.2	0.0
Flow-weighted average TDS con. of spillage from major dam (mg/l) [8]	111.0	106.5	111.0	106.5
Mean annual outflow from catchment (MAR) (mil.m³) [14]	150.30	37.14	150.30	37.14
Mean annual TDS load (t) [14]	16 572	3 971	16 572	3 971

WQ2000 version 3.0.2

APPENDIX C

SYSTEM DIAGRAM


Catchment
Water demand
Irrigation
Minor dam
Stored Inflow from upstream catchments
Effluent
Mine pumpage
Channel
Bed loss
Importation
Major dam
Cumulative upstream quaternary catchments
Water demand
Selected quaternary catchment
Water importation

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Herold CE; le Roux PJ

Development mostly leads to an increasing susceptibility to salinisation and other forms of water quality degradation of the country's water resources. Sustained development requires the early anticipation of associated water quality problems so that these effects can be rectified or obviated. This project is developing a prototype water quality planning tool for the Vaal River system (similar to *Water Resources 90* which provided assistance with water resource planning)

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