EXECUTIVE SUMMARY

Background

The middle Breede River valley in the Western Cape is an important area for the growing of vines and fruit under irrigation. Water is supplied from the Greater Brandvlei Dam, near Worcester. The bulk of the water is released into the Breede river, from which it is abstracted by the farmers. The river also serves as a drain for saline irrigation return-flows. This results in severe water quality problems in the summer. The expansion of irrigated lands will only add to this problem. Strategies which could be used to relieve this problem include the installation of drains to catch saline return-flow before it reaches the river, the upgrading of the canal water delivery system and the use of freshening releases from the Brandvlei Dam to lower salinity levels. These options either require significant capital investment, or the unproductive release of high-quality water.

The Daily Irrigation and Salinity Analysis (DISA) model is a physically-based hydrological simulation tool for the management of water supply to irrigation schemes. It was developed using the extensive research that had been conducted on salinization in the Breede River valley. The model requires the manual entry of large data sets, so that the configuration of the model for different scenarios or different catchments is a tedious procedure. This project stemmed from a perceived need by the Department of Water Affairs and Forestry to assist in the planning process by developing an interface between a geographical information system (GIS) and DISA.

Objectives

The aims of the project were as follows:

*The integration of a Geographical Information System with the DISA hydrosalinity model in order to demonstrate the application potential of GIS in hydrological modelling.

The following secondary aims are identified:

(a) To undertake a comprehensive review of the current status of efforts to integrate GIS and distributed hydrological models.

(b) To develop an application methodology that will enable the use of a GIS to collect, manipulate and provide the spatial data requirements for the Daily Irrigation and Salinity Analysis Model (DISA).

(c) To integrate the DISA model with Arc/Info.

(d) To verify that the methodology developed is functionally correct.

(e) To depict results of DISA model simulations by using and demonstrating GIS capabilities with maps, graphs, tables etc."

Summary of Findings

Literature Review

A preliminary study of the literature indicated that while the coupling of hydrological models and GIS has been proceeding for some time, little has been written about the principles and fundamental concepts involved in this activity. One approach has been to describe both hydrological models and GIS in terms of subsystems eg. subsystems for the user interface, data capture, data manipulation and analysis as well as data management and display. The coupling of models and GIS commonly occurs by linking their data management subsystems (see Figure A).

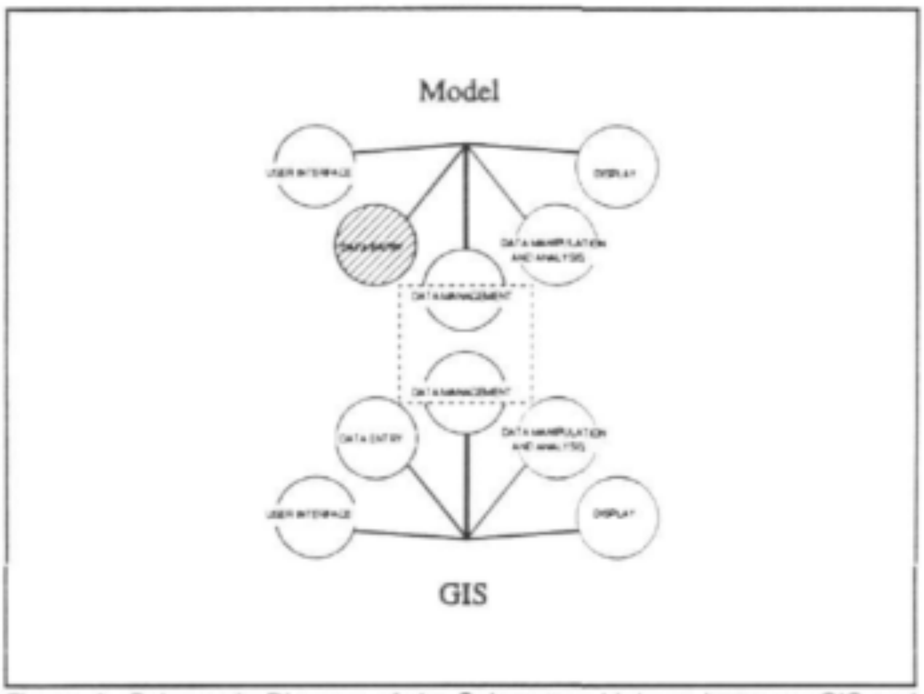

Figure A Schematic Diagram of the Subsystem Linkage between GIS and Models.

The different ways in which models and GIS can be coupled may then then be conceptualized in terms of the type of linkage established between the data management subsystems. The simplest form of linkage is the transfer of files between the model and the GIS, while an integrated system would combine the two sets of functionality in a single package. When data is exchanged between systems it is important that the data be represented in compatible ways eg. a model dealing only with features such as river reaches should be coupled with a GIS that can model linear networks rather than with a raster-based GIS.

Other perspectives on the coupling of models and GIS use the method of modelling and the user interface as organizing concepts. The modelling may be *internal* to the GIS, or it may be performed by software outside of the GIS environment, when it would be termed *external*. Coupled systems can be differentiated on the basis of whether a single user interface is presented or whether two different user interfaces have to be utilized to apply the software. These two views are closely related to the subsystems linkage classification, as an integrated system would also use internal modelling and a single user interface, while systems linked by simple file transfer would use external modelling and would probably have two different user interfaces. Figure B shows how the three perspectives on interfacing GIS and models may be integrated conceptually.

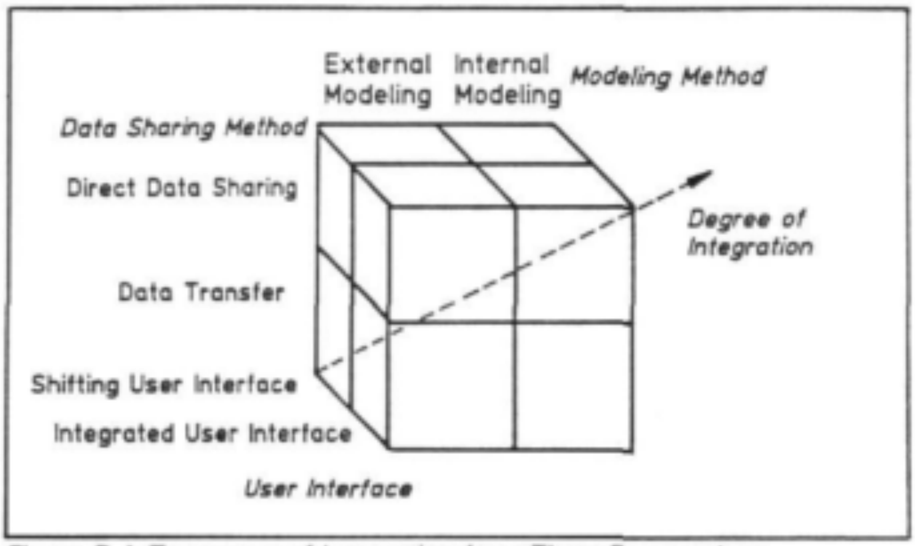

Figure B A Taxonomy of Integration from Three Perspectives

While the mechanics of establishing a simple coupling between a model and a GIS may be relatively straightforward, there are questions about the quality of results which may be obtained using this methodology. The management of error in GIS and the effect on GIS products is an area of ongoing research, but it is important to have an estimate of error in inputs to hydrological models. This is further complicated by the computational complexity and data intensive nature of distributed hydrological models. It has been suggested that the development of user-friendly GIS interfaces to hydrological models may lead to an abuse of modelling by individuals that do not understand the limitations of GIS data and the inherent complexity of hydrological models.

A number of authors have suggested ways to address the underlying problems in an automated way, but these are research proposals which are unlikely to provide practical solutions in the near future. Effective use of coupled GIS and hydrological models requires a sound understanding of both GIS and the model involved, however easy the system may be to operate. One closely related field of research is spatial decision support systems (SDSS). SDSS share a number of characteristics with decision support systems (DSS), namely the ability to address problems that are not well defined by using analytical and modelling techniques together with database systems, powerful presentation functions and ease of operation and modification. SDSS add to this the capability to capture, represent and analyse spatial data.

The literature review also examined the available references on applications of GIS with hydrological modelling, and noted that limited attention was given to the details of the coupling in the hydrological literature. The design and development of the spatial database was discussed in some detail, but little was mentioned on systems linkage and the user interface. Few references addressed the important topic of the effectiveness of coupled systems, i.e. the degree of confidence that can be attached to the results of such modelling. It was noted that most applications involved the coupling of pre-existing hydrological modelling software and GIS, and that a simple file transfer system was frequently used. Although the coupling of GIS and hydrological models had been widely demonstrated, it was not possible to determine whether or not this is a cost-effective strategy. It is difficult to evaluate the cost-effectiveness of information technology such as GIS, as its importance lies in the way that it frees skilled human resources to become more productive.

The Interfacing of DISA and Arc/Info

This project involved the use of an existing model together with Arc/Info. A simple file transfer linkage was therefore established between the two systems. As the particular strengths of GIS lie in its data capture and integration capabilities, and DISA already has a well-developed user interface, it was decided that Arc/Info could contribute most as a pre-processor of spatial information for DISA . The DISA user-interface would still be used to enter non-spatial information (see Figure C).

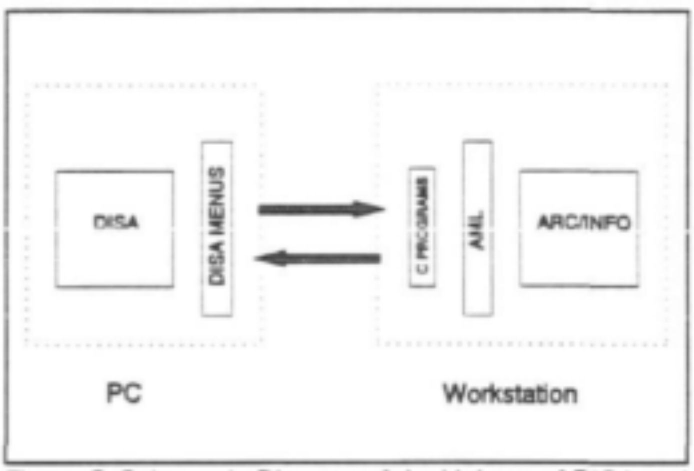

Figure C Schematic Diagram of the Linkage of DISA and Arc/Info

A GIS database was designed to receive all the spatial information required by DISA. The available spatial data was captured, and the derived data transferred into the database. It was found that the visual display of spatial data was very helpful in detecting errors in the data capture process. The results of the DISA model for the original configuration were then compared against the results obtained using the GIS-derived information. It was found that the results of the model were very similar at the point where the Breede river leaves the study area, and maximum salinities are expected (Zanddrift weir). Substantial differences were observed at return-flow cells with widely differing areas, however.

A configuration file was generated for the DISA model containing the information held in the GIS database, using the Arc/Info's own macro language as well as the C programming language. It was successfully read into the DISA configuration editor, demonstrating the success of the interface. An existing configuration file for DISA was read into the Arc/Info database, exported to DISA format again and visually compared against the original to confirm that the interface process did not introduce errors.

It was concluded that the use of GIS offers a number of significant advantages in the application of the DISA model, including faster spatial data capture, powerful visual tools for error detection and automated spatial data analysis. Although the presentation of the results of DISA were limited to the use of the existing model post-processor, all of the other objectives of the project have been met in full. The literature review synthesized both the theoretical and applications literature in a field that has been noted for its fragmentation, and provided a sound basis for the development of the interface between the DISA model and the Arc/Info GIS.

Research Needs

- The use of GIS offers much greater advantages when data capture from maps can be reduced or eliminated. A review of digital data sources available in Southern Africa, and their suitability for use in hydrological modelling is recommended. This would help reduce the large data capture costs associated with GIS.

- The identification of suitable standards for data storage in hydrological modelling is recommended, so that interfaces between models and GIS can be established more easily. The WDM format that has been established by the USGS is an example of one such standard for time series data.

- The representation of variation over time is limited in GIS. This means that the presentation of time series data from hydrological modelling within a GIS environment requires a great deal of programming expertise and effort. The Institute for Water Quality Studies has developed a sophisticated system (AQCES) to perform such a task for water quality time series. It is recommended that a system such as this should be adapted for use with models rather than independently developing GIS post-processors for models, wherever possible.

- It is recommended that the presentation of DISA output within GIS be addressed by interfacing

AQCES and DISA, as it was not possible to develop this aspect within the scope of the project.

- The interface that has been developed in the course of this project is suitable for operational use. It is recommended that the software system be applied in the configuration of DISA for a new catchment in order to demonstrate the benefit of GIS for hydrological modelling.

Technical Issues

Technical issues have been addressed in a series of appendices to the main text. These include details of the GIS database design, a discussion of the coding of the interface, the methodology developed for the use of Arc/Info with the DISA model and a detailed listing of the results obtained from GIS data capture in comparison with the original model configuration. The software that was developed in the course of this project is being archived by Ninham Shand Inc. (Cape Town), from whom it may be obtained.