Information Systems for Water Resources Monitoring and Assessment

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ABSTRACT

Recent changes in legislation, with resultant changes in institutional responsibilities and water resources management priorities, have led to substantially new information requirements for water resources management decision-making processes. The Department of Water Affairs and Forestry, as custodian of the nation's water resources, has undertaken to improve information management for decision-making for integrated water resources management by coordinating information flow within the Department and between the Department and other organisations. The Monitoring and Assessment Information System (MAIS) is the focus of these efforts and is based on the precept that information needs are defined by the business processes of water resources management. Data acquisition programme design, data storage and management requirements, as well as the generation and dissemination of information, should fully support meeting of these information needs.

1 INTRODUCTION

The National Water Act (Act 36 of 1998) radically changed the way water resources are to be managed in South Africa. Among the significant changes are the focus on meeting the basic human needs of present and future generations, promoting equitable access to water, promoting the efficient, sustainable and beneficial use of water in the public interest, and the delegation of management functions to a regional or catchment level. The information required to support the new management decisions will, therefore, be different from that required in the past.

An analysis of DWAF's monitoring and assessment capability was initiated in response to mandates created by the NWA and other new water-related legislation and changing requirements from information users. A clear consensus emerged from an analysis of stakeholder concerns that more integration is needed with respect to providing relevant, consolidated information for different hydrological components (for example, surface and ground water), with additional information on biological and habitat characteristics and on social impacts of water resource management decisions. The information must be supported by excellent, stable, and consistent information technology (IT) platforms. The development of a Monitoring and Assessment Information Systems (MAIS) strategy, therefore, focused on the need to provide a more co-ordinated effort to identify, produce and use relevant, water-related information.

2 CONCERNS RELATED TO INFORMATION MANAGEMENT

The current situation with respect to monitoring and assessment programmes has several concerns that were identified during project investigations. The primary concerns that MAIS aims to address are:

- current monitoring and assessment programmes are perceived to be poorly aligned to the information needs of the core functions of water resource management – particularly new needs that arise from the legislation;
- difficulty in accessing or integrating data and information available on disparate IT platforms;
- lack of coordination that produces duplication of infrastructure, resources and effort, particularly with respect to the data acquisition, data storage, processing and management components of these programmes;
- shortage of skills required for adequate information management and support for capacity building, and
- widespread and often duplicated data manipulation throughout the Department to meet needs not currently addressed by the information providers;
- lack of an overall framework for information required from all water management institutions.

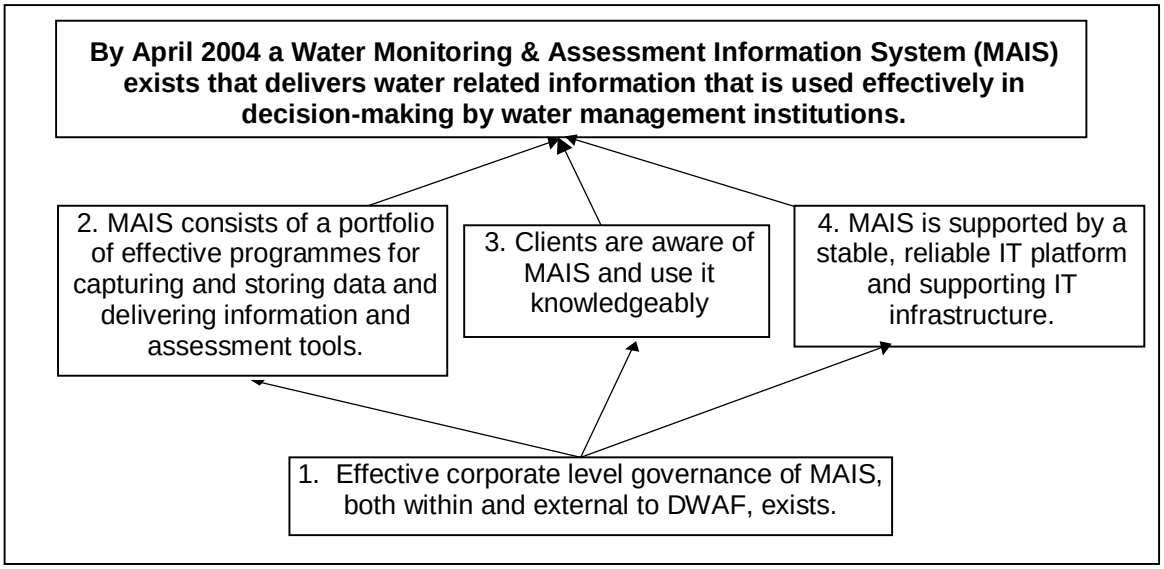

Figure 1. Goal of MAIS and the four conditions necessary to achieve it.

3 MAIS OBJECTIVES

The overall goal of MAIS is to create a Monitoring and Assessment Information System that delivers water related information, which is used effectively in decision-making by water management institutions. Four conditions, as shown in **Figure 1**, were identified during the analysis that are together necessary and sufficient for the establishment of an integrated MAIS. Two prerequisites were also identified that are not directly part of MAIS, but must be completed by others in collaboration with MAIS, in order to successfully accomplish the objective. The prerequisites are (1) corporate governance of IT in DWAF is effective in establishing consistent data management, access, and storage and (2) the organisational structure and business processes of the Department accurately reflect its mandate and core functions.

The project is intended to provide a process that will facilitate the establishment of the conditions necessary to achieve the goal of delivering information for effective decision-making by water management institutions. Condition 1, effective governance, will be addressed by the development of recommendations for corporate MAIS governance and facilitation of general corporate IT governance. Condition 2, a portfolio of effective programmes, will be addressed by an analysis of information requirements for water resources management and the development of generic integrated monitoring programme design guides to streamline and standardise designs for effective monitoring programmes. The communication and capacity building components of the project will address Condition 3, knowledgeable clients. Condition 4, effective IT platforms, will be addressed by the development of a master system plan for MAIS and implementation of governance recommendations. The project is expected to be completed in 2004.

3.1 Components of DWAF's Monitoring and Assessment Information System

The main features of MAIS are a number of monitoring and assessment programmes (hereafter referred to as integrated monitoring programmes) that all have the same functional components, namely:

- Data acquisition
- Data storage and management
- Information generation and dissemination

Integrated monitoring programmes are the sets of data acquisition, storage, and management requirements, together with the analysis and publication or access requirements that are necessary to produce a specific series of information products that have been negotiated with information users. The integrated monitoring programmes would be combined as a coherent portfolio into a corporate MAIS, with the content of the DATA ACQUISITION component defined by the INFORMATION GENERATION AND DISSEMINATION requirements.

Integrated monitoring programmes are likely to be able to share logistics and part of the technical infrastructure required for their DATA ACQUISITION components. They will also share the same monitoring and assessment system-design principles and data and information standards, naming conventions, *etc*.

It is anticipated that almost all the integrated monitoring programmes in MAIS would share the same IT platform and infrastructure for their DATA STORAGE AND MANAGEMENT component. The DATA STORAGE AND MANAGEMENT component would ensure the infrastructure, including hardware and standards, were in place. Specific details would emerge from the requirements for data access, data security, applications, and networking requirements for the Information Products. The data and intermediate information products required would be stored and managed according to corporate security requirements, to ensure the integrity of the databases and to provide access to information in accordance with the Access to Information Act (Act 2 of 2000).

One would expect more specific requirements to exist around the INFORMATION GENERATION AND DISSEMINATION component, because this is where matching with individual user requirements occurs.

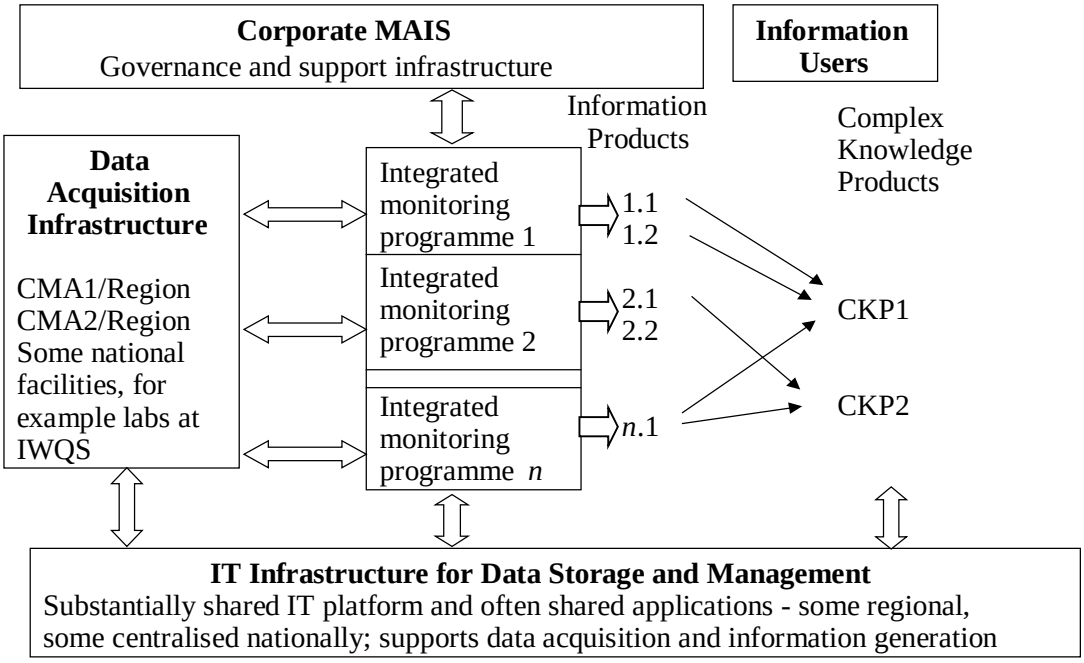

Figure 2. Provisional infrastructure relationships of MAIS functions

However, there are a number of ways in which the information generation component of each of the integrated monitoring programmes can be facilitated by sharing generic information generation processes and tools such as graphics or statistical software applications. **Figure 2** shows provisional infrastructure relationships for MAIS. Complex knowledge products are described in Section 4.1.

A number of efforts, many quite successful, are already underway to report information in a systematic manner. This approach is not intended to obstruct those efforts, but to provide an overall framework in which they, and others, can benefit from similar development.

The benefits of this approach will only be achieved with a coherent MAIS system backed by a strong level of corporate governance. The governance must apply to the interactions within each integrated monitoring programme, between all integrated monitoring programmes, and between DWAF and external organisations involved in water monitoring and assessment.

3.2 Corporate Governance of MAIS

The integration of existing disparate operations into a single co-ordinated information system requires a balance of consistency and control that provides for individual accountability for distinct integrated monitoring programmes. On one hand, co-ordination and control will be required to enable synergies between programmes, allow identification and usage of reusable functionality, and reduce duplicated effort. The success and long-term effectiveness of integrated monitoring programmes are likely to require accountability at a single point to ensure the existence and functioning of the diverse components to meet client's needs. On the other hand, a large number of people will be involved at many levels, each with individual needs. Sustainability of the effort requires that their needs be met. The governance structure must account for these opposing requirements. The actual implementation of the corporate governance of MAIS should proceed in parallel with implementation of the restructuring initiative currently underway in the Department and in the development of Catchment Management Agencies and other water management institutions.

3.3 Participation with Other Initiatives

DWAF is currently re-structuring and transforming the water resources functions of the Department to address new imperatives in water resources management and in service delivery under Batho Pele principles. There are strong linkages with the MAIS effort. Information Management is one of the six key functions identified within water resources management, together with policy and strategy, physical implementation, regulatory functions, institutional support, and auditing.

Information technology is a core enabling technology in each of the components of MAIS. It is obvious there are many and strong interfaces between MAIS and the Department's corporate IT structures. This design and implementation will therefore be conducted with close participation by the IT function in DWAF. The responsibility of Corporate IT Management will be to supervise and provide input to the preliminary design for the MAIS Master System Plan and design and develop implementation plans for data storage and management infrastructure.

Many other project level initiatives are being undertaken to describe business processes for water resources and many deal with information requirements. A MAIS communication strategy has been developed to address the need for interaction at many levels.

4 OUTPUT FROM THE INFORMATION SYSTEM

An important perspective in describing MAIS is the functional model displayed in **Figure 3**. The rows in the graphic represent the generic components of the information system, Data Acquisition, Data Storage and Management, and the Information Products that result from Information Generation and Dissemination. The row at the bottom, labelled Complex Knowledge Products, are the documents, reports, decisions, recommendations, *etc* that are used in conducting the business of water resources management. Complex knowledge products use output from the information system as input into their assessment and decision-making processes. Complex knowledge products indicate any form of information use and are not restricted to publication of paper documents.

4.1 Complex Knowledge Products

Because the output from the information system is defined by the need for input to Complex Knowledge Products, some precision in the definition is required to allow the outputs to be clearly described. While the distinction is somewhat arbitrary, given the continuous change from data through information to knowledge, more examples are given below to clarify the concept.

Complex Knowledge Products can only be generated through experienced practitioners in a particular domain of water resources management adding their tacit knowledge (insight / understanding /

experience) to the information they obtain from different sources to reach a conclusion, recommendation, or decision. Although the processes they apply may be standardised, the specific conclusions, recommendations and / or decisions they reach are usually case specific. Examples of typical Complex Knowledge Products are:

- A catchment management plan,
- Evaluation (including recommendations for license conditions) of a water use license application,
- Assessment of a dam safety application,

Assessment of whether or not a user complies with the conditions stipulated in a water use license,

- Establishing the management class of a water resource, including the reserve and Resource Quality Objectives (RQOs), and
- Assessment of the current status of a water resource compared to its RQOs.

4.2 Information Products

In contrast, Information Products result from processing data using standard tools and applications. The repeated production of a particular information product does NOT require tacit knowledge of the water resources management domain in which the information is to be applied. Typical examples of Information Products are:

- A time series of measured flow, salinity, rainfall, *etc*. at a given point, plus important statistics such as the median, trend, frequency distribution *etc*.
- A map showing the distribution of vegetation, soil types, land use, *etc*. of an area.

Some Information Products require extensive knowledge to create the product, however, once it is created, it can serve as a static representation of the knowledge and form an important input into a number of decision-making processes. Land cover maps are one example of these Information Products.

Another feature in the Information Products/Complex Knowledge Product differentiation is the amount of processing applied to primary data. For example, if one looks at the hydrological information required as input to the process of developing a catchment situation assessment, one finds that the currently available observed time series of flows and the related statistics for a given catchment are seldom adequate. These records often:

- have gaps (periods during which no data were collected),
- are often too short to allow reliable estimates of hydrological statistics,
- do not cover important parts of the catchment,
- have trends embedded in them that result from human-induced impacts, or
- require additional processing in some other way.

So further processing of the existing information or generation of new information to overcome these limitations is necessary. Some examples of the processing are:

- Patch flow records (use statistical tools to fill the gaps in the observed records),
- Use rainfall records (which are often much longer than observed flow records) to generate longer duration flow records using a calibrated hydrological model, or
- Use a hydrological model to simulate flow records from which trends caused by human-induced impacts are estimated and removed.

As described above, an important criterion in distinguishing information and knowledge products is the need for increasing amounts of tacit domain knowledge to produce the more complex outputs. As the tacit knowledge required for a given product becomes codified, (for example in the form of standard methods for patching flow records) such products previously considered Complex Knowledge Products can be treated as Information Products because they now require little additional tacit domain knowledge for their repeated production. The inclusion of meta-data with stored data can sometimes reduce the need for specialist input to the analysis, but is unlikely to have a major impact on the category of a specific product.

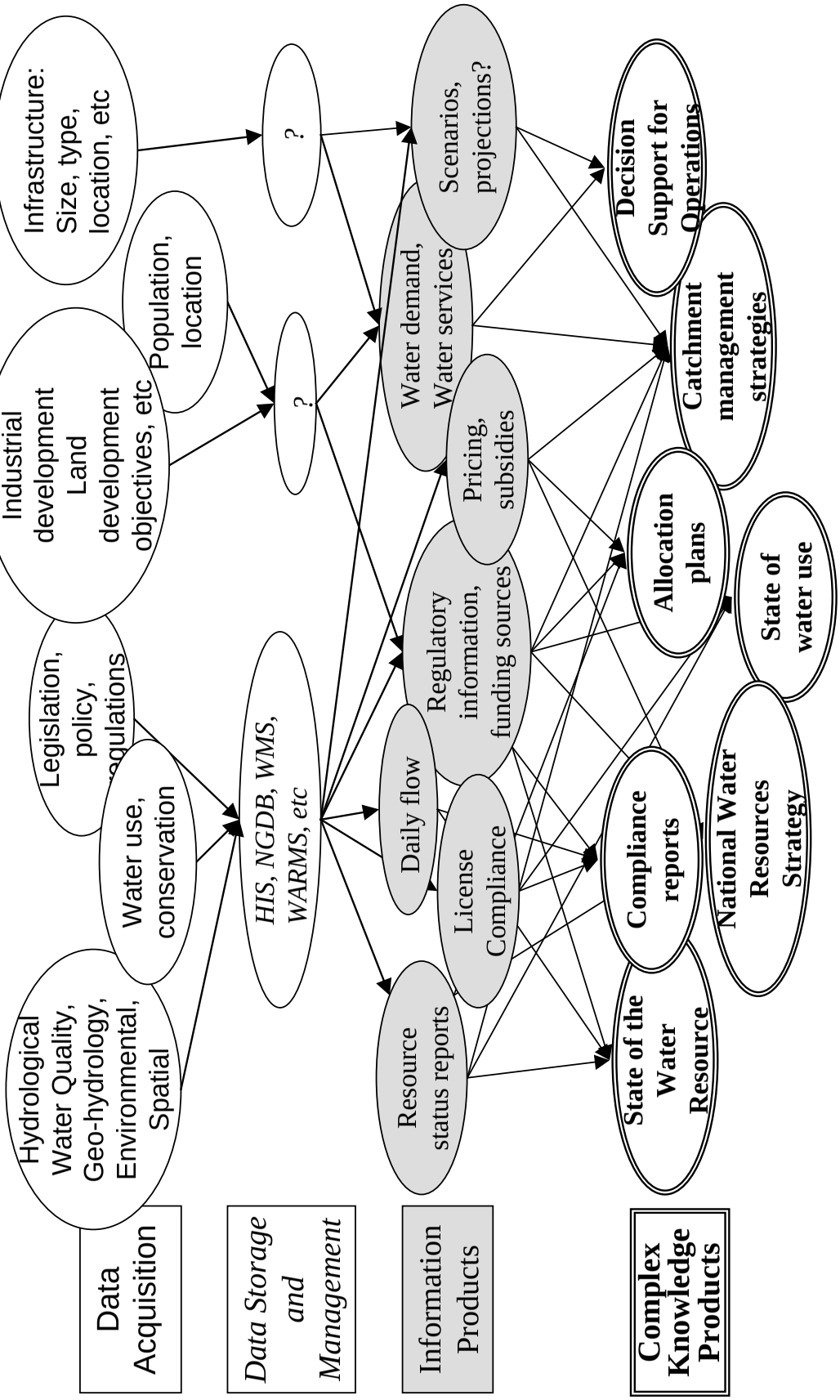

Figure 3. Functional model of MAIS with example

A related feature is the uniqueness of the need for information. In the case where an analysis would only apply to a single information need, it would be considered a Complex Knowledge Product, regardless of the domain knowledge required. If an analysis produced a standard product that were used in a large number of decisions, it should be considered an Information Product, even if its creation is very complex and knowledge intensive.

In analysing the development of a number of Complex Knowledge Products, it is clear that a series of processes occurs, often using the output of a previous processing step as input to the next process. This creates a series of Information Products intermediate Information Products Complex Knowledge Products. Complex Knowledge Products often serve as input to other Complex Knowledge Products.

Because the distinction between Information Products and Complex Knowledge Products is fuzzy and will remain so, it is pointless to attempt an accurate definition as the basis for establishing the information system boundaries. Instead, we propose that a boundary is established through negotiation between MAIS owners and the relevant information users and that these boundaries are re-negotiated from time to time as information needs and capabilities change. The negotiation process will form an important component of information flow. It will effectively provide the criteria by which information flow is judged to be adequate and information is identified as appropriate.

5 MAIS 3 PROJECT SCOPE

The project outcome will be a process to streamline and rationalise data acquistion and data access based on information reporting requirements. A portfolio of projects to apply the process to the entire range of integrated monitoring programme requirements will be designed in this project and implemented in a follow-up phase that is scheduled to begin in 2002. The entire range of data requirements is expected to be very large, therefore for this project phase, a representative selection of information products will be made and integrated monitoring programmes designed to supply that information. Generic design guides will describe the process so it can more easily be applied to other information products.

While the recommended changes will be focussed on DWAF's data acquisition and information dissemination activities, the Department's data relationships with external organisations, including central government departments as well as regional and local institutions, are seen as fundamental to the success of improving the use of water-related information. MAIS would form a single point of entry into DWAF's water resources-related information system. It would provide standard Information Products to external information users as well as set standards, guidelines, procedures, *etc* for data storage and management of data collected by external organisations and stored in MAIS. MAIS would participate in establishing the standards for data acquisition and data storage and management for water users who are required to collect and submit water-related data as part of water use licensing conditions. It will co-ordinate the establishment of specific information reporting requirements, including content, format, media, *etc* for Catchment Management Agencies (CMAs) as part of the function which requires auditing of the effectiveness of policy implementation by CMAs.

In co-ordinating information flow with the Department of Water Affairs and Forestry and between the Department and other organisations, MAIS will play an important role in standardising data acquisition activities, in facilitating data exchange through consistent application of data storage and management requirements, and in disseminating water related information through the provision of relevant information products.

6 CONCLUSIONS

Recent changes in legislation, with resultant changes in institutional responsibilities and water resources management priorities, have led to substantially new information requirements for water resources management decision-making processes. The Department of Water Affairs and Forestry, as custodian of the nation's water resources, has undertaken to improve the management of information for decision-making for integrated water resources management by coordinating data acquisition, data storage and management, and information generation and dissemination within the Department and between the Department and other organisations. The Monitoring and Assessment Information System (MAIS) is the focus of these efforts and is based on the precept that information needs are defined by the business processes of water resources management. Data acquisition programme design, as well as the generation and dissemination of information, should fully support meeting these information needs.