

Information Management for Water Resources Planning

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Abstract – With the progressive implementation of the South African National Water Act (1998), it has become apparent that there will be increased water resource planning information and analysis needs. This paper shows how existing water resources planning processes and aging decision support tools were analysed to derive an interim design strategy, of which the overall and information management design considerations are discussed. The generic information management systems that are being developed will make provision for future expansion of information types and new software needs, as new processes for successful implementation of the Act are identified. The Water Resources Yield Model Information Management Systems is introduced as a first application of the interim information management strategy.

Background

With the progressive implementation of the South African National Water Act (Act No. 36 of 1998), it has become apparent that there will be an increase in water resource planning information and analysis needs.

South Africa's political transition created a broad awareness that new water legislation was needed to redress the iniquities of the previous political dispensation. This set the stage for a comprehensive process of public participation leading to the development of new water resources management policies and legislation.

Some of the principle changes of the National Water Act are the replacement of water use rights based on land ownership with a system of administrative authorisations, and the acknowledgement of the importance of the ecological requirements when it

comes to the allocation of water. These changes are fundamental and critically important to the country's water resource management policies and approaches [1].

Some of the main requirements of the National Water Act that impact on water resource planning information management needs are addressed in the following three sub-sections. (For the purposes of this paper "information" refers to data that has been analyzed, modelled and/or interpreted to provide meaning for a specific purpose. "Data" is used in the context of unprocessed information as collected for input to the water resources planning process).

Broader participation

The National Water Act promotes equitable access to, and sustainable use of water resources by stakeholders at regional, national and international levels. This broad stakeholder participation is in alignment with the basic approaches of integrated water resources management.

Promotion of equitable access and sustainable use requires broader involvement in water resources management and planning through the establishment of new water management institutions called Catchment Management Agencies (CMAs) [2]. Water resources planning information must therefore be made more freely available and shared amongst stakeholders, while ensuring consistency of this information and the data on which this information is based.

New focus on ecology and demand management

The National Water Act recognizes that there are areas in South Africa where water stress is being or will be experienced in the near future. To adhere to the principles of sustainable development, the importance of the ecological Reserve is acknowledged and protected by the Act. The ecological Reserve refers to the water required to protect the aquatic ecosystems of the water resource.

In the past, development of water resources, based on supply management principles, had high priority. As the limit of water resource use is reached in certain areas, the focus of water resource management will move from supply to demand management options. Demand management is encouraged in the National Water Act through provisions for national policy development.

Both the ecological Reserve and demand management are new priority areas when considering management and planning of water resources in South Africa. Additional information is being generated as the understanding of these issues improve, requiring adaptations to current decision support practises.

Compulsory licensing

The Act requires the undertaking of compulsory licensing of any aspect of water use in respect of one or more water resources within a specific geographic area. Licensing requires that a responsible authority prepare schedules for allocating quantities of water to existing and new users. The procedure is to be used in areas, which are, or are soon likely, to be under "water stress" [3].

This process will require additional modelling capabilities that are not catered for in the current modelling practises. Up to now the main focus of decision support systems is to determine the assured yield of infrastructure based resources. Scenario analyses are done by determining the impact on assurance of yield, given projected land use and water requirements.

To address these issues, an assessment was undertaken with regards to current decision support systems and computer assisted processes for water resources systems analysis. To make provision for the future requirements of the National Water Act, a decision support software and information management system development strategy had to be formulated.

Status quo assessment

In order to assess the current status of software and information management in the computer assisted water resources planning processes, a Business Process Analysis (BPA) [4] and a software and process Quality Assurance and Risk Assessment was undertaken [5].

The BPA made use of a Departmental standard methodology for software development planning called a Use Case Analysis. The BPA was implemented at a high level for the complete planning analysis process. Elements of the planning process included in the analysis are indicated in Figure 1.

The BPA aimed at:

- obtaining improved understanding of software used,
- identifying sequential steps during the process and rate the steps on relative effort required,

resources and level of skills necessary, and the impact of the step on the complete process,

- identifying data flow processes and mechanisms, and
- determining priorities for improvement to the systems and process in terms of efficiency, effectiveness and improved accuracy.

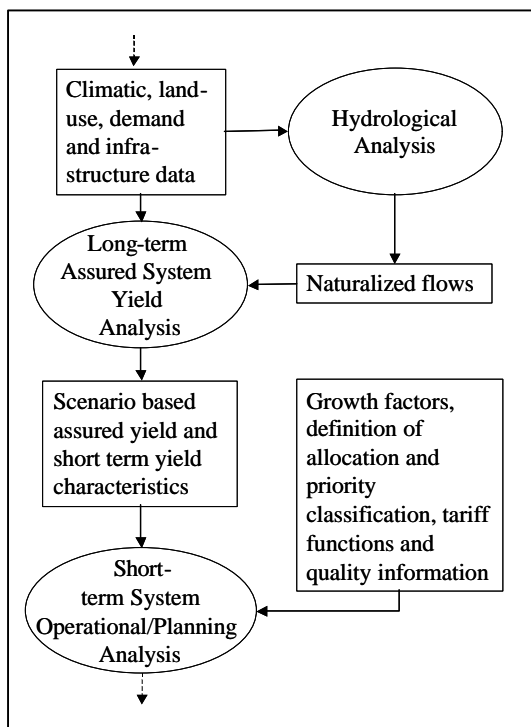


Figure 1: Section of the water resources planning process covered in the BPA.

The benefit of undertaking the business process analysis was:

- Documentation of the complete high-level process, identifying role-players (and skills), data requirements and systems involved, as well as the time estimates for each task in the process.
- Development of an interactive analysis tool for prioritizing sections of the process for improved efficiency and effectiveness.

The Quality Assurance and Risk Assessment was done on the two main models used in the water resources planning process, in terms of the risk associated with owning and maintaining this legacy software.

From these two assessments certain problematic issues were identified related to the:

- decision support software
- information management, and
- the overall water resources planning process.

Decision support software

The computer assisted planning process evolved during the past two decades, and today involves multiple computer systems (e.g. 80+ pre- and post-processor systems in addition to the main models). The theoretical basis for these models is still substantially adequate and well tested for determination of long-term strategic planning in the highly variable conditions of southern Africa.

The Water Resources Yield Model (WRYM) and the Water Resources Planning Model (WRPM) are modelling systems that were developed during the 1980's and have been used extensively throughout South Africa over the past two decades. These two models are often referred to as the "systems models".

The technology that the models were developed in (*FORTRAN*) is fast growing out of date. In addition, it is expensive and risky to maintain the models due to the few and highly qualified individuals that have the necessary experience. The dated technology does not allow for modern object orientated programming, which hampers the maintenance of the

models by other less-experienced individuals.

There are limited Graphical User Interfaces (GUIs) for these models, which makes them difficult to operate and assess. This also limits the sharing of data and prevents expansion of the relatively small users group of the models.

Information management

The software systems used in the planning process are DOS-based programs that make use of in- and output ASCII files. This hampers transparent and systematic sharing of data and analysis results.

Some of the major findings of the BPA are that:

- the planning analysis process dedicated 46 – 50% of effort to inefficient data and information management processes,
- the multitude of files involved, makes study and scenario management difficult,
- the documentation, schematics of the systems models and other metadata are not linked to data, making managing and revisiting the data time-consuming, and
- the complicated input file structures makes data verification difficult.

In addition, no centralized management system exists where all the information and scenarios can be captured for efficient future re-use and to minimize risk of information loss.

Overall water resources planning process

With regards to the overall process the following conclusions were drawn:

- Approximately 64% of the cost of planning studies goes towards setting up and obtaining scenario based answers from the two main systems models (WRYM and WRPM).
- 59% of all activities require at least a moderate skills level.
- 42% of the overall process involves the manipulation of data input and output files, which is relatively unproductive and error prone.

Requirements for a development strategy

Recognizing the problems associated with the software and the planning process it supports, opportunities for improvements in efficiency and effectiveness were investigated.

Although many of the processes to ensure successful implementation of the National Water Act are still being defined, the current software, information management and the effectiveness and efficiency of the planning process need to be improved. This should be done in anticipation of new requirements, to effectively share the valuable information arising from these important systems analyses and to facilitate expansion of the user community of the models in accordance with the transformation goals of the Department.

A development strategy was formulated to address at least the following requirements:

- Reduce the risks in loss of data and information
- Improve the Department's ability to store and manage data and information
- Improve interfacing with other information systems
- Improve data verification

- Improve efficiency and effectiveness of updating data
- Improve understanding of data through use of metadata
- Facilitate sharing and communication of information for joint decision-making and stakeholder participation.

To illustrate how these above mentioned requirements would be met, the following two sections of the software and information management systems development strategy are discussed below:

- Design considerations
- Software development methodology

Design considerations

An overall structural and an information management design for the improvement to the efficiency and effectiveness of the decision support system assisted water resources planning process was developed.

Overall structural design

Figure 2 depicts schematically the overall structural design for the decision support systems that support the water resources planning process. The design requires the:

- development of accessible, well-designed and generic information management systems (IMSs) for the structured storage and efficient use (as well as sharing) of systems analysis input data and results information (Figure 2, annotation 1),
- development of GUIs for the input data stored in the IMSs, to serve as interface with the models and therefore ensuring wider use (Figure 1, annotation 2), and
- investigation (over the longer-term) into other models and at the same time reducing duplication in data processing of WRYM and WRPM, effectively making it a single and more efficient model (Figure 2, annotation 3).

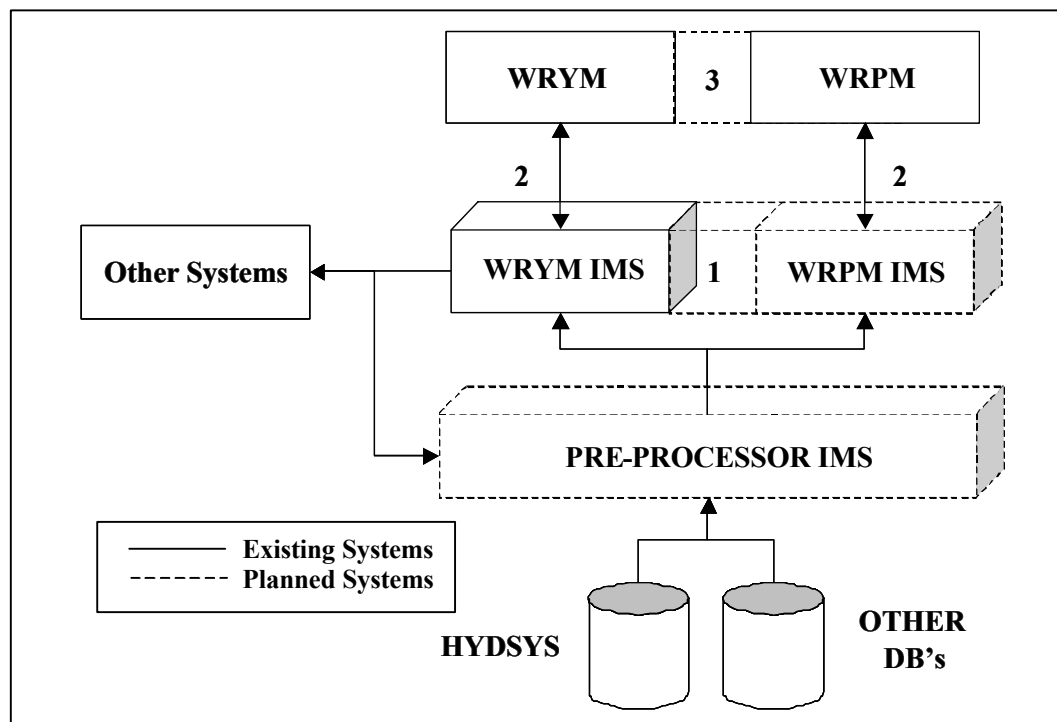


Figure 2: Current overall structural design

Information Management Design

The analysis of the water resources planning process and the assisting software, identified that the current data and information management give rise to significant inefficiencies. It became clear that improved information management design would have a significant impact on the efficiency of the overall water resources planning process.

Figure 3 provides a schematical representation of the generic information management design of Water Resources Systems Analysis IMSs.

One generic information management system design will make provision for all types of information required during the water resources planning process, from climatological to licensing information.

In addition to the types of information, different granularities of information (both temporal and spatial), as well as variant forms of the original data sets will be housed. An example is raw rainfall station data, patched rainfall records for the same station as well as a catchment rainfall record for the area.

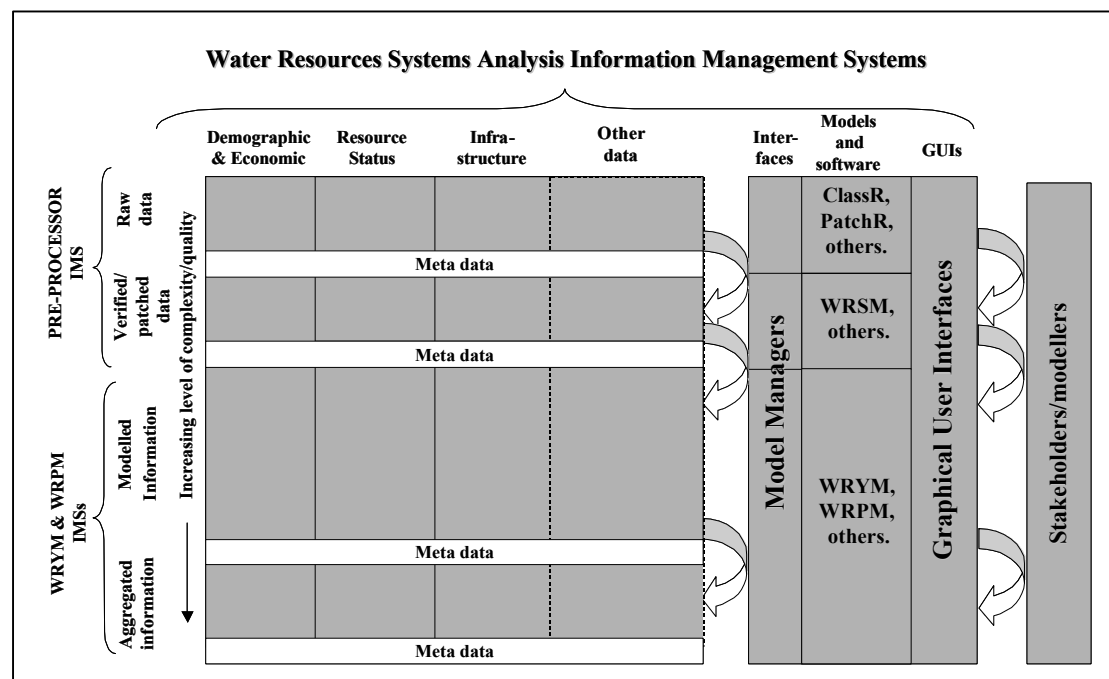


Figure 3: Structure of a Water Resources Planning Information Management System

Metadata about the different types and levels of complexity of information is required to enable references to sources and accuracy of the information. Metadata also assist when sequentially updating modelled information from verified data, which was in turn obtained from raw data. The frequency of the data and information updating are inversely

correlated to the complexity of the data or information, i.e. raw data is the easiest to update and thus relatively frequently updateable, where the modelled results information will only happen as a result of big studies. Metadata therefore would assist with the efficiency of the overall updating process.

To ensure the independency of the information stored from the models and software used on the information, the concept of model managers is made use of. The model managers are interfaces for importing and verifying existing model configuration data into the IMS. Once in the IMS, the structured information can then be translated back in a usable format for the software and models.

In using the model managers, inefficient data handling processes can eventually be limited to a minimum. Access to all the stored information can, in addition, be provided to any other new models or software selected by just incorporating a model manager for the new systems.

The current systems models also have configuration input files that allow for the development of GUIs to improve the user interactions with the models.

Software development methodology

To illustrate the how the software development methodology contributed toward the requirements of the development strategy the following issues are described in more detail:

- Overall software development methodology
- Development of open public interfaces
- Model management
- Data archive management

Overall software development methodology

A modern and efficient software development methodology is employed for the development of the IMSs, with documented user requirements and system design. This is required to overcome the problems associated with interfacing with the DOS based models. Formalised software testing

strategies were used to ensure a high level of system quality.

Based on the work of Beck [6] and Fowler [7] a methodology similar to “Extreme Programming” was used. This methodology produces high quality software systems at a relatively low cost.

The software design documentation was produced using a widely supported notation “Unified Modelling Language” (UML) [8]. An example of such a design is provided in the “Initial application of strategy” section.

Development of open public interfaces

The DOS based models have the problem that the data is not easily accessible due to the use of file based data structures and not having the benefits of a structured database that can be easily accessed and interrogated. Once the input data and results information has been housed in a well-structured database, the software development strategy will ensure that as much as possible of the model’s data and functionality is made available in an open and accessible manner. An example of such a data structure design is provided in the “Initial application of strategy” section.

Microsoft’s “Common Object Model” for the model data structure is to be supported. This feature allows a user to make use of conventional spreadsheet applications (such as MSExcel) and their macros-functionality to produce scripts for running the models. In addition these spreadsheets can be used to adjust and capture input data, as well as initiate the running of the model and interrogating the results. This effectively automates scenario analyses.

Model management

To ensure improved information management, an integrated database design is being employed, which captures the information for each of the models in standard input and output tables. Each model expects a certain table structure for its' input and is responsible for writing to output tables of a certain structure.

Each analysis model will therefore use a portion of the integrated database, which makes most of the tables for a given model private (tables used only by that specific model). Some tables can however be made shareable by other models.

These tables allow for the development of smaller sub-model managers for example, software "Wizards" that assists in configuring initial model setups or assist with input data validation. This is possible because the data is stored in open and published data tables.

In addition, other existing analysis models do not have to be changed to be incorporated into the overall generic design. This is achieved by compiling model managers (data transfer modules) that read or write the existing data file formats into and out of the database.

Data archive management

One of the ongoing challenges in the water resource systems analysis field is the management of the large amounts of data and information that are generated during the many catchment studies. Up until now, this data has been captured in hard copy format and to a limited extent in digital CD format

in governmental and consulting firm archives.

Hard copy and CD formats aren't very accessible forms of archiving and often means that the data is often not readily re-usable. A lack of integrated metadata also results in a lack of confidence in the data. An example solution to data archiving issues is provided in the following section.

Initial application of strategy

The development strategy and the information management considerations have lead to the development of an Information Management System (IMS) for the WRYM (WRYM-IMS). The Vaal Catchment system data was used as the first application of this IMS.

The development was based on the BPA which formed the user requirement analysis, of which a part is illustrated in Figure 4.

The generic development architecture is used for the IMS development, which allows for the incorporation of other similar system models (such as the WRPM). Figure 5 provides an example of the data structure for the WRYM IMS.

An "off-the-shelf" system was implemented to manage the archiving of study data. Figure 6 illustrates how the data from all studies is stored in a single archive on a file server. The data is extracted into the required database, which can be shipped with a given version of the system. Old, legacy data can be put into the archives without any modification required.

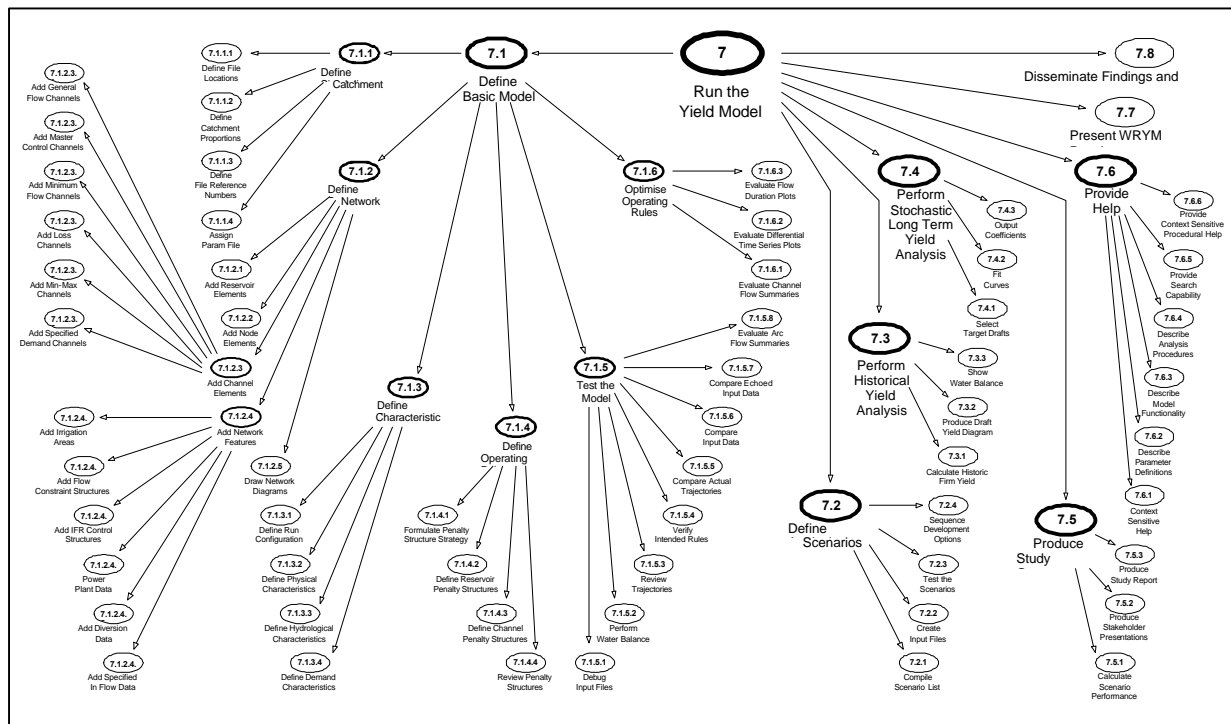


Figure 4: Detailed business process analysis of the WRYM

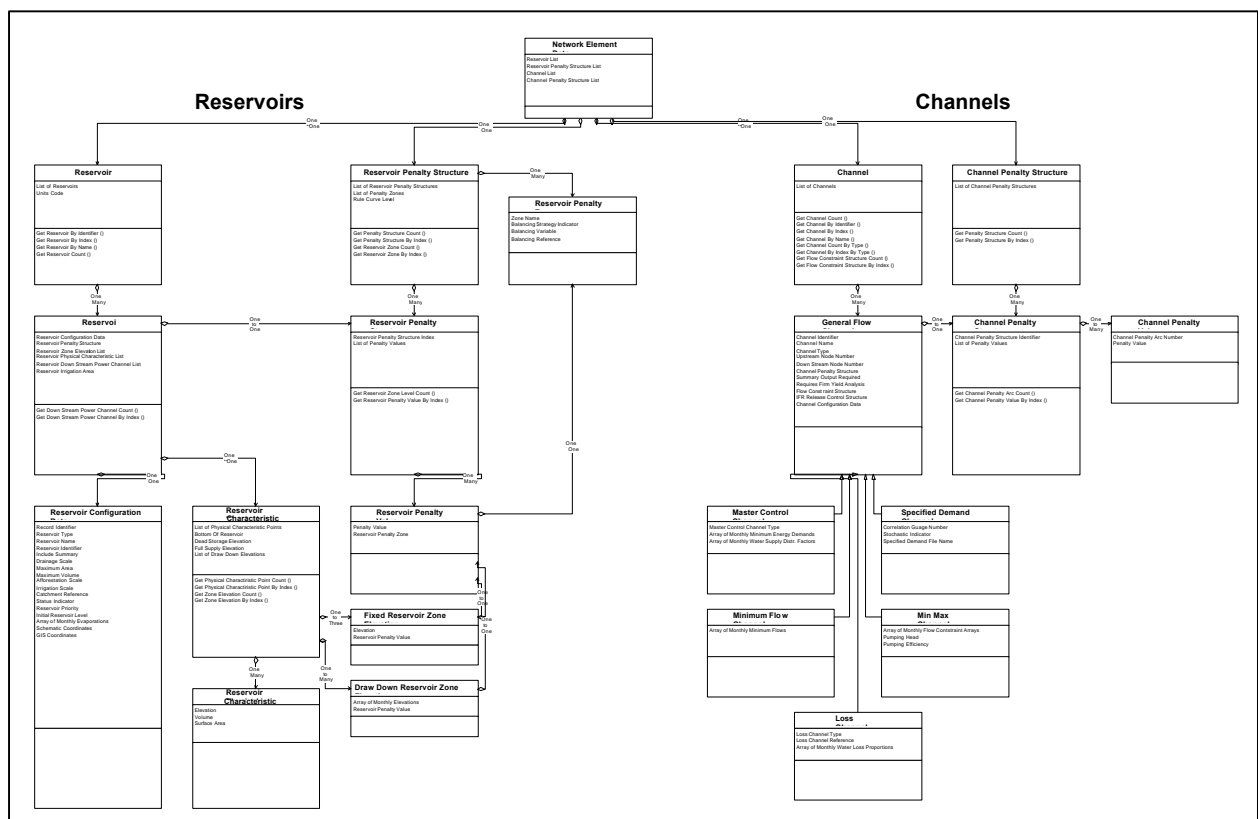


Figure 5: Example data structure for the WRYM IMS

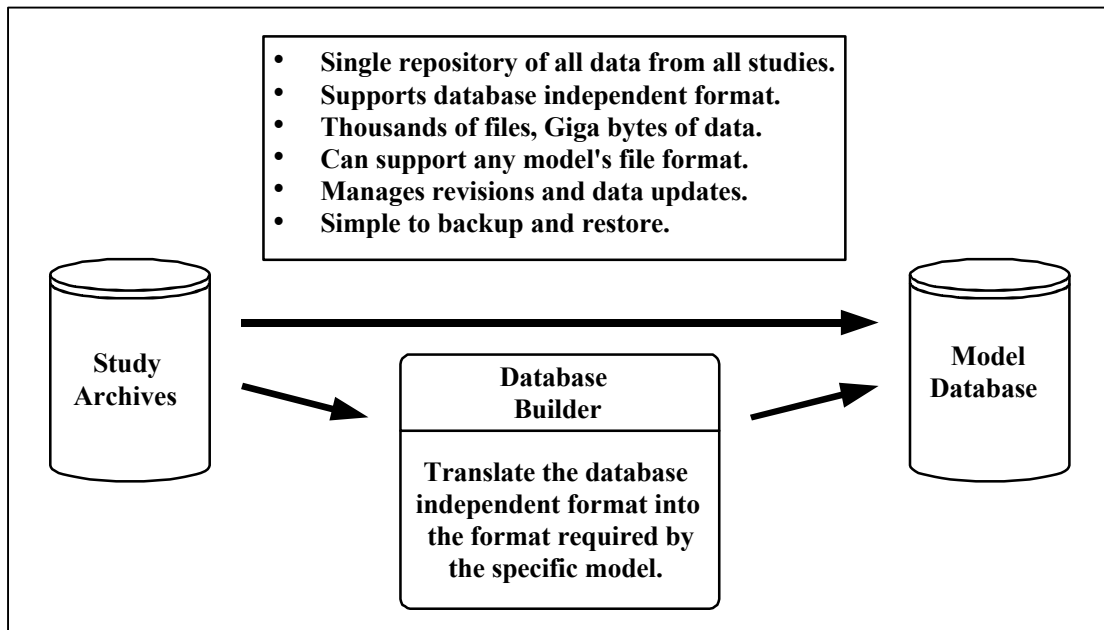


Figure 6: Data archiving management

The WRYM IMS can currently import and organize completed catchment studies, view the data, make changes to the data and run the model with the changed input data. In addition the IMS has a GUIs for viewing the results information and the associated system network (as an overlay to a GIS layer of the modelled area). This network vizulaizer GUI is now being used in the development of a wizard based interface for setting up a new WRYM study configuration.

Eventually all pre- and post-processors will be built into the system, effectively eliminating the current inefficiencies in the data and information management processes.

Conclusions

While the process of successful implementation of the National Water Act is underway, preparation for adapting current processes and

software are being made to ensure that additional requirements can be efficiently handled.

At the same time the development and information management strategies being implemented are being carried out in a generic fashion to allow for potential changes in future decision support software.

The databases need to be extendable, and the current process analysis tools have been configured for the current processes (BPA). Changes to the current process can easily be incorporated and assessed.

The first application of the development and information management strategy is already nearly completed. The system is usable and extendable, and promises improved integration of information management in water resources planning.

Acknowledgements

The Department of Water Affairs and Forestry is acknowledged for permission to publish this paper, WRP Pty (Ltd) for their valuable support and expertise without which the work described in this paper would not have been possible. The views

expressed in this document are those of the authors and do not necessarily reflect those of the Department.

References

- [1] Turton, A. & Henwood, R. (2002) *Hydropolitics in the Developing World: A Southern African Perspective*, African Water Institute Research Unit (AWIRU), University of Pretoria, South Africa, Chapter 14: Water demand management and social adaptive capacity – A South African case study
- [2] Harris, J & Haasbroek, B J J. (1999) *Water demand management: South Africa case study*. Contract report to the IUCN Regional Office for Southern Africa (IUCN-ROSA), Harare. Pretoria: Division of Water, Environment & Forestry Technology, CSIR.
- [3] Republic of South Africa, *National Water Act*. Act No 36 of 1998, Section 42, Pretoria: Government Gazette
- [4] Department of Water Affairs and Forestry (2003) *Business analysis for hydrological, systems and planning evaluation processes*. Sub-Directorate: Systems Analysis, Internal Report, Pretoria, South Africa
- [5] Department of Water Affairs and Forestry (2003) *Maintenance and updating of hydrological and systems software: Quality assurance and risk assessment*. Sub-Directorate: Systems Analysis, Internal Report, Pretoria, South Africa
- [6] Beck, K. (2000) *Extreme Programming Explained – Embrace Change*. Reading, MA: Addison Wesley Longman, Inc.
- [7] Fowler, M. (1999) *Refactoring: Improving the design of existing code*. Addison-Wesley Publishing Co.
- [8] www.omg.org *Unified Modeling Language Specification*. Object Management Group.