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Application of geographic information systems to the assessment and management of mining impact: A project outline

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Environmental Research Institute of the

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(*eriss*)

Alligator Rivers Region

Application of Geographic Information Systems to the Assessment and Management of Mining Impact: A Project Outline

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Key Words: Geographic Information System, Impact Assessment, Soil Erosion, Hydrology, SIBERIA Landform Evolution Model, GIS-Environmental Model Linkage

ABSTRACT

A research project has been established to develop a GIS that interacts with sediment transport, hydrology and landform evolution modelling techniques for use in long term "total catchment management". The Jabiluka minesite is situated in the Swift Creek catchment, which flows directly into the RAMSAR listed Magela Creek floodplain in the World Heritage Kakadu National Park, Northern Territory. A field program has been established to collect data on discharge and sediment movement in the Swift Creek catchment through gauging of the main channel and several tributaries. Data collected on discharge and sediment movement will be used in the formation of an erosion and hydrology oriented GIS database. These data will be utilised in the calibration of the sediment transport, hydrology and landform evolution models. Linking these models with the GIS will provide a valuable tool for the proactive management of wide ranging catchment management scenarios.

1 Introduction

The impact of mining activities on a complex and relatively poorly understood environment represents one of the most important issues currently facing decision-makers. Environmental models attempt to simulate spatially distributed, time variable environmental processes (Steyaert, 1993). Geographic Information Systems (GISs), through their ability to capture, manipulate, process and display geo-referenced data, are able to describe the spatial environment (Burrough and McDonnell, 1998). GISs and environmental modelling are therefore complementary, with the overlap and relationship between these technologies being clearly apparent (Fedra, 1993). Since GIS and environmental modelling have evolved separately they have different data structures, functions and methods for inputting and outputting spatial information (Maidment, 1996). Over the past two decades there has been considerable research into the integration of these two technologies to the extent that the synthesis of spatial data representations and environmental models has been described as the new 'Holy Grail' (Raper and Livingstone, 1996). Currently there exist many different approaches to linking environmental models with GIS, from the very simple, in which the GIS is used for writing model input and the analysis of model output, to closely integrated systems (Charnock *et al.*, 1996).

In June 1998, construction of the portal, retention pond and other headworks for the ERA Jabiluka mine (ERAJM), Northern Territory, commenced. Swift Creek, a major downstream tributary of the Magela Creek, which flows directly into the Magela Creek floodplain located in Kakadu National Park, will be the first catchment to be affected should any impact occur as a result of mining operations at Jabiluka. The Rehabilitation of Mine Sites group at the Environmental Research Institute of the Supervising Scientist (***eriss***) carries out independent research into the environmental effects of uranium mining and has established a collaborative project with the Northern Territory University, entitled "Application of Geographic Information Systems to assessment and management of mining impact". This research project will develop a GIS that interacts with sediment transport, hydrology and landform evolution modelling techniques for use in long term "total catchment management". The project will use data from the Swift Creek Catchment.

This project will primarily use the SIBERIA landform evolution model, developed by Dr Garry Willgoose of the University of Newcastle, to investigate the impact of the ERAJM on sediment movement in the Swift Creek catchment. The SIBERIA model has been used by ***eriss*** to investigate post-mining rehabilitated landform design since 1993 (Willgoose and Riley, 1993; Evans *et al.*, 1998). However, the model has only been used to examine landform evolution on mine-site scale landforms. This project represents the first attempt to apply the model on a catchment wide basis in the region. The shift from mine-site scale modelling of landforms to catchment scale modelling of mining impact will be facilitated by the linkage of the SIBERIA model with a GIS. Linking the model with a GIS will greatly enhance the modelling process as the GIS will assist in the derivation, storage, manipulation, processing and visualisation of geo-referenced data at a catchment wide scale. Parameterisation of the SIBERIA model requires the use of a separate hydrology model and sediment transport model to derive a discharge/area relationship, long-term sediment loss and a sediment transport rate. As such, this project can be broken into five primary objectives:

1. Establish a spatial database,
2. Calibrate and link a hydrology model to a GIS,
3. Calibrate and link a sediment transport model to a GIS,
4. Calibrate and link a landform evolution model to a GIS, and
5. Apply the linked GIS to interactive, long term assessment and management

This report will provide a research plan detailing the activities, timelines and milestones proposed to achieve these objectives.

2 Study Area

The Swift Creek catchment is located approximately 230 km east of Darwin and approximately 20 km south-west of the town of Oenpelli (Figure 2.1a). The Swift Creek catchment lies partly in the Jabiluka Mineral Lease (JML) and partly in the surrounding Kakadu National Park (KNP), and contains the ERAJM site in its western section. The catchment is elongated with a length of approximately 11.5 km, a maximum width of approximately 7.5 km and a total area upstream from the most downstream gauging site of almost 46 km^2 (Fig. 2.1b). Within the catchment two distinct landform regions are represented (Fig. 2.1b). Occupying the eastern, southern and western sections of the catchment is the upland plateau region, which consists of highly dissected sandstone with shallow sandy soils and exposed rock. The central and northern sections of the catchment contain the Swift Creek floodplain. This area is generally flat and covered by deep sandy soils. The catchment differentiation is important as each landform region has distinctly different hydrological and geomorphological systems. Located within the monsoon tropics climatic zone, the catchment experiences a distinct wet season from October to April and dry season for the remainder of the year. The average annual rainfall is approximately 1450 mm. However, perhaps more importantly in terms of landform evolution is the high rainfall intensity associated with wet season storms, with events of 100 mm/hr and a duration of 10 minutes expected to occur annually (Finnegan, 1993).

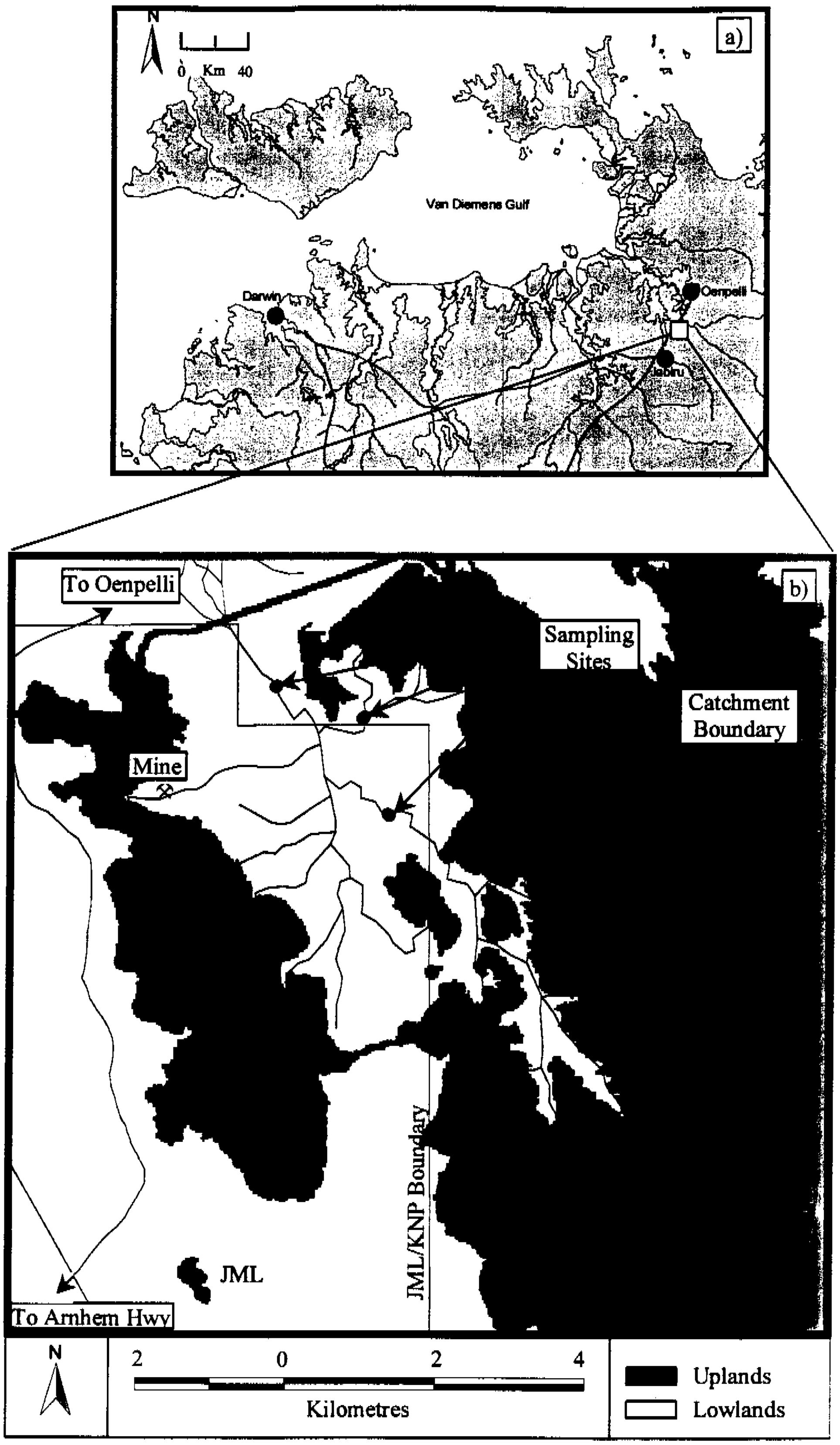

FIGURE 2.1: A) THE STUDY AREA LOCATION IN RELATION TO THE TOWNS OF DARWIN, JABIRU AND OENPELLI. **B)** THE SWIFT CREEK CATCHMENT SHOWING THE DISTINCTION BETWEEN THE UPLAND AND LOWLAND GEOMORPHIC REGIONS.

3 Research methods

3.1 Establishment of a spatial database

3.1.1 Data

In order to determine the impacts of the Jabiluka mining operations on sediment movement in the Swift Creek Catchment, the Rehabilitation of Mine Sites group at ***eriss*** have developed a field program with three primary stream gauging sites to determine the catchment baseline characteristics (Figure 2.1b). Data collected by this field program will be entered into the spatial database and will be used in the calibration of the hydrology, erosion and landform evolution models. Data that are to be or have been collected include both spatial and attribute information including; 1) maps of catchment geomorphology, morphologically homogeneous channel reaches, historical channel stability, discrete sediment storages and riparian vegetation and; 2) hydrology and sediment movement information including pluviographs, suspended sediment concentrations, turbidity, bed load movement, sediment grain size distributions, bed scour and bank erosion rates and knickpoint migration rates.

A digital elevation model (DEM) interpreted from 1:30 000 aerial photography by AiResearch Mapping will form the basis of much of the hydrological and erosion modelling (Fig. 3.1). DEMs are rectangular grids of evenly spaced terrain heights generated from spot height data, contour data, scanned aerial photographs or satellite imagery. DEMs, through the development of new methods and algorithms, allow the extraction of terain and drainage features to be fully automated. For example, DEMs have been used to delineate drainage networks and watershed boundaries, to calculate slope characteristics and to produce flow paths of surface runoff (Moore *et al.*, 1992; Quinn *et al.*, 1992). DEMs have also been incorporated into many erosion, non-point source pollution and hydrologic models. However, to use DEMs efficiently and appropriately the optimal cell size, or resolution, must be chosen (Figure 3.2). Resolution is among the most important attibutes and will determine the usefulness and cost of a DEM (PowerData, 1996).

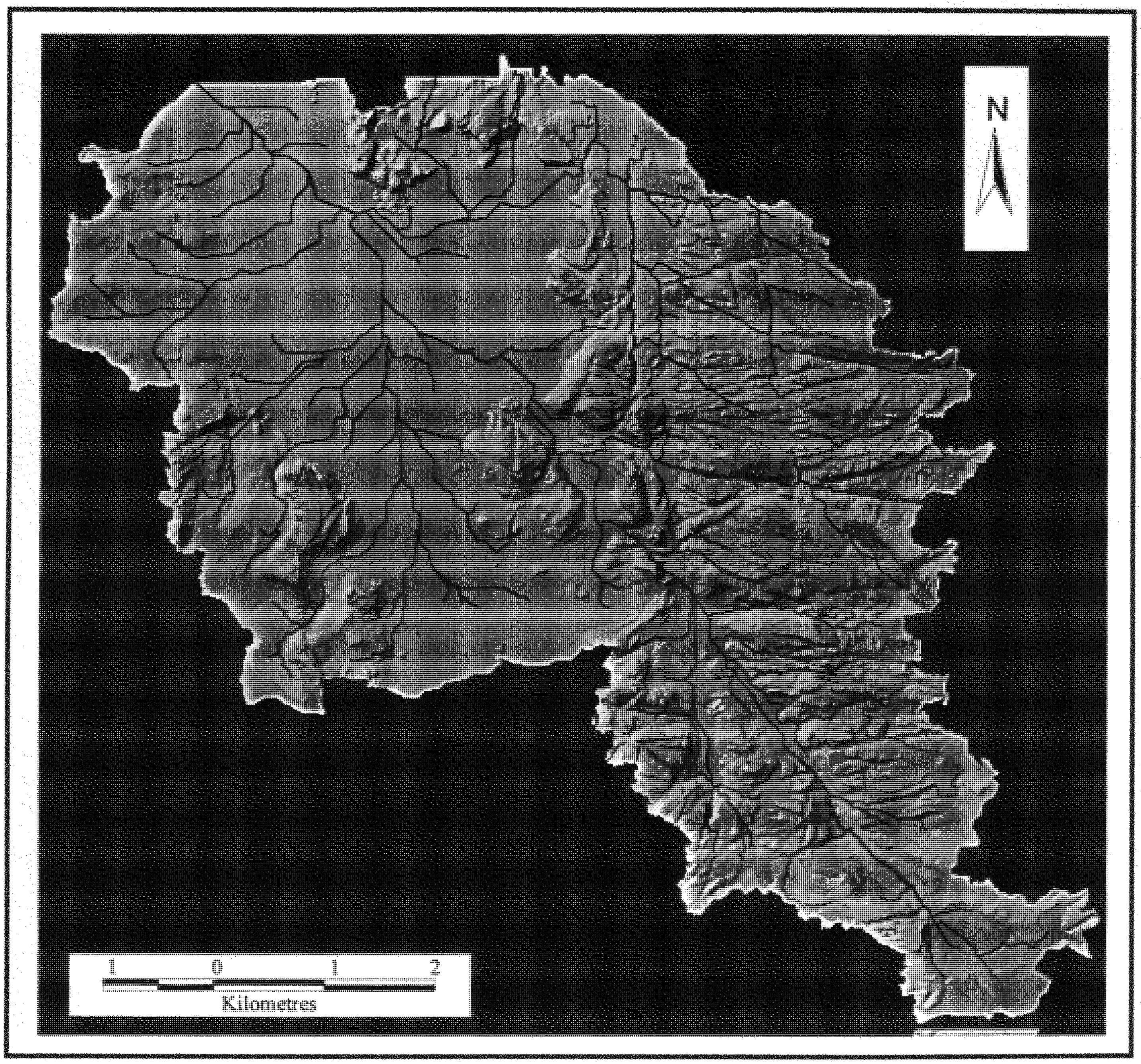

FIGURE3.1: THE DEM OF THE SWIFT CREEK CATCHMENT WITH THE DERIVED DRAINAGE NETWORK DRAPED OVER THE SURFACE.

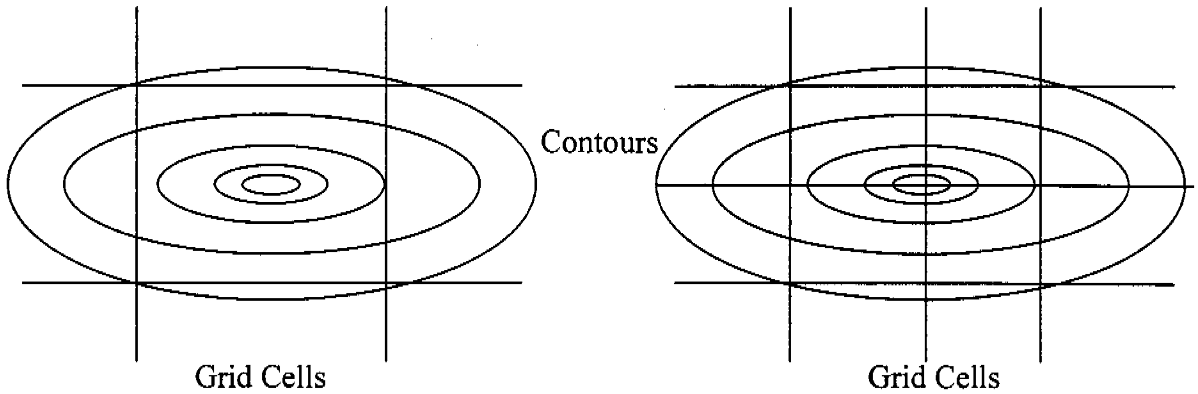

FIGURE 3.2: CELL SIZE IS IMPORTANT AS SURFACES TEND TO BE AVERAGED OR 'SMOOTHED' BY LARGER GRID CELL SIZES.

The existing ***eriss*** spatial database in Jabiru contains approximately 12Gbytes of data, including thematic coverages, aerial photography, satellite imagery and DEM data. ***eriss*** also has access to a comprehensive satellite imagery archive stored at the Environmental Resources Information Network (ERIN) in Canberra, details of which are available through the internet. The base GIS consists of the topographic 1:250000 digital data product produced by AUSLIG (which includes layers of drainage, waterbodies, roads etc) with some of the data available at 100k scale. Additional data layers are related to individual projects and have been obtained in the field or from aerial photography or other imagery (Bull, 1999).

3.1.2 Database development

In the past the primary limiting factor during the establishment and application of a geographical information system (GIS) was the lack of technical possibilities. However, with the proliferation of advanced computer equipment and software, the primary issues currently associated with GIS development relate to its context and intended use (Erik de Man, 1988). Clarke (1991) developed a general GIS acquisition model based on current systems development and project management practices which comprises four stages; 1) analysis of requirements; 2) specification of requirements; 3) evaluation of alternatives; and 4) system implementation. Devonport (1992) modified this approach in his development of a prototype approach for GIS development in the Alligator Rivers Region Research Institute of the Office of the Supervising Scientist (now ***eriss***). This approach viewed the implementation phase of

Clarke's model as a continuous cycle of processes from data capture through to presentation of results. This approach will be adopted in this research as it provides, to some extent, the functional requirements of dynamism, feedback mechanisms and flexibility (Devonport 1992).

Within this approach, consideration must be paid to GIS software selection. The GIS software selection process will consider existing GIS software at ***eriss***, user-friendliness of various software packages, the software's ability to incorporate external models and both spatial and attribute data sets, functionality contained within the software and costs associated with incorporating the software into the existing ***eriss*** network. The current GIS software used by ***eriss*** is ARC/INFO and ArcView. It is most likely that this software will be used within this project as ArcView is relatively simple to use and is becoming increasingly functional whilst ARC/INFO has a higher degree of functionality and processing power than ArcView.

3.2 Calibrate and link a hydrology model to a GIS

3.2.1 DISTFW hydrology model description and calibration

The Distributed parameter Field-Williams (DISTFW) hydrology model is a sub-catchment based rainfall-runoff model based on a one-dimensional kinematic wave flood routing model called the Field-Williams Generalised Kinematic Wave Model (Field and Williams, 1983; 1987). DISTFW has been frequently used to generate parameters required by the SIBERIA landform evolution model (eg Evans *et al.*, 1998; Willgoose and Riley, 1998). The DISTFW hydrology model is a distributed hydrological model that is applied on a digital terrain model (DTM) basis. Each grid cell is considered to be an individual sub-catchment and drainage from node to node and through nodes occurs by a kinematic wave on the overland flow (Willgoose and Riley, 1998). Hydrological processes represented by the model include (Finnegan, 1993):

1. Nonlinear storage of water on hillslope surfaces,
2. Philip infiltration from the surface storage to a linear groundwater store,

3. Discharge from the surface storage to the channel,

4. Discharge from the groundwater storage to the channel, and

5. Routing of the runoff down the channel using the kinematic wave (Figure 3.3).

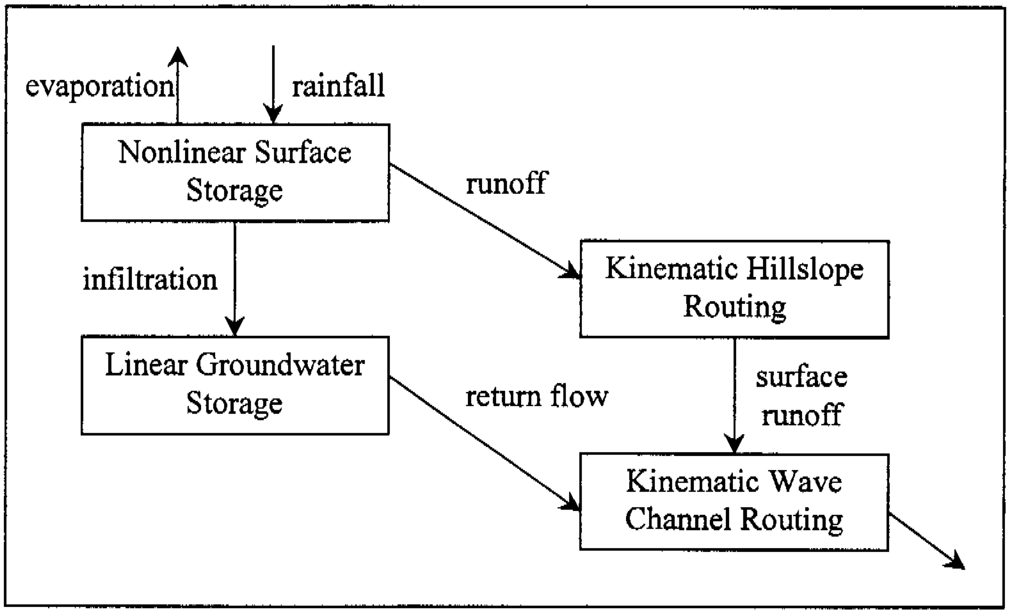

FIGURE 3.3: CONCEPTUAL VIEW OF THE DISTFW RAINFALL-MODEL (AFTER WILLGOOSE AND RILEY, 1998).

The calibration process for the DISTFW hydrology model involves using a non-linear regression package, NLFIT, to fit model parameter values. The combined DISTFW-NLFIT package will use observed rainfall and the resulting discharge hydrograph data from the three previously described sampling sites to derive the best fit model parameter values that produce a predicted hydrograph similar to the observed hydrograph for the upstream catchment. Output from the DISTFW model is used in the calculation of the long term sediment yield to derive input for the SIBERIA landform evolution model (Evans *et al.*, 1998).

3.2.2 DISTFW model and GIS integration

Although the components of hydrological modelling predate GIS by more than a century, the two disciplines have converged strongly over the last 20 years. GIS is concerned with representing the spatial features of the Earth, while hydrological modelling is focussed on the movement of water and its constituents through these features (Maidment, 1993). The convergence of these disciplines is therefore an obvious and predictable step in the evolution of hydrologic modelling (Clark, 1998). This project's proposed method for linking the DISTFW hydrology model with the GIS will use a 'tight coupling' approach, as described by Fedra (1993) (Figure 3.4).

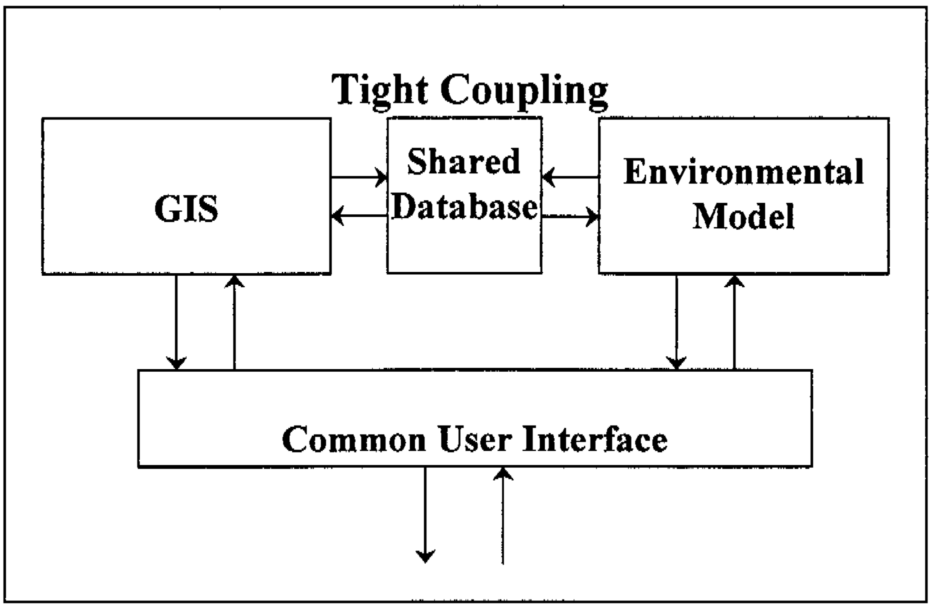

FIGURE 3.4: A SCHEMATIC REPRESENTATION OF THE TIGHT COUPLING APPROACH TO BE USED FOR THE INTEGRATION OF THE HYDROLOGY MODEL AND GIS (AFTER FEDRA, 1993).

This level of integration will provide a common user interface for both the GIS and the model, with the file or information sharing between the respective components being transparent to the end user. The DISTFW hydrology model and the GIS will share the same database. As much of the input data requirements of DISTFW are spatially variable (eg topographic survey information and rainfall) the GIS will further be able to provide much of the input requirements of the model. There are various methods to implement this approach. This project will use the higher-level application language associated with ArcView (Avenue) in the creation of links between the GIS and DISTFW.

3.3 Calibrate and link a sediment transport model to a GIS

3.3.1 Sediment transport model description and calibration

The sediment transport model (STM) to be used in this study is a standard erosion model used by geomorphologists and soil scientists and has previously been used in the calibration of the SIBERIA landform evolution model. The model is derived from the equation described in Evans *et al.*, (1998) of the form:

$$Q_s = \beta_2 Q^{m_1} S^{n_1} \tag{3.1}$$

where,

Q_s = total sediment discharge in a channel, gully or plot (g s^{-1})

Q = total instantaneous discharge (L s^{-1})

S = local slope (m m^{-1})

The parameters β_2, m_1 and n_1 are fixed by flow geometry and erosion physics. This equation includes a shear stress component and has been used to fit parameter values for a relationship between instantaneous discharge and sediment discharge (Willgoose and Riley, 1993). The equation was considered by Smith and Bretherton (1972) to apply to all elements of a surface, including channel and non-channel elements, and to bedload transport. The equation is also considered applicable to total sediment loss (T) during a rainfall event by substituting a function of cumulative runoff over the duration of the event for the instantaneous discharge:

$$T = \beta_2 S^{n_1} (\int Q^{m_1}\, dt) \tag{3.2}$$

Multiple regression using logarithmic transformations is used to fit the parameters β_2, m_1 and n_1, such that equation 3.2 can be expressed as:

$$\log T = \log \beta_2 + n_1 \log S + x \log (\int Q^{m_1}\, dt) \tag{3.3}$$

The calibration process involves assigning an arbitrary value to m_1 to determine a value for $\int Q^{m_1}\, dt$ (cumulative Q^{m_1}) for each event. This value is then substituted back into equation 3.3 for regression analysis. This process is continued until the value of the coefficient x is equal to one. *Log* β_2 is fitted as a constant (Evans *et al.*, 1998).

3.3.2 Sediment transport model and GIS integration

Linking soil erosion models with a GIS provides a powerful tool for land management. Utilising a GIS in erosion assessment allows the rapid production of modified input-maps for more rapid scenario assessment, the simulation of large catchments at a greater level of detail and greater ease of interpretation of results through visualisation (De Roo, 1996). Futher, the analysis of DEMs within GISs provides a detailed description of the catchment morphology for erosion model input (Mitas and Mitasova, 1998). As the sediment tranport model (STM) required for SIBERIA parameter derivation consists of a single equation, the integration approach adopted for this project will involve embedding the sediment transport equation within the GIS (Figure 3.5). That is, the model will become one of the analytical functions of the GIS. The coupling of software components in this system will occur within a single application with shared memory, as opposed to simply having a shared database and a common interface. This approach represents the tightest method of integration (Loague and Corwin, 1998).

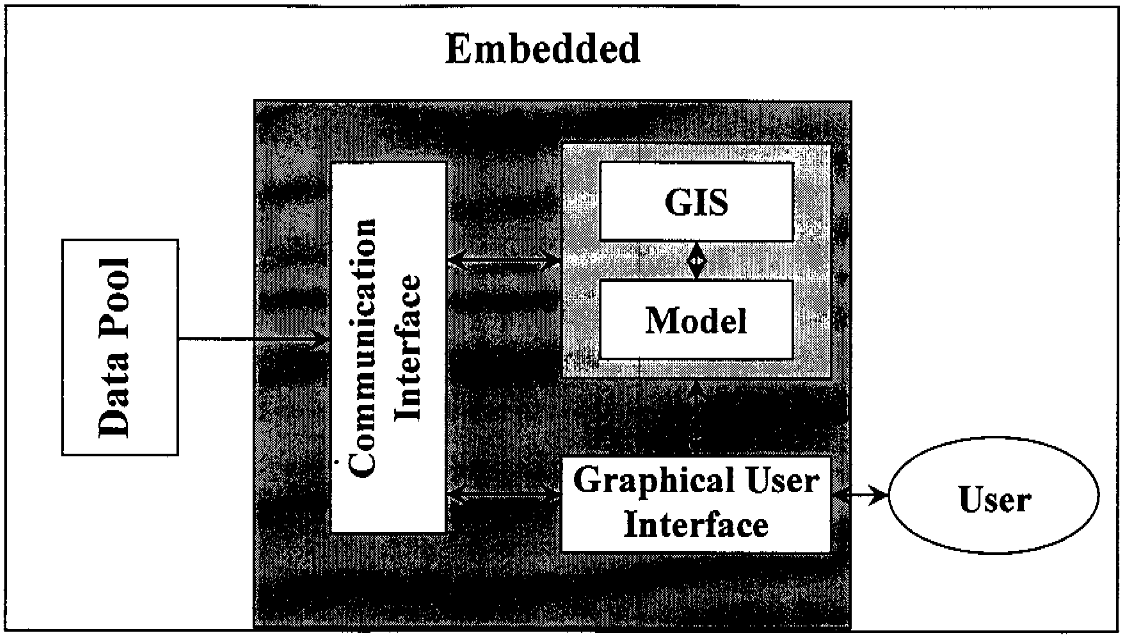

FIGURE 3.5: LINKING THE SEDIMENT TRANSPORT MODEL (STM) WITH THE GIS WILL INVOLVE EMBEDDING THE STM EQUATION WITHIN THE GIS (AFTER LIAO AND TIM, 1997).

3.4 Calibrate and link a landform evolution model to a GIS

3.4.1 Siberia landform evolution model description and calibration

SIBERIA, developed by Dr G R Willgoose of the University of Newcastle and originally described in Willgoose *et al.,* (1989), is a computer model designed for examining the erosional development of catchments and their channel networks (Figure 3.6). The model incorporates the interaction between hillslopes and the growing channel network based on physically observable mechanisms. Catchment elevations, including both hillslopes and channels, are simulated by a mass transport continuity equation applied over geologic time (Willgoose and Riley, 1998). An explicit differentiation is made between the processes that act on the hillslope and those acting within the channel network. Channels are dominated by fluvial erosion processes whilst hillslopes are shaped by both fluvial and diffusive processes. Channel network growth is controlled within the model by a physically based threshold mechanism. That is, if a channel initiation function (based on slope and discharge) exceeds some predetermined threshold (dependent on local resistance to channelisation), then channel head advancement occurs. Interaction between the elevations on the hillslopes and the growing channel network occurs through the different transport processes in each regime and the resultant preferred drainage to the channels. It is the interaction of these processes which produces the long-term catchment form (Willgoose and Riley, 1998).

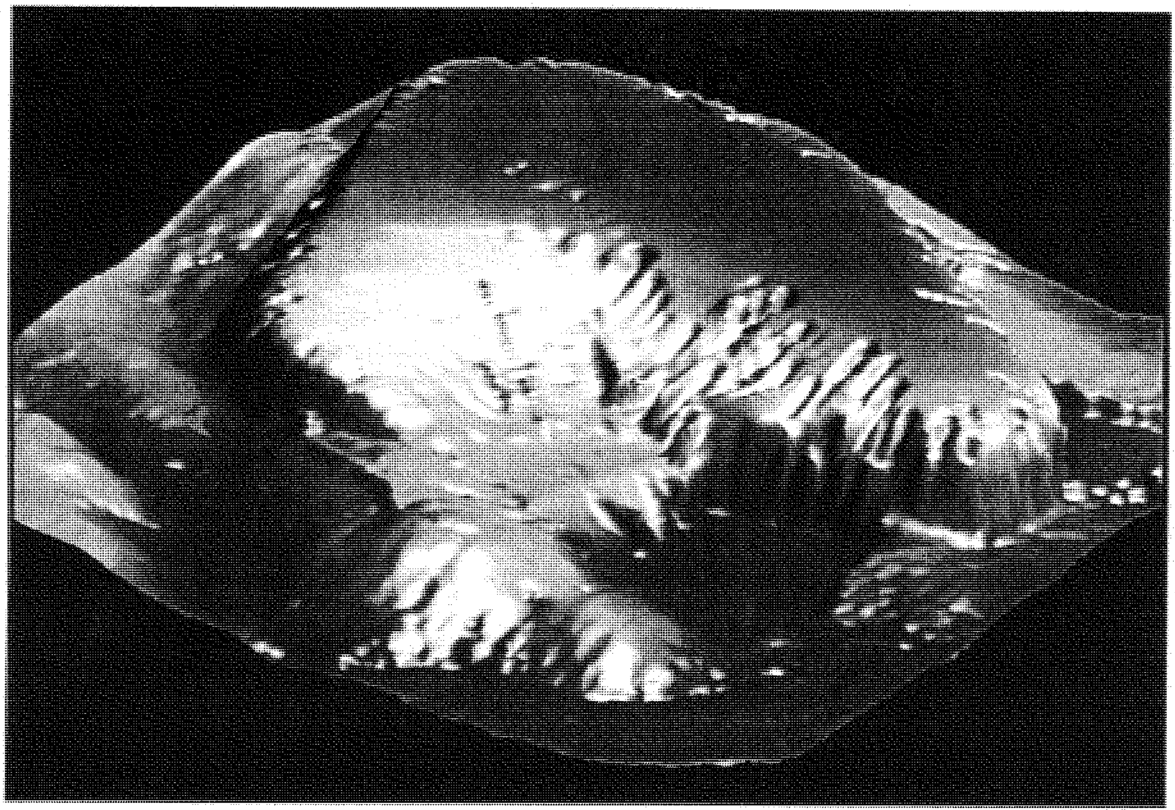

FIGURE 3.6: MODELLED LANDFORM EVOLUTION ON A PROPOSED POST-MINING LANDFORM, SHOWING THE DEVELOPMENT OF GULLIES AND DEPOSITIONAL FANS (AFTER EVANS, 1997).

Calibration of the SIBERIA landform evolution model involves deriving parameters using the previously described sediment transport equation and DISTFW hydrology model (Figure 3.7). In addition to these parameters, it is necessary to derive long term average SIBERIA model parameters for the landform being modelled. This complex process, as described by Willgoose and Riley (1993), is essentially composed of three parts including; 1) yielding the temporal average discharge area relationship; 2) calculation of the runoff series and long term sediment loss rate and; 3) application of a slope correction function.

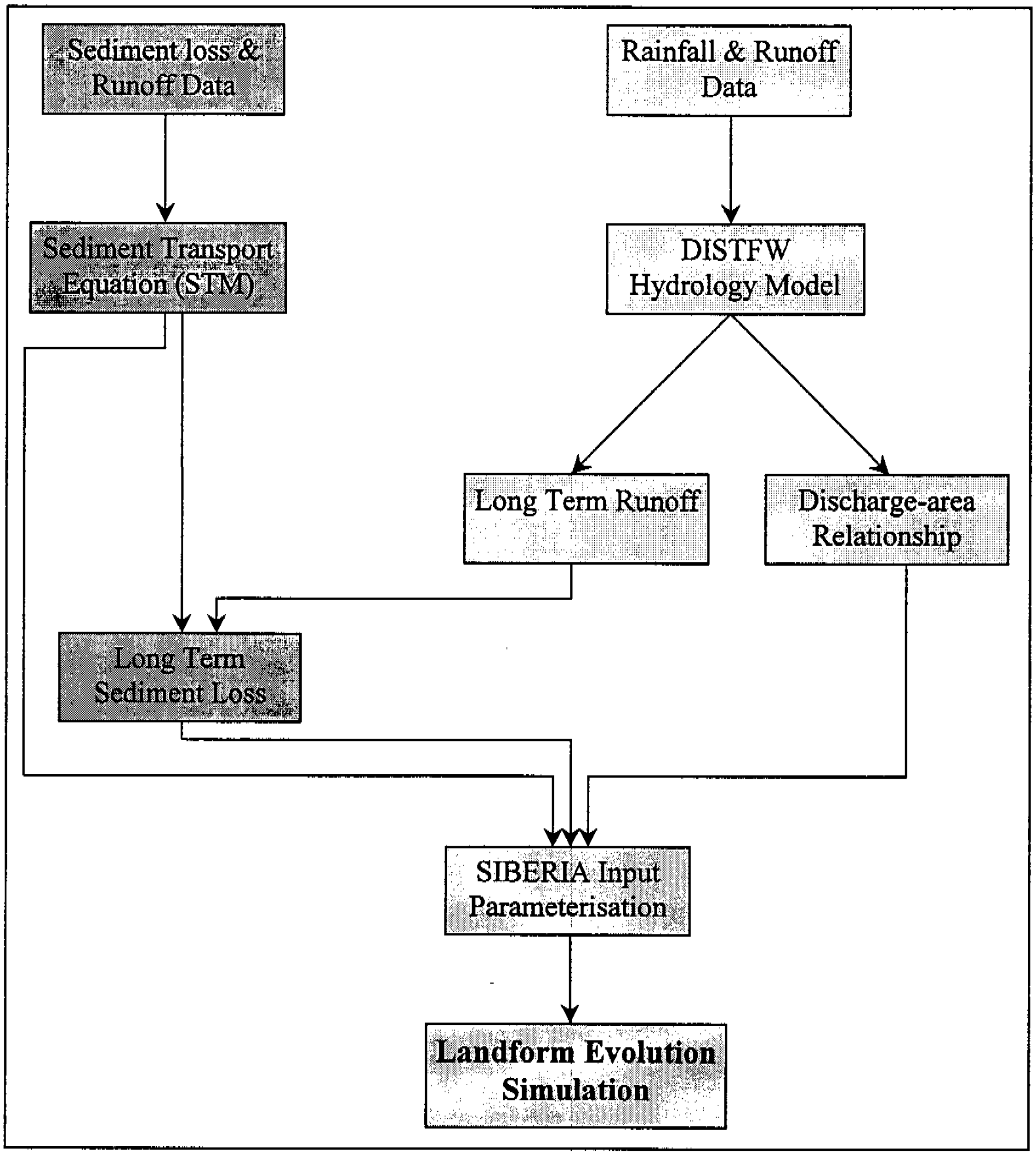

FIGURE 3.7: A FLOW CHART OF THE SIBERIA PARAMETERISATION PROCESS (AFTER EVANS *ET AL.*, 1998)

3.4.2 SIBERIA landform evolution model and GIS integration

The SIBERIA landform evolution model is computationally intensive and does not lend itself to interactive use. Therefore, integration of this model with a GIS requires the use of a relatively simple approach. Loose coupling, which represents the simplest form of integrating GIS and environmental models, involves transferring data from one system to another through the storage of data in one system and the subsequent reading of the data by the other (Figure 3.8). That is, some of the input data for the model may be read from GIS files whilst some of the model output may be in a format that allows processing and display with GIS (Fedra, 1993). The central role of the GIS in the actual process of modelling is therefore negligible in the loose coupling approach (Clark, 1998). The separate functionality of the programs that implement the GIS and those that implement the models is the most significant characteristic of loose coupling (Loague and Corwin, 1998). An important advantage of loose coupling is that the linkages remain flexible, with it being possible to interchange the model with another.

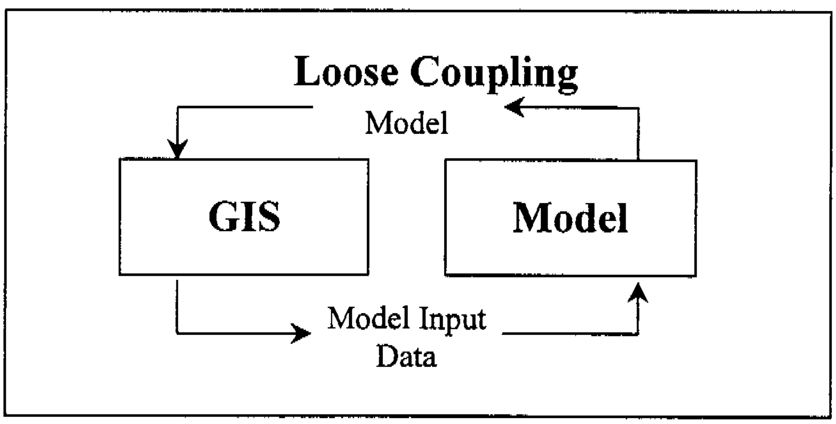

FIGURE 3.8: THE LOOSE COUPLING APPROACH TO BE USED IN THE LINKAGE OF THE SIBERIA LANDFORM EVOLUTION MODEL AND THE GIS (AFTER LOAGUE AND CORWIN, 1998).

3.5 Apply an interactive GIS to long term assessment and management

One of the primary advantages of linking environmental models to a GIS is the possibility of rapidly producing modified input-maps with different management practices to simulate alternative scenarios (De Roo, 1996). Desmet and Govers (1995), for example, were able to rapidly assess the impact of varying a length proportionality factor on landform evolution within an agricultural landscape by using a GIS based simple landscape evolution model.

The draft Environmental Impact Statement (EIS) for the Jabiluka uranium mine project (Kinhill, 1996) provides descriptions of mine development alternatives. These include the Ranger Mill Alternative (RMA), the Jabiluka Mill Alternative (JMA) and the Pancontinental proposal. With respect to the JMA the Government has required ERA (Energy Resources of Australia) to put all tails back down in the mine stopes specially excavated silos. Once the GIS/modelling technology has been developed, various scenarios of mine site design will be modelled to assess possible impacts of the Jabiluka mine on landform evolution within the Swift Creek catchment. It is expected that these model simulations will focus on the final development alternative, e.g. JMA, addressing various design scenarios incorporated in the alternative such as waste rock dump and infrastructure design variation. Impacts of the alternative management scenarios on catchment evolution will be assessed over both long- and short-term time scales. Outcomes derived from these modelling scenarios can be used in the formation of management recommendations once final decisions on mine development and design are made.

4 Research Plan

The project "Application of GIS to the Assessment and Management of Mining Impact" commenced on the 1 of Feburary, 1999 and is expected to be completed by the 1 of Feburary, 2002. A general research plan has been devised for the period of the project (Table 4.1). The sequence of tasks to be implemented through the duration of the project follow from each of the project objectives. The general structure of the research plan is therefore based upon these project objectives. The research plan also inlcudes a description of the activities carried out during the first 5 months of the project, which have now been completed.

Table 4.1. A timeline showing the activities to be completed throughout the project's duration

Project Period	1999											2000												2001												
Introductory Period	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
NTU and *eriss* familiarisation	■	■	■																																	
Stream Sampling	■	■	■	■							■	■	■	■	■								■	■	■	■	■									
Digital Elevation Model Construction			■	■	■																															
ArcView/ARCINFO installation				■	■																															
Spatial Database Establishment	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Initial Literature Review			■	■	■	■	■																													
Analysis of *eriss* Requirements						■	■	■																												
Evaluate Information Storage Methods							■	■	■																											
Develop Data Entry User Interfaces							■	■	■																											
GIS Customisation							■	■	■	■	■																									
STM Calibration and GIS Linkage	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
SIBERIA Familiarisation									■	■	■	■																								
Investigate STM and GIS Linkage												■	■																							
Integrate STM with the GIS														■	■	■																				
STM Calibration and Sensitivity Analysis																■	■																			
DISTFW Calibration and GIS Linkage	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Investigate DISTFW and GIS Linkage																		■	■																	
Link/Integrate DISTFW with the GIS																			■	■	■															
DISTFW Calibration and Sensitivity																						■	■													
SIBERIA Calibration and GIS Linkage	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Investigate SIBERIA and GIS Linkage																								■	■											
Link SIBERIA with the GIS																									■	■	■	■								
SIBERIA Calibration and Sensitivity																												■	■							
Application of interactive GIS	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Apply GIS to Management Scenarios																														■	■					
Analyse GIS/Model Output for																																■	■			
Critical Analysis of GIS/Model																																	■			
Final Report Preparation																																		■	■	■

4.1 Introductory Period (February, 1999 to June, 1999)

The first 5 months of the project served as an introductory period and was primarily concerned with gathering background information, which would form a solid basis for the project (Table 4.2). The PhD candidate selected to implement this approach arrived from Perth in January 1999. Therefore, during the first two months considerable time was spent becoming familiar with the NTU and ***eriss*** environments. This process, however, is on-going. During the first three months time was also spent in the field, collecting data for the "Impacts of the Jabiluka mining operations on sediment movement in the Swift Creek catchment" project, to be entered into the GIS. This allowed familiarisation with the Jabiluka mine and Swift Creek catchment and gave a context for the data being entered into the GIS.

A DEM of the Swift Creek Catchment was constructed by AiResearch Mapping Pty Ltd. This involved interpreting 1:30 000 aerial photography for the eastern half of the catchment, whilst a DEM, previously constructed for ERA covering the catchment's western half, was used to form a DEM of the whole catchment. A 5m DEM grid, breaklines coverage and contour coverage were supplied by AiResearch by the 16 June, 1999.

ArcView and ARC/INFO GIS software have been established within the Rehabilitation of Mine Sites group, the ordering of which was primarily carried out by Dr Ann Bull. One ArcView license and one ARC/INFO license now reside within the Rehabilitation of Mine Sites group, with a further two ArcView license being available through the network.

Research for an initial literature review, to form chapter one of the thesis, commenced in April, 1999. This involved many database searches and the subsequent formation and submission of numerous Inter-Library Loan (ILL) requests. Writing of the literature review was started once sufficient literature was received. At present, approximately three quarters of this chapter has been written. The literature review also involved the construction of a literature database. During the month of June, three presentations on the project were made at NTU, ***eriss*** and the Northern Australian Remote Sensing and GIS (NARGIS) conference respectively.

Table 4.2: Major Tasks completed within the period February 1999 to June 1999.

Introductory Period	
Tasks	**Completion Month**
NTU Familiaristion	April 1999
eriss Familiarisation	April 1999
Field Work (stream sampling)	May 1999
Digital Elevation Model Construction	June 1999
eriss ArcView / ARC/INFO software installation	June 1999
Project Proposal	June 1999

4.2 Spatial Database Establishment (July, 1999 to December, 1999)

As described in section 3.1.2, the approach adopted to establish the GIS database is based on Devonport's (1992) modified version of Clarke's (1991) model in which the implementation phase is viewed as a continuous cycle of processes from data capture through to presentation of results (Figure 4.1). However, the base GIS will be established by December 1999, with further improvements being made through the project duration as required (Table 4.3).

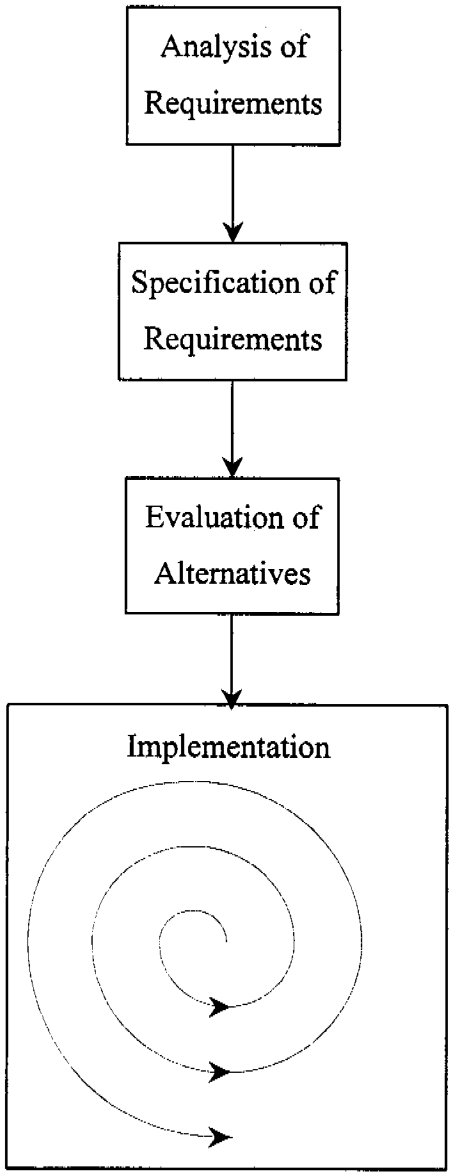

FIGURE 4.1: A FLOW CHART DEPICTING THE MODIFIED GENERAL GIS ACQUISITION MODEL DEVELOPED BY CLARKE (1991).

The literature review is expected to be completed by August, 1999, after which the focus of this project will be on the establishment of a spatial database and the formation of a user-specific GIS for the Rehabilitation of Mine Sites group. The initial phase of the GIS development will involve identifying the individual needs of the Rehabilitation of Mines Sites group. This will include gauging the level of GIS expertise which currently exists in the group, establishing the intended use of the GIS and identifying the various forms of data to be entered into the GIS.

Following the identification of the ***eriss*** GIS requirements, an evaluation of various information storage methods will be undertaken. This will form the first step in the actual formation of the GIS, as it will determine the required data structure and will influence the way in which the GIS interacts with the data. Once the data storage structures have been determined, data entry user interfaces or methodologies will be developed. This will maintain data consistency and integrity, and will significantly increase the rate at which data entry will occur. Customisation of the final GIS user interface and data preparation/entry will take place over the entire spatial database establishment phase of the project, with the final GIS expected to be completed by December, 1999. A report documenting the progress of this project stage will be submitted by 31 December, 1999.

Table 4.3: Major Tasks to be completed within the period July 1999 to December 1999.

Spatial Database Establishment	
Tasks	**Completion Month**
Initial Literature Review	August 1999
Analysis of eriss Requirements	September, 1999
Evaluate Information Storage Methods	October, 1999
Develop Data Entry User Interfaces	October, 1999
GIS Customisation	December, 1999
eriss Progress Report	December, 1999

4.3 STM Calibration and GIS linkage (January, 2000 to June, 2000)

The period spanning January, 2000 to June, 2000 will be occupied with calibrating the sediment transport model and integrating the model with the GIS (Table 4.4). The first step in this process is to become familiar with the basics of the SIBERIA landform evolution model. This will require an examination of the formats of the various input/output files required by SIBERIA and associated models and the development of an understanding of the way in which the models interact, within an application environment. Once this base understanding exists, a detailed investigation of the STM will take place. This is necessary to establish the most appropriate method for linking the model to the GIS and applying the model at a catchment scale.

A method will be developed to link the STM to the GIS based on knowledge of the model itself and of methods used elsewhere to the link environmental models with GIS. Subsequent to linking the model with the GIS, the model will be calibrated using data collected from the Swift Creek Catchment during the 1998/1999 and 1999/2000 wet seasons. An important issue at this time will revolve around whether it will be possible to calibrate the linked model/GIS or whether the model will have to be calibrated outside the GIS environment. Once calibrated, a sensitivity analysis of the linked model/GIS will be conducted to indicate the stability of the linked model/GIS. A project report documenting this phase of the project will be completed by the end of June, 2000.

Table 4.4: Major tasks to be completed within the period January 2000 to June 2000.

STM Calibration and GIS linkage	
Tasks	**Completion Month**
Initial SIBERIA Familiarisation	January, 2000
Introduction to Input/Output File Formats of SIBERIA and Associated Models	January, 2000
Examine the Connectivity between SIBERIA and Associated Models	January, 2000
Examine the STM in detail	February, 2000
Further Investigate Potential Methods for STM – GIS integration	February, 2000
Integrate the STM with the GIS	May, 2000
Calibrate the STM	May, 2000
Conduct a Sensitivity Analysis	June, 2000
eriss Progress Report	June, 2000

4.4 DISTFW Calibration and GIS linkage (July, 2000 to November, 2000)

The sequence of tasks involved with calibrating and linking the DISTFW hydrology model with a GIS is similar to that adopted during the STM calibration and GIS linkage (Table 4.5). That is, the hydrology model will be examined in detail to establish the functionality of the model. With this knowledge an appropriate method for integrating the DISTFW model with the GIS will be designed and implemented. A significant part of this task will be involved with developing a user-friendly graphic interface for the linked model/GIS. The model will subsequently be calibrated for the Swift Creek catchment and the linked model/GIS will be subjected to a sensitivity analysis. The progress report required by ***eriss*** for December, 2000 will primarily focus on this phase of the research, documenting the calibration and linkage of the DISTFW hydrology model with the GIS.

Table 4.5: Major tasks to be completed within the period July, 2000 to November, 2000.

DISTFW Calibration and GIS linkage	
Tasks	**Completion Month**
Examine the DISTFW Hydrology Model in detail	July, 2000
Investigate Methods for Integration of DISTFW/GIS	July, 2000
Link/Incorporate DISTFW with the GIS	October, 2000
Calibrate the DISTFW model	November, 2000
Sensitivity Analysis	November, 2000
eriss Progress Report	December, 2000

4.5 SIBERIA Calibration and GIS linkage (December, 2000 to June, 2001)

The research phase associated with linking the SIBERIA landform evolution model with the GIS covers a period of seven months, from December, 2000 to June, 2001 (Table 4.6). This longer period for model/GIS integration reflects the greater complexity of the SIBERIA landform evolution model. However, the general steps involved with this project phase are essentially the same as those involved with linking the STM and DISTFW models with the GIS. Becoming familiar with the operation of the SIBERIA model is once again the first step. Developing and implementing a method for linking the two technologies will occupy a significant portion of time, spanning four months. Finally, the calibration of the model and the sensitivity analysis parts of this project phase will be conducted during the months of

May and June, 2001. A progress report on this section of the project will be completed by the 30 June, 2001.

Table 4.6: Major tasks to be completed within the period December, 2000 to June, 2001.

SIBERIA Calibration and GIS linkage	
Tasks	**Completion Month**
Examine the SIBERIA Landform Evolution Model in Detail	January, 2001
Investigate Methods for Integration of SIBERIA/GIS	January, 2001
Link/Incorporate SIBERIA with the GIS	May, 2001
Calibrate the SIBERIA model	May, 2001
Sensitivity Analysis	June, 2001
eriss Progress Report	June, 2001

4.6 Application of an interactive GIS to long-term assessment and management (July, 2001 to January, 2002)

The final objective to be achieved by this project is to apply the interactive GIS to the long-term assessment and management of possible impacts associated with the ERAJM (Table 4.7). The first step in this phase is therefore to identify the various management scenarios that are possibly going to be applied to the ERAJM (eg the JMA – waste rock dump design, infrastructure design etc (as described in section 3.5)). The interactive GIS will be applied to these scenarios and the modelled output analysed to identify the impact of each alternative on landform evolution within the Swift Creek Catchment. The results of this analysis will be further used in the formation of management recommendations for the mine. The application of the interactive GIS to real life problems will aid the identification of possible problems associated with the interactive GIS. This will allow the opportunity to refine the tool and will give an understanding of any potential application limitations. Final results will be produced using the interactive GIS and a draft copy of the final ***eriss*** project report will be completed by the 31 December, 2001. The final project report will be completed by the 30 June, 2002.

Table 4.7: Major tasks to be completed within the period July, 2001 to January, 2002.

Application of an interactive GIS to long-term assessment and management	
Tasks	**Completion Month**
Develop Management Scenarios	July, 2001
Apply Interactive GIS to Scenarios	July, 2001
Analyse Differences Between Scenarios	August,2001
Determine Management Recommendations	August, 2001
Identify Problems Associated with the Interactive GIS	September, 2001
Produce Final Results (Maps and Other Data)	September, 2001
eriss Draft Final Report	December, 2001
eriss Final Project Report	June, 2002

5 Summary

This research project, representing a collaborative effort between ***eriss*** and the Northern Territory University (NTU), will develop a GIS that interacts with sediment transport, hydrology and landform evolution modelling techniques for use in long term "total catchment management". More specifically, data collected by ***eriss*** on discharge and sediment movement will be used in the formation of an erosion and hydrology oriented GIS database. These data will be utilised in the calibration of the sediment transport, hydrology and landform evolution models. Linking these models with the GIS will provide a valuable tool for the proactive management of wide ranging catchment management scenarios.

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