FLOOD DAMAGE MANAGEMENT AIDS FOR INTEGRATED SUSTAINABLE DEVELOPMENT PLANNING IN SOUTH AFRICA

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Water Research Commission

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Report to the Water Research Commission

by

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The title of the project is "Aids for flood damage assessment and flood control planning in irrigation and urban areas".

The Steering Committee responsible for the project consists of the following members:

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Mr H L Weepener	:	Institute for Soil Climate and Irrigation, ARC
Mr M Braune	:	SRK Consulting
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Mr M Butler	:	CASE

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Signed: ....
M F VILJOEN
PROJECT LEADER

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ANUFLOOD	-	Computer program developed by the Australian National University to calculate flood damage
ARC	-	Agricultural Research Council
CASE	-	Community Agency for Social Enquiry
CBA	-	Cost-benefit analysis
CBO	-	Community based organisations
CD	-	Compact disk
CMA	-	Catchment Management Agency
CRES	-	Centre for Resource and Environmental Studies
CUMEC	-	Cubic metre per second
DCD	-	Department of Constitutional Development
DMP	-	Disaster management plans
DTM	-	Digital terrain model
DWAF	-	Department of Water Affairs and Forestry
EAD	-	Expected annual flood damage computation
EIA	-	Environmental impact assessment
FAP	-	Flood Action Plan
FLODCAL	-	Flood damage questionnaire model
FLODSIM	-	Flood damage simulation model for irrigation areas
GIS	-	Geographic Information System
HECRAS	-	Steady state flood hydraulics model
IDP	-	Integrated development plans
LDO	-	Land development objective
MAD	-	Mean annual damage
MAR	-	Mean annual rainfall
MAUT	-	Multi-attribute utility theory
MAVT	-	Multi-attribute value theory
MCDA	-	Multiple criteria decision analysis
MCDM	-	Multiple criteria decision making
NGO	-	Non-governmental organisation
QEIA	-	Qualitative economic impact assessments
RII	-	Relative impact index
RMF	-	Regional maximum flood
SANDF	-	South African National Defence Force
SAPS	-	South African Police Service
SCBA	-	Social cost-benefit analysis
SIA	-	Social impact assessment
SMART	-	Simple multi-attribute rating technique
SRK (Consulting)		Steffen, Robertson and Kirsten Consulting engineers and scientists
SWS	-	Government Water Scheme (Staat Water Skema)
TEWA	-	Computer model for tangible economic flood water damage assessment
TLC	-	Transitional local council

UFS	-	University of the Free State
UOFS		University of the Orange Free State
WCD	-	World Commission on Dams
WRC	-	Water Research Commission

EXECUTIVE SUMMARY

INTRODUCTION

The floods of 1988 and the assignment to revise the National Flood Management Policy of South Africa served as motivation to start with the so called *ex ante* stage of flood damage research in South Africa. The main aim of the *ex ante* research stage (comprising 3 phases) was to develop flood damage management aids (loss functions, computer programmes, and questionnaires) to assist planners and authorities involved in flood damage assessment and management.

The aims of the first phase (1992-1994) were specified as follows:

- Develop loss functions to determine potential damage for different land use types in demarcated flood plains of the specified research area.
- Develop the outline of a computer database in which loss functions can be stored and apply it to the research area.
- Develop a computer programme to determine the benefits of different combinations of flood control measures with the loss functions in the database.
- Demonstrate the application of the computer programme for flood management planning in the research area.

During this phase, it was possible to develop a complete set of loss functions for the research area (Upington on the Orange River and Vereeniging on the Vaal River) and to develop computer programmes to determine optimum combinations of flood control measures. FLODSIM was developed for the irrigation area and ANUFLOOD (from CRES in Australia) adapted for the urban areas. The findings of this phase were documented in WRC Reports No 490/1/96, 490/2/96 and 490/3/96.

In order to overcome the shortcomings of the results of phase 1, i.e. that computer programmes and loss functions were location specific, phase 2 (1995-1997) was necessary. The research area was expanded to include the Mfolozi sugar cane production area in Kwazulu Natal, the Uitenhage and Despatch formal urban areas along the Swartkops River in the Eastern Cape and the Soweto-on-Sea informal urban area along the Chatty River, also in the Eastern Cape. The specific aims were as follows:

- Development of flood damage functions for alternative land use types in floodplains in irrigation and urban areas of South Africa.
- Further development of flood damage models and computer programmes to render them more generally applicable in irrigation and urban areas. Besides the utilization of new technology like remote sensing, the models also had to be adapted to be applicable at three levels of decision making namely local, provincial and national and also be in accordance with the revised national flood management policy. Development of guidelines to make the policy executable at three government levels also had to receive attention.
- Testing, validating and verifying the models and computer programmes in selected areas.

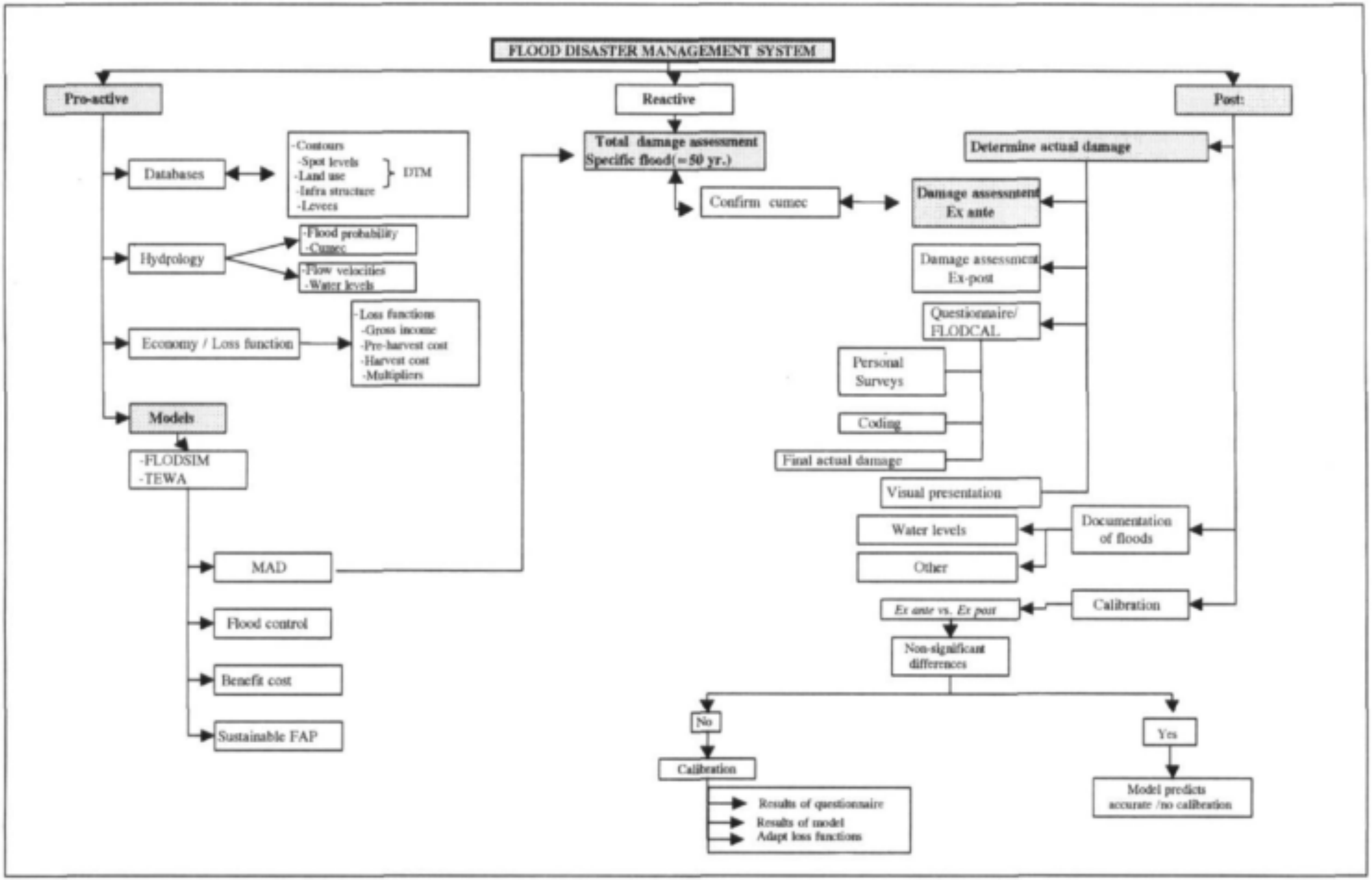

Figure 1: Continuous flood disaster management systems

With the generalised computer programmes (FLODSIM and TEWA; the latter being a GIS programme utilising the same information as ANUFLOOD) and standardised loss functions which resulted from this research in hand it was possible to apply them as flood control planning and management tools in different flood plains in South Africa. *The results of this research is documented in* WRC Reports *no.* 690/1/99 and 690/2/99.

In order to obtain full benefits it was recommended that these aids should be applied as part of a holistic approach to integrated hydrological catchment management, as is shown schematically in Figure 1. Phase 3 was conducted with this in mind. The main aims of this phase are refinement of the computer programmes, loss functions and questionnaires, and dissemination as flood management aids to all interested parties and role players involved in flood plain and flood control planning in South Africa. Besides applying and testing FLODSIM and TEWA in actual case studies along the Orange and Swartkops Rivers in consultation with SRK Consulting, a sociological study was requested to determine the suitability of the approach for determining acceptable flood control mitigation measures for a developing local community. The Community Agency for Social Enquiry (CASE) was asked to join the research team and to research the flood affected community of Pietermaritzburg, which experienced the 1995 Christmas Day flood. Aims and findings of the CASE research were to be specifically oriented to ensure that the process would contribute toward, and assess the feasibility of, the following:

- determine the social acceptability of different flood damage control measures for different communities or target groups in order to design acceptable combinations of measures, and to develop education or extension programmes to promote acceptability, change perceptions (if necessary) and build awareness of the flood problem.
- develop a questionnaire (or questions for inclusion in the economic questionnaire) to measure the sociological and social consequences/impacts of flooding.
- develop procedures or guidelines for technology transfer of the aids developed for flood damage assessment and flood damage control planning in irrigation and urban areas.
- develop guidelines or sociological criteria to ensure optimum and sustainable institutional arrangements, responsibilities and synchronisation of effort in respect of flood and disaster management and response.
- develop guidelines to improve flood communication with regard to formulating flood warning messages and identifying the most effective communication channels with the community.
- develop methodology to promote local community involvement in policy formulation and allocation of responsibilities with regard to flood management planning.

The purpose of this report is to present information regarding phase 3 of the research. In this executive summary the main results of the study are summarised.

RESULTS

Refinement of computer aids

During this research phase refinement of FLODSIM and TEWA (and the loss functions on which they are based) has been concluded to such an extent that they can be applied in practical circumstances. See Chapter 1 for a brief description of the models. In Figure 1 it is shown how they fit into a continuous (pro-active, reactive and post) disaster management system. This is necessary to give effect to the new policy on disaster management as is described in the Bill on Disaster Management that was published during January 2000. As part of the flood damage management aids a computer questionnaire FLODCAL has also been developed which can be used for *ex post* flood damage assessment and to provide information for calibrating the loss functions of FLODSIM and TEWA.

Application of FLODSIM and TEWA

In co-operation with SRK Consulting, FLODSIM and TEWA were tested for usefulness in practical applications. Using cost-benefit analysis it was demonstrated how they can be used to optimise certain structural flood mitigation measures. FLODSIM was applied along the Orange River in the vicinity of Upington to *inter alia* evaluate optimum levee heights. It was for instance shown that it would be optimal for levees to control the 20 year flood.

Three flood mitigation options, namely channel clearance, bunding and channelisation were investigated along the Swartkops and Chatty Rivers. Results have shown that channel clearance will provide the largest net benefit for Soweto-on-Sea along the Chatty River, while bunding will render the largest net benefit for Uitenhage/Despatch along the Swartkops River. In deciding on an optimal package of structural measures the following recommendation from the Consultants report (Annexure 2) must however be emphasised. "The selection of remediation measures at the various sections should take account of the cost (optimise) and appropriateness of a measure. At some points it may be prudent to combine the measures."

To put the discussion and conclusions from these case studies into perspective the Consultants reports in Annexures 1 and 2 must also be consulted.

Availability of the models

Demonstration software of FLODSIM, TEWA and FLODCAL are made available on a compact disc (CD) that is obtainable on demand.

User manuals

To guide potential users of FLODSIM, TEWA and FLODCAL in applying these computer programmess, user manuals have been prepared which are included as separate Annexures to this report. The manuals are not technical manuals but are constructed in such a way that they will enable potential users with some basic background knowledge of flood damage assessment and flood control planning, to run the programmess with limited or no assistance from the model developers.

Technology transfer

In order to bring the developed flood damage management aids to the attention of potential users a technology transfer phase is started. The inter-governmental structure for disaster management as proposed in the Bill on Disaster Management is utilised for this purpose. In short the technology transfer process comprises the following actions:

- Firstly, formal workshops will be held at predetermined flood afflicted areas. Existing disaster management structures will be used for this purpose. At these workshops a demonstration will be given of the application of these aids.
- Next, the new information will be presented to the Premiers of each province in order to make each province aware of new computer models and aids developed to assist provincial and local governments in disaster management.
- Finally, assistance will be rendered upon request to potential flood disaster areas to assist them in constructing their own disaster management plans as part of the integrated development planning process.

Sociological study

The sociological study conducted by CASE in Pietermaritzburg (and reported in Chapter 3) propounds important findings concerning the suitability of the present approach towards determining optimal acceptable flood control measures as well as disaster management for a developing community. The following are mentioned, amongst others:

- The cost-benefit approach, based on the economic efficiency criterium and dependent largely on the judgement of the planners concerned, to find an optimal package of flood control measures for a flood area, is not adequate. A multi-criteria analytical approach that is able to consider diverse criteria and needs and which involves many stakeholders at all levels of the community in decision making should rather be applied. In such an analytic framework the solution from the cost-benefit analysis will be one input for consideration in the multi-criteria decision making matrix.

- A social impact assessment should be conducted as part of the total analysis in order to consider or evaluate all relevant social and sociological aspects.

- Using only the monetary value of damage, as is presently the case in the analyses, does not reflect the value of damage to the low income group in real terms. Although the damage to the poor may be small in monetary terms because of their small income and/or asset base, the impact is more likely to be catastrophic in a number of respects from a human development perspective. Using a relative impact index (RII) that weighs the damage in terms of either income or value of household goods will reflect the true damages more closely.

- Immediate relief following a disaster should form an important part of disaster management. In Chapter 3 this is stated as follows:

  "Floods in particular are typically 'sudden onset' disasters. Immediate response decisions are required urgently to save and sustain lives of survivors, support local rescue efforts and restore lifeline services during the first days of the disaster. Some activities may be so urgent that they must be operationalised without detailed assessments."

- Response to disaster should demonstrate a sensitivity to the impacts of disasters by, for example:

  - "avoiding the prolongation of the 'transitional welfare' phase which runs real danger of destroying initiative and a sense of self-worth
  - seek out ways for those who are capable and willing to actively engage in, and exercise control over, relief, remediation and development activities - but without assuming that these capacities are there in equal measure throughout the communities affected by a disaster
  - whatever the social impacts of the disaster event itself (and the case study has demonstrated how multi-faceted and catastrophic these can be), avoid responses to the disaster which themselves are likely to compound or add new negative social consequences - e.g., replacing family homes with one-bedroomed houses
  - integrate trauma counseling for individuals and groups into the overall disaster response process."

Summary of conclusions

- The flood damage management aids have been completed to a stage where they can be applied in practice.

- Demonstration of the application of the aids with actual CASE study data proved their usefulness in practical applications, within the cost-benefit analytical framework.

- These aids can provide the decision support needed for implementation of the Disaster Management Policy on a continuous basis; i.e. during the pro-active, reactive and post flood phases.

- To promote application, focussed technology transfer actions are needed utilising the proposed institutional framework for disaster management.

- Broadening the theoretical cost-benefit analytical basis of the present economic-engineering approach to a multi criteria decision analysis basis, will enhance the social and sociological acceptability and applicability of flood damage management actions, especially for the developing community. The economic efficiency premise of the cost-benefit approach is proved inadequate as a means of assessing the relevant social and sociological impact of floods and the effect on flood management.

Summary of recommendations

- The flood damage management aids developed during this research must be acknowledged as the best presently available in South Africa for flood damage management. Having been tested as useful instruments in flood damage assessment and control, they must be brought to the attention of as many concerns, involved in practical flood damage assessment and management as possible.

- To promote the use, maintenance and further development of these decision support aids, one or more institutions should make it their business to take responsibility for rendering the various tasks needed to maintain their usefulness and relevance.

- Further development of these aids as part of a comprehensive multi-criteria decision analytical approach to flood disaster management, is considered highly essential. In this regard further developmental and applied research is recommended.

BENEFITS AND POTENTIAL USERS

The following potential users have been identified:

- All national governments involved in disaster management as well as integrated development planning. The following departments could be involved;
  - Department of Provincial and Local Government
  - Department of Water Affairs and Forestry
  - Department of Agriculture
  - Department of Housing
  - Department of Health
  - South African Police Service (SAPS)
  - South African National Defence Force (SANDF)
  - National Disaster Management Association
- Provincial governments involved in disaster management and integrated development planning.
- Local governments involved in disaster management and integrated development planning.
- Town and regional planners.
- Flood management consultants.
- Educational Institutions involved in disaster management training and education.
- Private training institutions involved in training simulations, e.g. Logtek.

The following benefits and/or outcomes are foreseen:

<u>Proactive phase:</u>

- Flood plain demarcation
  - Indicating the flood plain
  - Maps indicating potential flood prone areas
  - Water levels at predetermined places

- Hazard categories
  - Maps indicating high, medium and low hazard areas
- Hydrological risk assessment
  - Maps indicating high, medium and low risk areas
  - An aid to developing an appropriate evacuation plan
  - An aid to identifying areas giving rise to potential liability claims
  - An aid to reducing flooding risks in shortest possible time
- Predicted flood losses
  - An aid to predicting tangible flood damages
  - Evaluation of damage cost reduction
- Flood damage risk assessment
  - An aid to reducing risk areas
  - Information to adjust evacuation plan

- Evaluation of mitigation measures
  - Identifying of appropriate flood mitigation measures
  - An aid to prioritising mitigation options
- Aids to assisting in evacuation plans
- Proactive flood disaster management plan

<u>Reactive phase:</u>

- An aid to determining the potential flood loss of a real flood.

<u>Post disaster phase:</u>

- An aid to quantifing flood losses of a real flood
- An aid to documenting real floods
- Providing information to develop new loss functions
- Information to calibrate existing loss functions
- Information to calibrate flood damage and hydraulic simulation models

INTRODUCTION

The floods of 1988 and the assignment to revise the National Flood Management Policy of South Africa served as motivation to start with the so called *ex ante* stage of flood damage research in South Africa. The main aim of the *ex ante* research stage (comprising 3 phases) was to develop flood damage management aids (loss functions, computer programmes, and questionnaires) to assist planners and authorities involved in flood damage assessment and management.

The aims of the first phase (1992-1994) were specified as follows: (Viljoen, et al 1996)

- Develop loss functions to determine potential damage for different land use types in demarcated flood plains of the specified research area.
- Develop the outline of a computer database in which loss functions can be stored and apply it to the research area.
- Develop a computer programme to determine the benefits of different combinations of flood control measures with the loss functions in the database.
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In order to overcome the shortcomings of the results of phase 1, i.e. that computer programmes and loss functions were location specific, phase 2 (1995-1997) was necessary. The research area was expanded to include the Mfolozi sugar cane production area in Kwazulu Natal, the Uitenhage and Despatch formal urban areas along the Swartkops River in the Eastern Cape and the Soweto-on-Sea informal urban area along the Chatty River, also in the Eastern Cape. The specific aims were as follows: (Du Plessis, et al, 1999)

- Development of flood damage functions for alternative land use types in floodplains in irrigation and urban areas of South Africa.
- Further development of flood damage models and computer programmes to render them more generally applicable in irrigation and urban areas. Besides the utilization of new technology like remote sensing, the models also had to be adapted to be applicable at three levels of decision making namely local, provincial and national and also be in accordance with the revised national flood management policy. Development of guidelines to make the policy executable at three government levels also had to receive attention.
- Testing, validating and verifying the models and computer programmes in selected areas.

With the generalised computer programmes (FLODSIM and TEWA; the latter being a GIS programme utilising the same information as ANUFLOOD) and standardised loss functions which resulted from this research in hand it was possible to apply them as flood control planning and management tools in different flood plains in South Africa.

In order to obtain full benefits it is recommended that these aids should be applied as part of an holistic approach to integrated hydrological catchment management. Phase 3 was conducted with this in mind. The main aims of this phase are refinement of the computer programmes, loss functions and questionnaires, and dissemination as flood management aids to all interested parties and role players involved in flood plain and flood control planning in South Africa.

Besides applying and testing FLODSIM and TEWA in actual case studies along the Orange and Swartkops Rivers, a sociological study was done to determine the suitability of the approach for determining acceptable flood control mitigation measures for a developing local community. The Community Agency for Social Enquiry (C A S E) was commissioned to research the flood affected community of Pietermaritzburg, which experienced the 1995 Chrismas Day flood. Aims and findings of the C A S E research were to be specifically oriented to ensure that the process would contribute toward, and assess the feasibility of, the following: (Butler, 1998)

- determine the social acceptability of different flood damage control measures for different communities or target groups in order to design acceptable combinations of measures, and to develop education or extension programs to promote acceptability, change perceptions (if necessary) and build awareness of the flood problem.
- develop a questionnaire (or questions for inclusion in the economic questionnaire) to measure the sociological and social consequences/impacts of flooding.
- develop procedures or guidelines for technology transfer of the aids developed for flood damage assessment and flood damage control planning in irrigation and urban areas.
- develop guidelines or sociological criteria to ensure optimum and sustainable institutional arrangements, responsibilities and synchronization of effort in respect of flood and disaster management and response.
- develop guidelines to improve flood communication with regard to formulating flood warning messages and identifying the most effective communication channels with the community.
- develop methodology to promote local community involvement in policy formulation and allocation of responsibilities with regard to flood management planning.

The purpose of this report is to present information regarding phase 3 of the research. The report consists of five chapters plus annexures.

CHAPTER 1

MODEL DESCRIPTION

1.1 INTRODUCTION

In this chapter a brief description is given of the computer models and questionnaires developed during the research. These instruments are necessary to implement the new flood disaster management policy of South Africa. A core aspect of the new policy is the continuous management of disasters, namely pro-actively as well as in the reactive and post disaster phases. The methodological framework summarised in Figure 1.1 indicates the application of these flood damage decision support aids in a continuous disaster management process. Model descriptions are presented in accordance with the framework of Figure 1.1 This chapter is concluded by emphasising certain aspects regarding flood hydrology and flood hydraulics modelling.

1.2 PRO-ACTIVE DISASTER PHASE

As a prerequisite to the pro-active disaster phase it is envisaged that various data bases and simulation models, developed during this research, will be installed at provincial and local government level. Data bases such as contour lines, spot levels, land use patterns, infrastructure, hydrological and hydraulic data as well as economic data need to be acquired and stored in GIS format. These data bases are to be integrated with two simulation models, namely FLODSIM (flood damage simulation model for irrigation areas) and TEWA (flood damage simulation model for urban areas). A very important component of these flood damage simulation models is loss functions. A loss function defines the relationship between direct flood damage and certain flood characteristics such as depth of inundation, duration of inundation, area inundated, silt content and momentum flux of the flood waters for a specific damage category.

Before the application of the two simulation models is demonstrated, a short discussion of FLODSIM and TEWA will be given.

1.2.1 FLODSIM*

A typical flood damage simulation process (FLODSIM), based on GIS, is portrayed diagrammatically in Figure 1.2. As a starting point, various data bases have to be developed. After creating these data bases, the integration and modelling process starts (see Commencement in diagram). The dotted lines in Figure 1.2 indicate that a specific data base must be selected from a data bank, while the black solid lines indicate various inputs to FLODSIM.

A digital terrain model (DTM) is essential for FLODSIM, and can be created in several ways.

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* A detailed description of FLODSIM is given in WRC Report no 690/1/99

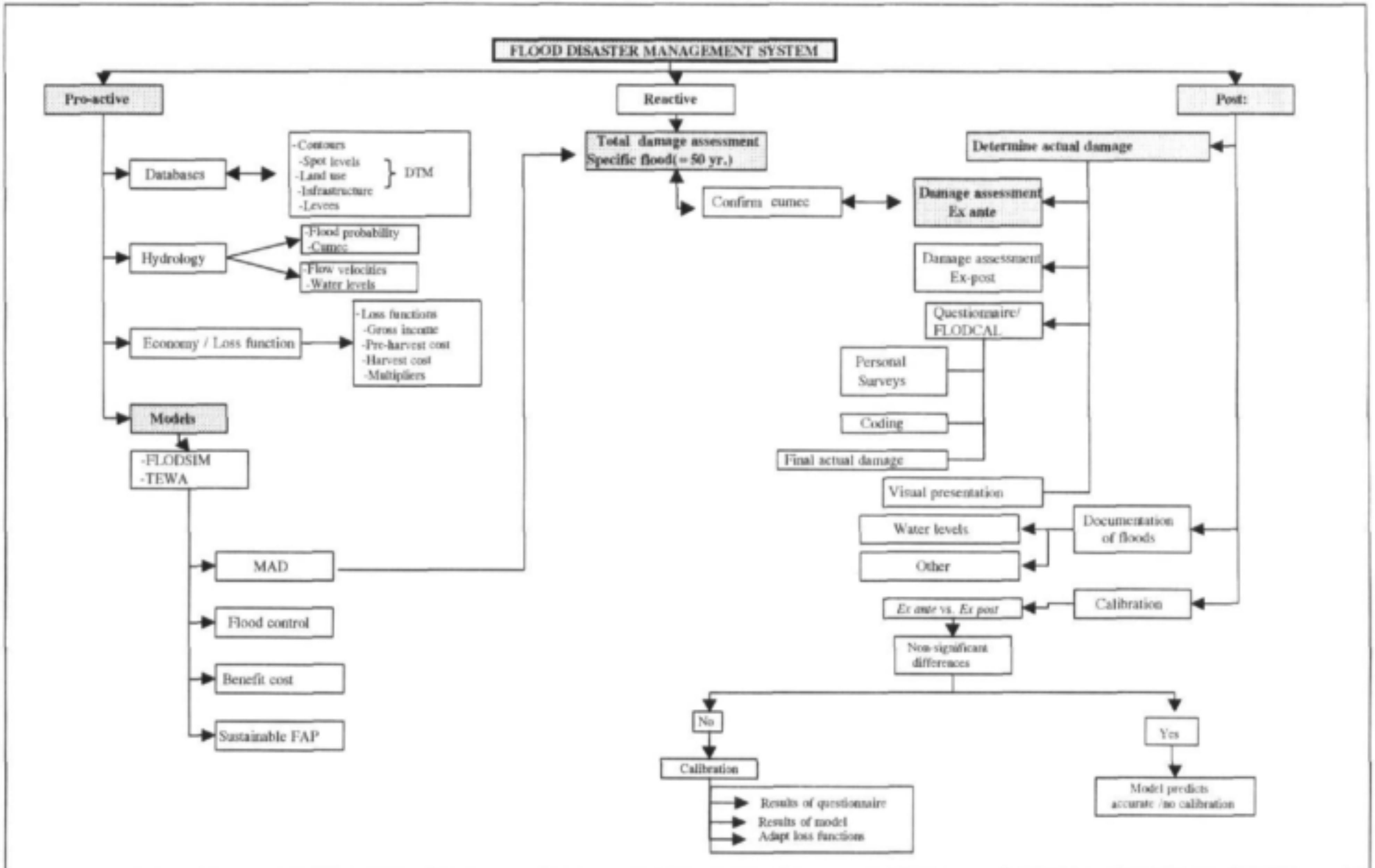

Figure 1.1: Continuous flood disaster management system

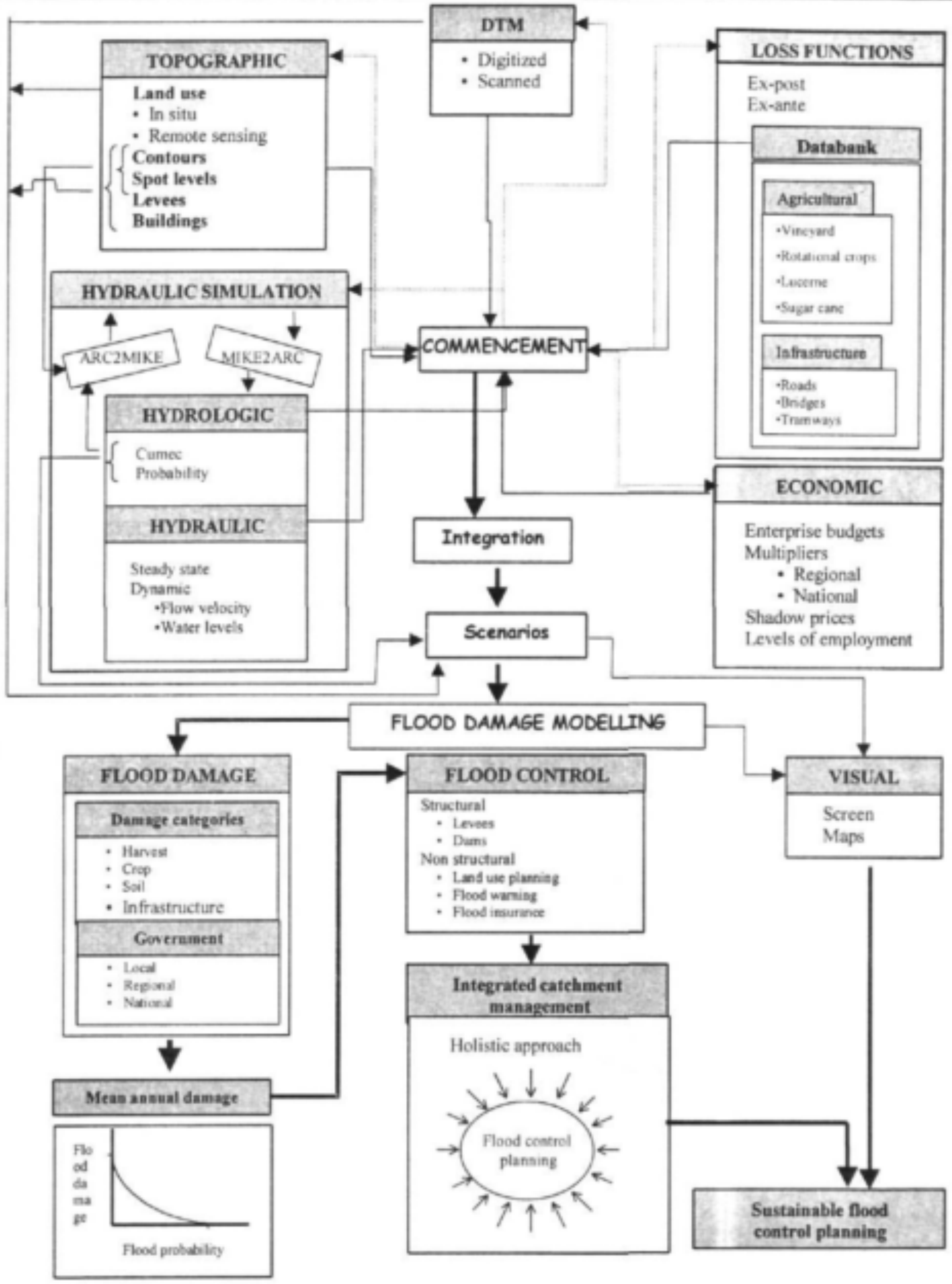

Figure 1.2: **A Typical FLODSIM simulation**
Source: *Du Plessis, 1998*

After an appropriate DTM has been constructed, loss functions are selected from the data bank to determine the damage caused by floods. Loss functions for vineyards, rotational crops, lucerne and sugar cane, as well as infrastructure such as roads, bridges and railways are available. Modules were recently extended to accommodate additional loss functions as well as providing for a more dynamic loss function approach, such as taking the duration of inundation into account as well.

The next step is to develop a topographical data base, which consists of land-use patterns, contour lines, spot heights, location and height of levees as well as the location and height of buildings in the area of investigation. The land-use pattern can be determined by using an in situ or a remote sensing approach. The in situ approach refers to a survey where researchers are in physical contact with the area of investigation. In contrast to this, the remote sensing approach refers to surveys where sensors are not in physical contact with the data. In this case data can be acquired by means of various sensors that can be mounted on aeroplanes or satellites. Contour lines and spot heights are essential data to create DTMs.

In order to use FLODSIM for effective flood planning in flood prone areas in South Africa, it is essential that both flood simulation models and GIS techniques are used (Muller & Rungoe, 1996). To achieve this, appropriate interfaces between MIKE 11 and FLODSIM had to be developed. Therefore a unique module was added to FLODSIM in such a way that it became possible to obtain hydraulic data from MIKE 11, with reference to specific scenarios, that were drawn up with FLODSIM.

After developing a topographical database, the economic data base is selected. The economic data base consists of enterprise budgets, multipliers (regional and national), shadow prices and employment rates. Information from enterprise budgets is used to calculate the total direct flood damage. With the total direct flood damage known, it is possible to calculate the secondary impacts of floods through the use of suitable multipliers.

When the data base has been specified in FLODSIM, it is possible to generate several scenarios by manipulating the topographical, hydrological, hydraulic and economic data. Flood damage can then be calculated for a specific scenario from a local, regional and national point of view. Scenarios can also be shown visually on the screen or on maps. Maps are essential for flood plain planning, and the depth and duration of inundation as well as flood lines and flood areas are indicated. After the flood damage has been determined for floods with different probabilities of reccurrence, it is possible to calculate the mean annual damage (MAD).

Structural and non-structural flood control measures can only be evaluated adequately within a Cost-Benefit Analysis (CBA) framework if the MAD is known[1]. Traditionally, flood damage modelling is calculated only for structural and non-structural control measures. This gave rise to the escalation of flood damage and the non-optimal utilisation of flood plains. Additional aspects have to be considered as well, so that local authorities in particular can be in a position to formulate sustainable flood management plans. For this purpose, a holistic approach to integrated catchment management, as described in WRC Report no. 690/1/99, is necessary.

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[1] In paragraph 3.3.4 it is argued that CBA should form part of a more comprehensive Multiple Criteria Decision Analysis (MCDA) framework to enhance the practical applicability of the analysis.

1.2.2 TEWA*

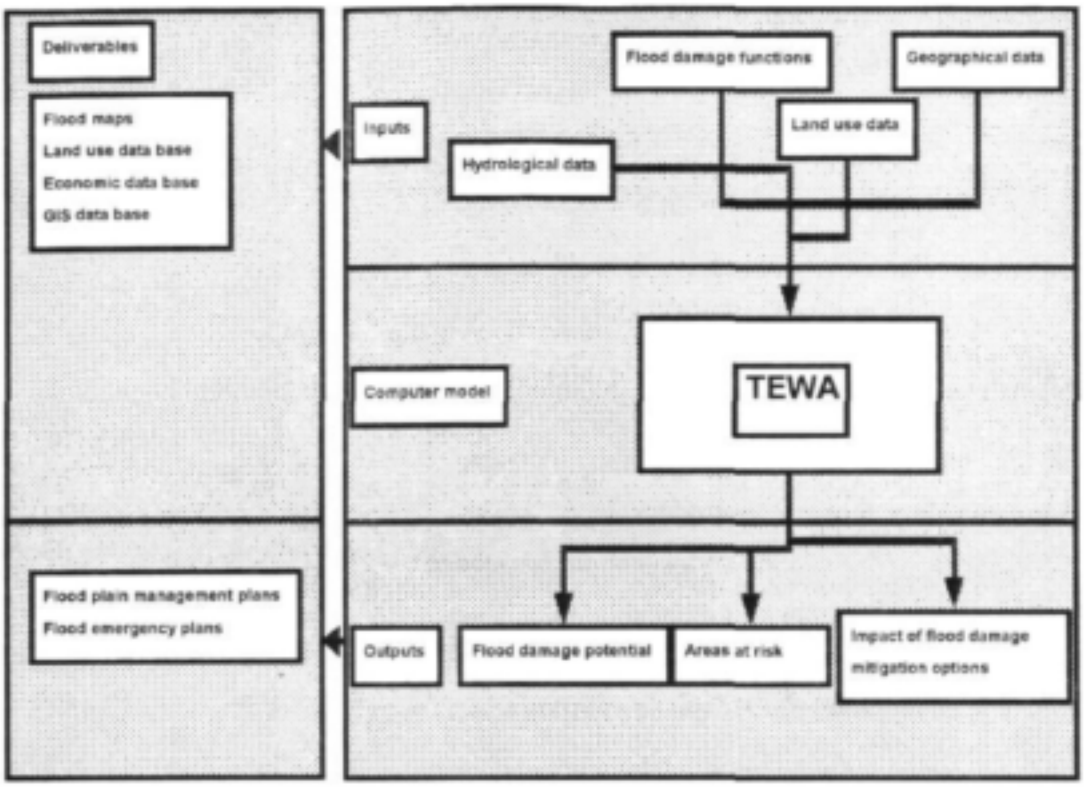


Figure 1.3 Inputs, outputs and deliverables of TEWA
Source: Booysen & Viljoen, 1998

TEWA is the acronym for a computer model for Tangible Economic flood Water damage Assessment, and is thus a computer model that calculates tangible flood damages. It can also be used to evaluate different flood damage mitigation options. TEWA is based on the principle that flood damage to an individual structure or property, groups of properties or flood plain zone is indicated by the monetary value of flood damage for different magnitudes of flooding. Damage caused to a property or a number of properties by a single flood event is calculated directly from flood damage functions.

All geographical and attribute data are stored in a GIS format which makes it relatively easy to combine the data from different sources to analyse and represent the results in different formats (e.g. tables, graphics, maps).

Figure 1.3 shows where TEWA fits into the calculating process. The process starts with the inputs TEWA require to calculate flood damage, which are flood damage functions, geographical data, land use data and hydrological data. With this input certain deliverables are also stipulated. Output of TEWA includes flood damage potential, area under risk and the impact of different flood damage mitigation options for a specific urban flood plain. The deliverables of these outputs are flood plain management, emergency and sustainable flood action plans. To obtain the

* A detailed description of TEWA is given in WRC Report no. 690/2/99

correct results TEWA must be used in conjunction with GIS software. In Figure 1.4 the use of TEWA in conjunction with ArcView is shown.

Linkage with ArcView makes it inter alia possible to visualise results obtained and to execute spatial analysis.

1.3 REACTIVE PHASE

Figure 1.1 represents an adapted approach to improve management of resources during the reactive phase of a flood. Once FLODSIM and/or TEWA are installed for a specific area it becomes possible to simulate the potential damage of the flood that has occurred. The magnitude (cumec) of the flood must however first be determined. This will give a broad indication of what the potential damage will be (and it may therefore not be necessary to determine the losses caused by a flood by using questionnaires to get a first round estimation of the impact of the actual flood). With more data on archive flood events available, the predictions will improve. It is therefore recommended that calibration of the simulation model be conducted after the occurrence of actual floods to improve the prediction ability of the model. This will be discussed in the next section.

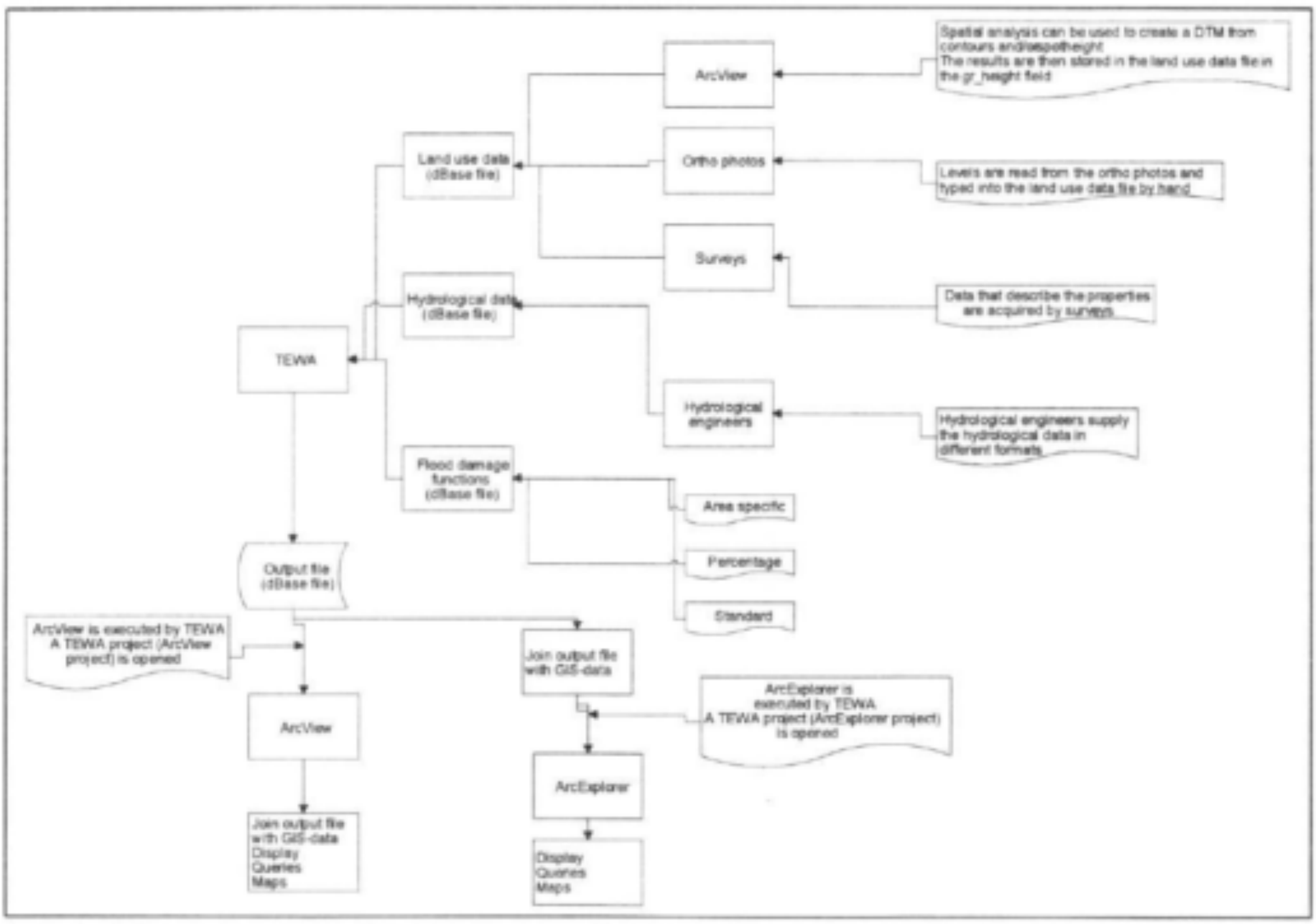


Figure 1.4 The methodology of TEWA to calculate flood damage
Source: Booysen, 2000

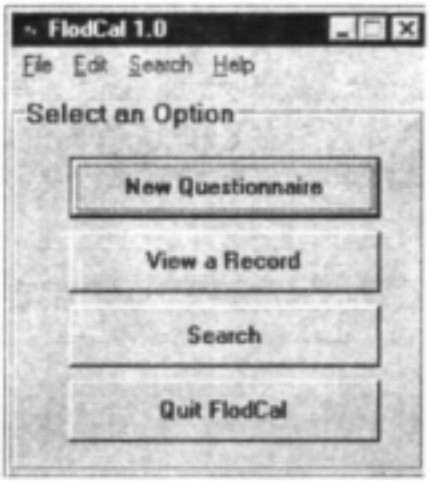
1.4 POST DISASTER PHASE

After the disruption of the current flood has passed and all activities have been normalised, a detailed flood damage survey is envisaged. Questionnaires developed during the research have been incorporated in a user-friendly computer model (FLODCAL), which is primarily used to determine the real economic losses of a specific flood. This computer model enables the surveyor to do a computer survey at flood victim venues to determine the impact of a specific flood. This can be done for the irrigation as well as residential, commercial, industrial and informal functional communities/sectors. Distinction is made between different damage categories i.e. harvest, crop, soil, infrastructure, household content and building damages. These damages are totalled to determine the total impact of a flood in a region.

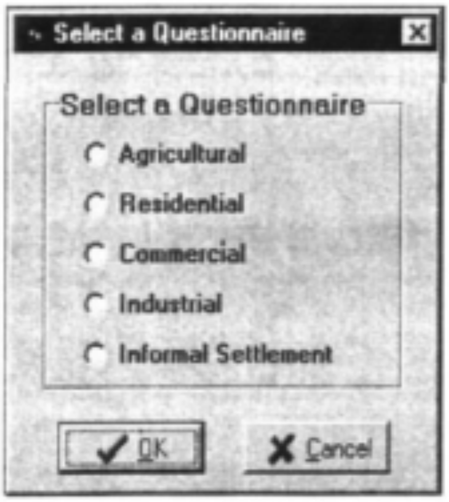
The secondary objective of the abovementioned computer questionnaire (FLODCAL) is to use the results to calibrate the hydraulic model (MIKE II) and also the flood damage simulation models (FLODSIM and TEWA). If, for instance, the predicted total flood damage is within certain boundaries when compared to the survey results, no calibration of the flood damage simulation models is necessary. If results between predicted and actual flood damage differ substantially, calibration is necessary. This may require a speciality service rendered by an institution like the Department of Agricultural Economics at the University of the Free State to make adjustments to the different loss functions.

1.4.1 FLODCAL

The layout of the first menu of FLODCAL is as follows:



First, an appropriate questionnaire has to be selected, e.g. agricultural, residential, commercial, industrial or informal settlement. After selecting the appropriate questionnaire, the detail (general information) of each respondent is inserted.



After this, the questionnaire (see Annexure 6 for detailed questionnaires) is completed electronically for each respondent. When the survey is completed, FLODCAL summarises the total flood damage for all respondents in order to determine the total real flood damage for the different categories. This is done separately for agricultural, residential, commercial, industrial and the informal settlement.

Table 1.1 is an example of the summary of total flood damage for all respondents in a region. The FLODCAL user manual in Annexure 5 presents more detail.

Table 1.1 Example of FLODCAL summary table		
Summary of Region		
AGRICULTURE	**Estimated Loss (R)**	**Actual Loss (R)**
Structural Damage	0.00	0.00
Vehicles	0.00	0.00
Soil and Harvest	0.00	0.00
Crop Damage	0.00	0.00
Livestock	0.00	0.00
Fixed Improvements	0.00	0.00
Other Damages	*0.00*	*0.00*
AGRICULTURAL TOTAL	**0.00**	**0.00**
RESIDENTIAL DAMAGE		
Structural Damage	0.00	0.00
Vehicles	0.00	0.00
Soil and Harvest	0.00	0.00
Crop Damage	0.00	0.00
Livestock	0.00	0.00
Fixed Improvements	0.00	0.00
Other Damages	0.00	0.00
RESIDENTIAL TOTAL	**0.00**	**0.00**
INDUSTRIAL DAMAGE		
Structural Damage	0.00	0.00
Vehicles	0.00	0.00
Soil and Harvest	0.00	0.00
Crop Damage	0.00	0.00
Livestock	0.00	0.00
Fixed Improvements	0.00	0.00
Other Damages	0.00	0.00
INDUSTRIAL TOTAL	**0.00**	**0.00**
COMMERCIAL DAMAGE		
Structural Damage	0.00	0.00
Vehicles	0.00	0.00
Soil and Harvest	0.00	0.00
Crop Damage	0.00	0.00
Livestock	0.00	0.00
Fixed Improvements	0.00	0.00
Other Damages	0.00	0.00
COMMERCIAL TOTAL	**0.00**	**0.00**
INFORMAL SETTLEMENT DAMAGE		
Structural Damage	0.00	0.00
Vehicles	0.00	0.00
Soil and Harvest	0.00	0.00
Crop Damage	0.00	0.00
Livestock	0.00	0.00
Fixed Improvements	0.00	0.00
Other Damages	0.00	0.00
INFORMAL SETTLEMENT TOTAL	**0.00**	**0.00**
TOTAL DAMAGE FOR REGION	**0.00**	**0.00**

1.5 FLOOD HYDROLOGY AND FLOOD HYDRAULICS MODELLING

Concerning flood hydrology and hydraulics modelling the following points should be emphasized.

1.5.1 Flood hydrology

The flood hydrology of the watercourse catchment being studied has to be established in order to obtain probable flood peaks and hence water levels via a hydraulic model. It is of utmost importance that accurate and realistic runoff hydrographs are established as these will have a marked effect on predicted water levels and hence flood damage costs.

The following should be considered:

- Where historical runoff data is available a statistical approach must be adopted to develop growth curves and predict peak flows for various return periods.
- Where very few or no flood runoff records are available, empirical and deterministic methods should be adopted. Various methods should be used to establish a confidence band and establish realistic peak flow rates. Where relevant, fully developed catchment conditions need to be considered.

The above methods and/or modelling should be carried out by a competent organisation with a sound understanding of flood hydrology.

1.5.2 Flood hydraulics

The flood hydraulics is another important input parameter to both the TEWA and FLODSIM model. The output of this model yields predicted high water levels based on the flood peaks determined by flood hydrology. The high water levels are in turn used to determine a depth of inundation and hence probable flood damage costs.

The following should be considered:

- For smaller watercourses where the potential storage capacity along the flood plain is small in relation to runoff volumes, a steady state model such as HECRAS or similar may be used to determine the high water levels.
- A dynamic model such as MIKE II or similar has to be used for water courses with a large storage capacity in relation to the rainfall volume.
- All controls such as dam spillways, road/bridge crossings and any other control structure have to be included in the model to yield realistic and accurate high-water levels.

The above modelling should be carried out by a competent organisation with a sound understanding of river engineering and hydraulic modelling.

CHAPTER 2

PRACTICAL APPLICATIONS

2.1 INTRODUCTION

The aim of this CHAPTER of the report is to illustrate that FLODSIM and TEWA can provide useful information for the planning of "structural" flood control measures. In order to achieve this actual case studies were conducted in conjunction with SRK Consulting. FLODSIM was tested in the Upington area along the Orange River and TEWA in the Uitenhage/Despatch area along the Swartkops River and Soweto-on-Sea along the Chatty River. Figure 2.1 shows the location of the study areas.

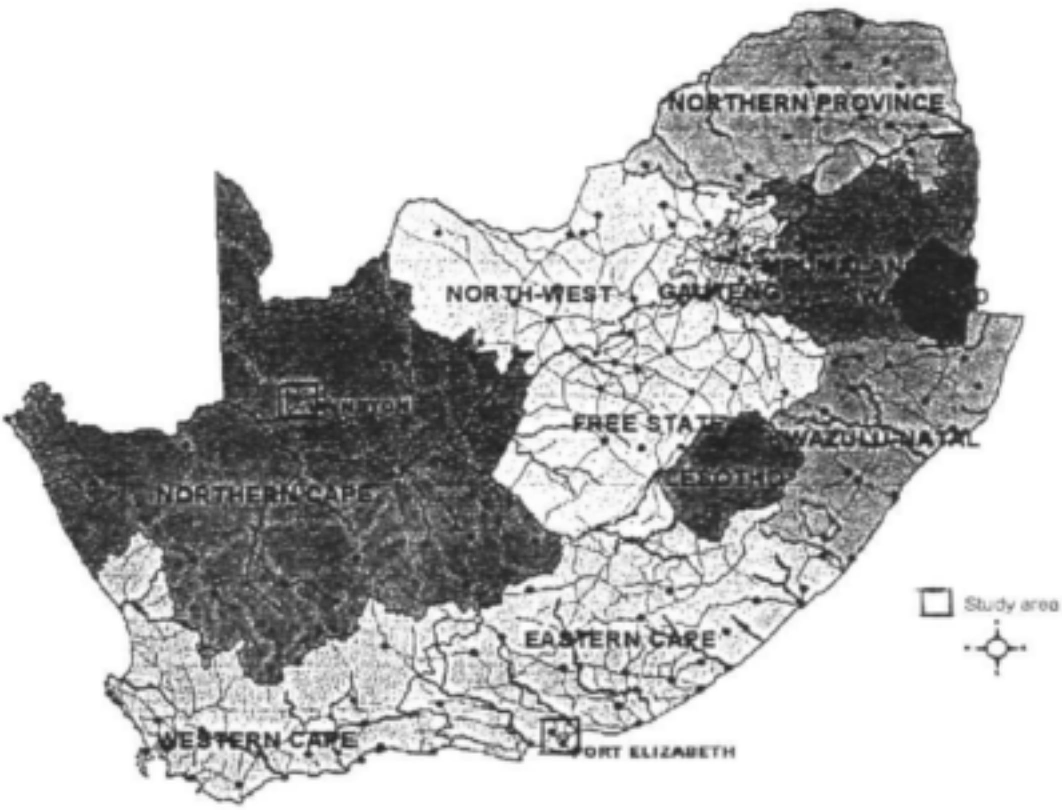


Figure 2.1: Orientation map on location of study areas.

2.2 FLODSIM

2.2.1 Determining the potential direct damage

This research phase capitalises on previous research regarding databases (topographical, land-use and loss functions) for the Upington area. A detailed survey was done on all the levees in the research area to determine the height of each levee individually. This information was used to upgrade the topographical database. A new economic database was also compiled and consists of 1999 financial information for various crops in the area. Regarding hydraulic information, SRK Consulting provided all the hydrological, hydraulic and capital cost estimates for flood control along the Orange River at Upington.

Because of the importance of the new levee information and the importance of the hydrological information to flood damage assessment, relevant aspects will be outlined in the next section.

2.2.1.1 Levee survey

The previous research estimated flood elevations for mainly two scenarios, namely no levees along the river and the present levees being in place, but at fixed heights of 1,6 m. It was therefore decided to execute a detail survey on the existing levees, in order to obtain realistic data to demonstrate the real applicability of FLODSIM. This information is summarised in Table 2.1.

Table 2.1: Existing levee levels in the Orange River from Gifkloof Weir to Manie Conradie Bridge, 1999*

Cross Section Number	Chainage	Levee levels (mamsl)
50	39539	-
49	38534	-
48	37463	810.62
47	36424	808.90
46	35727	807.74
45	35234	-
44	34329	-
43	33531	-
42	32671	802.67
41	31620	800.92
40	30645	800.08
39	29441	799.15
38	28375	798.40
37	27458	798.20
36	26568	797.00
35	25470	796.60
34	24542	796.40
33	23704	795.25
32	22947	794.21
31	22160	794.00
30	21122	793.85
29	20557	-
28	20118	793.20
27	19516	-
26	18928	-
25	18646	792.98
24	18371	792.90
23	17725	791.19
22	17151	789.49
21	16097	786.93
20A	15350	788.28
20	14779	785.68
19	13641	-
18	12496	784.21
17	11032	781.85
16	9535	782.57
15	8375	781.54
14	7413	779.60

From this information appropriate and more accurate hydrology simulation could be done.

2.2.1.2 Hydrological Information

The scope of the hydrological information for this study is summarised as follows:

- Review of previous studies.
- Review of flood hydrology.
- Estimation of flood levels for the full range of flows for the various levee scenarios.
- Estimation of the capital costs for the various scenarios.
- Provide recommendations to reduce damage to flood defences during floods.

The study maximised the use of previous study results to ensure that costs are contained. Two previous studies related to the current project are:

- "Vloedlynberamings in die Oranjeriviervallei" by Chunnett, Fourie and Partners, completed March 1993.
- "Benede-Oranjerivier S.W.S : Vloedlyne : Gifkloofstuwal tot by Manie Conradiebrug" by the sub-directorate Hydraulic Services of the Department of Water Affairs and Forestry (DWAF), completed April 1999."

From the above studies the following conclusions are made:

- The estimated flood probabilities for both studies are uncertain and review of the flood probabilities is recommended for both studies.
- The differences between steady state and dynamic routing of the flood flows at Upington are negligible. This is ascribed to the large volumes and long duration of the floods relative to the potential river channel storage.
- Both studies assumed fixed levee heights for the present system.

2.2.1.3 Review of Flood Hydrology

The concerns raised during the previous studies prompted SRK Consulting to review the design peak estimation to enable the UFS to compile the mean annual damage (MAD) for the Upington area with more certainty for the various scenarios. The lower Orange River is well gauged and statistical methods are therefore used. Several historical floods are also available. The annual maximum flood data at Upington and Prieska were used to estimate the design peaks.

The ten most significant floods in the Prieska and Upington area are ranked and listed in Table 2.2.

Table 2.2 : Flood peaks Lower Orange River*

Rank	Date (year)	Flood Peak (m^3/s)	
		Prieska	Upington
1	1874	14 500	-
2	1805	12 500	-
3	1881	12 400	-
4	1925	12 000	8 700
5	1898	7 600	-
6	1974	10 500	9 200
7	1934	9 100	6 700
8	1988	8 800	8 500
9	1 920	8 500	6 600
10	1967	7 500	7 200

*Table compiled 1999

The record at Prieska is longer and is also considered to be the more accurate of the two. The period of record at Prieska is from 1874 to present. From 1970 to present the data is significantly affected by the upstream impoundments in the Orange River (Gariep and Vanderkloof Dams) and the Vaal River (Bloemhof and Vaal Dams). The results are shown in Appendix 1 and the summarised results are shown in Table 2.3. The results for Upington used both sets of data to obtain the adjustment ratios. The distribution used was the Log-Pearson Type III and the General Extreme Value. The adopted peaks for Upington and the previously adopted peaks are listed in Table 2.3 below.

Table 2.3 : Estimated design peaks - Orange River at Upington*

Return Period (years)	Probability (1/T)	QT m^3/s	
		SRK	Previous Studies
2 (7)	0,50 (0,1429)	3200	-
5 (13)	0,20 (0,0769)	5400	4300
10 (22)	0,10 (0,0455)	6500	6000
20 (31)	0,05 (0,0323)	8000	8300
50 (54)	0,02 (0,0185)	10000	11800
100	0,01	11800	12200
200	0,005	13700	14400
500	0,002	16300	-
1000	0,001	18500	-
5000	0,0002	25100	-
10000	0,0001	27500	-
RMF	-	24500	24500

*The values in brackets are the flood probabilities taking account of the current upstream impoundments. Table compiled 1999.

The flood damages may be estimated using:

- annual flood probabilities as shown in Table 2.3, or
- the maximum probability of events occurring over a selected design period.

The economic design of civil structures are usually taken over a certain return period ranging from 15 years for roads to 100 years for large dams. The design life for well constructed levees for the purposes of this study is taken to be 50 years. From Table 2.4 it can be seen that the probability of having one 50 year event in the 50 year design period is 63,58% and that of having four ten year events is 74,97%. For damages the implication of taking it over a 50 year period instead of an annual basis is that the maximum probable damages for a ten year event will be 4 x 74,97/100 x damage. The maximum for other events including that of the probabilities including the existing upstream dams, are shown in Table 2.4.

Table 2.4 : Multiple event probability over 50-year design life*

T (Return Period)	Number of Events (n)	Probability (p)	Total Number (n x p/100)
2	21	89,87	18,87
5	8	80,96	6,48
7	7	72,57	5,08
10	4	74,97	3,00
13	3	84,33	2,53
20	2	72,06	1,44
27	2	69,00	1,38
31	2	57,00	1,14
50	1	63,58	0,64
54	1	61,65	0,62
100	1	39,50	0,40
200	1	22,17	0,22
500	1	9,52	0,10
1000	1	4,88	0,05
5000	1	1,00	0,01
10000	1	0,50	0,01

* Table compiled 1999

2.2.1.4 Estimation of Flood Elevations

In order to investigate alternative scenarios, flood damage control is based on ensuring that certain flows do not inundate the agricultural lands. The following scenarios (Table 2.5) were identified for investigation, based on the annual flood probabilities.

Table 2.5: Levee scenarios identified for land use as at 1999 for the Orange River at Upington

Scenario	Levees Design **
"0"	No levees
"1"	Levees 3200 m^3/s
"2"	Levees 5400 m^3/s
"3"	Levees 6500 m^3/s
"4"	Levees 8000 m^3/s
"5"	Levees 10000 m^3/s
"6"	Levees 11800 m^3/s
"7"	Levees 13700 m^3/s
"8"	Levees 16300 m^3/s
"9"	Levees 18500 m^3/s
"10"	Levees 25100 m^3/s
"11"	Levees 27500 m^3/s
"12"	True levee level at 1999*

* The present levee arrangements were taken as given and levels of the levees were supplied by the Department of Agriculture.

** The flows designed for and modelled relate to the flood probabilities with no existing dams.

The levees for the various scenarios are designed to keep the stated flows out of agricultural areas. The original proposals envisaged that SRK would use the MIKE-11 model set up by DWAF to estimate the flood levels for the scenarios and levee manipulation. Unfortunately the DWAF model data were lost and could not be retrieved. Due to the nature of the flooding a decision was taken to set up the Upington system on the HECRAS model with sectional and spatial information supplied by UFS.

The results, indicating flood levels at the sections selected for each of the scenarios, are shown in Annexure 1.

2.2.1.5 Economic analysis

With the abovementioned hydrology inputs from SRK Consulting it is possible to determine the total direct flood damage for the Orange River at Upington. Mainly, two scenarios were investigated, namely;

- The determination of optimal levee levels for the Orange River at Upington.
- The economic benefits of building a new dam in the Boegoeberg area.

The impact of various existing dams (Bloemhof, Gariep, Vaal and Vanderkloof) on the hydrology was also investigated. This information was then used to determine the impact of the dams on the economic analysis.

2.2.1.6 Optimal levee levels

A diversity of accurate information is needed to determine the optimal levee level. First, a range of simulations (hydrology and economic) have to be done, starting from no levees to the hypothetical construction of levees to protect farm activities in the flood plain. After the hydraulic simulations have been completed, the economic simulation process is started by integrating the hydraulic information (water levels) with FLODSIM databases.

Construction cost of levees plays an important role in determining optimal levee heights. The costs (inclusive of fees and contingencies) were done for the following possible combinations:

- New levees at full contractor costs.
- New levees at partial contractor costs. This assumes that the farmers will aid in construction.
- Adding on to the current levees at full contractor costs.
- Adding on to the current levees at partial contractor costs.

The construction of a dam at Boegoeberg was suggested to meet the same requirements regarding the storage of specific flows as required for levees.

The costs of all the scenarios are summarised in Table 2.6 below.

Table 2.6 : Flood protection construction costs (R million), 1999

Scenario	Levees				
	New	New Partial	Addition	Additional Partial	Dam
0	0	0	0	0	0
1	33,80	15,19	6,04	3,43	662,60
2	72,23	31,47	22,64	10,46	857,20
3	89,76	38,89	37,06	16,57	924,30
4	117,87	50,80	62,59	27,38	980,40
5	157,89	67,75	100,55	43,46	1050,20
6	192,90	82,57	134,15	57,69	1108,20
7	230,21	98,37	171,42	73,48	1157,70
8	286,56	122,24	227,77	97,34	1227,00
9	347,36	147,99	288,57	123,09	1262,70
10	452,65	192,59	393,86	167,69	1368,70
11	573,95	243,96	515,16	219,06	1400,30
12	60,90	26,65	0	0	0

The construction of a dam at Boegoeberg will not be solely for flood protection of the Upington area. Benefits to other areas will be flood protection for areas outside the study area (Kanon Island to Augrabies etc), irrigation assurance and general water supply. These are aspects that would require more investigation and the actual cost for flood protection at Upington could in fact be only 20 to 30% of the stated dam costs. Other aspects such as environmental and international concerns should also be taken into account.

The construction of the levees will however result in more infrastructure becoming prone to potential damage and maintenance. Table 2.7 indicates the potential damage and maintenance cost to the levees for various flood events. The damage is shown taking into and not taking into consideration the upstream impoundments.

The estimates in Table 2.7 assume:

- 90% levee destruction based on the average flow velocity and overtopping depth that occurs at the levees, i.e the estimated flow velocity of the levee. (It is therefore assumed that about 90% of the levee would be damaged.)
- Annual maintenance amount based on the events and flow depth and velocities. This will be used to repair erosion damages.
- Damage is related to depth of overtopping.

Table 2.7: Potential levee damage (R million), 1999

Return Period (years)		Scenario											
No dams	With dams	1	2	3	4	5	6	7	8	9	10	11	12
4	4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
5	13	0,0	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,0
10	22	0,0	3,6	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,3
20	30	0,0	7,2	4,5	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	6,1
50	54	0,0	21,7	10,8	8,3	1,6	1,6	1,6	1,6	1,6	1,6	1,6	9,1
100	100	0,0	36,1	26,9	16,5	7,9	1,9	1,9	1,9	1,9	1,9	1,9	15,2
200	200	0,0	57,8	37,7	35,4	15,8	9,6	2,3	2,3	2,3	2,3	2,3	24,4
500	500	0,0	65,0	76,3	56,6	50,5	28,9	18,4	2,9	2,9	2,9	2,9	48,7
1000	1000	0,0	65,0	80,8	100,2	71,1	65,6	46,0	17,2	3,5	3,5	3,5	54,8
5000	5000	0,0	65,0	80,8	106,1	142,1	173,6	195,7	126,1	164,2	4,5	4,5	54,8
10000	10000	0,0	65,0	80,8	106,1	142,1	173,6	207,2	243,6	152,9	22,6	5,7	54,8

Table 2.8 shows the results when integrated with FLODSIM. New levees at full contractor costs were used in Table 2.8.

The mean annual flood damage (MAD) was calculated first for all possible levee scenarios (Table 2.8) to prevent damage to farm activities in the flood plain from different sized floods.

Table 2.8: Financial information (R million) of various flood mitigation options to determine the optimal levee height for Upington research area, 1999.

Mitigation option	MAD	BENEFIT	COST	TOTAL BENEFIT	TOTAL COST	NET BENEFIT
No levees	16.78	-	-	-	-	-
Prevent 5 year flood	15.38	1.40	72.22	17.08	86.89	-69.81
Prevent 10 year flood	8.98	7.80	89.76	95.31	96.00	-0.686
Prevent 20 year flood	5.01	11.77	117.87	143.96	118.87	25.09
Prevent 50 year flood	2.67	14.11	157.89	172.51	152.64	19.87
Prevent 100 year flood	1.71	15.07	192.90	184.33	183.92	0.408
Prevent 200 year flood	1.18	15.60	230.21	190.77	217.90	-27.14
Prevent 500 year flood	0.89	15.89	286.56	194.28	269.06	-74.78
Prevent 1000 year flood	0.76	16.02	347.36	195.91	325.02	-129.11
Prevent 5000 year flood	0.70	16.08	452.65	196.68	421.83	-225.15
Prevent 10000 year flood	0.68	16.10	573.95	196.96	534.04	-337.08

For no levees the MAD is thus calculated when no flood mitigation measure is applied. From Table 2.8 the MAD for this option is R16,78 million. Levees are then constructed to safeguard agricultural production and residential properties in the flood plain against flooding

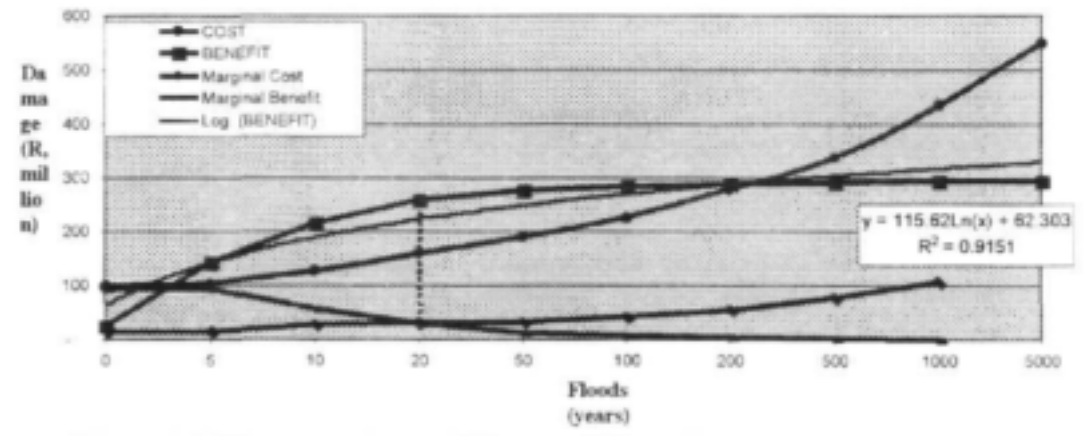


Figure 2.2: Optimal levee height for the Orange River at Upington, 1999

by the 5 year flood. The benefit of this is equal to R1,40 million. When comparing this benefit with the cost involved (R72,22 million) of constructing the levees, it is clear that no net benefit will realise. It is important however to note that this benefit is a mean annual benefit that must first be discounted over the life span of the specific mitigation measure. After this has been done, a total benefit of R17,08 million is obtained (an 8% discount rate has been used). Apart from the total direct construction cost, additional costs such as maintenance and repair costs due to floods, must also be taken into account. When such costs are added to the total direct construction cost, the present value of the total cost involved in preventing the 5 year flood equals R86,89 million. The net benefit can be calculated by subtracting the total cost from the total benefit. In this case a negative net benefit of R69,81 million occurs. From Table 2.8 it can be observed that the highest net benefit (R25,09 million) is obtained when the flood plain is protected against the 20 year flood.

It is possible to determine the exact levee height by fitting a trend line to the total net benefit information. A ln-function fits the net benefit 91 percent ($R^2=0,9151$). Where the slope of this line equals zero, the optimum levee height is determined (Figure 2.2).

$$Y = 115,62 \ln(X) + 62,303$$

Table 2.8 indicates that the optimal levee height equals the 20 year flood line. When calculated from the ln-function the optimal levee height is however equal to the 42 year flood line.

2.2.1.7 Hydrological impact of the Vaal, Bloemhof, Gariep and Vanderkloof dams

The abovementioned hydrological information does not include the effect of the Vaal, Bloemhof, Gariep and Vanderkloof Dams. SRK Consulting provided the UFS with new hydrological information which includes the impact of these dams. The impact of these dams is to reduce the probabilities of floods of different magnitudes from occurring, e.g. the 5 year flood (probability to occur once in 5 years) changes to the 13 year flood (probability to occur once in 13 years), the 10 year to the 22 year, the 20 year flood to the 31 year and the 50 year to the 54 year flood. All the remaining floods have the same flood frequency as before. The process of calculating the optimal levee height was repeated with the new hydrology information. Again a ln-function was fitted and the optimal levee height for levees was obtained for a 19,9 year flood. In this case the ln-function fits the data 97,67 percent, an increase of more than six percent in R^2.

$$Y = 53,876\ ln(X) + 83,14$$

Next, cross-section information was used to determine the levee height. This was done by first subtracting the water level (measured in metres above sea level) from the ground level. With interpolation it was possible to determine the optimal levee height at each cross-section. Table 2.9 shows these results.

Table 2.9: Optimal levee height (mamsl)* for Orange River from Gifkloof Weir to Manie Conradie Bridge, 1999

Cross Section Number	Chainage	Channel Invert	High flood Level) for 20-year flood	Levee Height	Reduction / Increase in Levee heights (m)
50	39539	802.57	811.66	-	-
49	38534	803.02	810.30	-	-
48	37463	801.66	809.72	810.62	-0,9
47	36424	801.13	808.04	808.90	-0,86
46	35727	800.61	806.36	807.74	-1,38
45	35234	799.76	805.02	-	-
44	34329	798.00	803.94	-	-
43	33531	795.42	803.56	-	-
42	32671	794.43	802.61	802.67	-0,06
41	31620	794.43	801.54	800.92	0,62
40	30645	793.11	801.22	800.08	1,14
39	29441	792.00	800.46	799.15	1,31
38	28375	790.34	799.71	798.40	1,31
37	27458	790.34	799.30	798.20	1,1
36	26568	790.30	798.40	797.00	1,4
35	25470	790.30	797.33	796.60	0,73
34	24542	788.06	796.63	796.40	0,23
33	23704	788.06	795.97	795.25	0,72
32	22947	787.82	795.55	794.21	1,34
31	22160	787.81	795.11	794.00	1,11
30	21122	787.23	794.06	793.85	0,21
29	20557	785.03	793.91	-	-
28	20118	784.05	793.54	793.20	0,34
27	19516	784.00	793.17	-	-
26	18928	784.00	792.55	-	-
25	18646	784.00	792.47	792.98	-0,51
24	18371	784.00	792.23	792.90	-0.67
23	17725	784.00	791.71	791.19	0,52
22	17151	784.00	790.89	789.49	1,4
21	16097	784.00	788.69	786.93	1,76
20A	15350	781,80	787.51	788.28	-0,77
20	14779	781.76	786.41	785.68	0,73
19	13641	777.11	785.94	-	-
18	12496	776.51	785.32	784.21	1,11
17	11032	775.00	784.57	781.85	2,66
16	9535	774.00	783.45	782.57	0,88
15	8375	775.00	781.43	781.54	-0,11
14	7413	772.07	780.94	779.60	1,34

*mamsl = metres above mean sea level

A negative value in Table 2.9 indicates that the existing levee is higher than the proposed levee height and a positive value indicates that the levee height at that location (indicated by the cross-section in Annexure 1) must be raised. From an economic perspective it can be seen in Table 2.9 that most of the levees must be raised to prevent overtopping by the 20 year flood.

2.2.1.8 Economic analysis for a new dam in the Boegoeberg area

The same procedure as previously was followed to determine the economic benefits of building a new dam. First the MAD was calculated when the dam was hypothetically constructed in such a way that it would prevent flooding of the flood plain by various sized floods. The results are shown in Table 2.10.

Table 2.10: Net benefit (R million) of a new dam at Boegoeberg, 1999.

Mitigation option	MAD	BENEFIT	COST	TOTAL BENEFIT	TOTAL COST	NET BENEFIT
No levees	11.22	-	-	-	-	-
Prevent 5 year flood	6.76	4.47	857.20	54.66	813.71	-759.06
Prevent 10 year flood	4.86	6.36	924.30	77.85	868.72	-790.87
Prevent 20 year flood	3.61	7.61	980.40	93.12	917.50	-824.38
Prevent 50 year flood	2.35	8.88	1.050.20	108.58	978.85	-870.27
Prevent 100 year flood	1.48	9.75	1.108.20	119.22	1.031.43	-912.21
Prevent 200 year flood	0.95	10.27	1.157,70	125.65	1.076.69	-951,04
Prevent 500 year flood	0.66	10.56	1.227.00	129.16	1.139.84	-1.101.68
Prevent 1000 year flood	0.53	10.69	1.262.70	130.79	1.172.56	-1.041.77
Prevent 5000 year flood	0.47	10.75	1.368.70	131.56	1.270.03	-1.138.46
Prevent 10000 year flood	0.45	10.78	1.400.30	131.84	1.299.17	-1.167.34

It is clear from Table 2.10 that construction of a new dam for flood control purposes alone is not economically viable. Other uses and aspects (i.e. other major benefits for irrigation farmers and negative impacts on the environment) must however be taken into account before a final decision can be made. Concerning flood control *per se* it must also be pointed out that not only the study area, but the total irrigation area down stream of Boegoebergdam will benefit from the new dam. This will increase the benefits arising from and thus increase the viability of building the new dam. The levees that already exist must also be accounted for in the final analysis.

2.3 CONCLUSION

The case study results, based on realistic benefit and cost estimates, illustrate FLODSIM to be an useful tool in providing information for flood mitigation planning in the research area. It is inter alia shown that as far as levee heights are concerned, it will be optimal to control the 20 year flood. The assumptions and calculations in the consultants' report (Annexure 1) on which this conclusion is based, must however also be taken into account.

It must also be stressed that an optimal package of flood control measures can only be determined in co-operation with the local community, evaluating also non-structural measures.

2.2 THE SWARTKOPS AND CHATTY RIVERS

The study took place in three areas in the Eastern Cape (Figure 2.3).

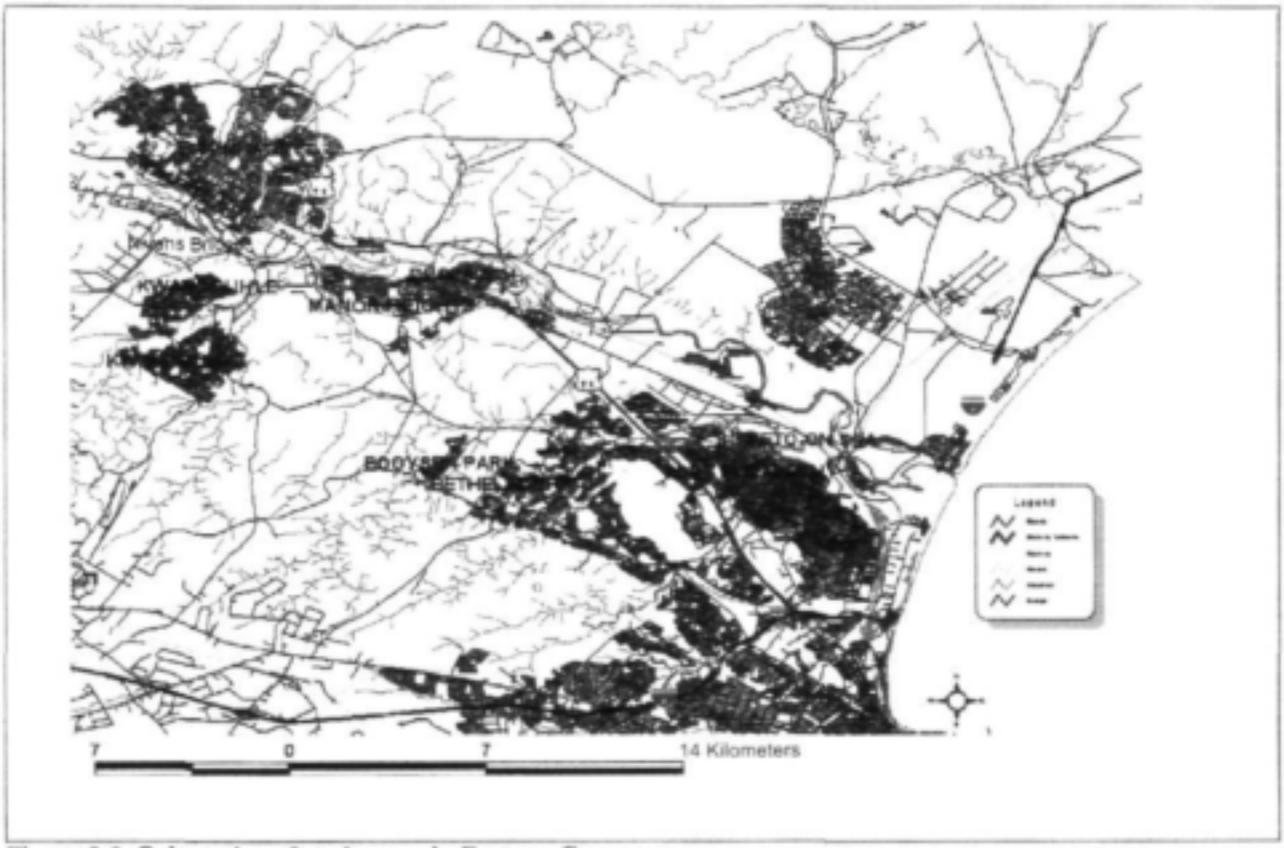


Figure 2.3 Orientation of study area in Eastern Cape

Two of the areas are along the Swartkops River. In these areas the emphasis falls on formal residential, commercial and industrial activities. The other area is situated along the Chatty River and is known as Soweto-on-Sea. Only informal housing is found in this area.

2.4.1 Topographic characteristics of the Swartkops river area

The land use include residential, commercial and industrial areas. In Uitenhage it is mainly residential and industrial, including well-known Volkswagen and Good Year industrial plants. The Despatch area is mainly residential and commercial.

The catchment of the study area stretches from Despatch in the east in a northwesterly direction for 60 km. It is confined to the Great Winterhoek Mountains in the north and the Elands Mountains in the south. The total area of the catchment is 1 120 km^2.

The mean annual rainfall (MAR) in the area varies between 250 mm and 830 mm. For the calculation of the MAR for the whole region, information about the spatial distribution of the rainfall of the region is necessary. An isohyet map was used. Where an area was joined with isohyet lines, it was accepted that the line represented the rainfall. For areas between two lines, the average of the two lines was taken as the rainfall. By using this method, 551 mm was calculated as the MAR. Flood peaks and levels were calculated by SRK Consultants through the use of models.

2.4.2 Topographic characteristics of the Chatty river

The Chatty River originates in the Groenbosse area of Port Elizabeth. Urban settlements in the catchment area are Booysen Park, Bethelsdorp, Kleinskool, KwaDwesi, KwaMagxaki, Zwide and Soweto-on-Sea. According to Mackay et al. (1994) approximate 80 000 people lived in approximately 15 000 squatters' shacks in Soweto-on-Sea during 1994. Many of them were unemployed and had no transport. Minimal services were provided at that time, roads were not maintained, only 200 taps served the whole community, sewage removal consisted of weekly removal of buckets and no facilities for garbage removal existed.

Because Soweto-on-Sea had initially developed with little control, 3 000 of the shacks were below the 1:50 year flood-line of the Chatty River. This had the implication that 16 000 people were subjected to flood danger during 1994.

2.4.3 Calculation of potential flood damage for the study area

The computer model TEWA, discussed earlier in this report, was used to calculate the potential damage for the study area. To understand the output of the calculations, it is important to know the principles underlying TEWA.

Like EAD (1989) TEWA is based on the principle that flood damage to an individual structure/property, groups of properties or flood plain zone is obtained by determining the monetary value of flood damage for different magnitudes of flooding. Damage caused to a property or properties by a single flood event is calculated directly from a flood damage curve. Mean annual damage is determined by calculating the integral of the graph of flood damages of different magnitudes.

Flood damage curves are a fundamental corner stone of the working of TEWA. Depth is plotted against potential damage and used to calculate damage to the particular property.

Based on the scattering of hydrological data, for example cross sections every 100 meters, and economic activities along the river, the flood plain is divided into zones. For calculation of flood damage to individual properties in a zone, the hydrological data of that zone was used to link depth of inundation to all the properties in that zone.

The main reason for calculating flood damage is to evaluate different flood plain management plans. The plans are compared to one another with regard to costs and benefits and prioritized applying various financial and other criteria.

GIS is another important part of the model. It is used to store geographical and attribute (associated) data, to combine data from different sources, do analyses and represent the results of the analyses.

2.4.3.1 Inputs used to calculate flood damage

As mentioned in the description of the model, certain inputs were needed to calculate flood damage and evaluate different measures to mitigate the impacts of floods. The important inputs were flood damage curves, land use data and hydrological data. Geographical data were used to locate the properties and to link topographic data like height above sea level to the properties.

The flood damage functions that were used to calculate flood damage for the study were the same ones that were used during the previous phase (Booysen et al. 1996) of developing computer models to calculate flood damage. Flood damage functions were developed for residential properties in Uitenhage, Despatch and Soweto-on-Sea. Commercial flood damage functions were developed for Uitenhage and Despatch and industrial flood damage functions for certain industries in the flood plain of Uitenhage. These flood damage functions were also used in the calculation of flood damage to the whole study area. The properties were classified into differrent categories. Residential properties of Uitenhage and Despatch were classified into three categories and commercial properties into nine categories . For each residential category the appropriate flood damage function was used to calculate the potential flood damage. For industrial flood damage this was not possible. During previous studies, flood damage was calculated only for industries for which a flood damage function was developed. The reason for the exclusion of other industries was that no standard flood damage functions could be established. This approach is in line with international studies (Smith 1996).

For this study however, it was decided that flood damage functions are going to be linked to all the industries in the study area. This decision was made because one of the aims of the study was to test different scenarios for the mitigation of flood damage. In achieving this aim, actual costs for the construction of the measures were used and to evaluate the scenarios properly, it was decided to link developed flood damage functions to the industrial properties in order to compare the cost with benefits. The criteria used to assign flood damage to industries were the type of goods produced and the floor area of the industry. For the other land uses the same flood damage functions were used.

All these functions were related to 1999 by using the production price index.

The same land use data file that was used in previous studies (Booysen, et al. 1996) , was used as input to calculate flood damage for the different scenarios. Land use data included the geographical location, the physical address and the classification of the property.

As in the case of previous studies, SRK Consultants provided the hydrological data. As Table 2.11 shows, hydrological information was provided in table format and the information was linked to cross-sections.

Table 2.11 Hydrological information for the Swartkops River, 1999

Cross Section Number	Chainage	High Flood Level (*mamsl) for different year floods										
		2	5	10	20	50	100	200	500	1000	5000	10000
48	32253	47.07	47.66	47.96	48.29	49.10	49.32	49.85	50.60	51.21	52.40	52.73
47	31477	44.82	45.57	45.96	46.28	47.26	47.45	48.01	48.71	49.06	50.28	50.63
46	30709	42.91	43.61	43.97	44.23	45.03	45.23	45.49	46.02	46.49	48.01	48.47
45	30095	41.85	42.46	42.81	43.09	44.04	44.32	44.76	45.31	45.78	47.29	47.74
44	29269	39.79	40.56	40.96	41.32	42.39	42.88	43.80	44.11	44.46	45.62	45.97
Nivans Bridge	29189											
42	29143	39.16	40.02	40.42	40.78	41.74	41.96	42.66	43.45	43.66	44.73	45.01
41	28030	35.35	35.99	36.32	36.61	37.63	37.92	38.00	38.39	38.84	40.48	41.06
40	27207	31.31	32.23	32.68	33.06	34.32	34.66	35.39	36.26	36.93	39.07	39.86
39	27079	31.14	32.02	32.47	32.85	34.11	34.44	35.20	36.08	36.74	38.90	39.71
38	26980	30.97	31.69	32.10	32.47	33.75	34.10	34.84	35.79	36.51	38.81	39.65
37	26770	30.17	31.03	31.53	31.96	33.37	33.73	34.48	35.53	36.27	38.65	39.52
36	26287	29.44	30.49	31.03	31.48	32.94	33.31	34.05	35.05	35.89	38.38	39.30
Mel Brook Ave.	26152											
34	26057	29.14	30.22	30.74	31.18	32.60	32.97	33.67	34.57	35.19	38.15	39.12
33	25130	27.72	28.79	29.41	29.90	31.45	31.83	32.49	33.66	34.70	38.00	39.00
32	24353	26.57	27.94	28.67	29.25	30.99	31.41	32.21	33.48	34.54	37.92	38.93
Frans Claasen Bridge	24309											
30	24224	26.23	27.78	28.52	29.11	30.85	31.27	32.17	33.45	34.53	37.91	38.92
29	23942	26.02	27.74	28.49	29.09	30.83	31.26	32.15	33.44	34.51	37.90	38.91
28 (R75 Bridge)	23683	25.06	26.60	27.31	27.81	29.21	29.57	30.35	31.37	32.21	34.88	35.62
27	23592	24.01	25.25	25.75	26.10	25.62	25.80	26.23	26.86	27.35	28.09	28.29
26	22968	22.43	22.99	23.30	23.61	24.65	24.88	25.35	26.35	27.22	28.81	29.23
25	22440	20.36	21.63	22.21	22.70	23.93	24.13	24.33	25.81	26.87	28.28	28.64
24	21519	19.79	20.99	21.58	22.05	23.09	23.09	23.76	25.50	26.55	27.73	28.01
Railway Bridge	21426											
22	21283	19.41	20.44	20.99	21.36	22.40	22.66	23.25	23.99	24.59	26.57	27.14
21	20919	18.96	20.17	20.76	21.10	22.14	22.40	22.99	23.71	24.29	26.21	26.75
20	20629	18.58	19.71	20.19	20.52	21.48	21.72	22.28	23.00	23.53	25.41	25.95
19	20076	18.03	18.93	19.31	19.58	20.45	20.64	21.28	21.97	21.68	22.82	23.26
18	19240	15.55	16.11	16.51	17.03	18.20	18.47	18.35	18.90	19.25	21.39	21.77
17	18322	12.72	13.85	14.42	14.84	16.02	16.36	16.82	17.42	17.69	20.67	20.91
16	17842	12.30	13.42	13.97	14.32	15.33	15.64	15.98	17.31	17.53	20.59	20.81
R367 Bridge												

* mamsl = metre above mean sea level

2.4.4 The evaluation of the different scenarios for the mitigation of floods and flood damage

To test the application validity of the computer model, four scenarios were developed for the mitigation of floods and flood damage in the study area. The first scenario was the 'as is' situation while the second scenario was the clearing of the river channel. Channelisation was tested as the third option while bunding was investigated as the fourth measure. These scenarios were derived after visits to the area and after consultation with different role players, for example the city engineers of Uitenhage and Despatch.

The following tables indicate the damage to the three different areas in the study: Uitenhage, Despatch and Soweto-on-Sea.

2.4.4.1 Soweto-on-Sea

Table 2.12 represent the potential damage that was calculated for Soweto-on-Sea that is situated along the Chatty River.

Table 2.12 Potential damage (R million) from different sized floods for Soweto-on-Sea, 1999

Chatty River		Existing scenario	Scenario 1	Scenario 2	Scenario 2
Frequency	**Probability**		**Channel Clearout**	**Channelisation**	**Bunding**
	0.000	-			
10000	0.0001	10,58	10,58	8,16	10,58
5000	0.002				
1000	0.0010	9,22	9,39	7,03	9,49
500	0.0020	9,48	9,48	7,02	9,48
200	0.0050				
100	0.0100	8,91			
50	0.0200	8,49			
20	0.0500	8,19			
10	0.1000	7,85			
5	0.2000				
2	0.5000	6,95			

The mean annual damage for the different scenarios was calculated by using the above table. The MAD for the 'as is' situation was calculated as R3,79 million. The reason for the high MAD is because flood damage already starts to occur with small floods. A MAD of R57 400 will occur when the Chatty River channel is cleared and a MAD of R42 800 when the river is channelised. Bunding produces a MAD of R57 500. From these values it is clear that implementing any of the three scenarios will have a large impact on the MAD. It is now necessary to look at the cost of implementing the scenarios The cost to implement the clearing of the channel was estimated at R2,56 million and to channelise the river course R6,89 million. The bunding of the river could cost R12,38 million.

This value is the total cost, and when it is compared to the mean annual benefit of the measures, the cost should be "spread" over the lifetime of the measure. After discussions with Van Bladeren, it was decided to take 50 years as a lifetime for all the measures, with maintenance expenses of 5 percent per year. All these expenses that have been incurred during the 50 year period, are discounted (at discount rates of 5, 8, 12 and 18 percent) to the present value. To compare the expenses with the mean annual damage, the yearly benefits should be repeated over the lifetime of the measures as well. Table 2.13 shows the result of these calculations for three mitigation measures. It is clear that the savings (reduction in damages) caused by the scenarios are approximately the same but that huge differences occur in the cost to implement the measures. The present value of the cost to implement clearout of the river channel calculated at a discount rate of 5 persent is R4,6 million, for channelisation it is R30,7 million and for bunding R22,5 million. At all discount rates the net benefit for implementing any of the scenarios is positive. The measure with the highest net benefit is the clearout of the channel.

Table 2.13 The present values (R million) for the savings, cost and net benefit for the Chatty River for implementing flood mitigation measures, 1999

Discount Rate %	Savings*			Cost			Net Benefit		
	Clearout	Channel-isation	Bunding	Clearout	Channel-isation	Bunding	Clearout	Channel-isation	Bunding
5	68,17	68,44	68,17	4,65	30,70	22,50	63,53	37,74	45,68
8	45,68	45,86	45,68	3,81	25,19	18,46	41,87	20,67	27,22
12	31,01	31,13	31,01	3,23	21,34	15,64	27,78	9,80	15,37
18	20,74	20,82	20,74	2,77	18,29	13,40	17,97	2,53	7,34

* Saving refers to reduction in damage

2.4.4.2 Uitenhage and Despatch (Swartkops River)

Table 2.14 represents the potential damage that was calculated for Uitenhage and Despatch, situated along the Swartkops River.

Table 2.14 **Potential damage (R million) from different sized floods calculated for Uitenhage and Despatch, 1999**

Swartkops River		Existing	Scenario 1	Scenario 2	Scenario 3
Frequency	**Probability**		**Channel Clearout**	**Channelisation**	**Bunding**
	0.000				
10000	0.0001	2867,06	2867,31	2007,25	2867,06
5000	0.0002	2855,55	2638,59	1437,17	2637,90
1000	0.0010	1805,30	1802,96	373,14	1805,30
500	0.0020	1103,11	1043,10	185,72	1046,41
200	0.0050	635,72	637,10	15,09	443,34
100	0.0100	302,30			
50	0.0200	294,72			
20	0.0500	11,29			
10	0.1000	1,25			
5	0.2000	0,51			
2	0.5000	0,09			

As in the calculation of the MAD for the Chatty River, the above table was used to calculate the MAD for the Swartkops River that included the Uitenhage and Despatch urban areas. It is clear from the table that the potential for flood damage is very high. This is mainly due to the presence of industries in Uitenhage.

The MAD for the 'as is' situation is R16,9 million. The MAD after the measures are implemented is R7,87 million if the river channel is cleared, R1,72 million if the river is channelised and R7,11 million if bunding is applied along the river. It seems that channelisation is most effective in reducing potential flood damage but to decide which measure is most economical, it is necessary to look at the cost involved in implementing the measures. The cost to implement the clearing of the channel was estimated at R 6,92 million and to channelise the river course R111,1 million. Bunding of the river would cost R 10,5 million. It is clear from this that although channelisation had the greatest impact on reducing the potential for flood damage, it was also the most expensive to implement.

The same approach as in the case of the Chatty River was followed to calculate the present value of the benefits or savings and the costs.

Table 2.15 The present values (R million) of the savings, cost and net benefit for Uitenhage and Despatch for implementing flood mitigation measures, 1999

Discount Rate %	Savings			Cost			Net Benefit		
	Clearout	Channel-isation	Bunding	Clearout	Channel-isation	Bunding	Clearout	Channel-isation	Bunding
6	164,76	277,21	178,76	12,57	201,93	19,09	152,19	75,27	159,66
8	110,41	185,76	119,79	10,32	165,68	15,67	100,09	20,07	104,12
12	74,95	126,10	81,32	8,74	140,37	13,27	66,21	-14,27	68,04
18	50,13	84,34	54,39	7,49	120,30	11,38	42,64	-35,96	43,01

It is clear from Table 2.15 that the implementing of bunding in certain areas along the Swartkops River will render the largest net present benefit. It is only the channelisation measure that presents a negative net benefit if the rate at which the present values were calculated is larger than 12 percent.

2.4.5 Conclusion

The case study results, based on realistic benefit and cost estimates, confirm TEWA to be a useful tool in providing information for flood mitigation planning in the research area.

From the three mitigation options investigated, channel clearance provides the largest net benefit for Soweto-on-Sea along the Chatty River while bunding will render the largest benefit for Uitenhage/Despatch along the Swartkops River. Channelisation will have only limited use. In deciding on an optimal package of structural measures, the following recommendation from the consultants report must be emphasised. "The selection of remediation measures at the various sections should take account of the cost (optimised) and appropriateness of a measure. At some points it may be prudent to combine the measures."

To put the discussion and conclusion from this case study into perspective, the consultants' report in Annexure 2 must also be consulted.

CHAPTER 3

FLOODS, DEVELOPMENT AND DECISION-MAKING: INTEGRATING SOCIAL AND DEVELOPMENTAL CONCERNS INTO DISASTER MANAGEMENT AND CONTROL[1]

3.1 INTRODUCTION

The social dimensions of natural disasters like floods are fundamental. The existing social context conditions include, inter alia:

- vulnerability to disaster in the first instance
- the social impact of the disaster
- capacities for responding to disasters
- the needs arising from a disaster.

Disaster response, from the immediate relief stage through to reconstruction, has a political character and component which require the incorporation of local political and community leadership.

Disasters can negatively affect, or throw into sharp relief, a range of critical development factors including infrastructure, settlement patterns, economic activity, and social cohesion. Decision-making and provision in relation to relief and reconstruction needs constitute interventions which inevitably help shape development prospects and possibilities going forward.

For these reasons there is an emerging global consensus that disaster management must be cast in a broader developmental framework, particularly one which is people-centred and takes the social dimension on board as a central concern. At the broadest level this implies at least that:

- Reducing vulnerability to disasters is fundamentally tied to taking proactive steps to enhance the developmental conditions of populations recognisably at risk and to at minimum defend and secure existing developmental advantage/s against setbacks that a disaster would bring

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[1] Much of this discussion emerged as conclusions from a case study of the 1995 Christmas Day flood in Pietermaritzburg.

- Relief and reconstruction after disasters should be approached with the explicit intention of seeking opportunities for improving developmental prospects and securing improvements in quality of life
- Decision-making and the selection of measures for disaster management interventions must attempt to satisfy a range of stakeholders across a range of objectives.

It is generally recognised that "[m]any 'natural' disasters are the result of unsolved development problems. Development patterns that ignore sustainable water management are exposing communities to greater risks of floods and drought." (Domeisen 1997: 2). *Von Kotze et al* (1997) confirm the link between the natural and the social, and note that "[f]loods are naturally occurring hazards. They become disasters when human settlements occupy the floodplain[2]" (von Kotze et al 1997: 213). Domeisen goes on to point out that development itself impacts on flood risk:

> "Floods are growing more quickly than other disasters. Rapid development is changing local ecosystems, increasing flood risks. In urban areas, for example, the use of concrete has changed the capacity of soil to absorb water, leading to flash floods. Yet another cause for increased damage from floods has to do with location: more people are crowded along river banks, forced into cities (sometimes because of drought) at a rate too fast for cities to absorb them. The rise in flash floods is also partly due to deforestation, which contributes to hillside erosion and makes people vulnerable to landslides triggered by heavy rains.
>
> While drought is the leading killer, with nearly 74,000 reported deaths in 1996, floods are the most frequent and cause most economic losses" (Domeisen 1997: 3; see also von Kotze et al 1997: 213 for similar argumentation.).

At the global level too, the links between development and disaster management can be demonstrated. For example, global climate change impacts on the frequency and magnitude of extreme events and has introduced new risk elements into the planning and design of flood control and management initiatives. Global climate change is linked to the emission of 'greenhouse gases', which is in turn fundamentally tied to rates and patterns of modern industrial development.

The contention in Government's White Paper on Disaster Management that the solutions to the challenges of disaster management in South Africa are more than likely to be found in actively seeking the integration of risk aversion and reduction into development processes seems apposite. This is so because it places the selection of damage control and risk reduction options in a broader context of participatory

[2] They would presumably concede that the link holds too where human populations have some dependent relation to the floodplain even if they do not occupy it.

democracy and sustainable development. Thus, in the discussion of 'Risk Reduction in Development Planning', the White Paper argues that:

> "Urgent action should be taken to reduce the probability and severity of disaster occurrences through developmental action and planning. This is a broad-based initiative, aimed at significantly reducing the potential for loss of life and injury, as well as economic and environmental costs that result from natural and other threats".

The integration of socio-developmental factors into the conceptualisation and practice of disaster management is not a 'once-off' exercise since the two components mutually effect each other. At the local level, development does not only affect disaster management - disaster management interventions can affect development. For example, where a previous lack of land control measures (or other pressures) has led to an increase in population densities on former floodplains, the provision of flood control measures can produce a relative rise in property value and induce a cyclical investment pattern creating in turn a greater demand and pressure for more flood protection[3]. (Of course a further implication in this scenario is that, as a result of accelerated investment resulting from flood control measures, greater damage would result should the design capacity of the measure/s instituted be exceeded.)

A broader conceptualisation of the scope of flood management infrastructure decision-making is also justified by a concern that, where chiefly hydrological concerns and data constitute the basis, adequate data is critical - and often not available. This potentially introduces an unacceptably high degree of risk into the determination of the model flood. This suggests that the focus should perhaps be on flood hazard assessment and risk management which is critically linked to the socio-developmental factors which define vulnerability and risk.

> "Describing the objectives in terms of the avoidance of certain levels of damage to individual sections of society and the national economy as a whole rather than on the design flood level, may broaden the discussions of flood management options and lead to wider incorporation of the evaluation of options in the planning process" (World Commission on Dams, 1999 b.: 2)

It is necessary therefore to consider:

- what the key elements in an integrated, developmental disaster management system might be, and

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[3] Note that this entirely plausible process is likely only because of the way in which conventional economics tends to externalise both environmental costs and benefits. As a result, the 'free' services provided by intact environmental systems are not quantified and are therefore discounted.

- some of the ways in which the integration of socio-developmental concerns with disaster management and control might best be achieved.

3.2 KEY ELEMENTS IN AN INTEGRATED, DEVELOPMENTAL DISASTER MANAGEMENT SYSTEM

Based on the review of the Pietermaritzburg flood of 1995, relevant disaster and flood management literature and the emerging national policy framework for disaster management, the following summary framework or process might be tentatively posited:

- Gather, analyse and interpret information
- Understand hazards & risk/s
- Map hazards
- Develop options for mitigation, reduction, management and/or prevention
- Decide on a strategy/ies
- Implement strategy/ies.

For each of these steps indicated, there exists a range of tools and options to draw on. These are briefly introduced below.

3.2.1 Gather, analyse and interpret information

Various data are a critical starting point. Such data include physical and environmental data as geohydrological and topographical inputs but also a range of social-economic and developmental data such as population densities, housing stock quality and investment/insurance indicators, current and anticipated trends and plans with respect to land use, or income and employment patterns. (Information issues are further discussed later in this chapter.)

3.2.2 Understand hazards & risk/s

Hazard assessment includes various physical data as well as an analysis of social and political conditions.

Vulnerability analysis is critical too for estimating the potential disaster hazards of specified elements at risk, where risk indicates expected losses[4] from a phenomenon and expresses the function of the probability of particular occurrences and the losses each would cause.

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[4] i.e., lives lost, persons injured, property damaged, economic activity and livelihoods disrupted.

> "For engineering purposes, vulnerability analysis involves the analysis of the theoretical and empirical data concerning the effects of particular phenomena on particular types of structures. For more general socio-economic purposes, it involves consideration of all significant elements in society, including physical, social and political considerations (both short and long term), and the extent to which essential services and traditional and local coping mechanisms are able to continue functioning" (von Kotze et al, 1996: 6).

3.2.3 Map hazards

Hazard mapping has been described as the:

> "process of establishing geographically where and to what extent particular phenomena are likely to pose a threat to people, property, infrastructure, and economic activities. Hazard mapping represents the results of hazard assessment on a map, showing frequency/probability of occurrences of various magnitudes or durations" (von Kotze et al, 1996: 5).

3.2.4 Develop options for mitigation, reduction, management and/or prevention

A majority of deaths and much destruction associated with floods can be prevented through mitigation and preparedness. Having identified vulnerable elements from integrated information sets, an overarching aim of any combination of measures is to reduce vulnerability[5].

Risk reduction measures

Risk reduction measures might include the following.

- Mapping the floodplain: at minimum, a basic flood frequency map (e.g., the 100 year flood line) should be mapped, together with such social and developmental factors as damage reports, population densities, infrastructural maps and so on.
- Multiple hazard mapping: to highlight areas vulnerable to more than one hazard.
- Land use control: to reduce danger to life, property and development, and to ensure that flood risk is not heightened through inappropriate new land use. In urban areas, the following should be addressed:
  - Reduce densities: "... the number of casualties is directly linked to the population densities of the neighbourhood at risk. ... For areas already settled,

[5] The following discussion of risk reduction and flood control measures is summarised from von Kotze *et al* 1997: 216-220).

especially squatter settlements, regulation of density can be a sensitive issue and would have to address the socio-economic implications of re-settlement. Unfortunately, many situations exist where dense unplanned settlements are located on floodplains. Planners must incorporate measures to improve sites and reduce vulnerability" (Von Kotze et al 1996: 217).

  - Prohibiting specific functions: for example, no development permitted within the 10 year flood line; high risk areas reserved for low risk functions only (e.g., sports facilities); high damage potential functions (e.g., hospitals) only permitted in low risk areas.
  - Relocation of elements that block a floodway.
  - Regulation of building materials: where rules are related to risk and flood protection measures taken for particular areas.
  - Provision of escape routes: especially for vulnerable populations.
- Other preventative measures might include:
  - Acquisition of flood plain by development agencies.
  - Establishing incentives (through loans, subsidies and tax breaks) to encourage development on safer sites with safer building materials and methods.
  - Diversify agricultural production.
  - Reforestation, range management and stock grazing controls to improve absorption.
  - Construct places of refuge on raised areas if evacuation is not possible.

Flood control measures

Most commonly used options include the following:

- Existing channel improvements (deepening and widening especially).
- Diversion and relief channel construction.
- Dikes and dams.
- Flood proofing - usually where individual property owners strengthen buildings to:
  - resist the force of water, and
  - retain structural integrity when inundated.
- Protection against erosion.
- Site improvement - often the elevation of sites can be effective.

3.2.5 Decide on a strategy/ies

Deciding between various options (or combinations thereof) is informed by risk assessment whereby the nature and scale of losses or damage from anticipated disaster/s in particular areas within a specified time frame are determined. Von Kotze et al makes the point that risk assessment (or risk analysis or evaluation) is:

"the social and political judgement of various risks by the individuals and communities that face them. This involves trading off perceived risks against potential benefits and also includes balancing scientific judgements against other factors and beliefs" (von Kotze et al 1997: 5).

The issues and methodological considerations pertinent to disaster mitigation intervention decision-making are particularly significant when framed in a broader, 'people-centred' developmental context and are therefore, discussed further in a subsequent section of this chapter.

3.2.6 Implement strategy/ies

From the perspective of highlighting the social and developmental components to disaster management, it is important to highlight here at least two considerations:

- Actual processes of planning, construction, site improvement, and so on, as well as the maintenance of these interventions, can be conceptualised so that they draw on and develop local-level skills, labour and responsibility and, in so doing, contribute to development and the overall reduction of vulnerability.
- Implementation must be monitored for impacts both to assess its efficacy against stated objectives and to provide a vital component in the information feedback loop so that the 'data set' for disaster management (and indeed for development) is up-to-date.

3.3 HOW TO INTEGRATE SOCIAL AND DEVELOPMENTAL CONCERNS INTO DISASTER MANAGEMENT AND CONTROL

It is suggested that there are opportunities for the integration of social and developmental concerns into disaster management and control at the following points of intersection:

- approach and conceptualisation
- information
- selection of control and mitigation measures
- decision-making and implementation

3.3.1 Approach and conceptualisation

As indicated above, the emphasis in disaster management must continue to shift away from a primary emphasis on the provision of relief after a disaster toward reducing levels of risk through developmental interventions to reduce the vulnerability of particular human settlements and populations.

The White Paper suggests the following strategies as examples of what can be done to incorporate risk reduction into development planning:

- Developing integrated disaster management strategies that emphasise risk reduction
- Ensuring that the most vulnerable communities can depend on reliable disaster management services. These services should alert them to natural and other threats and provide professional and humanitarian support in times of emergency. Timely disaster management actions contribute to sustainable development by limiting environmental and property damage, as well as loss of life and livelihood
- Establishing creative formal and informal initiatives that encourage risk-avoidance behaviour on the part of the individuals, private sector and government
- Ensuring that South Africa's transportation, telecommunications, electricity and public sector infrastructure networks are able to withstand expected natural and other threats. They are cornerstones for the movement of people, goods and services between urban centres and isolated rural areas. They are also the lifelines for communities when slow and sudden onset disaster events occur, as they will be relied upon to support ongoing development action, as well as humanitarian relief in times of stress
- Setting minimum building standards, especially for low-cost housing, to ensure *structural soundness to withstand the impact of extreme weather patterns*
- Ensuring that development of marginal areas is appropriate and properly planned (RSA 1999: 24)

Later in the White Paper it is further suggested that the proposed National Disaster Management Centre should:

> "Initiate the integration of risk reduction strategies into the setting of land development objectives [LDOs] in terms of the *Development Facilitation Act* and integrated development plans [IDPs] drawn up in terms of the *Local Government Transition Act*. This must be done in consultation with the relevant role players" (RSA 1999: 31).

3.3.2 Information

The integration of socially relevant data into the decision-making processes and the establishment of indicators for assessing and monitoring social impacts (both of disasters themselves and of risk reduction or disaster prevention measures) is obviously critical in this shift. Key points where such data appear critical are as follows:

- Baseline socio-demographic data
- Selection of measures (for risk reduction, mitigation or prevention)
- Immediate post-disaster impact assessment

In all three areas, it is also vital to consider how best to incorporate a distributional analysis of the relevant socio-developmental factors. Distributional analysis considers and evaluates the equity consequences of developments, policies and alternatives in terms of the distribution of costs, benefits, risks and impacts at local, regional, national, international and global levels, as well as among different social groups. The field of distributional analysis is however relatively underdeveloped - particularly with regard to the quantification and integration of multiplier and induced effects. Implications for the incorporation of distributional considerations into decision-making systems is further discussed later in this chapter.

Baseline socio-demographic data

Data collected during or immediately after a disaster concerning social impacts can only be interpreted meaningfully when they are read against baseline data. Without reliable baseline data which have been collected proactively and regularly, it is impossible to reliably measure the impact of disaster, to identify the 'starting point' of a disaster, or to distinguish between pre-existing chronic needs and problems created by the disaster itself.

Therefore, without an accurate picture of current socio-economic characteristics and demographic and settlement patterns, it is impossible to measure with any confidence either the social and developmental impact of a disaster on a particular population or settlement or the social impacts of developmental and mitigatory interventions made with the aim of reducing vulnerability.

The collection and interpretation of socio-economic and other baseline and attitudinal data is integral to the processes of development planning and facilitation. It is increasingly recognised that this can and should be conducted in a participatory and consultative manner[6], using appropriate tools. This allows for the possibility of integrated administration of research questions/instruments to gather data relevant to disaster mitigation and management into broader processes of social survey at the local level. Thus, at a simple level, representative samples of target populations could be asked for example:

- Have you or your community experienced a disaster in the area where you live (flood, fire, etc.)?
- What do you think caused it or made its impact worse?
- What was done at the time of the disaster?
- What should have been done beforehand to avoid it or lessen its impact?
- Did you suffer any losses (personal, material, financial, business, etc.)?

[6] Certainly this is the implication of new and recent local government regimes which require formulation of Integrated Development Plans and Land Development Objectives and so on.

- Were you compensated for any such loss? (if so, how?; and was the compensation sufficient or appropriate?)
- Has anything been done since then to avoid a recurrence or reduce its impact (by government, the community, business, etc.)?
- What else should be done (by government, the community, business, etc.)?

Such data would be useful for disaster management. In particular:

a. together with other relevant data, it would enable the identification and ranking of risk profiles and the isolation of high risk areas which may require the initiation of processes to develop specific mitigation or avoidance measures
b. could correlate community views regarding what should be done with technical, engineering, financial and other considerations and options to develop specific proposals for disaster mitigation and management.

3.3.3 Selection of measures

An integrated approach implies that:

- The views and interests of a broad range of stakeholders are a meaningful component of the decision-making process
- Social impacts of various alternatives are factored into the decision-making matrix
- Selection of disaster management measures is informed, and informs, broader processes of development planning and facilitation.

The research has demonstrated that people's choice constructs in relation to disaster management options are both complex and constrained by their context. For contexts of poverty, there is in some respects a corollary poverty of information that obtains. This suggests that the gesture toward community acceptability must carry the rider that local communities do not have the last word on the matter either. 'Western' development approaches are replete with the arrogant and mistaken notion of the inherent, objective appropriateness of scientific and technicist solutions arrived at by an elite of technicians and engineers.

As the Pietermaritzburg flood case study demonstrates there are additional layers that contribute to the crisis of legitimacy for officials, bureaucrats and technocrats in South Africa which relate to the historical reality that these skills were monopolised in the interests of whites and exercised predominantly in racialy-defined geographic areas - when councilors were brought on board the relief operations at an early stage it marked, in part, an acknowledgement that local government officials in this case simply did not know the areas they were responsiblle for well enough to provide effective and credible responses. In time this latter dimension may be attenuated as skillls and responsibilities are more democratically allocated and exercised and the racial monopolisation of those skills and responsibilities is broken down, but current reality affirms the importance of a socio-political dimension in appropriate disaster management practice.

It is also likely that the historic tendency to view the selection and evaluation of disaster management interventions from a largely technical, engineering and financial perspective reinforced a limited view of the set of measures to select from.

In the process of selecting and implementing a final package of flood and risk management measures from a range of alternatives, there must be an openness to exploration of non-structural options as well. Whether these non-structural approaches (e.g., flood forecasting, land use planning, disaster preparedness, flood insurance, population resettlement) are in parallel or independent of structural forms of flood protection, it should be borne in mind that these approaches also requires considerable management effort and resources.

In this light, the growing recognition that technicians, scientists, engineers and academics do not access objective truth by virtue of their discipline-specific skills is to be welcomed - but 'communities' do not have full and perfect information either.

It is also a mistake to assume that 'communities' are homogenous entities. Different histories (personal, familial and social) and different socio-economic conditions obtain and these will profoundly structure receptivity towards disaster management alternatives. The complex diversity of interest and capacities is fundamental to the debates concerning what constitutes the 'public interest'. These tensions are meant to be resolved, if imperfectly, through democratic governance and leadership mediating public opinion/s in relation to particular interests and to the resources and options that are pragmatically available.

An authoritarian resolution of these tensions may seem attractive in contexts of disaster and crisis but is unlikely to secure sustainable development packages or processes which include risk reduction and/or impact minimisation interventions. On the other hand, thoroughly democratic application of the principle of subsidiarity[7] tends to assume or imply a resilient, robust and mature democratic political culture at a very local level - a condition unlikely to obtain in a 'transitional' society like South Africa's for quite some time. Instead it is more likely to open disaster management interventions up for distortion by very particular and localised interests and powers (at minimum thereby increasing the likelihood of fraudulent abuse of relief and other measures by local 'leaders').

In the Pietermaritzburg flood case study, the attempts to resolve this socio-political dimension can be seen to have gone through at least three stages. The first involved

[7] Devolve the responsibility and authority for decision-making to the lowest level possible and highest level necessary.

activation of the existing civil protection protocols by officials of the TLC. The second, mentioned above, drew the political leadership of the city into the operations. But even this proved insufficient and, in a third phase, 'local', 'community' leaders were drawn in too. In the event, all were necessary but none proved entirely satisfactory. The experience does suggest the relative weakness (not surprising given this country's short history of democracy) of both democratic political culture and its integration with governance at the local level.

However these concerns do not necessarily invalidate a concern for political legitimacy and participation in disaster management. What it may suggest is that:

- a degree of learning and flexibility can be anticipated anyway, and
- a mix of strategies should be deployed, including the advisability of:
-
    - establishing the legitimacy of disaster management protocols proactively so that people are familiar with them and more likely to accept their application ('awareness')
    - training programmes to create volunteer corps from communities so that awareness raising is consolidated, reinforced and locally 'owned', and that the execution of disaster management protocols is not alien or distant from affected communities.

  The latter should not only build legitimacy and credibility but also assist in overcoming the near total sense of disempowerment in the face of disaster that is so clearly evident in the case study - people are more likely to sense that they can do something.

A further component of a participatory approach is the recognition that local people have knowledge, information and wisdom that is legitimate and significant. Thus 'participation' is not limited to a process of more thoroughly 'telling people what they need to know' or what the 'real' situation is. Nor can a participatory approach sustain the assumption that 'experts' have full and complete data as well as the appropriate sets of options and solutions.

In the Pietermaritzburg flood case study, officials were more or less compelled to acknowledge that, to an important degree, it was their incomplete knowledge and experience that had to change in order to respond effectively - apartheid's historical geography meant that they simply did not know enough about the areas they were responsible for - the existing civil protection plan had been developed for the 'old' white borough.

It emerges clearly in the focus groups conducted in the background case-study that, for some respondents, there was certainly no need to build awareness of the flood problem - people had experienced flooding before and still lived in areas they knew to be vulnerable. Rather, the problem lay elsewhere, namely:

- socio-economic conditions that constrain the *de facto* options available to many of those occupying high risk land
- historic, racist neglect of African areas and predicaments
- persistent failure (extending into the present) of the authorities to provide real alternatives or initiate meaningfull risk mitigation processes.

At a general level, it is widely accepted that:

> 'sustainable development' can only be achieved on the basis of a balanced appraisal, prior to their approval and implementation, of ... development policies, plans, [projects] and programmes... Environmental impact assessment (EIA) is a tool which is widely used to assess the environmental impacts of individual development projects. Cost-benefit analysis (CBA) and social impact assessment (SIA) are used to appraise their likely economic and social consequences. A balanced appraisal requires the integrated application of each of these three appraisal methods. The emergence of sustainable development as a major policy objective is now leading to these three methods being adapted and applied, in an integrated manner, in strategic-level appraisals of development policies, plans and programmes" (Manchester University 1999).

This broad approach is relevant to an integrated conceptualisation of disaster management and validates a concern for the social and developmental impacts of disaster mitigation and risk reduction planning and activity. Wolf has argued that the social dimension must be affirmed because "social relations and institutions mediate and often shape ... [the] contours" of the biophysical constitution of humans and the non-human environment:

> For instance, although earthquakes are geophysical phenomena, the loss of life associated with them largely results from human settlement patterns conducive to risk exposure and to failures in infrastructure and domestic architecture. Similarly, the causes of famine are more likely to be political than environmental (Wolf 1997: 3).

Disaster management could therefore usefully draw on the growing body of literature and practice associated with social impact assessment (SIA). An important consequence of such dialogue should be to reinforce the central idea that disaster management must shift away from a reactive emphasis and towards a proactive, developmental mode.

Wolf explains that the aim of SIA is to provide means for protecting and enhancing the quality of life. Social impacts are 'people impacts' and include "all social and cultural consequences to human populations of any public or private actions that alter the ways in which people live, work, play, relate to each other, organise to meet their needs, and generally cope as members of society" (World Commission on Dams 1999 c.: 1):

> "SIA practitioners seek to analyze and evaluate the conditions, causes, and consequences of social change on people where they live, in families and communities..
>
> Unlike 'evaluation research' which gauges the effectiveness of programs already in operation, the task for SIA is anticipatory research. It seeks to place the expectation and attainment of desired outcomes of policy formation, program development, and project implementation on a more rational and reliable basis" (Wolf 1997: 1).

He goes on to argue that:

> "Along with the knowledge of consequences, social impact assessment also implies an ethic of consequences. SIA practitioners must take professional and personal responsibility for their knowledge and the uses to which it is put. In addition, they must recognize and respect the integrity and dignity, of persons and groups who are the subjects of their studies. In the process, SIA can contribute to social development by means of endogenous capacity building and the empowerment of peoples to control the forces of change which may potentially affect them" (Wolf 1997: 2).

The SIA approach then also underscores the value of participatory methodology and affirms (and can provide supportive tools for) the practice of consultative, 'people-centred' development. Within the framework of sustainable development, and the implementation of the various tools associated with it (e.g., environmental impact assessment, as well as SIA), "[s]ubjective data (opinions, perceptions, attitudes/feelings) are accepted as relevant factors" (Johnston 1998: 37). Wolf points out that by defining itself as an 'assessment' tool, rather than an 'analytical' one, SIA assumes the inclusion of both expert analysis and public evaluation. "This also points to the important (indeed, indispensable) role of public participation in the assessment process" (Wolf 1997: 3). As such, this approach presents a way of

> "taking responsibility for the knowledge of consequences, powerfully reinforced by direct contact with affected groups and persons. It is also a means for asserting demands for accountability on the part of change proponents and agents, and a general balancing in society of rights and responsibilities " (Wolf 1997: 6).

Economic impact assessments are obviously not unconnected with social impacts. However, SIA methods are distinct from, and complement, the economic impact methods (including, e.g., Input-Output Analysis, Cost-Benefit Analysis, and Regional Multiplier-and-Accerator Analysis) which focus on quantitative impacts. Among the economic impact methods, Qualitative Economic Impact Assessments (QEIA) have parallels with SIA since they focus on qualitative impacts and usually consider and investigate, *inter alia*:

- Opportunity costs: e.g., what will be lost in terms of alternative land uses, alternative allocations of resources (especially public resources), or existing activities, should a certain development or project go ahead?
- Opportunities created: what new economic opportunities or (regional, local) strategic advantages might be created flowing from a project?
- Wider effects: e.g., what changes in property prices or the image of an area might result?, how would a project relate to planning initiatives at various levels?
- Skills development: can skills required at different stages of the project be enhanced, sourced or developed within local populations, using local training institutions?
- Local services and housing: e.g., are there backlogs to be addressed to service the proposed project?

QEIA can be a useful basis for proposing certain mitigation and enhancement measures.

With regard to SIA methods specifically, it is critical to bear in mind that their application is not a mechanical process driven by a standardised checklist of tasks, inputs and outputs. Useful in describing and interpreting specific characteristics and dimensions of 'societies', they are best understood as tools and techniques requiring appropriate research design and rationale for their use. This so particularly because the social dimension is dynamic, adaptive and unpredictable unlike physical and natural realms where predictable laws operate with more or less predictable outcomes. Social dynamics are historically, geographically and contextually specific and not amenable to deterministic modeling - rather they operate as complex adaptive systems with probabilistic (stochastic) processes and outcomes.

Issues usually addressed in SIAs include:

- Demographic changes
- Lifestyle or quality of life changes
- Social problems (crime, illness etc.)
- Community stress and conflict.

As with economic impact assessments, SIA studies would usually indicate:

- Status of the impact (positive or negative)
- Extent
- Duration
- Intensity
- Probability of occurrence
- Significance

- Degree of confidence in predictions
- Mitigation and/or enhancement measures.

Some of the main methods associated with SIA would include[8]:

- Demographic analysis
- Investigating community perceptions of impacts
- Systems approach [not often employed]
- Social indicators.

von Kotze and Holloway's 1996 publication: ***Reducing Risk: Participatory learning activities for disaster mitigation in southern Africa,*** is a very useful resource enabling community-based and participatory processes. The authors describe the book as a "tool for those who work with at-risk communities", being a "series of participatory learning activities intended to increase understanding about community risk and vulnerability, and strengthen the training capacities of those involved in community-based disaster-management" (von Kotze *et al*, 1996: vi).

Reducing Risk is based on four assumptions which are congruent with the overall findings and orientation of the current discussion, namely:

- risk reduction efforts are more effective and sustainable if integrated with existing community-based services
- the relationship between disaster mitigation agencies and at-risk communities should be one of 'active partnership'
- emergency operations are opportunities for, not only relief, but also promoting prevention, mitigation, preparedness, and recovery
- disaster-related initiatives must include gender, and involve women in design and implementation because the greatest impact of recurrent threats falls on women.

Preparation of the learning materials found in the book was guided by the following principles:

- Context specific
  - related to a southern Africa risk profile
- Experience-based
  - learning comes from participants' experience of dealing with risk
  - by sharing coping strategies, participants' acknowledge each other as valuable resources

[8] It is inappropriate for our purposes to attempt a description of each such method since, as indicated, there is no set 'formula' for their application. Rather the specific needs and conditions would inform selection and overall research design on a case-by-case basis.

- enables independent, logical problem solving in the field
- participatory
  - the activities encourage participants to monitor and manage their own learning processes which transfers responsibility for learning away from facilitators to the participants
  - effective disaster reduction itself should be participatory at all stages
- analytical
  - designed to encourage learners' critical thinking, planning and response skills
  - risk problems are unique to each context, so decisions and actions must flow from an analysis of particular dynamics and pressures, and causes and effects
  - approach indicates a shift from training based on technical information to respond to emergencies towards long-term vulnerability reduction planning
- applied
  - imparts practical skills and understandings for more effective and efficient responses to threats.

Examples of exercises from the book indicate the value, and relative ease of application, of participatory methods for gathering information vital to disaster management in a manner which empowers those effected by risk to take responsibility and ownership of the problems they face and make meaningful contributions to the reduction of risk.

The aim then is, in Chapter, to marry sound and appropriate technical options with community-defined needs in an overall development framework.

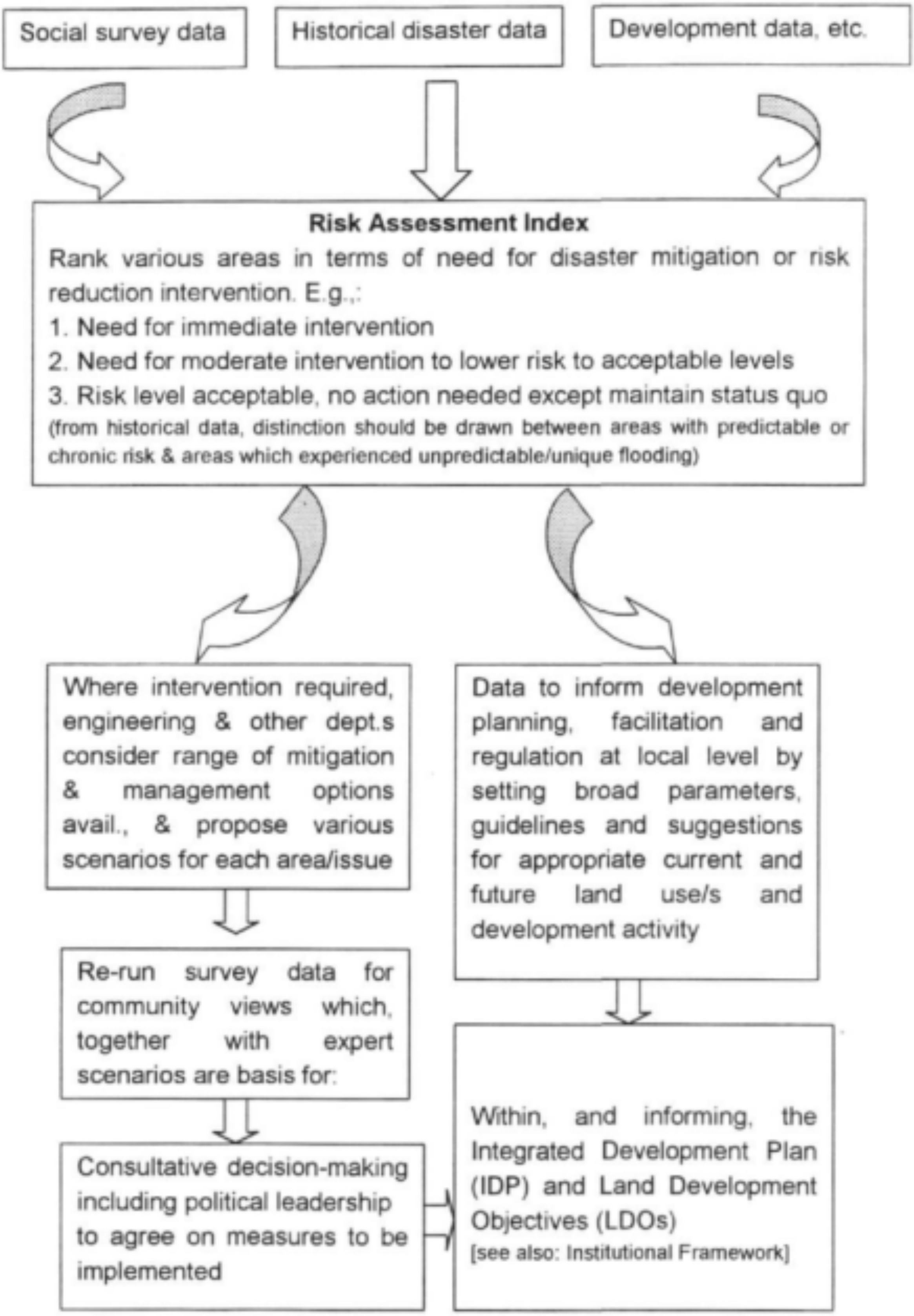
Part of the answer is to avoid securing communities' views, input, and control only after or during the crisis event. If information gathering, consultation and development planning are done in a proactive, ongoing manner, which is part of governance processes at the local level, it is more likely that pitfalls can be avoided (or at least managed)[9], and mitigation or risk reduction actions can be integrated into processes of development planning.

Concerns exist as to the effectiveness of SIAs (and Environmental Impact Assessments too) in providing adequate support for decision-making processes - especially since, in practice, they are often insufficiently applied in the early stages making them appear less relevant to the analysis of alternatives. Furthermore, the introduction of another evaluation procedure into already complex decision-making procedures raises concern. Certainly it appears that the integration of a thorough assessment of distributional and

[9] For example, those responsible for disaster and relief response would be less pressured to accept at face value demands made by those claiming to be local community leaders for compensation on their terms and there would be an enhanced ability to secure greater shared responsibility for mitigation interventions.

developmental criteria into disaster control measures selection is likely to render a conventional Cost Benefit Analysis framework inadequate. In light of this there is growing discussion about the need for a framework of 'multi-criteria decision making' (which is discussed more fully in the section 'decision-making' in this chapter).

In practice, SIA has tended to focus on assessing local populations with insufficient consideration of up- and down-stream riverine populations. This must be avoided and the modeling of likely areas of impact (both of floods and of mitigation and control interventions) should be useful in helping to identify such affected populations who may be located outside of the immediate geographic area.


Social survey data
Historical disaster data
Development data, etc.
Risk Assessment Index
Rank various areas in terms of need for disaster mitigation or risk reduction intervention. E.g.,:
1. Need for immediate intervention
2. Need for moderate intervention to lower risk to acceptable levels
3. Risk level acceptable, no action needed except maintain status quo
(from historical data, distinction should be drawn between areas with predictable or chronic risk & areas which experienced unpredictable/unique flooding)
Where intervention required, engineering & other dept.s consider range of mitigation & management options avail., & propose various scenarios for each area/issue
Data to inform development planning, facilitation and regulation at local level by setting broad parameters, guidelines and suggestions for appropriate current and future land use/s and development activity
Re-run survey data for community views which, together with expert scenarios are basis for:
Consultative decision-making including political leadership to agree on measures to be implemented
Within, and informing, the Integrated Development Plan (IDP) and Land Development Objectives (LDOs)
[see also: Institutional Framework]

3.3.4 Decision-making[10] and implementation

From CBA to MCDA

A Cost-Benefit Analysis (CBA) model has provided the underlying decision-making framework for the selection of flood damage control measures in this project. The connection between CBA and flood control is well established - indeed van Zyl (1997) argues that

> "... modern water resource planning began with the enactment of the Flood Control Act of 1936 in the United States when, for the first time, formal cost-benefit analysis became a planning requirement" (van Zyl 1997: 30).

The CBA approach has important attributes - not least of which is to reinforce a proactive approach to disaster management by highlighting the importance of forward-looking analyses that locate the relative merits of alternative preventative measures in a broader set of economic data. The importance of incorporating a social dimension is recognised in the field of CBA itself, where *Social* Cost-Benefit Analysis (SCBA) has become a norm, reflecting a shift from an early pre-occupation with efficiency considerations towards a more holistic conception which nevertheless holds these attributes within a formal, and apparently 'objective', decision-making calculation.

The inclusion of a social dimension in the CBA framework is enabled by monetising social impacts so that SCBA may be defined as:

1. measuring the gains and losses to individuals, using money as the measuring rod of those gains and losses.
2. Aggregating the money valuations of the gains and losses of individuals and expressing them as net social gains or losses (Pearce, quoted in van Zyl 1997: 37).

In principle this development has enabled the flexible adaptation of the basic CBA approach to include consideration of social, distributional and environmental elements in the decision-making framework. However, the attempt to include these aspects has exposed the CBA framework to severe criticism. Since ultimately these factors must be expressed in terms of the common numeraire (i.e., all the costs and benefits must be 'monetised') to enable comparison, the methodological and ethical complexities tend to undermine the efficacy - and indeed legitimacy - of the approach. To monetise the essentially non-market considerations of social and environmental 'costs and benefits', artificial market pricing must be achieved by replacing market prices with shadow prices (or social or accounting prices) to determine non-use values through contingent valuation methods.

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[10] The discussion on MCDA/M which follows, draws extensively from van Zyl,1997.

The valuation of un-priced costs and benefits is usually achieved using the following valuation techniques:

Valuation using:	Methods:
1. Conventional markets	• Change in production approach • Replacement cost approach • Preventative expenditure approach • Human capital approach
2. Implicit markets	• Travel cost approach • Property value approach[11] • Conjoint analysis
3. Artificial markets	• Contingent valuation method

All are more or less contentious although the determination of use-values is less so than the determination of non-use value - the latter, especially through contingent valuation methods. Such valuation methods are contentious 'ethically' (especially with regard to monetisation of the value of the environment) and methodologically. No specific procedure has emerged for determining appropriate weights for establishing distributional impacts, and attaching weights to the welfare of different groups presents theoretical problems as well as being a politically charged issue. Theoretically it is difficult to 'objectively' decide on appropriate weights and to identify the distribution of costs and benefits among income groups (van Zyl 1997: 49).

Given these difficulties it is perhaps not surprising that much of the history and practice of SCBA has tended to prioritise considerations of economic efficiency - especially over distributional and environmental considerations. This is reinforced by a further central characteristic of the CBA framework, namely that the comparison of alternatives must not only be based on a common numeraire but the performance of the various attributes must also be evaluated against a single objective. Implicit in the incorporation of social and other non-market criteria however was the recognition that, in fact, decisions were required to satisfy a range of criteria.

Shifts in the nature of decision-making have been driven not only by the need to incorporate social and environmental aspects but also by a broader imperative to transform the nature of decision-making itself towards a more participatory and transparent process. Here too CBA has been found wanting. A corollary of its rigour and comprehensiveness (a strength of SCBA) is that the intricate and time consuming analysis required in SCBA requires a specialist understanding of the method - this makes it a relatively inaccessible method:

> "Although SCBA uses inputs from other disciplines, the actual analysis is in the hands of an individual. It is thus not a participatory process increasing the risk

[11] 'Hedonic' pricing

of individual bias. Politically, SCBA may encounter opposition if the public feel that the ability to influence important public investment decisions is in the hands of one analyst. This may run counter to the public's need to be involved in a transparent and democratic process" (van Zyl 1997: 67).

Meier & Munasinghe (1994: 75) summarise their experience with SCBA in these types of situations as follows:

> "In short, whatever the theoretical promise of being able to internalise all of the significant externalities into a single benefit-cost criterion, in practice there are well defined limits to what can be done. It is this limitation that points to the use of multi-attribute decision analysis methods."

Mirrilees et al. (1994, p. C.1-9) reinforce this assertion concluding that:

> "CBA is a good and valuable technique with which to determine, from a set of feasible decisions, the one that is most economically efficient. But it is not a sound basis on which to decide which decision is optimal from the viewpoint of non-economic criteria."

The extent to which the application of CBA techniques is increasingly contentious is reflected in the motivation for an international conference focussing on 'the politics of cost-benefit analysis', where the conference convenors point out that:

> "... cost-benefit analysis faces growing resistance at a variety of levels. Grassroots opponents of roads and hydroelectric dams around the world have persistently contested the ways the technique values land, forests, streams, fisheries and livelihoods, as well as its reliance on unaccountable experts and neglect of equity issues; ordinary people surveyed by cost-benefit analysts have commonly refused to answer questions about how much money they would pay to save a wilderness or how much they would accept to allow it to be destroyed; Third World delegations to the Intergovernmental Panel on Climate Change have angrily rejected a cost-benefit analysis of policy options regarding global warming which valued statistical lives in industrialized and non-industrialized countries differently. In the US, the role of CBA has become, in the words of one prominent legal scholar, 'one of the most hotly disputed issues in law and policy' following the Reagan administration's executive orders calling for the application of CBA to all regulatory decisions and legislative proposals. Eminent economists, philosophers, lawyers, anthropologists, sociologists, biologists and political scientists have meanwhile argued that in many cases the technique does not clarify but rather obscures rational deliberative processes involving plural values, faces intractable difficulties regarding predictability, discount rates, and opportunity costs, and is based on a deeply controversial political theory. As

one scholar has concluded, 'far from resolving controversy, cost-benefit analysis generates it.'

> "... While many CBA proponents suggest that the answer lies in a combination of further technical refinements of CBA, greater care in its application, and education of the public about its merits, such measures have proved repeatedly ineffective in overcoming resistance to the technique in more than 50 years of attempts. Indeed, the diagnosis that the CBA deadlock is rooted in nothing more than popular misunderstandings of the technique, incorrect application, or technical 'bugs', has itself further reinforced opposition to CBA."

The question arises then as to whether decision-making can still be 'held' or framed in a relatively formal and objective model where:

- value is not artificially reduced to a common numeraire (money);
- one criterion (economic efficiency) does not effectively trump other concerns (e.g., distributional issues, and social and environmental impacts); and
- a wider range of stakeholders (indeed 'the public') play a meaningful role.

Multiple Criteria Decision Analysis (MCDA) or Multiple Criteria Decision Making (MCDM) techniques have been developed for this purpose.

> They "emerged approximately thirty years ago in the operations research field as a response to increased awareness of the need to consider several objectives at the same time (Goicoechea et al., 1982). MCDA can thus be viewed as a part of the transformation from single objective methods such as cost-benefit analysis to multiobjective analysis. 'The key philosophical departure point defining MCDM as a formal approach to types of problem solving (or mess reduction), lies in attempting to represent such imprecise goals in terms of a number of individual (relatively precise, but generally conflicting) criteria' (Stewart, 1992, p. 569). This was in contrast with optimising approaches that attempted to find solutions in terms of a single criterion" (van Zyl 1997: 68).

In the MCDA approach then, the focus is on finding satisfactory alternatives that are acceptable across a number of objectives as opposed to optimal solutions that dealt with single objective functions.[12]

[12] Van Zyl illustrates the application of MCDA specifically with references to water resource planning exercises where flood control is one criteria in the overall decision-making matrix, rather than the only or principal consideration. This is consistent with the overall approach developed in this chapter where it is argued that the selection of flood control measures should be understood in a broader developmental context.

Methodology

A range of MCDA methods have developed, each with particular strengths and weaknesses. An attractive option from amongst these is Multi-Attribute Value or Utility Theory (MAVT or MAUT). This is robust and flexible and, rendered through SMART (Simple Multi-Attribute Rating Technique), is relatively simple and transparent.[13] Simple Multi-attribute Rating Technique (SMART) originally developed by Edwards (1971) consists of eight stages articulated by Goodwin & Wright (1992) as follows:

Stage 1: Identify the decision maker, or decision makers. In a group decision making context involving multiple stakeholders, the decision maker could be the group itself.

Stage 2: Identify the alternative courses of action or options.

Stage 3: Identify the attributes (also referred to as criteria) which will be used to measure performance in relation to the objectives of the project.
Once this is done each alternative (*a*) can be described by a vector of attributes:

$z^a = (z^a_1, z^a_2, \ldots , z^a_p)$

where *p* is the number of attributes and z^a_i is the attribute representing the outcome of decision alternative *a* as it effects attribute *i* (Stewart, 1992). The identification process should be done in consultation with the relevant stakeholders.

Stage 4: For each attribute, assign values to measure the performance of the alternative on that attribute.

This is done using an interval scale of say 0 to 100. The worst alternative (*a*) measured against attribute *i* is given a score of 0 ($V^a_i(z_i) = 0$)and the best alternative (*b*) based on attribute *i* is given a score of 100 ($V^b_i(z_i) = 100$). The scores of the other alternatives are ranged in-between so that the gaps indicate the strength of preference for that alternative, based on that attribute. In this way the alternatives are not simply ranked and an approximate value function $V_i(z_i)$ can be derived for each attribute (Joubert et al., 1997).

[13] Van Zyl briefly discusses other MAVT techniques including analytic hierarchy process; goal programming and reference point approaches; outranking approaches; game theory; and fuzzy set theory. However, he concludes later: "Numerous authors have convincingly argued that simpler MCDA methods such as the simple multi-attribute rating technique (SMART) are to be preferred to complex ones in water resource planning. Snell (1994) points out that one could argue in favour of one of the more obtuse decision aids such as outranking or compromise programming, but gains in theoretical rigour would not outweigh losses in transparency and ease of understanding. ... Henig & Buchanan (1996, p. 11) conclude that, "...solution methods should not operate like a 'black box' with incomprehensible workings." (in van Zyl 1997).

It is also possible to derive utility functions in place of value functions following the work of von Neumann & Morgenstern (1947) and later Keeney and Raiffa (1976). According to Stewart (1992), however, these are rather tedious and often mystifying to the decision maker. In addition, they do not ensure improved results over value functions.

Stage 5: Determine a weight for each attribute.

This can be done using swing weights which are derived by asking the decision maker to compare the change (swing) from the least-preferred to the most-preferred value on one attribute to a similar change in another attribute (Goodwin & Wright, 1991). The decision maker is given a hypothetical alternative and asked which attribute he or she would prefer to raise to its best level while all the others stayed at their worst levels. The chosen attribute is then given a weight of 100. The second most influential attribute is then weighted according to its impact compared to that of the first and so on for each attribute relative to the others. By using this method, the weighting of each attribute is made directly comparable.

Weighting techniques differ for each MCDA method and have generated substantial debate on their merits. See Roy & Mousseau (1996) for a comparison of the different techniques.

Stage 6: For each alternative, take a weighted average of the values assigned to that alternative.

This involves combining stages 4 and 5 in order to determine comparable scores for each alternative that can be used to determine preferences.

The interpretation of the scores should be in terms of the value profiles. This will give a more holistic impression of the performance of alternatives as it will highlight cases where alternatives might score highly overall, but zero for one attribute (Joubert et al., 1997). In cases such as these, an alternative with a slightly lower overall score might be preferred to one which scores zero on an attribute.

Stage 7: Make a provisional decision.

Based on the scores obtained in stage 6, it should be possible to make a provisional decision on the most preferred alternative(s).

Stage 8: Perform sensitivity analysis.

Before a final decision can be made, a sensitivity analysis should be performed to highlight how the analysis is affected by changing scores (stage 4) and weights (stage 5).

In group decision making situations with conflicting objectives, Joubert et al. (1997) suggest that each stakeholder group should complete the above stages and then be brought together to look for compromise solutions. It is hoped that going through the stages may make stakeholders more willing to explore compromises.

The determination of a single set of attributes and sub-attributes to measure the performance of alternatives in relation to objectives is advisable as it allows for direct comparisons between the views of different stakeholder groups. In order to determine a suitable set of attributes and sub-attributes there are a number of theoretical considerations that should govern their choice:

1. Attributes need to be clearly defined and the reasons for their choice carefully considered. It is pointless to choose attributes that will not affect the decision at hand because they are not relevant or important enough.
2. Double counting should be avoided, i.e. attributes should not capture the same impacts or considerations.
3. Attributes should be conceptually distinct to ensure that they are preference independent[14] (Meier & Munasinghe, 1994).
4. The use of too many attributes tends to complicate analysis and draws attention away from what is really important. A proliferation of attributes can make weighting more difficult (and may introduce a bias simply because one is reluctant to weight any particular attribute as near zero) as well as introduce too many trade-offs making their comprehension more difficult for decision makers (Meier & Munasinghe, 1994). Meier & Munasinghe (1994) recommend assigning one attribute to each of the most important impact issues.
5. Attributes that can be measured or predicted within time and budget constraints are preferable.
6. The splitting of attributes into sub-attributes needs to be handled carefully as research has suggested that when attributes are divided into many sub-attributes they tend to be over-weighted in relation to other attributes (Weber et al., 1988).

Keeping a balance between simplicity and completeness of detail throughout the process of selecting attributes is recommended (Marttunen & Hämäläinen, 1995). (van Zyl 1997: 116)

In assigning value to measure performance of an option against each attribute [stage 4] it is important to ensure that all the stakeholders involved have access to all the information relevant to decision making. It must be possible for the stakeholders to

[14]A set of attributes is preference independent of its complement (i.e. the other attributes) if the trade-offs a decision maker is willing to make among the set do not depend upon the levels of its complement (Meier & Munasinghe, 1994).

assign values to all the attributes based on reliable information. EIAs, feasibility studies and other studies should provide the bulk of this information. (van Zyl 1997: 118).

Strengths of MCDA

Multi-criteria decision-making and planning can facilitate the identification, ranking, screening and selection of feasible options that meet technical, economic, social and environmental objectives with maximised acceptance in a transparent and participatory manner (WCD 1998 d: 1). MCDA allows a complex decision to be broken down into manageable components. One of its main advantages is that it defines separate objectives stemming from overall goals against which options can be evaluated. In this way complex decision problems can be treated as a series of separate smaller, more manageable, decision problems.

The process can be opened up to allow for meaningful stakeholder participation in decision making as opposed to domination of the process by one decision maker or analyst. It thus has the potential to be a democratic and transparent methodology. (Stewart et al, 1993 and 1997).

This representativeness also serves to lessen the income distributional problems inherent in SCBA. Joubert et al (1997) point out that the Hicks/Kaldor approach [a dominant SCBA approach] is biased in favour of the already affluent as they are more willing and able to compensate those that have experienced a decrease in utility. In addition, the bias can have particularly serious consequences when an environment is preserved purely because the rich use it as a recreational 'playground' while the needs of the poor to subsist from it are not given adequate consideration.

> "The potential pro-rich bias inherent in the Hicks/Kaldor compensation approach is avoided, as all stakeholders (rich and poor) are represented, the criteria chosen are those which reflect their values (in a non-monetary sense) and preferences are not governed by ability to pay" (Joubert et al., 1997, p. 127).

MCDA does not involve the use of monetary valuation techniques for intangibles. This allows the technique to avoid the associated ethical and practical problems discussed elsewhere. At the same time the technique does not exclude the incorporation of results derived through the use of monetary valuation techniques. If credible valuations (which tend to be concerned with use values as they are easier to determine) are available, they can be used in a MCDA. In the controversial and difficult determination of non-use values such as existence and option value the avoidance of monetary valuation techniques is a definite advantage. As Joubert et al. (1997) point out, existence value can be operationalised in MCDA through the direct use of criteria such as uniqueness of environment or level of biodiversity.

The environment

MCDA is generally better suited to dealing with environmental considerations than SCBA. Indeed, MCDA emerged partly in response to the need for adequate consideration of difficult or controversially quantifiable aspects such as the environment in decision making. The weaknesses of SCBA in dealing with the environment include inadequacies in terms of environmental valuation and income distributional considerations whereas MCDA avoids environmental valuation and incorporates income distributional concerns.

Social impacts

Social impacts associated with certain water supply options such as displacement of local inhabitants from dam sites, impacts of imported workers and in-migration into areas by job seekers need to be considered in decision making. Issues of this nature have been difficult to deal with within the SCBA framework. For example, in the case of displacement, Meier & Munasinghe (1994) cite a case in Sri Lanka, where the compensation offered to local inhabitants (derived through valuation) for moving away from a proposed dam site did not do much to dampen their opposition to the dam. The sums offered as compensation thus did not capture the full willingness to accept compensation of the locals who would have had to undergo major disruption and stood to lose ancestral lands.

SCBA can also be considered inadequate in evaluating and comparing the intangible societal benefits projects may have, such as skills enhancement and technological knowledge transfer. These are a form of positive externality which should be considered a benefit, however, there are no techniques for their adequate valuation in SCBA, causing them to be merely mentioned or ignored. MCDA, on the other hand, can incorporate these considerations directly through the use of the appropriate criteria. This would allow for comparisons between options in terms of intangible societal benefits.

Democratic process

Any decision making framework should be compatible with consultative, democratic decision making. It would also be ideal if it was transparent, and thus rendered decision makers accountable for their actions. One of the main strengths of MCDA is that it can use a participatory approach which allows direct public input in decision making. SCBA, on the other hand, places the power to influence decisions in the hands of the expert/s conducting the SCBA. It is also not particularly transparent as society's values are assumed to be reflected in the monetary estimates derived in valuations that form part of SCBA. Members of society are not directly asked to openly articulate their values. This makes it difficult to see the trade-offs that are involved in decision making.

The fact that MCDA promotes compromise and eventual consensus among stakeholders as part of the MCDA process is a further advantage of the method. In situations where decisions are made without this taking place it is often necessary to embark on a time consuming and expensive campaign aimed at justifying decisions to stakeholders and the general public after they have been made. This can happen when SCBA decisions have to be 'defended'. Also in the case of environmental impact assessments, stakeholder inputs have the potential to be ignored in making a decision, necessitating post decision justification and attempts at building consensus around what has already been decided.

MCDA type analysis is not cheap, but because it avoids the intricacies of SCBA, it tends to be less costly if there are significant environmental and social impacts which would otherwise have to be quantified.

Weaknesses and criticisms

> "To date multi-criteria planning - especially for the efficient, comprehensive, transparent, and participatory assessment and selection of options for the sustainable development and management of water and energy resources - remains under-executed and weakly institutionalized in most parts of the world" (World Commission on Dams, 1999 d.: 1).

MCDA has been criticised on the grounds that it is a way of justifying projects that do not make sense financially through the injudicious use of broader, imprecise criteria. MCDAs that use generalised judgements instead of more precise measures have been criticised for their lack of rigour as they have not included the precise measurement of aspects such as expected probability and attitude towards risk. This criticism is essentially methodological and thus falls away when the desired level of importance for each criterion is determined in a properly carried out, rigorous analysis.

"Some efforts in multi-objective evaluation have suffered from inadequate care in specifying objectives, identifying trivial physical impacts as their objectives rather than employing measures representing legitimate public goals" (Young & Haveman, 1985, p. 493). MCDA thus has the disadvantage of being potentially open to manipulation particularly for political reasons (Thomas, 1979). This disadvantage will not however necessarily manifest itself unless the MCDA analysis is sub-standard.

The large number of MCDA methodologies available can be seen as a reflection of uncertainty in the field as to which MCDA methods are best. This is illustrated in the literature by the many articles comparing and contrasting different MCDA methods. On the other hand, the various MCDA methods allow for greater choice of methods 'tailor made' for specific problems. Hämäläinen (1992) advocates methodological flexibility and points out that decision analysts can miss opportunities for application by being too restrictive in their own choice of decision analysis methods.

The fact that MCDA methods often rely solely on value judgements can be seen as a potential disadvantage if this leads to the scrapping of important empirical research. 'Hard' facts are replaced by 'softer' opinions which are thought to have a greater chance of being incorrect. Once again this problem will not necessarily surface in a good MCDA, but should be guarded against.

It can be particularly difficult to get accurate data on environmental and social effects. Often studies on such effects need to take place over a long time span when adaptations to environmental effects are gradual in nature. (van Zyl 1997: 124)

Mirrilees et al. (1994, p. C.1-9) go on to argue that: "... for a comprehensive analysis of a decision CBA should be treated as one input into these MCDM methods."

3.4 A NOTE ON IMMEDIATE POST-DISASTER IMPACT ASSESSMENT

The broader project on flood control initiated by the flood damage research team at UFS is not directly concerned with servicing and mapping immediate post-disaster impact assessment. The various data captured and generated by competent post-disaster impact assessment are of course a vital input to the subsequent mapping and analysis of damage, hazard and risk discussed above. To that extent, engagement with those responsible for immediate relief provision and damage assessment would be beneficial if synchronisation of the information needs of the computer-based mapping systems and information gathering protocols in the immediate aftermath of floods could be achieved.

Nonetheless, some comment based on the case study seems appropriate. Even where disaster management is firmly proactive and steps have been taken to reduce risk, there is no guarantee that disasters will not occur. Indeed this is an important learning from the case study: key features of the particular location and impacts of the Pietermaritzburg floods would have been almost impossible to predict on the basis of historical patterns of flooding in the region. It has already been noted that global climate change and the resultant increase in incidence and intensity of extreme events has added further uncertainty into risk and disaster management (especially in relation to flooding).

When disasters do happen, their impact/s on people and communities must be established - in the first instance to at least facilitate relief and recovery actions. In the case of rapid onset disasters, these actions must be undertaken as soon as possible and the data to support decisions-making in this regard must be gathered very quickly indeed. Floods in particular are typically 'sudden onset' disasters. Immediate response decisions are required urgently to save and sustain lives of survivors, support local rescue efforts and restore lifeline services during the first days of the disaster. Some activities may be so urgent that they must be operationalised without detailed assessments. Even so, assessment is fundamental to disaster response and should aim to determine the impact of the disaster. That this impact has a social dimension is clear.

In the process of assessing social implications of disasters themselves or of possible mitigatory interventions, information gathering could be conducted concerning possible impacts on, inter alia: demographic patterns and indicators; economic activity; public health and safety; the environment; private goods and assets; public goods and assets; and social intercourse. For example:

Demographic patterns and indicators

- Has the event had a statistically significant impact on absolute numbers of people in particular areas - particularly from deaths and displacement?
- Has the age and family structure of a population been affected?
- Has the event resulted in population movement/s - are these temporary displacements or more likely permanent resettlement?
- If so, where have people moved to - what social impacts have resulted in host populations/areas?
- What pre-existing sociological vulnerability levels existed before in the affected population (e.g., Human Development Index scores; income levels; levels of private insurance; baseline primary health indicators; dependency ratios; age structure)?

Economic activity

- What economic activity occurs in the affected area?;
- What economic activity is/was dependent on the presence of a population that has been dislocated/disrupted by the event?;
- What economic impacts are occurring (or might be anticipated) elsewhere as a result of local impacts/disruption?

Public health and safety

Include psychological well-being assessment

Environment

Private goods and assets

Land and property aspects - e.g., do people own land and houses affected by the event?
Average value and levels of investment;
Extent of loss and damage;
Relative significance of loss and damage

Public goods and assets

- Extent and characterisation of infrastructure damage/loss?;
- Social responses to, and impacts of, such loss and damage?;
- What alternatives are people accessing - are they paying for these (more or less than normal)?;
- What standard and quality are they accessing?

Social intercourse

- What were the dominant/critical characteristics of civil society in the affected area? [baseline];
- Have social networks been disrupted?;
- Are certain networks intact and of assistance?

At one level it seems unlikely that disaster management in itself can aim to 'repair' sociological damage to a large extent since the social fabric is woven from so many diverse strands - and is constantly being woven. A consideration of the Pietermaritzburg flood case study suggests however that the practice of disaster response could demonstrate sensitivity to the social impacts of disasters by, for example:

- avoiding the prolongation of the 'transitional welfare' phase which runs real danger of destroying initiative and a sense of self-worth
- seek out ways for those who are capable and willing to actively engage in, and exercise control over, relief, remediation and development activities - but without assuming that these capacities are there in equal measure throughout the communities affected by a disaster
- whatever the social impacts of the disaster event itself (and the case study has demonstrated how multi-faceted and catastrophic these can be), avoid responses to the disaster which themselves are likely to compound or add new negative social consequences - e.g., replacing family homes with one-bedroomed houses
- integrate trauma counseling for individuals and groups into the overall disaster response process.

Disaster management should also demonstrate sensitivity to developmental impacts of disasters and explore developmental possibilities in the responses to them. As Handmer has noted: " A crucial point about vulnerability is that it is not distributed uniformly - and there are generally large variations between people even within small communities" (Handmer 1997: 3). In this regard, there is a need to more fully understand the compound vulnerabilities of the poor. Damage assessment has too often relied on quantification in terms of monetary valuations of damage. This approach produces gross distortions - damage sustained in affluent or highly developed areas calculated in this manner is inevitably both higher (because of the monetary value of housing, infrastructure, possessions and general levels and intensity of investment) and more measurable (especially because large components are quantified for insurance claims). Neither of these (higher or more readily measurable values) give any indication of the extent to which a disaster has been disastrous. The quantifiable money-value of damage in a poor informal settlement for example will be less but its impact more likely to be catastrophic at a number of levels (including economic) from a human development perspective[15]. For example, one could

- investigate and assess, not just loss of property but impacts on income
- assess to what extent livelihoods were dependent on what was destroyed or damaged by the disaster - many 'informal sector' and other economic activities engaged by the poor are dependent on servicing various needs within the immediate community.

One could explore the possibility of using some form of 'relative impact index' in relation at least to the disbursement of public monies in compensation for victims. Instead of simply assessing the value and extent of losses experienced, one could divide that loss value by either income (which would be relatively easy for victims to know) or by total value of household goods (which would be relatively accessible for independent verification by on-site investigation). Such indices could certainly help to reverse the tendencies discussed above though it is acknowledged that complexities and a slightly raised potential for fraud arise with two values to validate with respect to any claim.

Certain trends in the management of disasters and risk globally may even exacerbate the vulnerability of the poor. With regard to the financing of mitigation and other measures, there is a growing tendency to protect higher value areas (e.g., urban areas, industry and key infrastructure) since here there is the possibility of cost recovery from the beneficiaries of measures taken. "Rural areas and poorer urban areas are unlikely to have the same degree of protection or access to alternatives" (World Commission on Dams 1997 b., 2).

3.5 CONCLUSIONS

This chapter was drafted to address certain specific objectives which assist in articulating the findings of the case study with a need to incorporate social and developmental concerns into the broader UFS-initiated study into aids for flood damage assessment and control.

In the original brief for the Pietermaritzburg flood case study, it was specified that the "findings of the CASE research would be specifically oriented to ensure that the process would contribute toward, and assess the feasibility of, the following specific objectives":

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[15] Note further that this approach tends to externalise not only the hidden costs for the world of the poor but the environmental costs too.

- determine social acceptability of different flood damage control measures for different communities/target groups in order to design acceptable combinations of measures and to develop education/extension programmes to promote acceptability, change perceptions (if necessary) and build awareness of the flood problem[16]
- develop a questionnaire (or questions for inclusion in the economic questionnaire) to measure the sociological and social consequences/impacts of flooding
- develop a procedure or guidelines for technology transfer of the aids developed for flood damage assessment and flood damage control planning in irrigation and urban areas
- develop guidelines/sociological criteria to ensure optimum and sustainable institutional arrangements, responsibilities and synchronisation of effort in respect of flood and disaster management and response
- develop guidelines to improve flood communication with regard to inter alia formulating of flood warning messages and identifying the most effective communication channels with the community
- develop a methodology to promote local community involvement in policy formulation and allocation of responsibilities with regard to flood management planning.

In this chapter, key learnings from the case study have been interrogated for their significance in terms of a systematic understanding of processes of disaster management. In general, whereas the relevant physical, financial and technical considerations are more or less reducible to evaluation against a single criteria in a formal and mechanistic framework (CBA), the incorporation of a social dimension necessitates flexibility and the meaningful integration of conventionally 'non-expert' inputs into decision-making processes. Because the 'social' is contextually-specific and adaptive, and because sustainable development practice requires the participation of those who will be affected by decisions, it is not possible to determine *a priori* a 'checklist' of generically -valid procedures whose application will yield socially and developmentally appropriate disaster management. The chapter has indicated the range of tools and approaches that might be drawn upon to achieve greater integration of social-developmental aspects into disaster management practice and decision-making. However, the actual selection of tools and overall process design and implementation must emerge from a particular set of needs and capacities on a case-by-case basis.

Determine social acceptability of different flood damage control measures for different communities/target groups in order to design acceptable combinations of measures and to develop education/extension programmes to promote

[16] The researchers have made the assumption that what is NOT implied in this question is an assumption that certain 'types' of communities or target groups inherently tend to prefer or find more acceptable certain packages of flood control measures.

acceptability, change perceptions (if necessary) and build awareness of the flood problem[17]

The research indicates that determination of acceptability is

a. contextually specific and usually complex
b. an important component of decision-making, but not the only one.

Therefore it is not advisable nor really feasible to anticipate that acceptability can be determined beforehand in an generalisable manner. This chapter has suggested instead how the contextually specific data, and the knowledge and priorities of affected communities might be incorporated into the decision-making process. It follows logically that the development of "education/extension programmes to promote acceptability, change perceptions (if necessary) and build awareness of the flood problem " must follow on the basis of a good understanding of the specific local histories, conditions and priorities.

Develop a questionnaire (or questions for inclusion in the economic questionnaire) to measure the sociological and social consequences/impacts of flooding

Issues relating to gathering information on social aspects are discussed in particular in the section on "Information" and in "A note on post-disaster impact assessment". It is noted that the integration of socially relevant data into the decision-making processes and the establishment of indicators for assessing and monitoring social impacts (both of disasters themselves and of risk reduction or disaster prevention measures) is critical. Key points where such data appear critical include: baseline socio-demographic data; selection of measures (for risk reduction, mitigation or prevention); and immediate post-disaster impact assessment. With respect to baseline data, it is argued that the collection and interpretation of a range of socio-demographic and socio-economic data are necessary in order, not only to plan for development processes but to be able to measure subsequent disaster impacts meaningfully. Suggestions are made as to how disaster-specific questions might be formulated for inclusion into social surveys. Given the overall argument of the chapter that flood mitigation must be located in a broader developmental framework, key supplementary social data relevant to the process of selecting of flood control measures meaningfully involved in the decision-making process and their input is vital alongside other considerations. The chapter also points out that the field of social impact assessments provides useful tools for ensuring the inclusion of social aspects relating to the future impacts of flood mitigation interventions and options. With regard to SIA methods specifically, it is critical to bear in mind that their application is not a mechanical process driven by a standardised

[17] The researchers have made the assumption that what is NOT implied in this question is an assumption that certain 'types' of communities or target groups inherently tend to prefer or find more acceptable certain packages of flood control measures.

checklist of tasks; lifestyle or quality of life changes; social problems (crime, illness etc.); community stress and conflict. Some of the main methods associated with SIA would include: demographic analysis: investigating community perceptions of impacts; systems approaches and social indicators.

Develop a procedure or guidelines for technology transfer of the aids developed for flood damage assessment and flood damage control palling in irrigation and urban areas

This is discussed in the section on "Technology transfer" in Chapter 4. It is pointed out that options for the appropriate location of the technology range along a continuum from total transfer to the local level to centralised control. The various strengths and weaknesses along that continuum are explored and it is argued that an optimum approach might best be characterised by flexibility, recognising that capacities are spread very unevenly - especially at the local level. Should certain aspects of the White Paper on Disaster Management, as well as other related institutional and financial proposals currently under development, materialise, these developments could make it possible to transfer both the technologies and skills which are required to implement the modeling systems to a sufficiently decentralised level (at least provincial and, where possible, local) to avoid dependence on a single national centre.

Develop guidelines/sociological criteria to ensure optimum and sustainable institutional arrangements, responsibilities and synchronisation of effort in respect of flood and disaster management and response

This is addressed in "Allocation and integration of responsibilities" in Chapter 4 of the report.

Develop guidelines to improve flood warning messages and identifying the most effective communication channels with the community and develop a methodology to promote local community involvement in policy formulation and allocation of responsibilities with regard to flood management planning

Implicit throughout the chapter is an emphasis, congruent with the thrust of the White Paper on Disaster Management, on participatory methods, drawing and building on existing local resources in civil society, and building participation into development governance at the local level.

CHAPTER 4

POLICY AND EMPOWERMENT ISSUES

4.1 INTRODUCTION

The relevance of the flood damage management aids developed during this research is emphasised by the Bill on Disaster Management that will be submitted to Parliament in the year 2000. This Bill is the culmination of developments that already started in the 1980's and which stressed the importance of integrated disaster management as part of development planning and programming. Westgate, 1999 puts it as follows:

"Since the mid-1980s, a common conceptual approach to disaster management has sought to place it in a development context. This approach, while agreeing with the importance of responding to disasters when they occur, seeks to ensure that response is well organised and practised beforehand through the development and implementation of a strategy of preparedness. Furthermore, the approach seeks, first and foremost, to emphasise the importance of risk reduction through the implementation of a set of measures aimed at mitigating or preventing the negative effects of disasters. The ultimate goal of this approach would be to integrate disaster management into the process of development planning and programming ."

The following are some requirements to implement the concepts into realistic action.

4.2 INTEGRATING DISASTER MANAGEMENT INTO DEVELOPMENT PLANNING

The integration of disaster management into development planning and programming can only be effective and realistic if governments and disaster managers are committed to see it through. The following needs to be considered in this regard:

- There must be a political will and commitment to implement the programme. The higher the level of the political authority the better the potential for success.
- If governments are serious about the implementation of such programmes then resources have to be available to ensure effective implementation.
- Disaster management is of a multi-sectoral nature. Thus, the ability to co-ordinate effectively is a major requirement as is the clarity with which the responsibilities and tasks of the sectors are laid down. This is practical integration – an acceptance by the sectors that disaster management is an integrated part of their programmes, to be implemented by them by staff whose job descriptions also carry the disaster management commitment.
- Implementing of such programmes must be cost effective. This involves looking for ways in which disaster management can be implemented without the programme becoming a huge extra cost to government. Existing resources and programmes must be used, rather to create new ones.
- Effective developmental disaster management programmes will only be effective if true ownership of the programme is accepted. True ownership must rest with those who are targeted under the programme. These are the

vulnerable and, by implication, the poor – the people who do not have options or choices (Westgate, 1999). To assure this, there must be first the political will to ensure success in disaster management.

- Disaster management must be sustainable. This means keeping the issues alive. Westgate (1999) indicates two useful approaches to keep the issues in the public mind, namely training and public awareness. Training cannot only take place when money is available or once every five years. Therefore, the training process must be integrated and ensure that people are being trained on a regular basis so that people can know what their responsibilities are in the implementation of disaster management programmes. In the same way public awareness can contribute to sustainability. "Ongoing public awareness, with the momentum shifting to community representatives, can lay the foundations of this ownership". Public awareness must be a two way process which establishes dialogue, rather to focus too much on officials passing on to communities what they feel communities should know (Westgate, 1999).

Finally, mitigation actions and development are not synonymous and therefore not too much emphasis must be placed on mitigation. Mitigation actions aim to reduce the impact from future disasters, while development aims to build community capacity and to promote self-reliance in relation to social and economic parameters. According to Westgate (1999) the precursor to any effective risk and vulnerability reduction is not purely the implementation of a comprehensive disaster management programme; it is the implementation of a sound development programme.

4.3 INSTITUTIONAL FRAMEWORK FOR FLOOD DAMAGE DETERMINATION AND CONTROL

The new White Paper on Disaster Management (1999) indicated preparation strategies, policies and plans for disaster management in South Africa. These are key functions of the Disaster Management Centre. In this regard the White Paper is clear that the Centre must initiate the integration of risk reduction strategies into the setting of land development objectives in terms of the Development Facilitation Act (Act 67 of 1995), and Integrated Development Plans (IDP's) drawn up in terms of the Local Government Transition Act (Act 97 of 1996). This must be done in consultation with the relevant role players.

The integrated development planning process, using Free State Province as an example, is outlined in Figure 4.1 and starts at the work plan for a province according to provincial regulations. After the formulation of land development objectives and integrated development plans, all plans are implemented, monitored and reviewed (Figure 4.1).

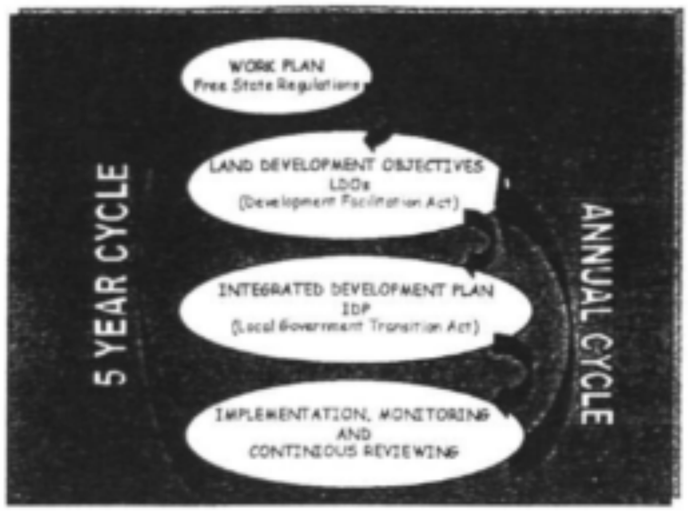

Figure 4.1 Integrated Development Planning Process

Disaster management is a critical component of sustainable development. This goal can be achieved by using the IDP process where land development objectives will be identified and formulated. Figure 4.2 outlines critical steps of preparation of land development objectives.

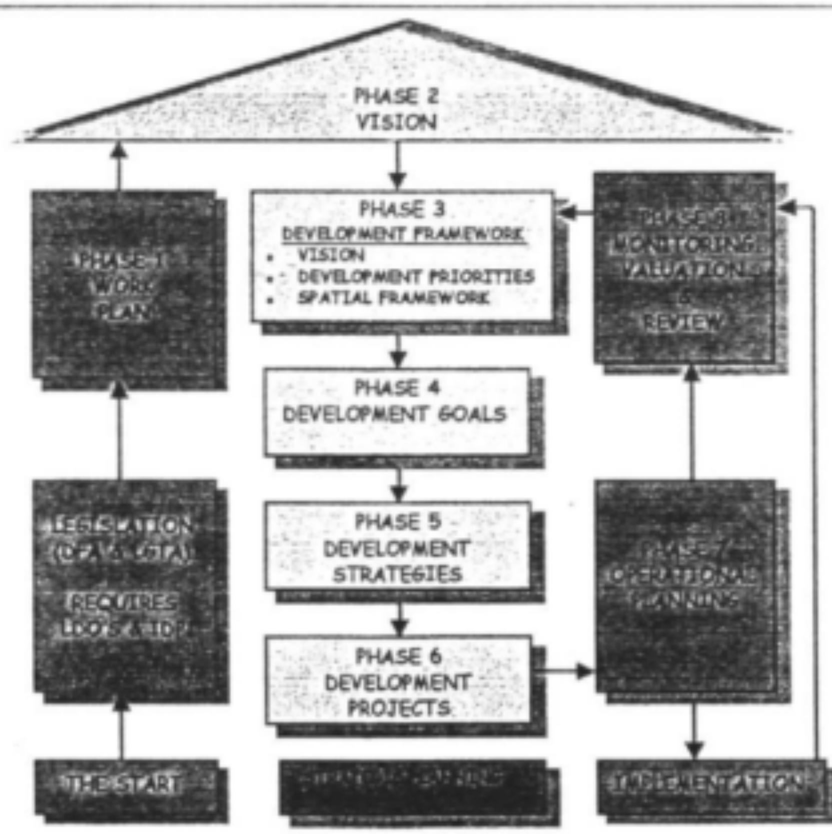

Figure 4.2 Preparation of land development objectives: Critical steps

Figure 4.2 fits into the normal strategic planning process, from the formulation of a vision, goals, strategies, plans to the implementation phase.

It became evident that a certain deficiency existed with regard to disaster management in South Africa. The latter exists since the current White Paper on Disaster Management indicates (par 3.4.2) that Disaster Management Plans (DMPs) should be prepared within the IDP process. The DMPs should thus, similar to other plans (Water Services Plan, etc.) be prepared as part of the IDP process (Figure 4.3). The latter will not only ensure that planning is done in a holistic and integrated manner but will also warrant comprehensive public participation. Public participation is a specific requirement of the IDP process.

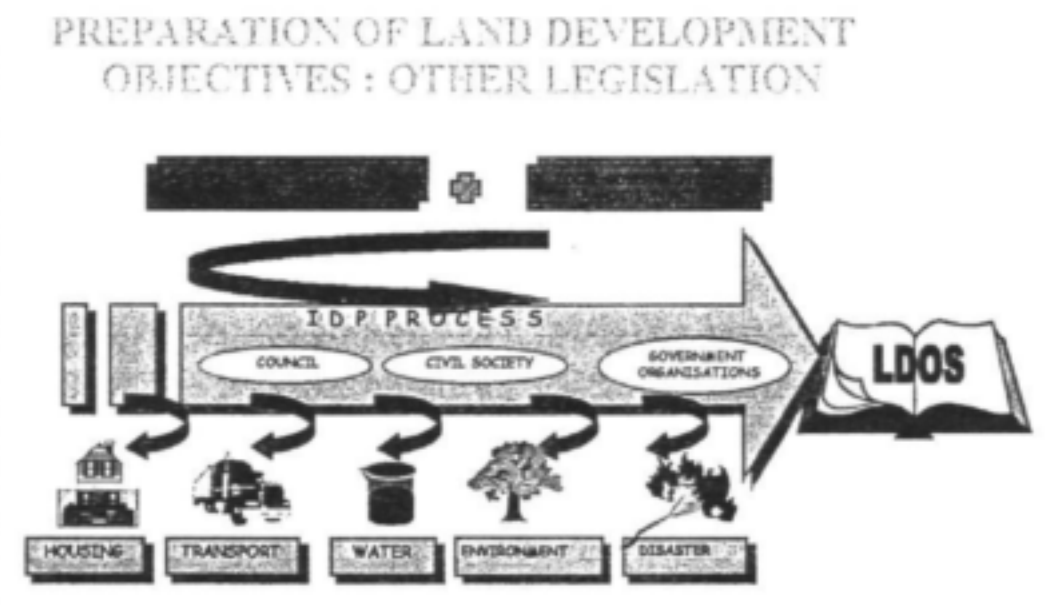

Figure 4.3 Preparation of land development objectives: Other legislation

This process as outlined in Figure 4.3 will ensure and promote a cost effective, pro-active disaster management system for South Africa and will also eliminate duplication and ineffective structures. The completion of land development objectives and operational planning is outlined in Figure 4.4. This will ensure that disaster is identified within provinces, that disaster management plans are formulated, implemented and continuously evaluated, reviewed and adjusted over time. The latter will ensure execution of the continuous disaster management process mentioned in the White Paper.

In preparation for the technology transfer phase of these procedures, methods and computer models, it became clear that disaster management differs in each region or province. This has been confirmed by the National Disaster Management Association of Southern Africa: the Chairman of the Association indicated that disaster management at provincial level is grouped with the department that accommodates Local Government. For example, disaster management in Gauteng is grouped under Development Planning and Local Government, in the Free State under Local Government and Housing and in Kwa-Zulu Natal under Finance, Local Government and Planning. Thus, the framework for disaster management as outlined in this section can only be used as a guideline to implement a cost effective disaster management system on ground level, based on a bottom-up approach to ensure that all duplications (information, manpower, etc.) are eliminated.

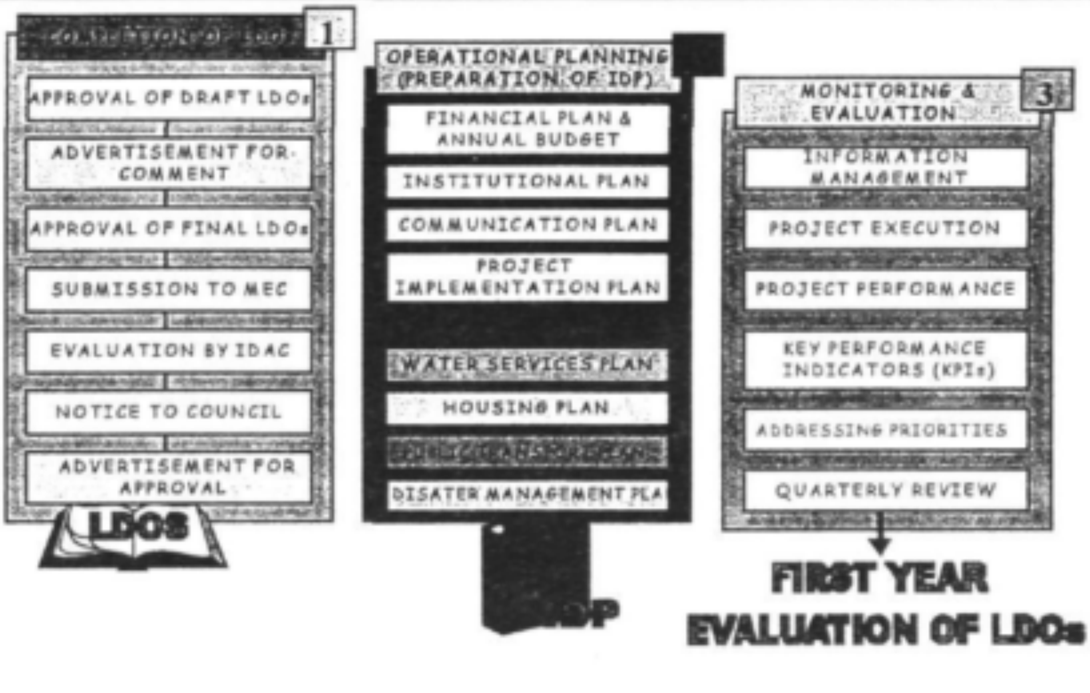

Figure 4.4 Completion of LDOs and Operational Planning

4.4 BILL ON DISASTER MANAGEMENT

During February 1998 the Ministry for Provincial Affairs and Constitutional Development (now Department of Provincial and Local Government) issued a Green Paper on Disaster Management, followed by the White Paper on disaster management. The White Paper on Disaster Management culminated in the Bill published in the Government Gazette No 20814 (Vol 415 dated 21 January 2000: General Notice No: 258 of 2000).

The main aim of this Bill is "to provide for an integrated, co-ordinated and common approach to disaster management policy that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, a rapid and effective response to disasters and post-disaster recovery; for the establishment of a national disaster management centre and provincial and municipal disaster management offices; and to provide for incidental matters" (Bill, 2000).

This Bill explains disaster management as a continuous and integrated multi-sectoral, multi-disciplinary process of planning, and implementation of measures, aimed at:

- Preventing or reducing the risk of disasters.
- Mitigating the severity or consequences of disasters.
- Emergency preparedness.
- A rapid and effective response to disasters.
- Post-disaster recovery and rehabilitation.

The President must further appoint an Inter-governmental Committee on Disaster Management consisting of;

- Cabinet members involved in disaster management.
- Members of provincial Executive Councils involved in disaster management in the provinces.
- Representatives of organised local government
    - The minister is the chairperson of the Committee
    - The Committee must advise and make recommendations to the Cabinet on issues concerning disaster management and the Minister on the establishment of a national framework for disaster management aimed at ensuring an integrated and common approach to disaster management in the Republic by all national, provincial and municipal organs of state, statutory functionaries, non-governmental institutions involved in disaster management, the private sector, communities and individuals.

The Minister must on his part, establish a national disaster management framework, which must outline a coherent, transparent and inclusive policy on disaster management appropriate for the Republic as a whole with a proportionate emphasis on disasters of different kinds, severity and magnitude that occur or may occur in Southern Africa. This disaster management framework must inter alia:

- Guide the development and implementation of the concept of disaster management as envisaged by the new Act.
- Establish prevention and mitigation as the core principle of the disaster management policy.
- Lay the basis for regional co-operation in disaster management with other southern African states and the establishment of joint standards of practice.
- Provide incentives for disaster management capacity-building and training.

In order to guide all disaster management activities, a National Disaster Management Centre has been established. The Bill on Disaster Management stated various functions of the Disaster Management Centre. The following is of importance:

- The Centre must establish links of communication with foreign disaster management agencies, including institutions performing similar functions as the Centre, to exchange information and to have access to international expertise on disaster management.
- The Centre must act as a repository of and conduit for information concerning disasters and disasters management and must for this purpose;
    - Collect information on all aspects of disasters and disaster management.
    - Process and analyse such information.
    - Develop and maintain an electronic database.

The electronic database developed by the Centre must contain extensive information concerning disasters that occur or may occur in Southern Africa and disaster management issues, including information on:

- Risk factors underlying disasters and ways and means to reduce such risks.
- Prevention and mitigation.
- Early warning systems, etc.

The Centre must also develop guidelines for, and initiate, support and assist in, the preparation and regular review and updating of disaster management plans and strategies by organs of state and other institutional role players involved in disaster management as well as the assistance in the integration of these concepts and principles (particularly strategies on prevention and mitigation) within national, provincial and local development plans, programmes and initiatives.

Guidelines must also be given by the Centre to assess and prevent or reduce the risk of disasters, including ways and means to determine levels of risk, assess the vulnerability of communities to potential disasters, increase the capacity of communities to deal with disasters and monitor the likelihood of, and the state of alertness to, disasters.

It is also the responsibility of the Centre to develop and implement appropriate prevention and mitigation methodologies and to integrate these methodologies with development plans, programmes and initiatives. Lastly, the Centre must promote formal and informal initiatives that encourage risk avoidance behaviour by organs of state, the private sector, non-governmental organisations, communities and individuals.

As for other bills and acts, the Bill on Disaster Management also requests the preparation of disaster management plans, setting out its role and responsibilities regarding emergency response and post-disaster recovery and rehabilitation, its capacity to fulfil its roles and responsibilities and contingency strategies and emergency procedures in the event of a disaster, including measures to finance these strategies. These plans and strategies had to be formulated and implemented by national, provincial and local government. The only difference between mentioned government levels, is that the premier of the province is responsible for all disaster management activities at provincial government level.

Municipalities must also establish a disaster management office for its municipal area.

4.5 TECHNOLOGY TRANSFER

At the end of more than 25 year of flood damage research at the University of the Free State, the question can be asked what will happen with all concepts, procedures and models developed. When the first phase of the ex ante stage started in 1992, with the main aim to develop simulation models to determine the potential negative impact of floods before they occur, the national government was busy reformulating the national flood management policy for South Africa. Since then, the political arena changed and the new government came with a national disaster management policy after the 1994 election. This opens new horizons for flood control in South Africa, because the emphasis shifts form reactive to proactive planning. Disaster management is now a continuous process and proactive, reactive and post disaster are equally important.

In this section the opinions, knowledge and experience of the research team, including research done by SRK Consulting and CASE that forms an integral part of this report, will be used to formulate a technology transfer strategy. To put this into perspective a note on the appropriate location of technology is presented.

4.5.1 A note by CASE on appropriate location of technology

Options for the appropriate location of the technology range along a continuum, from total transfer to the local level, to centralised control. In the localised variant, a local government (or a specific department) would own, maintain and use for its own purposes the hard and software and would also secure, input and analyse all data required for the operation of the package. In the centralised model, local governments would enter into a relationship with the central body[1] and negotiate access to outputs of the system as and when needed. Merits can be identified at both ends of the spectrum.

From a constitutional perspective, local government has responsibility for disaster management. Adopting the localised variant would indicate strong local-level ownership of, and commitment to, the problematics and challenges of disaster management. In addition, disaster and risk profiles are 'site specific' and to that extent, it can be anticipated that the database needs and modelling possibilities will be unique to each locality. Finally, while national government (and even international agencies where appropriate) have a key role to play, the actual management of disasters is in all probability better managed at local, and perhaps provincial, level.

There are also compelling advantages for a centralised system. Not least of these is that a greater degree of operational cost-efficiency (on the bases of scale) may be achieved. There is also the prospect of greater control over the integrity, quality, 'up-to-dateness' and standardisation of data inputs appropriate to the design and needs of the computer-based system - in turn this will help safeguard accuracy and a degree of quality control over outputs associated with the use of the system in future. Finally, there is a danger that the sheer size and complexity of the computer hardware required to run the system may put it beyond the financial and skills-related reach of most local governments which are cash-strapped and under-capacitated.

Perhaps the question of technology transfer should be approached with flexibility aiming to address a range of otherwise divergent criteria, e.g,:

- to maximise potential benefits
- ensure quality outputs and service delivery
- enable cost efficiencies
- enable access for as large a number of potential users as possible
- use and draw on existing capacities, whilst simultaneously
- developing a more diverse base of capacities throughout the country.

[1] presumably, either University of the Free State, the Water Research Commission or its agent, or a national governmental level - e.g., the proposed National Disaster Management Centre

Where local governments have sufficient capacities (in terms of existing computer infrastructure, staff complements and capacities, and financial resources) and where disaster management is understood as an important political priority, such better capacitated local governments may find it most appropriate to adopt the strictly localised option.

At the other end of the spectrum, less resourced local governments who nonetheless recognise that governance and development facilitation must incorporate disaster management concerns, would be better served by being able to discuss with a centralised agency what their needs are and these might be met and integrated with other concerns and programmes in a cost effective and developmental manner.

Should such flexibility be feasible in principle, it is likely that any number of permutations could be developed to suit the specific needs of the various role-players and potential users. For example, a specific local government may not have the requisite skills-base or computer infrastructure but is located in an area served by a tertiary educational institution. In such an instance, it may be possible to draw on the skills and capacities of that third party in a multi-party arrangement to ensure that the disaster management and development planning needs of the local government are adequately served (e.g., a computer department might input the relevant data, provide access to the required hardware and software and run the modelling and analysis exercise). The benefits are manyfold and all institutions involved could conceivably benefit. Other possibilities arise where locally based development NGOs and/or CBOs could be drawn in as partners for various aspects - e.g., data collection, consultative decision-making processes and so on. Again, benefits would be multifold.

Should certain aspects of the White Paper, as well as other related institutional and financial proposals currently under development, bear fruit, it is possible that a decentralised emphasis could be sustained. In particular:

a. a new Disaster Management Act may make provision for greater financial support to enable capacity building in the local government sphere, and
b. the establishment of joint operation centres at provincial level with responsibility for disaster management could provide an accessible institutional, systems and skills base to provide support for local governments who lack capacity in this regard.

Combined, these developments could make it possible to transfer both technologies and skills which are required to implement the modelling systems to a sufficiently decentralised level (at least provincial and, where possible, local) to avoid dependence on a single national centre.

Specific application/s of the technological capacities of the systems developed by flood damage research teams should be discussed further within the overall project, as well as on a case-by-case basis depending on defined needs and capacities. At a general level however, it appears that the mapping and analytic capacities are best suited to both hazard and vulnerability[2] mapping, as well as providing useful aids for cost-

[2] especially if certain socio-economic data are incorporated into a geographical information system (GIS) where such would help demonstrate aspects and levels of vulnerabilities of a particular context.

benefit aspects of decision-making with regard to the selection of measures for risk reduction and mitigation.

Finally, it might be that the benefits of the system's application and use would be more readily understood and accessed if the system were 'packaged' principally as an aid to development planning and facilitation, rather than disaster management narrowly defined. Local government as a whole is under pressure to both prioritise the many demands made on it and to deliver 'development'. In the overall system proposed above, such an approach is entirely legitimate and justified.

4.5.2 Technology transfer strategy

A new project proposal regarding technology transfer of computer models and aids for proactive flood disaster management has been proposed to and approved by the WRC. This project officially started during January 2000.

Referring to the Bill on Disaster Management it is clear that responsibilities are decentralised to provincial and local governments with a co-ordinating role by the National Disaster Management Centre. Therefore local governments have to take action. No appropriate management support tools exist at all government levels to assist in flood disaster management. In order to transfer new technology to all levels of government, South Africa has been divided into seven potential flood risk areas.

Referring to the Bill on Disaster Management: the Minister is the chairperson of a committee, representative of organised local government. In the event of a provincial disaster the Premier of the province and in the case of a local disaster the municipal manager may exercise this power to protect the public, provide relief to the public, preventing or combating disruption or dealing with the destructive and other effects of the disaster.

Regarding this inter-governmental structural framework the following strategy will be used to transfer new technology:

- First, formal workshops will be held in the short run at predetermined flood afflicted areas. Existing disaster management structures will be used for this purpose.
- Next, the new information will be presented to the Premiers of each province in order to make each province aware of new computer models and aids available to assist provincial and local governments in disaster management.
- Over the long run the IDP process will be used to identified disasters in regions as part of the LDO's (land development objectives). Disaster management plans will be formulated, similar as other plans (e.g. financial plans, institution plans, and water services etc.). After the implementation of various plans, the IDP will review all plans and ensure that plans will be updated continuously.

4.6 ALLOCATION AND INTEGRATION OF RESPONSIBILITIES: A PERSPECTIVE FROM THE PIETERMARITZBURG CASE STUDY

There are many players with different contributions, responsibilities, capacities and needs pertinent to disaster management. Co-ordination, harmonisation and synergy between these players are vital for effective disaster management. The Constitutional framework, institutional capacities, and existing relations and allocation of responsibilities within and between the various spheres of government (administrative and political), civil society and the private sector must all be considered in such a process. However, it is neither possible nor appropriate to be prescriptive or detailed in this regard because, *inter alia*:

- Local contexts, development needs and disaster profiles differ
- Current arrangements and responsibilities are not always clear and uniform nationally
- New policy on disaster management is being developed which may (indeed should) begin to rationalise the relevant institutional responsibilities and arrangements[1].

Nonetheless, there are certain overarching learnings, priorities and principles that are suggested by the case study and review (some of which relate to key elements of proposed government policy in the White Paper on Disaster Management).

In terms of the Constitution (Chapter A, Schedule 4), disaster management is a concurrent competency of national and provincial government while Chapter B Schedules 4 & 5 stipulate the local government is responsible for a number of functions relevant to disaster management.

The role of national government is fundamental for setting the overall policy, legislative and regulatory framework within which disaster management is exercised. Key proposals in the White Paper on Disaster Management should clarify and consolidate this role. At a broad level for example:

- the proposed National Disaster Management Centre (the Centre) would establish and implement an effective disaster management strategy and coordinate disaster management at various levels of government
- the proposed new Disaster Management Act would aim to create a uniform approach, eliminate confusion arising from current legislation and implement key policy objectives of the White Paper.

The role of the Centre, together with legislative review and consolidation, could be very significant in terms of the allocation and integration of responsibilities for disaster management. This is clear from a consideration of some of the key functions of the Centre noted earlier (in 4.2: New Government Policy):

1. information management (including the establishment of a comprehensive Disaster Management Information System, including electronic databases like GIS)
2. preparation of policies, strategies and plans, in conjunction with relevant government agencies and civil society formations, to ensure, *inter alia*, that key aspects of disaster management[2] are embraced at provincial and local level and that risk reduction is integrated into "the setting of land development objectives [LDOs] in terms of the *Development Facilitation Act* and integrated development plans [IDPs] drawn up in terms of the *Local Government Transition Act*." (RSA 1999: 31)

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[1] According to Mr G Killian of DCD a National Disaster Management Bill, currently being drafted, should be presented to Parliament by November 1999 (pers. comm. 16/07/99).

[2] These are: prevention, mitigation, preparedness, response, recovery and rehabilitation

3. assessing vulnerability, determining levels of risk and ensuring appropriate mitigation and effective disaster reduction
4. co-ordination and support during disaster and emergency situations
5. during non-Emergency Situations - should focus on longer-term risk reduction
6. conducting audits of the current capacity, structures, responsibilities and reporting mechanisms of all organs involved in disaster management and related activities - "The key strategy would be to dovetail the requirements and information needs of the Centre with national, provincial and local initiatives and programmes that are already functioning and which are effective" (RSA 1999: 35)
7. training and community awareness.

In practice, local government has a key role to play since it is usually the first sphere of government that must respond to disaster events and, in terms of local government policy, has growing responsibility for planning and facilitation of development. Should government accept, in a new Disaster Management Act, that disaster management and risk reduction must be integrated into LDOs and IDPs, this would compel local governments to include a relevant line item with funds, personnel and concrete plans attached in drawing up budgets for submission to Treasury. This would mark a significant step forward for the realisation of commitment to disaster management per se, and should assist its integration into development planning.

For effective and integrated disaster management in the local government sphere it might be suggested from the case study that the formulation of proactive and development disaster management strategies, projects and programmes should be, *inter alia*:

- Inter-departmental
- Participatory and consultative
- Coordinated and mutually reinforcing with respect to its contribution to national/regional and local goals of development
- Led and followed through by a dedicated, disaster management, official[3].

It is further suggested that in the formulation and implementation of development disaster management strategies, projects and programmes, partnerships should be actively sought and developed in order to draw in and utilise the capacities that exist within the region outside of local government, for example, in civil society (both NGOs and CBOs), in the private and educational sectors, and the public at large. It might reasonably be anticipated that, where such partnerships take the form of formal contacts for work done, it will be sensible to develop the relevant brief in consultation with the national Centre to draw on expertise and to consolidate a degree of consistency in approach and information collection.

The discussion of decision-making with respect to the selection of measures for flood protection and risk reduction or mitigation indicates that at least the following should also be characteristic of the process:

- flexibility in planning

[3] who would also be responsible for formulation of emergency response procedures and early warning systems as appropriate.

- the full inclusion and equal treatment of all options at early stages in the planning process
- the involvement of civil society stakeholders at key stages.

A fundamental contention of this contribution is that disaster management should be integrated into development planning, facilitation and regulation processes. The emerging international consensus is that:

> "The focus of prevention needs to be on reducing the vulnerability of human settlements and activities to floods, ... especially through emphasising the importance of flood warnings and emergency action, or through the need for land-use or building regulation" (Handmer 1997: 1).

The White Paper provides sufficient justification and indicative guidelines for achieving this objective through enabling the incorporation of disaster mitigation and risk reduction criteria into formal and required land-use and development regimes (LDOs and IDPs as noted above). The incorporation of flood risk reduction criteria into the formulation and implementation of land use control at the local level is undoubtedly critical. Handmer however also sounds a note of caution in this regard. He makes the important point that:

> "much of the world's population lives in settlements and buildings which are outside the control of formal planning systems. These people are not helped by improved regulations or planning" (Handmer 1997: 1).

In a global context where important dominant trends include a contraction of the role of the state in social and welfare intervention and a strong deregulatory emphasis, and a South African context with serious questions regarding the capacities of the local government sphere to cope with its multiple developmental and regulatory mandates, this question has deep resonance. While governments "still set the framework or context within which most (legal) activity occurs [and] ... control the legal arrangements for example" (Handmer 1997: 2) it is likely that sustainable institutional arrangements and allocation of responsibilities within that framework should encourage both community participation and partnership between government and other role-players and resources. Indeed Minister Valli Moosa, in his Foreword to the White Paper, puts a positive spin on the non-exclusive character of government's envisaged involvement in disaster management and argues that: "[t]he private sector and civil society have crucial roles to play. The fostering of partnerships between government and the private sector is a prerequisite for sustainable and effective disaster management to take place".

The Pietermaritzburg flood case study raises the question of the appropriate formulation and institutionalisation of flood warning systems. "Warning systems the world over fail all too often - in spite of the best efforts of the specialists and technicians who develop and operate the systems" (Handmer 1997: 3). Handmer argues that key attributes of most successful warning systems include the following:

- they are based on the priorities and needs of those at risk;
- they have a process for assessing those needs and for involving the community in the design and operation of the warning system; and
- there is cooperation and coordination between the relevant government, scientific and media organisations (Handmer 1997: 4).

These attributes are present in the modus operandi of an early warning system implemented in Costa Rica.

"Perspectives from Costa Rica: Community-Operated Early Warning System for Floods - Saving Lives and Property" (excerpt)

This successful River-Basin Monitoring Plan was launched in 1991, after the earthquake, when vegetation cover was lost and enormous amounts of sediment accumulated in river basins, increasing flood levels. Today, 32 two-way radio posts keep a vigilant eye on the high, middle and low-level altitudes of basins, and are equipped with rain gauges. A couple of times a day the community operator of the radio reports to the National Emergency Commission and the Meteorological Institute on water levels. They also get immediate information from these two entities when weather reports are issued.

The success of the system lies especially in the fact community members operate and manage it. In this area of largely indigenous communities, local participation ensures that messages are understood and acted upon -- a frequent stumbling block in the use of early warning systems. The community emergency committees carry out evacuation and even disaster mitigation measures and coordinate with the National Emergency Commission.

The plan has so far fulfilled the objectives it was designed to meet: minimize the death toll due to floods, establish an effective early warning system capable of alerting the population about the likelihood of a major flood, and improve the quality of life in areas constantly threatened by this type of natural disaster. The radio communication serves an additional social purpose in these areas where no telecommunication exists, in case of medical or other social emergencies.

(Molin Valdes, H, 1997: 2).

Domeisen points out that: "since the system has been established, the region has experienced the most serious floods in over 70 years. Despite this fact, only a few people have died from floods" (Domeisen 1997: 4).

Molin Valdes argues that the community-operated system in Cost Rica goes some way towards overcoming key difficulties associated with the efficacy and credibility of early warnings. Whereas "in Costa Rica, meteorological conditions generate frequent alerts [and as a result] some technicians and authorities are sometimes reluctant to provide too many early warnings, fearing a loss of credibility, ... the costs of not acting in a timely manner are high" (Molin Valdes, H, 1997: 2). It has been noted above that "local participation ensures that messages are understood and acted upon". Reinforcement of the underlying message however probably remains important too. After Hurricane Cesar in 1996, which devastated areas of Costa Rica where **no** community-operated early warning systems were in place, a public opinion study was carried out to provide guidance to the National Emergency Commission and the National Meteorological Institute, the two institutions entrusted with handling the warnings, to evaluate the effectiveness of public information. The survey found that: "the warnings about Hurricane Cesar were indeed known to the communities affected, but they did not feel that the threat was imminent or concerned themselves, even if they lived next to a river or at the foot of a dangerous slope.

> "The lesson is clear: the process of informing and educating the population about natural hazards must be permanently reinforced and the media have both a great responsibility in this regard and an outstanding potential to contribute to these efforts" (Molin Valdes, H, 1997: 3).

With respect to early warning systems, it is also true that the Pietermaritzburg flood case study has highlighted their inherent weakness in cases where there is insufficient time to respond to the threat of flooding and the flood itself. As Von Kotze et al (1996) note: "the very short lead time for the development of flash floods does not permit useful monitoring of actual river banks for warning purposes" (214).

As noted earlier, there was repeated discussion about installing a warning system after the Pietermaritzburg flood - and indeed these discussions marked one of the few instances of a forward looking response to the floods. However, the discussion suggests that Early Warning Systems may not always be the most sensible priority. In the Pietermaritzburg context, it appears more important perhaps to understand and reduce the propensity of the catchment for flash flooding through consideration of various issues including land use and the possibilities for catchment management, rehabilitation or re-vegetation and so on.

4.7 POLICY RECOMMENDATIONS

In January 2000 the Bill on Disaster Management was published and will be launched as the new Act on Disaster Management in June 2000. The emphasis has changed from a reactive approach (as required by the old Civil Protection Act) to a pro-active approach. The Bill on Disaster Management decentralised more responsibilities to provincial and local governments and requires mitigation and prevention actions. A real paradigm shift needs to take place by all levels of government to really understand how to mitigate and to prevent the negative effects of disasters. Notwithstanding the fact that a Bill on Disaster Management exists, it is still not clear how flood management fits into the contex of disaster management. Therefore, South Africa needs an appropriate flood management strategy, which will ensure a strategic approach to flood plain management. Best practice to achieve the vision and objectives of flood management requires that decision making is based on:

- a risk management approach;
- appropriate risk treatment measures which include both structural and non structural measures;
- a decision-making framework for future investment which facilitates setting priorities for competing projects;
- a clear definition of roles and responsibilities of flood management stakeholders;
- a clear definition of cost sharing principles;
- a strategic planning framework at national, provincial and local level;
- legislative support for Catchment Management Agencies (CMAs) functions, flood plain management plans and flood response plans; and

- a support system of best practice manuals and guidelines for use by flood management practitioners.

To achieve the abovementioned it is recommended that a national approach is followed, which can lead to the following significant advantages:

- Better and more efficient use of the nation's resources.
- A pro-active response to flood plain management.
- Development of a national database of flood-related information for flood-prone communities. This information is essential to a better and more efficient allocation of resources to floodplain management.
- A consistent means of "benchmarking" floodplain management issues and practices, which will help to determine funding priorities and fund allocation by all levels of governments.

It is recommended that major planning instruments at a regional level are the catchment management strategy and its floodplain management component, prepared by the Catchment Management Agency (CMA), the regional disaster response plan (an appropriate coordinator has still to be identified), and the regional disaster recovery plan (an appropriate coordinator has still to be identified). The main link must be generated from the national floodplain management strategy. From the national floodplain management strategy, integrated detail plans, e.g. water conservation plan, transportation plan and disaster management plan are defined within the integrated development planning process of a province. These elements link into the regional emergency response and recovery plans.

At local level the major planning instruments are the municipal planning scheme prepared by the municipal council, the flood plain management plan coordinated by the CMA and the municipal disaster management plan prepared by the municipal council. Important key outcomes of the local floodplain management plan are the flood study which identifies flood risk and links into the flood response plan, the land use zone and overlay delineation and specific land use planning guidelines which link into the municipal planning scheme.

The bottom line for South Africa is a political will to disaster management by national government and financial support to provincial and local governments to manage disasters pro-actively. From a policy perspective, the real question is how national government will get provincial and local governments interested in disaster management in a sustainable way. In the long run the emphasis must be to achieve sustainable development practices and it is therefore important to also involve the regional and town planners, the private sector and the community.

In conclusion it can be mentioned that computer models and management aids developed by the flood damage research team of the Department of Agricultural Economics at the University of the Free State can be useful to all levels of government to assist them in flood plain and flood disaster management and are also extremely useful to formulate sustainable development policies for provinces.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS*

5.1 SUMMARY

The *ex ante* stage of flood damage research in South Africa started in 1992 with the main aim to develop flood damage management aids (loss functions, computer programmes and questionnaires) to assist planners and authorities involved in flood damage assessment and management. During the first phase (1992-1994) the focus was on the development of these aids for specific localities (Upington on the Orange River and Vereeniging on the Vaal River). In order to generalise the results of phase 1, phase 2 (1995-1997) was necessary. The research area was expanded to include the Mfolozi sugar cane production area in Kwazulu Natal, the Uitenhage and Despatch formal urban areas along the Swartkops River in the Eastern Cape and the Soweto-on-Sea informal urban area along the Chatty River. Generalised computer programmes (FLODSIM and TEWA) and standardised loss functions which resulted from this phase are applicable in different flood plains in South Africa. To test the application of these aids as part of a holistic approach to integrated hydrological catchment management, phase 3 (which commenced in 1998) was conducted. A summary of the achievement of each of the specific objectives of phase 3 (the focus of the report) follows.

Objective 1 The completion and release of a set of flood damage management aids for application at local, provincial and national level.

The computer models FLODSIM and TEWA are completed and FLODCAL a computerised questionnaire developed. In Chapter 1 brief descriptions of FLODSIM, TEWA and FLODCAL are presented within the framework of proactive, reactive and post disaster management.

In Chapter 2 FLODSIM and TEWA are tested using actual case study information. FLODSIM is applied in the Lower Orange River, in the vicinity of Upington to research *inter alia* optimum levy heights. TEWA is tested along the Swartkops and Chatty Rivers by investigating the merits of different channel improving measures. Testing of both FLODSIM and TEWA were convincing, proving their application possibilities as decision support aids in actual flood control planning. In order to facilitate application, user manuals of FLODSIM, TEWA and FLODCAL are presented as annexures to the report.

A CD on which demonstrations of the application of FLODSIM, TEWA and FLODCAL are shown, is available on demand.

* This chapter should be read together with the executive summary and the conclusions/recommendations paragraphs of each chapter for a more comprehensive overview.

Objective 2 Establishment of the usefulness and benefit of flood control measures along major watercourses.

This objective is attended to in Chapter 2 of the report as is mentioned under Objective 1. Information to test FLODSIM and TEWA are presented by SRK Consulting and their reports are attached as Annexures 1 and 2.

Objective 3 Determining the suitability of the "techno-economic" approach to determine acceptable flood control mitigation measures for a developing local community.

The main results of the sociological study by CASE are presented as Chapter 3 of the report. Other contributions from the sociological study are integrated in Chapter 4 under "technology transfer" and "allocation and integration of responsibilities" and in Chapter 5 under "recommendations". The findings from the CASE study contribute to put the results of this research into a broader perspective.

5.2 CONCLUSIONS

- The flood damage management aids have been completed to a stage where they can be applied in practice for flood plain management as well as emergency and disaster management.

- Demonstration of the application of the aids with actual case study data proved their usefulness in practical applications, within the cost-benefit analytical framework.

- These aids can provide the decision support needed for implementation of the New Disaster Management Policy on a continuous basis; i.e. during the pro-active, reactive and post flood phases.

- To promote application, focussed technology transfer actions are needed utilising the proposed institutional framework for disaster management.

- Broadening the theoretical cost-benefit analytical basis of the present economic-engineering approach to a multi criteria decision analysis basis, will enhance the social and sociological acceptability and applicability of flood damage management actions, especially for the developing community. The economic efficiency premise of the cost-benefit approach is proved inadequate as a means of assessing the relevant social and sociological impact of floods and the effect on flood management.

5.3 RECOMMENDATIONS

- The flood damage management aids developed during this research must be acknowledged as the best presently available in South Africa for flood damage risk management. Having been tested as useful instruments in flood damage risk assessment and control, they must be brought to the attention of as many concerns involved in practical flood damage risk assessment and management as possible. This includes national, provincial and local authorities, non-governmental organisations as well as private and educational institutions.

- To promote the use, maintenance and further development of this integrated flood management approach, one or more institutions should make it their business to take responsibility for rendering the various tasks needed to maintain their usefulness and relevance.

- Further development of these aids as part of a comprehensive multi-criteria decision analytical approach to flood disaster management, is considered highly essential. In this regard further developmental and applied research is recommended.

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ANNEXURE 1

AIDS FOR FLOOD DAMAGE ASSESSMENT AND FLOOD DAMAGE CONTROL PLANNING IN IRRIGATION AND URBAN AREAS

HYDROLOGICAL HYDRAULIC AND CAPITAL COST ESTIMATES FOR FLOOD CONTROL MEASURES ALONG THE ORANGE RIVER AT UPINGTON

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REPORT 207878/2 **OCTOBER 1999**

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SUB-SECTION : HYDROLOGICAL HYDRAULIC AND CAPITAL COST ESTIMATES FOR FLOOD CONTROL MEASURES ALONG THE ORANGE RIVER AT UPINGTON

1 INTRODUCTION

The Department of Agricultural Economics of the University of the Orange Free State (UOFS) submitted a research proposal "Aids for Flood Damage Assessment and Flood Damage Control Planning in Irrigation and Urban Areas" to the Water Research Commission (WRC) in 1997. SRK Consulting (SRK) were part of that proposal responsible for engineering aspects which include the hydrological, hydraulic and capital cost estimates for flood control measures along the Orange river at Upington (Appendix A).

2 SCOPE OF WORK

The scope of work for the study is defined as the following:

- Review of previous studies.
- Review of flood hydrology.
- Estimation of flood levels for the full range of flows for the various levee scenarios.
- Estimation of the capital costs for the various scenarios.
- Provide recommendation to reduce damages to flood defences during floods.

The study maximised the use of previous study results to ensure that costs are contained.

3 REVIEW OF PREVIOUS STUDIES

Two previous studies related to the current project are:

- "Vloedlynberamings in die Oranjeriviervallei" by Chunnett, Fourie and Partners, completed March 1993.

- "Benede-Oranjerivier S.W.S : Vloedlyne : Gifkloofstuwal tot by Manie Conradiebrug" by the sub-directorate Hydraulic Services of the Department of Water Affairs and Forestry (DWAF) completed April 1999.

From the above studies the following conclusions are made:

- The estimated flood probabilities for both studies are uncertain and finalisation of the flood probabilities is recommended for both studies.

- The differences between steady state and dynamic routing of the flood flows at Upington are negligible. This is ascribed to the large volumes and long duration of the floods relative to the potential river channel storage.

- Both studies assumed fixed levee heights for the present system.

4 REVIEW OF FLOOD HYDROLOGY

The concerns raised during the previous studies prompted SRK to review the design peak estimation to enable the UOFS to compile the mean annual damage (MAD) for the Upington area with more certainty for the various scenarios. The lower Orange river is well gauged and statistical methods are therefore used. Several historical floods are also available. The annual maximum flood data at Upington and Prieska were used to estimate the design peaks.

The ten most significant floods in the Prieska and Upington area are ranked and listed in Table 4.1 below.

TABLE 4.1 : FLOOD PEAKS LOWER ORANGE RIVER

Rank	Date (year)	Flood Peak (m^3/s)	
		Prieska	Upington
1	1874	14 500	-
2	1805	12 500	-
3	1881	12 400	-
4	1925	12 000	8 700
5	1898	7 600	-
6	1974	10 500	9 200
7	1934	9 100	6 700
8	1988	8 800	8 500
9	1 920	8 500	6 600
10	1967	7 500	7 200

The record at Prieska is longer and is also considered to be the more accurate of the two. The period of record at Prieska is 1911 to present. The results for Upington used both sets of data to obtain the adjustment ratios. From 1970 to present the data is significantly affected by the upstream impoundments in the Orange river (Gariep and Vanderkloof dams) and the Vaal river (Bloemhof and Vaal dams). The distribution used were the Log-Pearson Type III and the General Extreme Value. The results are shown in Appendix B and the adopted peaks for

Upington and the previously adopted peaks are listed in Table 4.2 below.

TABLE 4.2 : ESTIMATED DESIGN PEAKS - ORANGE RIVER AT UPINGTON

Return Period - T (years)	Probability ($1/_T$)	Q_T (m^3/s)	
		SRK	Previous Studies
2 (7)	0,50 (0,1429)	3200	-
5 (13)	0,20 (0,0769)	5400	4300
10 (22)	0,10 (0,0455)	6500	6000
20 (31)	0,05 (0,0323)	8000	8300
50 (54)	0,02 (0,0185)	10000	11800
100	0,01	11800	12200
200	0,005	13700	14400
500	0,002	16300	-
1000	0,001	18500	-
5000	0,0002	25100	-
10000	0,0001	27500	-
RMF	-	24500	24500

Note: The values in brackets are the flood probabilities taking account of the current upstream impoundments.

The flood damages may be estimated using the following approaches to assign probabilities to the damages:

- Annual flood probabilities as shown in Table 4.2, or
- Considering the maximum probability of events occurring over a selected design period.

The economic design of civil structures are usually taken over a certain period of years ranging from 15 years for roads to 100-year for large dams. The design life for well constructed levees for the purposes of this study is taken to be 50-years. From Table 4.3 it can be seen that the probability of having one 50-year event in the 50-year design period is 63,58% and that of having four ten year events is 74,97%. For damages the implication of taking it over a 50-year period instead of an annual basis is that the maximum probable damages for a ten year event will be 4 x 74,97/100 x damage. The maximum for other events including that of the probabilities including the existing upstream dams, are shown in Table 4.3.

TABLE 4.3 : MULTIPLE EVENT PROBABILITY OVER 50-YEAR DESIGN LIFE

T (Return Period)	Number of Events (n)	Probability (p)	Total Number ($^{n \times p}/_{100}$)
2	21	89,87	18,87
5	8	80,96	6,48
7	7	72,57	5,08
10	4	74,97	3,00
13	3	84,33	2,53
20	2	72,06	1,44
27	2	69,00	1,38
31	2	57,00	1,14
50	1	63,58	0,64
54	1	61,65	0,62
100	1	39,50	0,40
200	1	22,17	0,22
500	1	9,52	0,10
1000	1	4,88	0,05
5000	1	1,00	0,01
10000	1	0,50	0,01

5 ESTIMATION OF FLOOD ELEVATIONS

5.1 Previous Studies

The two previous studies estimated flood elevations for mainly two scenarios:

- No levees along river, and
- Present levees are in place, but at fixed heights of 1,6 m to 1,7 m.

DWAF however also estimated the impact of levee manipulation at three sites.

5.2 Estimation of Flood Levels for Various Scenarios

The selection of scenario's for flood damage control is based on ensuring that certain flows do not inundate the agricultural lands.

5.2.1 Scenarios

SRK from their brief with UOFS defined the scenarios, based on the annual flood probabilities, to be investigated.

TABLE 5.1 : SCENARIOS INVESTIGATED

Scenario	Levees Design **
"0"	No levees
"1"	Levees 3200 m^3/s
"2"	Levees 5400 m^3/s
"3"	Levees 6500 m^3/s
"4"	Levees 8000 m^3/s
"5"	Levees 10000 m^3/s
"6"	Levees 11800 m^3/s
"7"	Levees 13700 m^3/s

Scenario	Levees Design **
"8"	Levees 16300 m^3/s
"9"	Levees 18500 m^3/s
"10"	Levees 25100 m^3/s
"11"	Levees 27500 m^3/s
"12"	Present true levee level*

* The present levee arrangements were taken as given and levels of the levees were supplied by the Department of Agriculture.

** The flows design for and modelled relate to the flood probabilities with no existing dams.

The levees for the various scenarios are designed to keep the stated flows out of agricultural areas.

5.2.2 Estimation of the Flood Elevations

The original proposals envisaged that SRK would use the MIKE-11 model set up by DWAF to estimate the flood levels for the scenarios and levee manipulation. Unfortunately the DWAF model data was lost and could not be retrieved. Due to the nature of the flooding a decision was taken to set-up the Upington system on the HEC-RAS model with sectional and spatial information supplied by UOFS. The remodelling of the system, using the section indicated in Appendix A, was however time consuming and was not planned for.

The results, indicating flood levels at the sections selected for each of the scenarios, are shown in Appendix C.

6 CAPITAL COST ESTIMATES

The capital costs were estimated for the following:

- Construction of levees, and
- The construction of a dam in the Boegoeberg area.

The costs (inclusive of fees and contingencies) were done for the following possible combinations:

- New levees at full contractor costs.
- New levees at partial contractor costs. This assumes that the farmers will aid in construction.
- Adding to the current levees at full contractor costs.
- Adding to the current levees at partial contractors costs.
- Construction of dam at Boegoeberg to same requirement regarding the keeping out of specific flows as for levees.

The cost estimates for all the scenarios are shown in Appendix D and summarised in Table 6.1 below.

TABLE 6.1 : FLOOD PROTECTION COSTS

Scenario	Costs (R x 1,000,000)				
	Levees				Dam
	New	New Partial	Upgrade	Upgrade Partial	
0	0	0	0	0	0
1	33,80	15,19	6,04	3,43	662,60
2	72,23	31,47	22,64	10,46	857,20
3	89,76	38,89	37,06	16,57	924,30
4	117,87	50,80	62,59	27,38	980,40
5	157,89	67,75	100,55	43,46	1050,20
6	192,90	82,57	134,15	57,69	1108,20
7	230,21	98,37	171,42	73,48	1157,70
8	286,56	122,24	227,77	97,34	1227,00
9	347,36	147,99	288,57	123,09	1262,70
10	452,65	192,59	393,86	167,69	1368,70
11	573,95	243,96	515,16	219,06	1400,30
12	60,90	26,65	0	0	0

The construction of a dam at Boegoeberg will not solely be for flood protection of the Upington area. Benefits to other areas would be flood protection for areas outside the study area (Kanon Island to Augrabies etc), irrigation certainty and general water supply. These are aspects that would require more investigation and the actual cost for flood protection at Upington could in fact be only 20 to 30% of the stated dam costs. It should, however, be remembered that environmental and international concerns (Namibia) may make a dam not viable.

The construction of the levees will however result in more infrastructure that could be damaged potentially and would also require maintenance. Table 6.2 indicates the potential damages and maintenance costs to the levees for various flood events. The damages are shown for the events taking the current upstream impoundments into consideration and no upstream impoundments.

TABLE 6.2 : POTENTIAL LEVEE DAMAGES (R x million)

Return Period (years)		Scenario											
No dams	With dams	1	2	3	4	5	6	7	8	9	10	11	12
4	4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
5	13	0,0	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,0
10	22	0,0	3,6	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,3
20	30	0,0	7,2	4,5	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	6,1
50	54	0,0	21,7	10,8	8,3	1,6	1,6	1,6	1,6	1,6	1,6	1,6	9,1
100	100	0,0	36,1	26,9	16,5	7,9	1,9	1,9	1,9	1,9	1,9	1,9	15,2
200	200	0,0	57,8	37,7	35,4	15,8	9,6	2,3	2,3	2,3	2,3	2,3	24,4
500	500	0,0	65,0	76,3	56,6	50,5	28,9	18,4	2,9	2,9	2,9	2,9	48,7
1000	1000	0,0	65,0	80,8	100,2	71,1	65,6	46,0	17,2	3,5	3,5	3,5	54,8
5000	5000	0,0	65,0	80,8	106,1	142,1	173,6	195,7	126,1	164,2	4,5	4,5	54,8
10000	10000	0,0	65,0	80,8	106,1	142,1	173,6	207,2	243,6	152,9	22,6	5,7	54,8

The estimates in Table 6.2 assumed:

- 90% maximum levee destruction.
- Annual maintenance amount based on the events and flow depth and velocities. This

will be used to repair erosion damages.

- Damage is related to depth of overtopping.

7 HYDRO-ECONOMIC ASSESSMENT

The hydro-economic assessment is shown in Appendix E. The flood damage costs were supplied by the UOVS for all the modelled flows. The analysis was conducted for two probability sets:

- No upstream impoundments (pre 1970)
- Present upstream impoundments (post 1970).

The construction of a dam at Boegoeberg was excluded due to its high cost when compared to the flood damage. The other benefits need to be assessed in more detail before such a dam can be included.

7.1 No Upstream Impoundments

From the results in Appendix E, the following is derived:

- The optimum levee height is between scenario 4 and 6. This relates to a probability of between 20 years to 100 years.
- The selection of the design flow, which in turn is related to a flooding probability, will be determined by the costing scenario.

Since the levees are present to a certain degree and the lack of resources, i.e. funds, in the study area to complete the works, the most likely scenario is the upgrading of the levees at full contractors costs. This would indicate that the optimum design flow is approximately 11 500 m^3/s to 11 800 m^3/s or a flood return period of between 45 years to 50 years.

7.2 Upstream Impoundments Included

The interpretation is similar to that discussed in 7.1. The results also indicate that the design flow will be similar to that obtained in Section 7.1.

7.3 Hydro-economic Conclusion

Both probability scenarios indicate that the design flows for levee at Upington should be between 45 years to 50 years. If the levees were to be totally reconstructed the design will be based on a flow of 8 000 m^3/s which related to a present probability of 31 years to 40 years.

The overall results would seem to indicate that further upgrading of the current levee system does have benefits that make it feasible.

8 CURRENT SYSTEM UPGRADES

With reference to Appendix A and the probability of overtopping in Appendix B (Scenario 12) the levees that require further upgrades to at least the 31 year flood level are those at the following sections:

- North channel (Kanoneiland), Sections 1 to 5.
- South channel (Kanoneiland), Section 1 and 2.
- Main channel (Kanoneiland to Gifkloof), Sections 8 to 10, Section 14, Sections 16 to 20, Sections 21 to 23, Section 28, Sections 30 to 33, Sections 35 to 41.

The above mentioned 31-year flood levels refer to the upstream dams probability and a flow of 8 000 m^3/s. This is the minimum level to which upgrades can be applied and justified. As stated in Section 7 the upgrades are optimised when designing for the 45-50 year event. The lower design is recommended due to practical consideration regarding the availability of funds and resources.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The following conclusions are made:

- The flood hydrology would indicate that the existing upstream impoundments altered the magnitudes of especially the more frequent events.
- The use of a design period of 50 years significantly increases the probability of the occurrence of an event and for the lesser events the occurrence of that event more than one.
- Capital costs for reducing flood damages are based on a larger range of events than the previous studies and should enable the optimisation of measures.
- The construction of a dam is not at this stage considered to be viable due to environmental and international concerns.
- Based on costs and the flooding probabilities, the current levees are sufficient to keep out floods less than the 10-year event on average for the whole reach. There are areas where events less than the 10 year event will cause damages.
- The upgrading of the levee to flow of between 11 500 m^3/s to 11 800 m^3/s is justified.

9.2 Recommendations

It is recommended that the following be used for a realistic assessment of flood control benefits:

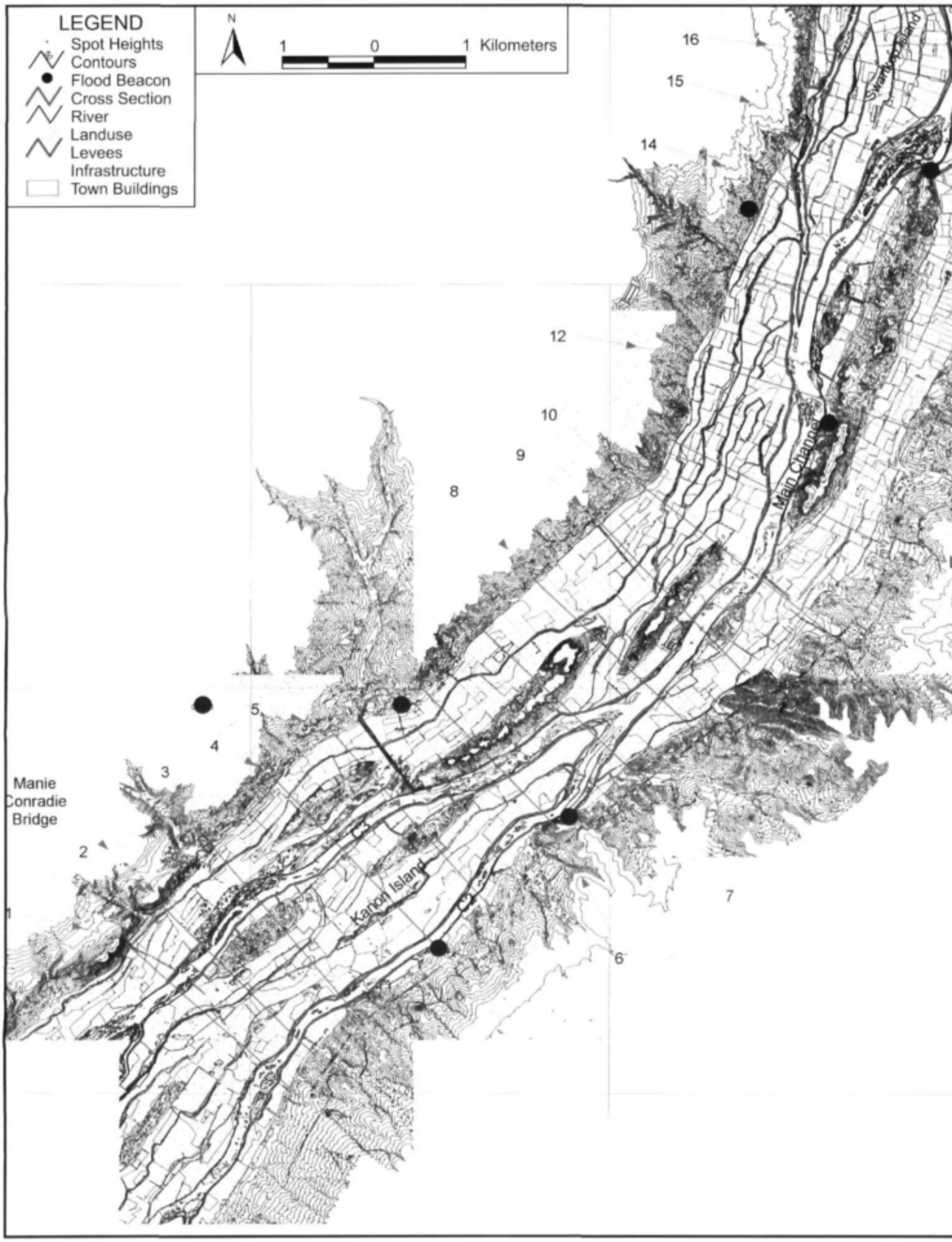
- The flood probabilities that include the existing upstream impoundments
- The "additional full" levee option for costs, and
- That the potential levee damages as indicated in Table 6.2 be used to define the costs for the upkeep of the levees.
- The upgrading of levees commence with those levees mentioned in Section 8.
- The lack of resource could however preclude an overall upgrade of the levees to the 50-year event and it is recommended that the design be taken to 8 000 m^3/s for the meantime of the sections indicated in Section 8.

The use of the design period of 50-years may also be used to assess the benefits of measures since all costs including damages can be taken to be present cost. This would take away the uncertainties related to interests and escalation.

D VAN BLADEREN, Pr Eng
SRK Consulting

APPENDIX A

LOCALITY MAPS AND SECTIONS



SRK Consulting

ORANGE RIVER AT UPINGTON
APPENDIX A1

Strategic Information Management Systems

PROJECT No. 207878

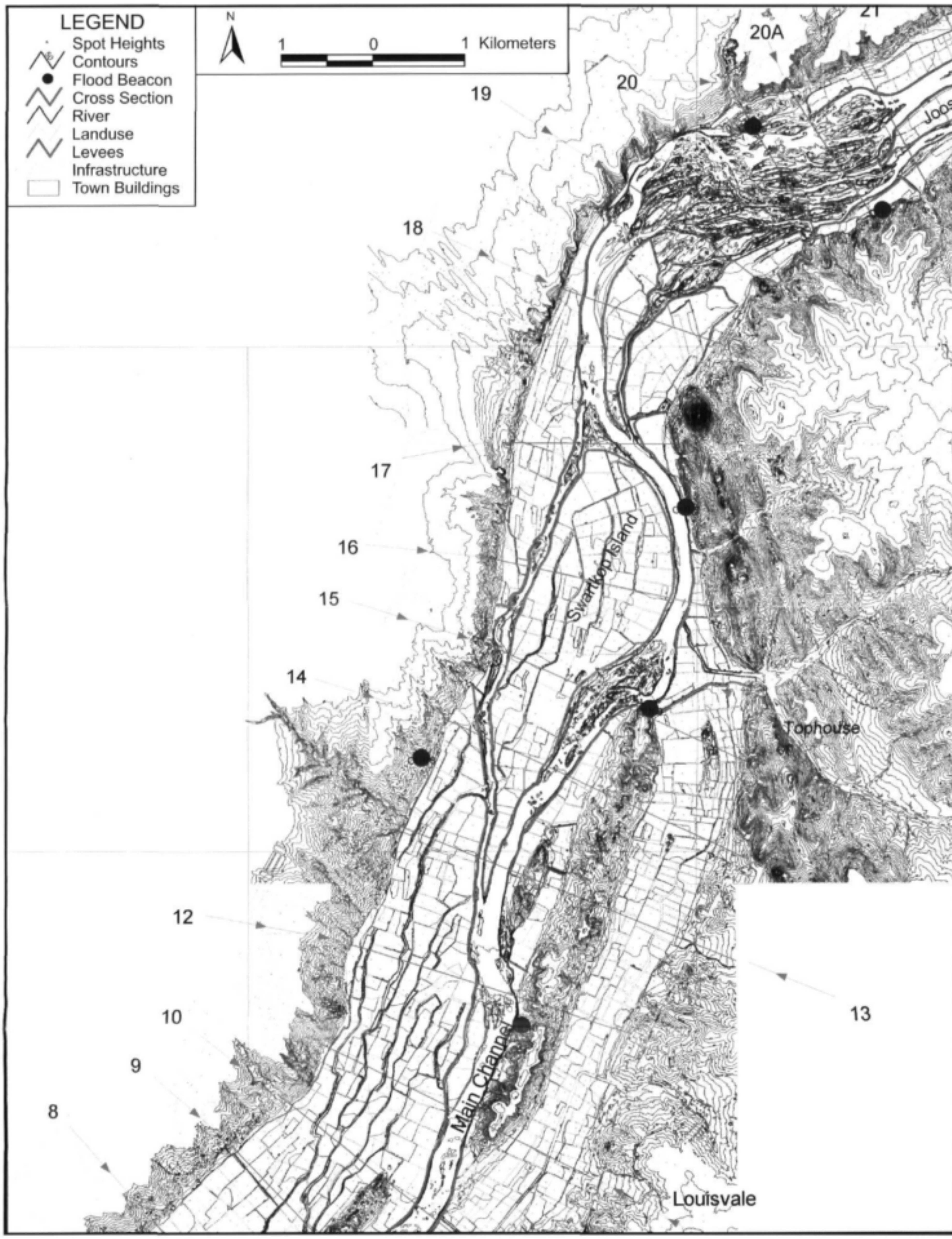
By T. Hepburn

Issue Date : 1 November 1999

Drawing No. 001
Scale 1 : 40 000

Revision Date : ____

Signed : ____



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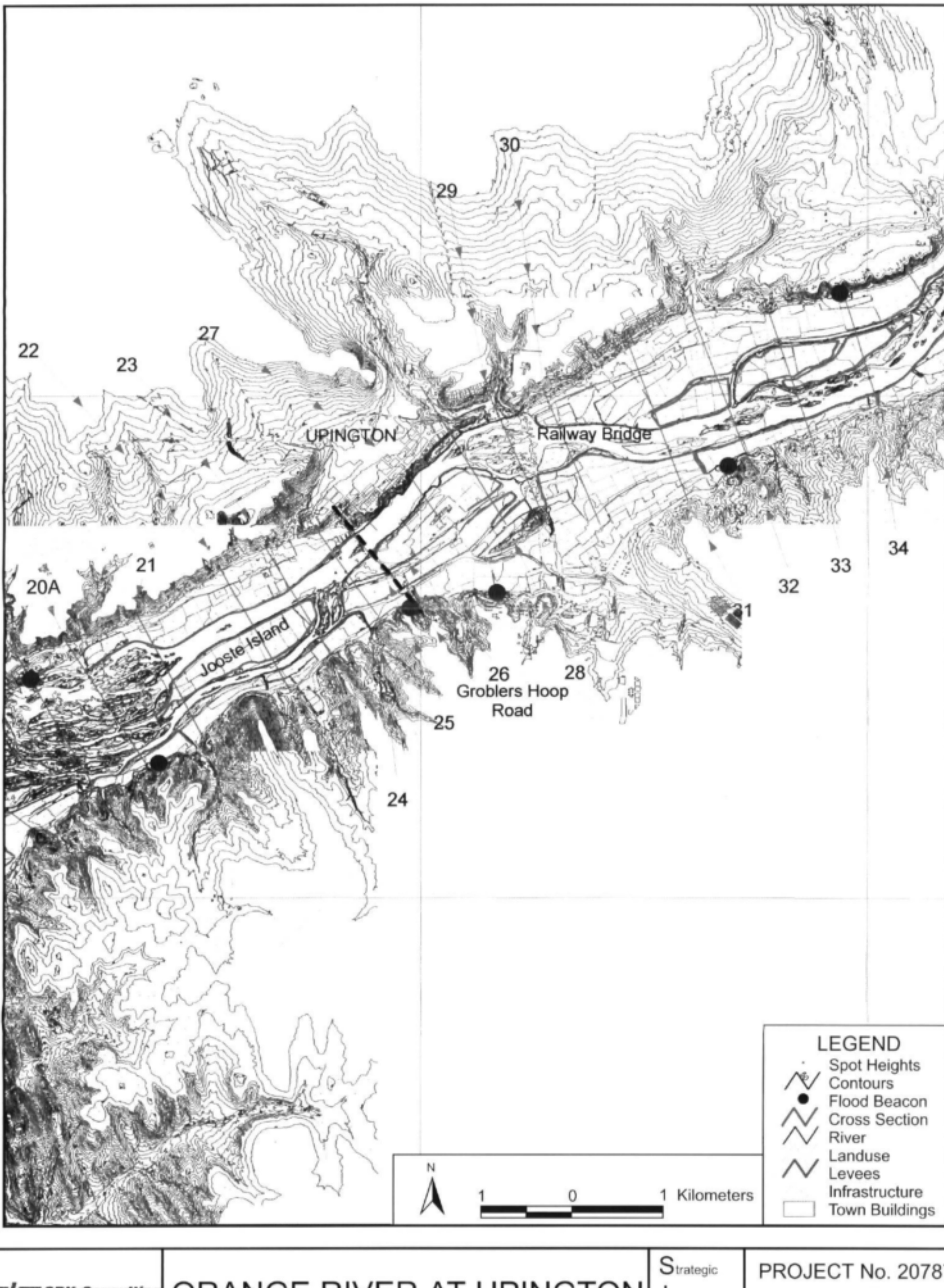
ORANGE RIVER AT UPINGTON
APPENDIX A2

Strategic Information Management Systems

PROJECT No. 207878

By	Issue Date : 1 November 1999	Revision Date : ____
T. Hepburn	Drawing No. 032 Scale 1 : 40 000	Signed : ____



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ORANGE RIVER AT UPINGTON
APPENDIX A3

Strategic
Information
Management
Systems

PROJECT No. 207878

By	Issue Date : 1 November 1999	Revision Date : ____
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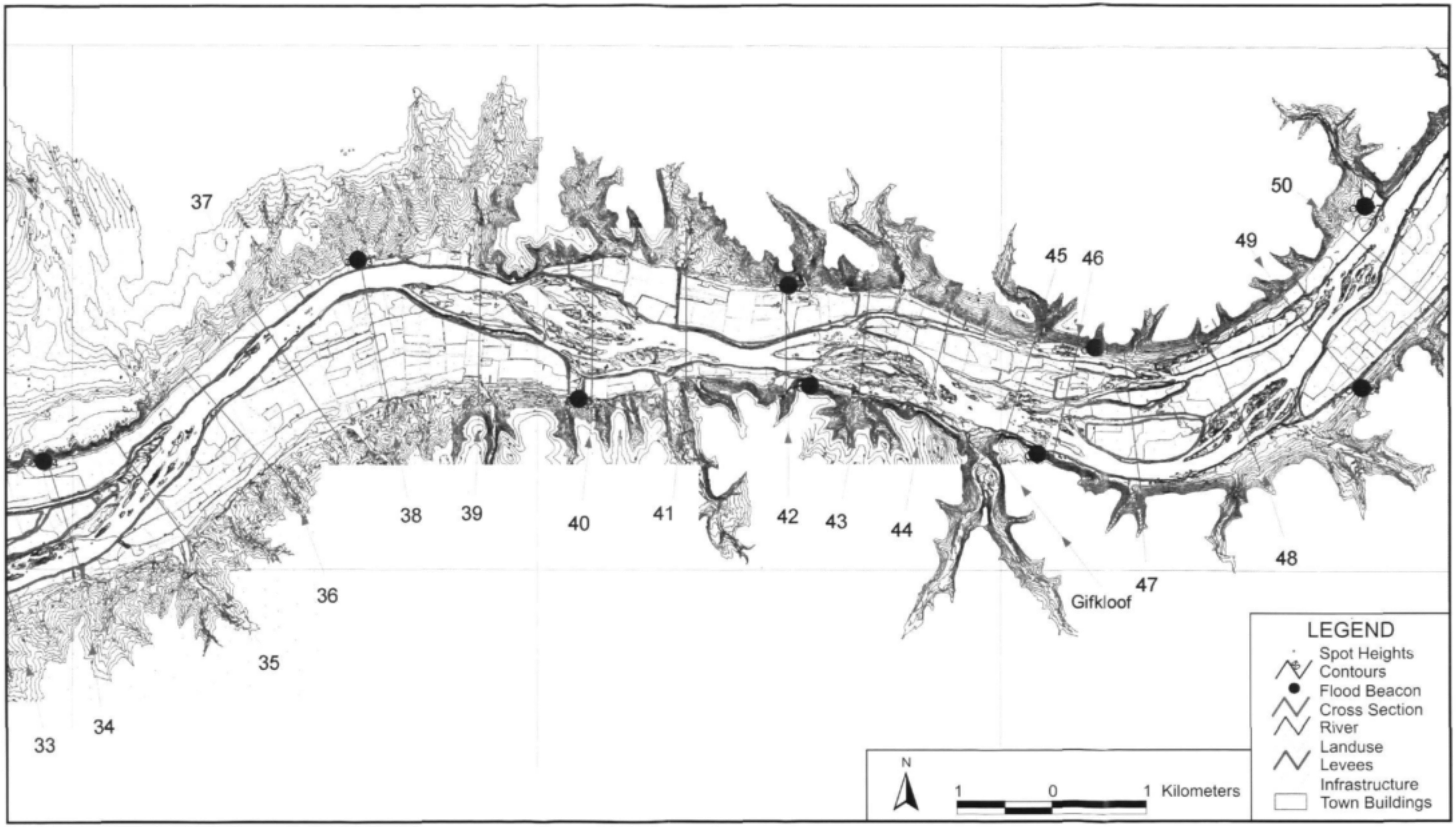

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ORANGE RIVER AT UPINGTON
APPENDIX A4

Strategic
Information
Management
Systems

PROJECT No. 207878

By	Issue Date : 1 November 1999	Revision Date : ____
T. Hepburn	Drawing No. 004 Scale 1 : 40 000	Signed : ________

APPENDIX B

HYDROLOGICAL ANALYSIS

Appendix B-1

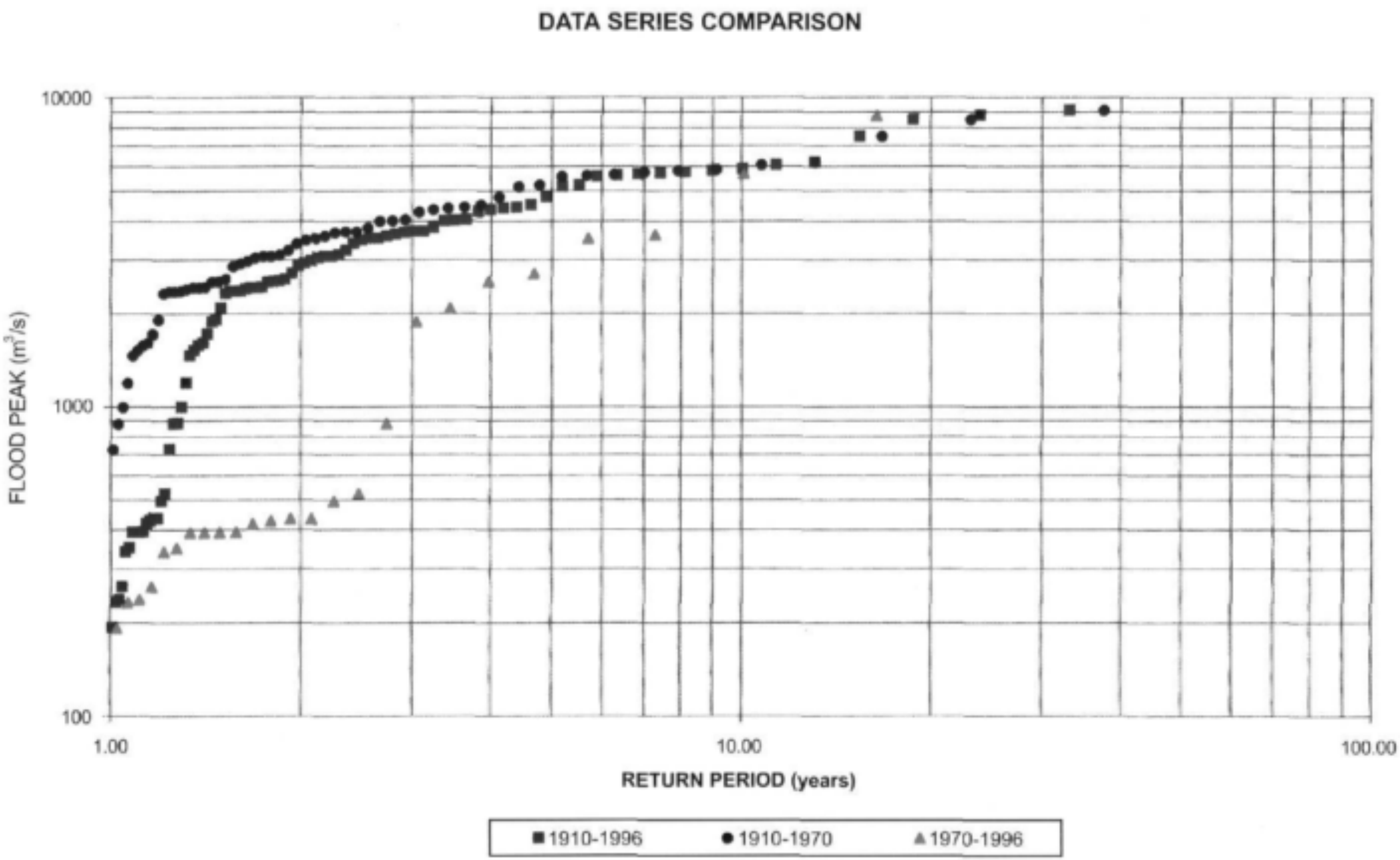
ANALYSIS OF DATA FOR VARIOUS PERIODS

Data			Comparison of Data for Various Periods							
			1910-1996			1910-1970		1970-1996		
Hidro-Year		Maximum Discharge (m^3/s)	Ranked Discharge (m^3/s)	Rank	Plotting Position	Ranked Discharge (m^3/s)	Plotting Position	Ranked Discharge (m^3/s)	Plotting Position
1910	11	2539	12044	1	143.67	12044	100.33	10460	43.67
1911	12	1717	10460	2	53.88	9096	37.63	8761	16.38
1912	13	2368	9096	3	33.15	8491	23.15	5716	10.08
1913	14	993	8761	4	23.94	7499	16.72	3618	7.28
1914	15	4778	8491	5	18.74	6168	13.09	3512	5.70
1915	16	3106	7499	6	15.39	6061	10.75	2700	4.68
1916	17	3666	6168	7	13.06	5874	9.12	2551	3.97
1917	18	5809	6061	8	11.34	5809	7.92	2084	3.45
1918	19	3035	5874	9	10.02	5760	7.00	1882	3.05
1919	20	8491	5809	10	8.98	5661	6.27	882	2.73
1920	21	2357	5760	11	8.13	5611	5.68	524	2.47
1921	22	2850	5716	12	7.43	5562	5.19	494	2.26
1922	23	6061	5661	13	6.84	5226	4.78	435	2.08
1923	24	4352	5611	14	6.34	5175	4.43	435	1.93
1924	25	12044	5562	15	5.90	4778	4.12	427	1.79
1925	26	1519	5226	16	5.53	4514	3.86	418	1.68
1926	27	4042	5175	17	5.19	4433	3.63	393	1.58
1927	28	2423	4778	18	4.90	4406	3.42	392	1.49
1928	29	2323	4514	19	4.63	4352	3.24	392	1.41
1929	30	4280	4433	20	4.40	4280	3.07	392	1.34
1930	31	5226	4406	21	4.18	4042	2.92	350	1.27
1931	32	2434	4352	22	3.99	4016	2.79	340	1.21
1932	33	878	4280	23	3.81	4000	2.66	262	1.16
1933	34	9096	4042	24	3.65	3808	2.55	238	1.11
1934	35	4406	4016	25	3.50	3701	2.45	233	1.07
1935	36	2357	4000	26	3.37	3701	2.35	193	1.02
1936	37	5611	3808	27	3.24	3666	2.26		
1937	38	3463	3701	28	3.12	3580	2.18		
1938	39	5175	3701	29	3.01	3522	2.10		
1939	40	4016	3666	30	2.91	3463	2.03		
1940	41	2588	3618	31	2.82	3375	1.97		
1941	42	3701	3580	32	2.73	3217	1.91		
1942	43	4433	3522	33	2.64	3106	1.85		
1943	44	5562	3512	34	2.57	3066	1.79		
1944	45	3522	3463	35	2.49	3066	1.74		
1945	46	2532	3375	36	2.42	3035	1.69		
1946	47	1463	3217	37	2.36	2966	1.64		
1947	48	5874	3106	38	2.29	2912	1.60		
1948	49	727	3066	39	2.23	2850	1.56		
1949	50	3375	3066	40	2.18	2588	1.52		
1950	51	3580	3035	41	2.12	2539	1.48		
1951	52	2912	2966	42	2.07	2532	1.45		
1952	53	2401	2912	43	2.02	2434	1.41		
1953	54	2966	2850	44	1.98	2423	1.38		
1954	55	6168	2700	45	1.93	2423	1.35		
1955	56	3701	2588	46	1.89	2401	1.32		
1956	57	4000	2551	47	1.85	2368	1.29		

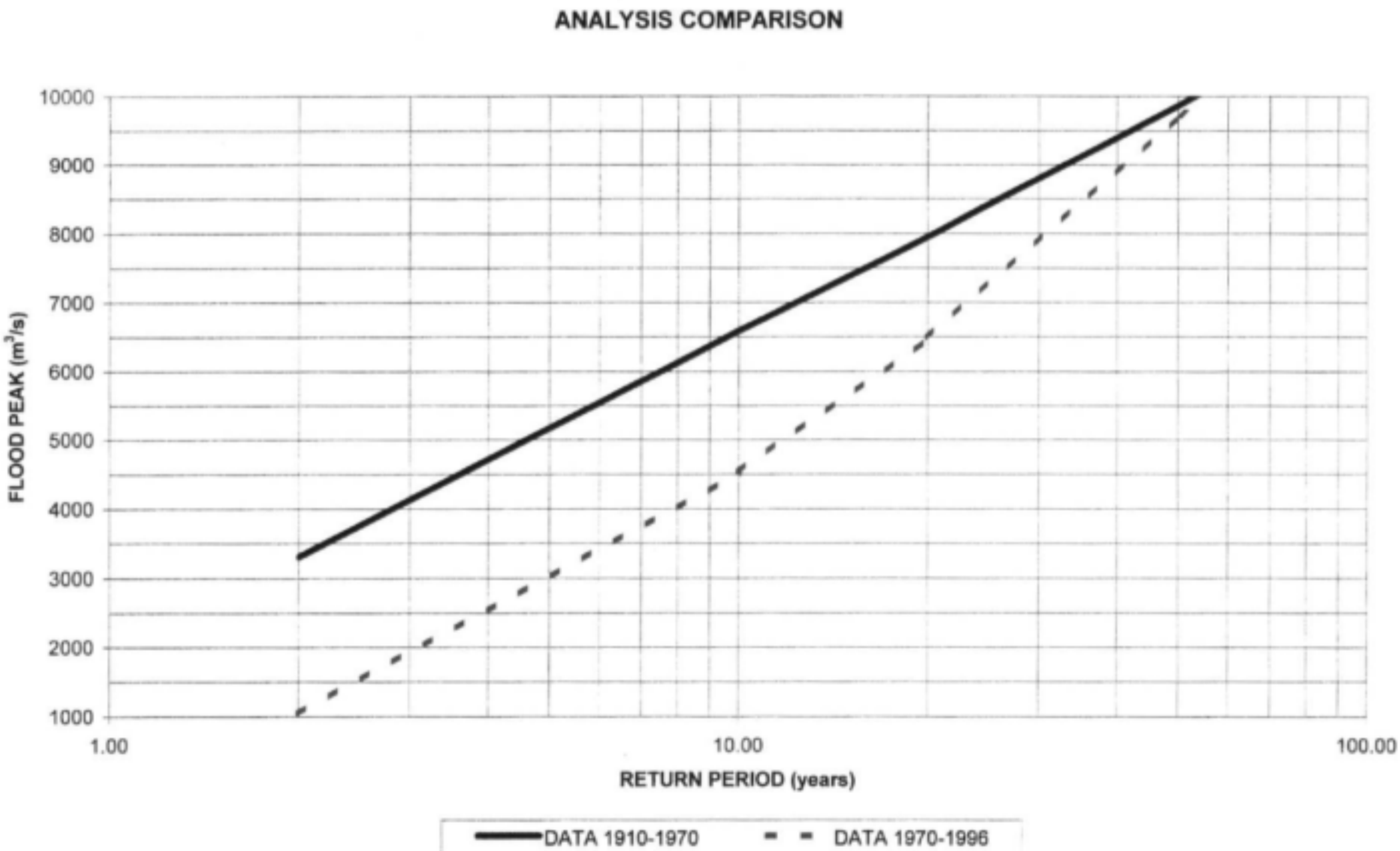
Appendix B-2

ANALYSIS OF DATA FOR VARIOUS PERIODS

Data			Comparison of Data for Various Periods						
			1910-1996			1910-1970		1970-1996	
Hidro-Year		Maximum Discharge (m^3/s)	Ranked Discharge (m^3/s)	Rank	Plotting Position	Ranked Discharge (m^3/s)	Plotting Position	Ranked Discharge (m^3/s)	Plotting Position
1957	58	5661	2539	48	1.81	2357	1.26		
1958	59	3066	2532	49	1.77	2357	1.24		
1959	60	1576	2434	50	1.74	2323	1.21		
1960	61	4514	2423	51	1.70	1914	1.19		
1961	62	3217	2423	52	1.67	1717	1.17		
1962	63	3066	2401	53	1.64	1604	1.14		
1963	64	2423	2368	54	1.61	1576	1.12		
1964	65	3808	2357	55	1.58	1519	1.10		
1965	66	5760	2357	56	1.55	1463	1.08		
1966	67	7499	2323	57	1.52	1188	1.06		
1967	68	1188	2084	58	1.50	993	1.05		
1968	69	1914	1914	59	1.47	878	1.03		
1969	70	1604	1882	60	1.45	727	1.01		
1970	71	392	1717	61	1.42				
1971	72	2551	1604	62	1.40				
1972	73	418	1576	63	1.38				
1973	74	10460	1519	64	1.36				
1974	75	3512	1463	65	1.33				
1975	76	5716	1188	66	1.31				
1976	77	2084	993	67	1.29				
1977	78	1882	882	68	1.28				
1978	79	392	878	69	1.26				
1979	80	262	727	70	1.24				
1980	81	435	524	71	1.22				
1981	82	393	494	72	1.20				
1982	83	233	435	73	1.19				
1983	84	392	435	74	1.17				
1984	85	340	427	75	1.16				
1985	86	494	418	76	1.14				
1986	87	427	393	77	1.13				
1987	88	8761	392	78	1.11				
1988	89	3618	392	79	1.10				
1989	90	350	392	80	1.08				
1990	91	882	350	81	1.07				
1991	92	524	340	82	1.06				
1992	93	193	262	83	1.04				
1993	94	238	238	84	1.03				
1994	95	435	233	85	1.02				
1995	96	2700	193	86	1.01				
Mean			**3190**			**3770**		**1849**	



DATA SERIES COMPARISON
10000
1000
100
FLOOD PEAK (m³/s)
1.00
10.00
100.00
RETURN PERIOD (years)
1910-1996
1910-1970
1970-1996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FLOOD PEAK (m³/s)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1.00
10.00
100.00
RETURN PERIOD (years)
DATA 1910-1970
DATA 1970-1996

APPENDIX C

ESTIMATED WATER LEVELS FOR VARIOUS SCENARIOS

Scenario " 0 " - Natural No Levees

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)												Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	RMF	
Main	50	39539	802.57	809.31	810.51	810.96	811.45	812.04	812.45	812.88	813.44	813.85	814.96	815.31	814.86	NA
	49	38534	803.02	808.61	809.70	810.12	810.54	811.05	811.41	811.79	812.28	812.65	813.67	814.00	813.58	NA
	48	37463	801.66	807.65	808.69	809.06	809.42	809.87	810.20	810.55	810.99	811.34	812.34	812.68	812.25	NA
	47	36424	801.13	806.55	807.43	807.73	808.07	808.50	808.81	809.15	809.59	809.96	811.02	811.38	810.93	NA
	46	35727	800.61	804.67	805.52	805.88	806.28	806.77	807.15	807.55	808.08	808.50	809.67	810.06	809.57	NA
	45	35234	799.76	803.20	804.18	804.55	805.02	805.62	806.08	806.55	807.14	807.60	808.83	809.24	808.73	NA
	44	34329	798.00	801.57	802.84	803.35	803.96	804.66	805.16	805.68	806.28	806.75	808.00	808.40	807.89	NA
	43	33531	795.42	800.97	802.39	802.95	803.59	804.30	804.80	805.32	805.92	806.38	807.61	808.00	807.50	NA
	42	32671	794.43	800.30	801.64	802.15	802.77	803.43	803.91	804.39	804.93	805.35	806.45	806.80	806.36	NA
	41	31620	794.43	799.69	800.80	801.19	801.66	802.24	802.68	803.12	803.67	804.11	805.29	805.68	805.19	NA
	40	30645	793.11	799.40	800.48	800.86	801.31	801.88	802.31	802.74	803.28	803.71	804.86	805.24	804.76	NA
	39	29441	792.00	798.81	799.83	800.18	800.60	801.14	801.55	801.96	802.48	802.90	804.05	804.43	803.95	NA
	38	28375	790.34	798.00	799.03	799.43	799.88	800.43	800.83	801.26	801.79	802.22	803.39	803.77	803.29	NA
	37	27458	790.34	797.44	798.49	798.89	799.34	799.89	800.29	800.71	801.24	801.67	802.85	803.24	802.75	NA
	36	26568	790.30	796.74	797.77	798.13	798.57	799.11	799.49	799.90	800.42	800.83	801.96	802.36	801.86	NA
	35	25470	790.30	795.08	796.34	796.78	797.27	797.87	798.27	798.70	799.23	799.65	800.80	801.19	800.70	NA
	34	24542	788.06	794.53	795.65	796.07	796.52	797.08	797.48	797.90	798.44	798.85	799.99	800.37	799.89	NA
	33	23704	788.06	794.17	795.14	795.50	795.93	796.47	796.86	797.28	797.81	798.23	799.36	799.74	799.27	NA
	32	22947	787.82	793.82	794.76	795.12	795.55	796.09	796.49	796.91	797.45	797.87	799.02	799.40	798.92	NA
	31	22160	787.81	793.29	794.32	794.67	795.10	795.65	796.05	796.47	797.01	797.43	798.57	798.95	798.47	NA
	30	21122	787.23	791.50	792.95	793.44	793.98	794.61	795.05	795.51	796.08	796.52	797.68	798.07	797.58	NA
	29	20557	785.03	791.41	792.84	793.32	793.85	794.45	794.89	795.33	795.90	796.33	797.48	797.86	797.38	NA
	28	20118	784.05	791.16	792.50	792.96	793.45	794.02	794.43	794.86	795.40	795.81	796.93	797.31	796.84	NA
	27	19516	784.00	790.73	792.07	792.54	793.04	793.63	794.04	794.48	795.03	795.44	796.56	796.93	796.46	NA
	26	18928	784.00	790.42	791.47	791.85	792.31	792.85	793.23	793.62	794.10	794.49	795.52	795.86	795.44	NA
	25	18646	784.00	790.32	791.38	791.75	792.20	792.73	793.10	793.49	793.97	794.35	795.38	795.71	795.29	NA
	24	18371	784.00	790.18	791.19	791.54	791.98	792.48	792.84	793.20	793.66	794.02	794.99	795.30	794.91	NA
	23	17725	784.00	789.81	790.74	791.08	791.51	791.99	792.31	792.65	793.08	793.42	794.34	794.64	794.26	NA
	22	17151	784.00	789.18	790.05	790.40	790.84	791.32	791.63	791.95	792.36	792.69	793.57	793.86	793.49	NA
	21	16097	784.00	787.12	788.01	788.38	788.75	789.28	789.59	789.92	790.33	790.66	791.56	791.86	791.48	NA
	20 A	15350	781.80	786.11	786.80	787.15	787.53	788.03	788.37	788.72	789.16	789.51	790.48	790.81	790.40	NA
	20	14779	781.76	784.23	785.42	785.85	786.34	786.93	787.33	787.71	788.19	788.57	789.57	789.91	789.48	NA
	19	13641	777.11	783.88	784.98	785.37	785.81	786.39	786.77	787.13	787.60	787.96	788.93	789.26	788.85	NA
	18	12496	776.51	783.28	784.36	784.71	785.11	785.66	786.01	786.35	786.78	787.11	788.01	788.32	787.93	NA

Scenario " 0 " - Natural No Levees

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)												Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	RMF	
	17	11032	775.00	782.49	783.40	783.71	784.05	784.48	784.80	785.11	785.49	785.80	786.60	786.87	786.53	NA
	16	9535	775.00	781.16	781.97	782.28	782.61	782.99	783.28	783.56	783.91	784.19	784.93	785.18	784.87	NA
	15	8375	774.00	779.11	780.61	780.92	781.28	781.69	782.03	782.36	782.72	782.99	783.74	784.00	783.68	NA
	14	7413	772.07	778.34	779.75	780.01	780.38	780.83	781.18	781.54	781.88	782.14	782.87	783.13	782.81	NA
	13	6209	772.07	776.63	778.11	778.47	778.93	779.49	779.82	780.18	780.54	780.82	781.60	781.87	781.53	NA
	12	4930	770.16	776.16	777.22	777.57	777.96	778.45	778.76	779.08	779.46	779.76	780.54	780.80	780.47	NA
	11	3545	769.00	775.71	776.53	776.83	777.17	777.58	777.87	778.16	778.53	778.82	779.55	779.81	779.48	NA
**	10	2493	769.00	775.04	775.84	776.13	776.47	776.88	777.17	777.47	777.85	778.15	778.85	779.11	778.78	NA
	9	1501	769.00	774.28	775.05	775.32	775.66	776.09	776.38	776.69	777.07	777.37	777.94	778.19	777.88	NA
	8	368	767.95	773.26	774.13	774.41	774.76	775.18	775.48	775.79	776.18	776.49	776.74	777.00	776.68	NA
C2	7	6627	768.02	771.95	773.20	773.50	773.87	774.31	774.61	774.92	775.32	775.63	776.47	776.75	776.40	NA
	6	5355	764.53	770.81	771.89	772.19	772.55	772.98	773.27	773.57	773.94	774.22	774.97	775.22	774.91	NA
	5	3998	763.64	770.02	770.69	770.94	771.22	771.58	771.84	772.11	772.44	772.69	773.37	773.60	773.31	NA
	4	2919	763.64	769.10	769.66	769.88	770.15	770.47	770.72	770.96	771.27	771.52	772.17	772.38	772.11	NA
	3	1648	763.64	768.07	768.61	768.83	769.08	769.40	769.63	769.86	770.15	770.38	770.97	771.16	770.92	NA
	2	759	763.48	767.36	767.81	768.00	768.21	768.48	768.68	768.87	769.11	769.30	769.80	769.96	769.75	NA
	1	100	763.48	766.54	766.86	767.00	767.16	767.36	767.51	767.66	767.86	768.01	768.41	768.55	768.38	NA
C3	7	6783	767.87	770.81	772.08	772.48	772.91	773.42	773.81	774.15	774.55	774.86	775.69	775.95	775.62	NA
	6	5564	764.52	770.33	771.29	771.60	771.98	772.44	772.77	773.10	773.48	773.77	774.56	774.81	774.49	NA
	5	4162	763.64	769.84	770.71	771.00	771.34	771.79	772.08	772.37	772.73	773.01	773.78	774.03	773.72	NA
	4	3098	763.64	769.01	769.90	770.22	770.59	771.02	771.30	771.58	771.94	772.22	773.00	773.24	772.93	NA
	3	1851	763.64	768.09	768.86	769.14	769.49	769.87	770.15	770.43	770.78	771.06	771.81	772.05	771.74	NA
	2	842	763.64	767.44	768.03	768.25	768.52	768.87	769.11	769.36	769.68	769.93	770.59	770.81	770.53	NA
	1	129	763.64	766.69	767.18	767.38	767.58	767.85	768.05	768.26	768.52	768.72	769.26	769.45	769.21	NA

** Water level in side canal downstream of Top House will be the same as the water level for this cross section 10

NA Not Applicable

Scenario " 1 " - Levees constructed for 3200m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	802.57	809.42	810.84	811.34	811.91	812.54	812.96	813.37	813.84	814.19	815.02	815.27	809.52
	49	38534	803.02	808.75	810.02	810.48	810.98	811.55	811.93	812.30	812.72	813.03	813.78	814.00	808.85
	48	37463	801.66	807.75	808.93	809.35	809.82	810.34	810.69	811.03	811.43	811.71	812.40	812.61	807.85
	47	36424	801.13	806.52	807.63	808.03	808.47	808.96	809.30	809.61	809.98	810.25	810.91	811.10	806.62
	46	35727	800.61	804.74	806.06	806.53	807.06	807.65	808.05	808.43	808.87	809.19	809.97	810.20	804.84
	45	35234	799.76	803.21	804.67	805.19	805.77	806.42	806.86	807.28	807.76	808.12	808.97	809.23	803.31
	44	34329	798.00	801.53	803.19	803.78	804.45	805.19	805.68	806.16	806.72	807.12	808.10	808.39	801.63
	43	33531	795.42	800.89	802.61	803.22	803.91	804.68	805.19	805.68	806.26	806.68	807.69	807.99	800.99
	42	32671	794.43	800.16	801.76	802.33	802.96	803.67	804.15	804.61	805.14	805.53	806.47	806.75	800.26
	41	31620	794.43	799.48	800.97	801.49	802.09	802.75	803.19	803.62	804.12	804.48	805.35	805.61	799.58
	40	30645	793.11	799.15	800.62	801.14	801.73	802.39	802.83	803.25	803.74	804.10	804.96	805.22	799.25
	39	29441	792.00	798.24	799.74	800.27	800.86	801.53	801.98	802.41	802.91	803.27	804.15	804.41	798.34
	38	28375	790.34	797.44	798.97	799.51	800.11	800.79	801.25	801.69	802.20	802.57	803.46	803.73	797.54
	37	27458	790.34	796.96	798.48	799.02	799.62	800.30	800.76	801.19	801.70	802.07	802.96	803.23	797.06
	36	26568	790.30	796.19	797.67	798.20	798.79	799.45	799.90	800.32	800.82	801.18	802.05	802.31	796.29
	35	25470	790.30	795.15	796.62	797.14	797.73	798.39	798.83	799.25	799.74	800.10	800.96	801.22	795.25
	34	24542	788.06	794.77	796.15	796.63	797.18	797.79	798.20	798.60	799.06	799.39	800.20	800.44	794.87
	33	23704	788.06	794.46	795.75	796.21	796.73	797.30	797.69	798.06	798.49	798.81	799.56	799.79	794.56
	32	22947	787.82	794.06	795.37	795.83	796.35	796.93	797.32	797.69	798.13	798.45	799.21	799.44	794.16
	31	22160	787.81	793.44	794.79	795.27	795.80	796.41	796.81	797.19	797.64	797.97	798.76	799.00	793.54
	30	21122	787.23	791.56	793.16	793.73	794.36	795.07	795.55	796.01	796.54	796.93	797.87	798.15	791.66
	29	20557	785.03	791.52	793.08	793.63	794.25	794.95	795.41	795.86	796.38	796.76	797.68	797.95	791.62
	28	20118	784.05	791.28	792.75	793.27	793.85	794.51	794.94	795.37	795.85	796.21	797.07	797.33	791.38
	27	19516	784.00	790.78	792.29	792.82	793.42	794.09	794.54	794.97	795.48	795.84	796.73	796.99	790.88
	26	18928	784.00	790.43	791.77	792.25	792.78	793.38	793.78	794.16	794.61	794.94	795.72	795.96	790.53
	25	18646	784.00	790.31	791.65	792.12	792.66	793.25	793.65	794.04	794.48	794.81	795.59	795.83	790.41
	24	18371	784.00	790.14	791.42	791.88	792.38	792.96	793.34	793.71	794.13	794.44	795.20	795.42	790.24
	23	17725	784.00	789.70	790.94	791.38	791.87	792.42	792.79	793.14	793.56	793.86	794.58	794.80	789.80
	22	17151	784.00	788.99	790.19	790.62	791.10	791.64	792.00	792.34	792.74	793.03	793.74	793.95	789.09
	21	16097	784.00	787.07	788.23	788.65	789.11	789.63	789.98	790.31	790.70	790.98	791.67	791.87	787.17
	20 A	15350	781.80	786.10	787.25	787.65	788.11	788.62	788.96	789.29	789.67	789.95	790.62	790.82	786.20
	20	14779	781.76	784.24	785.62	786.10	786.65	787.26	787.67	788.07	788.53	788.86	789.67	789.91	784.34
	19	13641	777.11	783.82	785.14	785.61	786.14	786.73	787.13	787.51	787.95	788.27	789.05	789.28	783.92
	18	12496	776.51	783.21	784.46	784.90	785.40	785.95	786.32	786.68	787.10	787.40	788.13	788.35	783.31
	17	11032	775.00	782.45	783.55	783.94	784.38	784.87	785.20	785.51	785.88	786.14	786.79	786.98	782.55
	16	9535	775.00	780.79	781.89	782.29	782.72	783.22	783.55	783.86	784.23	784.50	785.15	785.34	780.89

Scenario " 1 " - Levees constructed for 3200m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
	15	8375	774.00	779.15	780.38	780.81	781.30	781.84	782.21	782.56	782.97	783.27	783.98	784.20	779.25
	14	7413	772.07	778.32	779.55	779.98	780.47	781.02	781.39	781.74	782.15	782.45	783.16	783.38	778.42
	13	6209	772.07	776.58	778.00	778.50	779.06	779.70	780.12	780.52	781.00	781.34	782.17	782.42	776.68
	12	4930	770.16	776.13	777.39	777.84	778.34	778.90	779.27	779.64	780.05	780.36	781.10	781.32	776.23
	11	3545	769.00	775.65	776.71	777.09	777.51	777.99	778.30	778.61	778.96	779.22	779.84	780.03	775.75
	10	2493	769.00	775.15	776.22	776.60	777.03	777.51	777.83	778.14	778.49	778.75	779.38	779.57	775.25
	9	1501	769.00	774.32	775.35	775.71	776.12	776.58	776.88	777.18	777.52	777.77	778.37	778.55	774.42
	8	368	767.95	773.09	774.20	774.59	775.03	775.53	775.86	776.18	776.55	776.82	777.47	777.66	773.19
C2	7	6627	768.02	771.82	772.99	773.40	773.87	774.39	774.73	775.07	775.46	775.74	776.43	776.63	771.92
	6	5355	764.53	770.64	771.72	772.10	772.53	773.01	773.34	773.65	774.01	774.27	774.90	775.09	770.74
	5	3998	763.64	770.08	770.93	771.23	771.57	771.95	772.21	772.45	772.74	772.94	773.44	773.59	770.18
	4	2919	763.64	769.72	770.36	770.59	770.84	771.13	771.32	771.50	771.72	771.87	772.25	772.36	769.82
	3	1648	763.64	768.89	769.44	769.63	769.85	770.09	770.25	770.41	770.59	770.72	771.04	771.14	768.99
	2	759	763.48	767.98	768.45	768.62	768.81	769.02	769.16	769.30	769.46	769.57	769.85	769.93	768.08
	1	100	763.48	767.06	767.43	767.56	767.70	767.87	767.98	768.08	768.20	768.29	768.51	768.57	767.16
C3	7	6783	767.87	773.82	774.63	774.92	775.24	775.60	775.84	776.07	776.34	776.54	777.01	777.15	773.92
	6	5564	764.52	770.68	771.65	771.99	772.37	772.80	773.09	773.37	773.69	773.92	774.49	774.66	770.78
	5	4162	763.64	770.21	771.14	771.47	771.83	772.25	772.53	772.79	773.10	773.32	773.87	774.03	770.31
	4	3098	763.64	769.47	770.39	770.71	771.08	771.49	771.76	772.02	772.33	772.55	773.09	773.25	769.57
	3	1851	763.64	768.78	769.57	769.85	770.16	770.51	770.75	770.98	771.24	771.43	771.89	772.03	768.88
	2	842	763.64	768.00	768.69	768.93	769.20	769.51	769.72	769.91	770.14	770.31	770.71	770.83	768.10
	1	129	763.64	766.85	767.48	767.70	767.95	768.23	768.42	768.60	768.81	768.96	769.33	769.44	766.95

Scenario " 2 " - Levees constructed for 5400m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	802.57	809.42	810.65	811.17	811.76	812.42	812.87	813.29	813.78	814.14	815.01	815.27	810.75
	49	38534	803.02	808.75	809.85	810.32	810.85	811.44	811.84	812.22	812.66	812.99	813.77	814.00	809.95
	48	37463	801.66	807.75	808.85	809.28	809.76	810.30	810.66	811.00	811.41	811.70	812.41	812.62	808.95
	47	36424	801.13	806.52	807.38	807.81	808.29	808.82	809.18	809.53	809.93	810.22	810.93	811.14	807.48
	46	35727	800.61	804.74	805.60	806.12	806.71	807.37	807.81	808.23	808.72	809.08	809.94	810.20	805.70
	45	35234	799.76	803.21	804.19	804.76	805.40	806.12	806.61	807.07	807.61	808.00	808.95	809.23	804.29
	44	34329	798.00	801.53	802.94	803.56	804.25	805.03	805.55	806.05	806.63	807.06	808.08	808.39	803.04
	43	33531	795.42	800.89	802.55	803.17	803.86	804.64	805.16	805.66	806.24	806.66	807.68	807.99	802.65
	42	32671	794.43	800.16	801.89	802.44	803.06	803.76	804.22	804.67	805.19	805.56	806.48	806.75	801.99
	41	31620	794.43	799.48	801.25	801.75	802.30	802.93	803.35	803.75	804.21	804.55	805.37	805.62	801.35
	40	30645	793.11	799.15	801.03	801.51	802.04	802.65	803.05	803.44	803.88	804.21	805.00	805.24	801.13
	39	29441	792.00	798.24	800.33	800.80	801.32	801.90	802.30	802.67	803.11	803.43	804.20	804.43	800.43
	38	28375	790.34	797.44	799.27	799.78	800.35	800.99	801.42	801.83	802.31	802.66	803.51	803.76	799.37
	37	27458	790.34	796.96	798.68	799.20	799.78	800.44	800.88	801.30	801.79	802.14	803.00	803.26	798.78
	36	26568	790.30	796.19	797.70	798.23	798.82	799.49	799.93	800.36	800.85	801.22	802.09	802.35	797.80
	35	25470	790.30	795.15	796.51	797.05	797.66	798.35	798.80	799.24	799.75	800.12	801.02	801.29	796.61
	34	24542	788.06	794.77	796.10	796.60	797.16	797.79	798.21	798.62	799.09	799.43	800.26	800.51	796.20
	33	23704	788.06	794.46	795.81	796.26	796.77	797.35	797.73	798.10	798.52	798.83	799.59	799.81	795.91
	32	22947	787.82	794.06	795.42	795.88	796.39	796.97	797.36	797.73	798.16	798.47	799.23	799.46	795.52
	31	22160	787.81	793.44	794.76	795.24	795.79	796.40	796.80	797.19	797.65	797.98	798.78	799.02	794.86
	30	21122	787.23	791.56	793.42	793.96	794.57	795.25	795.70	796.14	796.65	797.02	797.91	798.18	793.52
	29	20557	785.03	791.52	793.41	793.93	794.51	795.17	795.61	796.03	796.52	796.87	797.73	797.99	793.51
	28	20118	784.05	791.28	793.11	793.59	794.14	794.75	795.15	795.54	796.00	796.33	797.13	797.37	793.21
	27	19516	784.00	790.78	792.25	792.79	793.40	794.09	794.55	794.99	795.50	795.87	796.77	797.04	792.35
	26	18928	784.00	790.43	791.86	792.33	792.87	793.47	793.86	794.25	794.69	795.02	795.80	796.04	791.96
	25	18646	784.00	790.31	791.80	792.27	792.79	793.38	793.78	794.15	794.59	794.91	795.69	795.92	791.90
	24	18371	784.00	790.14	791.64	792.08	792.58	793.14	793.51	793.87	794.28	794.59	795.32	795.54	791.74
	23	17725	784.00	789.70	791.13	791.55	792.02	792.56	792.91	793.25	793.65	793.93	794.63	794.84	791.23
	22	17151	784.00	788.99	790.24	790.66	791.14	791.67	792.02	792.37	792.76	793.05	793.75	793.96	790.34
	21	16097	784.00	787.07	787.97	788.42	788.91	789.48	789.85	790.21	790.63	790.93	791.67	791.89	788.07
	20 A	15350	781.80	786.10	786.82	787.28	787.79	788.37	788.75	789.12	789.55	789.87	790.62	790.85	786.92
	20	14779	781.76	784.24	785.82	786.29	786.82	787.41	787.81	788.19	788.63	788.95	789.73	789.96	785.92
	19	13641	777.11	783.82	785.53	785.97	786.45	787.00	787.37	787.72	788.13	788.43	789.14	789.36	785.63
	18	12496	776.51	783.21	784.86	785.27	785.73	786.25	786.60	786.93	787.32	787.60	788.28	788.48	784.96
	17	11032	775.00	782.45	784.10	784.46	784.86	785.31	785.62	785.91	786.24	786.49	787.08	787.26	784.20
	16	9535	775.00	780.79	782.05	782.44	782.88	783.38	783.71	784.03	784.40	784.67	785.32	785.51	782.15

Scenario " 2 " - Levees constructed for 5400m³/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
	15	8375	774.00	779.15	780.94	781.31	781.73	782.20	782.51	782.81	783.16	783.42	784.04	784.22	781.04
	14	7413	772.07	778.32	780.16	780.53	780.94	781.40	781.70	782.00	782.34	782.59	783.20	783.38	780.26
	13	6209	772.07	776.58	778.50	778.95	779.45	780.01	780.38	780.75	781.17	781.47	782.21	782.43	778.60
	12	4930	770.16	776.13	778.07	778.44	778.86	779.32	779.63	779.93	780.28	780.53	781.15	781.33	778.17
	11	3545	769.00	775.65	777.48	777.77	778.09	778.46	778.70	778.94	779.21	779.41	779.89	780.03	777.58
	10	2493	769.00	775.15	776.85	777.16	777.51	777.90	778.16	778.41	778.70	778.91	779.43	779.58	776.95
	9	1501	769.00	774.32	775.89	776.19	776.53	776.91	777.17	777.41	777.69	777.90	778.40	778.55	775.99
	8	368	767.95	773.09	774.40	774.77	775.19	775.66	775.97	776.27	776.62	776.87	777.49	777.67	774.50
C2	7	6627	768.02	771.82	773.23	773.63	774.08	774.58	774.91	775.24	775.61	775.88	776.54	776.74	773.33
	6	5355	764.53	770.64	771.77	772.15	772.57	773.05	773.36	773.67	774.02	774.28	774.90	775.09	771.87
	5	3998	763.64	770.08	771.23	771.50	771.80	772.14	772.36	772.58	772.83	773.01	773.46	773.59	771.33
	4	2919	763.64	769.72	770.98	771.14	771.32	771.51	771.65	771.77	771.92	772.03	772.29	772.37	771.08
	3	1648	763.64	768.89	770.20	770.31	770.43	770.56	770.65	770.74	770.84	770.91	771.09	771.14	770.30
	2	759	763.48	767.98	768.92	769.03	769.16	769.31	769.40	769.50	769.61	769.68	769.87	769.93	769.02
	1	100	763.48	767.06	767.83	767.91	768.01	768.11	768.19	768.25	768.33	768.39	768.53	768.57	767.93
C3	7	6783	767.87	773.82	774.51	774.81	775.15	775.53	775.78	776.02	776.31	776.51	777.01	777.16	774.61
	6	5564	764.52	770.68	772.66	772.89	773.14	773.43	773.62	773.81	774.02	774.18	774.56	774.67	772.76
	5	4162	763.64	770.21	771.30	771.61	771.96	772.35	772.61	772.86	773.15	773.36	773.88	774.03	771.40
	4	3098	763.64	769.47	770.90	771.17	771.47	771.80	772.03	772.24	772.49	772.68	773.12	773.25	771.00
	3	1851	763.64	768.78	769.92	770.16	770.43	770.73	770.93	771.13	771.35	771.52	771.91	772.03	770.02
	2	842	763.64	768.00	768.91	769.13	769.37	769.65	769.83	770.01	770.21	770.36	770.72	770.83	769.01
	1	129	763.64	766.85	767.55	767.77	768.01	768.28	768.46	768.63	768.83	768.98	769.33	769.44	767.65

Scenario " 3 " - Levees constructed for 6500m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	802.570	809.42	810.65	811.14	811.73	812.40	812.84	813.27	813.77	814.13	815.01	815.27	811.24
	49	38534	803.020	808.75	809.85	810.30	810.83	811.43	811.83	812.21	812.66	812.98	813.77	814.00	810.40
	48	37463	801.660	807.75	808.85	809.29	809.77	810.31	810.67	811.01	811.42	811.71	812.42	812.63	809.39
	47	36424	801.130	806.52	807.38	807.68	808.18	808.74	809.12	809.48	809.90	810.20	810.94	811.16	807.78
	46	35727	800.610	804.74	805.60	805.95	806.56	807.25	807.70	808.14	808.66	809.03	809.93	810.20	806.05
	45	35234	799.760	803.21	804.19	804.58	805.25	806.00	806.50	806.98	807.54	807.95	808.93	809.23	804.68
	44	34329	798.000	801.53	802.94	803.56	804.25	805.03	805.55	806.05	806.64	807.06	808.08	808.39	803.66
	43	33531	795.420	800.89	802.55	803.24	803.92	804.69	805.20	805.69	806.26	806.68	807.69	807.99	803.34
	42	32671	794.430	800.16	801.89	802.57	803.17	803.85	804.30	804.73	805.24	805.61	806.49	806.76	802.67
	41	31620	794.430	799.48	801.25	801.92	802.45	803.05	803.45	803.84	804.28	804.61	805.39	805.63	802.02
	40	30645	793.110	799.15	801.03	801.73	802.24	802.80	803.18	803.55	803.97	804.28	805.03	805.25	801.83
	39	29441	792.000	798.24	800.33	801.11	801.59	802.13	802.49	802.83	803.24	803.53	804.24	804.45	801.21
	38	28375	790.340	797.44	799.27	800.00	800.54	801.15	801.56	801.95	802.41	802.74	803.54	803.78	800.10
	37	27458	790.340	796.96	798.68	799.36	799.92	800.56	800.98	801.38	801.86	802.20	803.03	803.28	799.46
	36	26568	790.300	796.19	797.70	798.27	798.86	799.53	799.97	800.40	800.89	801.26	802.13	802.39	798.37
	35	25470	790.300	795.15	796.51	797.06	797.68	798.37	798.83	799.28	799.80	800.18	801.09	801.36	797.16
	34	24542	788.060	794.77	796.10	796.66	797.22	797.85	798.27	798.67	799.14	799.49	800.31	800.56	796.76
	33	23704	788.060	794.46	795.81	796.37	796.87	797.43	797.80	798.16	798.57	798.88	799.61	799.83	796.47
	32	22947	787.820	794.06	795.42	795.97	796.47	797.04	797.42	797.78	798.21	798.51	799.26	799.48	796.07
	31	22160	787.810	793.44	794.76	795.28	795.82	796.43	796.83	797.22	797.67	798.00	798.80	799.04	795.38
	30	21122	787.230	791.56	793.42	794.05	794.65	795.32	795.77	796.20	796.70	797.06	797.95	798.21	794.15
	29	20557	785.030	791.52	793.41	794.06	794.63	795.27	795.69	796.10	796.58	796.93	797.77	798.02	794.16
	28	20118	784.050	791.28	793.11	793.70	794.23	794.83	795.23	795.62	796.06	796.39	797.17	797.41	793.80
	27	19516	784.000	790.78	792.25	792.80	793.42	794.11	794.57	795.01	795.53	795.91	796.82	797.09	792.90
	26	18928	784.000	790.43	791.86	792.46	792.99	793.58	793.97	794.35	794.79	795.11	795.89	796.12	792.56
	25	18646	784.000	790.31	791.80	792.41	792.93	793.51	793.90	794.27	794.70	795.02	795.78	796.01	792.51
	24	18371	784.000	790.14	791.64	792.25	792.74	793.28	793.65	794.00	794.41	794.71	795.42	795.64	792.35
	23	17725	784.000	789.70	791.13	791.72	792.18	792.70	793.05	793.38	793.76	794.05	794.73	794.93	791.82
	22	17151	784.000	788.99	790.24	790.76	791.23	791.75	792.10	792.43	792.82	793.11	793.79	794.00	790.86
	21	16097	784.000	787.07	787.97	788.34	788.85	789.43	789.81	790.18	790.61	790.92	791.67	791.90	788.44
	20 A	15350	781.800	786.10	786.82	787.23	787.75	788.34	788.73	789.11	789.55	789.87	790.64	790.87	787.33
	20	14779	781.760	784.24	785.82	786.45	786.96	787.53	787.92	788.28	788.71	789.02	789.77	790.00	786.55
	19	13641	777.110	783.62	785.53	786.20	786.66	787.18	787.53	787.86	788.24	788.53	789.21	789.41	786.30
	18	12496	776.510	783.21	784.86	785.47	785.91	786.41	786.75	787.07	787.44	787.71	788.36	788.56	785.57
	17	11032	775.000	782.45	784.10	784.75	785.14	785.57	785.86	786.13	786.46	786.69	787.26	787.43	784.85

Scenario " 3 " - Levees constructed for 6500m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
	16	9535	775.000	780.79	782.05	782.65	783.09	783.59	783.92	784.24	784.61	784.88	785.53	785.72	782.75
	15	8375	774.000	779.15	780.94	781.72	782.09	782.50	782.77	783.04	783.34	783.57	784.11	784.27	781.82
	14	7413	772.070	778.32	780.16	780.97	781.32	781.71	781.97	782.22	782.51	782.72	783.24	783.39	781.07
	13	6209	772.070	776.58	778.50	779.37	779.81	780.30	780.63	780.95	781.32	781.59	782.24	782.43	779.47
	12	4930	770.160	776.13	778.07	778.88	779.23	779.63	779.89	780.15	780.44	780.66	781.17	781.33	778.98
	11	3545	769.000	775.65	777.48	778.23	778.49	778.78	778.97	779.16	779.38	779.53	779.92	780.03	778.33
	10	2493	769.000	775.15	776.85	777.55	777.84	778.17	778.39	778.60	778.84	779.02	779.45	779.58	777.65
	9	1501	769.000	774.32	775.89	776.55	776.84	777.16	777.38	777.59	777.83	778.01	778.43	778.56	776.65
	8	368	767.950	773.09	774.40	774.87	775.27	775.72	776.03	776.32	776.65	776.90	777.49	777.67	774.97
C2	7	6627	768.020	771.82	773.23	773.76	774.19	774.67	774.99	775.30	775.66	775.92	776.55	776.74	773.86
	6	5355	764.530	770.64	771.77	772.18	772.60	773.07	773.38	773.68	774.03	774.29	774.91	775.09	772.28
	5	3998	763.640	770.08	771.23	771.75	772.01	772.31	772.51	772.70	772.92	773.08	773.47	773.59	771.85
	4	2919	763.640	769.72	770.98	771.56	771.68	771.81	771.89	771.98	772.08	772.15	772.32	772.37	771.66
	3	1648	763.640	768.89	770.20	770.75	770.81	770.87	770.91	770.95	771.00	771.03	771.12	771.14	770.85
	2	759	763.480	767.98	768.92	769.30	769.39	769.49	769.56	769.63	769.70	769.76	769.89	769.93	769.40
	1	100	763.480	767.06	767.83	768.16	768.21	768.28	768.32	768.36	768.40	768.44	768.52	768.54	768.26
C3	7	6783	767.870	773.82	774.51	774.80	774.81	774.83	774.84	774.85	774.86	774.87	774.89	774.90	774.90
	6	5564	764.520	770.68	772.66	772.64	772.65	772.67	772.68	772.69	772.70	772.71	772.73	772.74	772.74
	5	4162	763.640	770.21	771.30	771.67	771.79	771.92	772.01	772.10	772.20	772.27	772.45	772.50	771.77
	4	3098	763.640	769.47	770.90	771.18	771.18	771.19	771.19	771.20	771.20	771.20	771.21	771.21	771.28
	3	1851	763.640	768.78	769.92	770.37	770.38	770.40	770.41	770.42	770.43	770.44	770.46	770.47	770.47
	2	842	763.640	768.00	768.91	769.28	769.29	769.31	769.32	769.33	769.34	769.35	769.37	769.38	769.38
	1	129	763.640	766.85	767.55	767.84	767.89	767.96	768.00	768.04	768.08	768.12	768.20	768.22	767.94

Scenario " 4 " - Levees constructed for 8000m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	802.570	809.42	810.65	811.14	811.66	812.36	812.82	813.27	813.78	814.16	815.08	815.35	811.76
	49	38534	803.020	808.75	809.85	810.30	810.73	811.38	811.82	812.24	812.72	813.08	813.93	814.19	810.83
	48	37463	801.660	807.75	808.85	809.29	809.72	810.35	810.77	811.17	811.64	811.98	812.80	813.05	809.82
	47	36424	801.130	806.52	807.38	807.68	808.04	808.65	809.06	809.45	809.91	810.24	811.04	811.28	808.14
	46	35727	800.610	804.74	805.60	805.95	806.36	807.09	807.57	808.04	808.58	808.97	809.92	810.21	806.46
	45	35234	799.760	803.21	804.19	804.58	805.16	805.93	806.44	806.94	807.51	807.93	808.94	809.24	805.26
	44	34329	798.000	801.53	802.94	803.56	804.38	805.14	805.64	806.13	806.69	807.11	808.10	808.40	804.48
	43	33531	795.420	800.89	802.55	803.24	804.13	804.86	805.35	805.81	806.36	806.76	807.71	808.00	804.23
	42	32671	794.430	800.16	801.89	802.57	803.44	804.07	804.48	804.88	805.35	805.69	806.51	806.76	803.54
	41	31620	794.430	799.48	801.25	801.92	802.78	803.32	803.68	804.02	804.43	804.72	805.43	805.64	802.86
	40	30645	793.110	799.15	801.03	801.73	802.64	803.13	803.46	803.78	804.15	804.42	805.07	805.26	802.74
	39	29441	792.000	798.24	800.33	801.11	802.08	802.53	802.83	803.12	803.46	803.70	804.29	804.47	802.18
	38	28375	790.340	797.44	799.27	800.00	800.88	801.43	801.80	802.15	802.56	802.86	803.58	803.80	800.98
	37	27458	790.340	796.96	798.68	799.36	800.18	800.77	801.16	801.54	801.98	802.30	803.08	803.31	800.28
	36	26568	790.300	796.19	797.70	798.27	798.93	799.59	800.03	800.45	800.95	801.30	802.17	802.43	799.03
	35	25470	790.300	795.15	796.51	797.06	797.68	798.39	798.86	799.32	799.85	800.23	801.16	801.44	797.78
	34	24542	788.060	794.77	796.10	796.66	797.29	797.92	798.34	798.74	799.21	799.55	800.37	800.62	797.39
	33	23704	788.060	794.46	795.81	796.37	797.00	797.54	797.90	798.24	798.64	798.93	799.64	799.85	797.10
	32	22947	787.820	794.06	795.42	795.97	796.56	797.11	797.48	797.84	798.25	798.55	799.27	799.49	796.66
	31	22160	787.810	793.44	794.76	795.28	795.77	796.39	796.80	797.20	797.66	798.00	798.82	799.06	795.87
	30	21122	787.230	791.56	793.42	794.05	794.24	794.99	795.49	795.98	796.54	796.95	797.93	798.23	794.34
	29	20557	785.030	791.52	793.41	794.06	794.26	794.97	795.45	795.90	796.44	796.82	797.76	798.04	794.36
	28	20118	784.050	791.28	793.11	793.70	793.73	794.43	794.90	795.34	795.87	796.25	797.17	797.44	793.83
	27	19516	784.000	790.78	792.25	792.80	793.51	794.19	794.65	795.09	795.59	795.97	796.86	797.13	793.61
	26	18928	784.000	790.43	791.86	792.46	793.07	793.66	794.05	794.43	794.87	795.19	795.96	796.19	793.17
	25	18646	784.000	790.31	791.80	792.41	793.02	793.60	793.98	794.35	794.78	795.10	795.85	796.08	793.12
	24	18371	784.000	790.14	791.64	792.25	792.85	793.39	793.76	794.10	794.51	794.80	795.52	795.73	792.95
	23	17725	784.000	789.70	791.13	791.72	792.23	792.76	793.11	793.44	793.84	794.12	794.81	795.02	792.33
	22	17151	784.000	788.99	790.24	790.76	791.23	791.76	792.11	792.45	792.84	793.13	793.82	794.03	791.33
	21	16097	784.000	787.07	787.97	788.34	788.76	789.36	789.76	790.14	790.59	790.92	791.70	791.94	788.86
	20 A	15350	781.800	786.10	786.82	787.23	787.81	788.40	788.80	789.18	789.62	789.95	790.73	790.96	787.91
	20	14779	781.760	784.24	785.82	786.45	787.24	787.79	788.16	788.51	788.92	789.22	789.94	790.16	787.34
	19	13641	777.110	783.82	785.53	786.20	787.03	787.52	787.85	788.16	788.53	788.79	789.44	789.6[illegible]	787.13
	18	12496	776.510	783.21	784.86	785.47	786.24	786.72	787.04	787.35	787.70	787.96	788.59	788.78	786.34
	17	11032	775.000	782.45	784.10	784.75	785.57	785.98	786.25	786.51	786.81	787.03	787.56	787.72	785.67
	16	9535	775.000	780.79	782.05	782.65	783.39	783.89	784.22	784.53	784.90	785.17	785.83	786.02	783.49

Scenario " 4 " - Levees constructed for 8000m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
	15	8375	774.000	779.15	780.94	781.72	782.59	782.93	783.15	783.37	783.62	783.80	784.24	784.37	782.69
	14	7413	772.070	778.32	780.16	780.97	781.82	782.12	782.32	782.51	782.74	782.90	783.29	783.41	781.92
	13	6209	772.070	776.58	778.50	779.37	780.27	780.68	780.95	781.21	781.51	781.74	782.27	782.43	780.37
	12	4930	770.160	776.13	778.07	778.88	779.81	780.10	780.29	780.47	780.69	780.84	781.22	781.33	779.91
	11	3545	769.000	775.65	777.48	778.23	779.13	779.30	779.42	779.53	779.65	779.75	779.97	780.04	779.23
	10	2493	769.000	775.15	776.85	777.55	778.38	778.61	778.76	778.90	779.07	779.19	779.49	779.58	778.48
	9	1501	769.000	774.32	775.89	776.55	777.34	777.57	777.72	777.87	778.04	778.17	778.47	778.56	777.44
	8	368	767.950	773.09	774.40	774.87	775.45	775.87	776.15	776.42	776.73	776.96	777.51	777.67	775.55
C2	7	6627	768.020	771.82	773.23	773.76	774.42	774.86	775.15	775.43	775.76	776.00	776.58	776.75	774.52
	6	5355	764.530	770.64	771.77	772.18	772.72	773.17	773.47	773.76	774.09	774.34	774.92	775.10	772.82
	5	3998	763.640	770.08	771.23	771.75	772.45	772.67	772.82	772.97	773.14	773.26	773.55	773.64	772.55
	4	2919	763.640	769.72	770.98	771.56	772.30	772.34	772.37	772.39	772.42	772.44	772.49	772.51	772.40
	3	1648	763.640	768.89	770.20	770.75	771.44	771.46	771.47	771.48	771.50	771.51	771.53	771.54	771.54
	2	759	763.480	767.98	768.92	769.30	769.77	769.80	769.82	769.84	769.87	769.89	769.93	769.94	769.87
	1	100	763.480	767.06	767.83	768.16	768.58	768.60	768.61	768.62	768.64	768.65	768.67	768.68	768.68
C3	7	6783	767.870	773.82	774.51	774.80	775.18	775.55	775.80	776.04	776.32	776.52	777.01	777.16	775.28
	6	5564	764.520	770.68	772.66	772.64	773.37	773.62	773.78	773.94	774.12	774.25	774.57	774.67	773.47
	5	4162	763.640	770.21	771.30	771.67	772.23	772.57	772.80	773.01	773.27	773.45	773.90	774.03	772.33
	4	3098	763.640	769.47	770.90	771.18	771.77	772.05	772.24	772.41	772.62	772.77	773.14	773.25	771.87
	3	1851	763.640	768.78	769.92	770.37	770.92	771.13	771.27	771.41	771.57	771.68	771.96	772.04	771.02
	2	842	763.640	768.00	768.91	769.28	769.70	769.92	770.06	770.20	770.36	770.47	770.76	770.84	769.80
	1	129	763.640	766.85	767.55	767.84	768.17	768.41	768.57	768.72	768.90	769.03	769.35	769.44	768.27

Scenario " 5 " - Levees constructed for 10000m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	802.570	809.42	810.65	811.14	811.66	812.30	812.78	813.24	813.77	814.16	815.10	815.38	812.40
	49	38534	803.020	808.75	809.85	810.30	810.73	811.27	811.73	812.17	812.69	813.06	813.97	814.24	811.37
	48	37463	801.660	807.75	808.85	809.29	809.72	810.26	810.71	811.14	811.64	812.01	812.90	813.16	810.36
	47	36424	801.130	806.52	807.38	807.68	808.04	808.47	808.92	809.35	809.84	810.21	811.09	811.35	808.57
	46	35727	800.610	804.74	805.60	805.95	806.36	806.93	807.44	807.93	808.50	808.91	809.91	810.21	807.03
	45	35234	799.760	803.21	804.19	804.58	805.16	806.06	806.55	807.03	807.58	807.98	808.95	809.24	806.16
	44	34329	798.000	801.53	802.94	803.56	804.38	805.51	805.96	806.39	806.89	807.26	808.14	808.40	805.61
	43	33531	795.420	800.89	802.55	803.24	804.13	805.32	805.74	806.14	806.60	806.94	807.76	808.01	805.42
	42	32671	794.430	800.16	801.89	802.57	803.44	804.61	804.95	805.27	805.64	805.91	806.57	806.77	804.71
	41	31620	794.430	799.48	801.25	801.92	802.78	803.92	804.19	804.45	804.75	804.96	805.49	805.65	804.02
	40	30645	793.110	799.15	801.03	801.73	802.64	803.84	804.06	804.28	804.53	804.71	805.15	805.28	803.94
	39	29441	792.000	798.24	800.33	801.11	802.08	803.33	803.51	803.68	803.88	804.03	804.38	804.49	803.43
	38	28375	790.340	797.44	799.27	800.00	800.88	801.99	802.28	802.55	802.87	803.11	803.67	803.84	802.09
	37	27458	790.340	796.96	798.68	799.36	800.18	801.21	801.54	801.86	802.23	802.50	803.15	803.35	801.31
	36	26568	790.300	796.19	797.70	798.27	798.93	799.76	800.18	800.59	801.07	801.41	802.25	802.50	799.86
	35	25470	790.300	795.15	796.51	797.06	797.68	798.50	798.97	799.42	799.95	800.34	801.26	801.54	798.60
	34	24542	788.060	794.77	796.10	796.66	797.29	798.15	798.55	798.93	799.37	799.70	800.48	800.71	798.25
	33	23704	788.060	794.46	795.81	796.37	797.00	797.85	798.16	798.46	798.81	799.07	799.69	799.87	797.95
	32	22947	787.820	794.06	795.42	795.97	796.56	797.40	797.73	798.04	798.41	798.67	799.32	799.51	797.50
	31	22160	787.810	793.44	794.76	795.28	795.77	796.52	796.92	797.30	797.75	798.07	798.86	799.09	796.62
	30	21122	787.230	791.56	793.42	794.05	794.24	795.03	795.53	796.01	796.58	796.99	797.97	798.27	795.13
	29	20557	785.030	791.52	793.41	794.06	794.26	795.09	795.56	796.00	796.52	796.90	797.82	798.09	795.19
	28	20118	784.050	791.28	793.11	793.70	793.73	794.43	794.91	795.36	795.90	796.28	797.22	797.50	794.53
	27	19516	784.000	790.78	792.25	792.80	793.51	794.30	794.75	795.18	795.68	796.05	796.94	797.20	794.40
	26	18928	784.000	790.43	791.86	792.46	793.07	793.88	794.26	794.62	795.04	795.34	796.08	796.30	793.98
	25	18646	784.000	790.31	791.80	792.41	793.02	793.83	794.20	794.55	794.96	795.26	795.97	796.19	793.93
	24	18371	784.000	790.14	791.64	792.25	792.85	793.65	793.99	794.32	794.71	794.98	795.66	795.86	793.75
	23	17725	784.000	789.70	791.13	791.72	792.23	792.93	793.27	793.61	793.99	794.27	794.95	795.15	793.03
	22	17151	784.000	788.99	790.24	790.76	791.23	791.82	792.18	792.53	792.93	793.22	793.93	794.14	791.92
	21	16097	784.000	787.07	787.97	788.34	788.76	789.36	789.77	790.16	790.62	790.95	791.75	791.99	789.46
	20 A	15350	781.800	786.10	786.82	787.23	787.81	788.66	789.03	789.39	789.81	790.11	790.84	791.06	788.76
	20	14779	781.760	784.24	785.82	786.45	787.24	788.27	788.59	788.89	789.25	789.51	790.13	790.32	788.37
	19	13641	777.110	783.82	785.53	786.20	787.03	788.10	788.37	788.63	788.93	789.15	789.68	789.84	788.20
	18	12496	776.510	783.21	784.86	785.47	786.24	787.22	787.50	787.77	788.08	788.31	788.86	789.02	787.32
	17	11032	775.000	782.45	784.10	784.75	785.57	786.61	786.84	787.06	787.32	787.51	787.96	788.10	786.71

Scenario " 5 " - Levees constructed for 10000m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height
				2	5	10	20	50	100	200	500	1000	5000	10000	(m)
	16	9535	775.000	780.79	782.05	782.65	783.39	784.29	784.63	784.96	785.34	785.61	786.28	786.48	784.39
	15	8375	774.000	779.15	780.94	781.72	782.59	783.70	783.93	784.14	784.40	784.58	785.03	785.16	783.80
	14	7413	772.070	778.32	780.16	780.97	781.82	782.91	783.18	783.43	783.73	783.94	784.46	784.62	783.01
	13	6209	772.070	776.58	778.50	779.37	780.27	781.37	781.82	782.25	782.75	783.11	784.00	784.26	781.47
	12	4930	770.160	776.13	778.07	778.88	779.81	780.95	781.41	781.85	782.36	782.73	783.63	783.90	781.05
	11	3545	769.000	775.65	777.48	778.23	779.13	780.22	780.46	780.68	780.95	781.14	781.60	781.74	780.32
	10	2493	769.000	775.15	776.85	777.55	778.38	779.37	779.40	779.43	779.47	779.50	779.56	779.58	779.47
	9	1501	769.000	774.32	775.89	776.55	777.34	778.31	778.35	778.39	778.43	778.46	778.54	778.56	778.41
	8	368	767.950	773.09	774.40	774.87	775.45	776.17	776.40	776.63	776.89	777.08	777.54	777.68	776.27
C2	7	6627	768.020	771.82	773.23	773.76	774.42	775.28	775.51	775.73	775.99	776.18	776.63	776.77	775.38
	6	5355	764.530	770.64	771.77	772.18	772.72	773.43	773.70	773.95	774.25	774.47	774.99	775.15	773.53
	5	3998	763.640	770.08	771.23	771.75	772.45	773.38	773.45	773.52	773.59	773.65	773.79	773.83	773.48
	4	2919	763.640	769.72	770.98	771.56	772.30	773.27	773.25	773.22	773.20	773.18	773.13	773.12	773.37
	3	1648	763.640	768.89	770.20	770.75	771.44	772.31	772.33	772.34	772.36	772.37	772.40	772.41	772.41
	2	759	763.480	767.98	768.92	769.30	769.77	770.33	770.35	770.36	770.38	770.39	770.42	770.43	770.43
	1	100	763.480	767.06	767.83	768.16	768.58	769.12	769.14	769.15	769.17	769.18	769.21	769.22	769.22
C3	7	6783	767.870	773.82	774.51	774.80	775.18	775.66	775.89	776.12	776.38	776.57	777.02	777.16	775.76
	6	5564	764.520	770.68	772.66	772.64	773.37	773.25	773.47	773.68	773.93	774.11	774.55	774.68	773.35
	5	4162	763.640	770.21	771.30	771.67	772.23	772.85	773.03	773.21	773.42	773.57	773.93	774.04	772.95
	4	3098	763.640	769.47	770.90	771.18	771.77	772.50	772.62	772.73	772.86	772.96	773.19	773.26	772.60
	3	1851	763.640	768.78	769.92	770.37	770.92	771.59	771.66	771.73	771.80	771.86	772.00	772.04	771.69
	2	842	763.640	768.00	768.91	769.28	769.70	770.21	770.31	770.40	770.51	770.59	770.78	770.84	770.31
	1	129	763.640	766.85	767.55	767.84	768.17	768.58	768.72	768.84	769.00	769.11	769.37	769.45	768.68

Scenario " 6 " - Levees constructed for 11800m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	802.570	809.42	810.65	811.14	811.66	812.30	812.76	813.23	813.77	814.16	815.11	815.40	812.86
	49	38534	803.020	808.75	809.85	810.30	810.73	811.27	811.66	812.12	812.66	813.06	814.01	814.29	811.76
	48	37463	801.660	807.75	808.85	809.29	809.72	810.26	810.66	811.12	811.65	812.04	812.97	813.25	810.76
	47	36424	801.130	806.52	807.38	807.68	808.04	808.47	808.80	809.26	809.80	810.19	811.13	811.41	808.90
	46	35727	800.610	804.74	805.60	805.95	806.36	806.93	807.47	807.95	808.52	808.93	809.91	810.21	807.57
	45	35234	799.760	803.21	804.19	804.58	805.16	806.06	806.79	807.22	807.72	808.09	808.98	809.24	806.89
	44	34329	798.000	801.53	802.94	803.56	804.38	805.51	806.34	806.70	807.13	807.44	808.19	808.41	806.44
	43	33531	795.420	800.89	802.55	803.24	804.13	805.32	806.17	806.49	806.87	807.15	807.81	808.01	806.27
	42	32671	794.430	800.16	801.89	802.57	803.44	804.61	805.45	805.68	805.96	806.16	806.64	806.78	805.55
	41	31620	794.430	799.48	801.25	801.92	802.78	803.92	804.77	804.93	805.11	805.25	805.57	805.67	804.87
	40	30645	793.110	799.15	801.03	801.73	802.64	803.84	804.73	804.83	804.94	805.03	805.23	805.29	804.83
	39	29441	792.000	798.24	800.33	801.11	802.08	803.33	804.27	804.31	804.36	804.40	804.48	804.51	804.37
	38	28375	790.340	797.44	799.27	800.00	800.88	801.99	802.80	802.99	803.21	803.37	803.75	803.87	802.90
	37	27458	790.340	796.96	798.68	799.36	800.18	801.21	801.97	802.22	802.51	802.72	803.23	803.38	802.07
	36	26568	790.300	796.19	797.70	798.27	798.93	799.76	800.36	800.75	801.20	801.52	802.31	802.55	800.46
	35	25470	790.300	795.15	796.51	797.06	797.68	798.50	799.11	799.55	800.07	800.45	801.36	801.63	799.21
	34	24542	788.060	794.77	796.10	796.66	797.29	798.15	798.79	799.14	799.55	799.85	800.57	800.79	798.89
	33	23704	788.060	794.46	795.81	796.37	797.00	797.85	798.50	798.75	799.03	799.24	799.74	799.89	798.60
	32	22947	787.820	794.06	795.42	795.97	796.56	797.40	798.02	798.29	798.60	798.82	799.37	799.53	798.12
	31	22160	787.810	793.44	794.76	795.28	795.77	796.52	797.07	797.43	797.85	798.15	798.89	799.11	797.17
	30	21122	787.230	791.56	793.42	794.05	794.24	795.03	795.62	796.09	796.65	797.05	798.02	798.31	795.72
	29	20557	785.030	791.52	793.41	794.06	794.26	795.09	795.71	796.13	796.63	796.99	797.86	798.12	795.81
	28	20118	784.050	791.28	793.11	793.70	793.73	794.43	794.93	795.39	795.93	796.32	797.26	797.54	795.03
	27	19516	784.000	790.78	792.25	792.80	793.51	794.30	794.89	795.31	795.79	796.14	796.99	797.25	794.99
	26	18928	784.000	790.43	791.86	792.46	793.07	793.88	794.48	794.81	795.20	795.49	796.17	796.38	794.58
	25	18646	784.000	790.31	791.80	792.41	793.02	793.83	794.43	794.76	795.14	795.41	796.08	796.28	794.53
	24	18371	784.000	790.14	791.64	792.25	792.85	793.65	794.24	794.54	794.90	795.15	795.77	795.96	794.34
	23	17725	784.000	789.70	791.13	791.72	792.23	792.93	793.45	793.77	794.14	794.41	795.06	795.25	793.55
	22	17151	784.000	788.99	790.24	790.76	791.23	791.82	792.24	792.59	793.00	793.29	794.01	794.22	792.34
	21	16097	784.000	787.07	787.97	788.34	788.76	789.36	789.87	790.25	790.70	791.02	791.81	792.04	789.97
	20 A	15350	781.800	786.10	786.82	787.23	787.81	788.66	789.35	789.67	790.03	790.30	790.95	791.14	789.45
	20	14779	781.760	784.24	785.82	786.45	787.24	788.27	789.04	789.29	789.57	789.78	790.29	790.44	789.14
	19	13641	777.110	783.82	785.53	786.20	787.03	788.10	788.90	789.09	789.32	789.48	789.87	789.99	789.00
	18	12496	776.510	783.21	784.86	785.47	786.24	787.22	787.94	788.16	788.42	788.61	789.06	789.20	788.04
	17	11032	775.000	782.45	784.10	784.75	785.57	786.61	787.37	787.54	787.75	787.90	788.25	788.36	787.47

Scenario " 6 " - Levees constructed for 11800m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
	16	9535	775.000	780.79	782.05	782.65	783.39	784.29	784.94	785.25	785.62	785.89	786.53	786.72	785.04
	15	8375	774.000	779.15	780.94	781.72	782.59	783.70	784.53	784.65	784.80	784.90	785.15	785.23	784.63
	14	7413	772.070	778.32	780.16	780.97	781.82	782.91	783.72	783.88	784.07	784.21	784.54	784.64	783.82
	13	6209	772.070	776.58	778.50	779.37	780.27	781.37	782.19	782.55	782.98	783.29	784.04	784.26	782.29
	12	4930	770.160	776.13	778.07	778.88	779.81	780.95	781.80	782.17	782.60	782.92	783.67	783.90	781.90
	11	3545	769.000	775.65	777.48	778.23	779.13	780.22	781.04	781.20	781.38	781.51	781.82	781.92	781.14
	10	2493	769.000	775.15	776.85	777.55	778.38	779.37	779.57	779.63	779.71	779.76	779.89	779.93	779.67
	9	1501	769.000	774.32	775.89	776.55	777.34	778.31	779.06	779.08	779.10	779.11	779.15	779.16	779.16
	8	368	767.950	773.09	774.40	774.87	775.45	776.17	776.72	776.93	777.17	777.34	777.76	777.89	776.82
C2	7	6627	768.020	771.82	773.23	773.76	774.42	775.28	775.94	776.09	776.26	776.39	776.70	776.79	776.04
	6	5355	764.530	770.64	771.77	772.18	772.72	773.43	774.00	774.22	774.47	774.65	775.10	775.23	774.10
	5	3998	763.640	770.08	771.23	771.75	772.45	773.38	774.11	774.15	774.20	774.23	774.32	774.34	774.21
	4	2919	763.640	769.72	770.98	771.56	772.30	773.27	774.02	774.05	774.09	774.12	774.18	774.20	774.12
	3	1648	763.640	768.89	770.20	770.75	771.44	772.31	772.95	772.97	772.99	773.00	773.04	773.05	773.05
	2	759	763.480	767.98	768.92	769.30	769.77	770.33	770.73	770.75	770.77	770.78	770.82	770.83	770.83
	1	100	763.480	767.06	767.83	768.16	768.58	769.12	769.53	769.55	769.57	769.58	769.62	769.63	769.63
C3	7	6783	767.870	773.82	774.51	774.80	775.18	775.66	776.04	776.29	776.58	776.79	777.30	777.45	776.14
	6	5564	764.520	770.68	772.66	772.64	773.37	773.25	773.70	774.00	774.36	774.61	775.23	775.42	773.80
	5	4162	763.640	770.21	771.30	771.67	772.23	772.85	773.38	773.74	774.15	774.45	775.18	775.40	773.48
	4	3098	763.640	769.47	770.90	771.18	771.77	772.50	773.06	773.42	773.85	774.16	774.91	775.13	773.16
	3	1851	763.640	768.78	769.92	770.37	770.92	771.59	772.09	772.25	772.43	772.56	772.88	772.98	772.19
	2	842	763.640	768.00	768.91	769.28	769.70	770.21	770.58	770.62	770.68	770.71	770.80	770.83	770.68
	1	129	763.640	766.85	767.55	767.84	768.17	768.58	768.88	768.97	769.08	769.16	769.34	769.40	768.98

Scenario " 7 " - Levees constructed for 13700m³/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	802.570	809.42	810.65	811.14	811.66	812.30	812.76	813.23	813.78	814.18	815.14	815.43	813.33
	49	38534	803.020	808.75	809.85	810.30	810.73	811.27	811.66	812.07	812.64	813.06	814.06	814.36	812.17
	48	37463	801.660	807.75	808.85	809.29	809.72	810.26	810.66	811.09	811.66	812.07	813.07	813.37	811.19
	47	36424	801.130	806.52	807.38	807.68	808.04	808.47	808.80	809.21	809.79	810.20	811.22	811.52	809.31
	46	35727	800.610	804.74	805.60	805.95	806.36	806.93	807.47	808.13	808.67	809.06	810.02	810.30	808.23
	45	35234	799.760	803.21	804.19	804.58	805.16	806.06	806.79	807.60	808.05	808.38	809.16	809.40	807.70
	44	34329	798.000	801.53	802.94	803.56	804.38	805.51	806.34	807.23	807.58	807.84	808.46	808.64	807.33
	43	33531	795.420	800.89	802.55	803.24	804.13	805.32	806.17	807.09	807.39	807.61	808.13	808.29	807.19
	42	32671	794.430	800.16	801.89	802.57	803.44	804.61	805.45	806.36	806.58	806.74	807.13	807.25	806.46
	41	31620	794.430	799.48	801.25	801.92	802.78	803.92	804.77	805.69	805.90	806.05	806.42	806.53	805.79
	40	30645	793.110	799.15	801.03	801.73	802.64	803.84	804.73	805.69	805.83	805.94	806.19	806.27	805.79
	39	29441	792.000	798.24	800.33	801.11	802.08	803.33	804.27	805.26	805.24	805.23	805.19	805.18	805.36
	38	28375	790.340	797.44	799.27	800.00	800.88	801.99	802.80	803.64	803.70	803.75	803.86	803.89	803.74
	37	27458	790.340	796.96	798.68	799.36	800.18	801.21	801.97	802.75	802.91	803.03	803.32	803.41	802.85
	36	26568	790.300	796.19	797.70	798.27	798.93	799.76	800.36	800.98	801.38	801.68	802.39	802.60	801.08
	35	25470	790.300	795.15	796.51	797.06	797.68	798.50	799.11	799.74	800.23	800.59	801.46	801.72	799.84
	34	24542	788.060	794.77	796.10	796.66	797.29	798.15	798.79	799.47	799.82	800.07	800.68	800.86	799.57
	33	23704	788.060	794.46	795.81	796.37	797.00	797.85	798.50	799.18	799.36	799.50	799.82	799.92	799.28
	32	22947	787.820	794.06	795.42	795.97	796.56	797.40	798.02	798.68	798.90	799.06	799.44	799.56	798.78
	31	22160	787.810	793.44	794.76	795.28	795.77	796.52	797.07	797.67	798.04	798.30	798.95	799.14	797.77
	30	21122	787.230	791.56	793.42	794.05	794.24	795.03	795.62	796.23	796.76	797.14	798.07	798.35	796.33
	29	20557	785.030	791.52	793.41	794.06	794.26	795.09	795.71	796.36	796.81	797.14	797.93	798.17	796.46
	28	20118	784.050	791.28	793.11	793.70	793.73	794.43	794.93	795.46	796.00	796.39	797.33	797.61	795.56
	27	19516	784.000	790.78	792.25	792.80	793.51	794.30	794.89	795.50	795.95	796.28	797.08	797.32	795.60
	26	18928	784.000	790.43	791.86	792.46	793.07	793.88	794.48	795.11	795.45	795.70	796.31	796.49	795.21
	25	18646	784.000	790.31	791.80	792.41	793.02	793.83	794.43	795.06	795.39	795.64	796.22	796.40	795.16
	24	18371	784.000	790.14	791.64	792.25	792.85	793.65	794.24	794.85	795.16	795.39	795.94	796.10	794.95
	23	17725	784.000	789.70	791.13	791.72	792.23	792.93	793.45	793.99	794.33	794.58	795.18	795.36	794.09
	22	17151	784.000	788.99	790.24	790.76	791.23	791.82	792.24	792.70	793.10	793.39	794.08	794.29	792.80
	21	16097	784.000	787.07	787.97	788.34	788.76	789.36	789.87	790.48	790.89	791.19	791.91	792.13	790.58
	20 A	15350	781.800	786.10	786.82	787.23	787.81	788.66	789.35	790.11	790.41	790.62	791.14	791.30	790.21
	20	14779	781.760	784.24	785.82	786.45	787.24	788.27	789.04	789.86	790.06	790.21	790.57	790.68	789.96
	19	13641	777.110	783.82	785.53	786.20	787.03	788.10	788.90	789.74	789.88	789.98	790.22	790.29	789.84
	18	12496	776.510	783.21	784.86	785.47	786.24	787.22	787.94	788.68	788.92	789.09	789.51	789.63	788.78
	17	11032	775.000	782.45	784.10	784.75	785.57	786.61	787.37	788.14	788.35	788.51	788.88	788.99	788.24

Scenario " 7 " - Levees constructed for 13700m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
	16	9535	775.000	780.79	782.05	782.65	783.39	784.29	784.94	785.52	786.03	786.40	787.30	787.57	785.62
	15	8375	774.000	779.15	780.94	781.72	782.59	783.70	784.53	785.23	785.68	786.01	786.79	787.03	785.33
	14	7413	772.070	778.32	780.16	780.97	781.82	782.91	783.72	784.35	784.65	784.88	785.41	785.57	784.45
	13	6209	772.070	776.58	778.50	779.37	780.27	781.37	782.19	782.58	782.96	783.23	783.90	784.10	782.68
	12	4930	770.160	776.13	778.07	778.88	779.81	780.95	781.80	782.11	782.51	782.80	783.50	783.71	782.21
	11	3545	769.000	775.65	777.48	778.23	779.13	780.22	781.04	781.13	781.70	782.11	783.11	783.41	781.23
	10	2493	769.000	775.15	776.85	777.55	778.38	779.37	779.57	779.78	780.67	781.32	782.89	783.36	779.88
	9	1501	769.000	774.32	775.89	776.55	777.34	778.31	779.06	779.62	779.87	780.06	780.50	780.63	779.72
	8	368	767.950	773.09	774.40	774.87	775.45	776.17	776.72	777.29	777.44	777.55	777.81	777.89	777.39
C2	7	6627	768.020	771.82	773.23	773.76	774.42	775.28	775.94	776.65	777.10	777.43	778.21	778.45	776.75
	6	5355	764.530	770.64	771.77	772.18	772.72	773.43	774.00	774.88	775.65	776.22	777.58	777.99	774.98
	5	3998	763.640	770.08	771.23	771.75	772.45	773.38	774.11	774.88	775.61	776.15	777.44	777.83	774.98
	4	2919	763.640	769.72	770.98	771.56	772.30	773.27	774.02	774.81	775.54	776.08	777.36	777.75	774.91
	3	1648	763.640	768.89	770.20	770.75	771.44	772.31	772.95	773.63	773.96	774.20	774.78	774.95	773.73
	2	759	763.480	767.98	768.92	769.30	769.77	770.33	770.73	771.13	771.38	771.57	772.01	772.14	771.23
	1	100	763.480	767.06	767.83	768.16	768.58	769.12	769.53	769.96	770.07	770.15	770.34	770.40	770.06
C3	7	6783	767.870	773.82	774.51	774.80	775.18	775.66	776.04	776.41	776.67	776.86	777.31	777.45	776.51
	6	5564	764.520	770.68	772.66	772.64	773.37	773.25	773.70	774.17	774.48	774.71	775.26	775.42	774.27
	5	4162	763.640	770.21	771.30	771.67	772.23	772.85	773.38	773.92	774.29	774.56	775.21	775.40	774.02
	4	3098	763.640	769.47	770.90	771.18	771.77	772.50	773.06	773.62	774.00	774.27	774.93	775.13	773.72
	3	1851	763.640	768.78	769.92	770.37	770.92	771.59	772.09	772.61	772.70	772.77	772.94	772.99	772.71
	2	842	763.640	768.00	768.91	769.28	769.70	770.21	770.58	770.96	770.93	770.91	770.86	770.85	771.06
	1	129	763.640	766.85	767.55	767.84	768.17	768.58	768.88	769.16	769.25	769.32	769.47	769.52	769.26

Scenario " 8 " - Levees constructed for 16300m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	802.570	809.42	810.65	811.14	811.66	812.30	812.76	813.23	813.85	814.24	815.20	815.48	813.95
	49	38534	803.020	808.75	809.85	810.30	810.73	811.27	811.66	812.07	812.61	813.06	814.13	814.45	812.71
	48	37463	801.660	807.75	808.85	809.29	809.72	810.26	810.66	811.09	811.68	812.13	813.21	813.53	811.78
	47	36424	801.130	806.52	807.38	807.68	808.04	808.47	808.80	809.21	809.86	810.30	811.35	811.66	809.96
	46	35727	800.610	804.74	805.60	805.95	806.36	806.93	807.47	808.13	809.10	809.43	810.23	810.47	809.20
	45	35234	799.760	803.21	804.19	804.58	805.16	806.06	806.79	807.60	808.70	808.93	809.50	809.67	808.80
	44	34329	798.000	801.53	802.94	803.56	804.38	805.51	806.34	807.23	808.40	808.55	808.91	809.02	808.50
	43	33531	795.420	800.89	802.55	803.24	804.13	805.32	806.17	807.09	808.28	808.39	808.64	808.72	808.38
	42	32671	794.430	800.16	801.89	802.57	803.44	804.61	805.45	806.36	807.55	807.63	807.84	807.90	807.65
	41	31620	794.430	799.48	801.25	801.92	802.78	803.92	804.77	805.69	806.87	807.01	807.33	807.43	806.97
	40	30645	793.110	799.15	801.03	801.73	802.64	803.84	804.73	805.69	806.93	807.01	807.19	807.25	807.03
	39	29441	792.000	798.24	800.33	801.11	802.08	803.33	804.27	805.26	806.53	806.63	806.88	806.96	806.63
	38	28375	790.340	797.44	799.27	800.00	800.88	801.99	802.80	803.64	804.70	805.20	806.40	806.76	804.80
	37	27458	790.340	796.96	798.68	799.36	800.18	801.21	801.97	802.75	803.75	804.01	804.64	804.83	803.65
	36	26568	790.300	796.19	797.70	798.27	798.93	799.76	800.36	800.98	801.76	801.99	802.53	802.69	801.86
	35	25470	790.300	795.15	796.51	797.06	797.68	798.50	799.11	799.74	800.56	800.87	801.62	801.85	800.66
	34	24542	788.060	794.77	796.10	796.66	797.29	798.15	798.79	799.47	800.35	800.50	800.86	800.97	800.45
	33	23704	788.060	794.46	795.81	796.37	797.00	797.85	798.50	799.18	800.05	800.11	800.24	800.28	800.15
	32	22947	787.820	794.06	795.42	795.97	796.56	797.40	798.02	798.68	799.52	799.54	799.58	799.59	799.62
	31	22160	787.810	793.44	794.76	795.28	795.77	796.52	797.07	797.67	798.42	798.60	799.05	799.18	798.52
	30	21122	787.230	791.56	793.42	794.05	794.24	795.03	795.62	796.23	797.02	797.35	798.16	798.40	797.12
	29	20557	785.030	791.52	793.41	794.06	794.26	795.09	795.71	796.36	797.19	797.44	798.04	798.22	797.29
	28	20118	784.050	791.28	793.11	793.70	793.73	794.43	794.93	795.46	796.11	796.49	797.40	797.67	796.21
	27	19516	784.000	790.78	792.25	792.80	793.51	794.30	794.89	795.50	796.28	796.55	797.20	797.40	796.38
	26	18928	784.000	790.43	791.86	792.46	793.07	793.88	794.48	795.11	795.89	796.06	796.48	796.61	795.99
	25	18646	784.000	790.31	791.80	792.41	793.02	793.83	794.43	795.06	795.85	796.01	796.40	796.52	795.95
	24	18371	784.000	790.14	791.64	792.25	792.85	793.65	794.24	794.85	795.62	795.77	796.13	796.24	795.72
	23	17725	784.000	789.70	791.13	791.72	792.23	792.93	793.45	793.99	794.65	794.85	795.34	795.48	794.75
	22	17151	784.000	788.99	790.24	790.76	791.23	791.82	792.24	792.70	793.21	793.50	794.18	794.39	793.31
	21	16097	784.000	787.07	787.97	788.34	788.76	789.36	789.87	790.48	791.37	791.58	792.07	792.22	791.47
	20 A	15350	781.800	786.10	786.82	787.23	787.81	788.66	789.35	790.11	791.13	791.21	791.39	791.45	791.23
	20	14779	781.760	784.24	785.82	786.45	787.24	788.27	789.04	789.86	790.93	790.92	790.89	790.88	791.03
	19	13641	777.110	783.82	785.53	786.20	787.03	788.10	788.90	789.74	790.83	790.76	790.59	790.54	790.93
	18	12496	776.510	783.21	784.86	785.47	786.24	787.22	787.94	788.68	789.65	789.72	789.87	789.92	789.75
	17	11032	775.000	782.45	784.10	784.75	785.57	786.61	787.37	788.14	789.18	789.23	789.34	789.37	789.28

Scenario " 8 " - Levees constructed for 16300m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
	16	9535	775.000	780.79	782.05	782.65	783.39	784.29	784.94	785.52	786.38	786.68	787.42	787.64	786.48
	15	8375	774.000	779.15	780.94	781.72	782.59	783.70	784.53	785.23	786.30	786.50	786.97	787.11	786.40
	14	7413	772.070	778.32	780.16	780.97	781.82	782.91	783.72	784.35	785.36	785.42	785.57	785.61	785.46
	13	6209	772.070	776.58	778.50	779.37	780.27	781.37	782.19	782.58	783.53	783.67	784.00	784.10	783.63
	12	4930	770.160	776.13	778.07	778.88	779.81	780.95	781.80	782.11	783.11	783.26	783.61	783.71	783.21
	11	3545	769.000	775.65	777.48	778.23	779.13	780.22	781.04	781.13	782.03	782.36	783.17	783.41	782.13
	10	2493	769.000	775.15	776.85	777.55	778.38	779.37	779.57	779.78	780.48	781.18	782.86	783.36	780.58
	9	1501	769.000	774.32	775.89	776.55	777.34	778.31	779.06	779.62	780.44	780.60	780.98	781.10	780.54
	8	368	767.950	773.09	774.40	774.87	775.45	776.17	776.72	777.29	778.03	778.22	778.69	778.83	778.13
C2	7	6627	768.020	771.82	773.23	773.76	774.42	775.28	775.94	776.65	777.59	777.80	778.30	778.45	777.69
	6	5355	764.530	770.64	771.77	772.18	772.72	773.43	774.00	774.88	775.90	776.41	777.62	777.99	776.00
	5	3998	763.640	770.08	771.23	771.75	772.45	773.38	774.11	774.88	775.90	776.37	777.49	777.83	776.00
	4	2919	763.640	769.72	770.98	771.56	772.30	773.27	774.02	774.81	775.84	776.30	777.42	777.75	775.94
	3	1648	763.640	768.89	770.20	770.75	771.44	772.31	772.95	773.63	774.50	774.76	775.37	775.56	774.60
	2	759	763.480	767.98	768.92	769.30	769.77	770.33	770.73	771.13	771.61	772.04	773.06	773.37	771.71
	1	100	763.480	767.06	767.83	768.16	768.58	769.12	769.53	769.96	770.52	770.67	771.05	771.16	770.62
C3	7	6783	767.870	773.82	774.51	774.80	775.18	775.66	776.04	776.41	776.93	777.01	777.21	777.27	777.03
	6	5564	764.520	770.68	772.66	772.64	773.37	773.25	773.70	774.17	774.78	774.83	774.95	774.99	774.88
	5	4162	763.640	770.21	771.30	771.67	772.23	772.85	773.38	773.92	774.61	774.65	774.74	774.77	774.71
	4	3098	763.640	769.47	770.90	771.18	771.77	772.50	773.06	773.62	774.34	774.26	774.06	774.00	774.44
	3	1851	763.640	768.78	769.92	770.37	770.92	771.59	772.09	772.61	773.26	773.25	773.23	773.22	773.36
	2	842	763.640	768.00	768.91	769.28	769.70	770.21	770.58	770.96	771.44	771.77	772.57	772.81	771.54
	1	129	763.640	766.85	767.55	767.84	768.17	768.58	768.88	769.16	769.52	769.78	770.41	770.60	769.62

Scenario " 9 " - Levees constructed for 18500m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	802.570	809.42	810.65	811.14	811.66	812.30	812.76	813.23	813.85	814.35	815.24	815.51	814.45
	49	38534	803.020	808.75	809.85	810.30	810.73	811.27	811.66	812.07	812.61	813.07	814.19	814.52	813.17
	48	37463	801.660	807.75	808.85	809.29	809.72	810.26	810.66	811.09	811.68	812.21	813.31	813.64	812.31
	47	36424	801.130	806.52	807.38	807.68	808.04	808.47	808.80	809.21	809.86	810.50	811.45	811.73	810.60
	46	35727	800.610	804.74	805.60	805.95	806.36	806.93	807.47	808.13	809.10	809.94	810.34	810.46	810.04
	45	35234	799.760	803.21	804.19	804.58	805.16	806.06	806.79	807.60	808.70	809.62	809.66	809.67	809.72
	44	34329	798.000	801.53	802.94	803.56	804.38	805.51	806.34	807.23	808.40	809.36	809.36	809.36	809.46
	43	33531	795.420	800.89	802.55	803.24	804.13	805.32	806.17	807.09	808.28	809.25	808.85	808.73	809.35
	42	32671	794.430	800.16	801.89	802.57	803.44	804.61	805.45	806.36	807.55	808.52	808.05	807.91	808.62
	41	31620	794.430	799.48	801.25	801.92	802.78	803.92	804.77	805.69	806.87	807.83	807.53	807.44	807.93
	40	30645	793.110	799.15	801.03	801.73	802.64	803.84	804.73	805.69	806.93	807.92	807.41	807.26	808.02
	39	29441	792.000	798.24	800.33	801.11	802.08	803.33	804.27	805.26	806.53	807.55	807.10	806.97	807.65
	38	28375	790.340	797.44	799.27	800.00	800.88	801.99	802.80	803.64	804.70	805.53	806.48	806.77	805.63
	37	27458	790.340	796.96	798.68	799.36	800.18	801.21	801.97	802.75	803.75	804.53	804.85	804.94	804.63
	36	26568	790.300	796.19	797.70	798.27	798.93	799.76	800.36	800.98	801.76	802.35	802.93	803.10	802.45
	35	25470	790.300	795.15	796.51	797.06	797.68	798.50	799.11	799.74	800.56	801.20	802.15	802.44	801.30
	34	24542	788.060	794.77	796.10	796.66	797.29	798.15	798.79	799.47	800.35	801.04	801.61	801.78	801.14
	33	23704	788.060	794.46	795.81	796.37	797.00	797.85	798.50	799.18	800.05	800.75	801.10	801.20	800.85
	32	22947	787.820	794.06	795.42	795.97	796.56	797.40	798.02	798.68	799.52	800.20	799.78	799.65	800.30
	31	22160	787.810	793.44	794.76	795.28	795.77	796.52	797.07	797.67	798.42	799.03	799.50	799.64	799.13
	30	21122	787.230	791.56	793.42	794.05	794.24	795.03	795.62	796.23	797.02	797.86	798.77	799.04	797.96
	29	20557	785.030	791.52	793.41	794.06	794.26	795.09	795.71	796.36	797.19	797.86	798.67	798.91	797.96
	28	20118	784.050	791.28	793.11	793.70	793.73	794.43	794.93	795.46	796.11	796.90	798.12	798.49	797.00
	27	19516	784.000	790.78	792.25	792.80	793.51	794.30	794.89	795.50	796.28	796.90	797.99	798.32	797.00
	26	18928	784.000	790.43	791.86	792.46	793.07	793.88	794.48	795.11	795.89	796.53	797.51	797.81	796.63
	25	18646	784.000	790.31	791.80	792.41	793.02	793.83	794.43	795.06	795.85	796.50	797.47	797.76	796.60
	24	18371	784.000	790.14	791.64	792.25	792.85	793.65	794.24	794.85	795.62	796.25	797.28	797.59	796.35
	23	17725	784.000	789.70	791.13	791.72	792.23	792.93	793.45	793.99	794.65	795.20	795.04	794.99	795.30
	22	17151	784.000	788.99	790.24	790.76	791.23	791.82	792.24	792.70	793.21	793.68	794.40	794.62	793.78
	21	16097	784.000	787.07	787.97	788.34	788.76	789.36	789.87	790.48	791.37	792.13	792.84	793.05	792.23
	20 A	15350	781.800	786.10	786.82	787.23	787.81	788.66	789.35	790.11	791.13	791.97	792.48	792.63	792.07
	20	14779	781.760	784.24	785.82	786.45	787.24	788.27	789.04	789.86	790.93	791.80	792.21	792.33	791.90
	19	13641	777.110	783.82	785.53	786.20	787.03	788.10	788.90	789.74	790.83	791.71	792.06	792.16	791.81
	18	12496	776.510	783.21	784.86	785.47	786.24	787.22	787.94	788.68	789.65	790.43	790.78	790.88	790.53
	17	11032	775.000	782.45	784.10	784.75	785.57	786.61	787.37	788.14	789.18	790.01	789.69	789.59	790.11

Scenario " 9 " - Levees constructed for 18500m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
				2	5	10	20	50	100	200	500	1000	5000	10000	
	16	9535	775.000	780.79	782.05	782.65	783.39	784.29	784.94	785.52	786.38	787.08	787.78	787.99	787.18
	15	8375	774.000	779.15	780.94	781.72	782.59	783.70	784.53	785.23	786.30	787.17	786.69	786.55	787.27
	14	7413	772.070	778.32	780.16	780.97	781.82	782.91	783.72	784.35	785.36	786.19	785.36	785.11	786.29
	13	6209	772.070	776.58	778.50	779.37	780.27	781.37	782.19	782.58	783.53	784.33	784.71	784.82	784.43
	12	4930	770.160	776.13	778.07	778.88	779.81	780.95	781.80	782.11	783.11	783.94	784.08	784.12	784.04
	11	3545	769.000	775.65	777.48	778.23	779.13	780.22	781.04	781.13	782.03	782.81	783.27	783.41	782.91
	10	2493	769.000	775.15	776.85	777.55	778.38	779.37	779.57	779.78	780.48	781.23	782.87	783.36	781.33
	9	1501	769.000	774.32	775.89	776.55	777.34	778.31	779.06	779.62	780.44	781.23	780.79	780.66	781.33
	8	368	767.950	773.09	774.40	774.87	775.45	776.17	776.72	777.29	778.03	778.64	778.11	777.95	778.74
C2	7	6627	768.020	771.82	773.23	773.76	774.42	775.28	775.94	776.65	777.59	778.37	778.44	778.46	778.47
	6	5355	764.530	770.64	771.77	772.18	772.72	773.43	774.00	774.88	775.90	776.73	777.70	777.99	776.83
	5	3998	763.640	770.08	771.23	771.75	772.45	773.38	774.11	774.88	775.90	776.73	777.58	777.83	776.83
	4	2919	763.640	769.72	770.98	771.56	772.30	773.27	774.02	774.81	775.84	776.68	777.50	777.75	776.78
	3	1648	763.640	768.89	770.20	770.75	771.44	772.31	772.95	773.63	774.50	775.20	775.51	775.60	775.30
	2	759	763.480	767.98	768.92	769.30	769.77	770.33	770.73	771.13	771.61	771.97	773.10	773.44	772.07
	1	100	763.480	767.06	767.83	768.16	768.58	769.12	769.53	769.96	770.52	770.96	771.48	771.63	771.06
C3	7	6783	767.870	773.82	774.51	774.80	775.18	775.66	776.04	776.41	776.93	777.32	772.94	771.64	777.42
	6	5564	764.520	770.68	772.66	772.64	773.37	773.25	773.70	774.17	774.78	775.27	775.40	775.44	775.37
	5	4162	763.640	770.21	771.30	771.67	772.23	772.85	773.38	773.92	774.61	775.17	775.36	775.42	775.27
	4	3098	763.640	769.47	770.90	771.18	771.77	772.50	773.06	773.62	774.34	774.92	775.10	775.15	775.02
	3	1851	763.640	768.78	769.92	770.37	770.92	771.59	772.09	772.61	773.26	773.78	773.63	773.59	773.88
	2	842	763.640	768.00	768.91	769.28	769.70	770.21	770.58	770.96	771.44	771.81	771.97	772.02	771.91
	1	129	763.640	766.85	767.55	767.84	768.17	768.58	768.88	769.16	769.52	769.79	771.21	771.64	769.89

Scenario " 10 " - Levees constructed for 25100m³/s flood level + 0.1m

Reach	Cross Section Number	Chainage	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
			2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	809.42	810.65	811.14	811.66	812.30	812.76	813.23	813.85	814.35	815.26	815.69	815.36
	49	38534	808.75	809.85	810.30	810.73	811.27	811.66	812.07	812.61	813.07	814.35	814.82	814.45
	48	37463	807.75	808.85	809.29	809.72	810.26	810.66	811.09	811.68	812.21	813.59	814.10	813.69
	47	36424	806.52	807.38	807.68	808.04	808.47	808.80	809.21	809.86	810.50	811.96	812.52	812.06
	46	35727	804.74	805.60	805.95	806.36	806.93	807.47	808.13	809.10	809.94	811.57	812.19	811.67
	45	35234	803.21	804.19	804.58	805.16	806.06	806.79	807.60	808.70	809.62	811.27	811.91	811.37
	44	34329	801.53	802.94	803.56	804.38	805.51	806.34	807.23	808.40	809.36	811.03	811.67	811.13
	43	33531	800.89	802.55	803.24	804.13	805.32	806.17	807.09	808.28	809.25	810.91	811.56	811.01
	42	32671	800.16	801.89	802.57	803.44	804.61	805.45	806.36	807.55	808.52	809.90	810.72	810.00
	41	31620	799.48	801.25	801.92	802.78	803.92	804.77	805.69	806.87	807.83	809.05	810.72	809.15
	40	30645	799.15	801.03	801.73	802.64	803.84	804.73	805.69	806.93	807.92	809.05	810.50	809.15
	39	29441	798.24	800.33	801.11	802.08	803.33	804.27	805.26	806.53	807.55	806.57	810.07	808.67
	38	28375	797.44	799.27	800.00	800.88	801.99	802.80	803.64	804.70	805.53	808.57	808.80	808.67
	37	27458	796.96	798.68	799.36	800.18	801.21	801.97	802.75	803.75	804.53	806.66	807.53	806.76
	36	26568	796.19	797.70	798.27	798.93	799.76	800.36	800.98	801.76	802.35	804.96	805.39	805.06
	35	25470	795.15	796.51	797.06	797.68	798.50	799.11	799.74	800.56	801.20	803.25	803.40	803.35
	34	24542	794.77	796.10	796.66	797.29	798.15	798.79	799.47	800.35	801.04	802.76	802.90	802.86
	33	23704	794.46	795.81	796.37	797.00	797.85	798.50	799.18	800.05	800.75	802.48	802.60	802.58
	32	22947	794.06	795.42	795.97	796.56	797.40	798.02	798.68	799.52	800.20	801.87	802.27	801.97
	31	22160	793.44	794.76	795.28	795.77	796.52	797.07	797.67	798.42	799.03	800.53	800.67	800.63
	30	21122	791.56	793.42	794.05	794.24	795.03	795.62	796.23	797.02	797.86	799.47	799.93	799.57
	29	20557	791.52	793.41	794.06	794.26	795.09	795.71	796.36	797.19	797.86	799.47	799.58	799.57
	28	20118	791.28	793.11	793.70	793.73	794.43	794.93	795.46	796.11	796.90	798.84	798.95	798.94
	27	19516	790.78	792.25	792.80	793.51	794.30	794.89	795.50	796.28	796.90	798.24	798.71	798.34
	26	18928	790.43	791.86	792.46	793.07	793.88	794.48	795.11	795.89	796.53	797.82	798.27	797.92
	25	18646	790.31	791.80	792.41	793.02	793.83	794.43	795.06	795.85	796.50	797.78	798.24	797.88
	24	18371	790.14	791.64	792.25	792.85	793.65	794.24	794.85	795.62	796.25	797.45	797.87	797.55
	23	17725	789.70	791.13	791.72	792.23	792.93	793.45	793.99	794.65	795.20	797.16	797.59	797.26
	22	17151	788.99	790.24	790.76	791.23	791.82	792.24	792.70	793.21	793.68	794.93	795.13	795.03
	21	16097	787.07	787.97	788.34	788.76	789.36	789.87	790.48	791.37	792.13	793.86	794.00	793.96
	20 A	15350	786.10	786.82	787.23	787.81	788.66	789.35	790.11	791.13	791.97	793.77	793.90	793.87
	20	14779	784.24	785.82	786.45	787.24	788.27	789.04	789.86	790.93	791.80	793.64	793.84	793.74
	19	13641	783.82	785.53	786.20	787.03	788.10	788.90	789.74	790.83	791.71	793.55	793.75	793.65

Scenario " 10 " - Levees constructed for 25100m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
			2	5	10	20	50	100	200	500	1000	5000	10000	
	18	12496	783.21	784.86	785.47	786.24	787.22	787.94	788.68	789.65	790.43	791.99	793.12	792.09
	17	11032	782.45	784.10	784.75	785.57	786.61	787.37	788.14	789.18	790.01	791.60	792.31	791.70
	16	9535	780.79	782.05	782.65	783.39	784.29	784.94	785.52	786.38	787.08	787.97	788.65	788.07
	15	8375	779.15	780.94	781.72	782.59	783.70	784.53	785.23	786.30	787.17	787.97	788.65	788.07
	14	7413	778.32	780.16	780.97	781.82	782.91	783.72	784.35	785.36	786.19	786.83	788.65	786.93
	13	6209	776.58	778.50	779.37	780.27	781.37	782.19	782.58	783.53	784.33	786.83	787.36	786.93
	12	4930	776.13	778.07	778.88	779.81	780.95	781.80	782.11	783.11	783.94	786.16	786.86	786.26
	11	3545	775.65	777.48	778.23	779.13	780.22	781.04	781.13	782.03	782.81	784.82	784.96	784.92
	10	2493	775.15	776.85	777.55	778.38	779.37	779.57	779.78	780.48	781.23	782.96	783.66	783.06
	9	1501	774.32	775.89	776.55	777.34	778.31	779.06	779.62	780.44	781.23	782.96	783.58	783.06
	8	368	773.09	774.40	774.87	775.45	776.17	776.72	777.29	778.03	778.64	777.43	777.96	777.53
C2	7	6627	771.82	773.23	773.76	774.42	775.28	775.94	776.65	777.59	778.37	779.68	780.37	779.78
	6	5355	770.64	771.77	772.18	772.72	773.43	774.00	774.88	775.90	776.73	777.08	777.83	777.18
	5	3998	770.08	771.23	771.75	772.45	773.38	774.11	774.88	775.90	776.73	777.08	777.83	777.18
	4	2919	769.72	770.98	771.56	772.30	773.27	774.02	774.81	775.84	776.68	777.00	777.75	777.10
	3	1648	768.89	770.20	770.75	771.44	772.31	772.95	773.63	774.50	775.20	773.14	773.65	773.24
	2	759	767.98	768.92	769.30	769.77	770.33	770.73	771.13	771.61	771.97	773.14	773.65	773.24
	1	100	767.06	767.83	768.16	768.58	769.12	769.53	769.96	770.52	770.96	773.09	773.60	773.19
C3	7	6783	773.82	774.51	774.80	775.18	775.66	776.04	776.41	776.93	777.32	778.49	778.60	778.59
	6	5564	770.68	772.66	772.64	773.37	773.25	773.70	774.17	774.78	775.27	775.91	776.35	776.01
	5	4162	770.21	771.30	771.67	772.23	772.85	773.38	773.92	774.61	775.17	775.86	776.35	775.96
	4	3098	769.47	770.90	771.18	771.77	772.50	773.06	773.62	774.34	774.92	775.52	776.01	775.62
	3	1851	768.78	769.92	770.37	770.92	771.59	772.09	772.61	773.26	773.78	773.70	774.15	773.80
	2	842	768.00	768.91	769.28	769.70	770.21	770.58	770.96	771.44	771.81	773.70	774.15	773.80
	1	129	766.85	767.55	767.84	768.17	768.58	768.88	769.16	769.52	769.79	773.58	774.02	773.68

Scenario " 11 " - Levees constructed for 27500m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
			2	5	10	20	50	100	200	500	1000	5000	10000	
Main	50	39539	809.42	810.65	811.14	811.66	812.30	812.76	813.23	813.85	814.35	815.42	815.97	816.07
	49	38534	808.75	809.85	810.30	810.73	811.27	811.66	812.07	812.61	813.07	814.62	815.24	815.34
	48	37463	807.75	808.85	809 29	809.72	810.26	810.66	811.09	811.68	812.21	813.97	814.68	814.78
	47	36424	806.52	807.38	807.68	808.04	808.47	808.80	809.21	809.86	810.50	812.68	813.51	813.61
	46	35727	804.74	805.60	805.95	806.36	806.93	807.47	808.13	809.10	809.94	812.45	813.34	813.44
	45	35234	803.21	804.19	804.58	805.16	806.06	806.79	807.60	808.70	809.62	812.24	813.16	813.26
	44	34329	801.53	802.94	803.56	804.38	805.51	806.34	807.23	808.40	809.36	812.07	813.00	813.10
	43	33531	800.89	802.55	803.24	804.13	805.32	806.17	807.09	808.28	809.25	811.99	812.93	813.03
	42	32671	800.16	801.89	802.57	803.44	804.61	805.45	806.36	807.55	808.52	811.24	812.18	812.28
	41	31620	799.48	801.25	801.92	802.78	803.92	804.77	805.69	806.87	807.83	810.51	811.42	811.52
	40	30645	799.15	801.03	801.73	802.64	803.84	804.73	805.69	806.93	807.92	810.71	811.66	811.76
	39	29441	798.24	800.33	801.11	802.08	803.33	804.27	805.26	806.53	807.55	810.37	811.33	811.43
	38	28375	797.44	799.27	800.00	800.88	801.99	802.80	803.64	804.70	805.53	807.76	808.49	808.59
	37	27458	796.96	798.68	799.36	800.18	801.21	801.97	802.75	803.75	804.53	806.65	807.36	807.46
	36	26568	796.19	797.70	798.27	798.93	799.76	800.36	800.98	801.76	802.35	803.92	804.43	804.53
	35	25470	795.15	796.51	797.06	797.68	798.50	799.11	799.74	800.56	801.20	802.95	803.55	803.65
	34	24542	794.77	796.10	796.66	797.29	798.15	798.79	799.47	800.35	801.04	802.95	803.60	803.70
	33	23704	794.46	795.81	796.37	797.00	797.85	798.50	799.18	800.05	800.75	802.69	803.36	803.46
	32	22947	794.06	795.42	795.97	796.56	797.40	798.02	798.68	799.52	800.20	802.08	802.72	802.82
	31	22160	793.44	794.76	795.28	795.77	796.52	797.07	797.67	798.42	799.03	800.71	801.29	801.39
	30	21122	791.56	793.42	794.05	794.24	795.03	795.62	796.23	797.02	797.86	799.73	800.38	800.48
	29	20557	791.52	793.41	794.06	794.26	795.09	795.71	796.36	797.19	797.86	799.73	800.38	800.48
	28	20118	791.28	793.11	793.70	793.73	794.43	794.93	795.46	796.11	796.90	798.63	799.23	799.33
	27	19516	790.78	792.25	792.80	793.51	794.30	794.89	795.50	796.28	796.90	798.63	799.23	799.33
	26	18928	790.43	791.86	792.46	793.07	793.88	794.48	795.11	795.89	796.53	798.26	798.87	798.97
	25	18646	790.31	791.80	792.41	793.02	793.83	794.43	795.06	795.85	796.50	798.24	798.85	798.95
	24	18371	790.14	791.64	792.25	792.85	793.65	794.24	794.85	795.62	796.25	797.93	798.53	798.63
	23	17725	789.70	791.13	791.72	792.23	792.93	793.45	793.99	794.65	795.20	796.67	797.20	797.30
	22	17151	788.99	790.24	790.76	791.23	791.82	792.24	792.70	793.21	793.68	795.25	795.89	795.99
	21	16097	787.07	787.97	788.34	788.76	789.36	789.87	790.48	791.37	792.13	794.38	795.17	795.27
	20 A	15350	786.10	786.82	787.23	787.81	788.66	789.35	790.11	791.13	791.97	794.33	795.16	795.26
	20	14779	784.24	785.82	786.45	787.24	788.27	789.04	789.86	790.93	791.80	794.23	795.07	795.17
	19	13641	783.82	785.53	786.20	787.03	788.10	788.90	789.74	790.83	791.71	794.16	795.00	795.10

Scenario " 11 " - Levees constructed for 27500m^3/s flood level + 0.1m

Reach	Cross Section Number	Chainage	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)
			2	5	10	20	50	100	200	500	1000	5000	10000	
	18	12496	783.21	784.86	785.47	786.24	787.22	787.94	788.68	789.65	790.43	792.60	793.34	793.44
	17	11032	782.45	784.10	784.75	785.57	786.61	787.37	788.14	789.18	790.01	792.33	793.13	793.23
	16	9535	780.79	782.05	782.65	783.39	784.29	784.94	785.52	786.38	787.08	789.06	789.76	789.86
	15	8375	779.15	780.94	781.72	782.59	783.70	784.53	785.23	786.30	787.17	789.58	790.41	790.51
	14	7413	778.32	780.16	780.97	781.82	782.91	783.72	784.35	785.36	786.19	788.48	789.26	789.36
	13	6209	776.58	778.50	779.37	780.27	781.37	782.19	782.58	783.53	784.33	786.53	787.29	787.39
	12	4930	776.13	778.07	778.88	779.81	780.95	781.80	782.11	783.11	783.94	786.27	787.07	787.17
	11	3545	775.65	777.48	778.23	779.13	780.22	781.04	781.13	782.03	782.81	785.04	785.81	785.91
	10	2493	775.15	776.85	777.55	778.38	779.37	779.57	779.78	780.48	781.23	783.48	784.28	784.38
	9	1501	774.32	775.89	776.55	777.34	778.31	779.06	779.62	780.44	781.23	783.48	784.28	784.38
	8	368	773.09	774.40	774.87	775.45	776.17	776.72	777.29	778.03	778.64	780.40	781.04	781.14
C2	7	6627	771.82	773.23	773.76	774.42	775.28	775.94	776.65	777.59	778.37	780.61	781.40	781.50
	6	5355	770.64	771.77	772.18	772.72	773.43	774.00	774.88	775.90	776.73	779.11	779.95	780.05
	5	3998	770.08	771.23	771.75	772.45	773.38	774.11	774.88	775.90	776.73	779.11	779.95	780.05
	4	2919	769.72	770.98	771.56	772.30	773.27	774.02	774.81	775.84	776.68	779.07	779.92	780.02
	3	1648	768.89	770.20	770.75	771.44	772.31	772.95	773.63	774.50	775.20	777.18	777.89	777.99
	2	759	767.98	768.92	769.30	769.77	770.33	770.73	771.13	771.61	771.97	772.82	773.04	773.14
	1	100	767.06	767.83	768.16	768.58	769.12	769.53	769.96	770.52	770.96	772.21	772.62	772.72
C3	7	6783	773.82	774.51	774.80	775.18	775.66	776.04	776.41	776.93	777.32	778.39	778.75	778.85
	6	5564	770.68	772.66	772.64	773.37	773.25	773.70	774.17	774.78	775.27	776.67	777.15	777.25
	5	4162	770.21	771.30	771.67	772.23	772.85	773.38	773.92	774.61	775.17	776.74	777.27	777.37
	4	3098	769.47	770.90	771.18	771.77	772.50	773.06	773.62	774.34	774.92	776.53	777.06	777.16
	3	1851	768.78	769.92	770.37	770.92	771.59	772.09	772.61	773.26	773.78	775.18	775.64	775.74
	2	842	768.00	768.91	769.28	769.70	770.21	770.58	770.96	771.44	771.81	772.80	773.12	773.22
	1	129	766.85	767.55	767.84	768.17	768.58	768.88	769.16	769.52	769.79	770.53	770.77	770.87

Scenario " 12 " - Present Levee

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)	1st Flood to Spill
				2	5	10	20	50	100	200	500	1000	5000	10000		
Main	50	39539	802.57	809.42	810.65	811.14	811.66	812.28	812.75	813.26	813.84	814.30	815.05	815.40	-	-
	49	38534	803.02	808.75	809.85	810.30	810.73	811.27	811.66	812.13	812.60	812.96	813.96	814.29	-	-
	48	37463	801.66	807.75	808.85	809.28	809.72	810.25	810.65	811.23	811.67	812.01	812.93	813.25	810.62	100
	47	36424	801.13	806.52	807.38	807.68	808.04	808.47	808.79	809.43	809.91	810.20	811.10	811.42	808.90	200
	46	35727	800.61	804.74	805.60	805.95	806.36	806.83	807.20	807.59	808.20	808.62	809.81	810.21	807.74	500
	45	35234	799.76	803.21	804.19	804.55	805.02	805.60	806.05	806.52	807.12	807.58	808.83	809.23	-	-
	44	34329	798.00	801.54	802.79	803.31	803.94	804.60	805.10	805.62	806.25	806.73	807.99	808.40	-	-
	43	33531	795.42	800.90	802.32	802.89	803.56	804.22	804.73	805.25	805.88	806.35	807.60	808.00	-	-
	42	32671	794.43	800.19	801.53	802.04	802.61	803.28	803.76	804.25	804.84	805.26	806.40	806.76	802.67	50
	41	31620	794.43	799.52	800.66	801.05	801.54	802.10	802.54	802.99	803.56	804.02	805.23	805.62	800.92	10
	40	30645	793.11	799.21	800.35	800.74	801.22	801.78	802.21	802.67	803.23	803.67	804.85	805.23	800.08	5
	39	29441	792.00	798.33	799.60	799.99	800.46	800.99	801.41	801.86	802.41	802.84	804.04	804.43	799.15	5
	38	28375	790.34	797.44	798.75	799.19	799.71	800.21	800.65	801.11	801.68	802.12	803.36	803.75	798.40	5
	37	27458	790.34	796.96	798.35	798.76	799.30	799.73	800.16	800.61	801.17	801.61	802.86	803.25	798.20	5
	36	26568	790.30	796.18	797.58	797.89	798.40	798.92	799.33	799.77	800.32	800.75	801.93	802.34	797.00	5
	35	25470	790.30	795.13	796.33	796.82	797.33	797.93	798.34	798.76	799.30	799.72	800.89	801.27	796.60	10
	34	24542	788.06	794.77	795.71	796.15	796.63	797.20	797.59	798.01	798.54	798.96	800.11	800.48	796.40	20
	33	23704	788.06	794.46	795.20	795.56	795.97	796.51	796.90	797.32	797.86	798.28	799.44	799.82	795.25	10
	32	22947	787.82	794.07	794.85	795.17	795.55	796.11	796.51	796.94	797.48	797.91	799.08	799.47	794.21	5
	31	22160	787.81	793.46	794.47	794.77	795.11	795.67	796.07	796.50	797.05	797.48	798.65	799.04	794.00	5
	30	21122	787.23	791.58	793.54	793.88	794.06	794.69	795.12	795.59	796.17	796.62	797.82	798.21	793.85	10
	29	20557	785.03	791.55	793.48	793.78	793.91	794.52	794.93	795.38	795.95	796.38	797.56	797.94	-	-
	28	20118	784.05	791.31	793.18	793.53	793.54	794.11	794.50	794.93	795.47	795.88	797.00	797.36	793.20	10
	27	19516	784.00	790.81	792.38	792.50	793.17	793.76	794.15	794.58	795.13	795.54	796.67	797.03	-	-
	26	18928	784.00	790.47	791.68	791.96	792.55	793.09	793.40	793.79	794.28	794.66	795.69	796.03	-	-
	25	18646	784.00	790.40	791.68	791.88	792.47	793.00	793.31	793.69	794.17	794.55	795.57	795.91	792.98	50
	24	18371	784.00	790.21	791.51	791.65	792.23	792.71	793.07	793.43	793.89	794.25	795.21	795.52	792.90	100
	23	17725	784.00	789.77	790.90	791.20	791.71	792.14	792.50	792.83	793.25	793.58	794.49	794.78	791.19	10
	22	17151	784.00	789.00	790.22	790.56	790.89	791.32	791.73	792.05	792.46	792.78	793.66	793.95	789.49	5
	21	16097	784.00	787.06	787.91	788.30	788.69	789.19	789.59	789.91	790.33	790.67	791.59	791.90	786.93	2
	20 A	15350	781.80	786.10	786.79	787.12	787.51	788.02	788.36	788.71	789.16	789.52	790.52	790.85	788.28	100
	20	14779	781.76	784.24	785.52	765.95	786.41	786.96	787.35	787.74	788.23	788.61	789.64	789.97	785.68	10
	19	13641	777.11	783.70	785.13	785.52	785.94	786.44	786.81	787.19	787.67	788.04	789.04	789.36	-	-
	18	12496	776.51	783.04	784.43	784.94	785.32	785.79	786.13	786.49	786.93	787.28	788.22	788.51	784.21	5
	17	11032	775.00	782.30	783.74	784.31	784.57	784.97	785.28	785.59	785.98	786.29	787.11	787.38	781.85	2
	16	9535	775.00	780.74	782.02	783.14	783.45	783.68	783.94	784.21	784.52	784.76	785.47	785.71	782.57	10
	15	8375	774.00	779.15	780.76	781.38	781.43	782.28	782.35	782.41	782.82	783.15	784.10	784.35	781.54	50
	14	7413	772.07	778.32	779.97	780.65	780.94	780.98	781.02	781.38	781.78	782.13	783.14	783.41	779.60	5

Scenario " 12 " - Present Levee

Reach	Cross Section Number	Chainage	Channel Invert	High Flood Level (m) For Various Flood Return Periods (no impoundment analysis)											Levee Height (m)	1st Flood to Spill
				2	5	10	20	50	100	200	500	1000	5000	10000		
	13	6209	772.07	776.60	777.96	778.54	779.14	779.59	779.99	780.37	780.78	781.13	782.08	782.39	778.95	20
	12	4930	770.16	776.16	777.34	777.84	778.01	778.60	778.99	779.35	779.70	780.04	780.95	781.25	778.42	50
	11	3545	769.00	775.68	776.48	776.76	777.18	777.68	778.01	778.31	778.38	778.68	779.51	779.80	777.07	20
	10	2493	769.00	775.33	775.92	776.07	776.47	776.92	777.21	777.38	777.70	778.02	778.90	779.21	774.42	2
	9	1501	769.00	774.67	775.53	775.53	775.91	776.35	776.58	776.77	776.95	777.26	778.16	778.48	774.80	5
	8	368	767.95	773.87	774.35	774.83	775.13	775.48	775.52	775.56	775.93	776.29	777.32	777.67	774.82	10
C2	7	6627	768.02	771.81	773.17	773.68	774.29	774.34	774.53	774.86	775.27	775.59	776.46	776.75	774.37	100
	6	5355	764.53	770.64	771.66	771.99	772.36	772.93	773.07	773.38	773.77	774.06	774.84	775.09	772.83	50
	5	3998	763.64	770.08	770.87	771.22	771.61	771.77	771.92	772.11	772.43	772.69	773.37	773.59	-	-
	4	2919	763.64	769.72	770.39	770.80	770.83	770.86	770.89	770.92	771.24	771.49	772.15	772.37	-	-
	3	1648	763.64	768.89	768.89	768.97	769.05	769.15	769.45	769.75	770.11	770.35	770.95	771.15	769.40	100
	2	759	763.48	768.00	768.77	768.97	769.19	769.41	769.49	769.57	769.65	769.72	769.77	769.94	768.58	5
	1	100	763.48	767.00	767.76	768.15	768.15	768.16	768.17	768.21	768.28	768.36	768.64	768.76	768.04	10
C3	7	6783	767.87	773.35	773.35	773.50	773.94	774.28	774.34	774.74	775.26	775.66	776.78	777.16	773.35	5
	6	5564	764.52	770.74	772.07	772.35	772.62	772.82	773.01	773.24	773.59	773.85	774.48	774.67	772.72	50
	5	4162	763.64	770.30	771.43	771.51	772.28	772.30	772.31	772.35	772.71	773.00	773.78	774.03	770.68	5
	4	3098	763.64	769.47	770.62	771.13	771.02	771.25	771.30	771.55	771.92	772.21	773.00	773.25	769.90	5
	3	1851	763.64	768.76	769.61	769.95	769.59	769.97	770.26	770.38	770.74	771.03	771.78	772.03	769.42	5
	2	842	763.64	768.01	768.48	768.52	768.74	768.89	769.13	769.38	769.70	769.95	770.61	770.83	768.48	5
	1	129	763.64	766.85	767.55	767.86	768.23	768.32	768.41	768.47	768.51	768.72	769.26	769.44	767.58	10

Note : Levee Height Column indicates actual levee heights as surveyed and used in the hydraulic model

APPENDIX D

CAPITAL ESTIMATES

Orange River Levee Volumes

Section(s)	Levee Segment	Levee Length (m)	Levee Volume (m^3) for Various Scenarios											
			Scenario 12	Scenario 11	Scenario 10	Scenario 9	Scenario 8	Scenario 7	Scenario 6	Scenario 5	Scenario 4	Scenario 3	Scenario 2	Scenario 1
48	A - B	950	13038	62754	46548	29269	23595	17906	14176	11022	7247	4636	2329	0
47	B - C 1	1650	49867	177397	127347	87454	72184	58060	49867	43676	36148	30315	25781	14429
47	B - C 2	1260	53222	161885	119954	85995	72802	60460	53222	47705	40927	35611	31430	20702
47	B - E	1350	57024	173448	128522	92138	78002	64779	57024	51112	43850	38154	33675	22181
47	D - E	1350	39701	143154	102497	70133	57761	46327	39701	34698	28621	23916	20263	11138
46	F - FA	220	3816	22551	15203	9655	7253	4865	3477	2483	1574	1009	584	0
46	G - GA	250	4664	26353	17879	11461	8672	5891	4267	3101	2028	1356	850	0
46	FA - GA	200	3732	21082	14303	9169	6938	4713	3414	2480	1622	1085	680	0
43	H - I	200	2289	35866	24558	18723	15078	11120	8475	6328	3808	2289	1313	0
40-43	I - J	3350	23525	638518	431952	341312	277589	206937	159301	120407	75450	47680	29775	0
40	J - K	90	291	18225	12067	9810	8004	5990	4622	3501	2216	1414	899	0
40	J - L	300	971	60749	40289	32699	26679	19968	15406	11671	7387	4714	2996	0
41,42	M - N	1350	12487	380173	279613	233761	200505	163038	136434	113886	86707	68526	55745	27812
41	N - O	120	867	22872	15612	12400	10123	7628	5915	4512	2904	1896	1235	5
40	N - P	750	2427	151873	100723	81748	66697	49920	38515	29177	18467	11785	7491	0
40	P - Q	170	550	34424	22831	18529	15118	11315	8730	6613	4186	2671	1698	0
34-40	R - S	6900	65843	1071324	957737	873850	543789	428469	347187	277535	193446	138069	97031	28839
34	S - T	150	3872	23823	20713	15006	12966	10572	8880	7415	5640	4481	3550	1717
31-34	S - W	2000	36935	337845	293597	215873	187624	155443	132114	111506	86944	70877	57437	30194
31	W - X	250	3494	32814	28539	20949	18184	15040	12727	10765	8333	6896	5503	2572
29-31	W - Y	1800	20038	206658	175329	123156	102031	81505	66759	54190	39069	33071	23950	7834
29	Y - Z	350	2986	34800	28612	19083	14832	11284	8844	6731	4284	3761	2206	0
35-39	U - V	4650	111035	865663	852885	567825	496017	410837	348899	294066	225816	177863	141625	66183
33,34	AA - AB 1	1610	11521	191928	162381	110156	92015	71103	56652	44411	30039	21022	14079	2376
33,34	AA - AB 2	1650	11807	216574	184788	128539	108442	98473	69696	55807	39749	29385	21137	6060
33	AE - AC	730	1570	80502	67332	44739	36839	28017	21892	16668	10767	7074	4278	0
33	AC - AD	500	1075	55138	46118	30643	25232	19190	14994	11416	7374	4845	2930	0
32-34	AE - AF	1050	4329	124240	104614	70773	58866	45501	36162	28143	18995	13193	8736	699
32	AG - AH	500	3314	68448	58720	41711	35584	28654	23704	19451	14302	11107	8442	3152
32	AI - AH	440	2916	60235	51674	36706	31314	25216	20860	17117	12586	9774	7429	2774
31	AH - AJ	500	2500	51976	44368	31048	26275	20916	17034	13792	9858	7592	5450	1226
31,32	AI - AJ	1300	7536	155840	133522	94104	80093	64077	52636	43015	31179	24131	17951	5583
28	AK - AL	420	2675	35037	32038	19018	14621	11397	9031	7015	4545	4449	2702	0
28	AM- AN	400	2547	33369	30513	18112	13025	10855	8601	6681	4329	4237	2573	0
28	AN - AO	640	4076	53390	48820	28979	22280	17367	13762	10660	6926	6779	4117	0
28	AP - AQ	450	2866	37540	34327	20376	15666	12211	9676	7516	4870	4767	2895	0
28	AQ - AR	250	1592	20856	19070	11320	8703	6784	5376	4176	2706	2648	1608	0
20A-24	AS - AT	3250	67925	418309	354240	259098	223473	151294	157357	133328	104390	84955	66633	33437
21-23	AU - AV 1	2350	20216	251665	214914	145546	123847	103784	83872	70200	53900	42954	32648	12318
21-23	AU - AV 2	2300	19786	228219	193596	128587	108477	119486	71679	58865	44013	34322	24892	7074

Orange River Levee Volumes

Section(s)	Levee Segment	Levee Length (m)	Levee Volume (m^3) for Various Scenarios											
			Scenario 12	Scenario 11	Scenario 10	Scenario 9	Scenario 8	Scenario 7	Scenario 6	Scenario 5	Scenario 4	Scenario 3	Scenario 2	Scenario 1
21	AW - AX	220	6470	34940	27561	19269	15887	12198	9747	7741	5559	4252	3418	2132
20,21	AX - AY	1200	14883	176453	137249	93700	75888	56719	43892	33372	21708	14496	9816	52947
17-19	AZ - BA	2380	13058	351136	276369	200777	167324	129764	104120	81672	55063	37398	25392	1791
17	BA - BB	310	1701	45736	35998	26152	21794	16902	13562	10638	7175	4871	3307	233
17	BA - BC1	650	4181	136144	108606	83213	71263	57554	48310	39941	29707	22628	17639	7439
16-19	BC2 - BD	4500	22500	662805	501064	379620	317146	246730	200614	158344	107928	73530	55084	20632
16	BD - BE	120	0	9876	6270	4763	3711	2580	1918	1271	543	90	0	0
17,18	BF - BG	2250	28823	390800	313921	235297	200092	160130	132491	107964	78329	58076	43926	14040
17,18	BF - BH	2200	6650	301696	235138	168214	138767	105882	83579	64191	41466	26576	16632	0
16	BI - BJ	100	7790	26300	20770	18260	16396	14241	12871	11416	9540	8119	7048	5032
16	BJ - BK	1150	89588	302445	238858	209985	188556	163772	148017	131280	109711	93372	81048	57864
15	BL - BM	1200	6000	139609	82513	66903	51672	35429	26290	16977	7107	1438	0	0
15	BN - BO	1000	1198	140962	88352	76461	62260	46837	38250	28376	17160	10063	4644	0
13-15	BP - BQ	2350	18571	357788	261162	198688	163599	125267	105750	84296	51245	32054	20216	3032
13-17	BR - BS 1	6050	30250	791292	560405	425342	345772	259681	214402	158813	95605	54644	24597	13311
13-17	BR - BS 2	5000	15912	618450	433152	325281	262001	193858	157608	114162	65285	34121	15378	201
9-13'	BT - BU	5650	45824	872971	736354	492694	410967	329124	302029	245617	169437	116399	77066	12150
9	BU - BV	200	988	30801	24513	17326	14443	11714	10005	7912	5539	3885	2694	562
12	BW - BX	250	2744	38816	33281	21515	17749	13669	12506	9563	6182	3906	2276	0
10	BY - BZ	1480	4710	230539	183731	130193	109735	92144	87150	82514	61313	45774	34253	12314
C2(7)-8	CA - CB	1850	38481	245847	143785	142117	119740	95280	78396	63944	46946	35224	26807	11782
C2(5-6)	CC - CD	600	17645	99000	59170	54989	45662	35331	27422	22794	17576	14012	11539	5770
C3(7)-8	CE - CF	1800	19758	131243	77014	77507	65609	51899	42602	34099	24401	17575	12760	2572
C3(7)	CF - CG	60	590	5808	2241	3262	2725	2134	1723	1364	948	659	454	22
C3(7)	CF - CH	750	0	39188	36313	24634	21197	16969	14208	11586	8584	6452	4971	1954
C3(6,7)	CI - CK	1820	182073	387611	323924	293243	270761	243994	224294	206186	210943	182816	182816	116894
C2(5-7)	CJ - CK	2350	69110	387750	231750	215374	178841	138380	107401	89277	68838	54879	45196	22598
C3(3-5)	CL - CM	3520	73920	471900	346419	317800	281268	238448	207275	178675	145351	119489	150605	59757
C3(2)	CM - CN	100	1014	9761	6226	6357	5529	4570	3864	3236	2473	1914	1914	637
C3(1,2)	CM - CO	930	24617	94179	105560	70775	64743	57297	51707	46521	39791	34611	34611	20850
C3(2)	CP - CQ	300	148	20170	11475	11789	9817	7580	5974	4582	2952	1815	1020	0
C3(1,2)	CR - CS	800	9409	47744	71762	34228	30808	26568	23434	20388	16561	13728	11386	6377
C2(1-4)	CT - CU	2670	77597	223738	159347	141920	122402	99711	82694	68335	50325	37774	28691	10704
C2(1-4)	CV - CW	2560	19878	340198	261350	240159	215481	185760	164000	143917	119173	100599	100599	57658
	Totals	**106370**	**1537004**	**14951213**	**11779967**	**9027260**	**7437702**	**5964507**	**4989241**	**4073838**	**3027686**	**2292550**	**1834347**	**829556**

Total Cost of New Levees (Full Contractor Costs) for Various Scenarios

Item	Scenario 12	Scenario 11	Scenario 10	Scenario 9	Scenario 8	Scenario 7	Scenario 6	Scenario 5	Scenario 4	Scenario 3	Scenario 2	Scenario 1
Total Volume (m^3)	1537004	14951213	11779967	9027260	7437702	5964507	4989241	4073838	3027686	2292550	1834347	829556
Cost @ R30/m^3 (R)	46110106	448536391	353399024	270817790	223131061	178935197	149677242	122215147	90830570	68776502	55030410	24886682
Emergency Spillways and Gates Cost (R)	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000
Sub-Total (R)	**47730106**	**450156391**	**355019024**	**272437790**	**224751061**	**180555197**	**151297242**	**123835147**	**92450570**	**70396502**	**56650410**	**26506682**
P & G (20 %)	9546021	90031278	71003805	54487558	44950212	36111039	30259448	24767029	18490114	14079300	11330082	5301336
Professional Fees (7.5 %)	3579758	33761729	26626427	20432834	16856330	13541640	11347293	9287636	6933793	5279738	4248781	1988001
Total (R)	**60855885**	**573949398**	**452649255**	**347358182**	**286557603**	**230207876**	**192903983**	**157889813**	**117874477**	**89755540**	**72229272**	**33796020**

Total Cost of New Levees (Partial Contractor Costs) for Various Scenarios

Item	Scenario 12	Scenario 11	Scenario 10	Scenario 9	Scenario 8	Scenario 7	Scenario 6	Scenario 5	Scenario 4	Scenario 3	Scenario 2	Scenario 1
Total Volume (m^3)	1537004	14951213	11779967	9027260	7437702	5964507	4989241	4073838	3027686	2292550	1834347	829556
Cost @ R15/m^3 (R)	23055053	224268195	176699512	135408895	111565530	89467598	74838621	61107574	45415285	34388251	27515205	12443341
Emergency Spillways and Gates Cost (R)	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000
Sub-Total (R)	**24675053**	**225888195**	**178319512**	**137028895**	**113185530**	**91087598**	**76458621**	**62727574**	**47035285**	**36008251**	**29135205**	**14063341**
P & G (5 %)	1233753	11294410	8915976	6851445	5659277	4554380	3822931	3136379	2351764	1800413	1456760	703167
Professional Fees (3 %)	740252	6776646	5349585	4110867	3395566	2732628	2293759	1881827	1411059	1080248	874056	421900
Total (R)	**26649057**	**243959251**	**192585073**	**147991206**	**122240373**	**98374606**	**82675311**	**67745780**	**50798108**	**38888911**	**31466021**	**15188408**

APPENDIX E

HYDRO-ECONOMIC ASSESSMENTS

Total Cost of Upgrading Levees (Full Contractors Costs) for Various Scenarios

Item	Scenario 12	Scenario 11	Scenario 10	Scenario 9	Scenario 8	Scenario 7	Scenario 6	Scenario 5	Scenario 4	Scenario 3	Scenario 2	Scenario 1
Total Volume (m^3)	1537004	13414209	10242964	7490256	5900698	4427503	3453292	2574883	1582253	914821	537977	103984
Cost @ R30/m^3 (R)	46110120	402426270	307288920	224707680	177020940	132825090	103598760	77246490	47467590	27444630	16139310	3119520
Emergency Spillways and Gates Cost (R)	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000
Sub-Total (R)	**47730120**	**404046270**	**308908920**	**226327680**	**178640940**	**134445090**	**105218760**	**78866490**	**49087590**	**29064630**	**17759310**	**4739520**
P & G (20 %)	9546024	80809254	61781784	45265536	35728188	26889018	21043752	15773298	9817518	5812926	3551862	947904
Professional Fees (7.5 %)	3579759	30303470	23168169	16974576	13398071	10083382	7891407	5914987	3681569	2179847	1331948	355464
Total (R)	**60855903**	**515158994**	**393858873**	**288567792**	**227767199**	**171417490**	**134153919**	**100554775**	**62586677**	**37057403**	**22643120**	**6042888**

Total Cost of Upgrading Levees (Partial Contractors Costs) for Various Scenarios

Item	Scenario 12	Scenario 11	Scenario 10	Scenario 9	Scenario 8	Scenario 7	Scenario 6	Scenario 5	Scenario 4	Scenario 3	Scenario 2	Scenario 1
Total Volume (m^3)	1537004	13414209	10242964	7490256	5900698	4427503	3453292	2574883	1582253	914821	537977	103984
Cost @ R15/m^3 (R)	23055060	201213135	153644460	112353840	88510470	66412545	51799380	38623245	23733795	13722315	8069655	1559760
Emergency Spillways and Gates Cost (R)	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000	1620000
Sub-Total (R)	**24675060**	**202833135**	**155264460**	**113973840**	**90130470**	**68032545**	**53419380**	**40243245**	**25353795**	**15342315**	**9689655**	**3179760**
P & G (5 %)	1233753	10141657	7763223	5698692	4506524	3401627	2670969	2012162	1267690	767116	484483	158988
Professional Fees (3 %)	740252	6084994	4657934	3419215	2703914	2040976	1602581	1207297	760614	460269	290690	95393
Total (R)	**26649065**	**219059786**	**167685617**	**123091747**	**97340908**	**73475149**	**57692930**	**43462705**	**27382099**	**16569700**	**10464827**	**3434141**

Total Costs (Estimate) for New Dam at Boegoeberg

Item	Scenario 12	Scenario 11	Scenario 10	Scenario 9	Scenario 8	Scenario 7	Scenario 6	Scenario 5	Scenario 4	Scenario 3	Scenario 2	Scenario 1
Storage Capacity ($10^6 m^3$)	0.0	2600.0	4600.0	5600.0	6600.0	8100.0	9600.0	11100.0	13600.0	15100.0	20600.0	22600.0
Height (m)	0.0	45.6	48.8	49.9	50.8	51.9	52.9	53.7	54.8	55.4	57.2	57.7
Capital Costs (R million)	0.0	481.9	623.4	672.2	720.3	763.8	806.0	842.0	892.4	918.3	995.4	1018.4
Design Costs (7.5%) (R million)	0.0	36.1	46.8	50.4	54.0	57.3	60.4	63.1	66.9	68.9	74.7	76.4
P&G (20%) (R million)	0.0	96.4	124.7	134.4	144.1	152.8	161.2	168.4	178.5	183.7	199.1	203.7
Contengencies(10%) (R million)	0.0	48.2	62.3	67.2	72.0	76.4	80.6	84.2	89.2	91.8	99.5	101.8
Total (R million)	**0.0**	**662.6**	**857.2**	**924.3**	**990.4**	**1050.2**	**1108.2**	**1157.7**	**1227.0**	**1262.7**	**1368.7**	**1400.3**

Appendix E-2

TOTAL LEVEE DAMAGES-TLD- (R million)FOR EACH FLOOD EVENT FOR VARIOUS SCERIO'S-UPSTREAM DAMS EXCLUDED

Flood Return	VARIOUS LEVEE SCENARIOS											
Period (years)	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.0
10	0	3.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3
20	0	7.2	4.5	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	6.1
50	0	21.7	10.8	8.3	1.6	1.6	1.6	1.6	1.6	1.6	1.6	9.1
100	0	36.1	26.9	16.5	7.9	1.9	1.9	1.9	1.9	1.9	1.9	15.2
200	0	57.8	37.7	35.4	15.8	9.6	2.3	2.3	2.3	2.3	2.3	24.4
500	0	65.0	76.3	56.6	50.5	28.9	18.4	2.9	2.9	2.9	2.9	48.7
1000	0	65.0	80.8	100.2	71.1	65.6	46.0	17.2	3.5	3.5	3.5	54.8
5000	0	65.0	80.8	106.1	142.1	173.6	195.7	126.1	104.2	4.5	4.5	54.8
10000	0	65.0	80.8	106.1	142.1	173.6	207.2	243.6	152.9	22.6	5.7	54.8

MEAN ANNUAL LEVEE DAMAGES -MALD- (R million/year) - UPSTREAM DAMS EXCLUDED

Flood Return	VARIOUS LEVEE SCENARIOS											
Period (years)	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00
5	0.00	0.22	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.02
10	0.00	0.27	0.13	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.16
20	0.00	0.43	0.23	0.14	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.23
50	0.00	0.29	0.19	0.12	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.12
100	0.00	0.23	0.16	0.13	0.06	0.03	0.01	0.01	0.01	0.01	0.01	0.10
200	0.00	0.18	0.17	0.14	0.10	0.06	0.03	0.01	0.01	0.01	0.01	0.11
500	0.00	0.06	0.08	0.08	0.06	0.05	0.03	0.01	0.00	0.00	0.00	0.05
1000	0.00	0.05	0.06	0.08	0.09	0.10	0.10	0.06	0.04	0.00	0.00	0.04
5000	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.01
10000	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.00
MALD	0.00	1.77	1.14	0.86	0.57	0.47	0.42	0.33	0.30	0.24	0.23	0.84

TOTAL LEVEE DAMAGES-TLD-50- (R million) OVER 50-YEARS (TLD-50)-UPSTREAM DAMS EXCLUDED

Flood Return	VARIOUS LEVEE SCENARIOS											
Period (years)	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	0.00
10	0.00	10.80	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	0.91
20	0.00	10.40	6.47	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	8.78
50	0.00	13.77	6.85	5.25	1.02	1.02	1.02	1.02	1.02	1.02	1.02	5.81
100	0.00	14.26	10.64	6.52	3.12	0.76	0.76	0.76	0.76	0.76	0.76	6.01
200	0.00	12.80	8.36	7.84	3.50	2.14	0.51	0.51	0.51	0.51	0.51	5.40
500	0.00	6.32	7.42	5.50	4.91	2.81	1.79	0.28	0.28	0.28	0.28	4.74
1000	0.00	3.17	3.94	4.89	3.47	3.20	2.25	0.84	0.17	0.17	0.17	2.67
5000	0.00	0.65	0.80	1.06	1.41	1.73	1.95	1.25	1.04	0.05	0.05	0.55
10000	0.00	0.32	0.40	0.53	0.71	0.87	1.03	1.22	0.76	0.11	0.03	0.27
TLD-50	0.0	77.0	52.1	40.5	27.1	21.5	18.2	14.8	13.5	11.8	11.7	35.1

COSTS OF FLOOD REMEDIATION FOR LEVEES AT FULL AND PARTIAL CONTRACTOR RATES & DAM AT BOEGOE BERG(R million)

CONSTRUCTION	LEVEL OF REMEDIATION SCENARIO											
OPTION	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
NEW LEVEES-FULL	0.00	72.23	89.76	117.87	157.89	192.90	230.21	286.56	347.36	452.65	573.95	60.86
UPGRADE CURRENT- FULL	0.00	22.64	37.06	62.59	100.55	134.15	171.42	227.77	288.57	393.86	515.16	0.00
NEW LEVEES-PARTIAL	0.00	31.47	38.89	50.80	67.75	82.58	98.37	122.24	147.99	192.59	243.96	26.65
UPGRADE CURRENT-PARTIAL	0.00	10.46	16.57	27.38	43.46	57.69	73.48	97.34	123.09	167.69	219.06	0.00
DAM	0.00	857.20	924.30	980.40	1050.20	1108.20	1157.70	1227.00	1262.70	1368.70	1400.30	0.00

COSTS OF FLOOD REMEDIATION FOR LEVEES AT FULL AND PARTIAL CONTRACTOR RATES & DAM AT BOEGOE BERG(R million) INCLUDING TLD-50

CONSTRUCTION	LEVEL OF REMEDIATION SCENARIO											
OPTION	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
NEW LEVEES-FULL	0.00	149.26	141.89	158.39	184.96	214.36	248.45	301.37	360.83	464.48	585.69	96.00
UPGRADE CURRENT- FULL	0.00	99.67	89.19	103.11	127.63	155.61	189.66	242.58	302.04	405.69	526.90	35.14
NEW LEVEES-PARTIAL	0.00	108.50	91.02	91.32	94.82	104.03	116.61	137.05	161.46	204.41	255.70	61.79
UPGRADE CURRENT-PARTIAL	0.00	87.50	68.70	67.90	70.53	79.15	91.71	112.15	136.56	179.51	230.80	35.14
DAM	0.00	934.23	976.43	1020.92	1077.27	1129.66	1175.94	1241.81	1276.17	1380.53	1412.04	35.14

Appendix E-3

TOTAL FLOOD DAMAGES (R million) FOR EACH FLOOD EVENT FOR VARIOUS SCERIO'S- UPSTREAM DAMS EXCLUDED

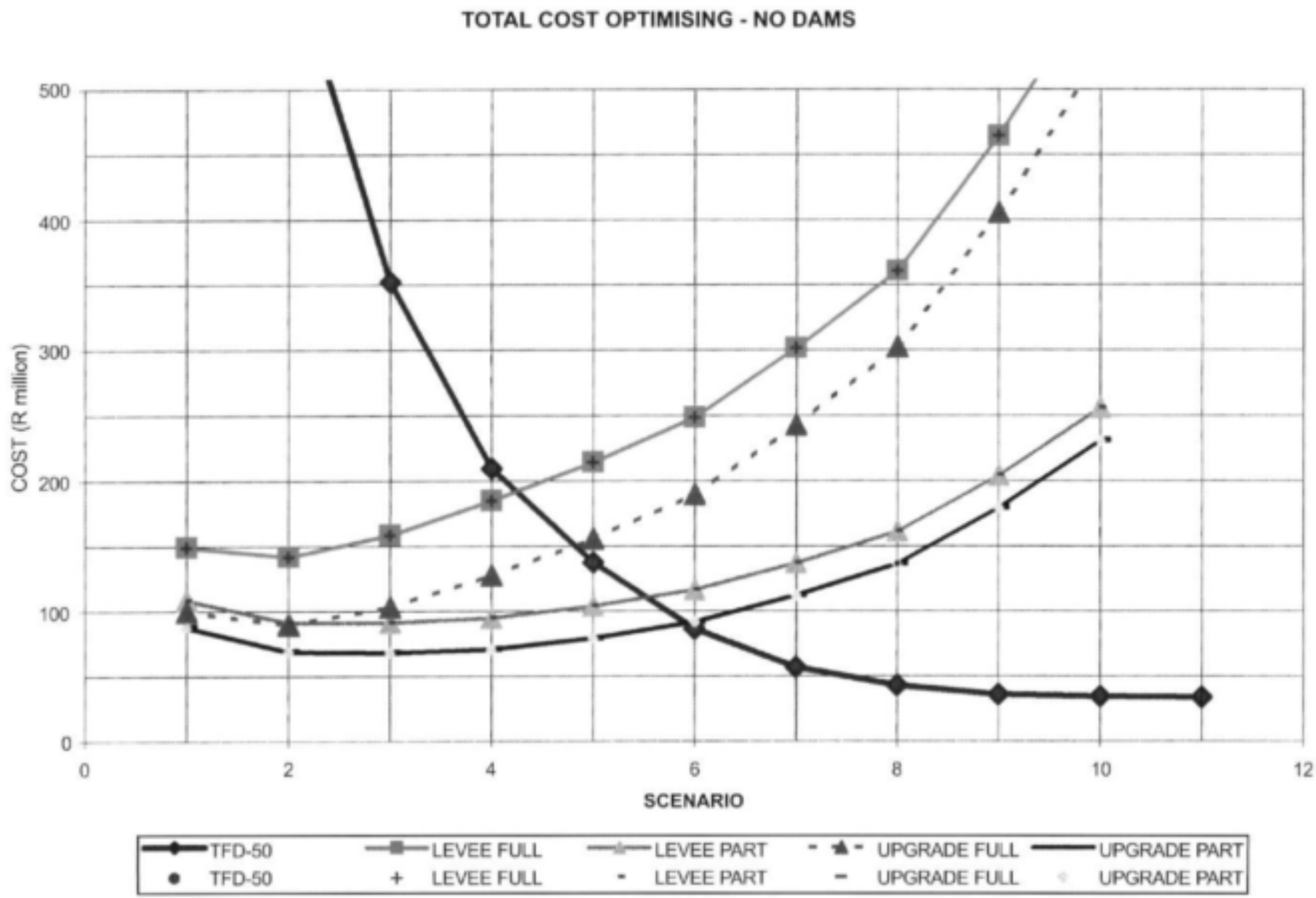
Flood Return Period (years)	VARIOUS LEVEE SCENARIOS										
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0	0	0	0	0	0	0	0	0	0	0	0
5	54.2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	11.0
10	70.0	90.2	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	41.5
20	87.3	105.8	109.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	61.3
50	106.1	116.2	117.4	125.7	4.6	4.6	4.6	4.6	4.6	4.6	4.6	98.6
100	117.1	122.6	122.8	130.0	136.7	5.0	5.0	5.0	5.0	5.0	5.0	106.4
200	124.9	127.9	127.5	132.8	139.1	142.0	5.3	5.3	5.3	5.3	5.3	116.4
500	132.2	132.3	131.6	136.5	140.9	143.4	148.6	5.5	5.5	5.5	5.5	123.5
1000	137.6	135.6	134.1	138.6	141.6	144.6	151.0	150.2	6.0	6.0	6.0	127.9
5000	145.8	140.7	138.7	141.7	143.9	146.4	154.3	154.7	149.0	6.5	6.5	137.6
10000	147.8	142.3	140.3	142.9	144.2	146.7	155.0	155.4	148.8	156.0	6.6	140.8

MEAN ANNUAL FLOOD DAMAGES - MAD-(R million) - UPSTREAM DAMS EXCLUDED

Flood Return Period (years)	VARIOUS LEVEE SCENARIOS										
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	1.35	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.28
5	6.21	4.61	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2.63
10	3.93	4.90	2.80	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	2.57
20	2.90	3.33	3.40	1.94	0.12	0.12	0.12	0.12	0.12	0.12	0.12	2.40
50	1.12	1.19	1.20	1.28	0.71	0.05	0.05	0.05	0.05	0.05	0.05	1.03
100	0.60	0.63	0.63	0.66	0.69	0.37	0.03	0.03	0.03	0.03	0.03	0.56
200	0.39	0.39	0.39	0.40	0.42	0.43	0.23	0.02	0.02	0.02	0.02	0.38
500	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.08	0.01	0.01	0.01	0.13
1000	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.06	0.00	0.00	0.11
5000	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.01
10000	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01
MAD	**16.77**	**15.38**	**8.98**	**5.01**	**2.67**	**1.71**	**1.18**	**0.89**	**0.76**	**0.70**	**0.68**	10.07

TOTAL FLOOD DAMAGES-TFD- (R million) OVER 50-YEARS (TFD-50)-UPSTREAM DAMS EXCLUDED

Flood Return Period (years)	VARIOUS LEVEE SCENARIOS										
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	350.77	13.41	13.41	13.41	13.41	13.41	13.41	13.41	13.41	13.41	13.41	71.25
10	209.82	270.52	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	124.46
20	125.77	152.43	157.30	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	88.36
50	67.45	73.90	74.65	79.91	2.90	2.90	2.90	2.90	2.90	2.90	2.90	62.83
100	46.25	48.43	48.50	51.34	54.01	1.99	1.99	1.99	1.99	1.99	1.99	42.02
200	27.68	28.36	28.26	29.44	30.85	31.49	1.17	1.17	1.17	1.17	1.17	25.81
500	12.86	12.87	12.80	13.27	13.70	13.95	14.47	0.54	0.54	0.54	0.54	12.01
1000	6.71	6.62	6.54	6.76	6.91	7.06	7.37	7.33	0.29	0.29	0.29	6.24
5000	1.45	1.40	1.38	1.41	1.43	1.45	1.54	1.54	1.48	0.06	0.06	1.37
10000	0.74	0.71	0.70	0.71	0.72	0.73	0.77	0.78	0.74	0.78	0.03	0.70
TFD-50	**849.5**	**608.6**	**352.2**	**209.7**	**137.4**	**86.4**	**57.1**	**43.1**	**36.0**	**34.6**	**33.9**	**435.0**



TOTAL COST OPTIMISING - NO DAMS
COST (R million)
500
400
300
200
100
0
0
2
4
6
8
10
12
SCENARIO
TFD-50
LEVEE FULL
LEVEE PART
UPGRADE FULL
UPGRADE PART
TFD-50
LEVEE FULL
LEVEE PART
UPGRADE FULL
UPGRADE PART

Appendix E-5

TOTAL FLOOD DAMAGES (R million) FOR EACH FLOOD EVENT FOR VARIOUS SCERIO'S- UPSTREAM DAMS INCLUDED

Flood Return Period (years)	VARIOUS LEVEE SCENARIOS										
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0	0	0	0	0	0	0	0	0	0	0	0
13	54.2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	11.0
22	70.0	90.2	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	41.5
31	87.3	105.8	109.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	61.3
54	106.1	116.2	117.4	123.7	4.6	4.6	4.6	4.6	4.6	4.6	4.6	98.8
100	117.1	122.6	122.8	130.0	136.7	5.0	5.0	5.0	5.0	5.0	5.0	106.4
200	124.9	127.9	127.5	132.8	139.1	142.0	5.3	5.3	5.3	5.3	5.3	116.4
500	132.2	132.3	131.6	136.5	140.9	143.4	148.8	5.5	5.5	5.5	5.5	123.5
1000	137.6	135.6	134.1	138.6	141.6	144.6	151.0	150.2	6.0	6.0	6.0	127.9
5000	145.8	140.7	138.7	141.7	143.9	146.4	154.3	154.7	149.0	6.5	6.5	137.6
10000	147.8	142.3	140.3	142.9	144.2	146.7	155.0	155.4	148.8	156.0	6.6	140.8

MEAN ANNUAL FLOOD DAMAGES-MAD- (R million/year)-UPSTREAM DAMS INCLUDED

Flood Return Period (years)	VARIOUS LEVEE SCENARIOS										
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	4.69	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.95
13	1.95	1.45	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.83
22	1.04	1.29	0.74	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.68
31	1.33	1.53	1.56	0.89	0.05	0.05	0.05	0.05	0.05	0.05	0.05	1.10
54	0.95	1.02	1.02	1.09	0.60	0.04	0.04	0.04	0.04	0.04	0.04	0.87
100	0.60	0.63	0.63	0.66	0.69	0.37	0.03	0.03	0.03	0.03	0.03	0.56
200	0.39	0.39	0.39	0.40	0.42	0.43	0.23	0.02	0.02	0.02	0.02	0.36
500	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.08	0.01	0.01	0.01	0.13
1000	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.06	0.00	0.00	0.11
5000	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.01
10000	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01
MAD	11.22	6.75	4.86	3.61	2.35	1.48	0.95	0.66	0.53	0.47	0.45	5.61

TOTAL FLOOD DAMAGES-TFD- (R million) OVER 50-YEARS (TFD-50)-UPSTREAM DAMS INCLUDED

Flood Return Period (years)	VARIOUS LEVEE SCENARIOS										
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	137.10	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	27.85
22	96.67	124.90	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	57.46
31	99.76	120.92	124.78	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	70.09
54	65.40	71.68	72.39	77.49	2.81	2.81	2.81	2.81	2.81	2.81	2.81	60.93
100	46.25	48.43	48.50	51.34	54.01	1.99	1.99	1.99	1.99	1.99	1.99	42.02
200	27.68	28.36	28.26	29.44	30.85	31.49	1.17	1.17	1.17	1.17	1.17	25.81
500	12.86	12.87	12.80	13.27	13.70	13.95	14.47	0.54	0.54	0.54	0.54	12.01
1000	6.71	6.62	6.54	6.76	6.91	7.06	7.37	7.33	0.29	0.29	0.29	6.24
5000	1.45	1.40	1.38	1.41	1.43	1.46	1.54	1.54	1.48	0.06	0.06	1.37
10000	0.74	0.71	0.70	0.71	0.72	0.73	0.77	0.78	0.74	0.78	0.03	0.70
TFD-50	494.8	421.1	304.6	193.5	123.5	72.5	43.2	29.2	22.1	20.7	19.9	304.5

Appendix E-6

TOTAL LEVEE DAMAGES TLD (R million)FOR EACH FLOOD EVENT FOR VARIOUS SCERIO'S-UPSTREAM DAMS INCLUDED

Flood Return Period (years)	VARIOUS LEVEE SCENARIOS											
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.0
22	0	3.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	3.3
31	0	7.2	4.5	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	6.1
54	0	21.7	10.8	8.3	1.6	1.6	1.6	1.6	1.6	1.6	1.6	9.1
100	0	36.1	26.9	16.5	7.9	1.9	1.9	1.9	1.9	1.9	1.9	13.2
200	0	57.8	37.7	35.4	15.8	9.5	2.3	2.3	2.3	2.3	2.3	24.4
500	0	65.0	76.3	36.6	50.5	28.9	18.4	2.9	2.9	2.9	2.9	48.7
1000	0	65.0	80.8	100.2	71.1	65.6	46.0	17.2	3.5	3.5	3.5	54.8
5000	0	65.0	80.8	106.1	142.1	173.6	195.7	126.1	104.7	4.5	4.5	54.8
10000	0	65.0	80.8	106.1	142.1	173.6	207.2	243.6	152.9	27.6	5.7	54.8

MEAN ANNUAL LEVEE DAMAGES -MALD- (R million/year) - UPSTREAM DAMS INCLUDED

Flood Return Period (years)	VARIOUS LEVEE SCENARIOS											
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0.00	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.00
13	0.00	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.00
22	0.00	0.07	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04
31	0.00	0.20	0.10	0.06	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.10
54	0.00	0.25	0.16	0.11	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.10
100	0.00	0.23	0.16	0.13	0.06	0.03	0.01	0.01	0.01	0.01	0.01	0.13
200	0.00	0.18	0.17	0.14	0.10	0.06	0.03	0.01	0.01	0.01	0.01	0.11
500	0.00	0.06	0.08	0.08	0.06	0.05	0.03	0.01	0.00	0.00	0.00	0.05
1000	0.00	0.05	0.06	0.08	0.09	0.10	0.10	0.06	0.04	0.00	0.00	0.04
5000	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.01
10000	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.00
MALD	0.00	1.19	0.88	0.72	0.49	0.40	0.34	0.26	0.22	0.16	0.16	0.57

TOTAL LEVEE DAMAGES-TLD-50- (R milion) OVER 50-YEARS (TLD-50)-UPSTREAM DAMS INCLUDED

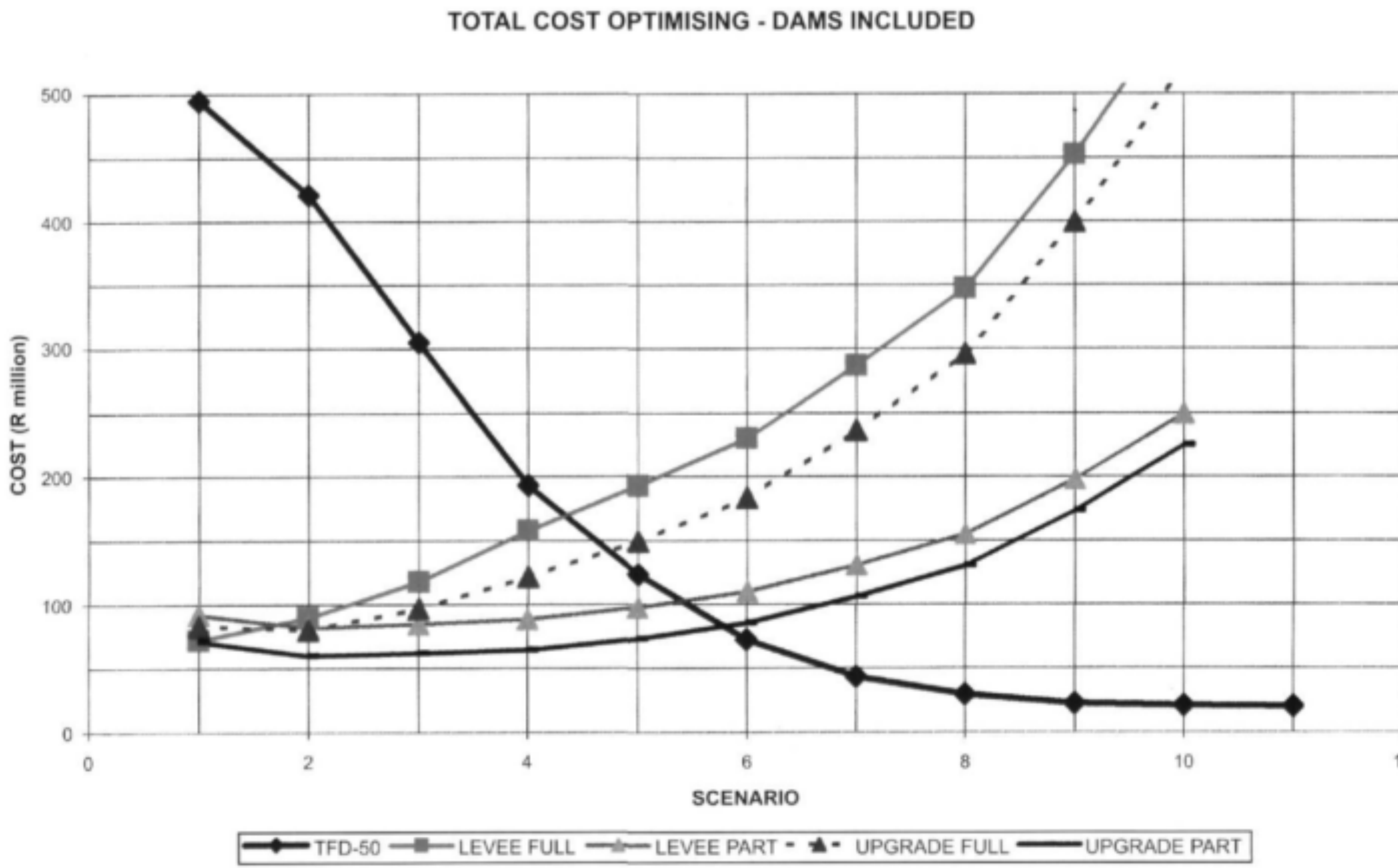
Flood Return Period (years)	VARIOUS LEVEE SCENARIOS											
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.00
22	0.00	4.12	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	0.35
31	0.00	4.59	2.85	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	3.87
54	0.00	13.35	6.64	5.09	0.99	0.99	0.99	0.99	0.99	0.99	0.99	5.63
100	0.00	14.26	10.64	6.52	3.12	0.78	0.78	0.78	0.78	0.78	0.78	6.01
200	0.00	12.80	8.36	7.84	3.50	2.14	0.51	0.51	0.51	0.51	0.51	5.40
500	0.00	6.32	7.42	5.50	4.91	2.81	1.79	0.28	0.28	0.28	0.28	4.74
1000	0.00	3.17	3.94	4.89	3.47	3.20	2.25	0.84	0.17	0.17	0.17	2.67
5000	0.00	0.65	0.80	1.06	1.41	1.73	1.95	1.25	1.04	0.05	0.05	0.55
10000	0.00	0.32	0.40	0.53	0.71	0.87	1.03	1.22	0.76	0.11	0.03	2.27
TLD-50	0.0	60.6	43.1	34.2	20.9	15.2	12.0	8.6	7.3	5.6	5.5	29.5

COSTS OF FLOOD REMEDIATION FOR LEVEES AT FULL AND PARTIAL CONTRACTOR RATES & DAM AT BOEGOE BERG(R million)

CONSTRUCTION OPTION	LEVEL OF REMEDIATION SCENARIO											
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
NEW LEVEES-FULL	0.00	72.23	89.76	117.87	157.89	192.90	230.21	286.56	347.36	452.65	573.85	60.86
UPGRADE CURRENT FULL	0.00	22.64	37.06	62.59	100.55	134.15	171.42	227.77	288.57	393.86	515.16	0.00
NEW LEVEES-PARTIAL	0.00	31.47	38.89	50.80	67.73	82.58	98.37	122.24	147.99	192.59	243.98	26.65
UPGRADE CURRENT PARTIAL	0.00	10.46	16.57	27.38	43.46	57.09	73.48	97.34	123.09	167.69	219.06	0.00
DAM	0.00	857.20	924.30	980.40	1050.20	1108.20	1157.70	1227.00	1262.70	1368.70	1400.30	0.00

COSTS OF FLOOD REMEDIATION FOR LEVEES AT FULL AND PARTIAL CONTRACTOR RATES & DAM AT BOEGOE BERG(R million) INCLUDING TLD-50

CONSTRUCTION OPTION	LEVEL OF REMEDIATION SCENARIO											
	Scenario 0	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
NEW LEVEES-FULL	0.00	132.78	132.83	152.05	178.75	208.15	242.23	295.15	354.61	458.26	579.48	90.35
UPGRADE CURRENT FULL	0.00	83.20	80.13	96.76	121.41	149.40	183.44	236.36	295.82	399.47	520.69	29.50
NEW LEVEES-PARTIAL	0.00	92.02	81.96	84.97	88.60	97.82	110.40	130.83	155.15	198.20	249.49	56.15
UPGRADE CURRENT PARTIAL	0.00	71.02	59.64	61.56	64.32	72.93	85.50	105.94	130.35	173.30	224.59	29.50
DAM	0.00	917.75	967.37	1014.58	1071.06	1123.44	1169.72	1235.59	1269.95	1374.31	1405.83	29.50


TOTAL COST OPTIMISING - DAMS INCLUDED
COST (R million)
500
400
300
200
100
0
0
2
4
6
8
10
12
SCENARIO
TFD-50
LEVEE FULL
LEVEE PART
UPGRADE FULL
UPGRADE PART

ANNEXURE 2

AIDS FOR FLOOD DAMAGE ASSESSMENT AND FLOOD DAMAGE CONTROL PLANNING IN IRRIGATION AND URBAN AREAS

HYDROLOGICAL HYDRAULIC AND CAPITAL COST ESTIMATES FOR FLOOD CONTROL MEASURES ALONG THE CHATTY AT SOWETO ON SEA AND ALONG THE SWARTKOPS RIVER FROM UITENHAGE TO DESPATCH

REPORT 207878/3 **OCTOBER 1999**

SRK Consulting

Engineers and Scientists

AIDS FOR FLOOD DAMAGE ASSESSMENT AND FLOOD DAMAGE CONTROL PLANNING IN IRRIGATION AND URBAN AREAS

HYDROLOGICAL HYDRAULIC AND CAPITAL COST ESTIMATES FOR FLOOD CONTROL MEASURES ALONG THE CHATTY AT SOWETO ON SEA AND ALONG THE SWARTKOPS RIVER FROM UITENHAGE TO DESPATCH

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REPORT 207878/3

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VBLA/pugh | REPORT 207878/2 | October 1999

AIDS FOR FLOOD DAMAGE ASSESSMENT AND FLOOD DAMAGE CONTROL PLANNING IN IRRIGATION AND URBAN AREAS

SUB-SECTION : HYDROLOGICAL HYDRAULIC AND CAPITAL COST ESTIMATES FOR FLOOD CONTROL MEASURES ALONG THE CHATTY AT SOWETO ON SEA AND ALONG THE SWARTKOPS RIVER FROM UITENHAGE TO DESPATCH

1 INTRODUCTION

The Department of Agricultural Economics of the University of the Orange Free State (UOFS) submitted a research proposal "Aids for Flood Damage Assessment and Flood Damage Control Planning in Irrigation and Urban Areas" to the Water Research Commission (WRC) in 1997. SRK Consulting (SRK) were part of that proposal responsible for engineering aspects which include the hydrological, hydraulic and capital cost estimates for flood control measures along the Chatty River at Soweto on Sea and along the Swartkops River from Uitenhage to Despatch.

2 SCOPE OF WORK

The scope of work for the study is defined as the following:

- Review of previous studies.
- Review of flood hydrology.
- Estimation of flood levels for the full range of flood probabilities.
- Estimation of the capital costs for the various remediation measures.
- Provide recommendation to reduce damages to flood defences during floods.

The study maximised the use of previous study results to ensure that costs are contained.

3 REVIEW OF PREVIOUS STUDIES

Two previous studies related to the current project in this area are:

- Floodline Study of the Swartkops River, WRC Project 490. SRK report 206878/1, May 1996.
- Chatty River Floodline Study. SRK report 223555/1, March 1997.

The Swartkops River report only provided flood probabilities up to the 100-year flood and the PMF. The Chatty River study provided flood probabilities up to the 200-year flood and the RMF. This study will assign probabilities to estimated flows from the 2-year event to the 10 000 year event. The previous studies did not provide remediation measures and their costs.

4 REVIEW OF FLOOD HYDROLOGY

The available flood estimates in the previous studies were used for the purposes of this study. The flood probability estimates for events larger than the 100-year event and the 200-year event is based on the incremental growth above these probabilities of the floods as derived from a regional growth curve. The regional growth curves were estimated from the analysis of 19 flow recording gauges with 33 years of record on average for each site in the area. The adopted peaks for this study is shown in Table 4.1.

TABLE 4.1 : ADOPTED FLOOD PEAKS (m^3/s)

	FLOOD RETURN PERIOD (years)										
River	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**500**	**1000**	**5000**	**10000**
Swartkop	120	400	600	800	1600	1850	2480	3587	4700	9500	11300
Chatty	150	260	360	470	660	830	988	1428	1880	3790	4790

For both rivers the RMF is at approximately 1000 years which is considered reasonable. The high 2-year flood for the Chatty River is mainly due to the impact if urbanization on runoff for especially the smaller floods. The Swartkops River has Groendal dam in its catchment, but due to its relatively small capacity, its impact on floods is considered negligible. A review of gauge records indicates a large portion of the flooding on the lower Swartkops is also derived from flash floods in the Elands River.

The flood damages may be estimated using the following approaches to assign probabilities to the damages:

- Annual flood probabilities as shown in Table 4.1, or
- Considering the maximum probability of events occurring over a selected design period.

The economic design of civil structures are usually taken over a certain period of years ranging from 15 years for roads to 100-year for large dams. The design life for well constructed levees for the purposes of this study is taken to be 50-years. From Table 4.2 it can be seen that the probability of having one 50-year event in the 50-year design period is 63,58% and that of having four ten year events is 74,97%. For damages the implication of taking it over a 50-year period instead of an annual basis is that the maximum probable damages for a ten year event will be 4 x 74,97/100 x damage. The maximum for other events are shown in Table 4.2.

TABLE 4.2: MULTIPLE EVENT PROBABILITY OVER 50-YEAR DESIGN LIFE

T (Return Period)	Number of Events (n)	Probability (p)	Total Number ($^{n} \times P/_{100}$)
2	21	89,87	18,87
5	8	80,96	6,48
10	4	74,97	3,00
20	2	72,06	1,44
50	1	63,58	0,64
100	1	39,50	0,40
200	1	22,17	0,22
500	1	9,52	0,10
1000	1	4,88	0,05
5000	1	1,00	0,01
10000	1	0,50	0,01

5 ESTIMATION OF FLOOD ELEVATIONS

5.1 Previous Studies

The two previous studies for the Chatty and Swartkops Rivers estimated flood elevations for the present systems with no remediation.

5.2 Estimation of Flood Levels for Various Scenarios

The selection of scenarios for flood damage control is based on ensuring that certain flows do not inundate the agricultural lands.

The scenarios modeled for both rivers are:

- Present system.
- General main channel clearance of larger trees and shrubs to reduce flow resistance.
- Channelisation with a compound channel to control the 100-year flood.
- Bunding and levee construction to control the 100-year flood.

The remediation actions were modeled for the whole reach of each river under review.

5.2.1 Estimation of the Flood Elevations

The modelling was done using the HEC-RAS model with sectional and spatial information in GIS format taken from previous projects in Port Elizabeth. The modelling of the system used the sections indicated in Appendix A. (Appendix A1 = Chatty River and Appendix A2 = Swartkops River).

The boundary condition for the two watercourses were:

- Chatty River upstream boundary condition was taken as normal depth and downstream, where the Chatty River flows into the Swartkops river, was taken as the level of the Swartkops river at the selected flood.
- Swartkops river upstream boundary condition was taken as normal depth and downstream the tidal range of approximately 1.5m was used.

The results, indicating flood levels at the sections selected for each of the scenarios, are shown in Appendix B1.

When estimating damages for the various remediation actions the following must be borne in mind:

- For the channel clearance option only the flood levels are lower and damages are possible for all return periods.

- The design for the channelisation and bunding option are such that these actions will exclude all floods equal to or less than the 100 year flood. Thus no damages are likely for floods less than 100 years. It is, however, possible that flood levels for the floods greater than the 100 year flood could be higher than the present situation due to the less favorable conveyance conditions the engineered section could have for the flows higher than the design flow selected.

The impact of the measures relative to the present situation is also shown in Appendix B2.

6 CAPITAL COST ESTIMATES

The capital costs were estimated for the following:

- Channel clearance;
- Channel construction; and,
- Construction of bunds.

The costs are inclusive of fees and contingencies.

The cost estimates for all the scenarios at each section are shown in Appendix C and summarised in Table 6.1. The estimation of remediation costs at each section will allow the combination of measures for a particular reach to be optimized.

TABLE 6.1: FLOOD PROTECTION COSTS – CHATTY AND SWARTKOPS RIVERS

Scenario	Total Costs (R x 1,000,000) and unit cost (per km)	
	Chatty	Swartkops
"1" Channel Clearance	2.56 (0.30)	6.92 (0.48)
"2" Channelisation	16.89 (1.95)	111.10 (7.72)
"3" Bunding	12.38 (1.46)	10.50 (0.73)

From table 6.1 the unit cost of remediation is related to the size of the channel and flow. The lower bunding unit cost for the Swartkops River is due to the better defined channel of the Swartkops river and lack of development within the lower, and more frequently flooded floodplain, unlike that of the Chatty River, where development has encroached onto the lower flood plains.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Chatty – The following was concluded from the results:

- The urbanization of the catchment has a very significant impact through increased runoff, especially on the more frequent events.
- The flooding of the lower portion is controlled more by conditions in the Swartkops River for the larger events.

Swartkops – The following was concluded from the results:

- The catchment of the Swartkops is not as significantly impacted upon with the exception of Groendal dam. The latter does not have such a significant attenuation potential due to its relatively small capacity. A large portion of the flooding is also derived from the Elands river.
- The presence of the R75 bridge is the single most important control on the Swartkops River for the more catastrophic floods i.e. greater than 200 years.

Remediation measures for both water courses show that:

- Channel clearance reduces flood levels marginally. Only a 200mm reduction in flood levels is achieved by increasing the conveyance of the watercourse.

- Channelisation has a significantly greater impact on the reduction in flood levels, It should, however, be borne in mind that channelisation is not regarded as a desired solution environmentally and does come at a cost.
- Bunding to prevent damages does not alter flood levels detrimentally for floods less than the design flood, For larger floods it could, however, have an adverse impact on the flood levels by rising them above the present. Failure of bunds for flows larger than the design flood could also result in more damages than what it would have been had the bund not been constructed.

7.2 Recommendations

The following is recommended:

- In terms of cost and ease of remediation channel clearance and selected bunding are preferred with only limited use of channelisation.
- The estimation flood damages for the remediated scenarios must take note of the comments in 5.2.1.
- The selection of remediation measures at the various sections should take account of the cost (optimise) and appropriateness of a measure. At some points it may be prudent to combine the measures.
- That the floodlines as provided be used as a guide for landuse development so as to ensure that impacts of floods are limited.

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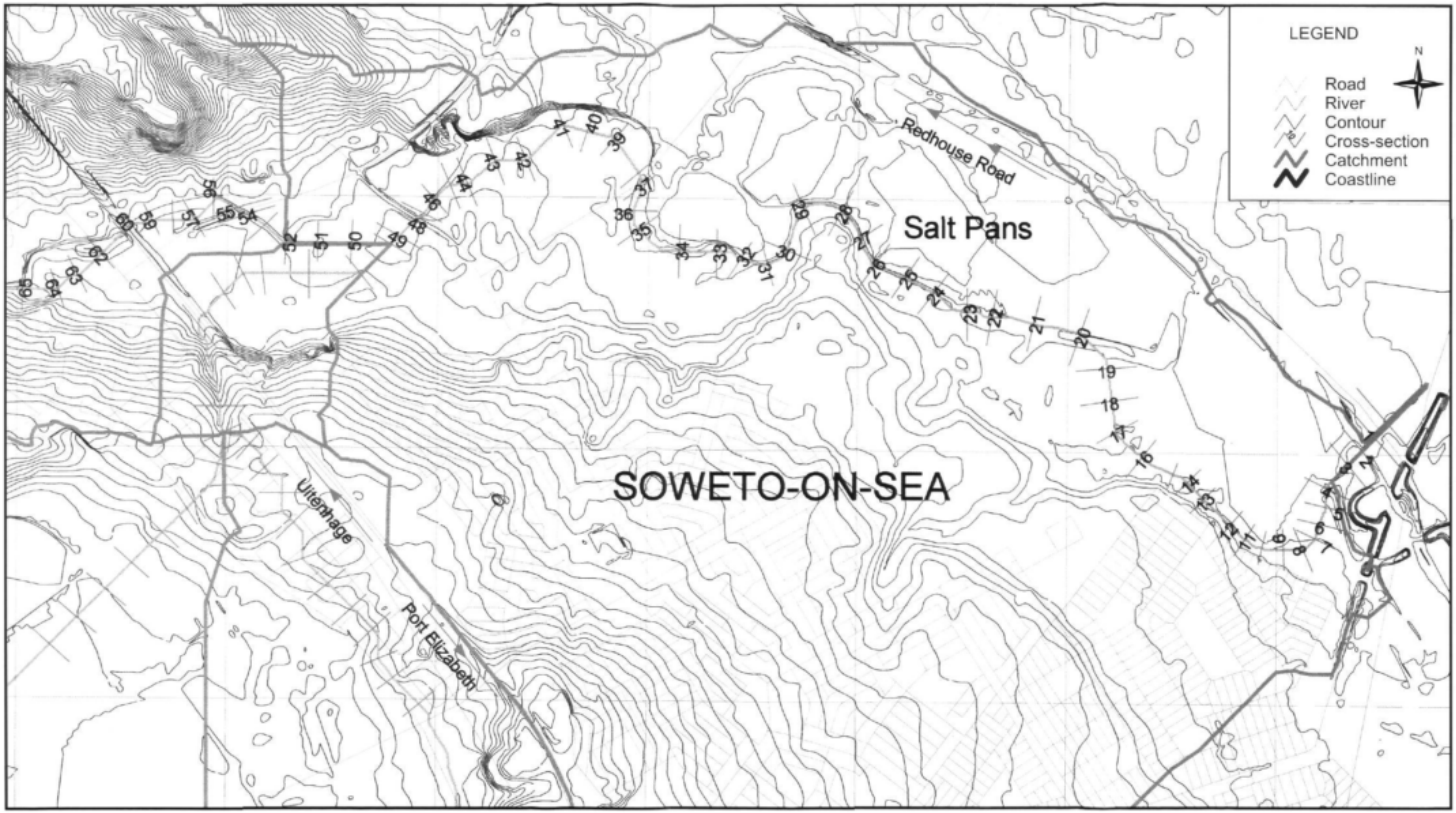
APPENDIX A

LOCALITY MAP AND SECTIONS

A1 – CHATTY RIVER



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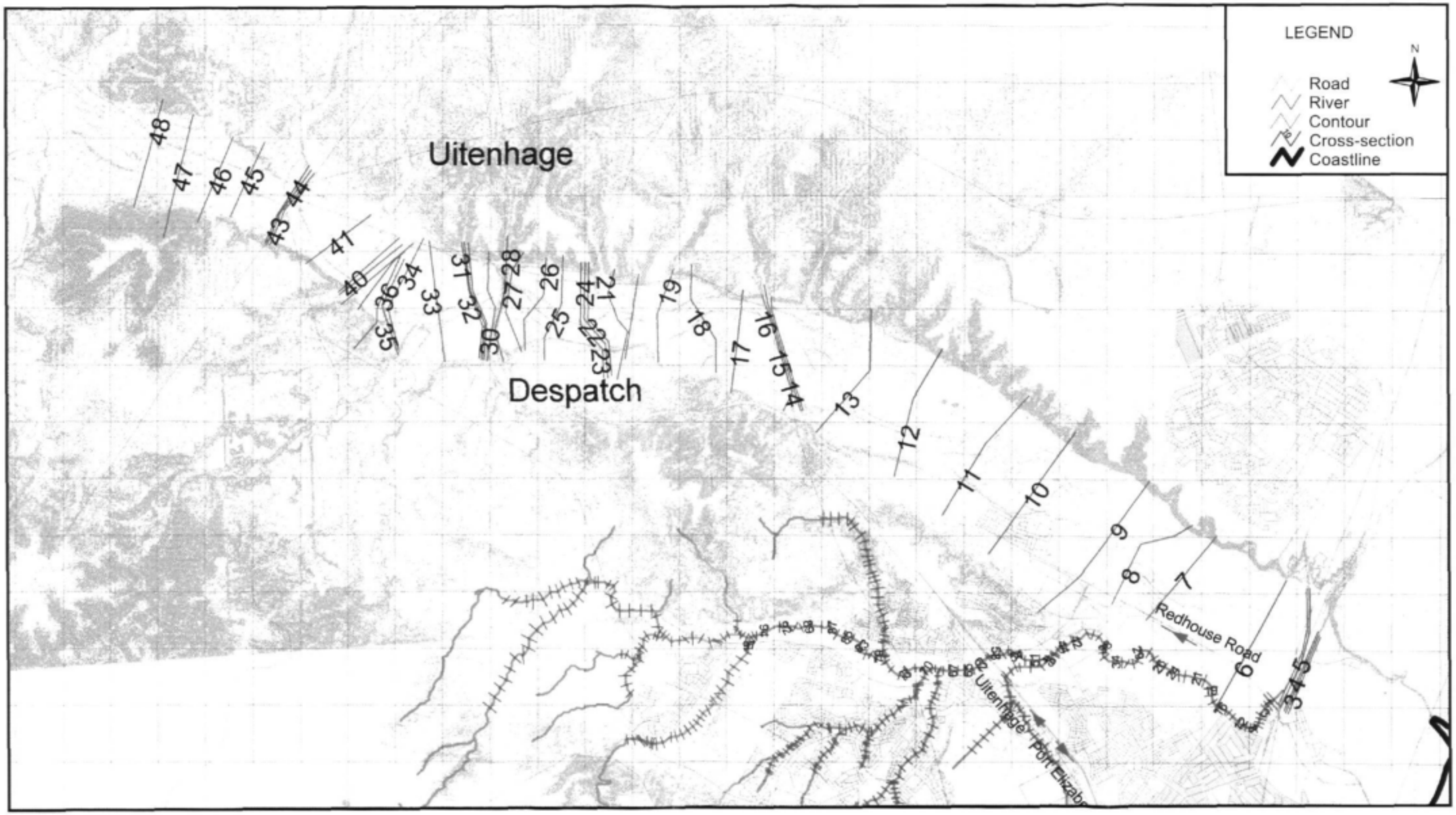
Chatty River
Soweto-on-Sea
Appendix A1

Not to Scale

A2 – SWARTKOPS RIVER



SRK Consulting

Swartkops River
Uitenhage - Despatch
Appendix A2

Not to Scale

APPENDIX B

B1 - ESTIMATED WATER LEVELS FOR VARIOUS SCENARIOS

Scenario 0 - "As Is" Situation

Reach	Cross Section Number	Chainage	High Flood Level										
			2	5	10	20	50	100	200	500	1000	5000	10000
Chatty Lower	67	8518.41	13.75	14.14	14.41	14.68	15.04	15.51	16.20	17.52	18.87	24.58	27.16
	66	8374.33	13.38	13.74	14.04	14.40	14.79	15.35	16.12	17.45	18.81	24.57	27.15
	65	8228.32	13.19	13.53	13.84	14.25	14.63	15.26	16.07	17.40	18.78	24.57	27.15
	64	8069.06	13.05	13.35	13.68	14.13	14.51	15.18	16.03	17.37	18.75	24.56	27.15
	63	7957.56	12.90	13.18	13.54	14.05	14.43	15.13	16.00	17.34	18.73	24.56	27.14
	62	7820.85	12.70	13.00	13.43	13.99	14.37	15.10	15.99	17.34	18.72	24.56	27.14
	61	7687.72	12.24	12.84	13.37	13.96	14.33	15.08	15.97	17.32	18.70	24.55	27.14
	extra	7680.00	12.13	12.56	12.96	13.43	12.75	13.22	14.68	15.45	16.24	19.59	20.88
	extra	7640.00	11.96	12.16	12.25	12.31	11.93	12.29	12.23	13.38	14.56	19.54	19.54
	60	7638.82	11.95	12.24	12.45	12.69	13.18	13.50	13.77	14.39	15.02	17.69	17.95
	59	7534.48	11.39	11.81	12.14	12.47	13.06	13.39	13.68	14.31	14.97	17.72	17.98
	58	7449.95	11.20	11.64	12.00	12.37	13.00	13.34	13.63	14.27	14.93	17.70	17.96
	57	7355.81	10.75	11.27	11.68	12.10	12.79	13.10	13.38	14.05	14.73	17.63	17.88
	56	7242.65	10.52	11.07	11.49	11.92	12.61	12.87	13.09	13.66	14.25	16.73	16.47
	55	7119.82	10.27	10.85	11.32	11.79	12.56	12.83	13.07	13.70	14.34	17.06	16.99
	54	7060.11	9.80	10.30	10.61	10.89	11.31	11.62	11.89	11.87	11.85	11.77	12.01
	53	7024.00	9.54	9.95	10.22	10.47	10.89	10.87	11.07	11.33	11.59	12.70	13.08
	52	6941.00	9.02	9.27	9.44	9.59	9.84	10.30	10.33	10.67	11.02	12.49	12.95
	50	6824.00	8.90	9.16	9.36	9.55	9.82	10.03	10.21	10.55	10.90	12.37	12.84
	48	6792.00	8.87	9.13	9.32	9.50	9.77	9.98	10.15	10.49	10.83	12.30	12.76
	46	6739.00	8.80	9.06	9.25	9.43	9.69	9.90	10.07	10.41	10.75	12.22	12.68
	45	6644.00	8.62	8.89	9.08	9.25	9.51	9.70	9.86	10.19	10.53	11.95	12.41
	43	6414.00	7.99	8.30	8.51	8.69	8.96	9.16	9.32	9.68	10.05	11.61	12.11
	41	6144.00	7.65	7.93	8.14	8.32	8.57	8.77	8.95	9.34	9.75	11.46	11.99
	40	6024.00	7.47	7.71	7.89	8.07	8.33	8.53	8.71	9.13	9.56	11.38	11.91
	38	5942.00	6.22	6.53	6.77	6.99	7.31	7.57	7.79	8.29	8.80	10.97	11.79
	36	5694.00	5.45	5.70	5.93	6.18	6.57	6.87	7.13	7.70	8.28	10.74	11.58
	34	5344.00	4.81	5.21	5.52	5.82	6.28	6.63	6.93	7.52	8.12	10.66	11.52
	32	5314.00	4.79	5.20	5.52	5.82	6.27	6.62	6.92	7.51	8.11	10.65	11.51
	31	5214.00	4.72	5.16	5.48	5.78	6.24	6.59	6.89	7.48	8.08	10.63	11.49
	29	5024.00	4.65	5.12	5.45	5.76	6.22	6.57	6.87	7.46	8.07	10.63	11.49
	27	4624.00	4.61	5.07	5.40	5.71	6.16	6.51	6.81	7.41	8.02	10.60	11.47
	25	4464.00	4.60	5.06	5.38	5.69	6.13	6.48	6.77	7.37	7.99	10.59	11.46
	24	4074.00	4.58	5.03	5.35	5.65	6.09	6.44	6.73	7.33	7.95	10.55	11.43
	22	3754.00	4.57	5.01	5.33	5.62	6.05	6.39	6.68	7.29	7.91	10.54	11.41
	20	3314.00	4.55	4.98	5.29	5.58	6.00	6.33	6.61	7.21	7.83	10.45	11.32
	18	3034.00	4.43	4.84	5.13	5.39	5.77	6.06	6.33	6.93	7.55	10.15	11.02
	17	2714.00	4.24	4.64	4.92	5.17	5.54	5.82	6.08	6.70	7.33	10.00	10.90
	15	2544.00	4.21	4.61	4.87	5.11	5.47	5.74	5.99	6.61	7.25	9.95	10.86
	13	2354.00	4.04	4.46	4.73	4.97	5.32	5.58	5.84	6.47	7.12	9.87	10.77
	12	2224.00	3.92	4.35	4.62	4.86	5.20	5.45	5.71	6.34	6.99	9.73	10.63
	10	1754.00	3.70	4.15	4.45	4.71	5.08	5.34	5.62	6.28	6.96	9.84	10.76
	8	1599.00	3.68	4.13	4.42	4.67	5.01	5.25	5.52	6.17	6.83	9.65	10.57
	6	1437.00	3.66	4.09	4.38	4.61	4.94	5.17	5.43	6.09	6.75	9.61	10.53
	5	1374.00	3.66	4.10	4.38	4.62	4.95	5.19	5.46	6.12	6.80	9.68	10.61
	3	1289.00	3.64	4.08	4.36	4.60	4.93	5.16	5.43	6.10	6.78	9.68	10.61
	1	88.30	3.06	3.37	3.60	3.79	4.18	4.44	4.91	5.65	6.41	9.62	10.59
	0	0.00	2.45	2.64	2.80	3.05	3.94	4.16	4.60	5.36	6.14	9.45	10.48

Scenario 1 - Channel Clearout (reduced roughness)

Reach	Cross Section Number	Chainage	High Flood Level										
			2	5	10	20	50	100	200	500	1000	5000	10000
Chatty Lower	67	8518.41	13.62	14.01	14.26	14.54	15.37	16.23	16.85	18.11	19.41	24.89	27.53
	66	8374.33	13.28	13.61	13.89	14.25	15.28	16.20	16.82	18.09	19.39	24.88	27.52
	65	8228.32	13.10	13.42	13.70	14.11	15.23	16.17	16.80	18.07	19.37	24.88	27.52
	64	8069.06	12.97	13.25	13.54	14.00	15.20	16.15	16.79	18.06	19.37	24.88	27.52
	63	7957.56	12.83	13.09	13.41	13.93	15.18	16.14	16.78	18.05	19.36	24.87	27.51
	62	7820.85	12.66	12.90	13.30	13.88	15.16	16.13	16.77	18.04	19.35	24.87	27.52
	61	7687.72	12.19	12.73	13.23	13.85	15.15	16.13	16.77	18.04	19.35	24.87	27.51
	extra	7680.00	12.01	12.40	12.74	13.24	14.51	15.40	15.89	16.47	17.07	19.59	21.11
	extra	7640.00	11.88	12.08	12.12	12.11	12.36	12.84	13.21	14.20	15.23	19.54	19.54
	60	7638.82	11.85	12.14	12.33	12.56	13.05	13.36	13.63	14.25	14.88	17.57	18.17
	59	7534.48	11.31	11.66	11.98	12.33	12.94	13.26	13.54	14.18	14.83	17.59	18.21
	58	7449.95	11.15	11.50	11.85	12.24	12.89	13.22	13.51	14.15	14.81	17.58	18.21
	57	7355.81	10.57	11.08	11.51	11.97	12.68	12.98	13.24	13.91	14.60	17.52	18.13
	56	7242.65	10.40	10.96	11.40	11.86	12.56	12.81	13.02	13.55	14.10	16.42	16.78
	55	7119.82	10.18	10.80	11.27	11.78	12.55	12.81	13.05	13.65	14.27	16.67	17.35
	54	7060.11	9.62	10.11	10.50	10.80	11.23	11.57	11.86	12.05	12.25	13.08	13.42
	53	7024.00	9.39	9.77	10.03	10.26	10.64	10.89	11.09	11.29	11.50	12.39	12.71
	52	6941.00	8.87	9.04	9.23	9.44	9.83	10.28	10.44	10.70	10.96	12.07	12.52
	50	6824.00	8.81	9.04	9.22	9.39	9.64	9.84	10.00	10.33	10.67	12.11	12.51
	48	6792.00	8.78	9.01	9.18	9.35	9.60	9.79	9.95	10.28	10.62	12.04	12.44
	46	6739.00	8.71	8.94	9.11	9.28	9.52	9.71	9.87	10.20	10.54	11.98	12.38
	45	6644.00	8.53	8.77	8.94	9.11	9.35	9.53	9.68	10.00	10.34	11.74	12.11
	43	6414.00	7.84	8.14	8.35	8.53	8.78	8.98	9.14	9.51	9.88	11.47	11.86
	41	6144.00	7.55	7.82	8.02	8.20	8.45	8.65	8.83	9.23	9.64	11.39	11.79
	40	6024.00	7.39	7.63	7.80	7.97	8.23	8.45	8.63	9.05	9.49	11.32	11.72
	38	5942.00	6.12	6.42	6.64	6.86	7.15	7.39	7.60	8.10	8.62	10.79	11.63
	36	5694.00	5.41	5.62	5.80	6.01	6.36	6.62	6.86	7.44	8.03	10.54	11.42
	34	5344.00	4.70	5.05	5.33	5.61	6.03	6.36	6.66	7.26	7.88	10.50	11.38
	32	5314.00	4.67	5.04	5.32	5.60	6.03	6.36	6.65	7.25	7.87	10.49	11.38
	31	5214.00	4.58	4.99	5.28	5.57	6.00	6.33	6.63	7.23	7.86	10.48	11.37
	29	5024.00	4.48	4.95	5.25	5.54	5.98	6.31	6.61	7.22	7.84	10.48	11.37
	27	4624.00	4.43	4.90	5.21	5.49	5.92	6.26	6.55	7.16	7.79	10.46	11.35
	25	4464.00	4.42	4.89	5.19	5.47	5.90	6.22	6.52	7.14	7.77	10.45	11.34
	24	4074.00	4.40	4.87	5.16	5.45	5.87	6.19	6.48	7.10	7.73	10.42	11.32
	22	3754.00	4.39	4.85	5.14	5.42	5.83	6.15	6.43	7.05	7.70	10.41	11.30
	20	3314.00	4.37	4.82	5.11	5.38	5.78	6.09	6.37	6.99	7.62	10.31	11.21
	18	3034.00	4.20	4.64	4.90	5.14	5.49	5.76	6.00	6.63	7.27	10.00	10.91
	17	2714.00	4.00	4.46	4.70	4.92	5.26	5.52	5.78	6.42	7.09	9.88	10.81
	15	2544.00	3.99	4.45	4.67	4.89	5.22	5.47	5.71	6.36	7.02	9.84	10.78
	13	2354.00	3.71	4.12	4.40	4.65	4.99	5.25	5.52	6.20	6.89	9.82	10.75
	12	2224.00	3.66	4.06	4.31	4.54	4.86	5.09	5.36	6.04	6.74	9.68	10.61
	10	1754.00	3.46	3.87	4.16	4.41	4.78	5.04	5.35	6.05	6.77	9.81	10.75
	8	1599.00	3.45	3.85	4.13	4.38	4.72	4.95	5.24	5.93	6.63	9.62	10.56
	6	1437.00	3.42	3.82	4.09	4.33	4.65	4.87	5.16	5.86	6.57	9.60	10.54
	5	1374.00	3.42	3.82	4.10	4.34	4.68	4.91	5.20	5.90	6.63	9.68	10.62
	3	1289.00	3.41	3.80	4.08	4.31	4.64	4.86	5.17	5.88	6.60	9.67	10.62
	1	88.30	2.92	3.22	3.44	3.63	4.04	4.29	4.82	5.58	6.35	9.64	10.62
	0	0.00	2.45	2.64	2.80	3.05	3.94	4.16	4.60	5.36	6.14	9.45	10.48

Scenario 2 - Channelization

Reach	Cross Section Number	Chainage	High Flood Level										
			2	5	10	20	50	100	200	500	1000	5000	10000
Chatty Lower	67	8518.41	13.31	13.66	13.90	14.16	14.58	15.06	15.58	16.88	18.21	23.83	25.30
	66	8374.33	13.26	13.60	13.83	14.08	14.51	15.02	15.55	16.85	18.18	23.82	25.30
	65	8228.32	13.19	13.51	13.74	13.99	14.43	14.97	15.52	16.82	18.17	23.83	25.31
	64	8069.06	13.05	13.33	13.53	13.78	14.25	14.85	15.43	16.75	18.10	23.82	25.30
	63	7957.56	12.91	13.15	13.31	13.59	14.12	14.78	15.39	16.71	18.07	23.82	25.30
	62	7820.85	12.73	12.94	13.06	13.43	14.03	14.73	15.36	15.69	18.05	23.82	25.30
	61	7687.72	12.19	12.28	12.68	13.30	13.96	14.70	15.34	16.67	18.04	23.81	25.29
	extra	7680.00	10.13	11.63	12.14	12.62	12.38	12.86	13.27	14.13	15.01	18.74	19.77
	extra	7640.00	10.98	11.22	11.34	10.60	10.72	11.01	11.18	11.76	12.36	14.88	15.68
	60	7638.82	11.02	11.35	11.59	11.81	12.24	12.75	12.99	13.62	14.27	17.02	17.56
	59	7534.48	10.93	11.23	11.46	11.69	12.16	12.72	12.95	13.60	14.26	17.08	17.64
	58	7449.95	10.87	11.17	11.41	11.64	12.13	12.71	12.95	13.60	14.27	17.10	17.66
	57	7355.81	10.46	10.68	10.81	10.97	11.78	12.44	12.64	13.33	14.04	17.04	17.59
	56	7242.65	9.49	10.10	10.59	11.08	11.85	12.48	12.68	13.30	13.93	16.61	17.05
	55	7119.82	9.45	10.07	10.57	11.06	11.83	12.48	12.68	13.32	13.97	16.74	17.22
	54	7060.11	8.97	9.26	9.47	9.66	9.96	8.75	8.83	9.03	9.24	10.12	10.44
	53	7024.00	8.94	9.21	9.41	9.60	9.88	10.10	10.29	10.34	10.40	10.64	10.99
	52	6941.00	8.83	9.06	9.23	9.38	9.60	9.76	9.89	10.22	10.57	12.02	12.39
	50	6824.00	8.75	8.97	9.14	9.30	9.55	9.75	9.91	10.25	10.60	12.07	12.42
	48	6792.00	8.72	8.93	9.10	9.26	9.51	9.70	9.86	10.20	10.54	12.01	12.36
	46	6739.00	8.66	8.87	9.03	9.19	9.43	9.62	9.78	10.12	10.47	11.95	12.29
	45	6644.00	8.45	8.61	8.76	8.93	9.17	9.36	9.52	9.86	10.21	11.68	11.98
	43	6414.00	7.71	8.01	8.23	8.42	8.69	8.90	9.07	9.45	9.83	11.46	11.76
	41	6144.00	7.58	7.82	8.02	8.20	8.46	8.66	8.83	9.23	9.65	11.40	11.70
	40	6024.00	7.39	7.63	7.80	7.97	8.24	8.46	8.64	9.06	9.50	11.33	11.62
	38	5942.00	5.13	5.45	5.69	5.92	6.30	6.60	6.87	7.45	8.05	10.58	11.49
	36	5694.00	4.95	5.21	5.39	5.58	5.91	6.20	6.46	7.08	7.71	10.39	11.28
	34	5344.00	4.54	4.75	4.97	5.23	5.68	6.02	6.34	6.98	7.64	10.41	11.30
	32	5314.00	4.49	4.70	4.94	5.22	5.67	6.01	6.33	6.97	7.63	10.40	11.30
	31	5214.00	4.27	4.55	4.85	5.15	5.62	5.97	6.30	6.94	7.60	10.39	11.29
	29	5024.00	3.89	4.42	4.77	5.10	5.58	5.94	6.27	6.92	7.58	10.39	11.29
	27	4624.00	3.84	4.36	4.72	5.04	5.53	5.88	6.21	6.86	7.53	10.37	11.27
	25	4464.00	3.83	4.35	4.70	5.03	5.51	5.85	6.18	6.84	7.51	10.36	11.26
	24	4074.00	3.80	4.32	4.68	5.00	5.48	5.83	6.15	6.81	7.48	10.33	11.24
	22	3754.00	3.78	4.29	4.64	4.96	5.43	5.77	6.09	6.75	7.44	10.32	11.22
	20	3314.00	3.72	4.22	4.56	4.87	5.34	5.67	5.99	6.65	7.34	10.22	11.13
	18	3034.00	3.68	4.17	4.50	4.80	5.26	5.57	5.88	6.53	7.20	10.04	10.94
	17	2714.00	3.64	4.11	4.44	4.73	5.18	5.49	5.79	6.45	7.12	9.97	10.87
	15	2544.00	3.61	4.08	4.40	4.68	5.11	5.41	5.71	6.37	7.05	9.91	10.83
	13	2354.00	3.58	4.03	4.34	4.63	5.06	5.35	5.66	6.32	7.00	9.88	10.79
	12	2224.00	3.55	3.99	4.30	4.58	5.00	5.29	5.58	6.24	6.91	9.77	10.67
	10	1754.00	3.49	3.91	4.22	4.50	4.93	5.22	5.53	6.21	6.90	9.84	10.76
	8	1599.00	3.46	3.88	4.18	4.45	4.86	5.13	5.43	6.09	6.77	9.65	10.57
	6	1437.00	3.43	3.84	4.14	4.40	4.80	5.06	5.36	6.03	6.72	9.62	10.54
	5	1374.00	3.43	3.84	4.14	4.40	4.81	5.08	5.38	6.06	6.75	9.68	10.61
	3	1289.00	3.41	3.81	4.10	4.37	4.78	5.04	5.34	6.02	6.72	9.68	10.61
	1	88.30	2.83	3.10	3.30	3.50	4.09	4.39	4.87	5.62	6.38	9.62	10.59
	0	0.00	2.43	2.62	2.77	3.05	3.94	4.16	4.60	5.36	6.14	9.45	10.48

Scenario 3 - Bunding

Reach	Cross Section Number	Chainage	High Flood Level										
			2	5	10	20	50	100	200	500	1000	5000	10000
Chatty Lower	67	8518.41	13.76	14.21	14.55	14.92	15.83	16.67	17.38	18.51	19.68	24.59	27.16
	66	8374.33	13.41	13.81	14.14	14.53	15.61	16.55	17.31	18.45	19.62	24.57	27.15
	65	8228.32	13.23	13.60	13.94	14.37	15.54	16.51	17.28	18.42	19.60	24.57	27.15
	64	8069.06	13.09	13.43	13.79	14.23	15.48	16.47	17.26	18.41	19.59	24.57	27.15
	63	7957.56	12.93	13.25	13.63	14.11	15.43	16.44	17.24	18.39	19.57	24.56	27.14
	62	7820.85	12.71	13.04	13.49	14.03	15.40	16.43	17.23	18.38	19.56	24.56	27.14
	61	7687.72	12.24	12.89	13.42	13.99	15.39	16.42	17.23	18.38	19.56	24.55	27.14
	extra	7680.00	12.13	12.62	13.03	13.48	14.86	15.82	16.54	17.02	17.51	19.59	20.88
	extra	7640.00	11.97	12.26	12.46	12.67	13.06	13.46	13.84	14.74	15.65	19.54	19.54
	60	7638.82	11.96	12.32	12.61	12.93	13.52	14.06	14.57	15.10	15.64	17.93	18.25
	59	7534.48	11.40	11.83	12.20	12.59	13.24	13.82	14.39	14.94	15.51	17.90	18.22
	58	7449.95	11.21	11.67	12.08	12.52	13.22	13.82	14.40	14.95	15.51	17.90	18.22
	57	7355.81	10.78	11.35	11.82	12.30	13.03	13.64	14.24	14.79	15.36	17.76	18.05
	56	7242.65	10.57	11.18	11.66	12.15	12.86	13.46	14.06	14.49	14.93	16.79	16.48
	55	7119.82	10.25	10.79	11.23	11.67	12.28	12.80	13.40	13.94	14.50	16.85	16.51
	54	7060.11	9.80	10.28	10.59	10.91	11.45	11.91	12.31	12.34	12.36	12.48	12.74
	53	7024.00	9.54	9.95	10.22	10.46	10.83	11.07	11.24	11.40	11.57	12.28	12.38
	52	6941.00	9.02	9.28	9.45	9.62	9.89	10.04	10.22	10.59	10.97	12.57	13.11
	50	6824.00	8.90	9.17	9.38	9.58	9.88	10.12	10.32	10.67	11.02	12.53	13.03
	48	6792.00	8.87	9.13	9.34	9.54	9.84	10.08	10.28	10.62	10.97	12.46	12.96
	46	6739.00	8.80	9.06	9.27	9.47	9.77	10.00	10.20	10.54	10.89	12.37	12.87
	45	6644.00	8.62	8.90	9.11	9.31	9.61	9.85	10.04	10.37	10.71	12.14	12.64
	43	6414.00	7.99	8.31	8.53	8.73	9.02	9.25	9.43	9.78	10.14	11.65	12.25
	41	6144.00	7.65	7.93	8.14	8.32	8.58	8.79	8.96	9.35	9.75	11.45	12.12
	40	6024.00	7.47	7.71	7.89	8.07	8.33	8.53	8.70	9.11	9.54	11.34	12.04
	38	5942.00	6.22	6.56	6.81	7.05	7.41	7.72	7.99	8.49	9.00	11.15	11.94
	36	5694.00	5.45	5.70	5.94	6.22	6.66	7.01	7.31	7.87	8.45	10.90	11.72
	34	5344.00	4.82	5.24	5.59	5.93	6.45	6.85	7.19	7.76	8.35	10.83	11.66
	32	5314.00	4.80	5.23	5.58	5.92	6.44	6.85	7.19	7.76	8.35	10.82	11.65
	31	5214.00	4.72	5.19	5.55	5.90	6.42	6.82	7.17	7.74	8.33	10.81	11.64
	29	5024.00	4.66	5.16	5.53	5.87	6.40	6.81	7.15	7.72	8.31	10.80	11.63
	27	4624.00	4.61	5.12	5.48	5.83	6.35	6.76	7.10	7.67	8.26	10.75	11.59
	25	4464.00	4.60	5.10	5.47	5.81	6.33	6.73	7.07	7.64	8.24	10.73	11.58
	24	4074.00	4.58	5.08	5.44	5.78	6.30	6.70	7.04	7.61	8.21	10.70	11.54
	22	3754.00	4.57	5.06	5.42	5.75	6.26	6.66	7.03	7.60	8.19	10.68	11.53
	20	3314.00	4.55	5.03	5.38	5.71	6.21	6.60	6.95	7.52	8.11	10.58	11.43
	18	3034.00	4.43	4.90	5.24	5.55	6.02	6.39	6.73	7.29	7.86	10.27	11.12
	17	2714.00	4.24	4.73	5.07	5.39	5.87	6.24	6.59	7.15	7.72	10.14	11.01
	15	2544.00	4.22	4.69	5.03	5.34	5.82	6.17	6.52	7.08	7.65	10.08	10.96
	13	2354.00	4.04	4.47	4.76	5.03	5.41	5.71	6.01	6.62	7.25	9.89	10.78
	12	2224.00	3.93	4.36	4.66	4.92	5.30	5.59	5.90	6.50	7.12	9.74	10.63
	10	1754.00	3.70	4.15	4.45	4.72	5.10	5.39	5.73	6.37	7.04	9.83	10.75
	8	1599.00	3.68	4.13	4.43	4.69	5.07	5.36	5.70	6.32	6.97	9.68	10.59
	6	1437.00	3.66	4.09	4.38	4.63	4.99	5.26	5.59	6.22	6.87	9.62	10.53
	5	1374.00	3.65	4.09	4.38	4.63	4.99	5.27	5.60	6.24	6.90	9.68	10.60
	3	1289.00	3.64	4.08	4.36	4.61	4.97	5.24	5.58	6.23	6.89	9.69	10.61
	1	88.30	3.06	3.37	3.60	3.79	4.16	4.38	4.96	5.69	6.44	9.61	10.59
	0	0.00	2.45	2.64	2.80	3.05	3.94	4.16	4.60	5.36	6.14	9.45	10.48

Scenario 0 - "As Is" situation

Reach	Cross Section Number	Chainage	High Flood Level										
			2	5	10	20	50	100	200	500	1000	5000	10000
Swartkops	48	32253	47.07	47.66	47.98	48.29	49.10	49.32	49.85	50.60	51.21	52.40	52.73
	47	31477	44.82	45.57	45.96	46.28	47.26	47.45	48.01	48.71	49.06	50.28	50.63
	46	30709	42.91	43.61	43.97	44.23	45.03	45.23	45.49	46.02	45.49	48.01	48.47
	45	30095	41.85	42.46	42.81	43.09	44.04	44.32	44.76	45.31	45.78	47.29	47.74
	44	29269	39.79	40.56	40.96	41.32	42.39	42.88	43.80	44.11	44.46	45.62	45.97
	42	29143	39.16	40.02	40.42	40.78	41.74	41.96	42.66	43.45	43.66	44.73	45.01
	41	28030	35.35	35.99	36.32	36.61	37.63	37.92	38.00	38.39	38.84	40.48	41.06
	40	27207	31.31	32.23	32.68	33.06	34.32	34.66	35.39	36.26	36.93	39.07	39.88
	39	27079	31.14	32.02	32.47	32.85	34.11	34.44	35.20	36.08	36.74	38.90	39.71
	38	26980	30.97	31.69	32.10	32.47	33.75	34.10	34.84	35.79	36.51	38.81	39.65
	37	26770	30.17	31.03	31.53	31.96	33.37	33.73	34.48	35.53	36.27	38.65	39.52
	36	26287	29.44	30.49	31.03	31.48	32.94	33.31	34.05	35.05	35.89	38.38	39.30
	34	26057	29.14	30.22	30.74	31.18	32.60	32.97	33.67	34.57	35.19	38.15	39.12
	33	25130	27.72	28.79	29.41	29.90	31.45	31.83	32.49	33.66	34.70	38.00	39.00
	32	24353	26.57	27.94	28.67	29.25	30.99	31.41	32.21	33.48	34.54	37.92	38.93
	30	24224	26.23	27.78	28.52	29.11	30.85	31.27	32.17	33.45	34.53	37.91	38.92
	29	23942	26.02	27.74	28.49	29.09	30.83	31.26	32.15	33.44	34.51	37.90	38.91
	28	23683	25.06	26.60	27.31	27.81	29.21	29.57	30.35	31.37	32.21	34.88	35.62
	27	23592	24.01	25.25	25.75	26.10	25.62	25.80	26.23	26.86	27.35	28.09	28.29
	26	22968	22.43	22.99	23.30	23.61	24.65	24.88	25.35	26.35	27.22	28.81	29.23
	25	22440	20.36	21.63	22.21	22.70	23.93	24.13	24.33	25.81	26.87	28.26	28.64
	24	21519	19.79	20.99	21.58	22.05	23.09	23.09	23.76	25.50	26.55	27.73	28.01
	22	21283	19.41	20.44	20.99	21.36	22.40	22.66	23.25	23.99	24.59	26.57	27.14
	21	20919	18.96	20.17	20.76	21.10	22.14	22.40	22.99	23.71	24.29	26.21	26.75
	20	20629	18.58	19.71	20.19	20.52	21.48	21.72	22.28	23.00	23.53	25.41	25.95
	19	20076	18.03	18.93	19.31	19.58	20.45	20.64	21.28	21.97	21.68	22.82	23.26
	18	19240	15.55	16.11	16.51	17.03	18.20	18.47	18.35	18.90	19.25	21.39	21.77
	17	18322	12.72	13.85	14.42	14.84	16.02	16.36	16.82	17.42	17.69	20.67	20.91
	16	17842	12.30	13.42	13.97	14.32	15.33	15.64	15.98	17.31	17.53	20.59	20.81
	14	17736	12.03	13.03	13.53	13.82	14.29	14.39	14.88	15.39	15.86	17.23	17.57
	13	15185	8.16	9.29	9.83	10.31	11.25	11.52	10.59	10.99	11.21	12.35	12.92
	12	13764	5.07	5.90	6.17	6.40	7.60	7.92	8.58	9.01	9.54	11.55	12.27
	11	11179	5.10	6.04	6.44	6.79	7.41	7.58	7.97	8.55	9.06	11.13	11.89
	10	9636	5.08	5.98	6.39	6.74	7.31	7.47	7.84	8.39	8.88	10.93	11.69
	9	7039	4.81	5.45	5.74	5.95	6.72	6.86	7.18	7.65	8.11	10.28	11.14
	8	5991	4.60	5.05	5.27	5.45	6.07	6.20	6.49	6.95	7.44	9.90	10.84
	7	4925	4.31	4.55	4.70	4.83	4.88	5.01	5.34	5.94	6.67	9.64	10.64
	6	2268	2.48	3.06	3.30	3.52	4.14	4.34	4.77	5.50	6.36	9.51	10.53
	5	272	1.67	2.35	2.75	3.05	3.94	4.16	4.60	5.38	6.26	9.45	10.48
	4	161	1.61	2.19	2.58	2.84	3.55	3.69	3.87	3.84	4.32	6.45	7.14
	3	106	1.58	2.13	2.57	2.86	3.67	3.85	4.22	4.70	4.99	5.96	6.28
	2	40	1.50	1.48	1.78	2.20	2.86	3.09	3.48	3.90	4.33	5.02	5.24
	1	0	1.51	1.61	1.75	1.91	2.56	2.63	2.86	3.18	3.46	4.50	4.91
	0	-50	1.50	1.50	1.50	1.50	1.80	2.13	2.30	2.55	2.77	3.51	3.58

Scenario 1 - Channel Clearout (reduced roughness)

Reach	Cross Section Number	Chainage	High Flood Level										
			2	5	10	20	50	100	200	500	1000	5000	10000
Swartkops	48	32253	46.95	47.54	47.79	48.02	48.81	49.01	49.49	50.22	50.86	52.19	52.62
	47	31477	44.82	45.34	45.67	45.97	46.83	47.05	47.44	48.15	48.56	49.73	50.15
	46	30709	42.80	43.46	43.79	44.04	44.78	44.96	45.41	45.78	46.20	47.72	48.17
	45	30095	41.69	42.27	42.61	42.88	43.76	44.00	44.59	45.27	45.61	47.16	47.62
	44	29269	39.71	40.44	40.80	41.11	42.09	42.38	43.16	44.53	44.35	45.36	45.72
	42	29143	39.03	39.81	40.18	40.49	41.42	41.63	42.09	43.00	43.09	44.49	44.78
	41	28030	35.28	35.81	36.10	36.34	37.19	37.43	37.99	38.18	38.88	40.06	40.53
	40	27207	31.15	32.00	32.40	32.73	33.79	34.09	34.73	35.80	36.49	38.77	39.61
	39	27079	31.03	31.84	32.24	32.58	33.66	33.96	34.60	35.64	36.33	38.62	39.47
	38	26980	30.87	31.49	31.80	32.10	33.17	33.48	34.19	35.23	36.00	38.53	39.43
	37	26770	30.04	30.77	31.19	31.57	32.84	33.18	33.90	34.93	35.82	38.43	39.33
	36	26287	29.33	30.23	30.72	31.11	32.47	32.83	33.57	34.61	35.42	38.24	39.18
	34	26057	29.01	29.96	30.44	30.81	32.14	32.50	33.22	34.20	34.93	38.05	39.04
	33	25130	27.56	28.47	29.11	29.61	31.20	31.60	32.32	33.54	34.62	37.97	38.97
	32	24353	26.44	27.84	28.58	29.17	30.92	31.35	32.17	33.45	34.52	37.91	38.91
	30	24224	26.07	27.73	28.47	29.06	30.82	31.24	32.14	33.43	34.51	37.90	38.91
	29	23942	25.93	27.70	28.46	29.07	30.81	31.24	32.14	33.43	34.50	37.89	38.89
	28	23683	25.06	26.60	27.31	27.81	29.21	29.57	30.35	31.37	32.21	34.88	35.62
	27	23592	23.88	24.90	25.46	25.78	26.68	26.91	27.59	28.29	28.68	30.64	31.17
	26	22968	22.29	22.85	23.05	23.31	24.21	24.40	24.85	25.95	26.88	28.32	28.68
	25	22440	20.36	21.34	21.93	22.28	23.62	23.76	24.12	25.71	26.81	28.29	28.63
	24	21519	19.63	20.83	21.46	21.68	23.38	23.47	23.74	25.52	26.60	27.99	28.28
	22	21283	19.28	20.18	20.70	21.16	22.20	22.46	23.04	23.85	24.47	26.53	27.11
	21	20919	18.78	19.93	20.49	20.97	21.99	22.25	22.82	23.63	24.23	26.23	26.79
	20	20629	18.38	19.44	19.87	20.21	21.12	21.34	21.86	22.58	23.19	25.27	25.86
	19	20076	17.84	18.73	19.12	19.45	20.25	20.44	20.81	21.76	22.30	22.22	22.59
	18	19240	15.55	16.07	16.34	16.60	17.71	17.99	18.54	18.41	18.88	21.38	21.74
	17	18322	12.56	13.58	14.07	14.50	15.59	15.91	16.33	17.39	17.64	20.86	21.12
	16	17842	12.13	13.20	13.65	14.09	15.03	15.36	16.39	17.33	17.55	20.83	21.08
	14	17736	11.81	12.78	13.09	13.51	14.00	14.06	14.80	15.21	15.70	17.13	17.46
	13	15185	8.02	9.05	9.54	9.95	11.01	11.27	10.29	10.85	11.03	11.99	12.53
	12	13764	4.86	5.75	6.02	6.40	7.60	7.92	8.58	8.85	9.36	11.34	12.06
	11	11179	4.95	5.97	6.26	6.60	7.29	7.45	7.82	8.36	8.84	10.91	11.67
	10	9636	4.92	5.91	6.21	6.55	7.19	7.34	7.69	8.20	8.66	10.71	11.48
	9	7039	4.70	5.25	5.48	5.64	6.38	6.63	6.94	7.38	7.80	10.03	10.93
	8	5991	4.53	4.93	5.13	5.29	5.84	6.03	6.26	6.66	7.14	9.73	10.70
	7	4925	4.29	4.46	4.57	4.66	4.55	4.69	5.07	5.73	6.52	9.57	10.58
	6	2266	2.35	2.94	3.17	3.39	4.05	4.26	4.70	5.46	6.33	9.49	10.52
	5	272	1.62	2.25	2.68	2.98	3.89	4.11	4.57	5.36	6.25	9.45	10.48
	4	161	1.57	2.11	2.51	2.78	3.49	3.63	3.83	3.82	4.32	6.45	7.14
	3	106	1.56	2.07	2.52	2.81	3.63	3.81	4.21	4.70	5.01	6.02	6.34
	2	40	1.49	1.42	1.78	2.20	2.86	3.08	3.47	3.92	4.35	5.08	5.29
	1	0	1.51	1.59	1.69	1.84	2.49	2.59	2.82	3.15	3.44	4.47	4.91
	0	-50	1.50	1.50	1.50	1.50	1.80	2.11	2.31	2.60	2.82	3.53	4.30

Scenario 2 - Channelization

Reach	Cross Section Number	Chainage	High Flood Level										
			2	5	10	20	50	100	200	500	1000	5000	10000
Swartkops	48	32253	46.39	46.96	47.25	47.49	48.19	48.39	48.85	49.60	50.28	51.96	52.58
	47	31477	44.28	44.64	44.84	45.03	45.90	46.11	46.58	47.30	47.80	49.48	49.62
	46	30709	42.30	42.95	43.27	43.54	44.16	44.33	44.72	45.19	45.60	47.13	47.62
	45	30095	41.18	41.62	41.89	42.12	42.88	43.10	43.64	44.67	45.07	46.75	47.24
	44	29269	39.32	39.93	40.26	40.55	41.51	41.77	42.37	44.00	43.30	45.13	45.54
	42	29143	38.54	39.13	39.45	39.72	40.52	40.72	41.18	41.86	42.45	43.70	44.22
	41	28030	34.70	35.02	35.17	35.31	35.87	36.03	36.42	37.03	37.58	39.34	39.65
	40	27207	30.52	31.07	31.38	31.64	32.50	32.73	33.28	34.13	34.90	37.53	38.15
	39	27079	30.46	31.00	31.30	31.56	32.42	32.65	33.20	34.06	34.92	37.43	38.05
	38	26980	30.37	30.78	31.01	31.23	32.02	32.24	32.78	33.64	34.41	37.08	37.71
	37	26770	29.45	30.03	30.34	30.62	31.54	31.80	32.39	33.31	34.12	37.00	37.67
	36	26287	28.66	29.29	29.64	29.95	30.95	31.21	31.83	32.78	33.63	36.70	37.38
	34	26057	28.28	28.93	29.28	29.57	30.51	30.76	31.34	32.23	33.03	35.22	35.89
	33	25130	27.04	27.61	27.92	28.20	29.11	29.36	29.94	30.79	31.61	33.16	33.65
	32	24353	25.80	26.44	26.77	27.06	28.03	28.32	28.96	29.79	30.77	32.04	32.68
	30	24224	25.29	25.65	25.85	26.03	26.77	26.94	27.33	27.55	27.81	31.47	32.51
	29	23942	24.34	24.98	25.29	25.55	26.38	26.61	27.13	27.96	28.70	31.58	32.54
	28	23683	23.84	24.12	24.32	24.50	25.11	25.27	25.66	26.27	26.85	28.80	29.45
	27	23592	23.04	23.62	23.91	24.14	24.79	24.95	25.38	26.12	26.83	27.49	29.88
	26	22968	21.30	21.68	21.88	22.09	22.98	23.27	23.92	24.39	25.85	27.77	28.01
	25	22440	19.67	20.36	20.79	21.19	22.43	22.81	23.55	23.79	25.72	27.82	28.12
	24	21519	18.82	19.80	20.27	20.71	21.98	22.37	23.09	23.31	25.56	27.59	27.84
	22	21283	18.55	19.23	19.57	19.85	20.73	20.94	21.47	22.28	22.95	24.96	25.57
	21	20919	18.16	18.53	18.73	18.92	19.54	19.80	20.36	21.13	21.80	23.91	24.52
	20	20629	17.10	17.87	18.25	18.57	19.51	19.74	20.25	20.99	21.61	23.52	24.09
	19	20076	16.91	17.54	17.86	18.13	18.94	19.15	19.59	20.27	20.81	21.42	21.88
	18	19240	14.90	15.26	15.46	15.63	16.21	16.37	16.79	17.29	17.81	20.89	21.20
	17	18322	12.28	13.43	14.00	14.37	15.41	15.72	15.31	16.50	17.36	20.54	20.75
	16	17842	12.27	13.40	13.96	14.31	15.31	15.61	15.02	16.53	17.35	20.55	20.77
	14	17736	12.03	13.03	13.53	13.82	14.29	14.39	14.88	15.39	15.86	17.23	17.57
	13	15185	8.16	9.29	9.83	10.31	11.25	11.52	10.59	10.99	11.21	12.35	12.92
	12	13764	5.07	5.90	6.17	6.40	7.60	7.92	8.58	9.01	9.54	11.55	12.27
	11	11179	5.10	6.04	6.44	6.79	7.41	7.58	7.97	8.55	9.06	11.13	11.89
	10	9636	5.08	5.98	6.39	6.74	7.31	7.47	7.84	8.39	8.88	10.93	11.69
	9	7039	4.81	5.45	5.74	5.95	6.72	6.86	7.18	7.65	8.11	10.28	11.14
	8	5991	4.60	5.05	5.27	5.45	6.07	6.20	6.49	6.95	7.44	9.90	10.84
	7	4925	4.31	4.55	4.70	4.83	4.88	5.01	5.34	5.94	6.67	9.64	10.64
	6	2266	2.46	3.06	3.30	3.52	4.14	4.34	4.77	5.50	6.36	9.51	10.53
	5	272	1.67	2.35	2.75	3.05	3.94	4.16	4.60	5.36	6.26	9.45	10.48
	4	161	1.61	2.19	2.58	2.84	3.55	3.69	3.87	3.84	4.32	6.45	7.14
	3	106	1.58	2.13	2.57	2.66	3.67	3.85	4.22	4.70	4.99	5.96	6.26
	2	40	1.50	1.48	1.78	2.20	2.86	3.09	3.48	3.90	4.33	5.02	5.24
	1	0	1.51	1.61	1.75	1.91	2.56	2.63	2.86	3.18	3.46	4.50	4.91
	0	-50	1.50	1.50	1.50	1.50	1.80	2.13	2.30	2.55	2.77	3.51	3.58

Scenario 3 - Bunding

Reach	Cross Section	Chainage	High Flood Level										
	Number		2	5	10	20	50	100	200	500	1000	5000	10000
Swartkops	48	32253	47.07	47.66	47.96	48.29	49.10	49.32	49.85	50.60	51.21	52.40	52.73
	47	31477	44.82	45.57	45.96	46.28	47.26	47.45	48.01	48.71	49.06	50.28	50.63
	46	30709	42.91	43.61	43.97	44.23	45.03	45.23	45.49	46.02	46.49	48.01	48.47
	45	30095	41.85	42.46	42.81	43.09	44.04	44.32	44.76	45.31	45.78	47.29	47.74
	44	29269	39.79	40.56	40.96	41.32	42.39	42.88	43.80	44.11	44.46	45.62	45.97
	42	29143	39.16	40.02	40.42	40.78	41.74	41.96	42.66	43.45	43.66	44.73	45.01
	41	28030	35.35	35.99	36.32	36.61	37.63	37.92	38.00	38.39	38.84	40.48	41.06
	40	27207	31.31	32.23	32.68	33.06	34.32	34.66	35.39	36.26	36.93	39.07	39.86
	39	27079	31.14	32.02	32.47	32.85	34.11	34.44	35.20	36.08	36.74	38.90	39.71
	38	26980	30.97	31.69	32.10	32.47	33.75	34.10	34.84	35.79	36.51	38.81	39.65
	37	26770	30.17	31.03	31.53	31.96	33.37	33.73	34.48	35.53	36.27	38.65	39.52
	36	26287	29.44	30.49	31.03	31.48	32.94	33.31	34.05	35.05	35.89	38.38	39.30
	34	26057	29.14	30.22	30.74	31.18	32.60	32.97	33.67	34.57	35.19	38.15	39.12
	33	25130	27.72	28.79	29.41	29.90	31.45	31.83	32.49	33.66	34.70	38.00	39.00
	32	24353	26.57	27.94	28.67	29.25	30.99	31.41	32.21	33.48	34.54	37.92	38.93
	30	24224	26.23	27.78	28.52	29.11	30.85	31.27	32.17	33.45	34.53	37.91	38.92
	29	23942	26.02	27.74	28.49	29.09	30.83	31.26	32.15	33.44	34.51	37.90	38.91
	28	23683	25.06	26.60	27.31	27.81	29.21	29.57	30.35	31.37	32.21	34.88	35.62
	27	23592	24.01	25.25	25.75	26.10	25.62	25.80	26.23	26.88	27.35	28.09	28.29
	26	22968	22.43	22.99	23.30	23.61	24.65	24.88	25.35	26.35	27.22	28.81	29.23
	25	22440	20.36	21.63	22.21	22.70	23.93	24.13	24.33	25.81	26.87	28.28	28.64
	24	21519	19.79	20.99	21.58	22.05	23.09	23.09	23.76	25.50	26.55	27.73	28.01
	22	21283	19.41	20.44	20.99	21.36	22.40	22.66	23.25	23.99	24.59	26.57	27.14
	21	20919	18.96	20.17	20.76	21.10	22.14	22.40	22.99	23.71	24.29	26.21	26.75
	20	20629	18.58	19.71	20.19	20.52	21.48	21.72	22.28	23.00	23.53	25.41	25.95
	19	20076	18.03	18.93	19.31	19.58	20.45	20.64	21.28	21.97	21.68	22.82	23.26
	18	19240	15.55	16.11	16.51	17.03	18.20	18.47	18.35	18.90	19.25	21.39	21.77
	17	18322	12.72	13.85	14.42	14.84	16.02	16.36	16.82	17.42	17.69	20.67	20.91
	16	17842	12.30	13.42	13.97	14.32	15.33	15.64	15.98	17.31	17.53	20.59	20.81
	14	17738	12.03	13.03	13.53	13.82	14.29	14.39	14.88	15.39	15.86	17.23	17.57
	13	15185	8.16	9.29	9.83	10.31	11.25	11.52	10.59	10.99	11.21	12.35	12.92
	12	13764	5.07	5.90	6.17	6.40	7.60	7.92	8.58	9.01	9.54	11.55	12.27
	11	11179	5.10	6.04	6.44	6.79	7.41	7.58	7.97	8.55	9.06	11.13	11.89
	10	9636	5.08	5.98	6.39	6.74	7.31	7.47	7.84	8.39	8.88	10.93	11.69
	9	7039	4.81	5.45	5.74	5.95	6.72	6.86	7.18	7.65	8.11	10.28	11.14
	8	5991	4.60	5.05	5.27	5.45	6.07	6.20	6.49	6.95	7.44	9.90	10.84
	7	4925	4.31	4.55	4.70	4.83	4.88	5.01	5.34	5.94	6.67	9.64	10.64
	6	2266	2.46	3.06	3.30	3.52	4.14	4.34	4.77	5.50	6.36	9.51	10.53
	5	272	1.67	2.35	2.75	3.05	3.94	4.16	4.60	5.36	6.26	9.45	10.48
	4	161	1.61	2.19	2.58	2.84	3.55	3.69	3.87	3.84	4.32	6.45	7.14
	3	106	1.58	2.13	2.57	2.86	3.67	3.85	4.22	4.70	4.99	5.96	6.26
	2	40	1.50	1.48	1.78	2.20	2.86	3.09	3.48	3.90	4.33	5.02	5.24
	1	0	1.51	1.61	1.75	1.91	2.56	2.63	2.86	3.18	3.46	4.50	4.91
	0	-50	1.50	1.50	1.50	1.50	1.80	2.13	2.30	2.55	2.77	3.51	3.58

B2 – FLOOD LEVEL COMPARISONS

Anuflood - Chatty River

2 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	2 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8518.41	13.75	13.62	13.31	13.76	-0.13	-0.44	0.01
	66	8374.33	13.38	13.28	13.26	13.41	-0.10	-0.12	0.03
	65	8228.32	13.19	13.10	13.19	13.23	-0.09	0.00	0.04
	64	8069.06	13.05	12.97	13.05	13.09	-0.08	0.00	0.04
	63	7957.56	12.90	12.83	12.91	12.93	-0.07	0.01	0.03
	62	7820.85	12.70	12.66	12.73	12.71	-0.04	0.03	0.01
	61	7687.72	12.24	12.19	12.19	12.24	-0.05	-0.05	0.00
	extra	7680.00	12.13	12.01	10.13	12.13	-0.12	-2.00	0.00
	extra	7640.00	11.96	11.88	10.98	11.97	-0.08	-0.98	0.01
	60	7638.82	11.95	11.85	11.02	11.96	-0.10	-0.93	0.01
	59	7534.48	11.39	11.31	10.93	11.40	-0.08	-0.46	0.01
	58	7440.95	11.20	11.15	10.87	11.21	-0.05	-0.33	0.01
	57	7355.81	10.75	10.57	10.46	10.78	-0.18	-0.29	0.03
	56	7242.65	10.52	10.40	9.49	10.57	-0.12	-1.03	0.05
	55	7119.82	10.27	10.18	9.45	10.25	-0.09	-0.82	-0.02
	54	7060.11	9.80	9.62	8.97	9.80	-0.18	-0.83	0.00
	53	7024.00	9.54	9.39	8.94	9.54	-0.15	-0.60	0.00
	52	6941.00	9.02	8.87	8.83	9.02	-0.15	-0.19	0.00
	50	6824.00	8.90	8.81	8.75	8.90	-0.09	-0.15	0.00
	48	6792.00	8.87	8.78	8.72	8.87	-0.09	-0.15	0.00
	46	6739.00	8.80	8.71	8.66	8.80	-0.09	-0.14	0.00
	45	6644.00	8.62	8.53	8.45	8.62	-0.09	-0.17	0.00
	43	6414.00	7.99	7.84	7.71	7.99	-0.15	-0.28	0.00
	41	6144.00	7.65	7.55	7.55	7.65	-0.10	-0.10	0.00
	40	6024.00	7.47	7.39	7.39	7.47	-0.08	-0.08	0.00
	38	5942.00	6.22	6.12	5.13	6.22	-0.10	-1.09	0.00
	36	5694.00	5.45	5.41	4.95	5.45	-0.04	-0.50	0.00
	34	5344.00	4.81	4.70	4.54	4.82	-0.11	-0.27	0.01
	32	5314.00	4.79	4.67	4.49	4.80	-0.12	-0.30	0.01
	31	5214.00	4.72	4.58	4.27	4.72	-0.14	-0.45	0.00
	29	5024.00	4.65	4.48	3.89	4.66	-0.17	-0.76	0.01
	27	4624.00	4.61	4.43	3.84	4.61	-0.18	-0.77	0.00
	25	4464.00	4.60	4.42	3.83	4.60	-0.18	-0.77	0.00
	24	4074.00	4.58	4.40	3.80	4.58	-0.18	-0.78	0.00
	22	3754.00	4.57	4.39	3.78	4.57	-0.18	-0.79	0.00
	20	3314.00	4.55	4.37	3.72	4.55	-0.18	-0.83	0.00
	18	3034.00	4.43	4.20	3.68	4.43	-0.23	-0.75	0.00
	17	2714.00	4.24	4.00	3.64	4.24	-0.24	-0.60	0.00
	15	2544.00	4.21	3.99	3.61	4.22	-0.22	-0.60	0.01
	13	2354.00	4.04	3.71	3.58	4.04	-0.33	-0.46	0.00
	12	2224.00	3.92	3.66	3.55	3.93	-0.26	-0.37	0.01
	10	1754.00	3.70	3.46	3.49	3.70	-0.24	-0.21	0.00
	8	1599.00	3.68	3.45	3.46	3.68	-0.23	-0.22	0.00
	6	1437.00	3.66	3.42	3.43	3.66	-0.24	-0.23	0.00
	5	1374.00	3.66	3.42	3.43	3.65	-0.24	-0.23	-0.01
	3	1289.00	3.64	3.41	3.41	3.64	-0.23	-0.23	0.00
	1	88.30	3.06	2.92	2.83	3.06	-0.14	-0.23	0.00
	0	0.00	2.45	2.45	2.43	2.45	0.00	-0.02	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chatty River

5 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	5 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8516.41	14.14	14.01	13.66	14.21	-0.13	-0.48	0.07
	66	8374.33	13.74	13.61	13.60	13.81	-0.13	-0.14	0.07
	65	8228.32	13.53	13.42	13.51	13.60	-0.11	-0.02	0.07
	64	8069.06	13.35	13.25	13.33	13.43	-0.10	-0.02	0.08
	63	7957.56	13.18	13.09	13.15	13.25	-0.09	-0.03	0.07
	62	7820.85	13.00	12.90	12.94	13.04	-0.10	-0.06	0.04
	61	7687.72	12.84	12.73	12.28	12.89	-0.11	-0.56	0.05
	extra	7680.00	12.56	12.40	11.63	12.62	-0.16	-0.93	0.06
	extra	7640.00	12.16	12.08	11.22	12.26	-0.08	-0.94	0.10
	60	7638.82	12.24	12.14	11.35	12.32	-0.10	-0.89	0.08
	59	7534.48	11.81	11.66	11.23	11.83	-0.15	-0.58	0.02
	58	7449.95	11.64	11.50	11.17	11.67	-0.14	-0.47	0.03
	57	7355.81	11.27	11.08	10.66	11.35	-0.19	-0.61	0.08
	56	7242.65	11.07	10.96	10.10	11.18	-0.11	-0.97	0.11
	55	7119.82	10.85	10.80	10.07	10.79	-0.05	-0.78	-0.06
	54	7060.11	10.30	10.11	9.26	10.28	-0.19	-1.04	-0.02
	53	7024.00	9.95	9.77	9.21	9.95	-0.18	-0.74	0.00
	52	6941.00	9.27	9.04	9.06	9.28	-0.23	-0.21	0.01
	50	6824.00	9.16	9.04	8.97	9.17	-0.12	-0.19	0.01
	48	6792.00	9.13	9.01	8.93	9.13	-0.12	-0.20	0.00
	46	6739.00	9.06	8.94	8.87	9.06	-0.12	-0.19	0.00
	45	6644.00	8.89	8.77	8.61	8.90	-0.12	-0.28	0.01
	43	6414.00	8.30	8.14	8.01	8.31	-0.16	-0.29	0.01
	41	6144.00	7.93	7.82	7.82	7.93	-0.11	-0.11	0.00
	40	6024.00	7.71	7.63	7.63	7.71	-0.08	-0.08	0.00
	38	5942.00	6.53	6.42	5.45	6.56	-0.11	-1.08	0.03
	36	5694.00	5.70	5.62	5.21	5.70	-0.08	-0.49	0.00
	34	5344.00	5.21	5.05	4.75	5.24	-0.16	-0.46	0.03
	32	5314.00	5.20	5.04	4.70	5.23	-0.16	-0.50	0.03
	31	5214.00	5.16	4.99	4.55	5.19	-0.17	-0.61	0.03
	29	5024.00	5.12	4.95	4.42	5.16	-0.17	-0.70	0.04
	27	4824.00	5.07	4.90	4.36	5.12	-0.17	-0.71	0.05
	25	4464.00	5.06	4.89	4.35	5.10	-0.17	-0.71	0.04
	24	4074.00	5.03	4.87	4.32	5.08	-0.16	-0.71	0.05
	22	3754.00	5.01	4.85	4.29	5.06	-0.16	-0.72	0.05
	20	3314.00	4.98	4.82	4.22	5.03	-0.16	-0.76	0.05
	18	3034.00	4.84	4.64	4.17	4.90	-0.20	-0.67	0.06
	17	2714.00	4.64	4.46	4.11	4.73	-0.18	-0.53	0.09
	15	2544.00	4.61	4.45	4.08	4.69	-0.16	-0.53	0.08
	13	2354.00	4.46	4.12	4.03	4.47	-0.34	-0.43	0.01
	12	2224.00	4.35	4.06	3.99	4.36	-0.29	-0.36	0.01
	10	1754.00	4.15	3.87	3.91	4.15	-0.28	-0.24	0.00
	8	1599.00	4.13	3.85	3.88	4.13	-0.28	-0.25	0.00
	6	1437.00	4.09	3.82	3.84	4.09	-0.27	-0.25	0.00
	5	1374.00	4.10	3.82	3.84	4.09	-0.28	-0.26	-0.01
	3	1289.00	4.08	3.80	3.81	4.08	-0.28	-0.27	0.00
	1	88.30	3.37	3.22	3.10	3.37	-0.15	-0.27	0.00
	0	0.00	2.84	2.84	2.82	2.84	0.00	-0.02	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chafty River

10 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	10 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chafty Lower	67	8518.41	14.41	14.26	13.90	14.55	-0.15	-0.51	0.14
	66	8374.33	14.04	13.89	13.83	14.14	-0.15	-0.21	0.10
	65	8228.32	13.84	13.70	13.74	13.94	-0.14	-0.10	0.10
	64	8069.06	13.68	13.54	13.53	13.79	-0.14	-0.15	0.11
	63	7957.56	13.54	13.41	13.31	13.63	-0.13	-0.23	0.09
	62	7820.65	13.43	13.30	13.06	13.49	-0.13	-0.37	0.06
	61	7687.72	13.37	13.23	12.68	13.42	-0.14	-0.69	0.05
	extra	7680.00	12.96	12.74	12.14	13.03	-0.22	-0.82	0.07
	extra	7640.00	12.25	12.12	11.34	12.46	-0.13	-0.91	0.21
	60	7638.82	12.45	12.33	11.59	12.61	-0.12	-0.86	0.16
	59	7534.48	12.14	11.98	11.46	12.20	-0.16	-0.68	0.06
	58	7449.96	12.00	11.85	11.41	12.08	-0.15	-0.59	0.08
	57	7355.81	11.68	11.51	10.81	11.82	-0.17	-0.87	0.14
	56	7242.65	11.49	11.40	10.59	11.66	-0.09	-0.90	0.17
	55	7119.82	11.32	11.27	10.57	11.23	-0.05	-0.75	-0.09
	54	7060.11	10.61	10.50	9.47	10.59	-0.11	-1.14	-0.02
	53	7024.00	10.22	10.03	9.41	10.22	-0.19	-0.81	0.00
	52	6941.00	9.44	9.23	9.23	9.45	-0.21	-0.21	0.01
	50	6824.00	9.36	9.22	9.14	9.38	-0.14	-0.22	0.02
	48	6792.00	9.32	9.18	9.10	9.34	-0.14	-0.22	0.02
	46	6739.00	9.25	9.11	9.03	9.27	-0.14	-0.22	0.02
	45	6644.00	9.08	8.94	8.76	9.11	-0.14	-0.32	0.03
	43	6414.00	8.51	8.35	8.23	8.53	-0.16	-0.28	0.02
	41	6144.00	8.14	8.02	8.02	8.14	-0.12	-0.12	0.00
	40	6024.00	7.89	7.80	7.80	7.89	-0.09	-0.09	0.00
	38	5942.00	6.77	6.64	5.69	6.81	-0.13	-1.08	0.04
	36	5694.00	5.93	5.80	5.39	5.94	-0.13	-0.54	0.01
	34	5344.00	5.52	5.33	4.97	5.59	-0.19	-0.55	0.07
	32	5314.00	5.52	5.32	4.94	5.58	-0.20	-0.58	0.06
	31	5214.00	5.48	5.28	4.85	5.55	-0.20	-0.63	0.07
	29	5024.00	5.45	5.25	4.77	5.53	-0.20	-0.68	0.08
	27	4624.00	5.40	5.21	4.72	5.48	-0.19	-0.68	0.08
	25	4464.00	5.38	5.19	4.70	5.47	-0.19	-0.68	0.09
	24	4074.00	5.35	5.16	4.68	5.44	-0.19	-0.67	0.09
	22	3754.00	5.33	5.14	4.64	5.42	-0.19	-0.69	0.09
	20	3314.00	5.29	5.11	4.56	5.38	-0.18	-0.73	0.09
	18	3034.00	5.13	4.90	4.50	5.24	-0.23	-0.63	0.11
	17	2714.00	4.92	4.70	4.44	5.07	-0.22	-0.48	0.15
	15	2544.00	4.87	4.67	4.40	5.03	-0.20	-0.47	0.16
	13	2354.00	4.73	4.40	4.34	4.76	-0.33	-0.39	0.03
	12	2224.00	4.62	4.31	4.30	4.66	-0.31	-0.32	0.04
	10	1754.00	4.45	4.16	4.22	4.45	-0.29	-0.23	0.00
	8	1599.00	4.42	4.13	4.18	4.43	-0.29	-0.24	0.01
	6	1437.00	4.38	4.09	4.14	4.38	-0.29	-0.24	0.00
	5	1374.00	4.38	4.10	4.14	4.38	-0.28	-0.24	0.00
	3	1289.00	4.36	4.08	4.10	4.36	-0.28	-0.26	0.00
	1	88.30	3.60	3.44	3.30	3.60	-0.16	-0.30	0.00
	0	0.00	2.80	2.80	2.77	2.80	0.00	-0.03	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chatty River

20 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	20 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8518.41	14.68	14.54	14.16	14.92	-0.14	-0.52	0.24
	66	8374.33	14.40	14.25	14.08	14.53	-0.15	-0.32	0.13
	65	8228.32	14.25	14.11	13.99	14.37	-0.14	-0.26	0.12
	64	8069.06	14.13	14.00	13.78	14.23	-0.13	-0.35	0.10
	63	7957.56	14.05	13.93	13.59	14.11	-0.12	-0.46	0.06
	62	7820.85	13.99	13.88	13.43	14.03	-0.11	-0.56	0.04
	61	7687.72	13.96	13.85	13.30	13.99	-0.11	-0.66	0.03
	extra	7680.00	13.43	13.24	12.62	13.48	-0.19	-0.81	0.05
	extra	7640.00	12.31	12.11	10.60	12.67	-0.20	-1.71	0.36
	60	7638.82	12.69	12.56	11.81	12.93	-0.13	-0.88	0.24
	59	7534.48	12.47	12.33	11.69	12.59	-0.14	-0.78	0.12
	58	7449.95	12.37	12.24	11.64	12.52	-0.13	-0.73	0.15
	57	7355.81	12.10	11.97	10.97	12.30	-0.13	-1.13	0.20
	56	7242.65	11.92	11.86	11.08	12.15	-0.06	-0.84	0.23
	55	7119.82	11.79	11.78	11.06	11.67	-0.01	-0.73	-0.12
	54	7060.11	10.89	10.80	9.66	10.91	-0.09	-1.23	0.02
	53	7024.00	10.47	10.26	9.60	10.46	-0.21	-0.87	-0.01
	52	6941.00	9.59	9.44	9.38	9.62	-0.15	-0.21	0.03
	50	6824.00	9.55	9.39	9.30	9.58	-0.16	-0.25	0.03
	48	6792.00	9.50	9.35	9.26	9.54	-0.15	-0.24	0.04
	46	6739.00	9.43	9.28	9.19	9.47	-0.15	-0.24	0.04
	45	6644.00	9.25	9.11	8.93	9.31	-0.14	-0.32	0.06
	43	6414.00	8.69	8.53	8.42	8.73	-0.16	-0.27	0.04
	41	6144.00	8.32	8.20	8.20	8.32	-0.12	-0.12	0.00
	40	6024.00	8.07	7.97	7.97	8.07	-0.10	-0.10	0.00
	38	5942.00	6.99	6.86	5.92	7.05	-0.13	-1.07	0.06
	36	5694.00	6.18	6.01	5.58	6.22	-0.17	-0.60	0.04
	34	5344.00	5.82	5.61	5.23	5.93	-0.21	-0.59	0.11
	32	5314.00	5.82	5.60	5.22	5.92	-0.22	-0.60	0.10
	31	5214.00	5.78	5.57	5.15	5.90	-0.21	-0.63	0.12
	29	5024.00	5.76	5.54	5.10	5.87	-0.22	-0.66	0.11
	27	4624.00	5.71	5.49	5.04	5.83	-0.22	-0.67	0.12
	25	4464.00	5.69	5.47	5.03	5.81	-0.22	-0.66	0.12
	24	4074.00	5.65	5.45	5.00	5.78	-0.20	-0.65	0.13
	22	3754.00	5.62	5.42	4.96	5.75	-0.20	-0.66	0.13
	20	3314.00	5.58	5.38	4.87	5.71	-0.20	-0.71	0.13
	18	3034.00	5.39	5.14	4.80	5.55	-0.25	-0.59	0.16
	17	2714.00	5.17	4.92	4.73	5.39	-0.25	-0.44	0.22
	15	2544.00	5.11	4.89	4.68	5.34	-0.22	-0.43	0.23
	13	2354.00	4.97	4.65	4.63	5.03	-0.32	-0.34	0.06
	12	2224.00	4.86	4.54	4.58	4.92	-0.32	-0.28	0.06
	10	1754.00	4.71	4.41	4.50	4.72	-0.30	-0.21	0.01
	8	1599.00	4.67	4.38	4.45	4.69	-0.29	-0.22	0.02
	6	1437.00	4.61	4.33	4.40	4.63	-0.28	-0.21	0.02
	5	1374.00	4.62	4.34	4.40	4.63	-0.28	-0.22	0.01
	3	1289.00	4.60	4.31	4.37	4.61	-0.29	-0.23	0.01
	1	88.30	3.79	3.63	3.50	3.79	-0.16	-0.29	0.00
	0	0.00	3.05	3.05	3.05	3.05	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chatty River

50 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	50 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8518.41	15.04	15.37	14.58	15.83	0.33	-0.46	0.79
	66	8374.33	14.79	15.28	14.51	15.61	0.49	-0.28	0.82
	65	8228.32	14.63	15.23	14.43	15.54	0.60	-0.20	0.91
	64	8069.06	14.51	15.20	14.25	15.48	0.69	-0.26	0.97
	63	7957.56	14.43	15.18	14.12	15.43	0.75	-0.31	1.00
	62	7820.65	14.37	15.16	14.03	15.40	0.79	-0.34	1.03
	61	7687.72	14.33	15.15	13.96	15.39	0.82	-0.37	1.06
	extra	7680.00	12.75	14.51	12.38	14.86	1.76	-0.37	2.11
	extra	7640.00	11.93	12.36	10.72	13.06	0.43	-1.21	1.13
	60	7638.82	13.18	13.05	12.24	13.52	-0.13	-0.94	0.34
	59	7534.48	13.06	12.94	12.16	13.24	-0.12	-0.90	0.18
	58	7449.95	13.00	12.89	12.13	13.22	-0.11	-0.87	0.22
	57	7355.81	12.79	12.68	11.78	13.03	-0.11	-1.01	0.24
	56	7242.65	12.61	12.56	11.85	12.86	-0.05	-0.76	0.25
	55	7119.82	12.56	12.55	11.83	12.28	-0.01	-0.73	-0.28
	54	7060.11	11.31	11.23	9.96	11.45	-0.08	-1.35	0.14
	53	7024.00	10.89	10.64	9.88	10.83	-0.25	-1.01	-0.06
	52	6941.00	9.84	9.83	9.60	9.89	-0.01	-0.24	0.05
	50	6824.00	9.82	9.64	9.55	9.88	-0.18	-0.27	0.06
	49	6792.00	9.77	9.60	9.51	9.84	-0.17	-0.26	0.07
	46	6739.00	9.69	9.52	9.43	9.77	-0.17	-0.26	0.08
	45	6644.00	9.51	9.35	9.17	9.61	-0.16	-0.34	0.10
	43	6414.00	8.96	8.78	8.69	9.02	-0.18	-0.27	0.06
	41	6144.00	8.57	8.45	8.46	8.58	-0.12	-0.11	0.01
	40	6024.00	8.33	8.23	8.24	8.33	-0.10	-0.09	0.00
	38	5942.00	7.31	7.15	6.30	7.41	-0.16	-1.01	0.10
	36	5694.00	6.57	6.36	5.91	6.66	-0.21	-0.66	0.09
	34	5344.00	6.28	6.03	5.68	6.45	-0.25	-0.60	0.17
	32	5314.00	6.27	6.03	5.67	6.44	-0.24	-0.60	0.17
	31	5214.00	6.24	6.00	5.62	6.42	-0.24	-0.62	0.18
	29	5024.00	6.22	5.98	5.58	6.40	-0.24	-0.64	0.18
	27	4624.00	6.16	5.92	5.53	6.35	-0.24	-0.63	0.19
	25	4464.00	6.13	5.90	5.51	6.33	-0.23	-0.62	0.20
	24	4074.00	6.09	5.87	5.48	6.30	-0.22	-0.61	0.21
	22	3754.00	6.05	5.83	5.43	6.26	-0.22	-0.62	0.21
	20	3314.00	6.00	5.78	5.34	6.21	-0.22	-0.66	0.21
	18	3034.00	5.77	5.49	5.26	6.02	-0.28	-0.51	0.25
	17	2714.00	5.54	5.26	5.18	5.87	-0.28	-0.36	0.33
	15	2544.00	5.47	5.22	5.11	5.82	-0.25	-0.36	0.35
	13	2354.00	5.32	4.99	5.06	5.41	-0.33	-0.26	0.09
	12	2224.00	5.20	4.86	5.00	5.30	-0.34	-0.20	0.10
	10	1754.00	5.08	4.78	4.93	5.10	-0.30	-0.15	0.02
	8	1599.00	5.01	4.72	4.86	5.07	-0.29	-0.15	0.06
	6	1437.00	4.94	4.65	4.80	4.99	-0.29	-0.14	0.05
	5	1374.00	4.95	4.68	4.81	4.99	-0.27	-0.14	0.04
	3	1269.30	4.93	4.64	4.78	4.97	-0.29	-0.15	0.04
	1	88.30	4.18	4.04	4.09	4.16	-0.14	-0.09	-0.02
	0	0.00	3.94	3.94	3.94	3.94	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chatty River

100 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	100 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8518.41	15.51	16.23	15.06	16.67	0.72	-0.45	1.16
	66	8374.33	15.35	16.20	15.02	16.55	0.85	-0.33	1.20
	65	8228.32	15.26	16.17	14.97	16.51	0.91	-0.29	1.25
	64	8069.06	15.18	16.15	14.85	16.47	0.97	-0.33	1.29
	63	7957.56	15.13	16.14	14.78	16.44	1.01	-0.35	1.31
	62	7820.85	15.10	16.13	14.73	16.43	1.03	-0.37	1.33
	61	7687.72	15.08	16.13	14.70	16.42	1.05	-0.38	1.34
	extra	7680.00	13.22	15.40	12.86	15.82	2.18	-0.36	2.60
	extra	7640.00	12.29	12.84	11.01	13.46	0.55	-1.28	1.17
	60	7638.82	13.50	13.36	12.75	14.06	-0.14	-0.75	0.56
	59	7534.48	13.39	13.26	12.72	13.82	-0.13	-0.67	0.43
	58	7449.95	13.34	13.22	12.71	13.82	-0.12	-0.63	0.48
	57	7355.81	13.10	12.98	12.44	13.64	-0.12	-0.66	0.54
	56	7242.65	12.87	12.81	12.48	13.46	-0.06	-0.39	0.59
	55	7119.82	12.83	12.81	12.48	12.80	-0.02	-0.35	-0.03
	54	7060.11	11.62	11.57	8.75	11.91	-0.05	-2.87	0.29
	53	7024.00	10.87	10.89	10.10	11.07	0.02	-0.77	0.20
	52	6941.00	10.30	10.28	9.76	10.04	-0.02	-0.54	-0.26
	50	6824.00	10.03	9.84	9.75	10.12	-0.19	-0.28	0.09
	48	6792.00	9.98	9.79	9.70	10.08	-0.19	-0.28	0.10
	46	6739.00	9.90	9.71	9.62	10.00	-0.19	-0.28	0.10
	45	6644.00	9.70	9.53	9.36	9.85	-0.17	-0.34	0.15
	43	6414.00	9.16	8.98	8.90	9.25	-0.18	-0.26	0.09
	41	6144.00	8.77	8.65	8.66	8.79	-0.12	-0.11	0.02
	40	6024.00	8.53	8.45	8.46	8.53	-0.08	-0.07	0.00
	38	5942.00	7.57	7.39	6.60	7.72	-0.18	-0.97	0.15
	36	5694.00	6.87	6.62	6.20	7.01	-0.25	-0.67	0.14
	34	5344.00	6.63	6.36	6.02	6.85	-0.27	-0.61	0.22
	32	5314.00	6.62	6.36	6.01	6.85	-0.26	-0.61	0.23
	31	5214.00	6.59	6.33	5.97	6.82	-0.26	-0.62	0.23
	29	5024.00	6.57	6.31	5.94	6.81	-0.26	-0.63	0.24
	27	4624.00	6.51	6.26	5.88	6.76	-0.25	-0.63	0.25
	25	4464.00	6.48	6.22	5.85	6.73	-0.26	-0.63	0.25
	24	4074.00	6.44	6.19	5.83	6.70	-0.25	-0.61	0.26
	22	3754.00	6.39	6.15	5.77	6.66	-0.24	-0.62	0.27
	20	3314.00	6.33	6.09	5.67	6.60	-0.24	-0.66	0.27
	18	3034.00	6.06	5.76	5.57	6.39	-0.30	-0.49	0.33
	17	2714.00	5.82	5.52	5.49	6.24	-0.30	-0.33	0.42
	15	2544.00	5.74	5.47	5.41	6.17	-0.27	-0.33	0.43
	13	2354.00	5.58	5.25	5.35	5.71	-0.33	-0.23	0.13
	12	2224.00	5.45	5.09	5.29	5.59	-0.36	-0.16	0.14
	10	1754.00	5.34	5.04	5.22	5.39	-0.30	-0.12	0.05
	8	1599.00	5.25	4.95	5.13	5.36	-0.30	-0.12	0.11
	6	1437.00	5.17	4.87	5.06	5.26	-0.30	-0.11	0.09
	5	1374.00	5.19	4.91	5.08	5.27	-0.28	-0.11	0.08
	3	1289.00	5.16	4.86	5.04	5.24	-0.30	-0.12	0.08
	1	88.30	4.44	4.29	4.39	4.38	-0.15	-0.05	-0.06
	0	0.00	4.16	4.16	4.16	4.16	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chatty River

200 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	200 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8518.41	16.20	16.85	15.58	17.38	0.65	-0.62	1.18
	66	8374.33	16.12	16.82	15.55	17.31	0.70	-0.57	1.19
	65	8228.32	16.07	16.80	15.52	17.28	0.73	-0.55	1.21
	64	8069.06	16.03	16.79	15.43	17.26	0.76	-0.60	1.23
	63	7957.56	16.00	16.78	15.39	17.24	0.78	-0.61	1.24
	62	7820.65	15.99	16.77	15.36	17.23	0.78	-0.63	1.24
	61	7687.72	15.97	16.77	15.34	17.23	0.80	-0.63	1.26
	extra	7680.00	14.68	15.89	13.27	16.54	1.21	-1.41	1.86
	extra	7640.00	12.23	13.21	11.18	13.84	0.98	-1.05	1.61
	60	7638.82	13.77	13.63	12.99	14.57	-0.14	-0.78	0.80
	59	7534.48	13.68	13.54	12.95	14.39	-0.14	-0.73	0.71
	58	7449.95	13.63	13.51	12.95	14.40	-0.12	-0.68	0.77
	57	7355.81	13.38	13.24	12.64	14.24	-0.14	-0.74	0.86
	56	7242.65	13.09	13.02	12.68	14.06	-0.07	-0.41	0.97
	55	7119.82	13.07	13.05	12.68	13.40	-0.02	-0.39	0.33
	54	7060.11	11.89	11.86	8.83	12.31	-0.03	-3.06	0.42
	53	7024.00	11.07	11.09	10.29	11.24	0.02	-0.78	0.17
	52	6941.00	10.33	10.44	9.89	10.22	0.11	-0.44	-0.11
	50	6824.00	10.21	10.00	9.91	10.32	-0.21	-0.30	0.11
	48	6792.00	10.15	9.95	9.86	10.28	-0.20	-0.29	0.13
	46	6739.00	10.07	9.87	9.78	10.20	-0.20	-0.29	0.13
	45	6644.00	9.86	9.68	9.52	10.04	-0.18	-0.34	0.18
	43	6414.00	9.32	9.14	9.07	9.43	-0.18	-0.25	0.11
	41	6144.00	8.95	8.83	8.83	8.96	-0.12	-0.12	0.01
	40	6024.00	8.71	8.63	8.64	8.70	-0.08	-0.07	-0.01
	38	5942.00	7.79	7.60	6.87	7.99	-0.19	-0.92	0.20
	36	5694.00	7.13	6.86	6.46	7.31	-0.27	-0.67	0.18
	34	5344.00	6.93	6.66	6.34	7.19	-0.27	-0.59	0.26
	32	5314.00	6.92	6.65	6.33	7.19	-0.27	-0.59	0.27
	31	5214.00	6.89	6.63	6.30	7.17	-0.26	-0.59	0.28
	29	5024.00	6.87	6.61	6.27	7.15	-0.26	-0.60	0.28
	27	4624.00	6.81	6.55	6.21	7.10	-0.26	-0.60	0.29
	25	4464.00	6.77	6.52	6.18	7.07	-0.25	-0.59	0.30
	24	4074.00	6.73	6.48	6.15	7.04	-0.25	-0.58	0.31
	22	3754.00	6.68	6.43	6.09	7.03	-0.25	-0.59	0.35
	20	3314.00	6.61	6.37	5.99	6.95	-0.24	-0.62	0.34
	18	3034.00	6.33	6.00	5.88	6.73	-0.33	-0.45	0.40
	17	2714.00	6.08	5.78	5.79	6.59	-0.30	-0.29	0.51
	15	2544.00	5.99	5.71	5.71	6.52	-0.28	-0.28	0.53
	13	2354.00	5.84	5.52	5.66	6.01	-0.32	-0.18	0.17
	12	2224.00	5.71	5.36	5.58	5.90	-0.35	-0.13	0.19
	10	1754.00	5.62	5.35	5.53	5.73	-0.27	-0.09	0.11
	8	1599.00	5.52	5.24	5.43	5.70	-0.28	-0.09	0.18
	6	1437.00	5.43	5.16	5.36	5.59	-0.27	-0.07	0.16
	5	1374.00	5.46	5.20	5.38	5.60	-0.26	-0.08	0.14
	3	1289.00	5.43	5.17	5.34	5.58	-0.26	-0.09	0.15
	1	88.30	4.91	4.82	4.87	4.96	-0.09	-0.04	0.05
	0	0.00	4.60	4.60	4.60	4.60	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chatty River

500 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	500 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8518.41	17.52	18.11	16.88	18.51	0.60	-0.64	1.00
	66	8374.33	17.45	18.09	16.85	18.45	0.64	-0.60	1.00
	65	8228.32	17.40	18.07	16.82	18.42	0.66	-0.58	1.02
	64	8069.06	17.37	18.06	16.75	18.41	0.69	-0.62	1.04
	63	7957.56	17.34	18.05	16.71	18.39	0.71	-0.63	1.05
	62	7820.85	17.34	18.04	16.69	18.38	0.71	-0.65	1.05
	61	7687.72	17.32	18.04	16.67	18.38	0.72	-0.65	1.06
	extra	7680.00	15.45	16.47	14.13	17.02	1.02	-1.32	1.57
	extra	7640.00	13.38	14.20	11.76	14.74	0.83	-1.62	1.36
	60	7638.82	14.39	14.25	13.62	15.10	-0.14	-0.76	0.71
	59	7534.48	14.31	14.18	13.60	14.94	-0.14	-0.72	0.63
	58	7449.95	14.27	14.15	13.60	14.95	-0.12	-0.67	0.68
	57	7355.81	14.05	13.91	13.33	14.79	-0.14	-0.72	0.75
	56	7242.65	13.66	13.55	13.30	14.49	-0.11	-0.36	0.83
	55	7119.82	13.70	13.65	13.32	13.94	-0.05	-0.38	0.25
	54	7060.11	11.87	12.05	9.03	12.34	0.18	-2.84	0.47
	53	7024.00	11.33	11.29	10.34	11.40	-0.03	-0.98	0.08
	52	6941.00	10.67	10.70	10.22	10.59	0.03	-0.44	-0.08
	50	6824.00	10.55	10.33	10.25	10.67	-0.22	-0.30	0.12
	48	6792.00	10.49	10.28	10.20	10.62	-0.21	-0.29	0.13
	46	6739.00	10.41	10.20	10.12	10.54	-0.21	-0.29	0.13
	45	6644.00	10.19	10.00	9.86	10.37	-0.18	-0.33	0.18
	43	6414.00	9.68	9.51	9.45	9.78	-0.17	-0.23	0.10
	41	6144.00	9.34	9.23	9.23	9.35	-0.11	-0.11	0.01
	40	6024.00	9.13	9.05	9.06	9.11	-0.08	-0.07	-0.01
	38	5942.00	8.29	8.10	7.45	8.49	-0.19	-0.84	0.20
	36	5664.00	7.70	7.44	7.08	7.87	-0.26	-0.62	0.18
	34	5344.00	7.52	7.26	6.98	7.76	-0.25	-0.54	0.25
	32	5314.00	7.51	7.25	6.97	7.76	-0.26	-0.54	0.25
	31	5214.00	7.48	7.23	6.94	7.74	-0.24	-0.54	0.26
	29	5024.00	7.46	7.22	6.92	7.72	-0.24	-0.54	0.26
	27	4624.00	7.41	7.16	6.86	7.67	-0.24	-0.54	0.27
	25	4464.00	7.37	7.14	6.84	7.64	-0.23	-0.53	0.27
	24	4074.00	7.33	7.10	6.81	7.61	-0.23	-0.52	0.28
	22	3754.00	7.29	7.06	6.75	7.60	-0.23	-0.53	0.32
	20	3314.00	7.21	6.99	6.65	7.52	-0.22	-0.56	0.31
	18	3034.00	6.93	6.63	6.53	7.29	-0.30	-0.40	0.36
	17	2714.00	6.70	6.42	6.45	7.15	-0.27	-0.25	0.45
	15	2544.00	6.61	6.36	6.37	7.08	-0.25	-0.24	0.47
	13	2364.00	6.47	6.20	6.32	6.62	-0.28	-0.15	0.15
	12	2224.00	6.34	6.04	6.24	6.50	-0.30	-0.10	0.16
	10	1754.00	6.28	6.05	6.21	6.37	-0.23	-0.08	0.09
	8	1569.00	6.17	5.93	6.09	6.32	-0.24	-0.08	0.16
	6	1437.00	6.09	5.86	6.03	6.22	-0.23	-0.06	0.14
	5	1374.00	6.12	5.90	6.06	6.24	-0.22	-0.07	0.12
	3	1289.00	6.10	5.88	6.02	6.23	-0.22	-0.08	0.13
	1	88.30	5.65	5.58	5.62	5.69	-0.07	-0.03	0.04
	0	0.00	5.36	5.36	5.36	5.36	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chatty River

1000 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	1000 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8518.41	18.87	19.41	18.21	19.68	0.54	-0.66	0.81
	66	8374.33	18.81	19.39	18.18	19.62	0.58	-0.63	0.81
	65	8228.32	18.78	19.37	18.17	19.60	0.60	-0.61	0.82
	64	8069.06	18.75	19.37	18.10	19.59	0.62	-0.64	0.84
	63	7957.56	18.73	19.36	18.07	19.57	0.63	-0.65	0.85
	62	7820.85	18.72	19.35	18.05	19.56	0.63	-0.67	0.85
	61	7687.72	18.70	19.35	18.04	19.56	0.65	-0.67	0.86
	extra	7680.00	16.24	17.07	15.01	17.51	0.82	-1.23	1.27
	extra	7640.00	14.56	15.23	12.36	15.65	0.67	-2.20	1.10
	60	7638.82	15.02	14.88	14.27	15.64	-0.13	-0.74	0.62
	59	7534.48	14.97	14.83	14.26	15.51	-0.14	-0.70	0.54
	58	7449.95	14.93	14.81	14.27	15.51	-0.12	-0.65	0.59
	57	7355.81	14.73	14.60	14.04	15.36	-0.13	-0.69	0.63
	56	7242.65	14.25	14.10	13.93	14.93	-0.15	-0.32	0.68
	55	7119.82	14.34	14.27	13.97	14.50	-0.07	-0.37	0.16
	54	7060.11	11.85	12.25	9.24	12.36	0.40	-2.61	0.51
	53	7024.00	11.59	11.50	10.40	11.57	-0.09	-1.19	-0.02
	52	6941.00	11.02	10.96	10.57	10.97	-0.06	-0.45	-0.05
	50	6824.00	10.90	10.67	10.60	11.02	-0.23	-0.30	0.13
	48	6792.00	10.83	10.62	10.54	10.97	-0.22	-0.29	0.14
	46	6739.00	10.75	10.54	10.47	10.89	-0.21	-0.28	0.14
	45	6644.00	10.53	10.34	10.21	10.71	-0.19	-0.32	0.18
	43	6414.00	10.05	9.88	9.83	10.14	-0.17	-0.22	0.09
	41	6144.00	9.75	9.64	9.65	9.75	-0.10	-0.10	0.00
	40	6024.00	9.56	9.49	9.50	9.54	-0.07	-0.06	-0.02
	38	5942.00	8.80	8.62	8.05	9.00	-0.19	-0.75	0.19
	36	5694.00	8.28	8.03	7.71	8.45	-0.26	-0.57	0.17
	34	5344.00	8.12	7.88	7.64	8.35	-0.23	-0.48	0.23
	32	5314.00	8.11	7.87	7.63	8.35	-0.23	-0.48	0.24
	31	5214.00	8.08	7.86	7.60	8.33	-0.22	-0.48	0.25
	29	5024.00	8.07	7.84	7.58	8.31	-0.22	-0.49	0.24
	27	4624.00	8.02	7.79	7.53	8.26	-0.22	-0.48	0.25
	25	4464.00	7.99	7.77	7.51	8.24	-0.21	-0.48	0.25
	24	4074.00	7.95	7.73	7.48	8.21	-0.21	-0.47	0.26
	22	3754.00	7.91	7.70	7.44	8.19	-0.21	-0.47	0.28
	20	3314.00	7.83	7.62	7.34	8.11	-0.21	-0.50	0.27
	18	3034.00	7.55	7.27	7.20	7.86	-0.27	-0.34	0.31
	17	2714.00	7.33	7.09	7.12	7.72	-0.24	-0.21	0.39
	15	2544.00	7.25	7.02	7.05	7.65	-0.23	-0.20	0.40
	13	2354.00	7.12	6.89	7.00	7.25	-0.23	-0.12	0.12
	12	2224.00	6.99	6.74	6.91	7.12	-0.25	-0.08	0.13
	10	1754.00	6.96	6.77	6.90	7.04	-0.19	-0.06	0.07
	8	1599.00	6.83	6.63	6.77	6.97	-0.20	-0.06	0.13
	6	1437.00	6.76	6.57	6.72	6.87	-0.19	-0.04	0.11
	5	1374.00	6.80	6.63	6.75	6.90	-0.18	-0.05	0.10
	3	1289.00	6.78	6.60	6.72	6.89	-0.18	-0.06	0.11
	1	88.30	6.41	6.35	6.38	6.44	-0.05	-0.03	0.03
	0	0.00	6.14	6.14	6.14	6.14	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chatty River

5000 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	5000 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8518.41	24.58	24.89	23.83	24.59	0.31	-0.75	0.01
	66	8374.33	24.57	24.88	23.82	24.57	0.31	-0.75	0.00
	65	8228.32	24.57	24.88	23.83	24.57	0.31	-0.74	0.00
	64	8069.06	24.56	24.88	23.82	24.57	0.32	-0.74	0.01
	63	7957.56	24.56	24.87	23.82	24.56	0.31	-0.74	0.00
	62	7820.85	24.56	24.87	23.82	24.56	0.31	-0.74	0.00
	61	7687.72	24.55	24.87	23.81	24.55	0.32	-0.74	0.00
	extra	7680.00	19.59	19.59	18.74	19.59	0.00	-0.85	0.00
	extra	7640.00	19.54	19.54	14.88	19.54	0.00	-4.66	0.00
	60	7638.82	17.69	17.57	17.02	17.93	-0.12	-0.67	0.24
	59	7534.48	17.72	17.59	17.08	17.90	-0.13	-0.64	0.18
	58	7449.95	17.70	17.58	17.10	17.90	-0.12	-0.60	0.20
	57	7365.81	17.63	17.52	17.04	17.76	-0.11	-0.59	0.13
	56	7242.65	16.73	16.42	16.61	16.79	-0.31	-0.12	0.06
	55	7119.82	17.06	16.87	16.74	16.85	-0.19	-0.32	-0.21
	54	7060.11	11.77	13.08	10.12	12.48	1.31	-1.65	0.71
	53	7024.00	12.70	12.39	10.64	12.28	-0.31	-2.06	-0.42
	52	6941.00	12.49	12.07	12.02	12.57	-0.42	-0.47	0.08
	50	6824.00	12.37	12.11	12.07	12.53	-0.26	-0.30	0.16
	48	6792.00	12.30	12.04	12.01	12.46	-0.26	-0.29	0.16
	46	6739.00	12.22	11.98	11.95	12.37	-0.24	-0.27	0.15
	45	6644.00	11.95	11.74	11.68	12.14	-0.21	-0.27	0.19
	43	6414.00	11.61	11.47	11.46	11.65	-0.14	-0.15	0.04
	41	6144.00	11.46	11.39	11.40	11.45	-0.07	-0.06	-0.01
	40	6024.00	11.38	11.32	11.33	11.34	-0.06	-0.05	-0.04
	38	5942.00	10.97	10.79	10.58	11.15	-0.18	-0.39	0.18
	36	5694.00	10.74	10.54	10.39	10.90	-0.20	-0.35	0.16
	34	5344.00	10.66	10.50	10.41	10.83	-0.16	-0.25	0.17
	32	5314.00	10.65	10.49	10.40	10.82	-0.16	-0.25	0.17
	31	5214.00	10.63	10.48	10.39	10.81	-0.15	-0.24	0.18
	29	5024.00	10.63	10.48	10.39	10.80	-0.15	-0.24	0.17
	27	4624.00	10.60	10.46	10.37	10.75	-0.14	-0.23	0.15
	25	4464.00	10.59	10.45	10.36	10.73	-0.14	-0.23	0.14
	24	4074.00	10.55	10.42	10.33	10.70	-0.13	-0.22	0.15
	22	3754.00	10.54	10.41	10.32	10.68	-0.13	-0.22	0.14
	20	3314.00	10.45	10.31	10.22	10.58	-0.14	-0.23	0.13
	18	3034.00	10.15	10.00	10.04	10.27	-0.15	-0.11	0.12
	17	2714.00	10.00	9.88	9.97	10.14	-0.12	-0.03	0.14
	15	2544.00	9.95	9.84	9.91	10.08	-0.11	-0.04	0.13
	13	2354.00	9.87	9.82	9.88	9.89	-0.05	0.01	0.02
	12	2224.00	9.73	9.68	9.77	9.74	-0.05	0.04	0.01
	10	1754.00	9.84	9.81	9.84	9.83	-0.03	0.00	-0.01
	8	1599.00	9.65	9.62	9.65	9.68	-0.03	0.00	0.03
	6	1437.00	9.61	9.60	9.62	9.62	-0.01	0.01	0.01
	5	1374.00	9.68	9.68	9.68	9.68	0.00	0.00	0.00
	3	1289.00	9.68	9.67	9.68	9.69	-0.01	0.00	0.01
	1	88.30	9.62	9.64	9.62	9.61	0.02	0.00	-0.01
	0	0.00	9.45	9.45	9.45	9.45	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Chatty River

10000 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	10000 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Chatty Lower	67	8518.41	27.16	27.53	25.30	27.16	0.37	-1.86	0.00
	66	8374.33	27.15	27.52	25.30	27.15	0.37	-1.85	0.00
	65	8228.32	27.15	27.52	25.31	27.15	0.37	-1.84	0.00
	64	8069.06	27.15	27.52	25.30	27.15	0.37	-1.85	0.00
	63	7957.56	27.14	27.51	25.30	27.14	0.37	-1.84	0.00
	62	7820.85	27.14	27.52	25.30	27.14	0.38	-1.84	0.00
	61	7687.72	27.14	27.51	25.29	27.14	0.37	-1.85	0.00
	extra	7680.00	20.88	21.11	19.77	20.88	0.23	-1.11	0.00
	extra	7640.00	19.54	19.54	15.68	19.54	0.00	-3.86	0.00
	60	7638.82	17.95	18.17	17.56	18.25	0.22	-0.39	0.30
	59	7534.48	17.98	18.21	17.64	18.22	0.23	-0.34	0.24
	58	7449.95	17.96	18.21	17.66	18.22	0.25	-0.30	0.26
	57	7355.81	17.88	18.13	17.59	18.05	0.25	-0.29	0.17
	56	7242.65	16.47	16.78	17.05	16.48	0.31	0.58	0.01
	55	7119.82	16.99	17.35	17.22	16.51	0.36	0.23	-0.48
	54	7060.11	12.01	13.42	10.44	12.74	1.41	-1.57	0.73
	53	7024.00	13.08	12.71	10.99	12.38	-0.37	-2.09	-0.70
	52	6941.00	12.95	12.52	12.39	13.11	-0.43	-0.56	0.16
	50	6824.00	12.84	12.51	12.42	13.03	-0.33	-0.42	0.19
	48	6792.00	12.76	12.44	12.36	12.96	-0.32	-0.40	0.20
	46	6739.00	12.68	12.38	12.29	12.87	-0.30	-0.39	0.19
	45	6644.00	12.41	12.11	11.98	12.64	-0.30	-0.43	0.23
	43	6414.00	12.11	11.86	11.76	12.25	-0.25	-0.35	0.14
	41	6144.00	11.99	11.79	11.70	12.12	-0.20	-0.29	0.13
	40	6024.00	11.91	11.72	11.62	12.04	-0.19	-0.29	0.13
	38	5942.00	11.79	11.63	11.49	11.94	-0.16	-0.30	0.15
	36	5694.00	11.58	11.42	11.28	11.72	-0.16	-0.30	0.14
	34	5344.00	11.52	11.38	11.30	11.66	-0.14	-0.22	0.14
	32	5314.00	11.51	11.38	11.30	11.65	-0.13	-0.21	0.14
	31	5214.00	11.49	11.37	11.29	11.64	-0.12	-0.20	0.15
	29	5024.00	11.49	11.37	11.29	11.63	-0.12	-0.20	0.14
	27	4624.00	11.47	11.35	11.27	11.59	-0.12	-0.20	0.12
	25	4464.00	11.46	11.34	11.26	11.58	-0.12	-0.20	0.12
	24	4074.00	11.43	11.32	11.24	11.54	-0.11	-0.19	0.11
	22	3754.00	11.41	11.30	11.22	11.53	-0.11	-0.19	0.12
	20	3314.00	11.32	11.21	11.13	11.43	-0.11	-0.19	0.11
	18	3034.00	11.02	10.91	10.94	11.12	-0.11	-0.08	0.10
	17	2714.00	10.90	10.81	10.87	11.01	-0.09	-0.03	0.11
	15	2544.00	10.86	10.78	10.83	10.96	-0.08	-0.03	0.10
	13	2354.00	10.77	10.75	10.79	10.78	-0.02	0.02	0.01
	12	2224.00	10.63	10.61	10.67	10.63	-0.02	0.04	0.00
	10	1754.00	10.76	10.75	10.76	10.75	-0.01	0.00	-0.01
	8	1599.00	10.57	10.56	10.57	10.59	-0.01	0.00	0.02
	6	1437.00	10.53	10.54	10.54	10.53	0.01	0.01	0.00
	5	1374.00	10.61	10.62	10.61	10.60	0.01	0.00	-0.01
	3	1289.00	10.61	10.62	10.61	10.61	0.01	0.00	0.00
	1	88.30	10.59	10.62	10.59	10.59	0.03	0.00	0.00
	0	0.00	10.48	10.48	10.48	10.48	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelization
Scenario 3 - Bunding

Anuflood - Swartkops River

2 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	2 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	47.07	46.95	46.39	47.07	-0.12	-0.68	0.00
	47	31477	44.82	44.82	44.28	44.82	0.00	-0.54	0.00
	46	30709	42.91	42.80	42.30	42.91	-0.11	-0.61	0.00
	45	30095	41.85	41.69	41.18	41.85	-0.16	-0.67	0.00
	44	29269	39.79	39.71	39.32	39.79	-0.08	-0.47	0.00
	42	29143	39.16	39.03	38.54	39.16	-0.13	-0.62	0.00
	41	28030	35.35	35.28	34.70	35.35	-0.07	-0.65	0.00
	40	27207	31.31	31.15	30.52	31.31	-0.16	-0.79	0.00
	39	27079	31.14	31.03	30.46	31.14	-0.11	-0.68	0.00
	38	26980	30.97	30.87	30.37	30.97	-0.10	-0.60	0.00
	37	26770	30.17	30.04	29.45	30.17	-0.13	-0.72	0.00
	36	26287	29.44	29.33	28.66	29.44	-0.11	-0.78	0.00
	34	26057	29.14	29.01	28.28	29.14	-0.13	-0.86	0.00
	33	25130	27.72	27.56	27.04	27.72	-0.16	-0.68	0.00
	32	24353	26.57	26.44	25.80	26.57	-0.13	-0.77	0.00
	30	24224	26.23	26.07	25.29	26.23	-0.16	-0.94	0.00
	29	23942	26.02	25.93	24.34	26.02	-0.09	-1.68	0.00
	28	23683	25.06	25.06	23.84	25.06	0.00	-1.22	0.00
	27	23592	24.01	23.88	23.04	24.01	-0.13	-0.97	0.00
	26	22968	22.43	22.29	21.30	22.43	-0.14	-1.13	0.00
	25	22440	20.36	20.36	19.67	20.36	0.00	-0.69	0.00
	24	21519	19.79	19.63	18.82	19.79	-0.16	-0.97	0.00
	22	21283	19.41	19.28	18.55	19.41	-0.13	-0.86	0.00
	21	20919	18.96	18.78	18.16	18.96	-0.18	-0.80	0.00
	20	20629	18.58	18.38	17.10	18.58	-0.20	-1.48	0.00
	19	20076	18.03	17.84	16.91	18.03	-0.19	-1.12	0.00
	18	19240	15.55	15.55	14.90	15.55	0.00	-0.65	0.00
	17	18322	12.72	12.56	12.28	12.72	-0.16	-0.44	0.00
	16	17842	12.30	12.13	12.27	12.30	-0.17	-0.03	0.00
	14	17736	12.03	11.81	12.03	12.03	-0.22	0.00	0.00
	13	15185	8.16	8.02	8.16	8.16	-0.14	0.00	0.00
	12	13764	5.07	4.86	5.07	5.07	-0.21	0.00	0.00
	11	11179	5.10	4.95	5.10	5.10	-0.15	0.00	0.00
	10	9636	5.08	4.92	5.08	5.08	-0.16	0.00	0.00
	9	7039	4.81	4.70	4.81	4.81	-0.11	0.00	0.00
	8	5991	4.60	4.53	4.60	4.60	-0.07	0.00	0.00
	7	4925	4.31	4.29	4.31	4.31	-0.02	0.00	0.00
	6	2266	2.46	2.35	2.46	2.46	-0.11	0.00	0.00
	5	272	1.67	1.62	1.67	1.67	-0.05	0.00	0.00
	4	161	1.61	1.57	1.61	1.61	-0.04	0.00	0.00
	3	106	1.58	1.56	1.58	1.58	-0.02	0.00	0.00
	2	40	1.50	1.49	1.50	1.50	-0.01	0.00	0.00
	1	0	1.51	1.51	1.51	1.51	0.00	0.00	0.00
	0	-50	1.50	1.50	1.50	1.50	0.00	0.00	0.00

Note : Scenario 0 - *As is Situation*
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

5 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	5 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	47.66	47.54	46.96	47.66	-0.12	-0.70	0.00
	47	31477	45.57	45.34	44.64	45.57	-0.23	-0.93	0.00
	46	30709	43.61	43.46	42.95	43.61	-0.15	-0.66	0.00
	45	30095	42.46	42.27	41.62	42.46	-0.19	-0.84	0.00
	44	29269	40.56	40.44	39.93	40.56	-0.12	-0.63	0.00
	42	29143	40.02	39.81	39.13	40.02	-0.21	-0.89	0.00
	41	28030	35.99	35.81	35.02	35.99	-0.18	-0.97	0.00
	40	27207	32.23	32.00	31.07	32.23	-0.23	-1.16	0.00
	39	27079	32.02	31.84	31.00	32.02	-0.18	-1.02	0.00
	38	26980	31.69	31.49	30.78	31.69	-0.20	-0.91	0.00
	37	26770	31.03	30.77	30.03	31.03	-0.26	-1.00	0.00
	36	26287	30.49	30.23	29.29	30.49	-0.26	-1.20	0.00
	34	26057	30.22	29.96	28.93	30.22	-0.26	-1.29	0.00
	33	25130	28.79	28.47	27.61	28.79	-0.32	-1.18	0.00
	32	24353	27.94	27.84	26.44	27.94	-0.10	-1.50	0.00
	30	24224	27.78	27.73	25.65	27.78	-0.05	-2.13	0.00
	29	23942	27.74	27.70	24.98	27.74	-0.04	-2.76	0.00
	28	23683	26.60	26.60	24.12	26.60	0.00	-2.48	0.00
	27	23592	25.25	24.90	23.62	25.25	-0.35	-1.63	0.00
	26	22968	22.99	22.85	21.68	22.99	-0.14	-1.31	0.00
	25	22440	21.63	21.34	20.36	21.63	-0.29	-1.27	0.00
	24	21519	20.99	20.83	19.80	20.99	-0.16	-1.19	0.00
	22	21283	20.44	20.18	19.23	20.44	-0.26	-1.21	0.00
	21	20919	20.17	19.93	18.53	20.17	-0.24	-1.64	0.00
	20	20629	19.71	19.44	17.87	19.71	-0.27	-1.84	0.00
	19	20076	18.93	18.73	17.54	18.93	-0.20	-1.39	0.00
	18	19240	16.11	16.07	15.26	16.11	-0.04	-0.85	0.00
	17	18322	13.85	13.58	13.43	13.85	-0.27	-0.42	0.00
	16	17842	13.42	13.20	13.40	13.42	-0.22	-0.02	0.00
	14	17736	13.03	12.78	13.03	13.03	-0.25	0.00	0.00
	13	15185	9.29	9.05	9.29	9.29	-0.24	0.00	0.00
	12	13764	5.90	5.75	5.90	5.90	-0.15	0.00	0.00
	11	11179	6.04	5.97	6.04	6.04	-0.07	0.00	0.00
	10	9636	5.98	5.91	5.98	5.98	-0.07	0.00	0.00
	9	7039	5.45	5.25	5.45	5.45	-0.20	0.00	0.00
	8	5991	5.05	4.93	5.05	5.05	-0.12	0.00	0.00
	7	4925	4.55	4.46	4.55	4.55	-0.09	0.00	0.00
	6	2266	3.06	2.94	3.06	3.06	-0.12	0.00	0.00
	5	272	2.35	2.25	2.35	2.35	-0.10	0.00	0.00
	4	161	2.19	2.11	2.19	2.19	-0.08	0.00	0.00
	3	106	2.13	2.07	2.13	2.13	-0.06	0.00	0.00
	2	40	1.48	1.42	1.48	1.48	-0.06	0.00	0.00
	1	0	1.61	1.59	1.61	1.61	-0.02	0.00	0.00
	0	-50	1.50	1.50	1.50	1.50	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

10 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	10 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	47.96	47.79	47.25	47.96	-0.17	-0.71	0.00
	47	31477	45.96	45.67	44.84	45.96	-0.29	-1.12	0.00
	46	30709	43.97	43.79	43.27	43.97	-0.18	-0.70	0.00
	45	30095	42.81	42.61	41.89	42.81	-0.20	-0.92	0.00
	44	29269	40.96	40.80	40.26	40.96	-0.16	-0.70	0.00
	42	29143	40.42	40.18	39.45	40.42	-0.24	-0.97	0.00
	41	28030	36.32	36.10	35.17	36.32	-0.22	-1.15	0.00
	40	27207	32.68	32.40	31.38	32.68	-0.28	-1.30	0.00
	39	27079	32.47	32.24	31.30	32.47	-0.23	-1.17	0.00
	38	26980	32.10	31.80	31.01	32.10	-0.30	-1.09	0.00
	37	26770	31.53	31.19	30.34	31.53	-0.34	-1.19	0.00
	36	26287	31.03	30.72	29.64	31.03	-0.31	-1.39	0.00
	34	26057	30.74	30.44	29.28	30.74	-0.30	-1.46	0.00
	33	25130	29.41	29.11	27.92	29.41	-0.30	-1.49	0.00
	32	24353	28.67	28.58	26.77	28.67	-0.09	-1.90	0.00
	30	24224	28.52	28.47	25.85	28.52	-0.05	-2.67	0.00
	29	23942	28.49	28.46	25.29	28.49	-0.03	-3.20	0.00
	28	23683	27.31	27.31	24.32	27.31	0.00	-2.99	0.00
	27	23592	25.75	25.46	23.91	25.75	-0.29	-1.84	0.00
	26	22968	23.30	23.05	21.88	23.30	-0.25	-1.42	0.00
	25	22440	22.21	21.93	20.79	22.21	-0.28	-1.42	0.00
	24	21519	21.58	21.46	20.27	21.58	-0.12	-1.31	0.00
	22	21283	20.99	20.70	19.57	20.99	-0.29	-1.42	0.00
	21	20919	20.76	20.49	18.73	20.76	-0.27	-2.03	0.00
	20	20629	20.19	19.87	18.25	20.19	-0.32	-1.94	0.00
	19	20076	19.31	19.12	17.86	19.31	-0.19	-1.45	0.00
	18	19240	16.51	16.34	15.46	16.51	-0.17	-1.05	0.00
	17	18322	14.42	14.07	14.00	14.42	-0.35	-0.42	0.00
	16	17842	13.97	13.65	13.96	13.97	-0.32	-0.01	0.00
	14	17736	13.53	13.09	13.53	13.53	-0.44	0.00	0.00
	13	15185	9.83	9.54	9.83	9.83	-0.29	0.00	0.00
	12	13764	6.17	6.02	6.17	6.17	-0.15	0.00	0.00
	11	11179	6.44	6.26	6.44	6.44	-0.18	0.00	0.00
	10	9636	6.39	6.21	6.39	6.39	-0.18	0.00	0.00
	9	7039	5.74	5.48	5.74	5.74	-0.26	0.00	0.00
	8	5991	5.27	5.13	5.27	5.27	-0.14	0.00	0.00
	7	4925	4.70	4.57	4.70	4.70	-0.13	0.00	0.00
	6	2266	3.30	3.17	3.30	3.30	-0.13	0.00	0.00
	5	272	2.75	2.68	2.75	2.75	-0.07	0.00	0.00
	4	161	2.58	2.51	2.58	2.58	-0.07	0.00	0.00
	3	106	2.57	2.52	2.57	2.57	-0.05	0.00	0.00
	2	40	1.78	1.78	1.78	1.78	0.00	0.00	0.00
	1	0	1.75	1.69	1.75	1.75	-0.06	0.00	0.00
	0	-50	1.50	1.50	1.50	1.50	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

20 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	20 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	48.29	48.02	47.49	48.29	-0.27	-0.80	0.00
	47	31477	46.28	45.97	45.03	46.28	-0.31	-1.25	0.00
	46	30709	44.23	44.04	43.54	44.23	-0.19	-0.69	0.00
	45	30095	43.09	42.88	42.12	43.09	-0.21	-0.97	0.00
	44	29269	41.32	41.11	40.55	41.32	-0.21	-0.77	0.00
	42	29143	40.78	40.49	39.72	40.78	-0.29	-1.06	0.00
	41	28030	36.61	36.34	35.31	36.61	-0.27	-1.30	0.00
	40	27207	33.06	32.73	31.64	33.06	-0.33	-1.42	0.00
	39	27079	32.85	32.58	31.56	32.85	-0.27	-1.29	0.00
	38	26980	32.47	32.10	31.23	32.47	-0.37	-1.24	0.00
	37	26770	31.96	31.57	30.62	31.96	-0.39	-1.34	0.00
	36	26287	31.48	31.11	29.95	31.48	-0.37	-1.53	0.00
	34	26057	31.18	30.81	29.57	31.18	-0.37	-1.61	0.00
	33	25130	29.90	29.61	28.20	29.90	-0.29	-1.70	0.00
	32	24353	29.25	29.17	27.06	29.25	-0.08	-2.19	0.00
	30	24224	29.11	29.06	26.03	29.11	-0.05	-3.08	0.00
	29	23942	29.09	29.07	25.55	29.09	-0.02	-3.54	0.00
	28	23683	27.81	27.81	24.50	27.81	0.00	-3.31	0.00
	27	23592	26.10	25.78	24.14	26.10	-0.32	-1.96	0.00
	26	22968	23.61	23.31	22.09	23.61	-0.30	-1.52	0.00
	25	22440	22.70	22.28	21.19	22.70	-0.42	-1.51	0.00
	24	21519	22.05	21.68	20.71	22.05	-0.37	-1.34	0.00
	22	21283	21.36	21.16	19.85	21.36	-0.20	-1.51	0.00
	21	20919	21.10	20.97	18.92	21.10	-0.13	-2.18	0.00
	20	20629	20.52	20.21	18.57	20.52	-0.31	-1.95	0.00
	19	20076	19.58	19.45	18.13	19.58	-0.13	-1.45	0.00
	18	19240	17.03	16.60	15.63	17.03	-0.43	-1.40	0.00
	17	18322	14.84	14.50	14.37	14.84	-0.34	-0.47	0.00
	16	17842	14.32	14.09	14.31	14.32	-0.23	-0.01	0.00
	14	17736	13.82	13.51	13.82	13.82	-0.31	0.00	0.00
	13	15185	10.31	9.95	10.31	10.31	-0.36	0.00	0.00
	12	13764	6.40	6.40	6.40	6.40	0.00	0.00	0.00
	11	11179	6.79	6.60	6.79	6.79	-0.19	0.00	0.00
	10	9635	6.74	6.55	6.74	6.74	-0.19	0.00	0.00
	9	7039	5.95	5.64	5.95	5.95	-0.31	0.00	0.00
	8	5891	5.45	5.29	5.45	5.45	-0.16	0.00	0.00
	7	4925	4.83	4.66	4.83	4.83	-0.17	0.00	0.00
	6	2266	3.52	3.39	3.52	3.52	-0.13	0.00	0.00
	5	272	3.05	2.98	3.05	3.05	-0.07	0.00	0.00
	4	181	2.84	2.78	2.84	2.84	-0.06	0.00	0.00
	3	106	2.86	2.81	2.86	2.86	-0.05	0.00	0.00
	2	40	2.20	2.20	2.20	2.20	0.00	0.00	0.00
	1	0	1.91	1.84	1.91	1.91	-0.07	0.00	0.00
	0	-50	1.50	1.50	1.50	1.50	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

50 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	50 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	49.10	48.81	48.19	49.10	-0.29	-0.91	0.00
	47	31477	47.26	46.83	45.90	47.26	-0.43	-1.36	0.00
	46	30709	45.03	44.78	44.16	45.03	-0.25	-0.87	0.00
	45	30095	44.04	43.76	42.88	44.04	-0.28	-1.16	0.00
	44	29269	42.39	42.09	41.51	42.39	-0.30	-0.88	0.00
	42	29143	41.74	41.42	40.52	41.74	-0.32	-1.22	0.00
	41	28030	37.63	37.19	35.87	37.63	-0.44	-1.76	0.00
	40	27207	34.32	33.79	32.50	34.32	-0.53	-1.82	0.00
	39	27079	34.11	33.66	32.42	34.11	-0.45	-1.69	0.00
	38	26980	33.75	33.17	32.02	33.75	-0.58	-1.73	0.00
	37	26770	33.37	32.84	31.54	33.37	-0.53	-1.83	0.00
	36	26287	32.94	32.47	30.95	32.94	-0.47	-1.99	0.00
	34	26057	32.60	32.14	30.51	32.60	-0.46	-2.09	0.00
	33	25130	31.45	31.20	29.11	31.45	-0.25	-2.34	0.00
	32	24353	30.99	30.92	28.03	30.99	-0.07	-2.96	0.00
	30	24224	30.85	30.82	26.77	30.85	-0.03	-4.08	0.00
	29	23942	30.83	30.81	26.38	30.83	-0.02	-4.45	0.00
	28	23683	29.21	29.21	25.11	29.21	0.00	-4.10	0.00
	27	23592	25.62	26.68	24.79	25.62	1.06	-0.83	0.00
	26	22968	24.65	24.21	22.98	24.65	-0.44	-1.67	0.00
	25	22440	23.93	23.62	22.43	23.93	-0.31	-1.50	0.00
	24	21519	23.09	23.38	21.98	23.09	0.29	-1.11	0.00
	22	21263	22.40	22.20	20.73	22.40	-0.20	-1.67	0.00
	21	20919	22.14	21.99	19.54	22.14	-0.15	-2.60	0.00
	20	20629	21.48	21.12	19.51	21.48	-0.36	-1.97	0.00
	19	20076	20.45	20.25	18.94	20.45	-0.20	-1.51	0.00
	18	19240	18.20	17.71	16.21	18.20	-0.49	-1.99	0.00
	17	18322	16.02	15.59	15.41	16.02	-0.43	-0.61	0.00
	16	17842	15.33	15.03	15.31	15.33	-0.30	-0.02	0.00
	14	17736	14.29	14.00	14.29	14.29	-0.29	0.00	0.00
	13	15185	11.25	11.01	11.25	11.25	-0.24	0.00	0.00
	12	13764	7.60	7.60	7.60	7.60	0.00	0.00	0.00
	11	11179	7.41	7.29	7.41	7.41	-0.12	0.00	0.00
	10	9636	7.31	7.19	7.31	7.31	-0.12	0.00	0.00
	9	7039	6.72	6.38	6.72	6.72	-0.34	0.00	0.00
	8	5991	6.07	5.84	6.07	6.07	-0.23	0.00	0.00
	7	4925	4.88	4.55	4.88	4.88	-0.33	0.00	0.00
	6	2266	4.14	4.05	4.14	4.14	-0.09	0.00	0.00
	5	272	3.94	3.89	3.94	3.94	-0.05	0.00	0.00
	4	161	3.55	3.49	3.55	3.55	-0.06	0.00	0.00
	3	106	3.67	3.63	3.67	3.67	-0.04	0.00	0.00
	2	40	2.86	2.86	2.86	2.86	0.00	0.00	0.00
	1	0	2.56	2.49	2.56	2.56	-0.07	0.00	0.00
	0	-50	1.80	1.80	1.80	1.80	0.00	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

100 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	100 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	49.32	49.01	48.39	49.32	-0.31	-0.93	0.00
	47	31477	47.45	47.05	46.11	47.45	-0.40	-1.34	0.00
	46	30709	45.23	44.96	44.33	45.23	-0.27	-0.90	0.00
	45	30095	44.32	44.00	43.10	44.32	-0.32	-1.22	0.00
	44	29269	42.88	42.36	41.77	42.88	-0.52	-1.11	0.00
	42	29143	41.96	41.63	40.72	41.96	-0.33	-1.24	0.00
	41	28030	37.92	37.43	36.03	37.92	-0.49	-1.89	0.00
	40	27207	34.66	34.09	32.73	34.66	-0.57	-1.93	0.00
	39	27079	34.44	33.96	32.65	34.44	-0.48	-1.79	0.00
	38	26980	34.10	33.48	32.24	34.10	-0.62	-1.86	0.00
	37	26770	33.73	33.18	31.80	33.73	-0.55	-1.93	0.00
	36	26287	33.31	32.83	31.21	33.31	-0.48	-2.10	0.00
	34	26057	32.97	32.50	30.76	32.97	-0.47	-2.21	0.00
	33	25130	31.83	31.60	29.36	31.83	-0.23	-2.47	0.00
	32	24353	31.41	31.35	28.32	31.41	-0.06	-3.09	0.00
	30	24224	31.27	31.24	26.94	31.27	-0.03	-4.33	0.00
	29	23942	31.26	31.24	26.61	31.26	-0.02	-4.65	0.00
	28	23683	29.57	29.57	25.27	29.57	0.00	-4.30	0.00
	27	23592	25.80	26.91	24.95	25.80	1.11	-0.85	0.00
	26	22968	24.88	24.40	23.27	24.88	-0.48	-1.61	0.00
	25	22440	24.13	23.76	22.81	24.13	-0.37	-1.32	0.00
	24	21519	23.09	23.47	22.37	23.09	0.38	-0.72	0.00
	22	21283	22.66	22.46	20.94	22.66	-0.20	-1.72	0.00
	21	20919	22.40	22.25	19.80	22.40	-0.15	-2.60	0.00
	20	20629	21.72	21.34	19.74	21.72	-0.38	-1.98	0.00
	19	20076	20.64	20.44	19.15	20.64	-0.20	-1.49	0.00
	18	19240	18.47	17.99	16.37	18.47	-0.48	-2.10	0.00
	17	18322	16.36	15.91	15.72	16.36	-0.45	-0.64	0.00
	16	17842	15.64	15.36	15.61	15.64	-0.28	-0.03	0.00
	14	17736	14.39	14.06	14.39	14.39	-0.33	0.00	0.00
	13	15185	11.52	11.27	11.52	11.52	-0.25	0.00	0.00
	12	13764	7.92	7.92	7.92	7.92	0.00	0.00	0.00
	11	11179	7.58	7.45	7.58	7.58	-0.13	0.00	0.00
	10	9636	7.47	7.34	7.47	7.47	-0.13	0.00	0.00
	9	7039	6.86	6.63	6.86	6.86	-0.23	0.00	0.00
	8	5991	6.20	6.03	6.20	6.20	-0.17	0.00	0.00
	7	4925	5.01	4.69	5.01	5.01	-0.32	0.00	0.00
	6	2266	4.34	4.26	4.34	4.34	-0.08	0.00	0.00
	5	272	4.16	4.11	4.16	4.16	-0.05	0.00	0.00
	4	161	3.69	3.63	3.69	3.69	-0.06	0.00	0.00
	3	106	3.85	3.81	3.85	3.85	-0.04	0.00	0.00
	2	40	3.09	3.08	3.09	3.09	-0.01	0.00	0.00
	1	0	2.63	2.59	2.63	2.63	-0.04	0.00	0.00
	0	-50	2.13	2.11	2.13	2.13	-0.02	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

200 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	200 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	49.85	49.49	48.85	49.85	-0.36	-1.00	0.00
	47	31477	48.01	47.44	46.58	48.01	-0.57	-1.43	0.00
	46	30709	45.49	45.41	44.72	45.49	-0.08	-0.77	0.00
	45	30095	44.76	44.59	43.64	44.76	-0.17	-1.12	0.00
	44	29269	43.80	43.16	42.37	43.80	-0.64	-1.43	0.00
	42	29143	42.66	42.09	41.18	42.66	-0.57	-1.48	0.00
	41	28030	38.00	37.99	36.42	38.00	-0.01	-1.58	0.00
	40	27207	35.39	34.73	33.28	35.39	-0.66	-2.11	0.00
	39	27079	35.20	34.60	33.20	35.20	-0.60	-2.00	0.00
	38	26980	34.84	34.19	32.78	34.84	-0.65	-2.06	0.00
	37	26770	34.48	33.90	32.39	34.48	-0.58	-2.09	0.00
	36	26287	34.05	33.57	31.83	34.05	-0.48	-2.22	0.00
	34	26057	33.67	33.22	31.34	33.67	-0.45	-2.33	0.00
	33	25130	32.49	32.32	29.94	32.49	-0.17	-2.55	0.00
	32	24353	32.21	32.17	28.96	32.21	-0.04	-3.25	0.00
	30	24224	32.17	32.14	27.33	32.17	-0.03	-4.84	0.00
	29	23942	32.15	32.14	27.13	32.15	-0.01	-5.02	0.00
	28	23683	30.35	30.35	25.66	30.35	0.00	-4.69	0.00
	27	23592	26.23	27.59	25.38	26.23	1.36	-0.85	0.00
	26	22968	25.35	24.85	23.92	25.35	-0.50	-1.43	0.00
	25	22440	24.33	24.12	23.55	24.33	-0.21	-0.78	0.00
	24	21519	23.76	23.74	23.09	23.76	-0.02	-0.67	0.00
	22	21283	23.25	23.04	21.47	23.25	-0.21	-1.78	0.00
	21	20919	22.99	22.82	20.36	22.99	-0.17	-2.63	0.00
	20	20629	22.28	21.86	20.25	22.28	-0.42	-2.03	0.00
	19	20076	21.28	20.81	19.59	21.28	-0.47	-1.69	0.00
	18	19240	18.35	18.54	16.79	18.35	0.19	-1.56	0.00
	17	18322	16.82	16.33	15.31	16.82	-0.49	-1.51	0.00
	16	17842	15.98	16.39	15.02	15.98	0.41	-0.96	0.00
	14	17736	14.88	14.80	14.88	14.88	-0.08	0.00	0.00
	13	15185	10.59	10.29	10.59	10.59	-0.30	0.00	0.00
	12	13764	8.58	8.58	8.58	8.58	0.00	0.00	0.00
	11	11179	7.97	7.82	7.97	7.97	-0.15	0.00	0.00
	10	9636	7.84	7.69	7.84	7.84	-0.15	0.00	0.00
	9	7039	7.18	6.94	7.18	7.18	-0.24	0.00	0.00
	8	5991	6.49	6.26	6.49	6.49	-0.23	0.00	0.00
	7	4925	5.34	5.07	5.34	5.34	-0.27	0.00	0.00
	6	2266	4.77	4.70	4.77	4.77	-0.07	0.00	0.00
	5	272	4.60	4.57	4.60	4.60	-0.03	0.00	0.00
	4	161	3.87	3.83	3.87	3.87	-0.04	0.00	0.00
	3	106	4.22	4.21	4.22	4.22	-0.01	0.00	0.00
	2	40	3.48	3.47	3.48	3.48	-0.01	0.00	0.00
	1	0	2.86	2.82	2.86	2.86	-0.04	0.00	0.00
	0	-50	2.30	2.31	2.30	2.30	0.01	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

500 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	500 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	50.60	50.22	49.60	50.60	-0.38	-1.00	0.00
	47	31477	48.71	48.15	47.30	48.71	-0.56	-1.41	0.00
	46	30709	46.02	45.78	45.19	46.02	-0.24	-0.83	0.00
	45	30095	45.31	45.27	44.67	45.31	-0.04	-0.64	0.00
	44	29269	44.11	44.53	44.00	44.11	0.42	-0.11	0.00
	42	29143	43.45	43.00	41.86	43.45	-0.45	-1.59	0.00
	41	28030	38.39	38.18	37.03	38.39	-0.21	-1.36	0.00
	40	27207	36.26	35.80	34.13	36.26	-0.46	-2.13	0.00
	39	27079	36.08	35.64	34.06	36.08	-0.44	-2.02	0.00
	38	26980	35.79	35.23	33.64	35.79	-0.56	-2.15	0.00
	37	26770	35.53	34.93	33.31	35.53	-0.60	-2.22	0.00
	36	26287	35.05	34.61	32.78	35.05	-0.44	-2.27	0.00
	34	26057	34.57	34.20	32.23	34.57	-0.37	-2.34	0.00
	33	25130	33.66	33.54	30.79	33.66	-0.12	-2.87	0.00
	32	24353	33.48	33.45	29.79	33.48	-0.03	-3.69	0.00
	30	24224	33.45	33.43	27.55	33.45	-0.02	-5.90	0.00
	29	23942	33.44	33.43	27.95	33.44	-0.01	-5.49	0.00
	28	23683	31.37	31.37	26.27	31.37	0.00	-5.10	0.00
	27	23592	26.86	28.29	26.12	26.86	1.43	-0.74	0.00
	26	22968	26.35	25.95	24.39	26.35	-0.40	-1.96	0.00
	25	22440	25.81	25.71	23.79	25.81	-0.10	-2.02	0.00
	24	21519	25.50	25.52	23.31	25.50	0.02	-2.19	0.00
	22	21283	23.99	23.85	22.28	23.99	-0.14	-1.71	0.00
	21	20919	23.71	23.63	21.13	23.71	-0.08	-2.58	0.00
	20	20629	23.00	22.58	20.99	23.00	-0.42	-2.01	0.00
	19	20076	21.97	21.76	20.27	21.97	-0.21	-1.70	0.00
	18	19240	18.90	18.41	17.29	18.90	-0.49	-1.61	0.00
	17	18322	17.42	17.39	16.50	17.42	-0.03	-0.92	0.00
	16	17842	17.31	17.33	16.53	17.31	0.02	-0.78	0.00
	14	17736	15.39	15.21	15.39	15.39	-0.18	0.00	0.00
	13	15185	10.99	10.85	10.99	10.99	-0.14	0.00	0.00
	12	13764	9.01	8.85	9.01	9.01	-0.16	0.00	0.00
	11	11179	8.55	8.36	8.55	8.55	-0.19	0.00	0.00
	10	9636	8.39	8.20	8.39	8.39	-0.19	0.00	0.00
	9	7039	7.65	7.38	7.65	7.65	-0.27	0.00	0.00
	8	5991	6.95	6.66	6.95	6.95	-0.29	0.00	0.00
	7	4925	5.94	5.73	5.94	5.94	-0.21	0.00	0.00
	6	2266	5.50	5.46	5.50	5.50	-0.04	0.00	0.00
	5	272	5.36	5.36	5.36	5.36	0.00	0.00	0.00
	4	161	3.84	3.82	3.84	3.84	-0.02	0.00	0.00
	3	106	4.70	4.70	4.70	4.70	0.00	0.00	0.00
	2	40	3.90	3.92	3.90	3.90	0.02	0.00	0.00
	1	0	3.18	3.15	3.18	3.18	-0.03	0.00	0.00
	0	-50	2.55	2.60	2.55	2.55	0.05	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

1000 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	1000 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	51.21	50.86	50.28	51.21	-0.35	-0.93	0.00
	47	31477	49.06	48.56	47.80	49.06	-0.50	-1.26	0.00
	46	33709	46.49	46.20	45.60	46.49	-0.29	-0.89	0.00
	45	30095	45.78	45.61	45.07	45.78	-0.17	-0.71	0.00
	44	29269	44.46	44.35	43.30	44.46	-0.11	-1.16	0.00
	42	29143	43.66	43.09	42.45	43.66	-0.57	-1.21	0.00
	41	28030	38.84	38.88	37.58	38.84	0.04	-1.26	0.00
	40	27207	36.93	36.49	34.90	36.93	-0.44	-2.03	0.00
	39	27079	36.74	36.33	34.92	36.74	-0.41	-1.82	0.00
	38	26980	36.51	36.00	34.41	36.51	-0.51	-2.10	0.00
	37	26770	36.27	35.82	34.12	36.27	-0.45	-2.15	0.00
	36	26287	35.89	35.42	33.63	35.89	-0.47	-2.26	0.00
	34	26057	35.19	34.93	33.03	35.19	-0.26	-2.16	0.00
	33	25130	34.70	34.62	31.61	34.70	-0.08	-3.09	0.00
	32	24353	34.54	34.52	30.77	34.54	-0.02	-3.77	0.00
	30	24224	34.53	34.51	27.81	34.53	-0.02	-6.72	0.00
	29	23942	34.51	34.50	28.70	34.51	-0.01	-5.81	0.00
	28	23683	32.21	32.21	26.85	32.21	0.00	-5.36	0.00
	27	23592	27.35	28.68	26.83	27.35	1.33	-0.52	0.00
	26	22968	27.22	26.88	25.85	27.22	-0.34	-1.37	0.00
	25	22440	26.87	26.81	25.72	26.87	-0.06	-1.15	0.00
	24	21519	26.55	26.60	25.56	26.55	0.05	-0.99	0.00
	22	21283	24.59	24.47	22.95	24.59	-0.12	-1.64	0.00
	21	20919	24.29	24.23	21.80	24.29	-0.06	-2.49	0.00
	20	20629	23.53	23.19	21.61	23.53	-0.34	-1.92	0.00
	19	20076	21.68	22.30	20.81	21.68	0.62	-0.87	0.00
	18	19240	19.25	18.88	17.81	19.25	-0.37	-1.44	0.00
	17	18322	17.69	17.64	17.36	17.69	-0.05	-0.33	0.00
	16	17842	17.53	17.55	17.35	17.53	0.02	-0.18	0.00
	14	17736	15.86	15.70	15.86	15.86	-0.16	0.00	0.00
	13	15185	11.21	11.03	11.21	11.21	-0.18	0.00	0.00
	12	13764	9.54	9.36	9.54	9.54	-0.18	0.00	0.00
	11	11179	9.06	8.84	9.06	9.06	-0.22	0.00	0.00
	10	9636	8.88	8.66	8.88	8.88	-0.22	0.00	0.00
	9	7039	8.11	7.80	8.11	8.11	-0.31	0.00	0.00
	8	5991	7.44	7.14	7.44	7.44	-0.30	0.00	0.00
	7	4925	6.67	6.52	6.67	6.67	-0.15	0.00	0.00
	6	2266	6.36	6.33	6.36	6.36	-0.03	0.00	0.00
	5	272	6.26	6.25	6.26	6.26	-0.01	0.00	0.00
	4	161	4.32	4.32	4.32	4.32	0.00	0.00	0.00
	3	106	4.99	5.01	4.99	4.99	0.02	0.00	0.00
	2	40	4.33	4.35	4.33	4.33	0.02	0.00	0.00
	1	0	3.46	3.44	3.46	3.46	-0.02	0.00	0.00
	0	-50	2.77	2.82	2.77	2.77	0.05	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

5000 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	5000 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	52.40	52.19	51.96	52.40	-0.21	-0.44	0.00
	47	31477	50.28	49.73	49.48	50.28	-0.55	-0.80	0.00
	46	30709	48.01	47.72	47.13	48.01	-0.29	-0.88	0.00
	45	30095	47.29	47.16	46.75	47.29	-0.13	-0.54	0.00
	44	29269	45.62	45.36	45.13	45.62	-0.26	-0.49	0.00
	42	29143	44.73	44.49	43.70	44.73	-0.24	-1.03	0.00
	41	28030	40.48	40.06	39.34	40.48	-0.42	-1.14	0.00
	40	27207	39.07	38.77	37.53	39.07	-0.30	-1.54	0.00
	39	27079	38.90	38.62	37.43	38.90	-0.28	-1.47	0.00
	38	26960	38.81	38.53	37.08	38.81	-0.28	-1.73	0.00
	37	26770	38.65	38.43	37.00	38.65	-0.22	-1.65	0.00
	36	26287	38.38	38.24	36.70	38.38	-0.14	-1.68	0.00
	34	26057	38.15	38.05	35.22	38.15	-0.10	-2.93	0.00
	33	25130	38.00	37.97	33.16	38.00	-0.03	-4.84	0.00
	32	24353	37.92	37.91	32.04	37.92	-0.01	-5.88	0.00
	30	24224	37.91	37.90	31.47	37.91	-0.01	-6.44	0.00
	29	23942	37.90	37.89	31.58	37.90	-0.01	-6.32	0.00
	28	23683	34.88	34.88	28.80	34.88	0.00	-6.08	0.00
	27	23592	28.09	30.64	27.49	28.09	2.55	-0.60	0.00
	26	22968	28.81	28.32	27.77	28.81	-0.49	-1.04	0.00
	25	22440	28.28	28.29	27.82	28.28	0.01	-0.46	0.00
	24	21519	27.73	27.99	27.59	27.73	0.26	-0.14	0.00
	22	21283	26.57	26.53	24.96	26.57	-0.04	-1.61	0.00
	21	20919	26.21	26.23	23.91	26.21	0.02	-2.30	0.00
	20	20629	25.41	25.27	23.52	25.41	-0.14	-1.89	0.00
	19	20076	22.82	22.22	21.42	22.82	-0.60	-1.40	0.00
	18	19240	21.39	21.38	20.89	21.39	-0.01	-0.50	0.00
	17	18322	20.67	20.86	20.54	20.67	0.19	-0.13	0.00
	16	17842	20.59	20.83	20.55	20.59	0.24	-0.04	0.00
	14	17736	17.23	17.13	17.23	17.23	-0.10	0.00	0.00
	13	15185	12.35	11.99	12.35	12.35	-0.36	0.00	0.00
	12	13764	11.55	11.34	11.55	11.55	-0.21	0.00	0.00
	11	11179	11.13	10.91	11.13	11.13	-0.22	0.00	0.00
	10	9636	10.93	10.71	10.93	10.93	-0.22	0.00	0.00
	9	7039	10.28	10.03	10.28	10.28	-0.25	0.00	0.00
	8	5991	9.90	9.73	9.90	9.90	-0.17	0.00	0.00
	7	4925	9.64	9.57	9.64	9.64	-0.07	0.00	0.00
	6	2266	9.51	9.49	9.51	9.51	-0.02	0.00	0.00
	5	272	9.45	9.45	9.45	9.45	0.00	0.00	0.00
	4	161	6.45	6.45	6.45	6.45	0.00	0.00	0.00
	3	106	5.96	6.02	5.96	5.96	0.06	0.00	0.00
	2	40	5.02	5.08	5.02	5.02	0.06	0.00	0.00
	1	0	4.50	4.47	4.50	4.50	-0.03	0.00	0.00
	0	-50	3.51	3.53	3.51	3.51	0.02	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

Anuflood - Swartkops River

10000 Year Flood Level Comparison

Reach	Cross Section Number	Chainage	10000 Year High Flood Level				Flood Level Difference		
			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Scenario 0	Scenario 2 - Scenario 0	Scenario 3 - Scenario 0
Swartkops	48	32253	52.73	52.62	52.58	52.73	-0.11	-0.15	0.00
	47	31477	50.63	50.15	49.62	50.63	-0.48	-1.01	0.00
	46	30709	48.47	48.17	47.62	48.47	-0.30	-0.85	0.00
	45	30095	47.74	47.62	47.24	47.74	-0.12	-0.50	0.00
	44	29269	45.97	45.72	45.54	45.97	-0.25	-0.43	0.00
	42	29143	45.01	44.78	44.22	45.01	-0.23	-0.79	0.00
	41	28030	41.06	40.53	39.65	41.06	-0.53	-1.41	0.00
	40	27207	39.86	39.61	38.15	39.86	-0.25	-1.71	0.00
	39	27079	39.71	39.47	38.05	39.71	-0.24	-1.66	0.00
	38	26980	39.65	39.43	37.71	39.65	-0.22	-1.94	0.00
	37	26770	39.52	39.33	37.67	39.52	-0.19	-1.85	0.00
	36	26287	39.30	39.18	37.38	39.30	-0.12	-1.92	0.00
	34	26057	39.12	39.04	35.89	39.12	-0.08	-3.23	0.00
	33	25130	39.00	38.97	33.65	39.00	-0.03	-5.35	0.00
	32	24353	38.93	38.91	32.68	38.93	-0.02	-6.25	0.00
	30	24224	38.92	38.91	32.51	38.92	-0.01	-6.41	0.00
	29	23942	38.91	38.89	32.54	38.91	-0.02	-6.37	0.00
	28	23683	35.62	35.62	29.45	35.62	0.00	-6.17	0.00
	27	23592	28.29	31.17	29.86	28.29	2.88	1.57	0.00
	26	22968	29.23	28.68	28.01	29.23	-0.55	-1.22	0.00
	25	22440	28.64	28.63	28.12	28.64	-0.01	-0.52	0.00
	24	21519	28.01	28.28	27.84	28.01	0.27	-0.17	0.00
	22	21283	27.14	27.11	25.57	27.14	-0.03	-1.57	0.00
	21	20919	26.75	26.79	24.52	26.75	0.04	-2.23	0.00
	20	20629	25.95	25.86	24.09	25.95	-0.09	-1.86	0.00
	19	20076	23.26	22.59	21.88	23.26	-0.67	-1.38	0.00
	18	19240	21.77	21.74	21.20	21.77	-0.03	-0.57	0.00
	17	18322	20.91	21.12	20.75	20.91	0.21	-0.16	0.00
	16	17842	20.81	21.08	20.77	20.81	0.27	-0.04	0.00
	14	17736	17.57	17.46	17.57	17.57	-0.11	0.00	0.00
	13	15185	12.92	12.53	12.92	12.92	-0.39	0.00	0.00
	12	13764	12.27	12.06	12.27	12.27	-0.21	0.00	0.00
	11	11179	11.89	11.67	11.89	11.89	-0.22	0.00	0.00
	10	9636	11.69	11.48	11.69	11.69	-0.21	0.00	0.00
	9	7039	11.14	10.93	11.14	11.14	-0.21	0.00	0.00
	8	5991	10.84	10.70	10.84	10.84	-0.14	0.00	0.00
	7	4925	10.64	10.58	10.64	10.64	-0.06	0.00	0.00
	6	2266	10.53	10.52	10.53	10.53	-0.01	0.00	0.00
	5	272	10.48	10.48	10.48	10.48	0.00	0.00	0.00
	4	161	7.14	7.14	7.14	7.14	0.00	0.00	0.00
	3	106	6.25	6.34	6.26	6.26	0.08	0.00	0.00
	2	40	5.24	5.29	5.24	5.24	0.05	0.00	0.00
	1	0	4.91	4.91	4.91	4.91	0.00	0.00	0.00
	0	-50	3.58	4.30	3.58	3.58	0.72	0.00	0.00

Note : Scenario 0 - As Is Situation
Scenario 1 - Channel Clearout
Scenario 2 - Channelisation
Scenario 3 - Bunding

APPENDIX C

CAPITAL ESTIMATES

CHATTY RIVER REMEDIAL WORKS COSTING

Cross Section Number	Chainage (m)	Scenario costing (R)		
		"1" Channel clearance	"2" Channelisation	"3" Bunding
67	8518	-	428,568	325,780
66	8374	43,224	118,167	538,461
65	8228	43,803	-	663,037
64	8069	47,778	-	497,723
63	7958	33,450	-	643,313
62	7821	41,013	-	480,898
61	7688	39,939	1,365	9,270
extra	7680	2,316	24,864	-
extra	7640	12,000	3,255	665
60	7639	354	328,713	248,111
59	7534	31,302	128,541	247,635
58	7450	25,359	144,333	186,951
57	7356	28,242	575,253	304,442
56	7243	33,948	867,363	516,073
55	7120	36,849	333,648	177,836
54	7060	17,913	214,179	33,825
53	7024	10,833	388,836	46,191
52	6941	24,900	180,789	37,175
50	6824	35,100	10,773	11,465
48	6792	9,600	32,739	37,019
46	6739	15,900	35,868	70,672
45	6644	28,500	216,006	171,863
43	6414	69,000	269,997	200,185
41	6144	81,000	15,582	63,050
40	6024	36,000	212,457	63,508
38	5942	24,600	878,178	215,213
36	5694	74,400	536,067	205,600
34	5344	105,000	18,333	11,066
32	5314	9,000	96,957	18,615
31	5214	30,000	367,353	54,649
29	5024	57,000	1,000,482	466,368
27	4624	120,000	356,454	301,643
25	4464	48,000	788,928	712,799
24	4074	117,000	416,892	559,882
22	3754	96,000	248,199	775,626
20	3314	132,000	1,207,395	464,557
18	3034	84,000	1,982,148	439,335
17	2714	96,000	551,649	212,213
15	2544	51,000	582,687	227,293
13	2354	57,000	525,777	138,700
12	2224	39,000	1,488,732	463,044
10	1754	141,000	215,628	160,844
8	1599	46,500	82,635	246,993
6	1437	48,600	65,226	115,812
5	1374	18,900	52,626	112,829
3	1289	25,500	822,990	868,213
1	88	360,210	60,711	30,954
0	0	26,490	11,487	-
Total	**8518**	**2,555,523**	**16,888,830**	**12,377,399**

Note: The costs include fees and P&G, but excludes VAT

SWARTKOPS RIVER REMEDIAL WORKS COSTING

Cross Section Number	Chainage (m)	Scenario costing (R)		
		"1" Channel clearance	"2" Channelisation	"3" Bunding
48	32253	-	3,276,672	34,942
47	31477	372,480	2,402,379	188,659
46	30709	368,640	1,942,668	709,915
45	30095	294,720	3,321,528	888,400
44	29269	396,480	539,490	95,203
42	29143	60,480	6,111,987	657,338
41	28030	534,240	6,827,478	-
40	27207	395,040	1,236,963	25,307
39	27079	61,440	873,600	23,253
38	26980	47,520	1,535,457	7,806
37	26770	100,800	2,683,464	-
36	26287	231,840	1,360,989	-
34	26057	110,400	7,380,513	60,529
33	25130	444,960	5,478,690	1,502,229
32	24353	372,960	915,180	484,996
30	24224	61,920	2,616,873	1,475,994
29	23942	135,360	6,222,321	865,692
28	23683	124,320	2,398,200	-
27	23592	43,680	7,097,013	-
26	22968	299,520	3,629,178	376,931
25	22440	253,440	5,419,197	950,352
24	21519	442,080	2,155,377	100,117
22	21283	113,280	2,590,203	329,712
21	20919	174,720	3,640,812	386,891
20	20629	139,200	8,433,327	665,028
19	20076	265,440	6,527,934	558,480
18	19240	401,280	9,245,334	46,833
17	18322	440,640	4,800,222	40,469
16	17842	230,400	436,821	29,843
Total	**14411**	**6,917,280**	**111,099,870**	**10,504,920**

Note: The costs include fees and P&G, but excludes VAT

ANNEXURE 3

FLODSIM MANUAL

ACKNOWLEDGEMENT

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INTRODUCTION

The primary aim with the development of FLODSIM (Flood damage simulation model) is the establishment of software for optimal floodplain management and integrated catchment management. Secondly, it is also a decision support tool for developing control in floodplains. If the mean annual damage, that has been impossible to estimate thus far is known, the benefits of various different combinations of flood damage measures can be analysed more readily. It facilitates and enhances the execution of benefit-cost analysis with an optimal flood mitigation measure package.

To give execution to the above-mentioned, potential flood damages must first be estimated. In this regard detailed topographical, hydrological and economic data of the area under investigation are required. An important requirement for FLODSIM to determine potential flood damage, is the development of loss functions.

FLODSIM is thus used by all persons involved in disaster management, floodplain management, integrated catchment management and planning institutions or firms involved in development control who will have access to a workstation. Because of the huge spatial data involved in FLODSIM it is not possible to run FLODSIM on a personal computer. The scope of FLODSIM's field of application is wide and the program can be used for policy analysis on a national, provincial and local level; i.e. to evaluate improvement of existing structural measures, compare the benefits of new structural and non-structural flood mitigation options and to support urban and regional planners to formulate development control policy.

The program has been developed to be as flexible as possible. Once FLODSIM is installed and set-up for a specific area of investigation it is user-friendly, mainly because the operator can run various scenarios by only pressing a button. It also becomes possible to manipulate the land use pattern and levees by hypothetical developing new levees, delete existing levees or even increase or decrease levee heights. The impact of this kind of scenario up stream and down stream can be determined/investigated to help authorities to optimal plan floodplains.

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INTRODUCTION

1.1 BACKGROUND

The Flood Damage Simulation Model (FLODSIM) estimates flood damage in a floodplain and can be used to evaluate flood damage mitigation measures. The model is of great value in floodplain management studies and can be applied to agricultural- and/or urban areas. Detailed topographic data of the area on which it is applied, are however required by the model. These data include an altitude grid (DTM), levee coverage, and at least one coverage representing land use. Other data such as a contour coverage and spot height coverage are optional.

Flood damage control measures are aimed at the minimisation of the physical extent of floods, to lighten the influence of floods on the community and to lower the probability of flood damage in different areas. Flood damage control measures can be grouped into structural and non-structural measures. Structural measures are implemented to change the physical nature and extent of floods. The volume of water running down, the flood peak, the form of the flood hydrograph, the extent of the area inundated and the speed and height of the water can for example be affected by these measures. Structural measures mainly include engineering works such as drainage networks, levees, dams and spillways. Examples of non-structural measures are effective warning systems, evacuation plans, flood awareness programs, insurance and training.

The benefits of different combinations of flood damage control measures can be determined by comparing the mean annual flood damage of the different combinations.

FLODSIM provides for three land use categories namely area-, linear- and location categories. An example of a land use type where the area is important, is cultivated fields. The damage to a field is calculated per hectare and then multiplied with the area of the field to determine the damage to the entire field. The linear category includes infrastructures such as roads, power lines, tramlines, drainage systems, etc. The damage to these structures is calculated per meter and then multiplied with the length. Residential-, commercial- and industrial structures belong to the location category. These structures are classified according to size and content and the same loss function is used for structures of the same class.

The terms cultivated fields, infrastructure and buildings are more readily understood than area-, linear- and location categories. The abovementioned terms are therefore used in the model to describe the three categories. The user should, however, be aware of the fact that the model can also be applied to other fields for example environmental studies, as long as loss functions are available. Note that the damage to cultivated fields are divided into harvest-, crop- and soil damage in FLODSIM.

1. According to Smith *et al.* (1981:19) a loss function defines the relationship between flood damage and certain flood characteristics such as depth of inundation, duration of inundation, area inundated, momentum flux and silt content of floodwaters for a specific damage category. These relationships can be expressed algebraically, graphically or in tabular form. Loss functions for several land use types are included in the model and additional loss functions can be added (developed by specialists) when necessary.

   Hydraulic and hydrologic information are calculated outside FLODSIM. Water surface profiles can be read from a file into FLODSIM while flood return periods are typed in manually. Topographic information, required by numerical flood models[1] T o calculate hydraulic information, can be exported from FLODSIM.

2. Normally a team consisting of hydrologists, hydraulic experts, agricultural economists, civil engineers, sociologists, geographers, urban and regional planners would work together to set up an floodplain management plan. The hydrologist would determine the flood hydrographs and flood probabilities of different floods while the hydraulic expert would do the simulations on numerical flood models to

[1] Also known as backwater packages

provide flood heights and flood velocities. Economists would develop the loss functions for different land use types and provide economic data like enterprise budgets, shadow prices, multipliers and employment figures. Civil engineers would suggest the different structural flood damage control measures that can be used and they might also determine the risks associated with these structures. Sociologists, geographers and urban and regional planners would inter alia be concerned with non-structural flood damage control measures and to test the acceptability by the community. It is the responsibility of the agricultural economist to integrate the above-mentioned data to formulate an holistic sustainable flood management plans for the area under investigation.

Chapter 2

INSTALLATION

The purpose of this chapter is to describe the installation of FLODSIM.

2.1 HARDWARE AND SOFTWARE REQUIREMENTS

The following items are required by FLODSIM:

- SUN Ultra 5 Workstation or better
- Minimum 64 Mbytes of available Random Access Memory (RAM)
- Minimum 4 Gbytes available hard disk space
- Solaris 2.6 or higher
- ARC/INFO version 7.1.1 or higher
- GRID version 7.1.1 or higher
- TIN version 7.1.1 or higher

2.2 DATA REQUIREMENTS

FLODSIM requires at least an altitute grid (DTM) and the land use coverage presenting the land use pattern in the area under investigation before FLODSIM can be installed. Only items that are required from the user will be listed for each coverage. The different item names are only suggestions and the user might want to choose his own item names.

2.2.1 Coverages and grids

The different coverages that can be included in the model will be described in this section. Attention must be given to some detail requirements of each coverage to ensure probable functioning of FLODSIM.

2.2.1.1 Altitude grid

The altitude grid plays a mayor role when the depth of inundation is calculated and FLODSIM can therefore not function without it. The altitude grid is usually constructed from contour lines and spot heights by using the 'topogrid' command in ARC/INFO. For flood damage assessment, 1 m contour lines are needed to create a altitude grid of at least 1 m accuracy. Other sources used to derive elevation data vary from ground surveys and photogrammetry to radar or laser altimetry. The different sources vary in cost, production time and quality of the product and these characteristics should be considered when the data source is chosen. For more information to create an altitude grid see ???

2.2.1.2 Levee coverage

The levee coverage represents existing levees in the area under investigation. The coverage will be duplicated by FLODSIM in order to have a coverage that can be edited to represent different flood mitigation measures that will be investigated hypothetically. In the absence of an original levee coverage an empty coverage will be created for the different flood mitigation measures. The levee coverage should have items for the average height and material of the structures (see Table 2.1). The height of the structures will have to be taken into account and should be measured from the ground in metres. It must be borne in mind not to allocate the elevation of the levee to this item.

Table 2.1 Items that should be added to the levee coverage

Item name	Width	Output	Type	N.dec
Height	4	4	F	2
Material	5	5	C	-

2.2.1.3 Contour and spot height coverages

Once the altitude is created by using contour lines and spot heights, the contour and spot height coverages are only used for display purposes in FLODSIM and are optional. Both coverages should contain an item representing the elevation (see Table 2.2 and Table 2.3). The elevation should be given in metres.

Table 2.2 Items that should be added to the spot height coverage

Item name	Width	Output	Type	N.dec
Elevation	6	6	N	2

Table 2.3 Items that should be added to the contour coverage

Item name	Width	Output	Type
Elevation	4	5	B

2.2.1.4 River coverage

As with the contour and spot height coverages, the river coverage is only used for display purposes in FLODSIM and is also optional. If the river coverage represents the centre of the river it can be used in the streams option with the 'topogrid' command. This will improve the drainage enforcement procedure with the result of a better altitude grid.

2.2.1.5 Cultivated fields coverage

This coverage usually contains cultivated fields, but any risk type that depends on the area may be included into this coverage. The coverage should have a symbol field that will represent the different crop types (see Table 2.4). The two letters that are used to distinguish between the different crop types are also used in the naming convention for the AML files that contain the programs for the different loss functions.

Table 2.4 Items that should be added to the cultivated fields coverage

Item name	Width	Output	Type
Crop_symbol	2	2	C

2.2.1.6 Infrastructure coverage

This coverage contains infrastructures such as roads, power lines, tramlines, drainage systems, etc. The coverage should have a symbol field that will represent the different infrastructure types (see Table 2.5). The two letters that are used to distinguish between the different infrastructures are also used in the naming convention for the AML files that contain the programs for the different loss functions.

Table 2.5 Items that should be added to the infrastructure coverage

Item name	Width	Output	Type
Infra_symbol	2	2	C

2.2.1.7 Building coverage

Residential-, commercial- and industrial structures can be included in the building coverage. Unlike cultivated fields and infrastructure a class number is used to distinguish between the different building classes. The class numbers should follow chronologically on each other, starting from one. Damage to these structures usually only depends on depth of inundation and the same program is therefore used for all the classes. It is important to note that the user cannot add his own programs as in the case of cultivated fields or infrastructure.

The coverage should have items for the damage class, indicating if the structure is raised and the height raised (see Table 2.6). The item indicating whether the structure is raised or not should contain a '1' when it is raised and a '0' otherwise. The height that the structure is raised should be given in metres.

Table 2.6 Items that should be added to the building coverage

Item name	Width	Output	Type	N.dec
Dam_class	3	3	I	-
Raised	2	2	I	-
Ht_raised	5	5	N	2

2.3 INSTALLING FLODSIM ON A WORK STATION

A program called 'Setup' is used to prepare FLODSIM for the study area on which it is to be applied. An example of the graphical user interface will be given in this paragraph but the user should note that it might differ for each individual area. The setup program will automatically adapt the menus according to the situation in the study area.

2.3.1 Copy the files from the CD to a hard disk

Copy all the files in the directory called 'system' from the CD to the hard disk. Make sure that the data files described in Paragraph 2.2 are all in the same directory.

2.3.2 Start the set-up program

Change the directory to …/system/setup
Start ARC/INFO
Run the *set-up* AML

Example:

unix_prompt> *cd /system/setup*

unix_prompt> *arc*

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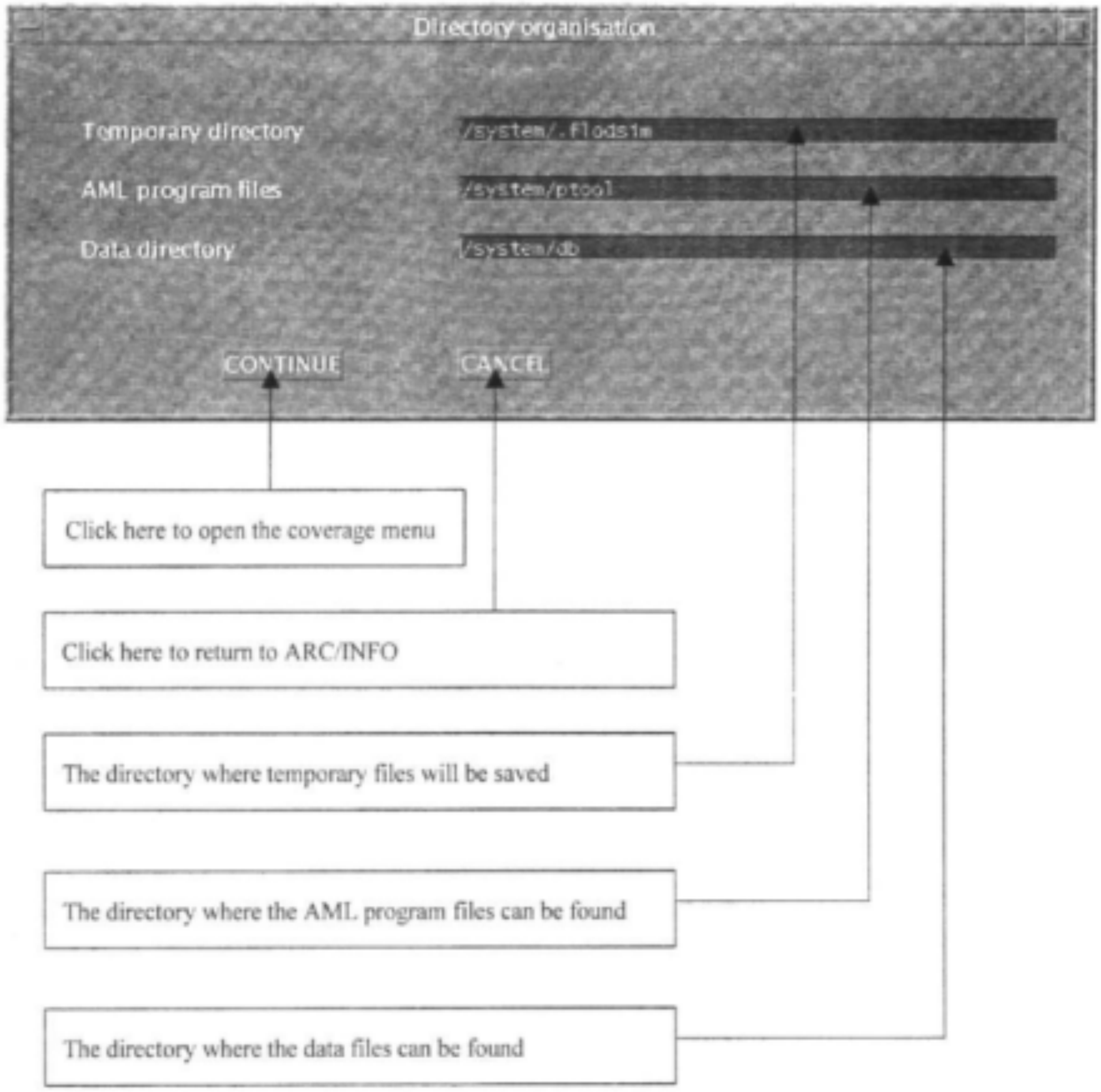
ARC Version 7.1.1 (Thu Feb 6 23:26:50 PST 1997)

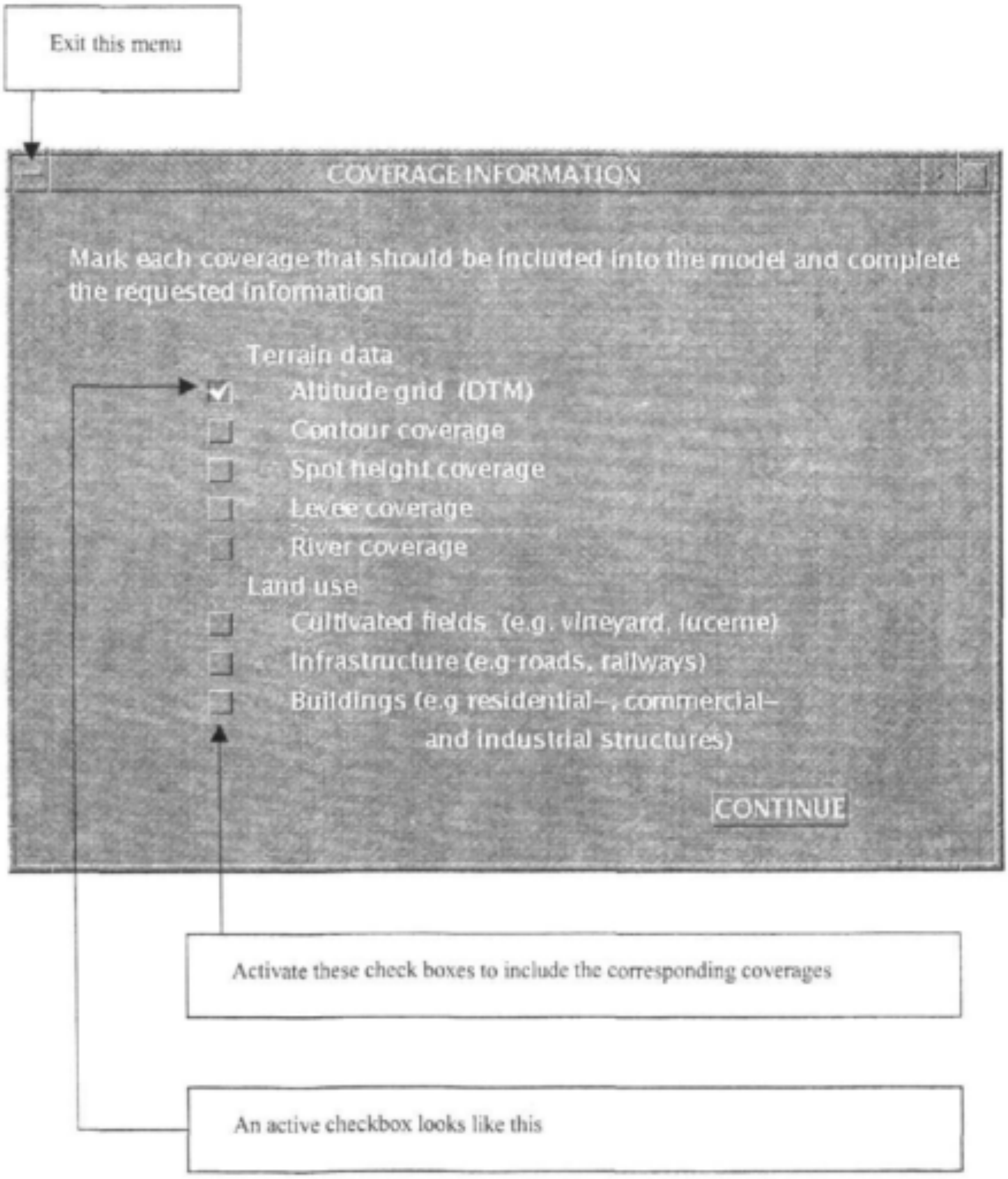
Arc: *&r setup*

The following menu will now be displayed:

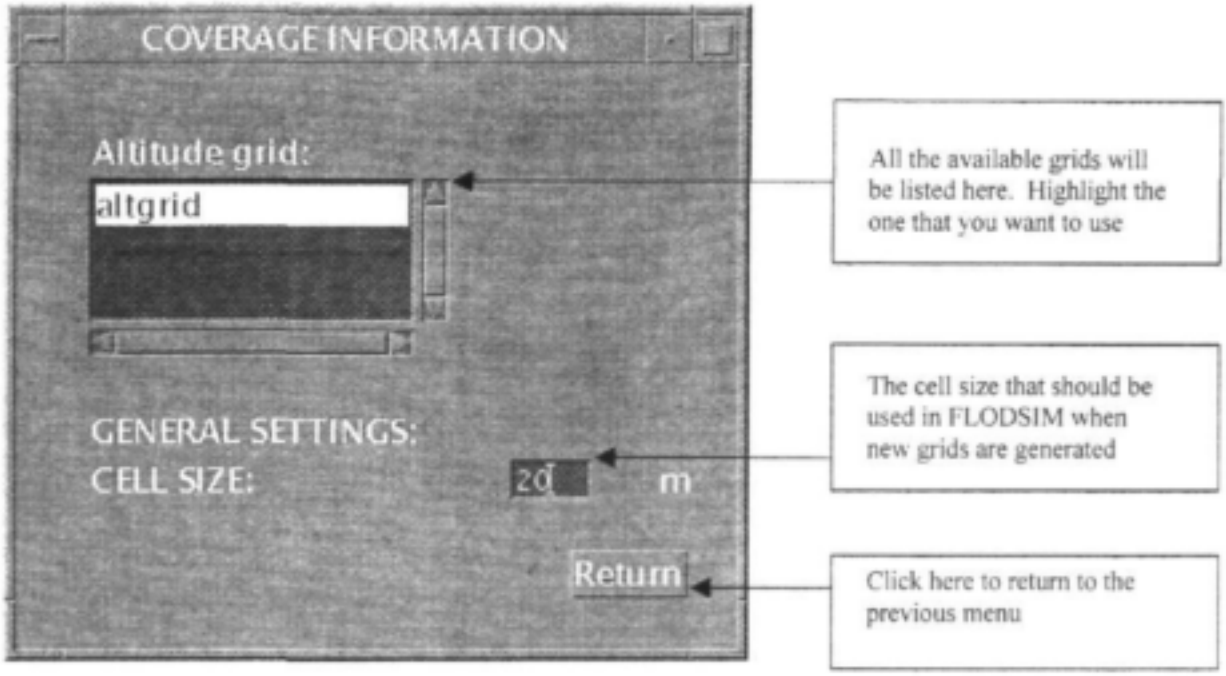


2.3.2.1 The coverage information menu

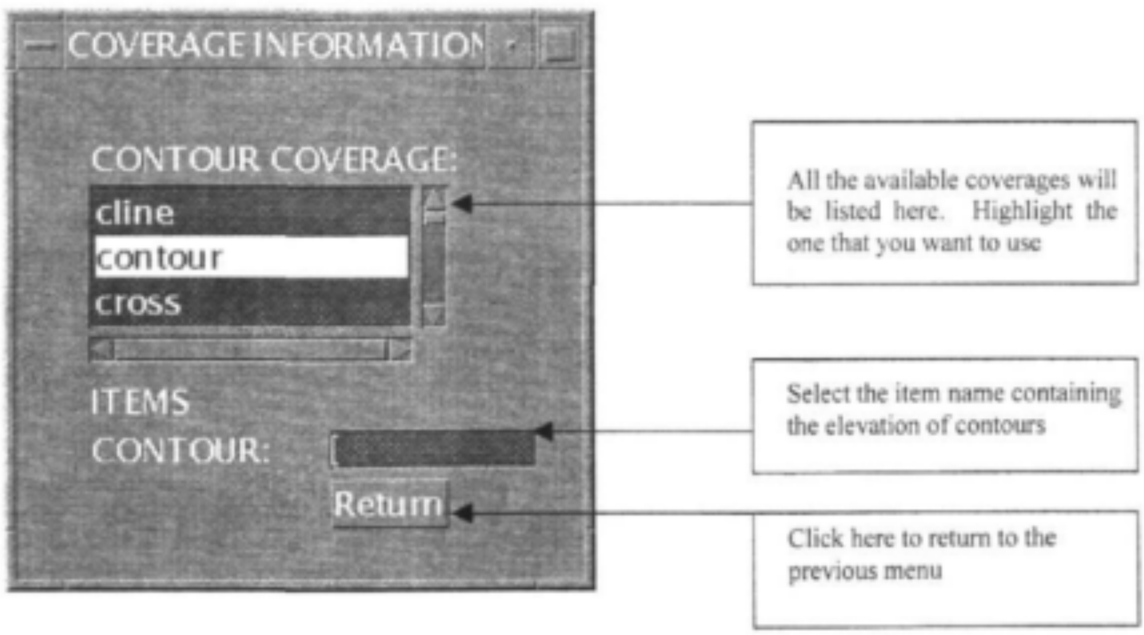
This menu gives the user the opportunity to indicate the coverages that should be included in the model. There is a checkbox next to each coverage that can be activated when it should be included into the model. When the checkbox is activated a menu will appear that will prompt the user to give more detail of the coverage.



2.3.2.1.1 Information menu for the altitude grid

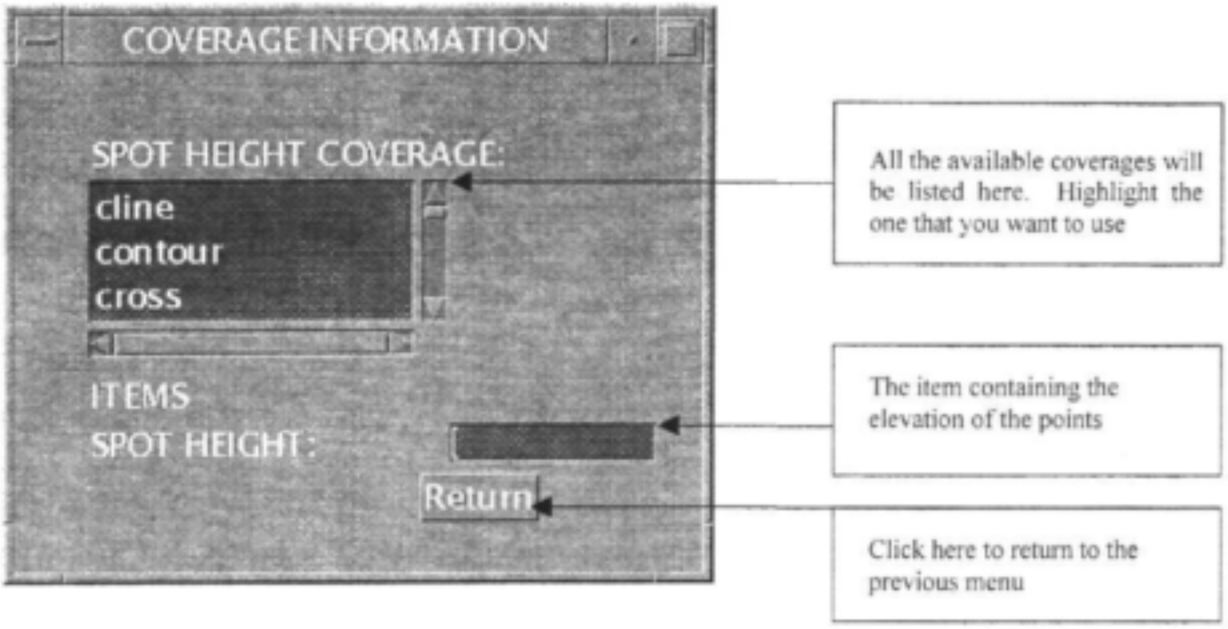


2.3.2.1.2 Information menu for the contour coverage

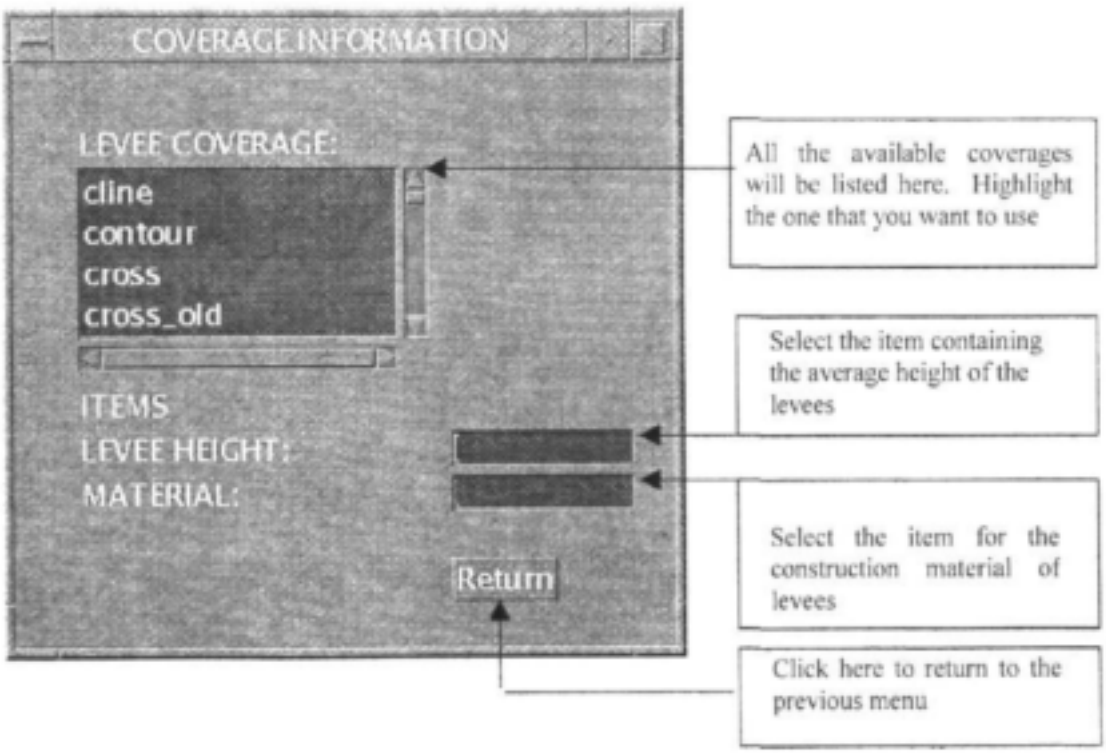


Note that items will only be accepted if it exists in the highlighted coverage. This will also apply to the following coverages.

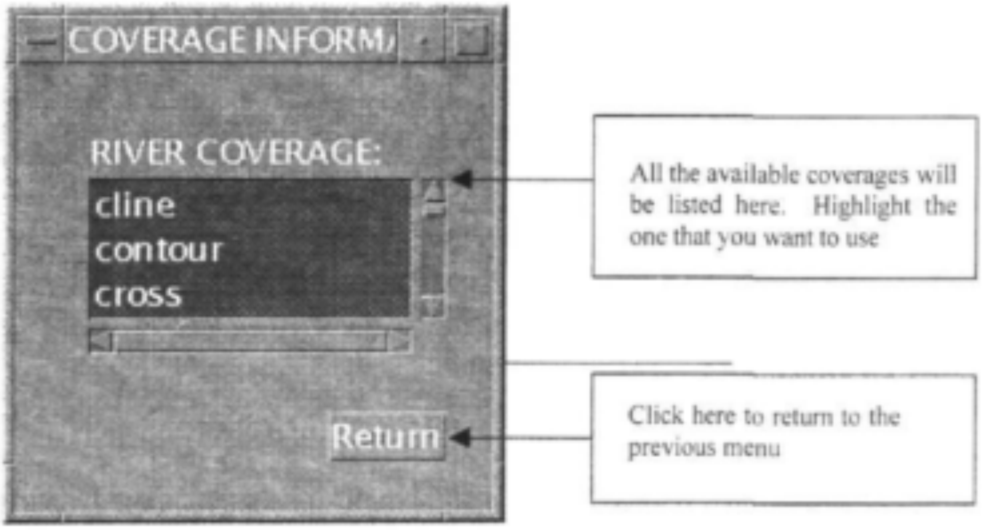
2.3.2.1.3 Information menu for the spot height coverage



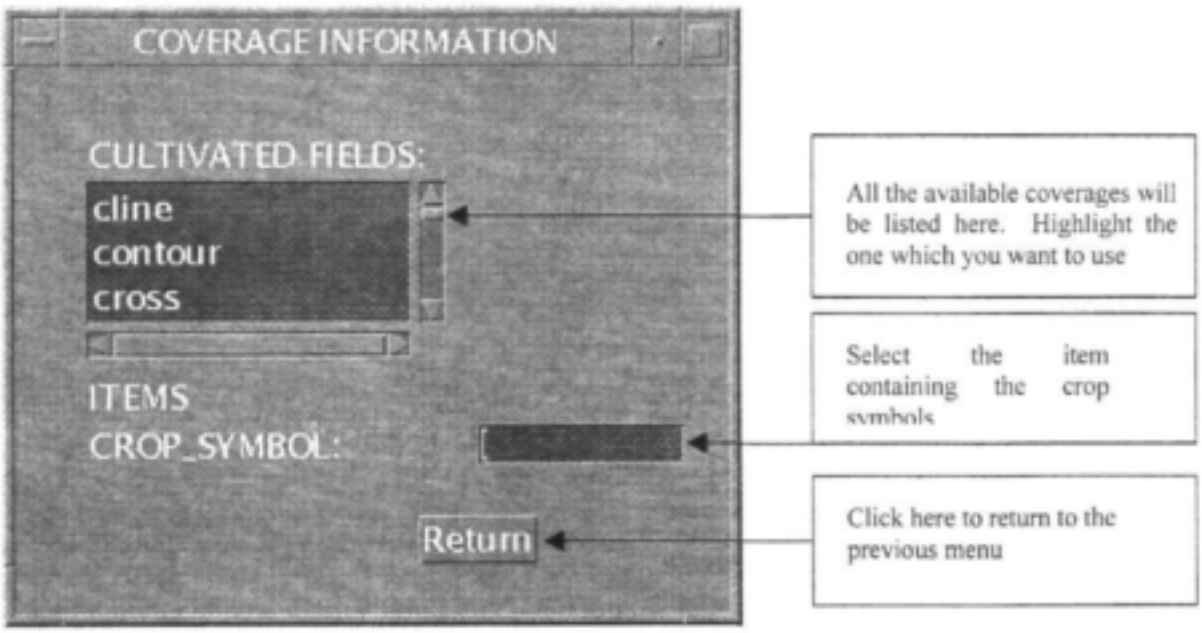
2.3.2.1.4 Information menu for the levee coverage



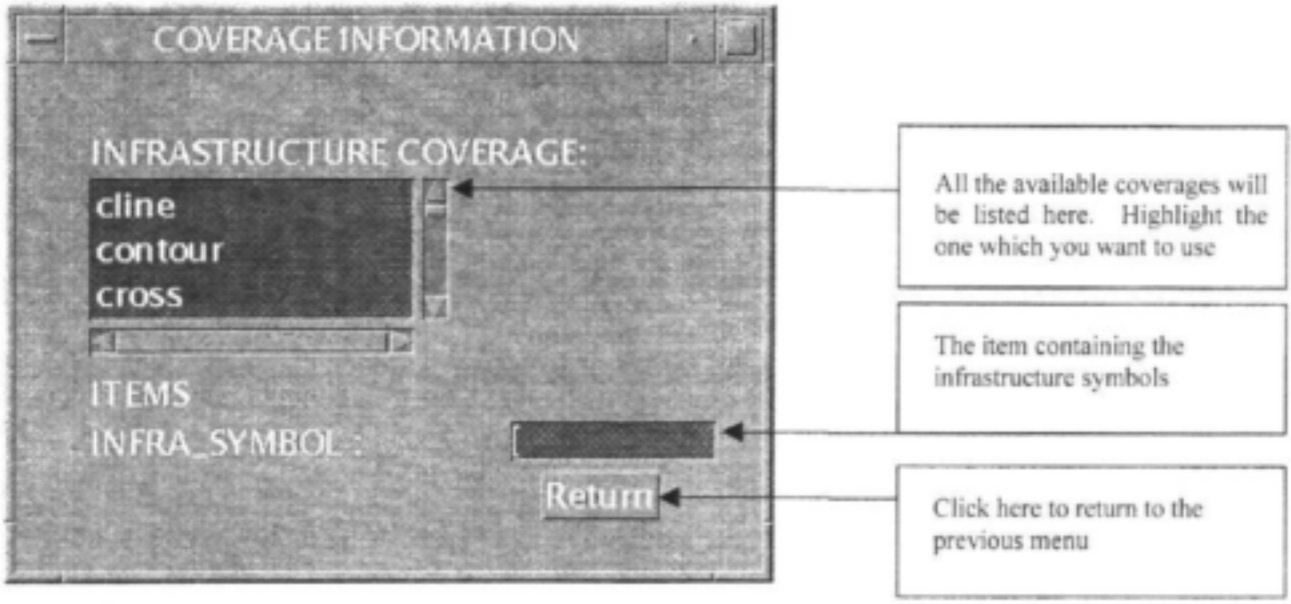
2.3.2.1.5 Information menu for the river coverage



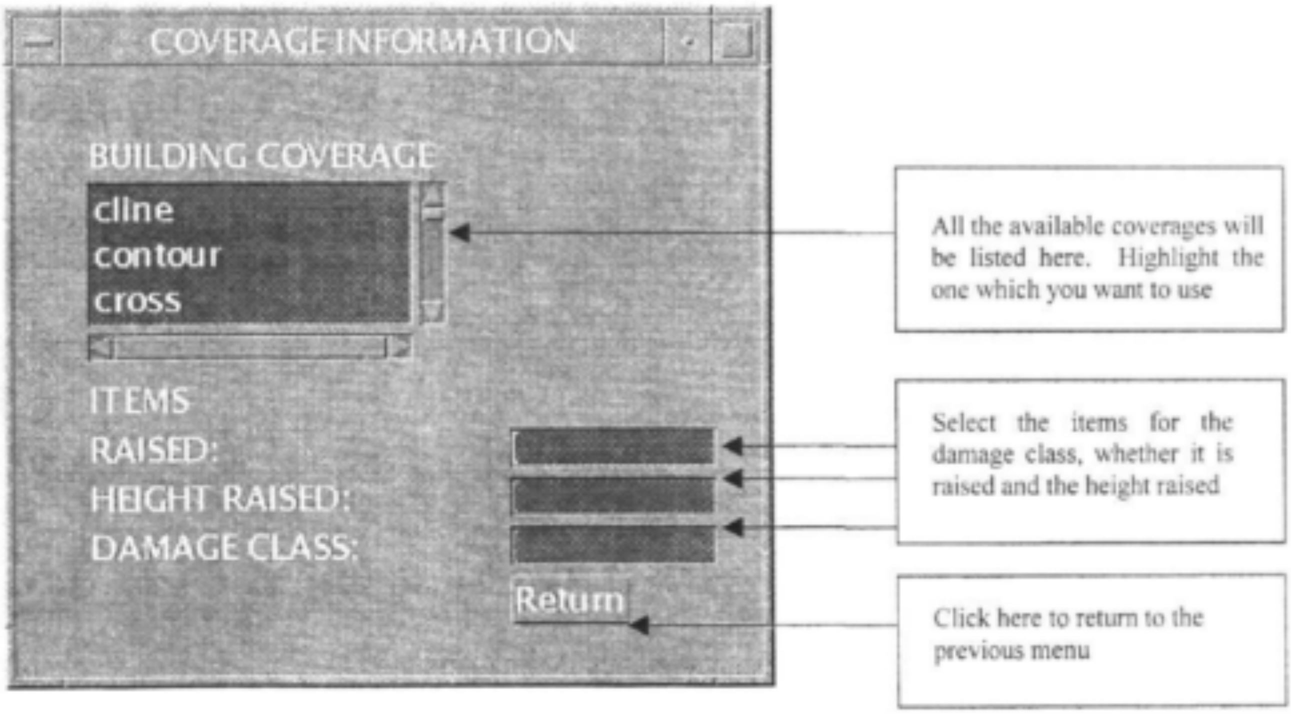
2.3.2.1.6 Information menu for the cultivated fields coverage



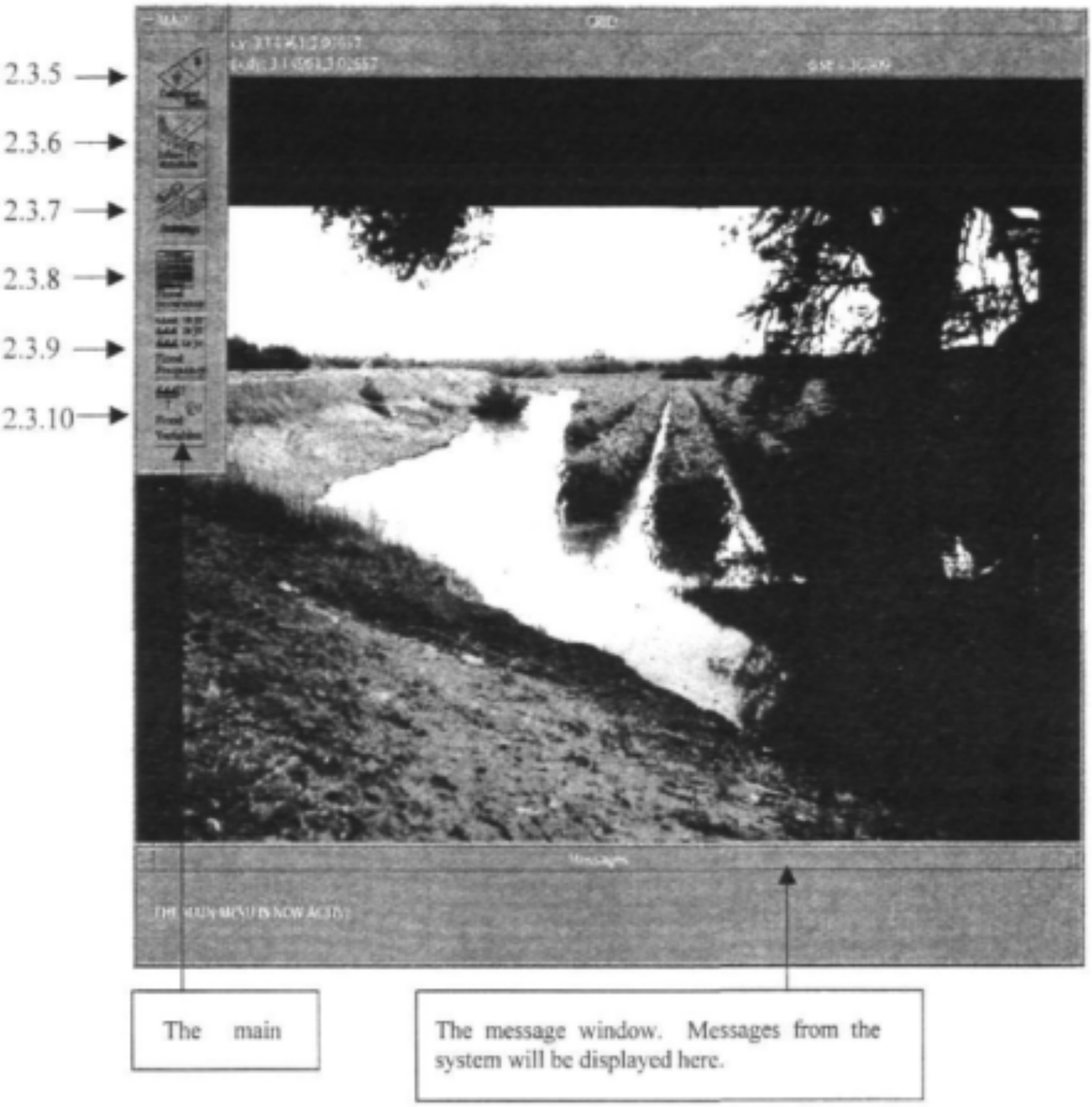
2.3.2.1.7 Information menu for the infrastructure coverage



2.3.2.1.8 Information menu for the building coverage

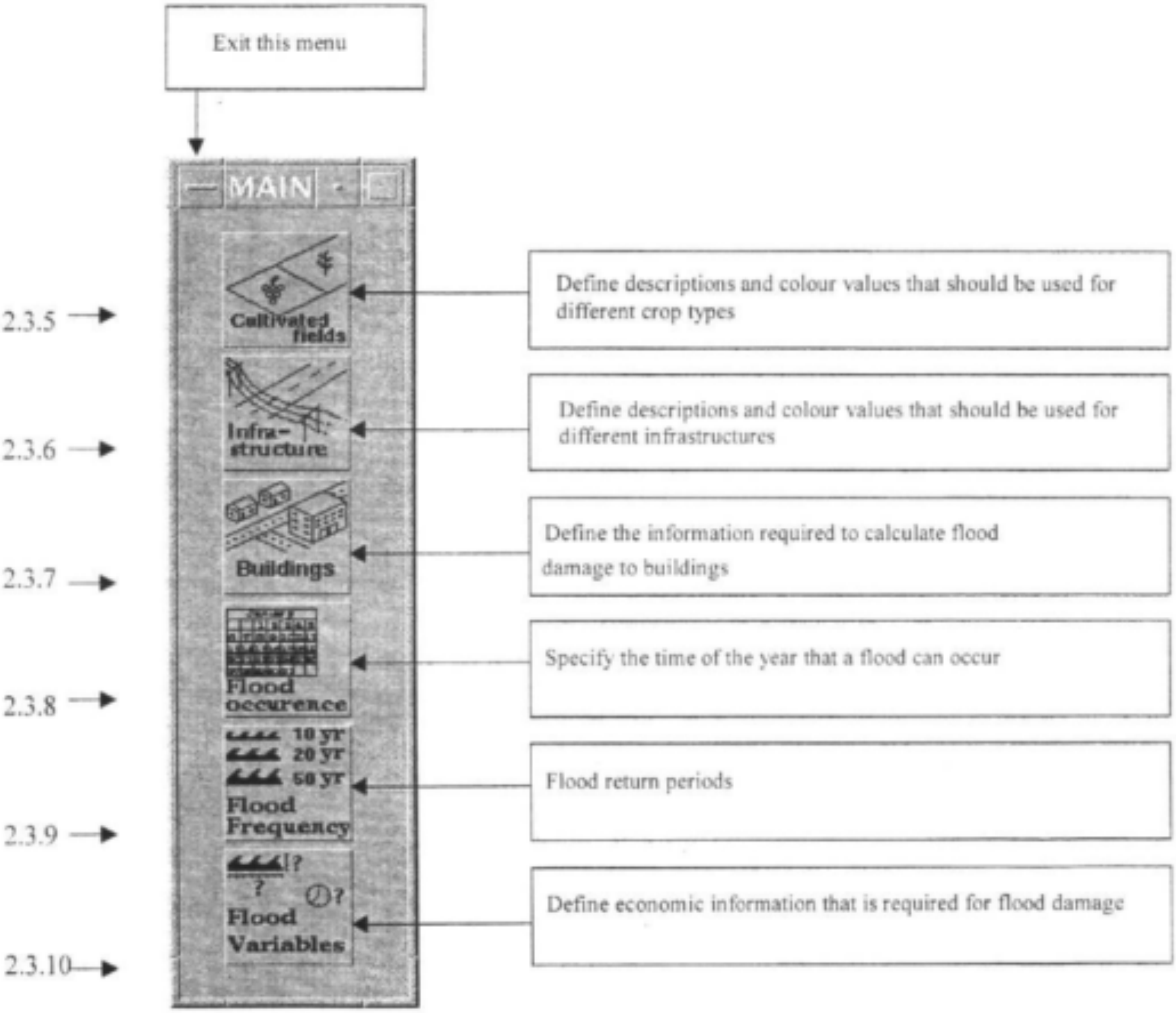


2.3.3 The screen layout (Press continue (see p2-7) to see this menu)



2.3.4 The main menu

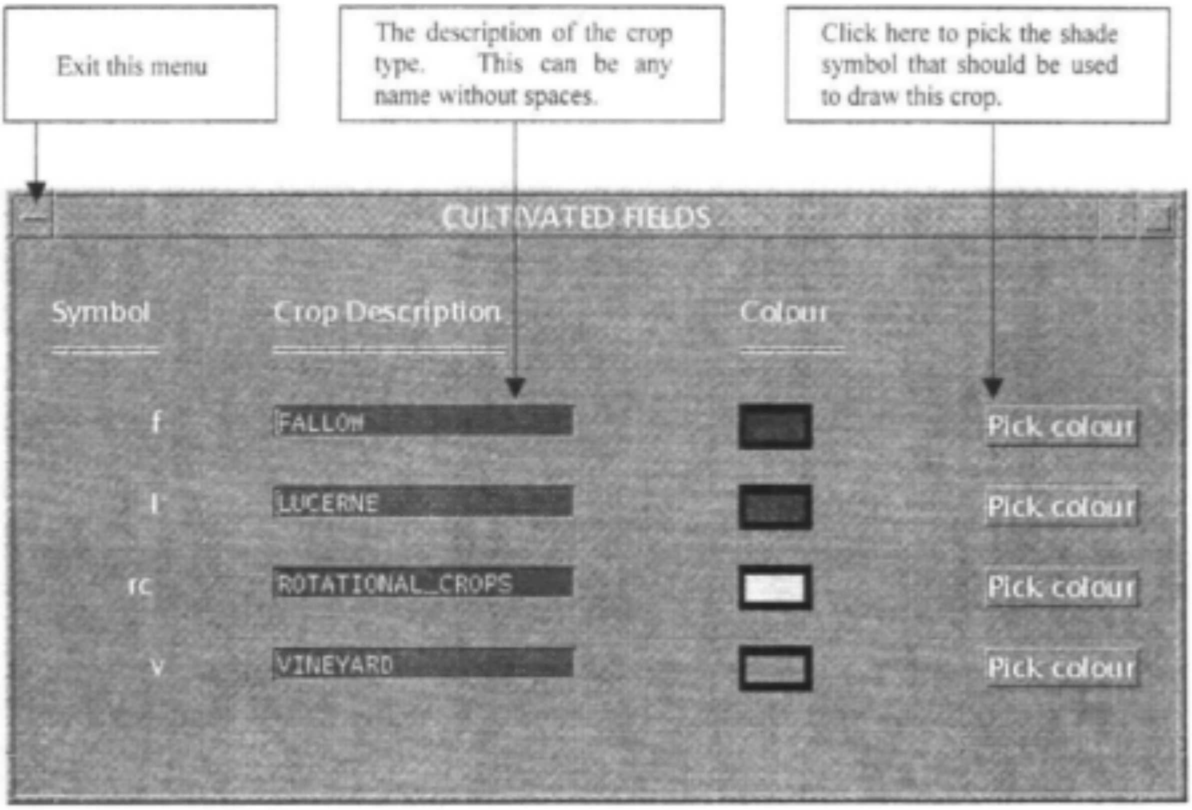
The main menu of FLODSIM consists of at least six components, depending on the coverages that have to be defined during installation. Options that were not marked in the previous menu will not be shown on the main menu.



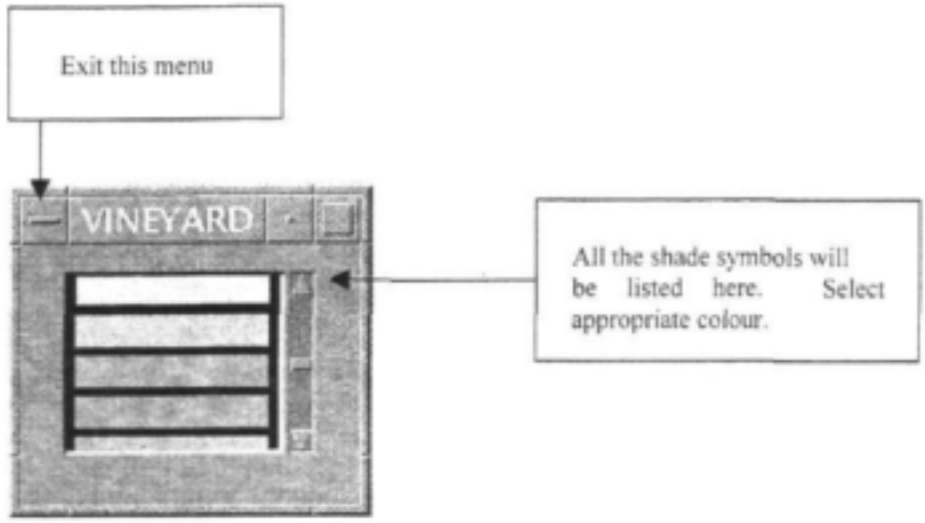
2.3.5 The cultivated fields menu

Click the cultivated fields icon in the main menu to display the cultivated fields menu. It is possible to define the crop description and colours of the land use pattern for each symbol that was automatically detected by the system.

During the set-up/installation phase, various symbols and colours can be detected.

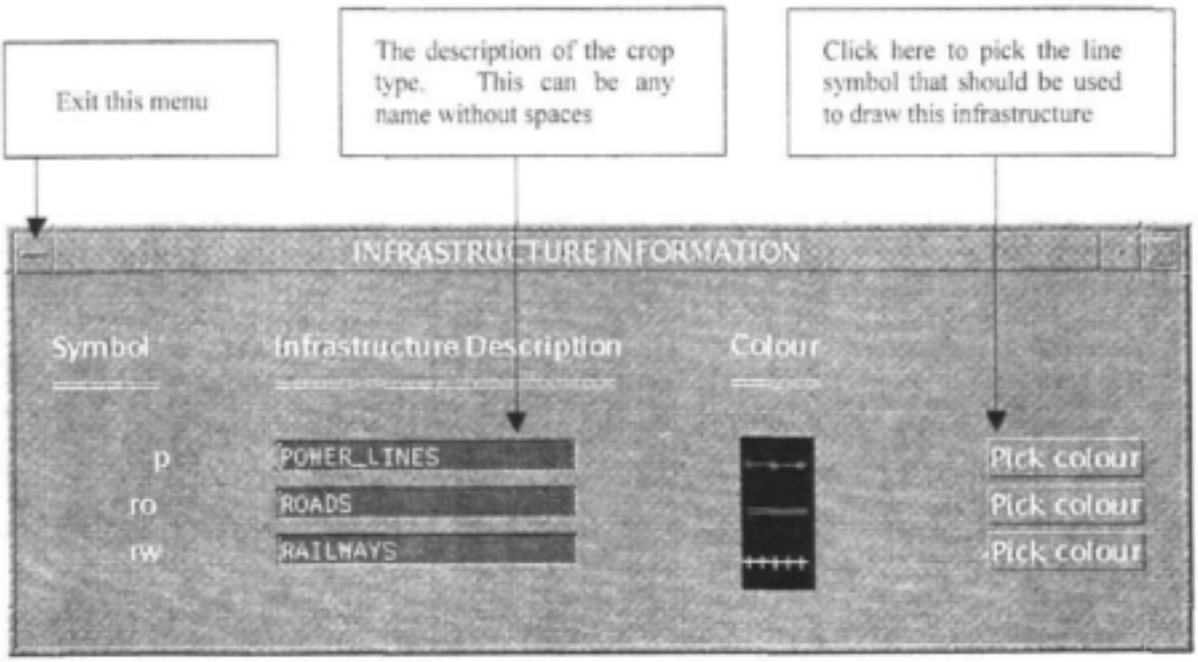


The shade symbol menu will appear when you click the "pick colour" button.

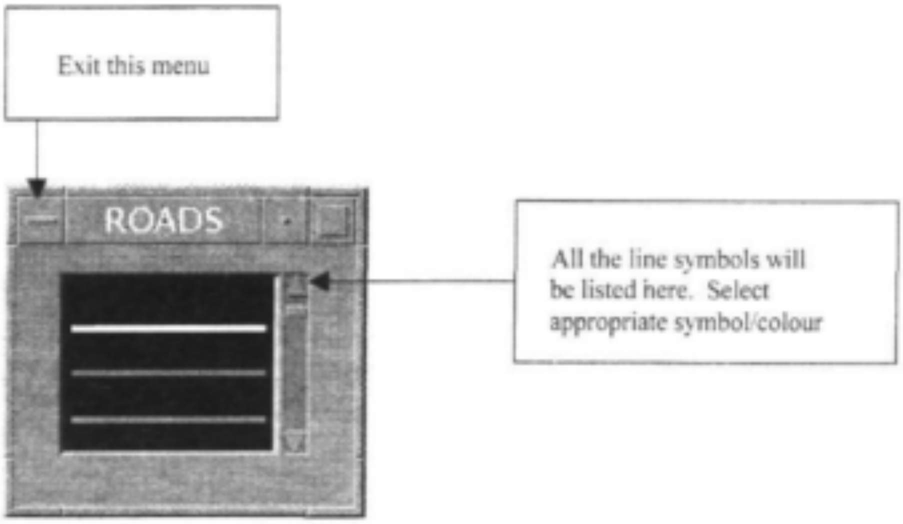


2.3.6 The infrastructure menu

The description and colours can be defined for each symbol with the infrastructure menu.

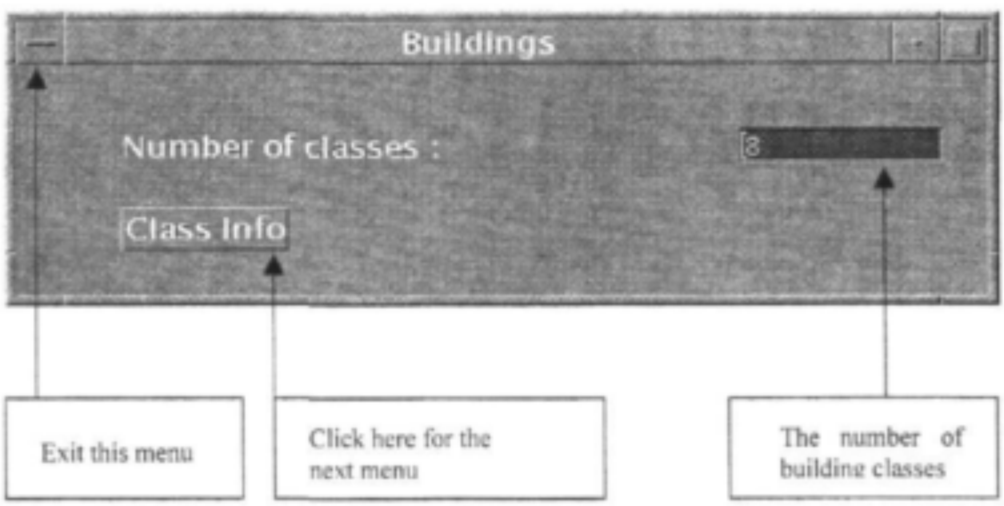


The line symbol menu will appear when you click the "pick colour" button.

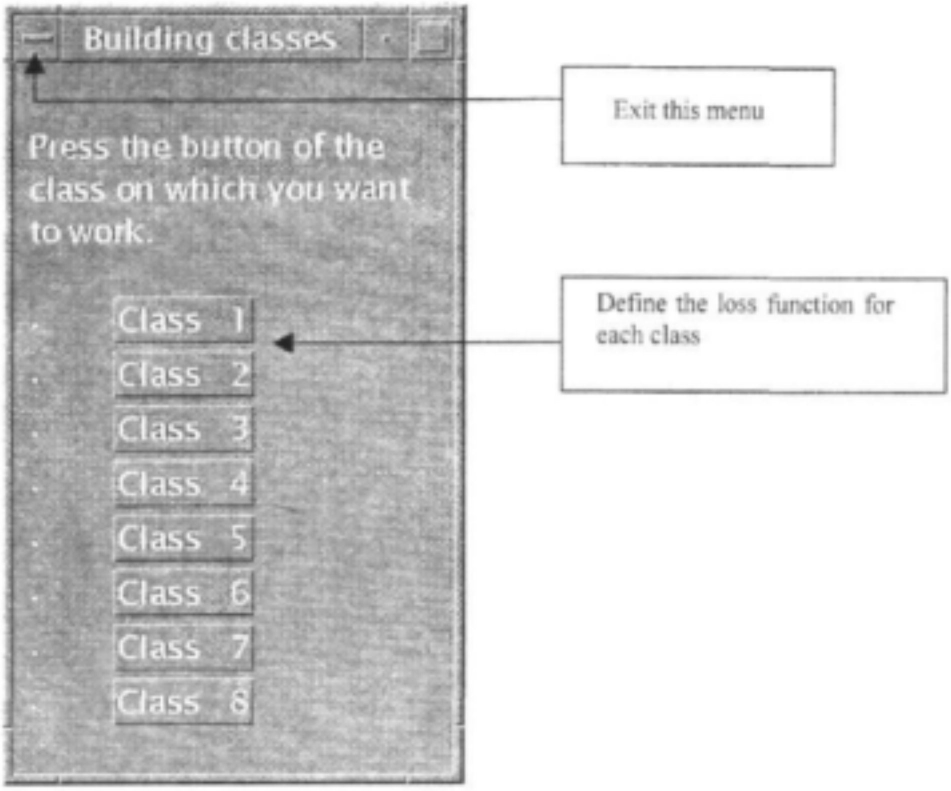


2.3.7 The buildings menu

The building menu enables the user to define loss functions for the different building classes. Building classes refer to a small or large house, depending on the classification used to develop the loss functions. The first menu prompts the user to give the number of classes that should be used and automatically adapts the sub-menus according to the number that is specify.

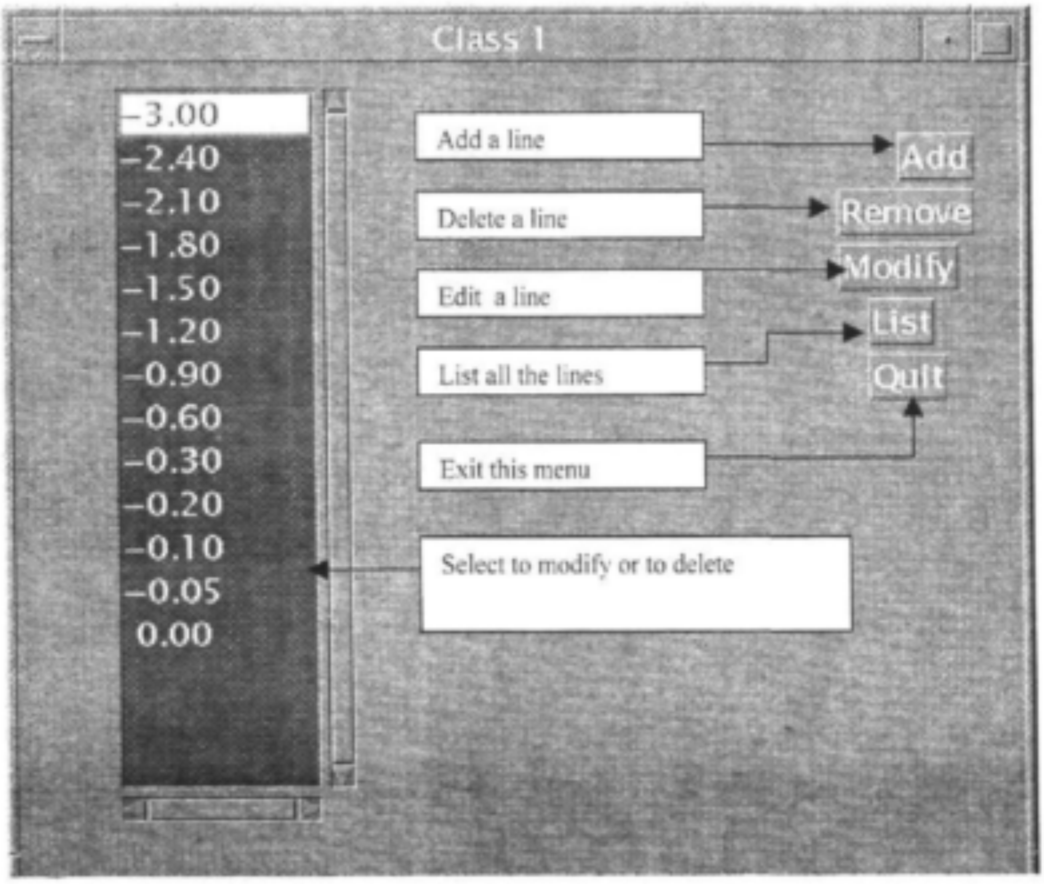


2.3.7.1 The class info menu

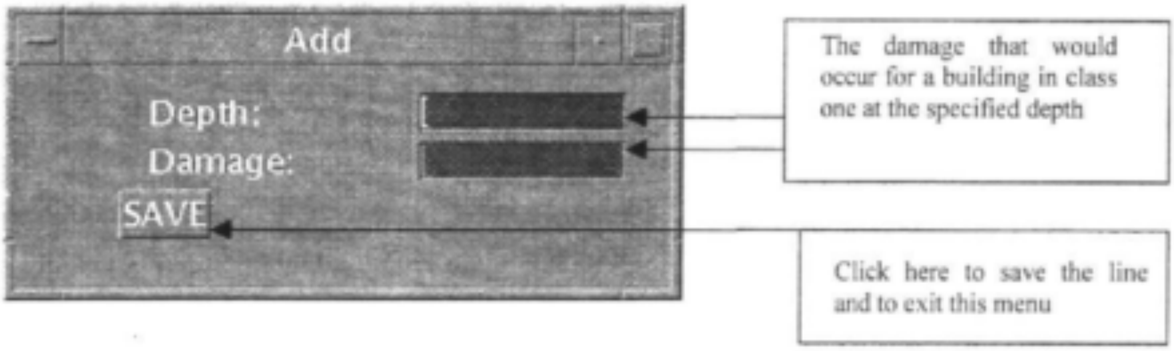


2.3.7.1.1 The menu for class 1 as example

This menu enables the user to define the potential flood damage at a specific depth.



Add button:

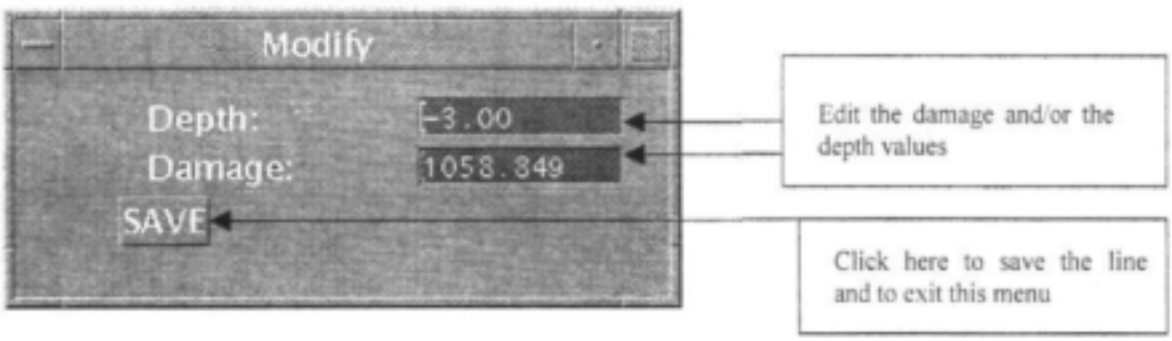


➢ ***Note that the inundation depth should be indicated with a negative number.***

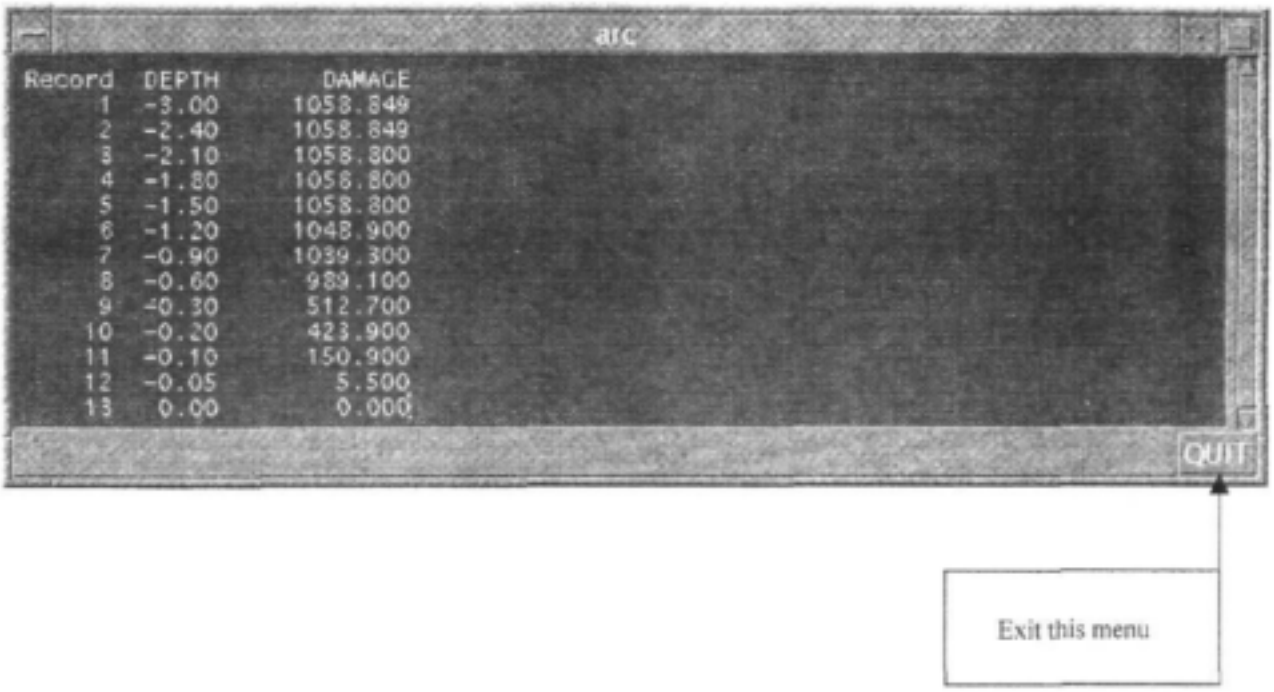
Remove button:

When you click on the Remove button the selected line will be removed

Modify button:



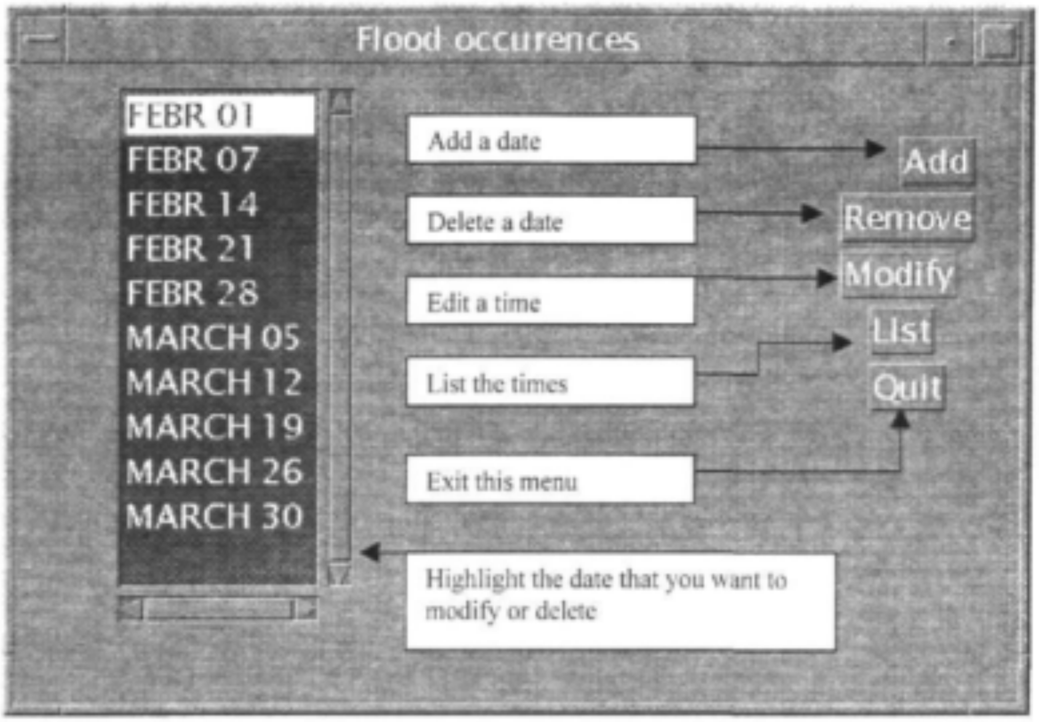
List button: The following loss function information will be visible to the user when the List button is selected



2.3.8 The flood occurrence menu

Depending on the area under investigation floods occur at various times during a year. The index of occurrence is determined by the land use type and its vulnerability to floods. The time of the year that a flood occurs is important as it has an influence on the potential flood damage. This information forms an important part of loss functions for the land use types in irrigation areas and will normally be defined by an agricultural economics specialist.

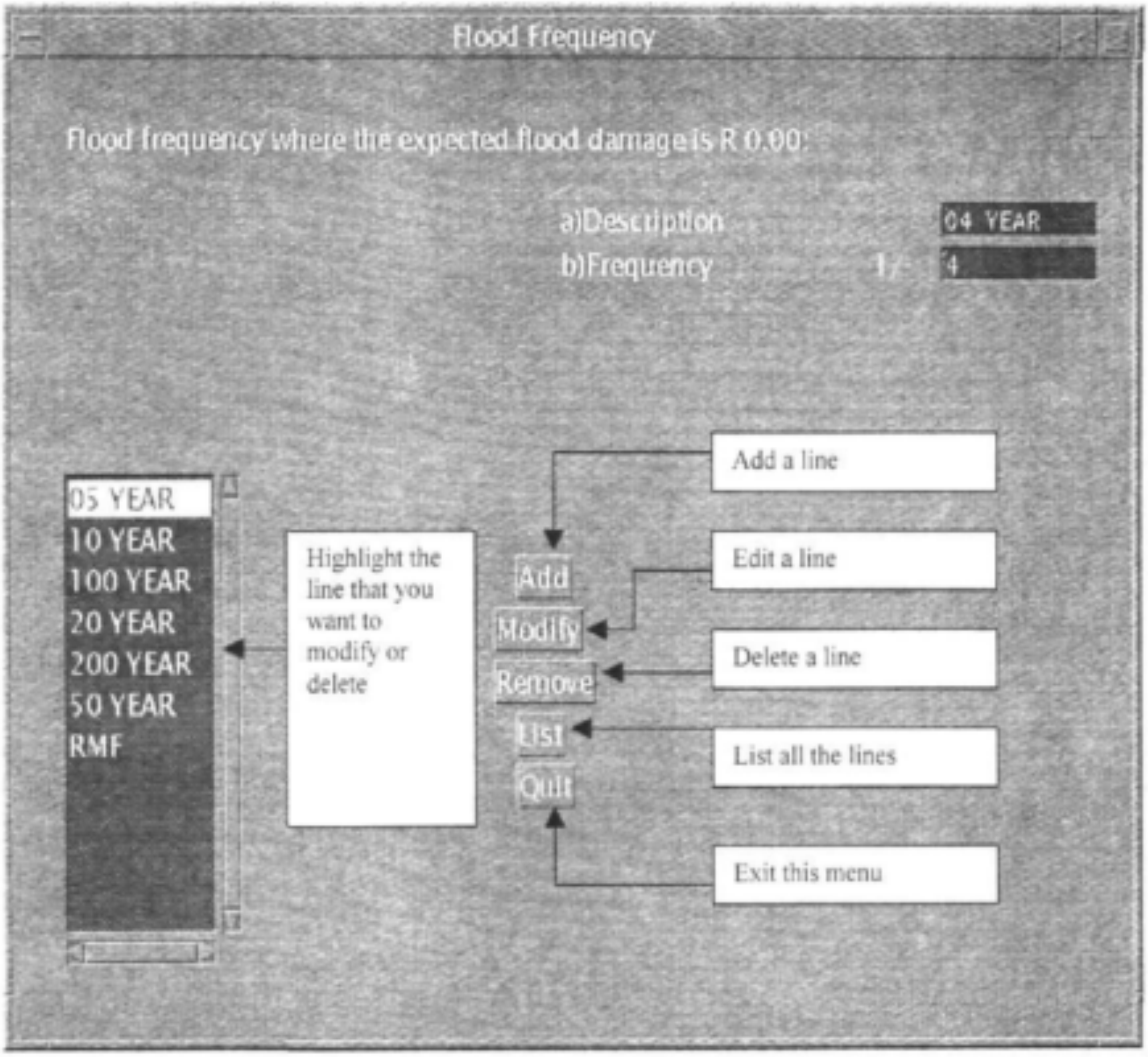
The sub-menus function the same way as the building menu and will not be repeated.



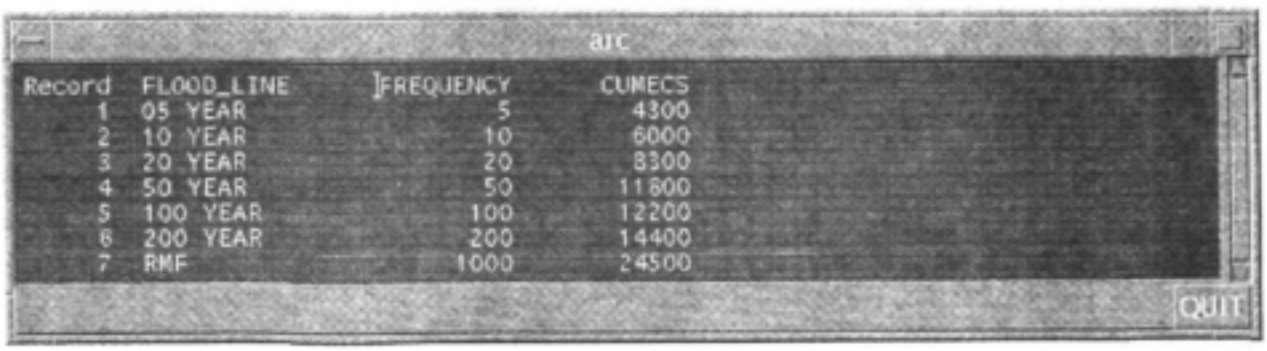
2.3.9 The flood frequency menu

Information needed by the flood frequency menu refers to hydrological information and will normally be given by a hydraulic engineer. Attention must be paid when this information is changed because it can change the end results significantly. This menu is used to define the frequency of floods with different sizes. The menu layout is the same as that of the buildings- and flood occurrence menus. Three fields, namely the description, frequency and the cumecs have to be defined for each flood.

➢ First, define the flood where the potential flood damage will be zero. It is needed for calculation purposes.



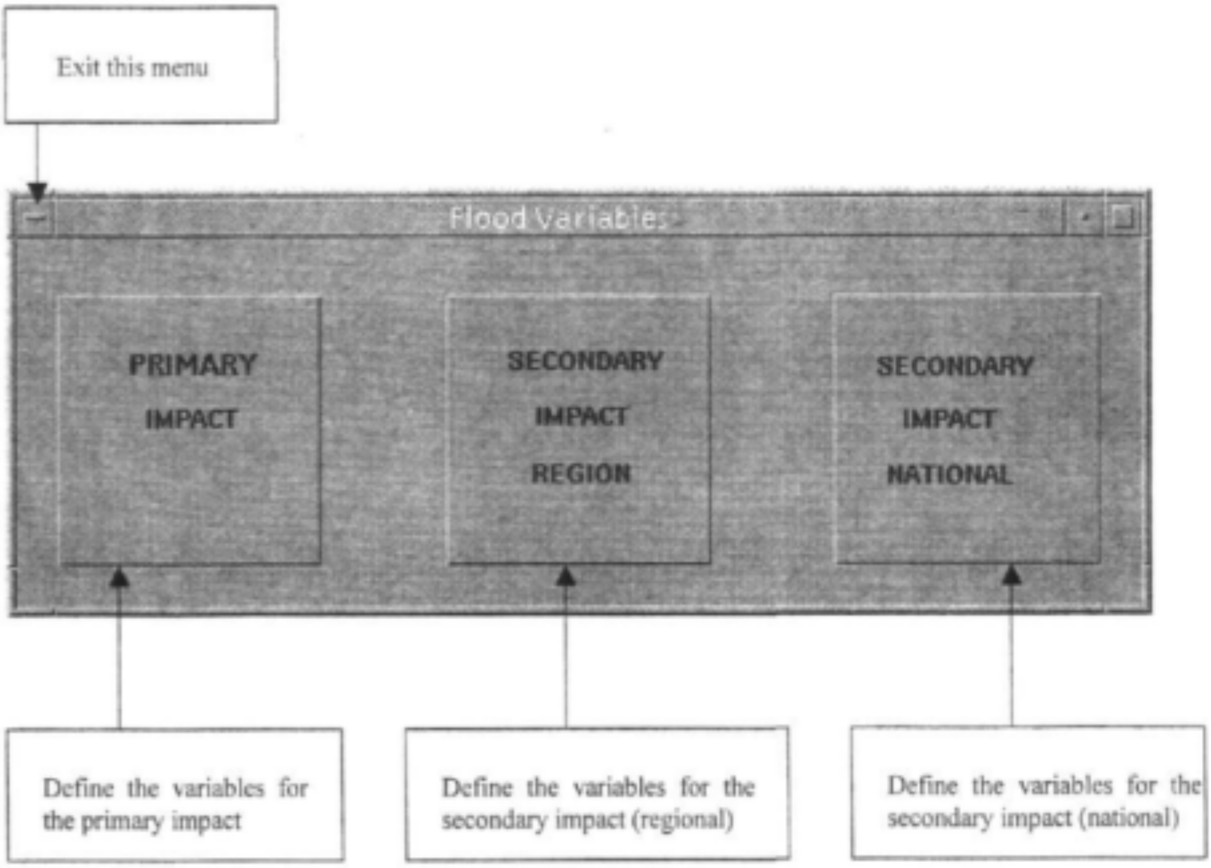
Here is an example of the values that were used for the Orange River at Upington:



Record	FLOOD_LINE	FREQUENCY	CUMECS
1	05 YEAR	5	4300
2	10 YEAR	10	6000
3	20 YEAR	20	8300
4	50 YEAR	50	11800
5	100 YEAR	100	12200
6	200 YEAR	200	14400
7	RMF	1000	24500

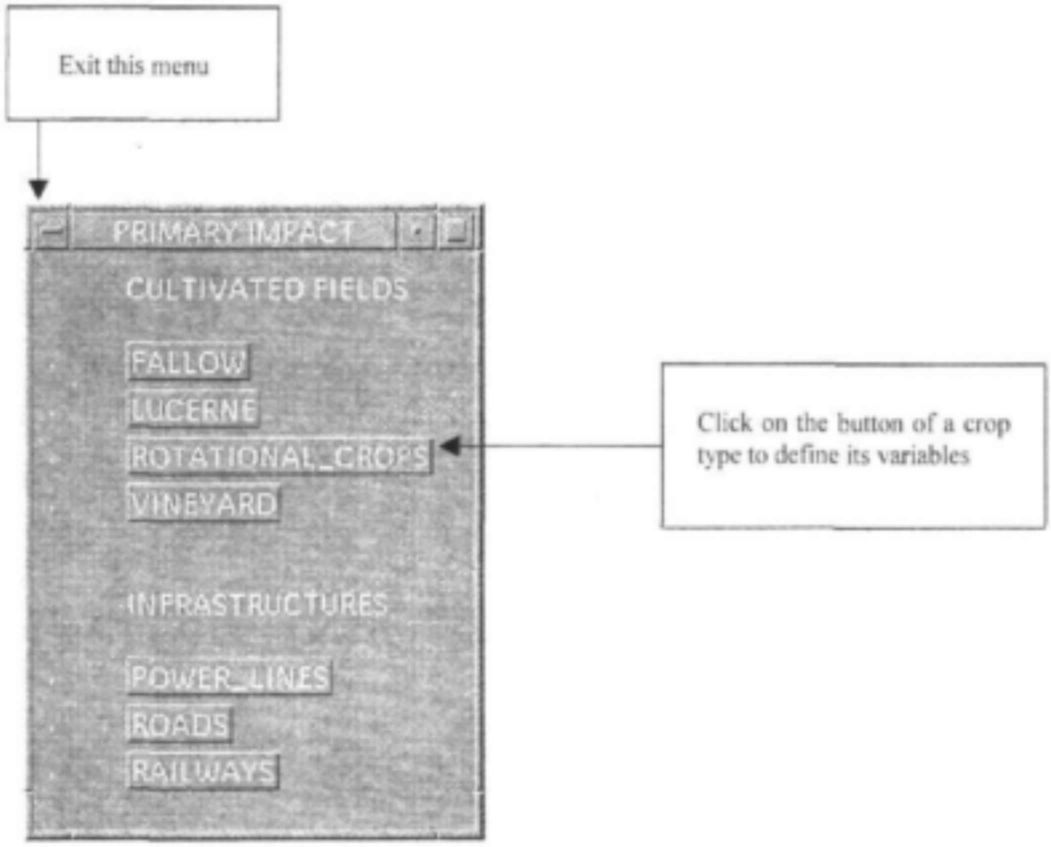
2.3.10 The flood variables menu

This information will normally be defined by an agricultural economist. More specifically this menu defines the variables for the primary impact, secondary regional impact and secondary national impact assessment purposes. The items in the primary impact menu will depend on the land use pattern that are included into the corresponding coverages. When the user click on a button in the primary impact menu, the program will display the menu for the specific crop or infrastructure type. When the menu does not exist, a message will be given in the message window. Refer to Appendix I for a list of available land use types.



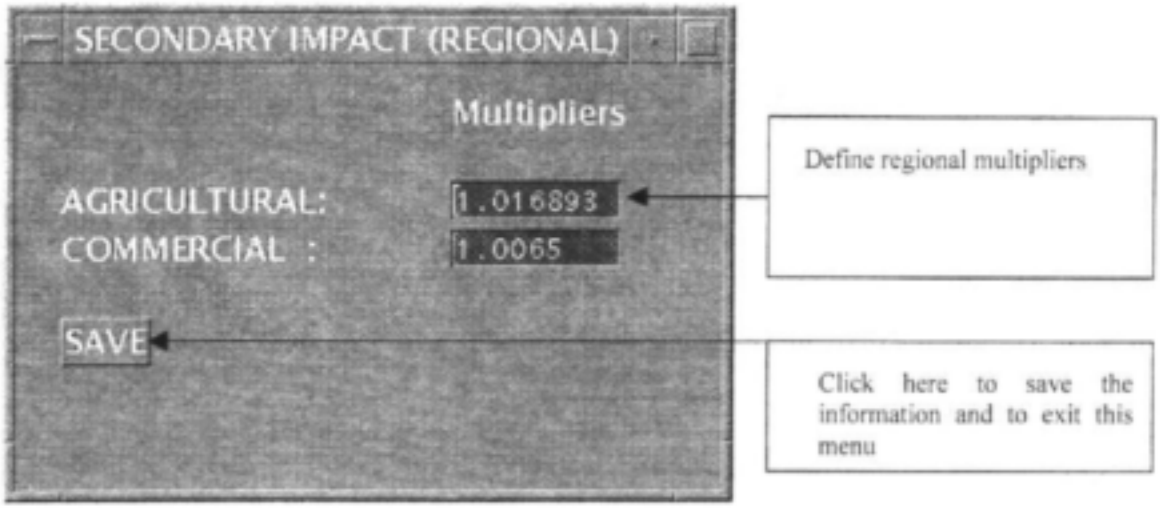
2.3.10.1 The primary impact menu

All the info in the primary impact menu refers to economical information and will be defined by an agricultural economist. Care must therefore be taken when changes are made.



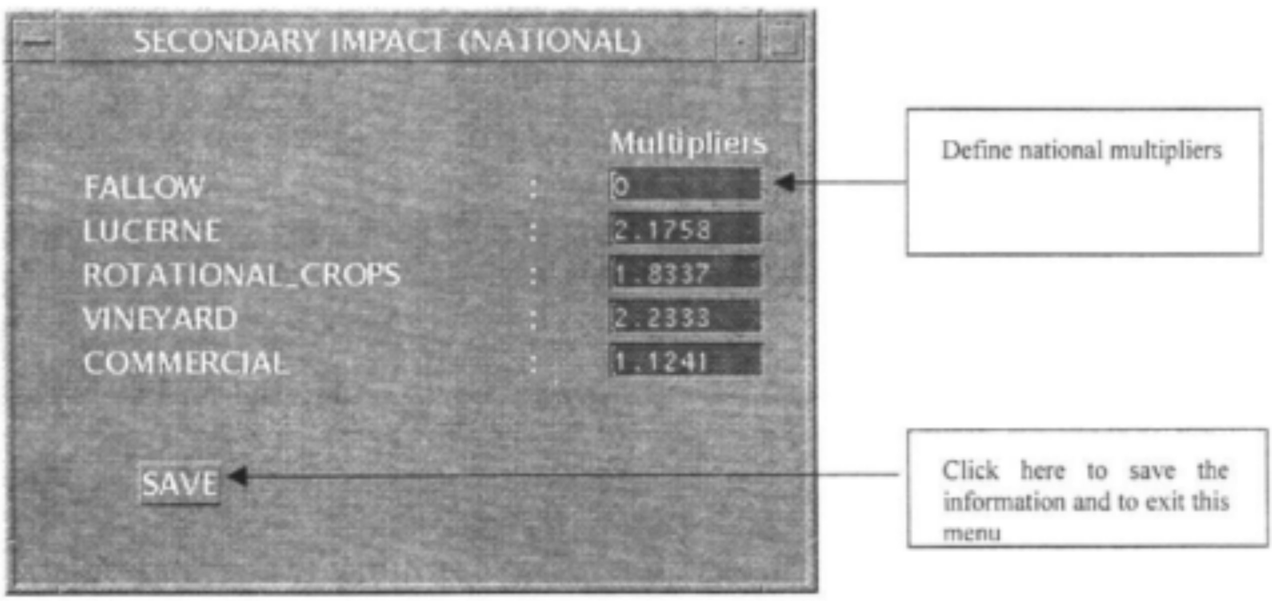
2.3.10.2 The secondary impact (regional) menu

Besides the direct impact of floods it also has secondary impact (multiplier effect) on the regional and national economy. This info will also be provided by an agricultural economist and is calculated by making use of the input output tables.



- Save new Info

2.3.10.3 The secondary impact (national) menu



Chapter 3

WORKING WITH FLODSIM

3.1 STEPS IN USING FLODSIM

After FLODSIM has been successfully installed and discussed/described in the previous section, it is possible to use FLODSIM for flood damage modelling purposes.

To start FLODSIM, the following steps must first be executed:

unix_prompt> *cd /system/ptool*

unix_prompt> *arc*

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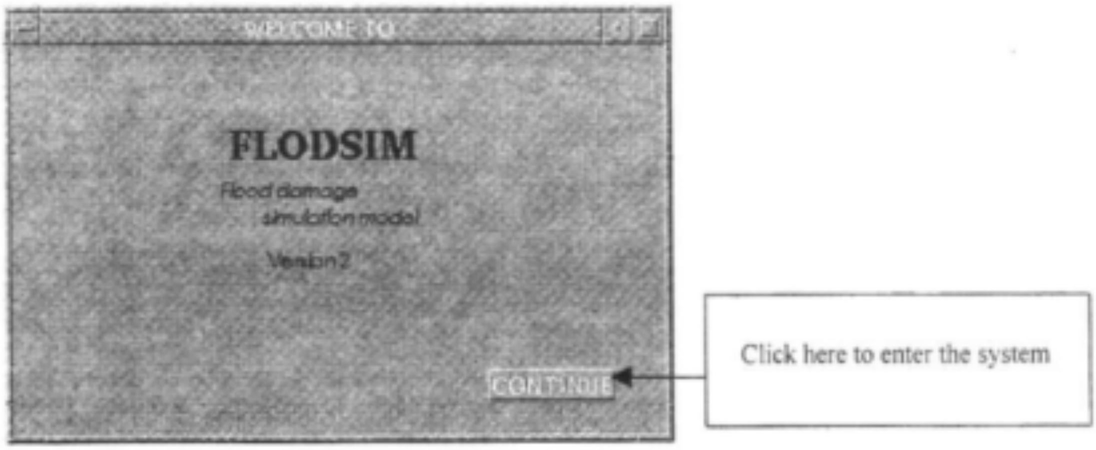
All rights reserved.
ARC Version 7.1.1 (Thu Feb 6 23:26:50 PST 1997)

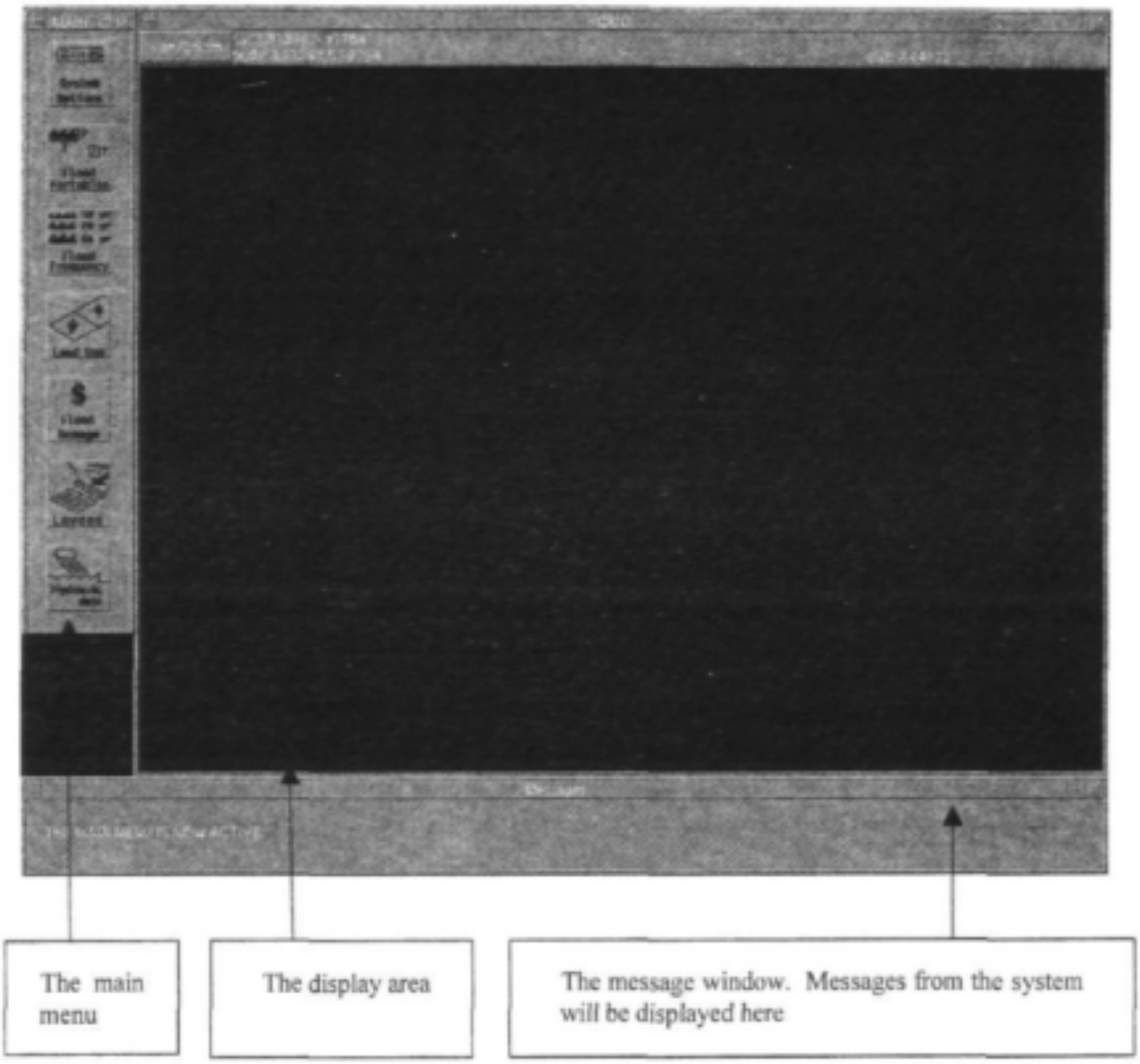
Arc: *&r startup*

The following menu will now be displayed:



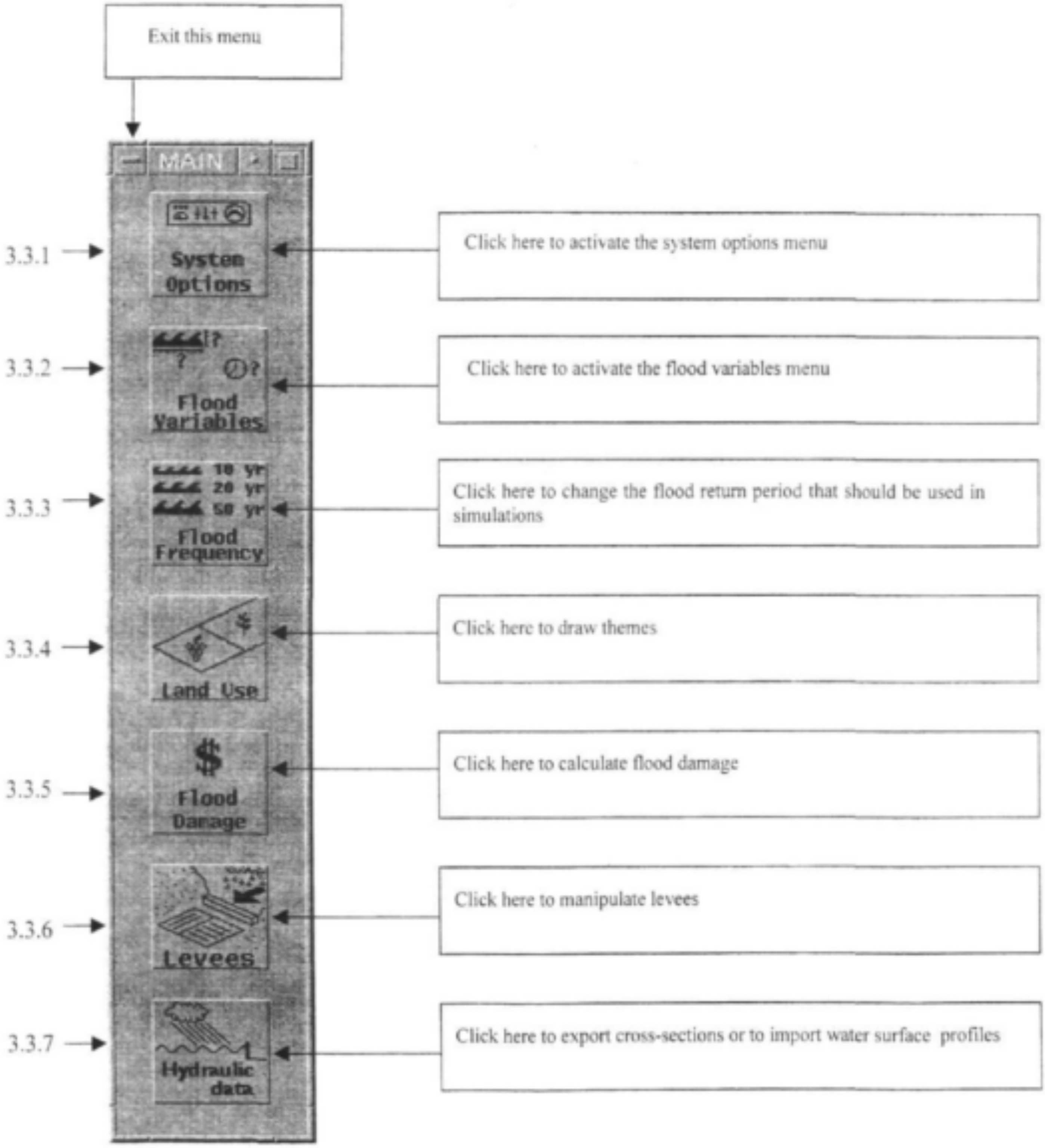
3.2 THE SCREEN LAYOUT

The screen layout of FLODSIM contains three areas, namely the main menu, the display area and the message window. The main menu will be discussed first in this section.



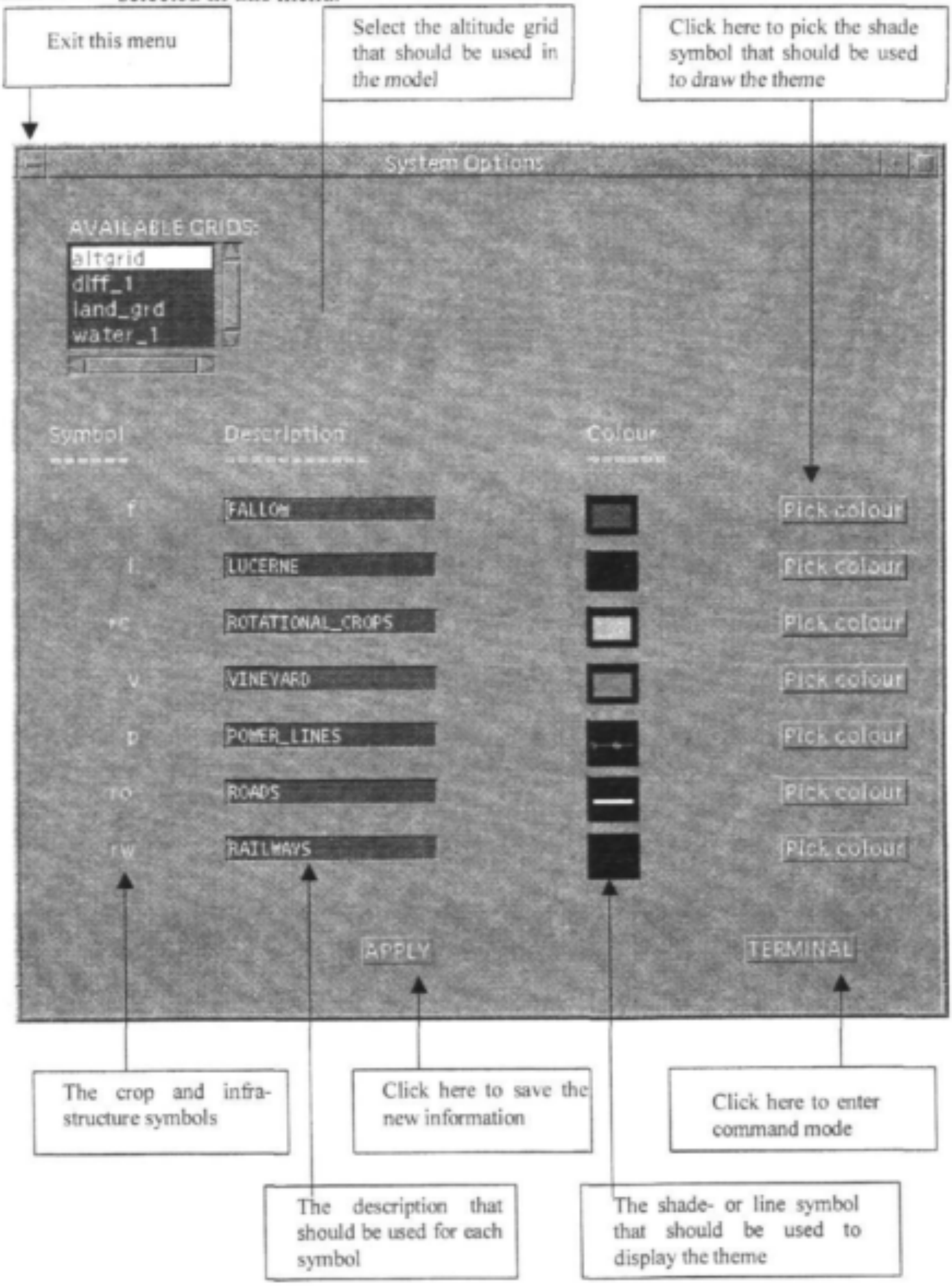
3.3 THE MAIN MENU

The main menu contains seven sub menus

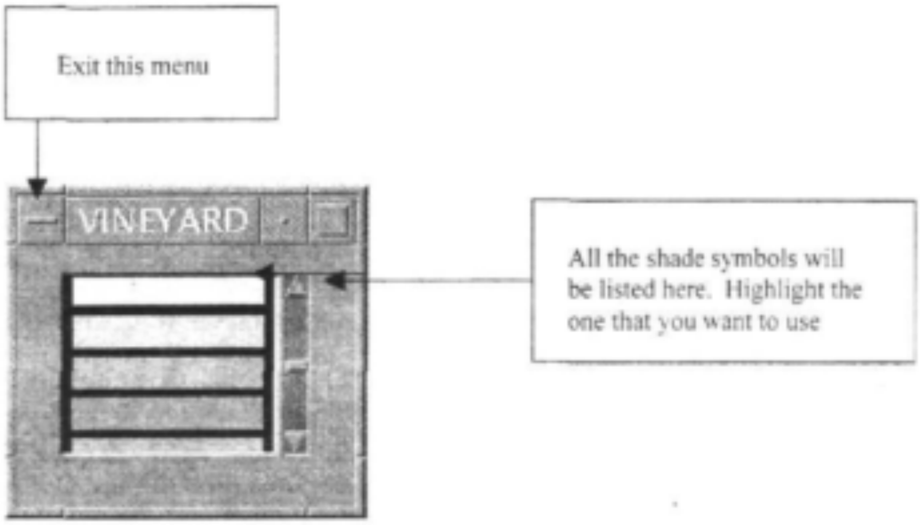


3.3.1 The system options menu

This menu is used to select the shade symbols that should be used to display the different crop- and infrastructure types. Another altitude grid can also be selected in this menu.

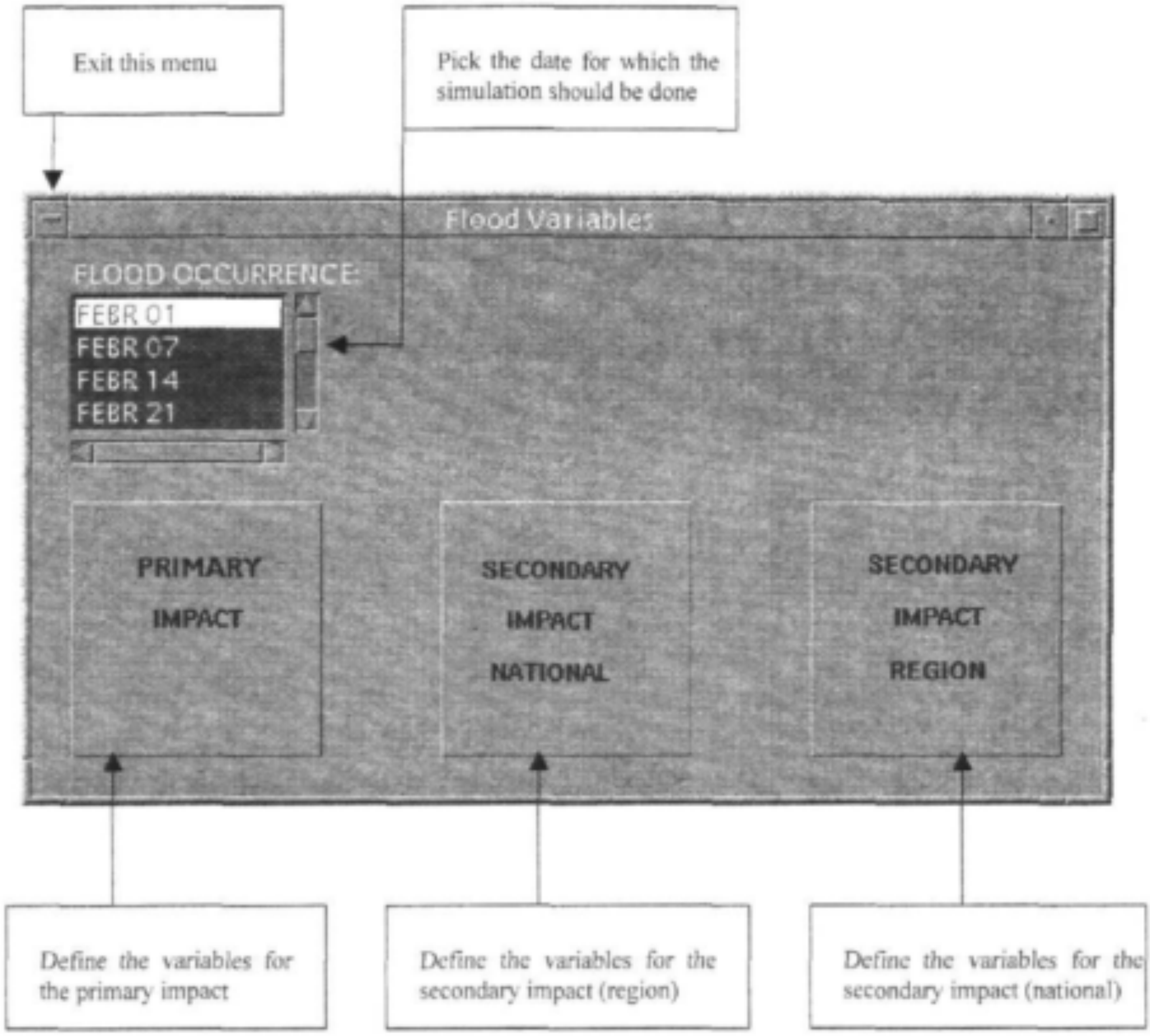


3.3.1.1 The shade symbol menu:



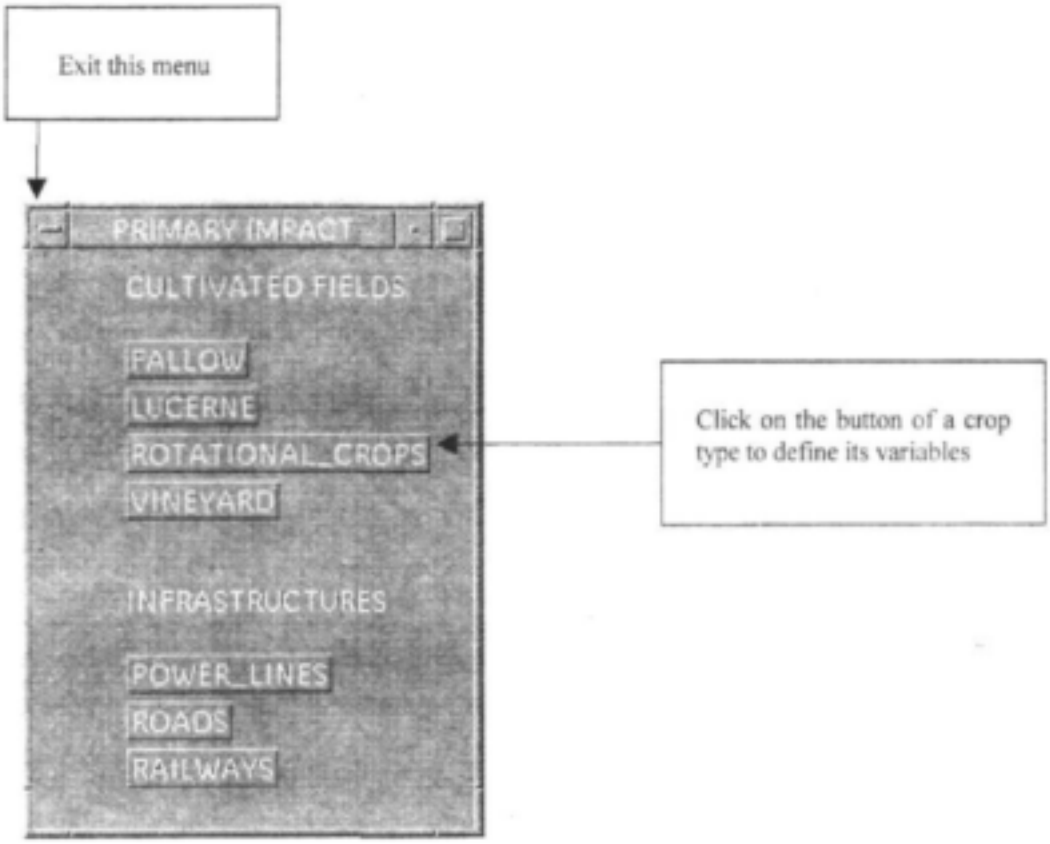
3.3.2 The flood variables menu

This menu is used to define the variables for the primary impact, secondary impact for the region and secondary national impact. The items in the primary impact menu will depend on the crop and infrastructure types that are included in the corresponding coverages. When you click on a button in the primary impact menu, the program will display the menu for the specific crop or infrastructure type if it can be found. When the menu does not exist, a message will be given in the message window. Refer the Appendix A for a list of available land use types.


Exit this menu
Pick the date for which the simulation should be done
Flood Variables
FLOOD OCCURRENCE:
FEBR 01
FEBR 07
FEBR 14
FEBR 21
PRIMARY IMPACT
SECONDARY IMPACT NATIONAL
SECONDARY IMPACT REGION
Define the variables for the primary impact
Define the variables for the secondary impact (region)
Define the variables for the secondary impact (national)

3.3.2.1 The primary impact menu:

The following menu will appear when the primary impact menu is selected.

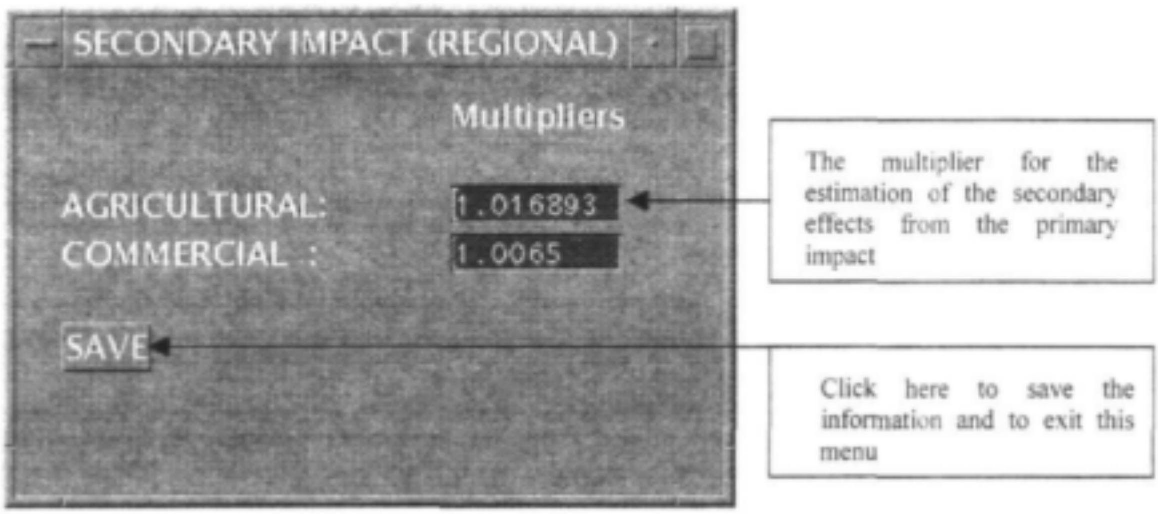


This menu enables the user to define various variables for the different land use types in the area of investigation. Variables such as cross income, pre-harvest and harvest cost can be specified. For infrastructure the total repair cost per unit is been specified.

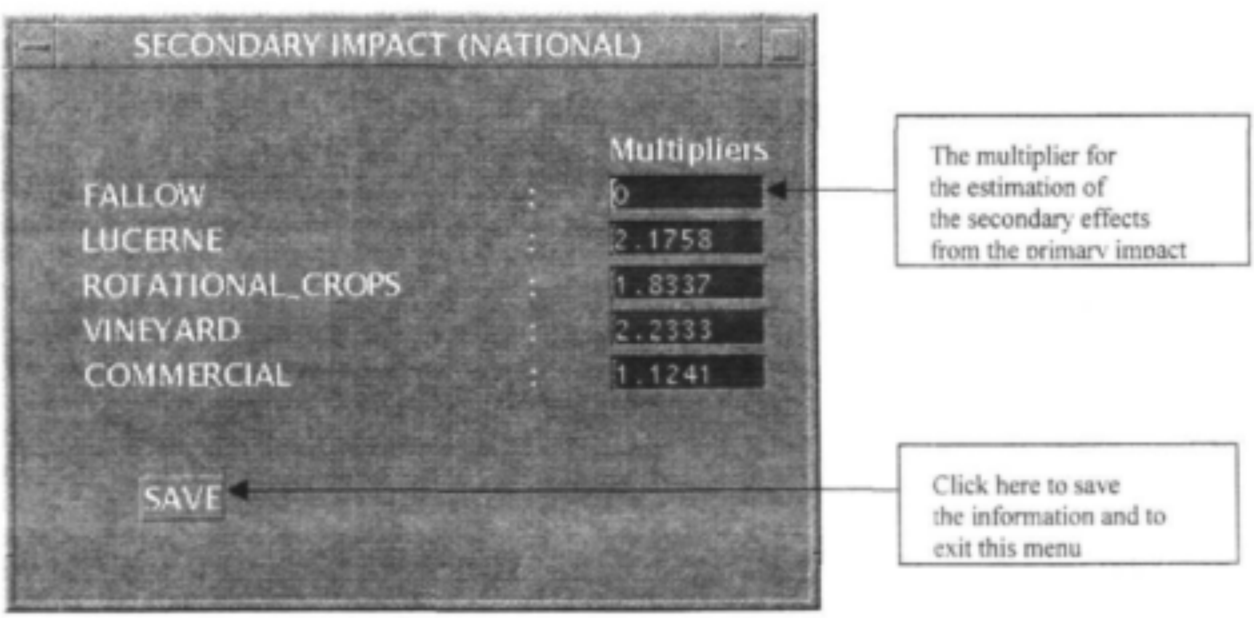
3.3.2.2 The secondary impact (regional) menu:

Besides the primary impact of floods, floods also have a secondary impact on a region and to the national economy. Multipliers for the region as well as for the national economy must first be calculated to determine the secondary impact of floods

- Care must be taken if variables are changed by the end user

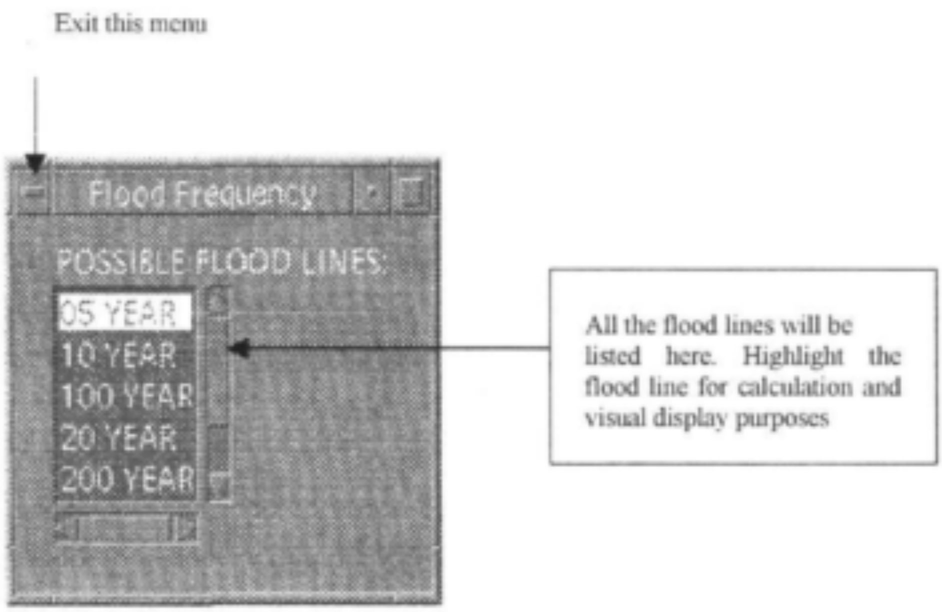


3.3.2.3 The secondary impact (national) menu:



3.3.3 The flood frequency menu

Normally a hydraulic engineer will provide all hydraulic and hydrological information. This information will inter alia take into account all possible floods than can occur in the area under investigation. It is therefore possible to calculate the impact of each individual flood by selecting a specific flood line. This is usefull when you want to calculate the total flood damage for a specific flood line. The areas inundated will be displayed for this flood line.

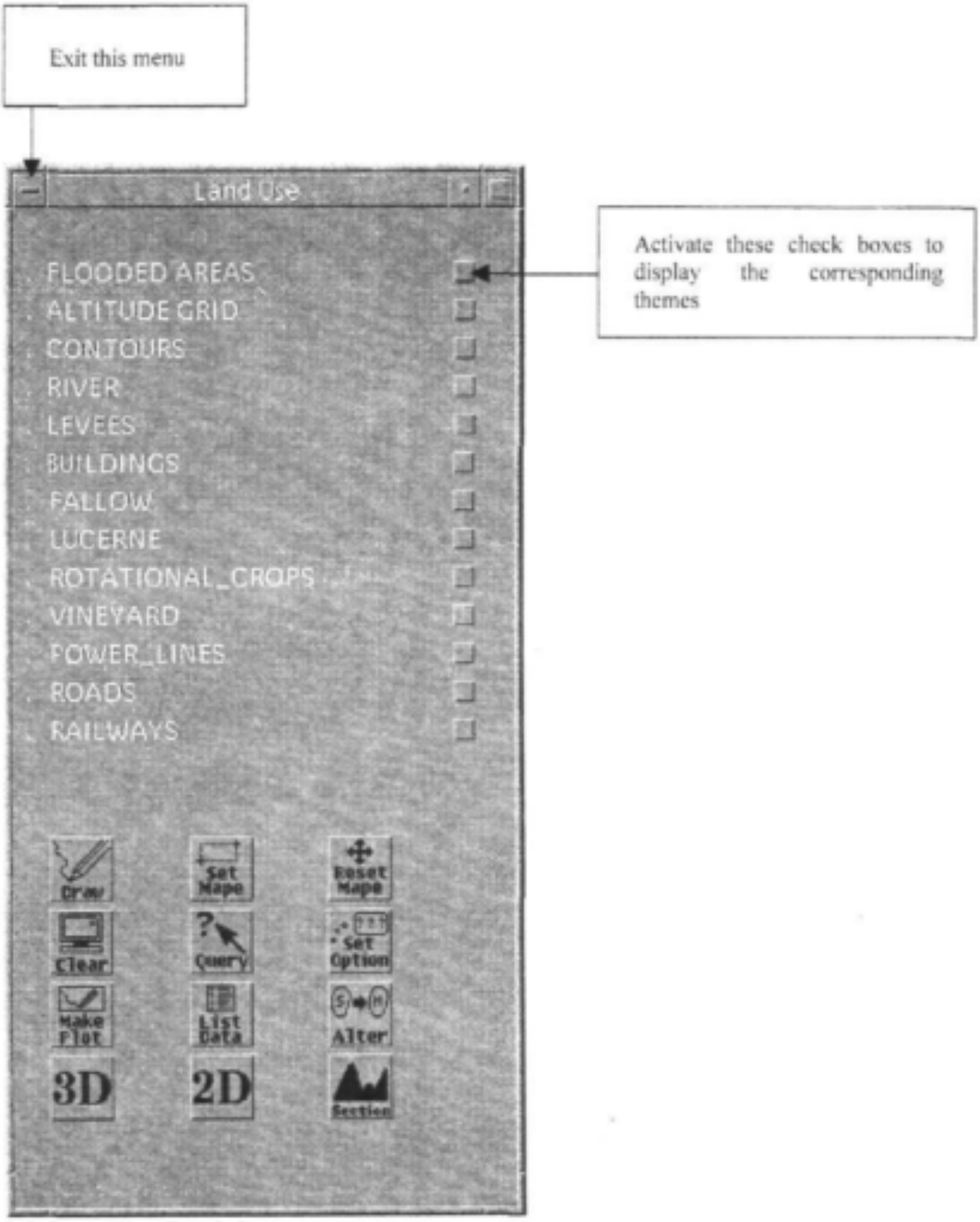


3.3.4 The land use menu

The land use menu is used to display the different themes. The crop types of cultivated fields can also be changed temporarily with this menu. This enables the user to determine the impact of different land use types as part of flood mitigation works. Flood damage can then be calculated for the temporary crop types (see Paragraph 3.3.6). Other functions that are supplied by this menu include three-dimensional displays, queries of cultivated fields, data listing of cultivated fields and the creation of plot files. The model still has to be expanded to supply additional functions for infrastructures and buildings. The menu contains the following buttons:

Button	**Description**
Draw	Draw the selected themes in the display area.
Set map	Set the new map extent.
Reset map	Reset the map extent.
Clear	Clear the current screen display.
Query	Query one cultivated field at a time.

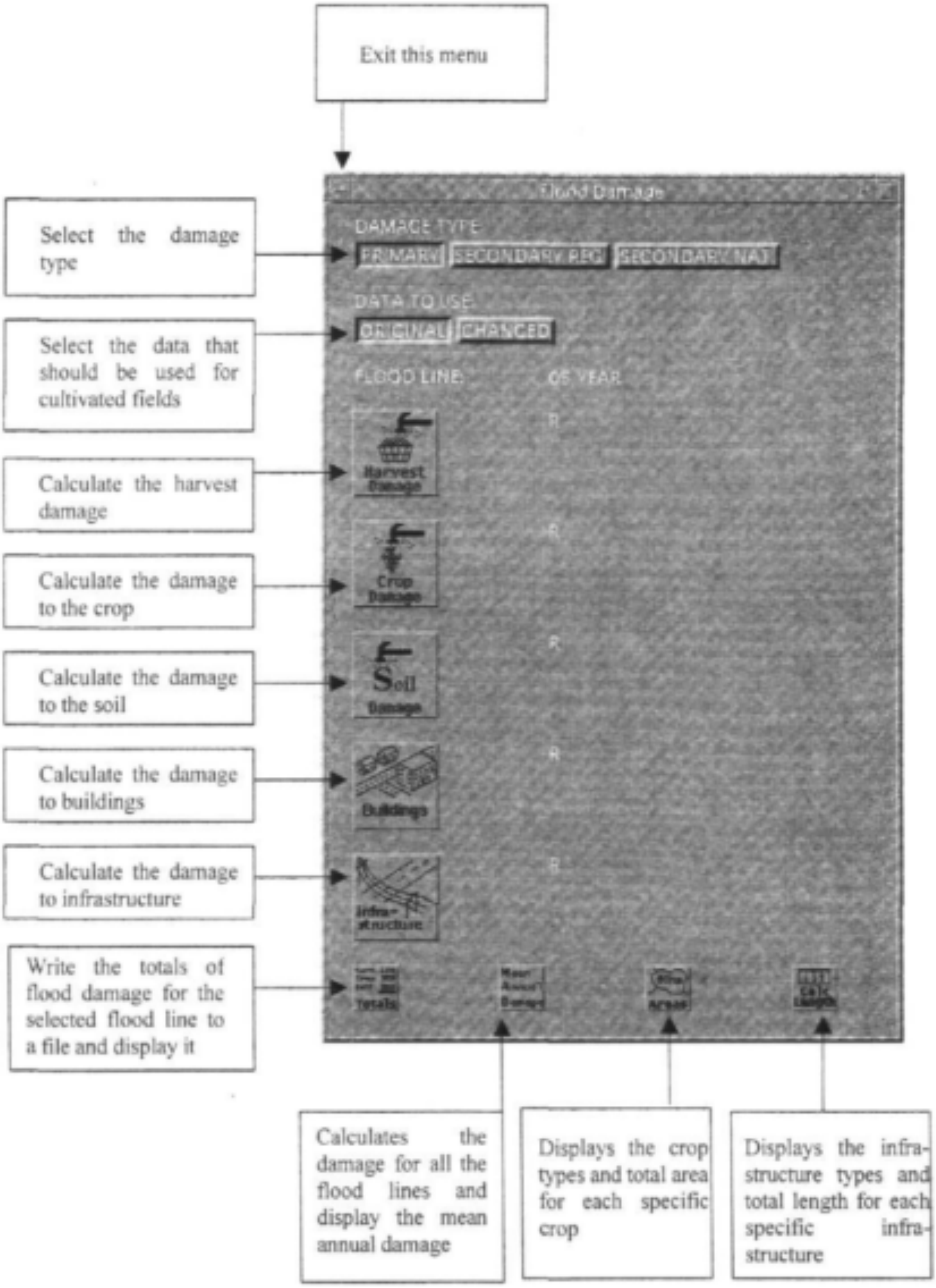
Button	**Description**
Set option	Set display and data to display options.
Make plot	Creates a plot file of what is currently displayed on the screen.
List data	Lists information of all the cultivated fields on the screen.
Alter	Change the attributes of the cultivated fields temporarily.
3D	Activates the 3D view.
2D	Return to normal 2D view.
Section	Define a cross section and display its profile on the screen.



3.3.5 The flood damage menu

After these adjustments have been made in FLODSIM as described above, it is possible to calculate the primary and secondary (regional and national) damages. Distinction is made between harvest, crop, soil, building and infrastructure damage. The different damage categories can thus be calculated separately for a specific flood.

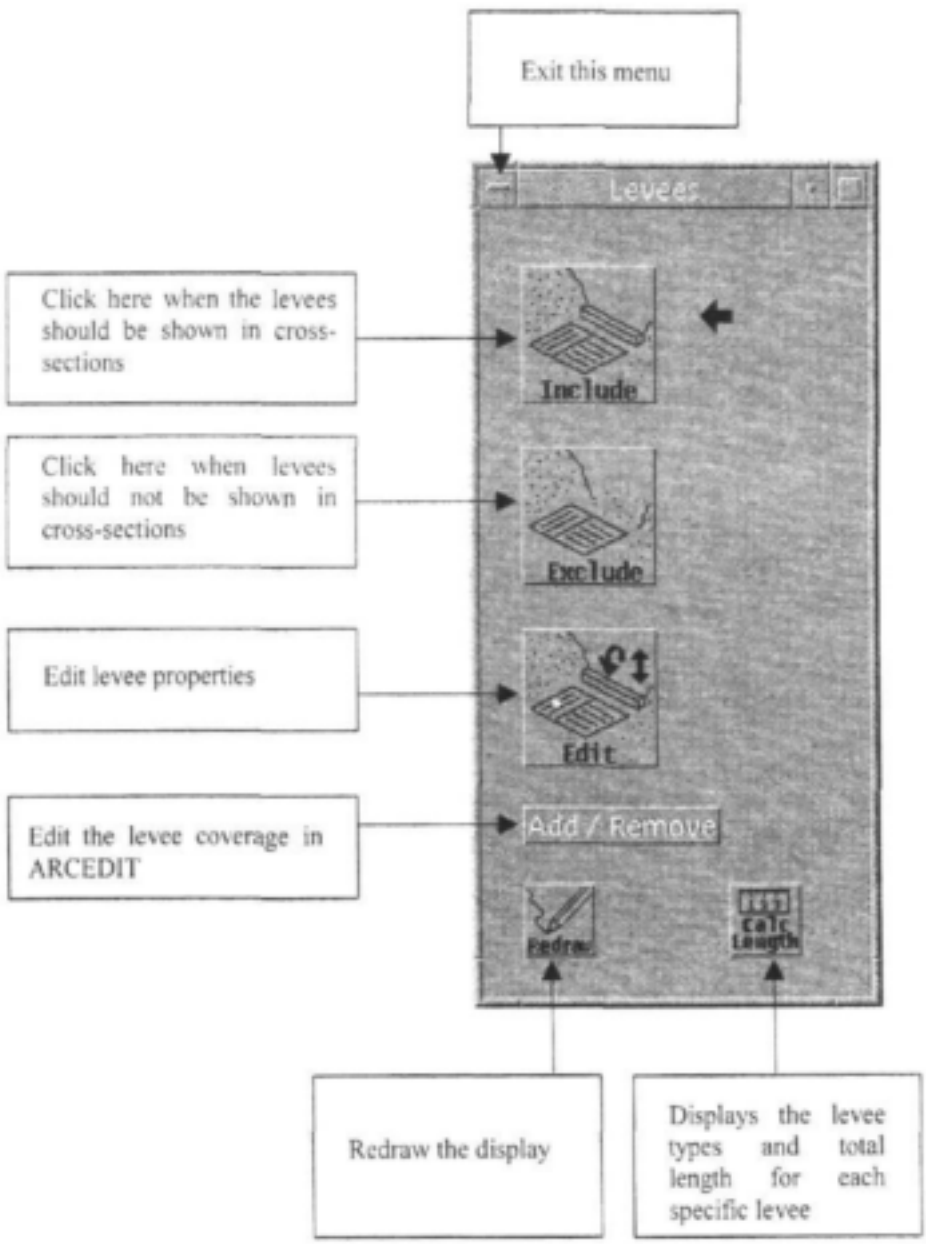
The mean annual damage button can be used if the user want to determine the impact of all potential floods. The mean annual damage is especially used in cost benefit analysis to determine the economic benefits of various flood mitigation options.



3.3.6 The levees menu

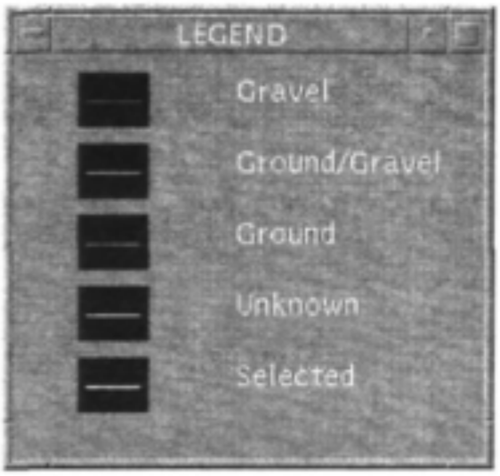
This menu enables the user to manipulate levees in the area of investigation. This menu can be used to set levee calculation options, to edit levee properties and to create new levee scenarios.

The edit menu will allow the user to edit the levee coverage, e.g. to increase or decrease levee heights. It is also possible to hypothetically add and/or remove levees in the area of investigation to determine the impact of it on the mean annual flood damage. In this way various levee scenarios can be compiled.

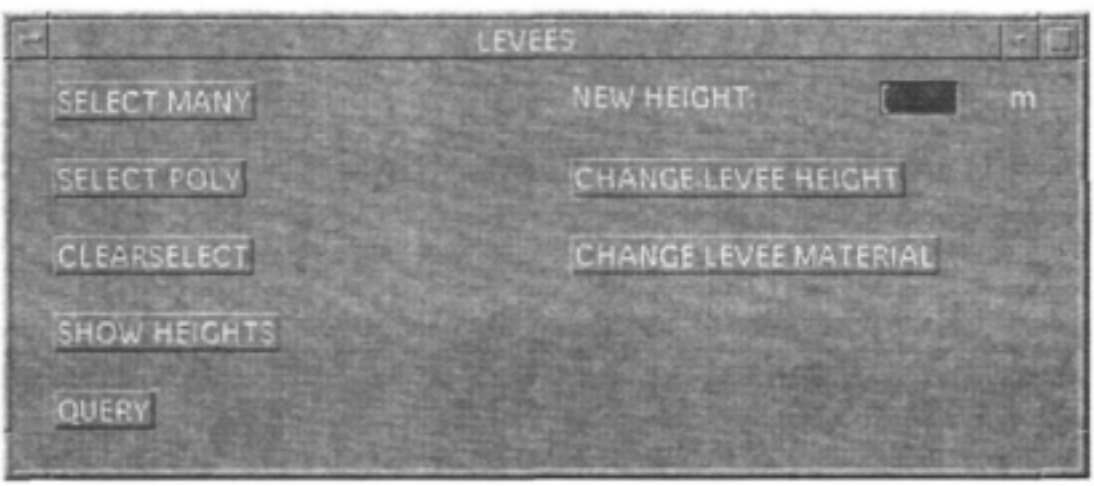


3.2.6.1 The edit menu

Levee properties are edited with this menu. The levees are displayed in the display area. Different line symbols are used to draw the levees according to the material used. The selected levees are displayed in yellow. The legend looks like this:



The levee edit menu consists of the following options:



Button	**Description**
Select many	Click this button to select a subset of levees. Select the levees with the left mouse button. Press the 9 key on the keyboard to stop selecting.
Select poly	Click this button to select a subset of levees that falls within the boundary of a digitised polygon. Use the left mouse button to add

the vertices of the selection polygon. Press the 9 key to close the polygon.

Button	**Description**
Clearselect	Clears the selected set of levees.
Show heights	Display the height of each levee.
Query	Query an individual levee
Change levee height	Change the height of the selected levees. The value in *new height* will be assigned to the levees.
Change levee material	Change the material of the selected levees. A menu will be displayed with the available material types. Highlight the material that should be allocated to the selected set of levees.

3.3.6.1 The add / remove menu

This menu can be used to edit the levee coverage in ARCEDIT and therefore enables the user to hypothetically add/or remove levees

Button	**Description**
Add	Add a levee. You must start and end the line with a node (middle mouse button). Define the actual line (vertices) with the left mouse button. Press the 9 key on the keyboard to stop adding lines.
Select	Select one or more levees. Selected lines will turn yellow.
Delete	Deletes the current selection of lines. If no lines are selected the system will prompt you to select a line.

Oops	Will undo your last action. Click this button if you want to undelete a line which you deleted.
Vertex move	Allows you to move any of the vertices of the levee.
Vertex add	Allows you to add vertices to the levee.

Button	**Description**
Vertex delete	Allows you to delete any of the vertices of the levee.
Snap	Allows you to snap two or more vertices together.
Zoom in	Zoom in on the display.
Zoom out	Zoom to the previous level.
Redraw	Redraw the screen.
Key	Enters command mode. In command mode you can use any ARCEDIT commands. Type &return to return to menu mode.
Save	Saves your work.

3.3.7 The hydraulic data menu

A new module has been developed to allow exporting of topographical data, e.g. when the river network is defined by FLODSIM by using cross sections. This information becomes an input to hydraulic simulation models to assess water levels, water velocities and flood frequencies. After this has been done, the water profiles that was determined with the hydraulic simulation model can be imported. This option must be executed by a hydraulic engineer. However, to be able to export cross sections and import water profiles, a new server session should be started.

The program that is used to export cross-sections uses Inter Application Communication (IAC). This requires the use of two Arc/Info sessions. The one session will be the client (this is the main program) while the other session will be the server. A server session must therefore first be started when exporting cross sections. Note that the server session is not required by any of the other functions that are provided in FLODSIM. The program that is used to export cross-sections is activated by the last button in the main menu (see Paragraph 3.3).

To start FLODSIM do the following:

Change the directory to …/system/ptool

Start ARC/INFO

Run the *startup* AML

Start the server session in a different window (only when you want to export cross-sections):

Change the directory to …/system/ptool

Start ARC/INFO

Run the *start_server* AML

Example:

The server session:

unix_prompt> *cd /system/ptool*

unix_prompt> *arc*

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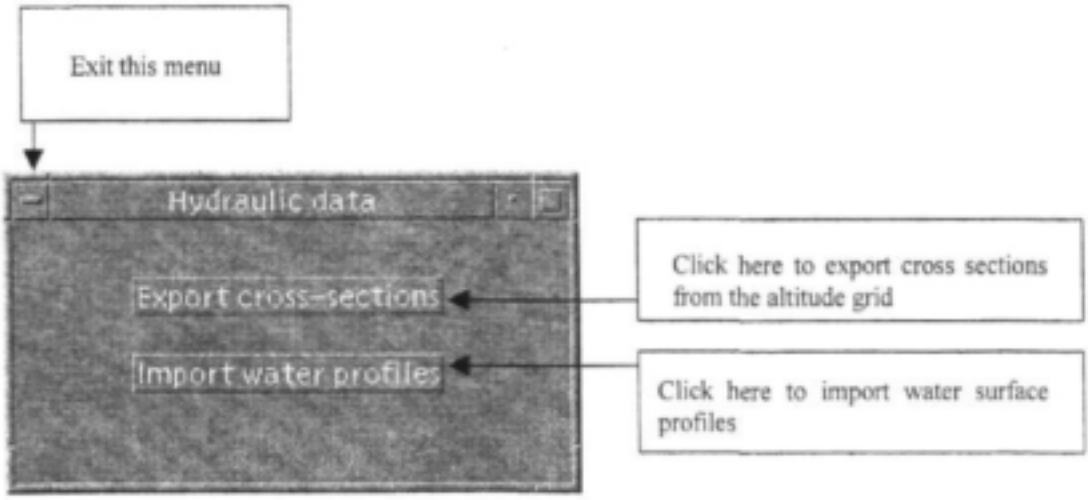
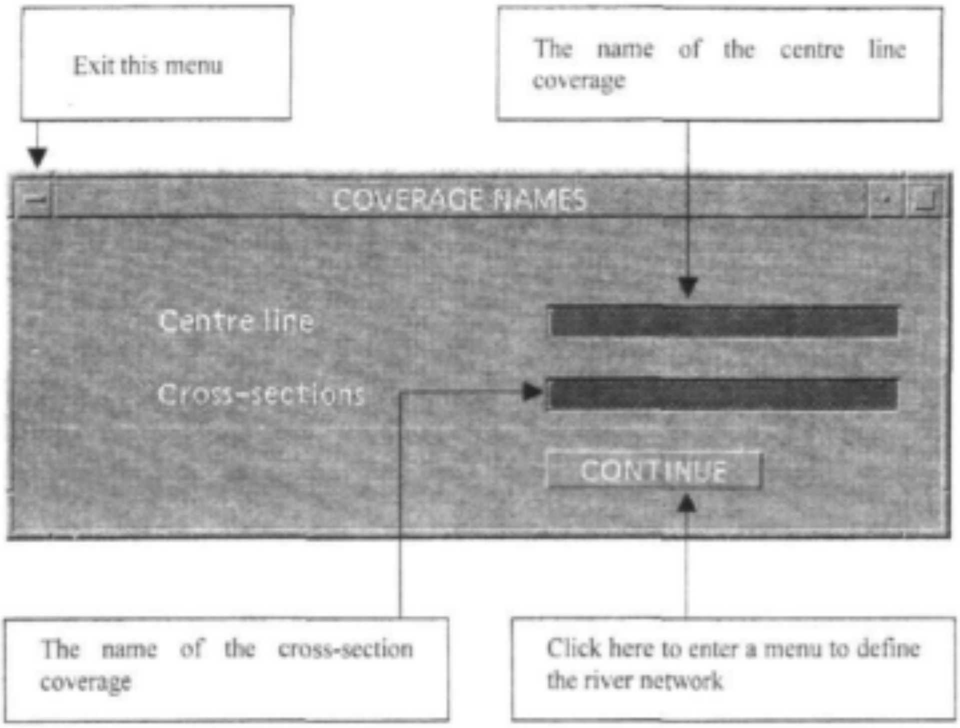
All rights reserved.
ARC Version 7.1.1 (Thu Feb 6 23:26:50 PST 1997)

Arc: *&r start_server*



3.3.7.1 The export cross-sections menu

The names of the coverages for centre lines and cross-sections are requested by this menu. The system will create new coverages if the specified coverages do not exist in the temporary directory.

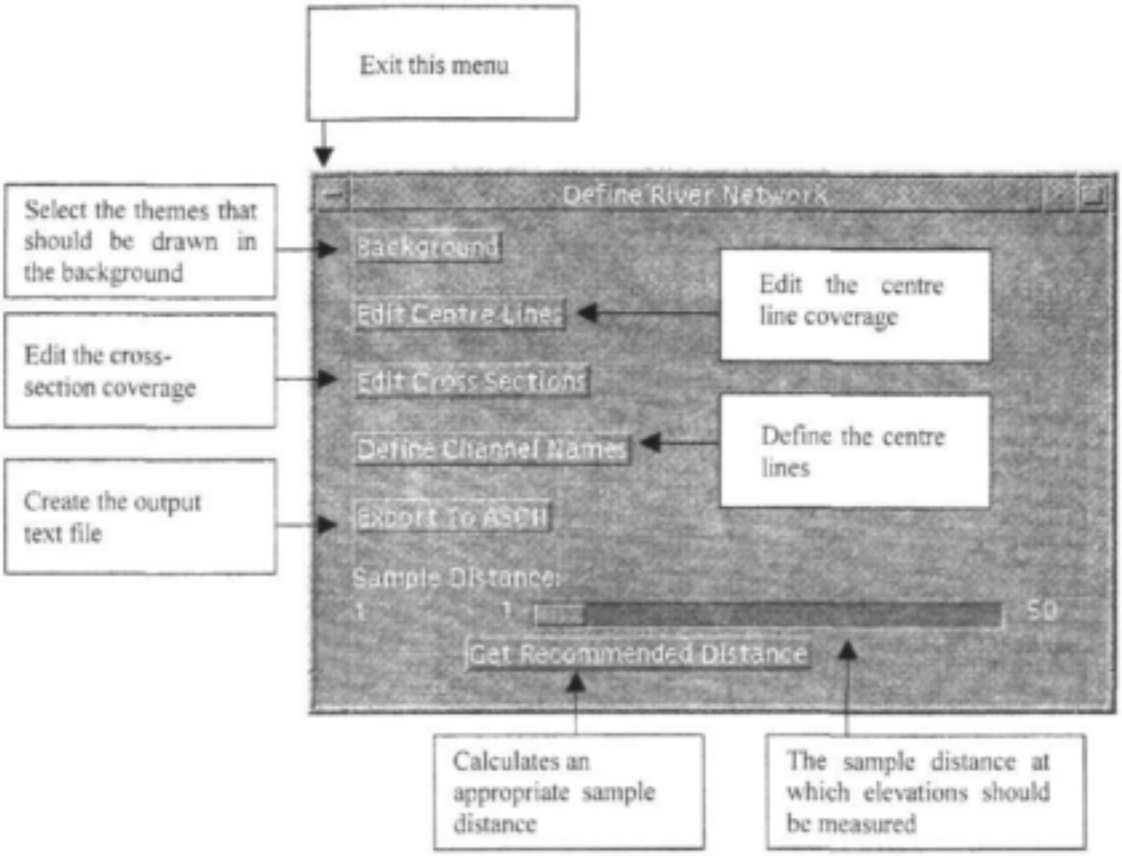


3.3.7.1.1 The define river network menu

Use this menu to export the river network and cross-sections to a text file. The format of the text file that is exported will be described in Chapter 4.

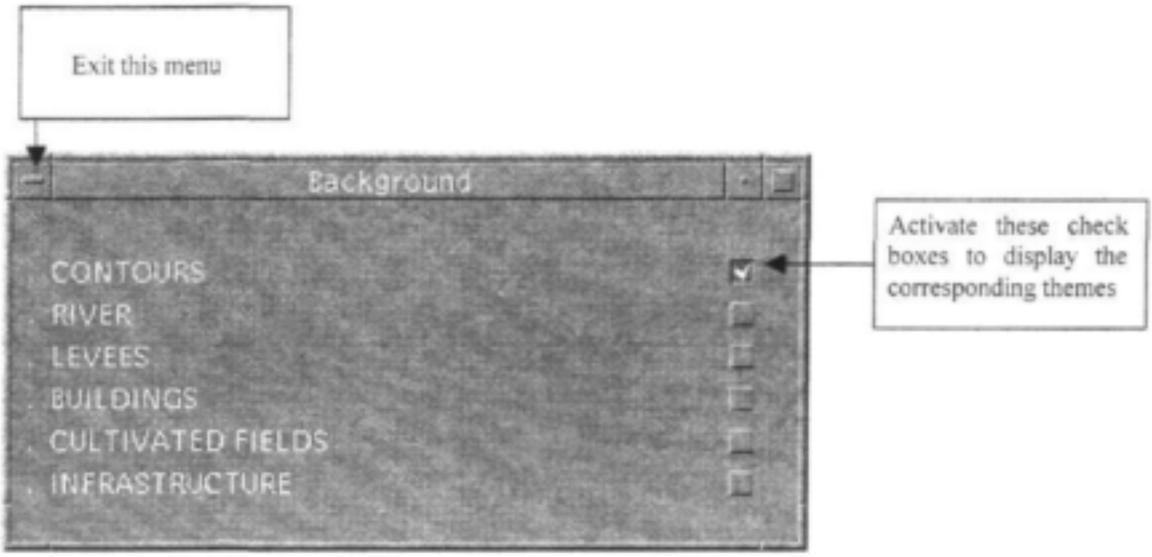
The river network and cross-sections can be digitised on the screen. The elevations of points in the cross-sections are automatically calculated by the system. The user may choose any of the themes to be displayed in the background while he is digitising.

The river is represented by a network configuration as a system of inter-connected branches. The network consists of centre lines representing the different channels. A centre line can be defined as a line connecting the points with maximum water speed in the cross-sections (Tchoukanski, 1995).



3.3.7.1.2 The background menu

Use this menu to select the themes that should be displayed in the background while the cross-sections and centre lines are digitised.



3.3.7.1.3 The edit centre lines menu

Use this menu to edit the centre line coverage. Note that the centre lines must be directed downstream.

Button	**Description**
Add	Add a centre line. You must start and end the line with a node (middle mouse button). Define the actual line (vertices) with the left mouse button. Press the 9 key on the keyboard to stop adding lines.
Select	Select one or more centre lines. Selected lines will turn yellow.
Delete	Deletes the current selection of centre lines. If no lines are selected the system will prompt you to select something.
Oops	Will undo your last action. Click this button if you want to undelete something which you deleted.

Vertex move	Allows you to move any of the vertices of the centre line.
Vertex add	Allows you to add vertices to the centre line.
Vertex delete	Allows you to delete any of the vertices of the centre line.
Snap	Allows you to snap two or more vertices together.
Zoom in	Zoom in on the display.
Zoom out	Zoom to the previous level.
Redraw	Redraw the screen.
Key	Enters command mode. In command mode you can use any ARCEDIT commands. Type &return to return to menu mode.
Save	Saves your work.

3.3.7.1.4 The edit cross-sections menu

Use this menu to edit the cross-section coverage

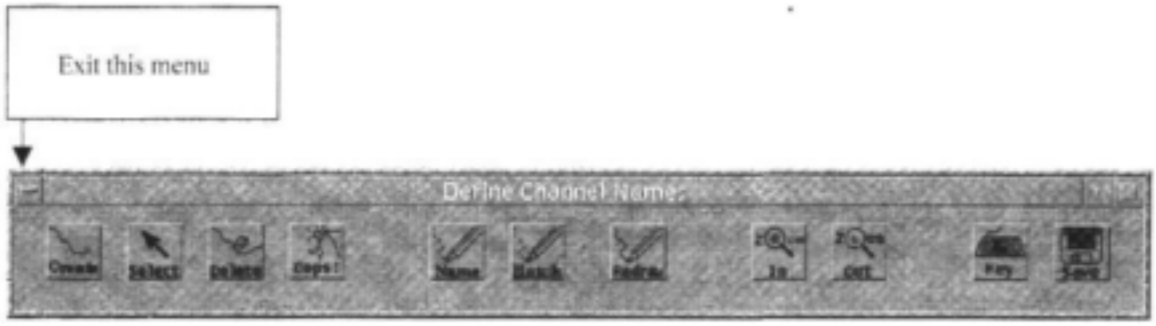
The following rules must be considered during the digitising of cross-sections:

- Cross-sections must be taken from left to right over a centre line when looking downstream.
- Cross-sections should be straight lines.
- Cross-sections are not allowed to cross each other.
- Cross-sections must cross a centre line, but are not allowed to cross more than one centre line.
- Cross-sections should be approximately perpendicular to the centre line.
- Cross-sections should extend far enough to cover the highest elevation expected to be reached by the flood.
- Cross-sections should not extend beyond the boundary of the DTM.

Button	**Description**
Add	Add a cross-section. Use the middle mouse button to start and end the line. Press the 9 key on the keyboard to stop adding lines.
Select	Select one or more cross-sections. Selected lines will turn yellow.
Delete	Deletes the current selection of cross-sections. If no lines are selected the system will prompt you to select something.
Oops	Will undo your last action. Click this button if you want to undelete something which you deleted.
Zoom in	Zoom in on the display.
Zoom out	Zoom to the previous level.
Button	**Description**
Redraw	Redraw the screen.
Section	Allows you to select a cross-section. The profile of the cross-section will then be displayed in a separate window.
Key	Enters command mode. In command mode you can use any ARCEDIT commands. Type &return to return to menu mode.
Save	Saves your work.
Vertex move	Allows you to move any of the nodes of the cross-section.

3.3.7.1.5 The define channel names menu

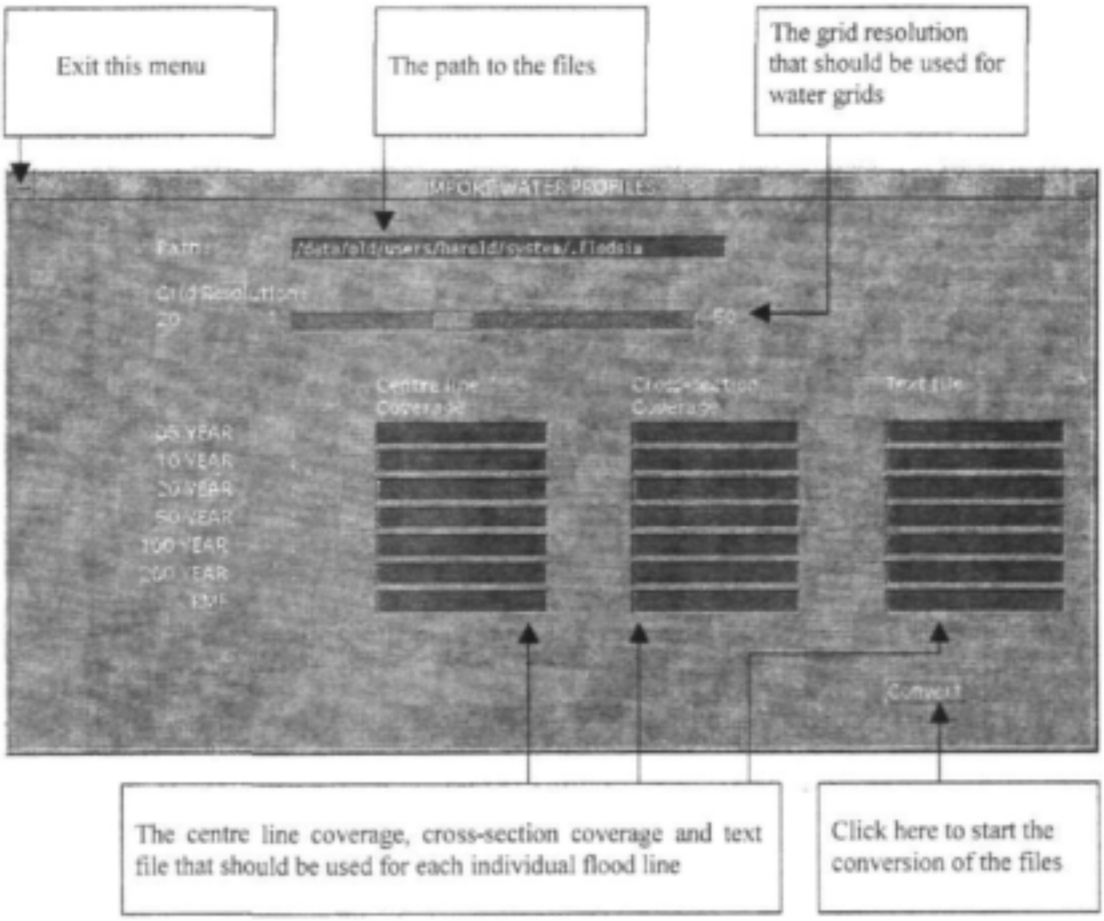
Use this menu to define the channels in the river system. A route system is used to define the different channels of the river network. Each channel is defined as a separate route that consists of a subset of centre lines. The channels can be identified by name and the system will automatically calculate the chainages for each channel.



Button	Description
Create	Prompts you to give the name that should be used to identify the channel that is represented by current selection of centre lines. If no lines are selected the system will prompt you to select something.
Select	Select one or more centre lines. Selected lines will turn yellow.
Delete	Prompts you to give the name of the channel that should be removed from the river network.
Oops	Will undo your last action.
Name	Displays each channel with a unique line symbol. The names of the channels are also displayed.
Button	**Description**
Hatch	Draws hatch lines along the channels.
Redraw	Redraw the screen.
Zoom in	Zoom in on the display.
Zoom out	Zoom to the previous level.
Key	Enters command mode. In command mode you can use any ARCEDIT commands. Type &return to return to menu mode.
Save	Saves your work.

3.3.7.2 The import water profiles menu

Use this menu to import the water surface profiles. The centre line coverages and cross-section coverages that are required for each flood line were created with the exportation of the river network (see Paragraph 3.3.7.1). The format of the text files that are also required by this menu is described in Chapter 4.



ACQUISITION OF HYDRAULIC DATA

4.1 INTRODUCTION

Topographic data required by numerical flood models usually consists of a river network and cross section profiles of the floodplain. Previously the cross-sections were acquired by means of ground surveys or aerial photography. Both these procedures are tedious and time consuming. The river network and cross section profiles can now easily be extracted from the DTM in FLODSIM and saved as a text file. After the hydraulic data were computed with the numerical flood model they are re-imported into FLODSIM by means of a text file.

An interface with Mike 11 was developed as an example system to illustrate the coupling between FLODSIM and numerical flood models. The interface can be categorised as an isolated system. The software that converts the input and output data is independent of both models. It is therefore possible to create interfaces between FLODSIM and other numerical flood models as well. Examples of other numerical flood models that use cross-sections to describe the topography are HEC-RAS (US Army Corps of Engineers, 1997:B.12- B.14), CFP (ECC, 1987:5-6), XP-SWMM and WSPRO (van Bladeren, 1998).

4.2 DEFINING THE RIVER NETWORK AND CROSS-SECTIONS

The graphical user interface of this module is described in detail in Chapter 3. The exporting process is fully automatic and is activated by the click of a button.

The output data is saved into two files. The first file describes the river network by giving the chainages where the different channels connect. The second file describes the cross-sections (see Figure 4.1). The names of these files will respectively be *cline.chn* and *cline.aio*. Where cline should be read as the name of the centre line coverage. The file extensions respectively mean *chainage* and *ARC/INFO output*.

```
Mfolozi
     1,26452.950,MAIN
     2,25678.560,MAIN
     3,25051.370,MAIN
0
     1,1,   0.000,       -60480.41009,    -42760.42602,    10.194
     1,1,   3334.375,    -57359.47412,    -43934.22909,    3.629
     1,1,   3922.329,    -56809.15573,    -44141.20719,    24.641
     2,1,   0.000,       -60537.26579,    -42914.74836,    15.304
     2,1,   3352.527,    -57665.97439,    -44645.38992,    4.278
     2,1,   3461.496,    -57572.64692,    -44701.64210,    12.054
     3,1,   0.000,       -60585.99918,    -43085.31545,    15.613
     3,1,   3420.693,    -57914.20798,    -45221.35680,    3.742
     3,1,   3993.179,    -57467.05759,    -45578.84421,    9.549
0
     1,1,   0.000,       -60480.41009,    -42760.42602,    10.194
     1,1,   33.000,      -60449.52247,    -42772.04304,    9.873
     1,1,   66.000,      -60418.63486,    -42783.66006,    7.591
     1,1,   99.000,      -60387.74724,    -42795.27708,    7.218
     1,1,   132.000,     -60356.85962,    -42806.89410,    7.530
     ...
     1,1,   3922.329,    -56809.15573,    -44141.20719,    24.641
     2,1,   0.000,       -60537.26579,    -42914.74836,    15.304
     2,1,   33.000,      -60509.00274,    -42931.78362,    10.215
     2,1,   66.000,      -60480.73969,    -42948.81888,    8.746
     2,1,   99.000,      -60452.47664,    -42965.85414,    8.312
     2,1,   132.000,     -60424.21360,    -42982.88941,    9.605
     ...
     2,1,   3461.496,    -57572.64692,    -44701.64210,    12.054
     3,1,   0.000,       -60585.99918,    -43085.31545,    15.613
     3,1,   33.000,      -60560.22397,    -43105.92220,    13.051
     3,1,   66.000,      -60534.44875,    -43126.52895,    13.059
     3,1,   99.000,      -60508.67353,    -43147.13570,    11.517
     3,1,   132.000,     -60482.89831,    -43167.74245,    8.988
     ...
     3,1,   3993.179,    -57467.05759,    -45578.84421,    9.549
```

Figure 4.1 The output file of FLODSIM that describes the river network

The file describing the cross-sections that is illustrated in Figure 4.1 consists of three parts. The different parts are delimited with a line that contains a '0'. The first part gives the section id, chainage of the section on the centre line of a channel in meters, and the channel name of each cross section. The second part gives the section id, surface id, the distance in meters from the starting point of the section and the x-, y-, and z co-ordinates of three points for each cross section. These three points include the starting point and ending point of the cross section as well as the point on which the section intersects the centre line of a channel. The last part of the file describes the profile of each cross section. The x-, y-, and z co-ordinates are given for regular points along the line. The user determines the intervals between the points, and for this example a distance of 33m was taken. The cross-sections in the output file will be in the same order in which they were digitised.

4.2.1 The interface between FLODSIM and Mike 11

Mike 11 is a professional engineering software package, developed by the Danish Hydraulic Institute (DHI, 1992). It consists of several modules and can be used for the simulation of flows, sediment transport and water quality in estuaries, rivers, irrigation systems and similar water bodies. The core of the Mike 11 system is the hydrodynamic module, which is an implicit, finite difference model for the computation of unsteady flows. The hydrodynamic module is often applied as a flood management tool to simulate flooding behaviour of rivers and floodplains.

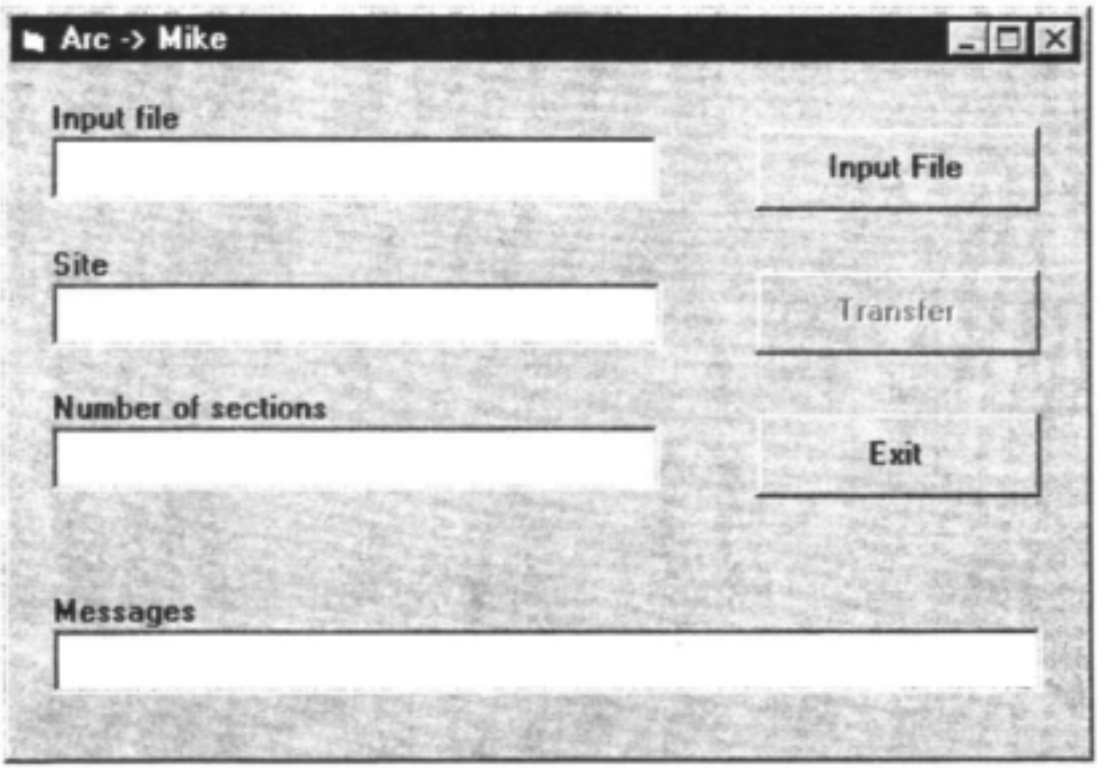


Figure 4.2 The front page of Arc2Mike

Two programs were written for the interface between FLODSIM and Mike 11. The first program, Arc2Mike (see Figure 4.2), does the conversion from the output file of FLODSIM (see Figure 4.1) into a format supported by Mike 11 (see Figure 4.3). The second program, Mike2Arc, converts the Mike 11 output file (see Figure 4.4) into the format of FLODSIM's input file (Figure 4.6). The input and output files of Mike 11 will be described in the remainder of this paragraph.

Mfolozi	*Topographical identification*
MAIN	*River or channel name*
26.453	*Chainage in kilometres*
Co-ordinates	*Explanatory text*
1 -57359.47 -43934.23	*Horizontal co-ordinates*
Profile 121	*Number of x-z co-ordinates*
0.00 10.19	*x1 z1*
33.00 9.87	*x2 z2*
66.00 7.59	*x3 z3*
99.00 7.21	*x4 z4*
132.00 7.53	*x5 z5*
...	
3922.00 24.64	*x121 z121*
********************	*End of the first cross-section*
Mfolozi	*Topographical identification*
MAIN	*River or channel name*
25.679	*Chainage in kilometres*
Co-ordinates	*Explanatory text*
1 -57665.97 -44645.39	*Horizontal co-ordinates*
Profile 107	*Number of x-z co-ordinates*
0.00 15.30	*x1 z1*
33.00 10.22	*x2 z2*
66.00 8.75	*x3 z3*
99.00 8.31	*x4 z4*
132.00 9.61	*x5 z5*
165.00 8.76	*x6 z6*
...	

Figure 4.3 The input file of Mike 11

Cross-sectional data can be read from a text file into the database of Mike 11 (DHI, 1995:2.14). The text files may be in several formats. The format used for the interface is described in Figure 4.3. The cross-sections are specified by a number of x-z co-ordinates where x is the distance from the beginning of the section and z is the corresponding bed elevation. A maximum number of 300 points is allowed for each cross-section (DHI, 1995:2.9). The cross-sections of the input file may be in any order and will be sorted in Mike 11 by channel name and chainage.

Mike 11 can write the results of the simulation to a text file (DHI, 1995:2.14). Mike 11 gives two options for the format of the output file (a summary or time series can be given). The summary file only gives the minimum and maximum water level of the flood for each cross-section. This file can be used when duration of inundation is unimportant as in the case with the Orange River. A file containing a time series is illustrated by Figure 4.4. With this file water levels are given over time-intervals, for example every hour during the total duration of the simulation. The interval can be defined in Mike 11. The channel

name and chainage (in kilometres) identify the cross-sections. The first cross-section in Figure 6.4 is for example 51 metres from the beginning of the main channel. The minimum distance allowed between two cross-sections can be defined in Mike 11 (DHI, 1995:2.22). If the distance between two cross-sections is longer than the defined distance Mike 11 will generate a cross-section at the required position. Hydraulic parameters at these additional cross-sections will be calculated by interpolating between the specified cross-sections. The results of the new cross-sections that were generated by Mike 11 will also be shown in the output file.

```
----------------------------------------------------------------------------
 DATA FILE: MFOLOZI.RDF      BOUNDARY FILE: 10.BSF
 PARAMETER: 10-1.RRF         CALCULATED : 12-JAN-1998, 16:10
----------------------------------------------------------------------------
                      MAIN     MAIN     MAIN     MAIN     MAIN
 HOURS:MIN            0.051    0.231    0.411    0.566    0.721
----------------------------------------------------------------------------
1998 1 1 0 0          12.83    12.67    12.46    12.16    11.77
1998 1 1 1 0          13.05    12.88    12.63    12.28    11.84
1998 1 1 2 0          13.21    13.04    12.79    12.40    11.91
1998 1 1 3 0          13.35    13.18    12.89    12.47    11.97
1998 1 1 4 0          13.47    13.29    12.98    12.53    12.02
1998 1 1 5 0          13.58    13.39    13.06    12.58    12.07
```

Figure 4.4 The output file of Mike 11

Mike2Arc will also determine the elevation where the water will be for longer than a critical period for each cross-section (see Figure 4.5). This is done by determining the duration of the water at levels from the flood peak downward with an interval declared by the user. Suppose the interval is 0.01 m and the flood peak is at 14 m above sea level then the duration of the water has to be computed for 13.99, 13.98, 13.97 ... until the duration is longer than the critical period. To determine the duration at 13.99 the first timestamp where the elevation-time graph crosses 13.99 has to be subtracted from the second timestamp where the elevation-time graph crosses 13.99. The required elevation will then be the first elevation at which the duration is equal to or longer than the critical period. In the case of sugarcane the critical periods would be the periods (for winter and summer) that the plant could be inundated before it is destroyed.

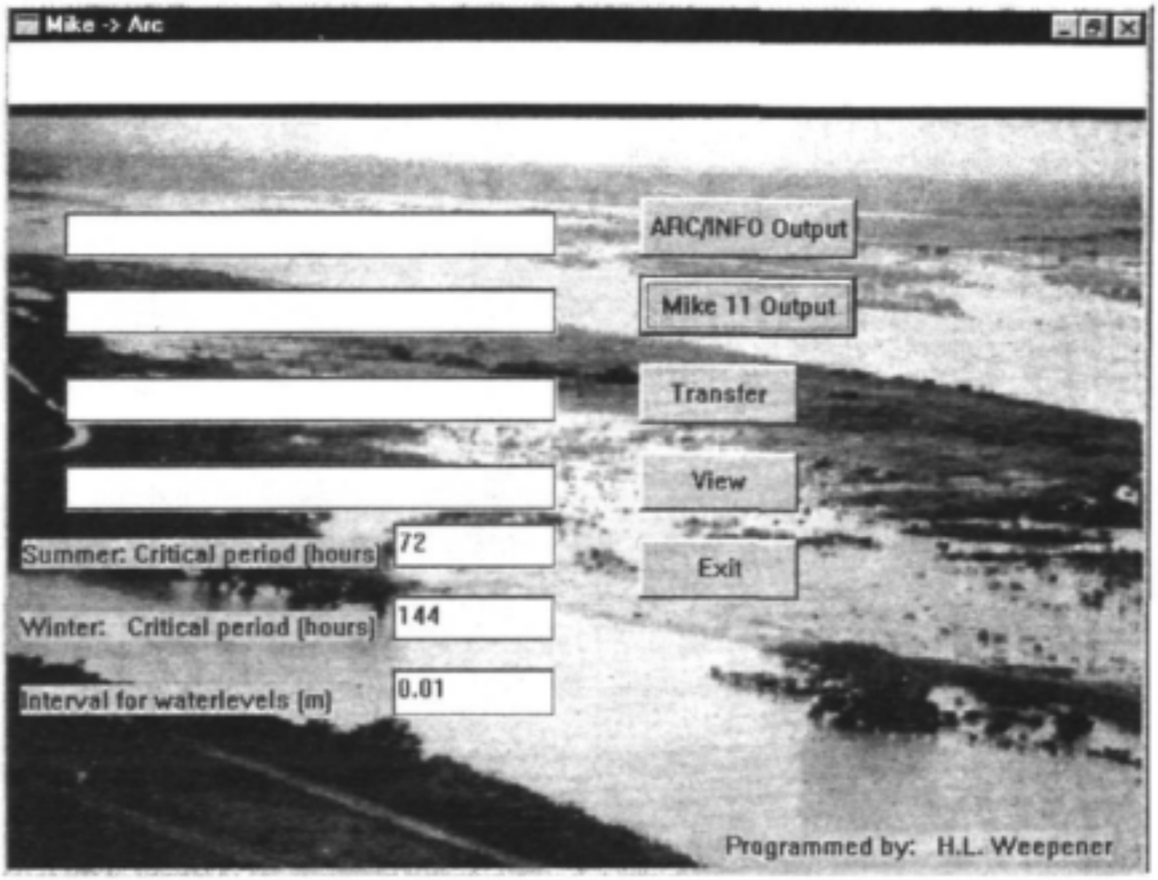


Figure 4.5 The front page of Mike2Arc

Two input files are required by Mike2Arc namely the output file from FLODSIM and the output file from Mike 11. The output file from FLODSIM is necessary to identify the original cross-sections. Only the original cross-sections will be included in the input file of FLODSIM.

4.2.2 Importing hydraulic data into FLODSIM

The input file required by FLODSIM must consist of at least three columns namely the channel name, chainage and flood peak of each cross-section (see Figure 4.6). Any number of additional fields may be added after the flood peak to provide for loss functions that are based on other flood characteristics. The same calculations, which are done for the flood peak, will also be done for the additional fields. Two additional fields were for example used for the Mfolozi River. Sugarcane may only be inundated for a certain period before it would be damaged. This period differs between winter and summer. The two fields that were added for the Mfolozi River represent respectively the elevation at which the water would stay for the critical periods (for the winter and summer) or longer.

Channel name	*Chainage*	*Flood peak*	*Summer*	*Winter*
MAIN,	51.00,	15.36,	14.23,	13.22
MAIN,	411.00,	14.56,	13.57,	12.81
MAIN,	721.00,	13.58,	12.50,	11.93
MAIN,	1196.00,	13.02,	11.80,	11.03
MAIN,	1682.00,	12.83,	11.72,	11.01
MAIN,	2196.00,	12.70,	11.68,	10.99
MAIN,	2665.00,	12.55,	11.62,	10.98
MAIN,	3144.00,	12.08,	11.35,	10.86

Figure 4.6 Input file for FLODSIM

The hydraulic properties for cultivated fields and buildings are saved in info-files. Only the distance of infrastructures that are inundated is computed for infrastructures.

A relate environment is automatically established by the system. The AML program files that determines the flood damage for buildings and cultivated fields use these relates to find the hydraulic properties of a specific entity in the corresponding table. The relates are respectively *rel_p_c* and *rel_p_b* for cultivated fields and buildings (*p* indicates the hydraulic property). The relates are automatically updated when the flood frequency change. The same names can therefore be used for all the flood frequencies. The distance of infrastructures that are inundated can be read from variables named *.i_inundation_length_ff_infra* (where *infra* indicates the symbol that are associated with the specific infrastructure category and *ff* the flood frequency)

CONSTRUCTION OF NEW LOSS FUNCTIONS

5.1 INTRODUCTION

Loss functions are usually constructed by agricultural economist specialists. Viljoen (1979:160-161) suggests that a combination of inductive- and deductive methods be used to develop loss functions. Reported damages of real floods are used with the inductive method, while flood damage is determined independently of real floods with the deductive method. The main advantage of the inductive method is that the relationships are based on real floods. With the deductive method relationships for different frequencies of floods can be determined in the absence of historical data.

It is difficult to quantify the amount of work that will have to be done to construct new loss functions and it will differ for different crop types. The most time will however go into the research work that has to be done by an agricultural economist. The programming of additional loss functions after it was constructed will not take long. The following paragraph will give some guidelines for the implementation of the loss-functions that were constructed by the agricultural economists. The access to hydraulic properties was already described in Paragraph 4.2.2 and will not be repeated in this paragraph.

5.2 HANDLING OF DIFFERENT CROP- AND INFRASTRUCTURE TYPES

A naming convention is used in FLODSIM to recognise the programs that calculate flood damage to different crops and infrastructures. Standard input and output variables are also used in these programs.

A symbol consisting of two letters is used to identify the crop- or infrastructure types. The AML program filenames for harvest-, crop- and soil damage should for example be hd_*crop*.aml, cd_*crop*.aml and sd_*crop*.aml (*crop* should be replaced with the two letters of the crop symbol). The filenames for flood damage to infrastructure should be fd_*infra*.aml (*infra* should be replaced with the two letters of the infrastructure symbol). A menu file with the name impact_c_*crop*.menu and impact_i_*infra*.menu can be used as interface with the user (*crop* and *infra* are again the symbols for the entities). This menus will be called from the primary impact menu (see Paragraph 2.3.10.1 and Paragraph 3.3.2.1). The values that are acquired can be written to a file with the name defaults_c_*crop*.aml or defaults_i_*infra*.aml. These files are called by defaults.aml if they exist.

A naming convention is also used for variable names. The Setup program will automatically check the cultivated fields and infrastructure coverages for the different symbols that are used. The number of crop symbols that are found is allocated to a variable called .c_number. The Setup program numbers the crop symbols and each individual crop symbol is allocated to .c_symbol_*i* (where *i* is the number that is assigned to the specific crop type). The user will be prompted to give a description and colour value for each crop type that will be saved as .c_type_*i* and .c_value_*i* respectively. The variable names for infrastructures are .i_number, .i_symbol_*i*, .i_type_*i* and .i_value_*i*.

Each AML program file (hd_*crop*.aml, cd_*crop*.aml, sd_*crop*.aml and fd_*infra*.aml) should have an argument for the number that was assigned to the crop or infrastructure type. This number should be used in the variable name for the expected total damage that was calculated by the program. The variables that are used to save the total harvest damage, total soil damage or total crop damage for the first crop type should respectively be named *.tot_hd_1*, *.tot_sd_1* and *.tot_cd_1*. The total damage for the first infrastructure type should be saved as *.tot_fd_i_1*.

FLODSIM will first check if the program exists before it will try to run it. If the program does not exist the damage will be considered as zero. This might be the case for annual crop types where there is no damage to the crop, but only damage to the harvest and the soil. At the moment programs exist to determine flood damage to vineyards, lucerne, rotational crops and sugarcane.

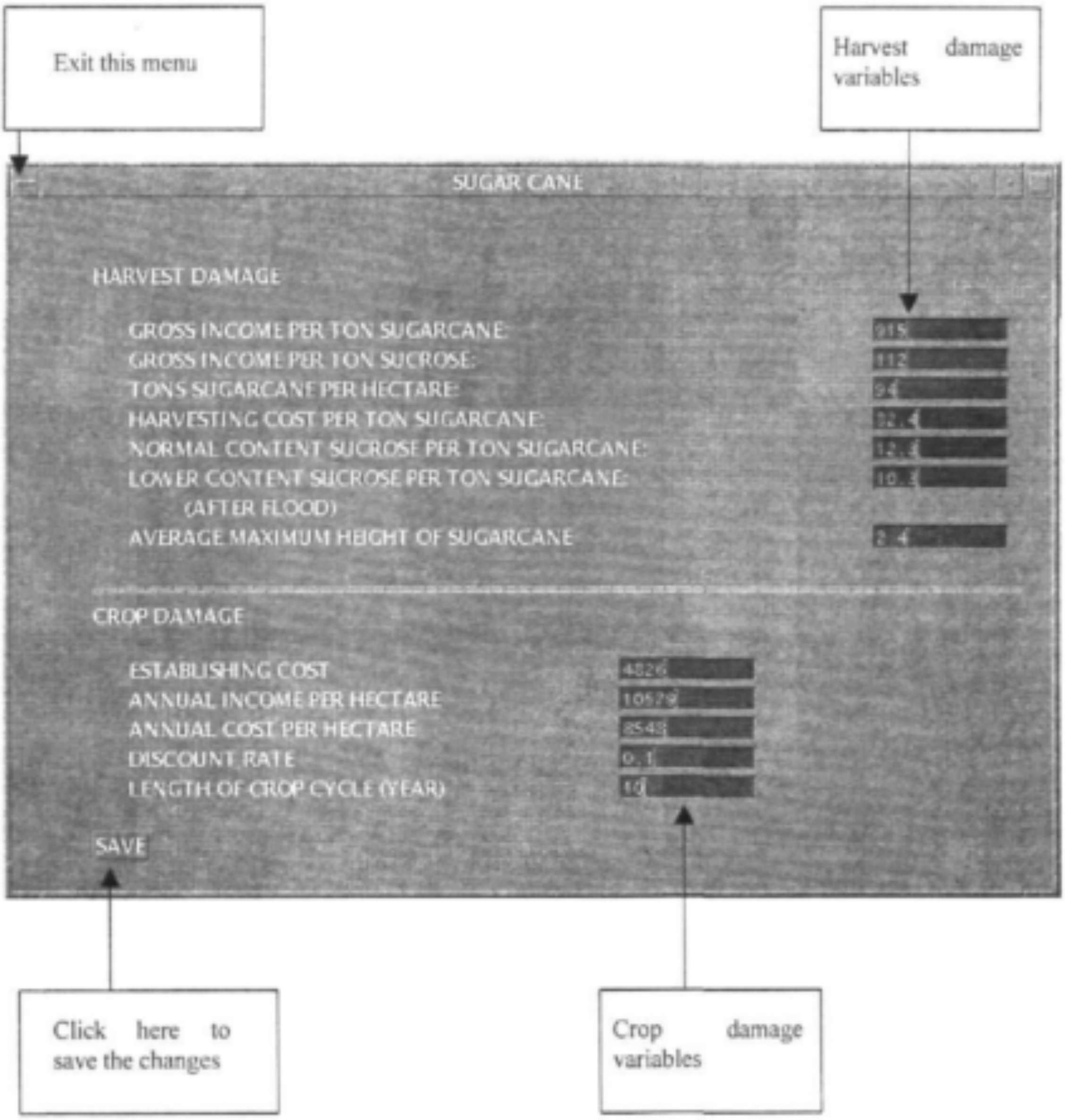
PROVISION FOR NEW LOSS FUNCTIONS

I.1 LOCATION SPECIFIC LOSS FUNCTIONS

Several loss functions were developed for the Lower Orange River area and for the Mfolozi floodplain that are location specific. Loss functions that were developed specifically for the Lower Orange River area include loss functions for fallow lands, and loss functions to determine soil damage to cultivated fields (vineyard, lucerne and rotational crops). Loss functions for railways, roads, bridges, drains, levees, and spillways were developed for the Mfolozi floodplain.

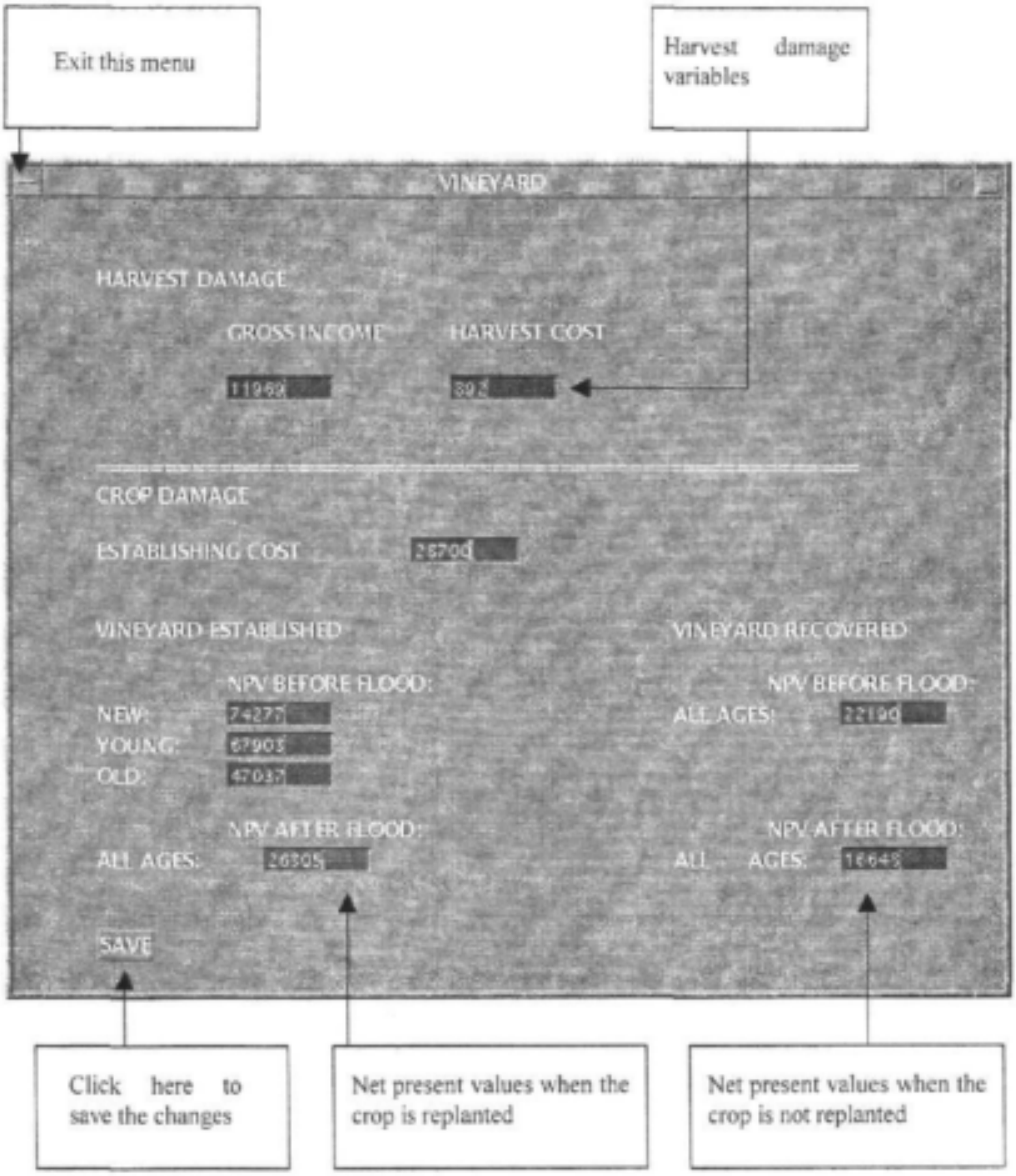
A.2 SUGAR CANE

The symbol used for sugar cane is 's'. Sugarcane may only be inundated for a certain period before it would be damaged. This period differs between winter and summer. Two additional hydraulic characteristics are therefore required. The two characteristics represent respectively the elevation at which the water would stay for the critical periods (for the winter and summer) or longer. The menu looks like this:



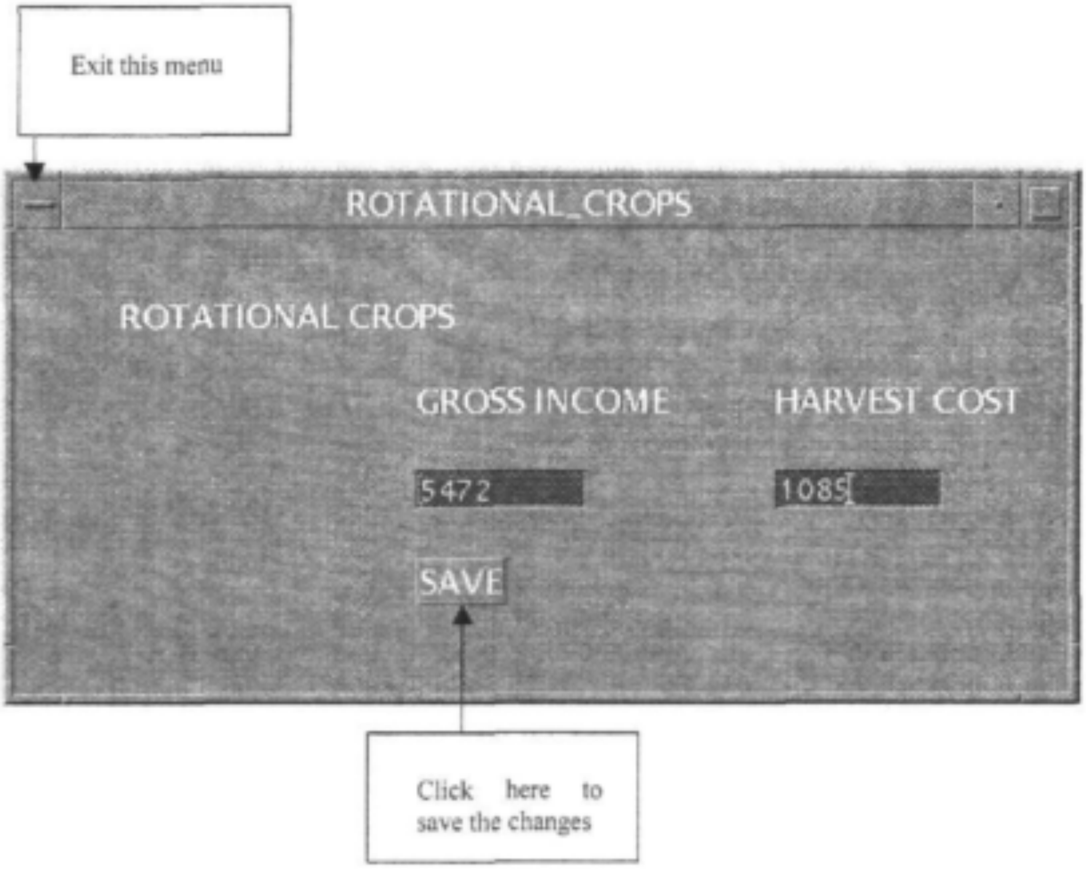
A.3 VINEYARD

The symbol used for vineyard is 'v'. The menu looks like this:



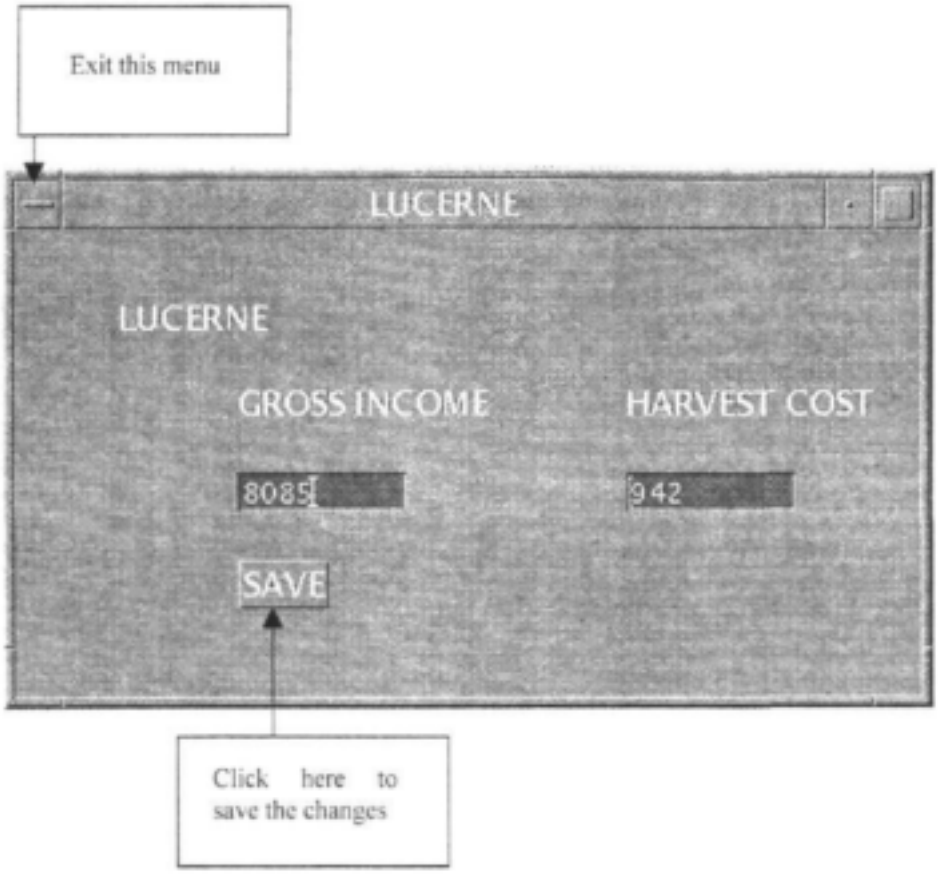
A.4 ROTATIONAL CROPS

The symbol used for rotational crops is 'rc'. The menu looks like this:



A.5 LUCERNE

The symbol used for lucerne is 'l'. The menu looks like this:



ANNEXURE 4

TEWA MANUAL

ANNEXURE 4

User's plus technical guide - TEWA

Introduction

In this section the User and Technical Guide will be presented to assist the user in the application of the TEWA model in urban flood plain management. The main aim of the User Guide is to give the user the knowledge about how to organize the information needed to calculate flood damage with **TEWA**. In other words the methods to get the model in a state to calculate flood damage, will be presented.

With the Technical Guide the purpose is to show the user how to use the software to calculate flood damage for different flood scenarios. The processes that start with creating an output file and end with a report depicting the damages, will be describe.

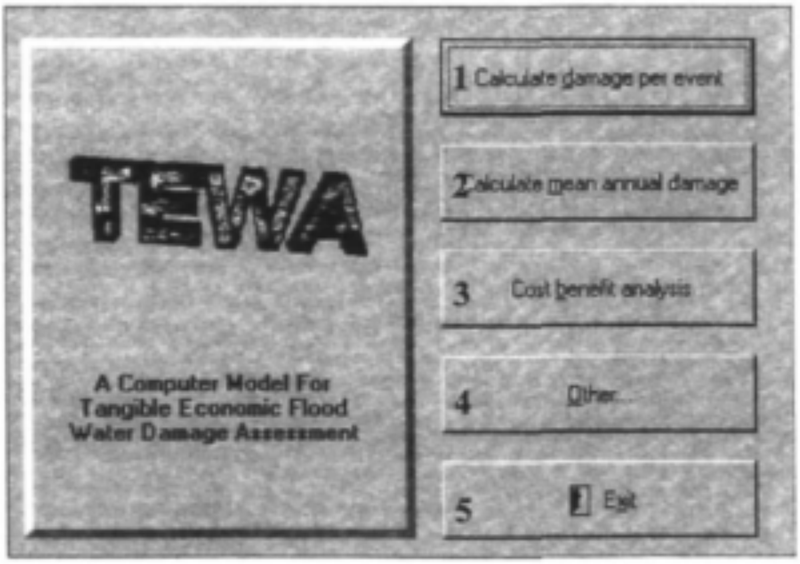
TECHNICAL GUIDE

Calculation of flood damage by using TEWA

The following section describes the method to calculate potential flood damage for a flood plain by using the computer application: **TEWA**. It starts with creation an output file and ends with a presentation of the total damage.

Procedure for using TEWA

If TEWA is not open, open it by clicking on the specified button.



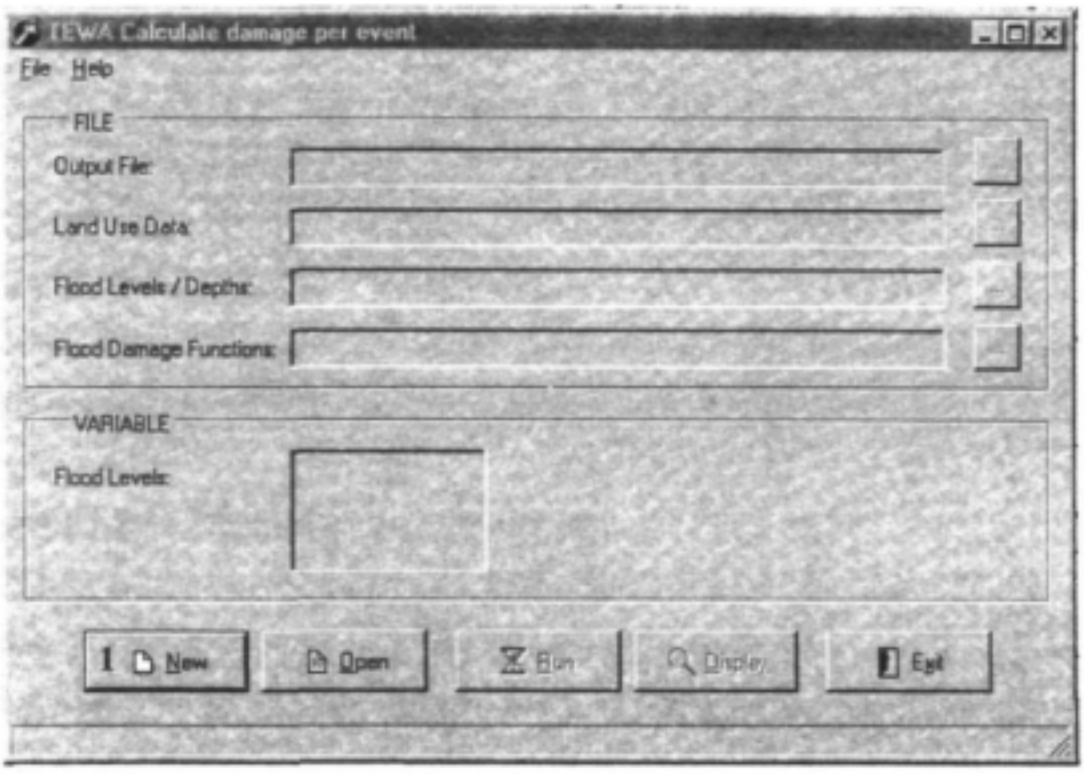
Five options are now available

1. Calculate damage per event
2. Calculate mean annual damage
3. Do cost benefit analysis
4. Join tables and import
5. Exit

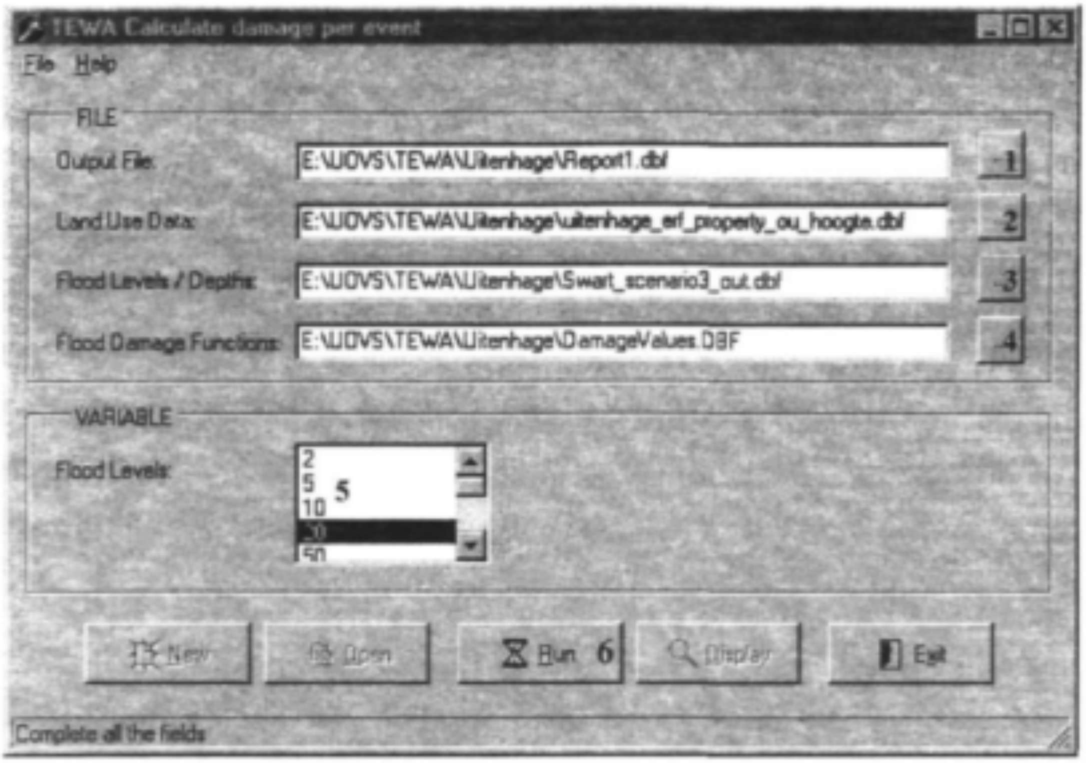
Each option will subsequently be discussed

Calculate damage per event

1. Select New to start a new calculation.



Next:



1. Create an output file.

The output file will contain the plot number, damage class, the depth of inundation and damage per property for the specified simulation.

- Navigate to the required directory
- Write the name of the output file (It is important that this name represents the simulation that must be executed, for example "Uitenhage_100" as an output file for the simulation to calculate the flood damage of a 1:100 year flood)
- Click on "Save" to save the file.

2. Select the Land Use Data File:

- Navigate to the required directory
- Select the Land Use Data File
- Open the file.

3. Select the hydrological data file (Flood levels/depth):

The same procedure followed to activate the Land Use Data file, must be followed to activate the Hydrological Data file.

4. Select the Flood Damage Function file:

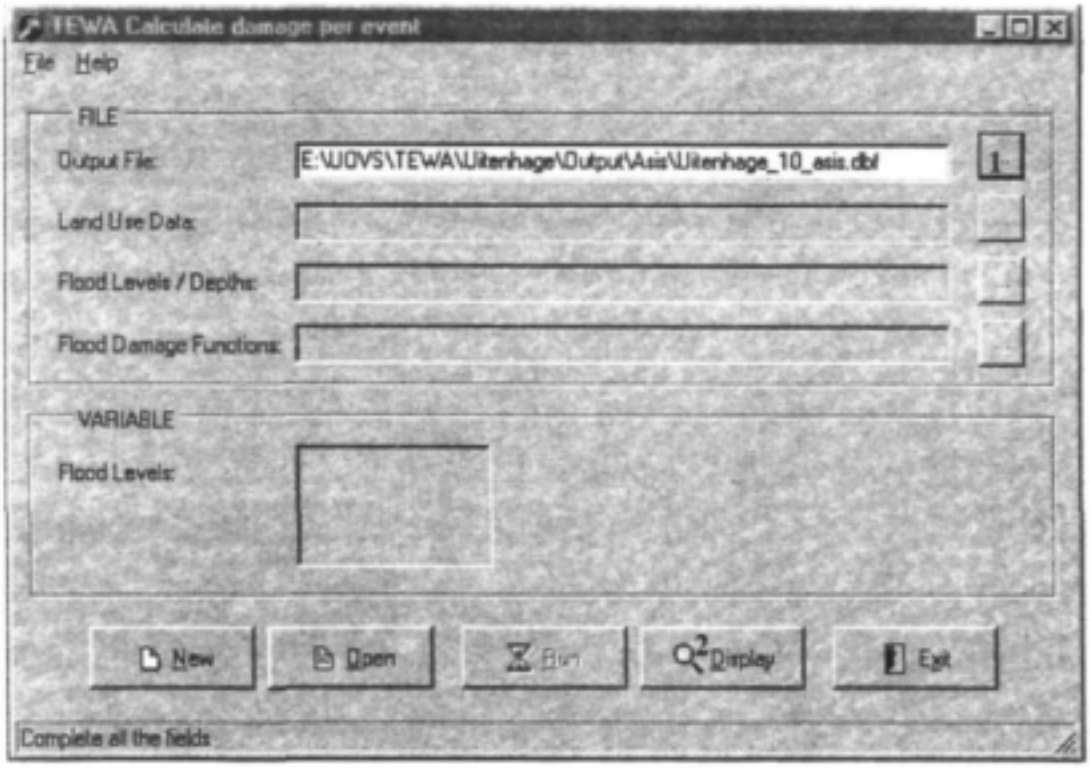
The same procedure followed to activate the Land Use Data file, must be followed to activate the Flood Damage Function file.

5. Select the event (flood frequency) for which the damage must be calculated by highlighting the relevant flood year in the Flood Levels section.

6. Click "Run" to execute the operation.

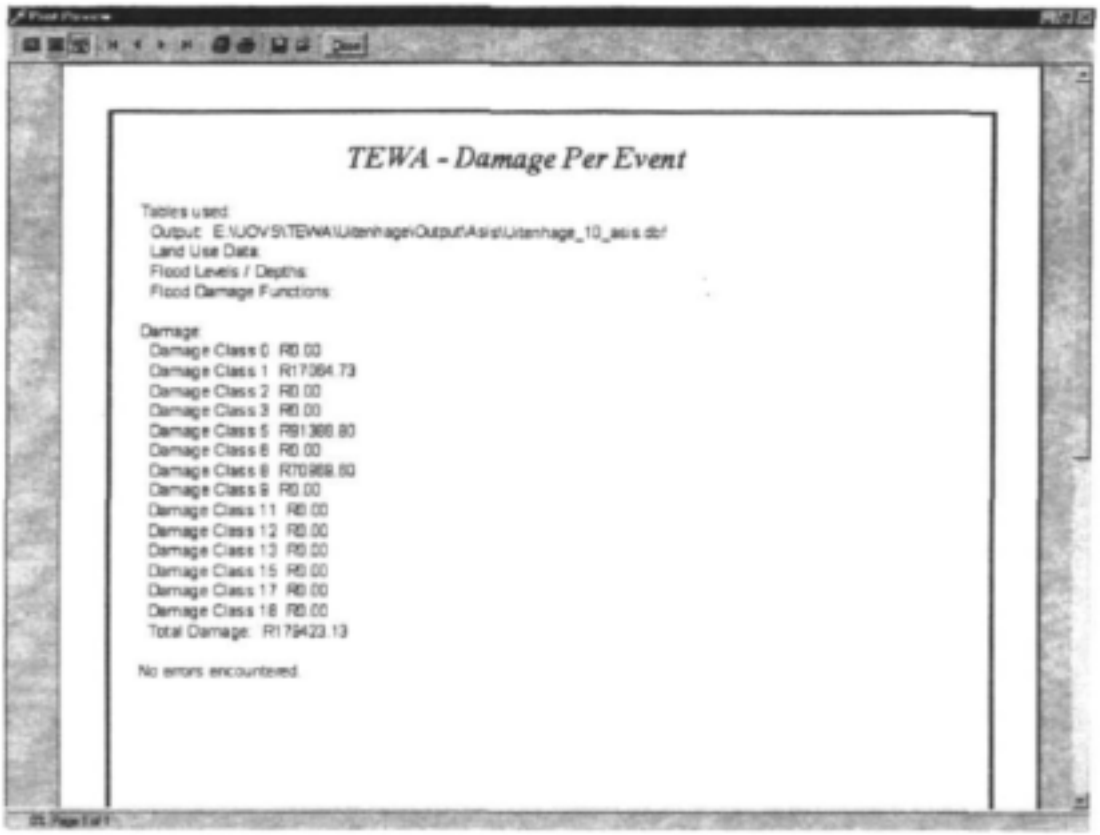
Display damages

The calculated damages can be displayed by using two methods. It can be displayed right after the calculations or an output file can be retrieved to view the damages. In the first case "Display" must be selected.



In the second case:

1. Select the output file.
2. Display the results.



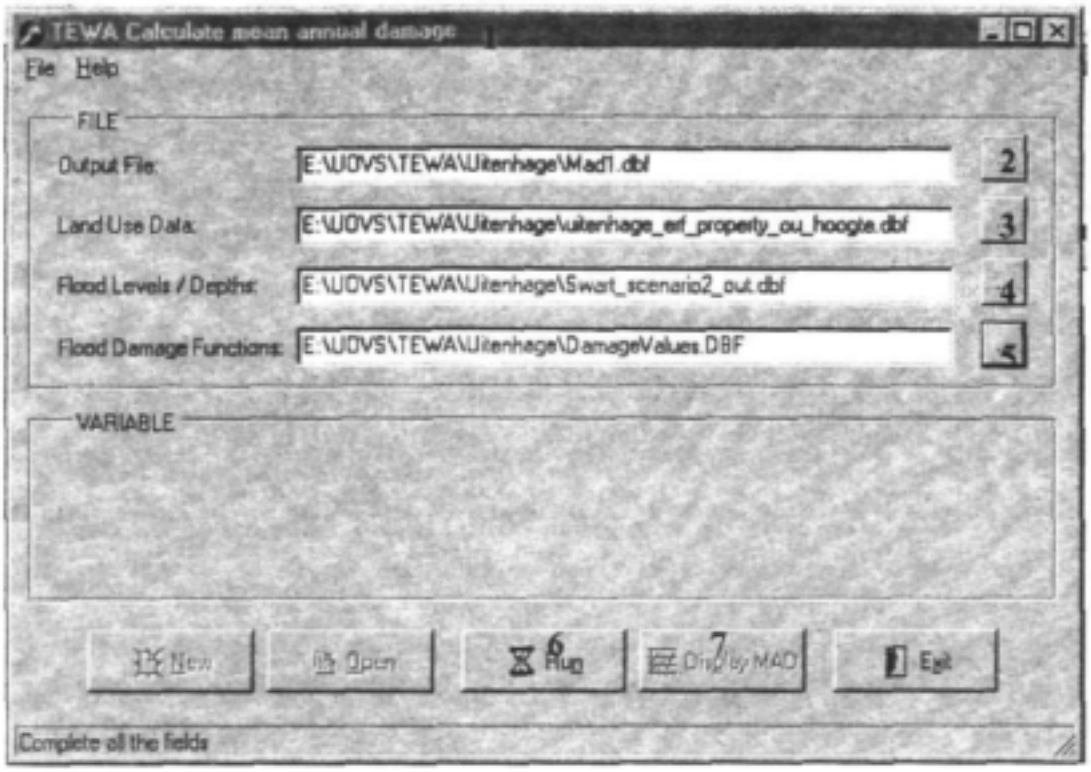
TEWA - Damage Per Event

Tables used:
Output: E:\UOVS\TEWA\Uitenhage\Output\Asis\Uitenhage_10_asis.dbf
Land Use Data:
Flood Levels / Depths:
Flood Damage Functions:

Damage:
Damage Class 0 R0.00
Damage Class 1 R17064.73
Damage Class 2 R0.00
Damage Class 3 R0.00
Damage Class 5 R91388.80
Damage Class 6 R0.00
Damage Class 8 R70969.60
Damage Class 9 R0.00
Damage Class 11 R0.00
Damage Class 12 R0.00
Damage Class 13 R0.00
Damage Class 15 R0.00
Damage Class 17 R0.00
Damage Class 18 R0.00
Total Damage: R179423.13

No errors encountered.

Calculate Mean Annual Damage



1. Select MAD

2. Create the Output File.

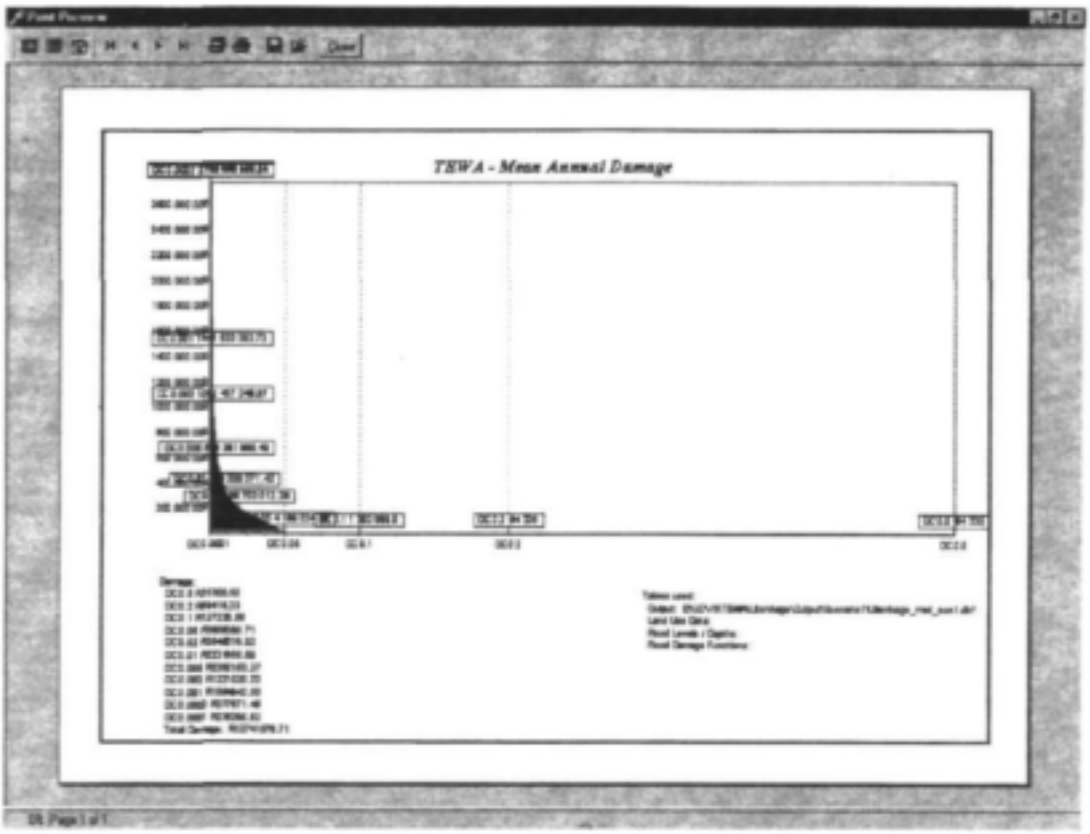
3. Select the Land Use Data file.

4. Select the Hydrological Data file.

5. Select the Flood Damage Function file.

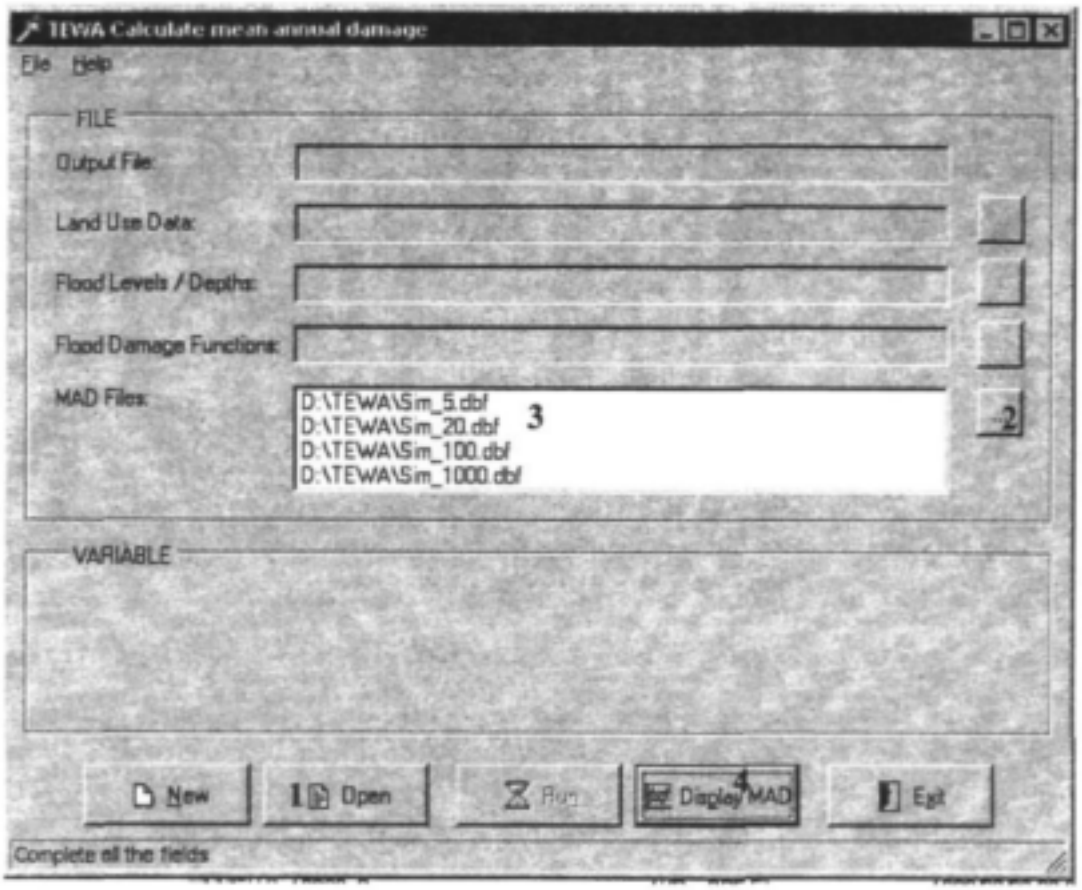
6. Click "Run" to execute.

7. Click "Display Mad" to display the MAD.



In the figure above the output, land use, hydrological and flood damage data files that were used in the simulation are shown. This enables the user to keep track of the files that were used.

The first method of calculating mean annual damage entails that flood damages must be calculated each time when the function is executed and this can be a very lengthy process. If the flood damage for each event is already calculated the second approached can be used.



1. Select open

2. Select the output files from previous calculated events

3. It is important to select the output files in the correct order

4. Click "Display MAD" to display the MAD.

GIS-linking

The output file of TEWA can be linked to a GIS-database of the study area. The method to do this, is by using an attribute that is common to both data sets. In most cases the unique number will be plot numbers.

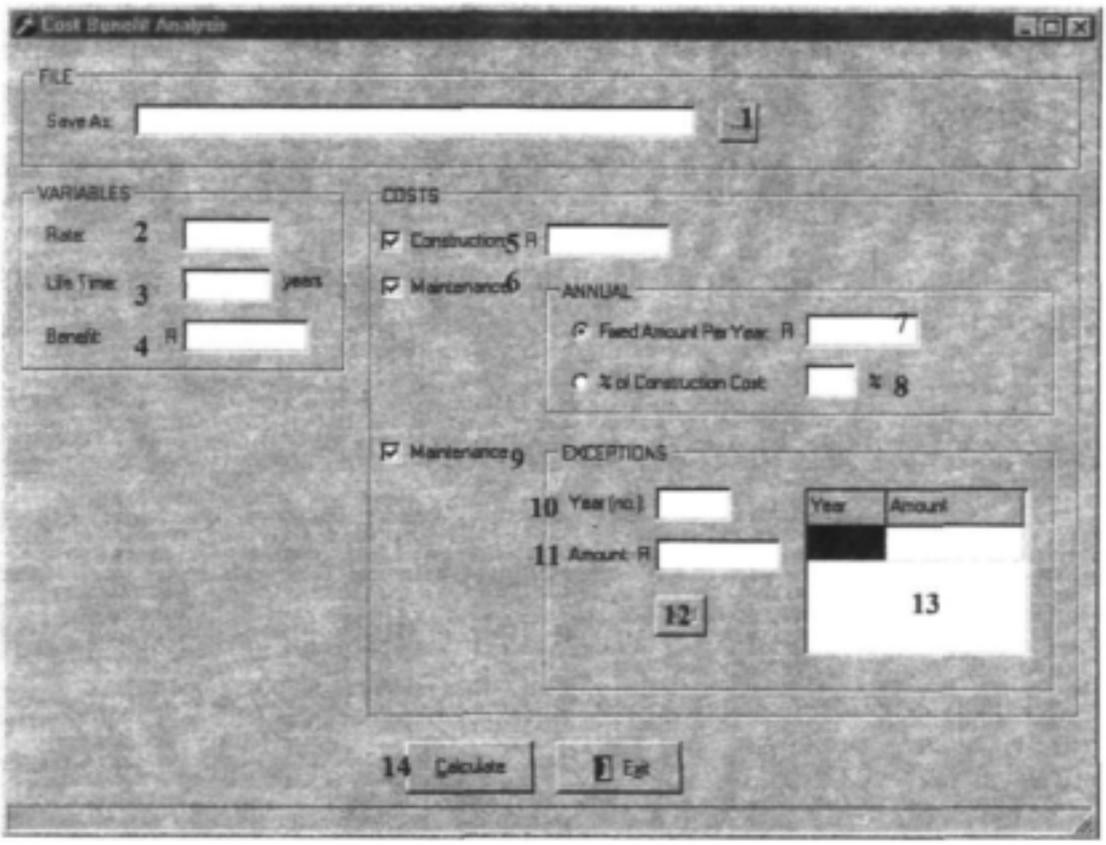
Cost Benefit Analysis

The cost benefit analysis application of TEWA do simple cost benefit calculations to evaluate different scenarios. The first step in this application is to specify the output location. In this case it can be a dBase file, a text file or a copy to the clipboard. This copy can be passed on to an appropriate report.

Three types of costs are typed in. The first is construction cost, the second maintenance cost, which can be typed in as a fixed amount or as a percentage of construction costs.

Other costs that can occur during the life span of the structure can be typed in by activating the "other cost" window. In this window the specific year and the amount for that year must be specified

After the input is completed the "calculate" button must be clicked to start the calculations.



1. Specify the output file.
2. Specify the discount rate.
3. Specify the economic life of the flood control measure in years.
4. Specify the yearly benefit (MAD)
5. Specify the construction cost.
6. Select "maintenance" if there is maintenance cost involved.
7. Specify the maintenance cost of the measure, if a fixed amount per year is relevant.
8. Specify the maintenance cost of the measure in terms of a percentage of the construction cost, if this option is relevant.

9. Click this maintenance button if maintenance cost if maintenance cost is not a fixed amount per year but can be specified at certain years in the life time of the measure, for example if at the tenth year the measure must be repaired after a flood event.

10. Specify the year of the cost.

11. Specify the amount of maintenance cost.

12. Select the "Add" button to add the year to selection (13).

14. Select "calculate" to execute the calculation.

Import of data

In normal cases the hydrological data will look like that in Table 1. But for TEWA to use the data it must be presented in the format of Table 2.

Table 1 Hydrological data for use by TEWA for the calculation of flood damage

Flood frequency in years

(Flood elevation in meters)

CSECTION	2	5	10	20	50	100	200	500	1000	5000	10000
48	47.07	47.66	47.96	48.29	49.10	49.32	49.85	50.60	51.21	52.40	52.73
47	44.82	45.57	45.96	46.28	47.26	47.45	48.01	48.71	49.06	50.28	50.63
46	42.91	43.61	43.97	44.23	45.03	45.23	45.49	46.02	46.49	48.01	48.47
45	41.85	42.48	42.81	43.09	44.04	44.32	44.78	45.31	45.78	47.29	47.74
44	39.79	40.56	40.96	41.32	42.39	42.88	43.80	44.11	44.45	45.62	45.97
42	39.16	40.02	40.42	40.78	41.74	41.96	42.66	43.45	43.66	44.73	45.01
41	35.35	35.99	36.32	36.61	37.63	37.92	38.00	38.39	38.84	40.48	41.06
40	31.31	32.23	32.68	33.06	34.32	34.66	35.39	36.26	36.93	39.07	39.86
39	31.14	32.02	32.47	32.65	34.11	34.44	35.20	36.08	36.74	38.90	39.71
38	30.97	31.69	32.10	32.47	33.75	34.10	34.84	35.79	36.51	38.81	39.65
37	30.17	31.03	31.53	31.96	33.37	33.73	34.48	35.53	36.27	38.65	39.52
36	29.44	30.49	31.03	31.48	32.94	33.31	34.06	35.05	35.89	38.38	39.30
34	29.14	30.22	30.74	31.18	32.60	32.97	33.67	34.57	35.19	38.15	39.12
33	27.72	28.79	29.41	29.90	31.45	31.83	32.49	33.66	34.70	38.00	39.00
32	26.57	27.94	28.67	29.25	30.99	31.41	32.21	33.48	34.54	37.92	38.93
30	26.23	27.78	28.52	29.11	30.85	31.27	32.17	33.45	34.53	37.91	38.92
29	26.02	27.74	28.49	29.09	30.83	31.26	32.15	33.44	34.51	37.90	38.91
	25.06	26.60	27.31	27.81	29.21	29.57	30.35	31.37	32.21	34.88	35.62
27	24.01	25.25	25.75	26.10	25.62	25.80	26.23	26.86	27.35	28.09	28.29
26	22.43	22.99	23.30	23.61	24.65	24.88	25.35	26.35	27.22	28.61	29.23
25	20.36	21.63	22.21	22.70	23.93	24.13	24.33	25.61	26.87	28.28	28.64
24	19.79	20.99	21.58	22.05	23.09	23.09	23.76	25.50	26.55	27.73	28.01
22	19.41	20.44	20.99	21.36	22.40	22.66	23.25	23.99	24.59	26.57	27.14
21	18.96	20.17	20.76	21.10	22.14	22.40	22.96	23.71	24.29	26.21	26.75
20	18.58	19.71	20.19	20.52	21.48	21.72	22.28	23.00	23.53	25.41	25.95
19	18.03	18.93	19.31	19.58	20.45	20.64	21.28	21.97	21.68	22.82	23.26
18	15.55	16.11	16.51	17.03	18.20	18.47	18.35	18.90	19.25	21.39	21.77
17	12.72	13.85	14.42	14.84	16.02	16.36	16.82	17.42	17.69	20.67	20.91
16	12.30	13.42	13.97	14.32	15.33	15.64	15.98	17.31	17.53	20.59	20.81

Table 2 Hydrological data in the format that are used by TEWA

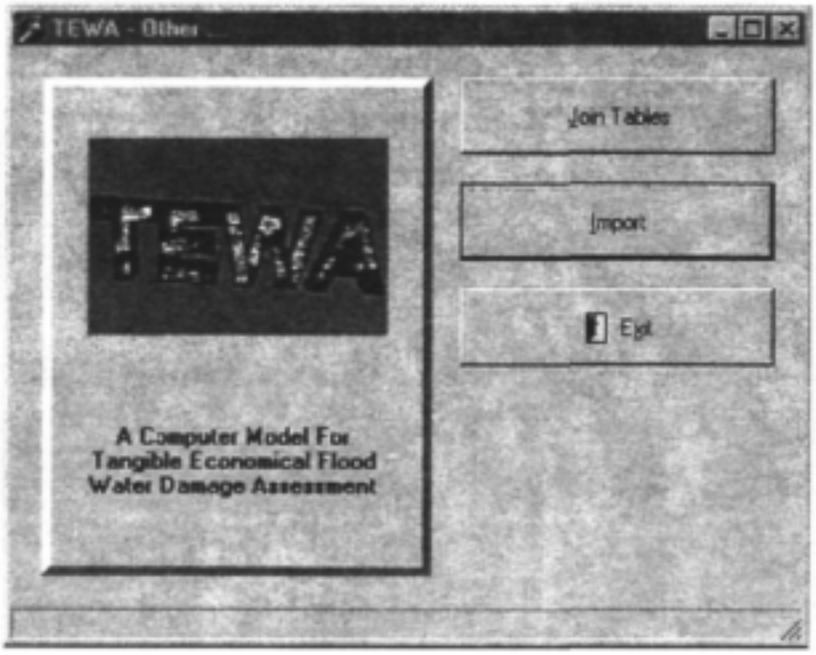
CSECT	FLEVEL	FDEPTH
48	2	47.07
48	5	47.66
48	10	47.96
48	20	48.29
48	50	49.10
48	100	49.32
48	200	49.85
48	500	50.60
48	1000	51.21
48	5000	52.40
48	10000	52.73
47	2	44.82
47	5	45.57
47	10	45.96
47	20	46.28
47	50	47.26
47	100	47.45
47	200	48.01
47	500	48.71
47	1000	49.06
47	5000	50.28
47	10000	50.63
46	2	42.91
46	5	43.61
46	10	43.97
46	20	44.23
46	50	45.03
46	100	45.23
46	200	45.49
46	500	46.02
46	1000	46.49
46	5000	48.01
46	10000	48.47

CSECT = Cross section;

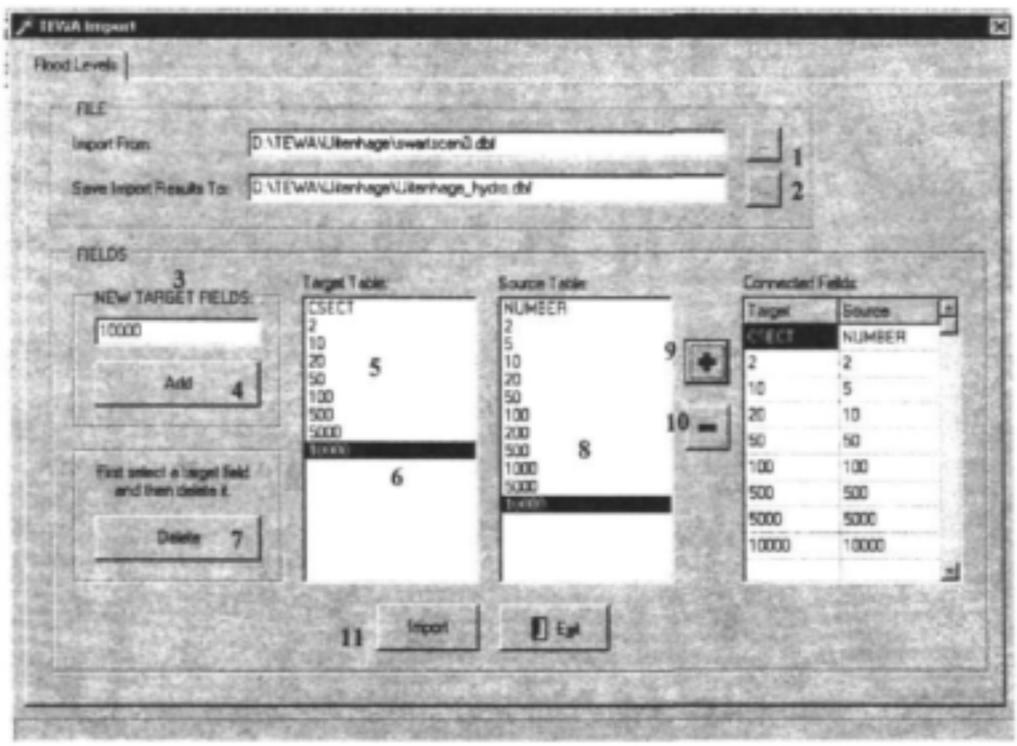
FLEVEL = Flood frequency/event in years

FDEPTH = Flood elevation in meters

To get from Table 1 to Table 2 the other the following procedure must be used.



Select "Import" under the Other application.



1. Select the input file.

2. Select the output file.

3. Select the new target fields.

4. Add this field to the new table (5).

6. Select the field and the corresponding flood event (8).

7. If it is necessary to delete a field, select :"Delete".

9. Add the event to the output table.

10. If it is necessary to remove the event, select :"-".

11. Select "Import" to execute the procedure.

The same procedure must be applied to import the flood damage functions.

The inputs of the computer model

As stated previously the three important inputs to the model are land use data, flood damage functions and hydrological data. The format of the input data must be in a specific format before it can be used in TEWA. The handling of hydrological data was explained in the previous section.

The land use data must be in the following format (Table 3).

Table 3 Land use data used by TEWA to calculate flood damages

PNR	CSECT	GHEIGHT	DCLASS
8101	33	31.700	18
8834	33	30.000	15
7382	33	33.200	15
7383	34	34.500	17
8333	34	34.000	15
5169	34	34.200	15
6820	34	34.200	17
12155	34	34.500	15
17655	34	34.200	15
7402	32	31.000	13
153	32	31.000	18
155	30	30.000	15
154	30	30.000	17
137	30	32.000	18
15405	32	32.000	15
8334	34	34.200	1
19036	37	35.400	15
19066	36	34.800	17
19036	37	35.400	15
15873	38	36.600	11
13096	39	36.600	11

PNR represents the plot number, CSECT the zone in which the property is situated or the cross-section with which the property is linked for the hydrological data. GHEIGT is the floor height of the property plus the ground height at that location (in meters). DCLASS is the damage function of the property. If other information about the property is needed, it can be part of the GIS-database.

The table below represents the flood damage function. In Table 4 damage in Rand for different depths of inundation and categories of properties are shown.

Table 4 Flood damage in Rand for different depths of inundation (metre) and categories of properties used by TEWA to calculate flood damage

Category	Depth of inundation (m)											
	0	0.05	0.1	0.2	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4
1	11	65	118	220	316	568	768	915	1009	1051	1051	1051
2	32	226	414	773	1109	1981	2648	3109	3366	3417	3417	3417
3	148	323	494	822	1129	1931	2552	2991	3249	3327	3327	3326
4	72	465	847	1575	2256	4017	5355	6269	6759	6827	6827	6826

As in the case of the hydrological data, the data in Table 4 must be converted to the format of Table 5 before it can be used in TEWA. The same method can be used, as with hydrological data, to transform the data.

Table 5 Flood damage function data in the format that are used by TEWA

DCLASS	WDEPTH	DVAL
1	0.00	0.00
1	0.10	143.43
1	0.20	267.42
1	0.30	384.11
1	0.60	1905.97
1	0.90	2149.08
1	1.20	2327.76
1	1.50	2442.02
1	1.80	2493.07
1	2.10	2493.07
1	2.40	2493.07
2	0.00	0.00
2	0.05	392.62
2	0.10	600.48
2	0.20	999.17
2	0.30	1372.35
2	0.60	3562.75
2	0.90	4317.60
2	1.20	4851.22
2	1.50	5164.83
2	1.80	5259.65
2	2.10	5259.65
2	2.40	5258.43

DCLASS = damage function of property

WDEPTH = depth of inundation in metre

DVAL = damage in Rand

ANNEXURE 5

FLODCAL MANUAL

Acknowledgement

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Programming

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Contents

Introduction

FlodCal support five sectors: Agricultural, Residential, Commercial, Industrial and Informal Settlement. Questionnaires on each of the named sectors could be completed, and calculations done according to the data typed in by the user. Since some of the sectors have too many questionnaires, images of all the different forms could not have been included in this user guide. Though, a diagram of all the forms in all the sectors is included (page 11). The diagram provides a quick overview of all the questionnaires.

The program is released in English only. In the Edit-menu | Languages, other languages could be added. This option is to be developed in future, thus it could be ignored by all users. It will have no effect if any other language is selected or a new language is added.

Detail user guide of Flodcal can be downloaded: http://www.uovs.ac.za/agric/watees

Getting Started

System Requirements

The minimum system requirements in order to install FlodCal is:

- 486 processor or higher
- 16 MB RAM
- 5 MB free space on your harddisk
- Microsoft Windows 95 or later

Installing FlodCal

The following procedure describes how to install FlodCal.

- Make sure that your PC is turned on and your operating system (e.g. Microsoft Windows 95) has started.
- Insert the FlodCal CD-ROM in your CD-ROM drive.

The setup program will start automatically. If not, follow the rest of the steps.

- In the Start Menu, choose Run.
- Type `d:\setup.exe`, where `d` is the letter of your CD-ROM drive, and press ENTER.
- Follow the instructions on the screen.
- When the installation of FlodCal is finished, you have to restart your computer.

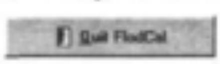
Note You have to type your name as well as the name of your company.

Starting FlodCal

The Setup program creates a FlodCal program folder (or other if you specified) in your Start Menu containing the FlodCal icon. To start FlodCal, click Start | Programs | FlodCal | FlodCal.

Quitting FlodCal

There are several ways to exit FlodCal. You can:

- Click on  in the main menu.
- Choose Exit from the File menu.
- Click on  in the topright corner.
- Press Ctrl-X.
- Press Alt-F4

Please note that you have to be at the main menu (New Questionnaire; View a Record; Quit Flodcal) to quit FlodCal.

Working with FlodCal

When FlodCal starts, the main menu appears:

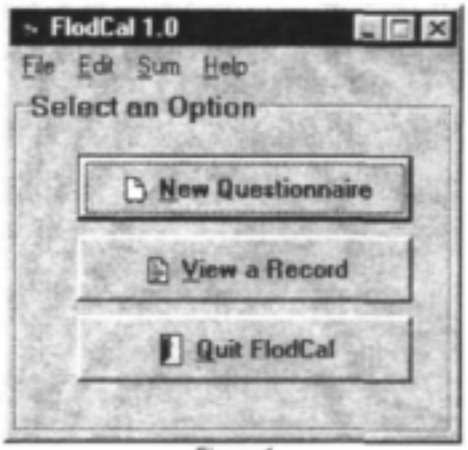


Figure 1

New Flood

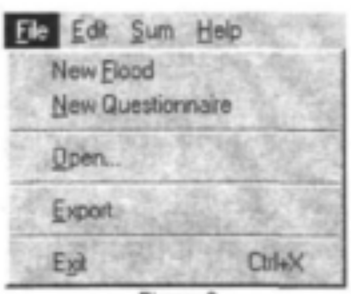
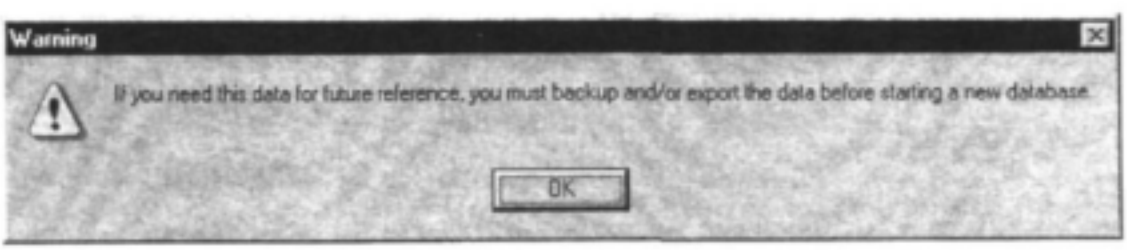
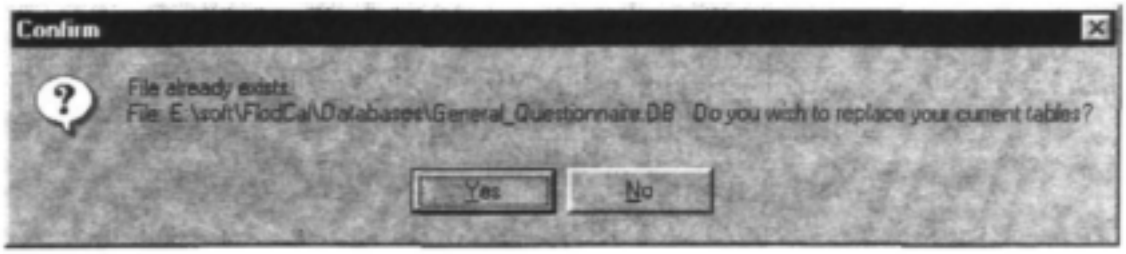


Figure 2

Open the File menu by clicking on File, or press Alt-F. Choose New Flood. If previous databasis-files already exist, the following boxes will appear on the screen.



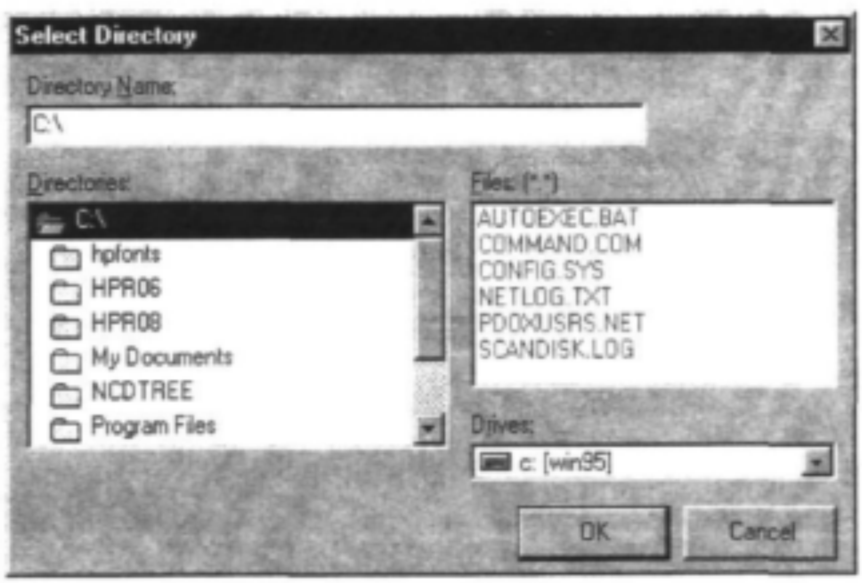
Click on 
.



Click on [Yes] in the Confirm-box, if you want to begin a new flood. Please be sure that the data of your previous flood is backed up, because the new flood's data will be written over the previous flood's. If the data of the previous flood has not been exported or backed up, click on [No] and go to the section "Export".

Export

In the File menu (Figure 2), choose Export.



Select the appropriate drive on which you want to export the data, by clicking on [▼] in the drives-box: [c: [win95]]. Select the appropriate directory (folder) in the directories-box or type the directory-name in at the top: [C:\]. The data will be exported to the drive and folder you have chosen.

New Questionnaire

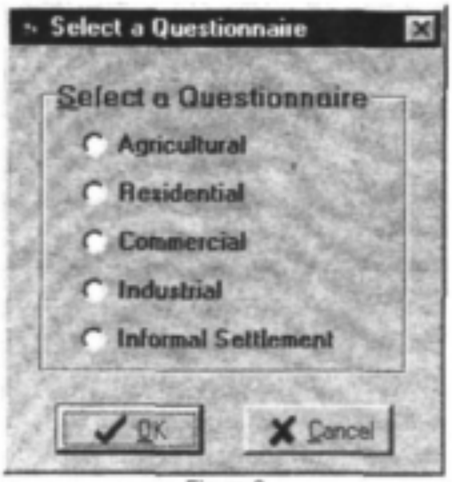


Figure 3

Select which type of questionnaire you want to complete by clicking on the ○ next to the appropriate questionnaire. The selected questionnaire is shown by a ◉ next to it. If you have accidentally chosen the wrong questionnaire, easily reselect the questionnaire that you want to complete. See the diagram on Questionnaires for a complete list of all the forms of every questionnaire.

The first form to complete in all questionnaires is general information. Figure 4 is the General Information form of the Agriculture Questionnaire.

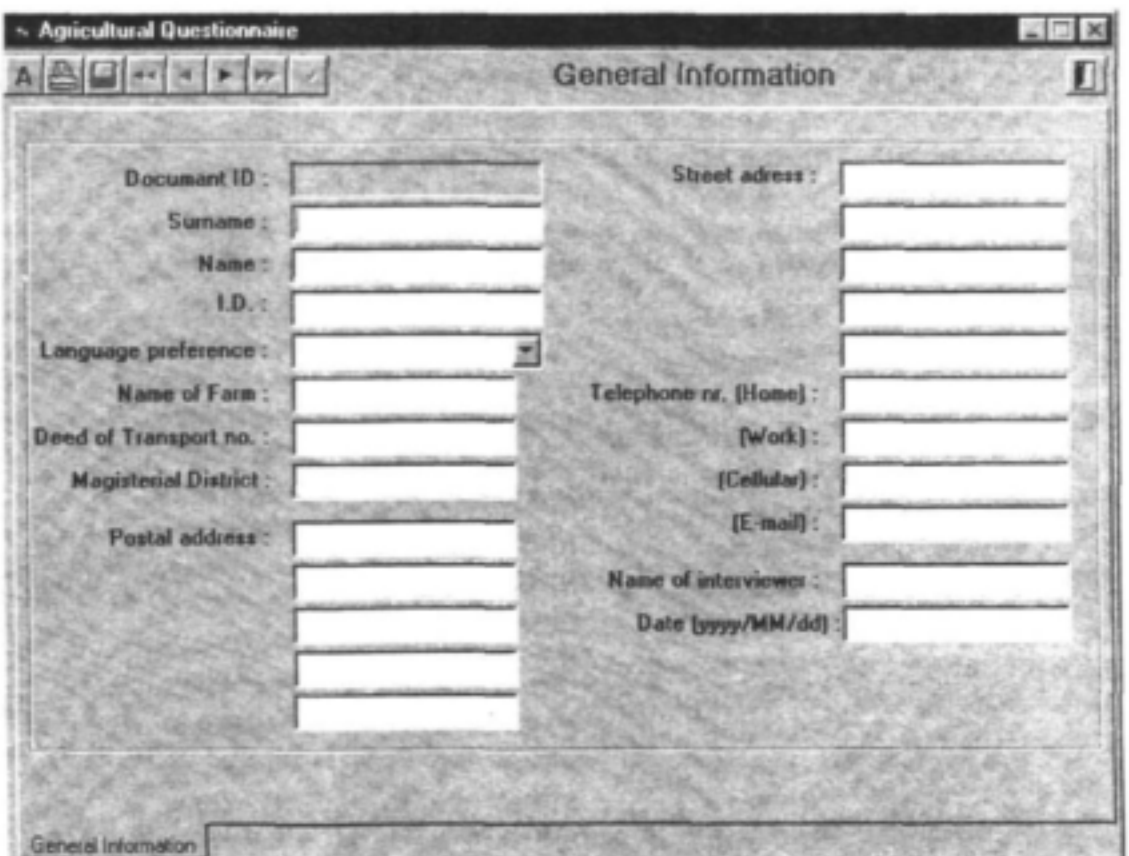
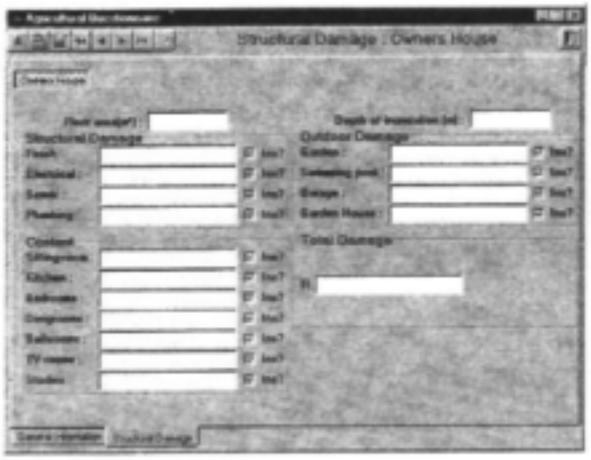


Figure 4

Make use of the following buttons (click on a button) and complete the questionnaire:

A Complete the actual cost of the same form



On the left is the form of the estimated cost and on the right is the form of the actual cost.

Print detailed questionnaires

Save the record your busy with

Scroll back to the first form

Scroll back one form at a time

Scroll forward one form at a time

Scroll forward to the last form

Save and exit

Close the questionnaire and go back to the main menu. You are prompted to confirm that you want to close the questionnaire.

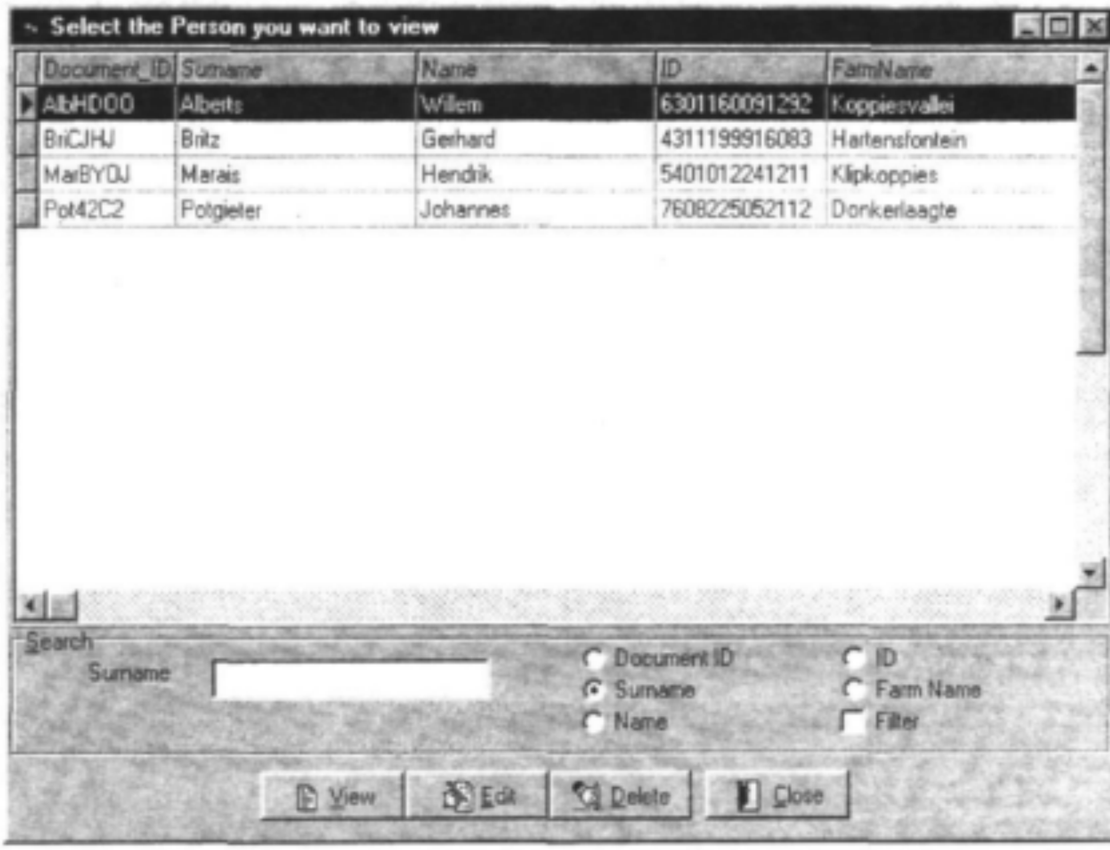
Note Some of the buttons will be enabled and others disabled as you work through the questionnaire.

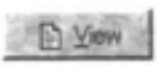
View a Record

Click on 

in the main menu. Select a questionnaire (figure 3).

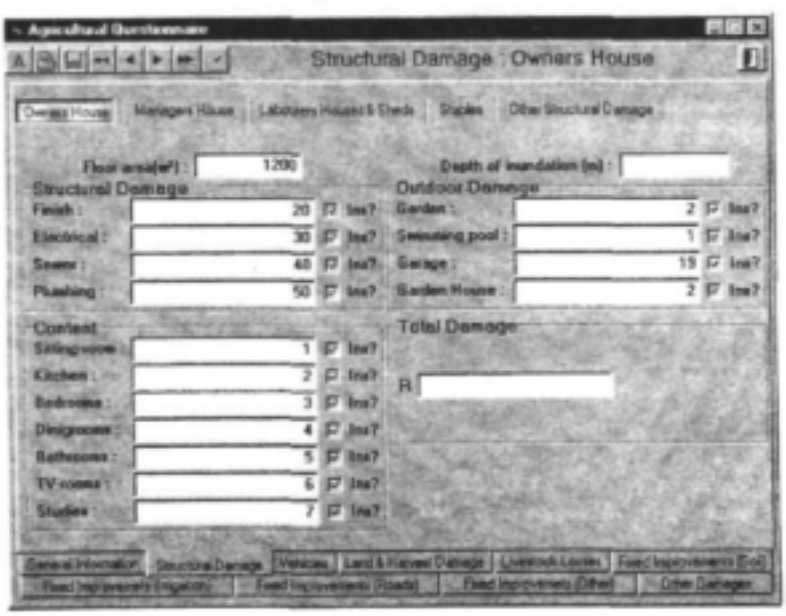
A list of all the records of the selected questionnaire is displayed on the screen. The selected record is shown by an arrow on the left.



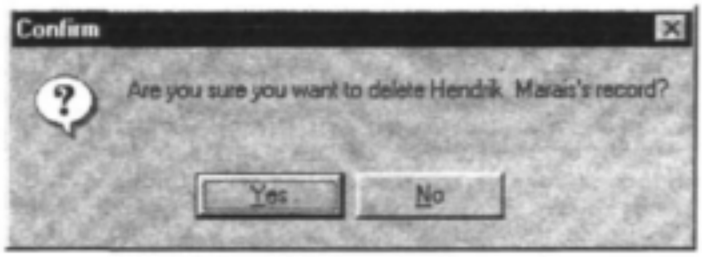


View the details of the selected record. Although you can change the information displayed, your changes would not be saved.

The details of the selected record are viewed, and you can change the original information. Your changes will be saved.



You are prompted to confirm that you want to delete the selected record.



Go back to the main menu.

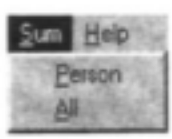
Search for a record

Select the field according to which you want to search for a specific record. Type the appropriate value in the box. The cursor will move to the record if found.

Note Only the first record in the list will be found. E.g. If two different records have identical surnames (search according to surname), only the first record in the list will be found.

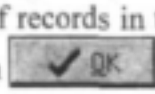
Calculation of Actual Flood Damage

After all questionnaires have been completed, the total actual damage for a specific flood event could be calculated. The various flood damages of all victims in a specific region could be computed here. Click on the Sum menu, or press Alt-S.



To calculate the damage of a specific flood for a single person, choose Person. To calculate all the damages of a specific flood, choose All.

Calculating a person's damage

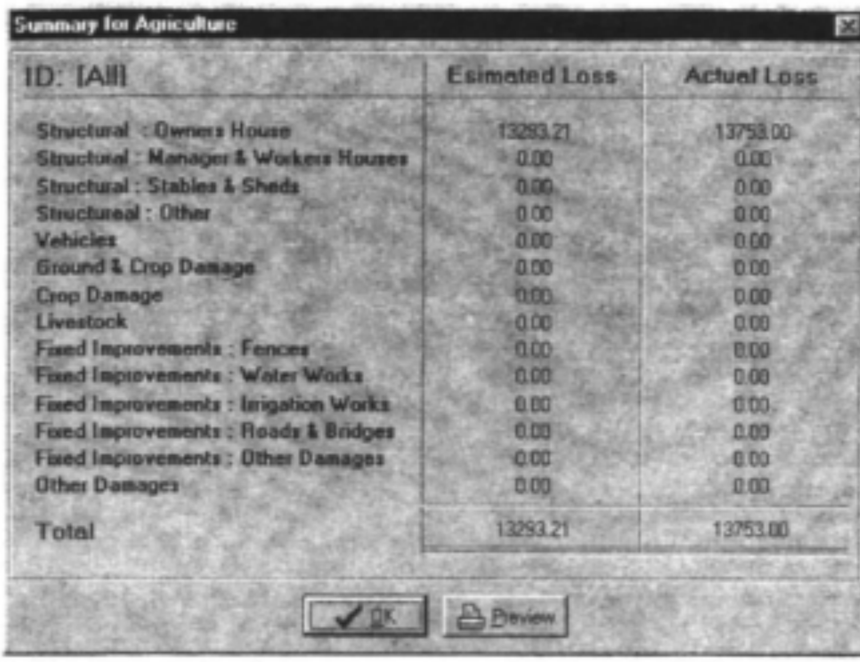
Select the sector (figure 3) of which you want to calculate one person's flood damage. The list of records in the sector you have chosen, is displayed. Select one record and click on 

.

Calculating all damages

Select the sector (figure 3) of which you want to calculate all the flood damages.

The results are shown when the calculations have been finished.

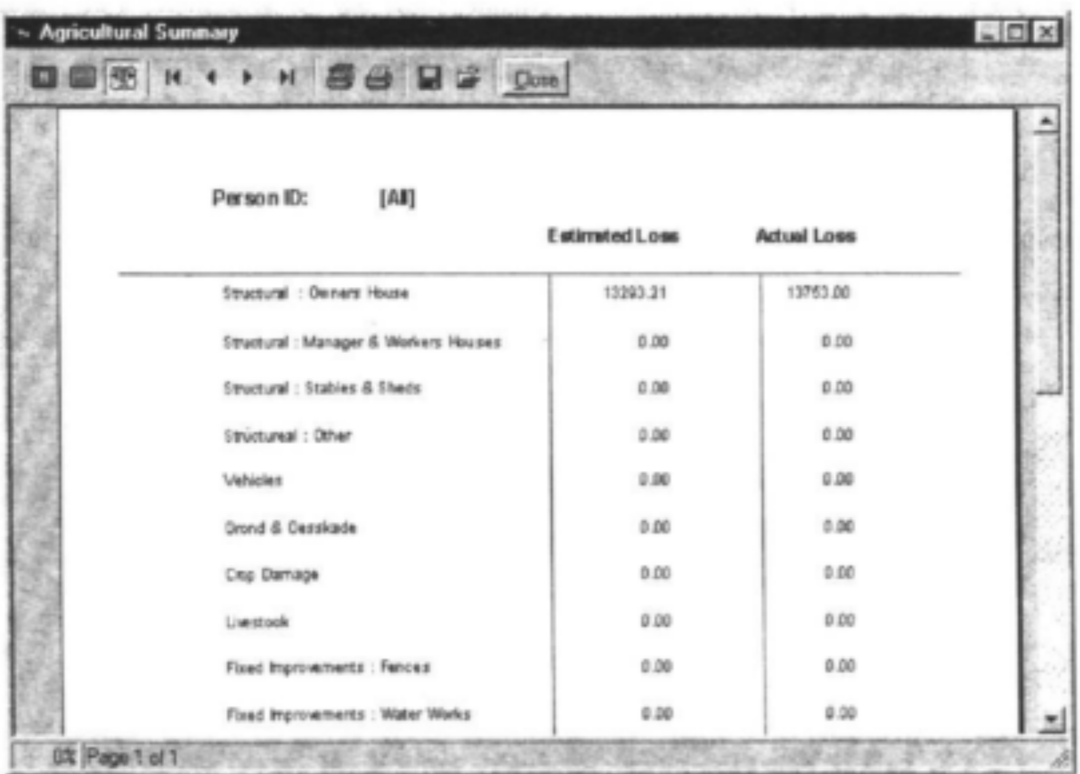


OK Return to the main menu.

Preview Display a print preview on the screen.

Printing the summary

Click on Preview to display the print preview.



Print the page as displayed in the print preview.

Close Return to the summary.

Diagram: Questionnaires

Agricultural

- General Information
- Structural Damage
  - Owners House
  - Managers House
  - Labourers Houses & Sheds
  - Stables
  - Other Structural Damage
- Vehicles
  - Vehicles
  - Trucks
  - Tractors
  - Machines
  - Implements
- Land & Harvest Damage
  - Soil Damage (Repairable)
  - Soil Damage (Irrepairable)
  - Harvest Damage
  - Crop Damage
- Livestock Losses
- Fixed Improvements (Soil)
  - Fences
  - Water Works
  - Water Works 2
  - Water Works 3
- Fixed Improvements (Irrigation)
  - Irrigation Works 1
  - Irrigation Works 2
  - Irrigation Works 3
  - Irrigation Works 4
  - Irrigation Works 5
- Fixed Improvements (Roads)
- Fixed Improvements (Other)
- Other Damages

Residential

- General Information
- Structural Damage
  - Owners House
- Vehicles
  - Vehicles
  - Trucks
  - Tractors
  - Machines
  - Implements
- Other Damages

Commercial

- General Information
- Commercial Damage
  - Direct Damage
  - Indirect Damage
- Vehicles
  - Vehicles
  - Trucks
  - Tractors
  - Machines
  - Implements
- Other Damages

Industrial

- General Information
- Structural Damage
  - Direct Damage
  - Indirect Damage
  - Other Structural Damage
- Vehicles
  - Vehicles
  - Trucks
  - Tractors
  - Machines
  - Implements
- Other Damages

Informal Settlement

- General Information
- Structural Damage
  - Owners House
  - Other Structural Damage
- Vehicles
  - Vehicles
  - Trucks
  - Tractors
  - Machines
  - Implements
- Other Damages

ANNEXURE 6

FLODCAL QUESTIONNAIRE

Annexure 6-1

Agricultural : General Information

Person ID :	
Language Preference :	
Surname :	
Name :	
I.D. :	
Name of Farm :	
Deed of Transport :	
Magisterial District :	
Postal Address :	
Street Address :	
Telephone Number (Home) :	
(Work) :	
(Cellular) :	
(E-mail) :	
Name of Interviewer :	
Date of Interview :	

THE INFORMATION WILL BE TREATED CONFIDENTIALLY

Annexure 6-2

Buildings (Owners House)

Floor Area (m^2) :		Depth of inundation (m) :	
Type / Classification	**Estimated Repair or Replacement Cost (R)**	**Insured (Yes / No)**	**Actual Repair or Replacement Cost (R)**
Structural Damage :			
Finishing :			
Electrical :			
Sewerage :			
Plumbing :			
Other :			
Total :			
Content Damage :			
Lounge			
Kitchen			
Bedrooms			
Dining rooms			
Bath rooms			
TV room			
Study			
Other :			
Total :			
Outdoor Damage :			
Garden (soil included)			
Swimming pool			
Garage			
Garden structure			
Other :			
Total :			
GRAND TOTAL			

Annexure 6-3

Agricultural : Buildings (Managers House)

Floor Area (m^2) :		Depth of inundation (m) :	
Type / Classification	**Estimated Repair or Replacement Cost (R)**	**Insured (Yes / No)**	**Actual Repair or Replacement Cost (R)**
Structural Damage :			
Finishing :			
Electrical :			
Sewerage :			
Plumbing :			
Other :			
Total :			
Content Damage :			
Sitting-room			
Kitchen			
Sleeping rooms			
Dining rooms			
Bath rooms			
TV room			
Studies			
Other :			
Total :			
Outdoor Damage :			
Garden (soil included)			
Swimming pool			
Garage			
Garden house			
Other :			
Total :			
Grand Total			

Annexure 6-4

Buildings (Labourer Houses)

Type / Classification	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)
Structure			
Content			
Outdoor damage			
Other			
Total			

Annexure 6-5

Buildings (Sheds)

Type / Classification	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)
Structure			
Content (Specify)			
Total			

Annexure 6-6

Buildings (Stables)

Type / Classification	Estimated Repair or Replacement Cost (R)	Insured Yes / No	Actual Repair or Replacement Cost (R)
Structure			
Content (Specify)			
Total			

Annexure 6-7

Agricultural Other Damages / Losses *

Type (Specify)	Estimated Damage (R)	Insured (Yes / No)	Actual Loss (R)

* E.g. detours, or any other indirect losses.

Agricultural Vehicles : motor cars and motor bikes

Type (specify)	Number	Model	Capacity	Age	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Agricultural Vehicles : Trucks

Type (specify)	Number	Model	Capacity	Age	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Agricultural Vehicles : Tractors

Type (specify)	Number	Model	Capacity	Age	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Self Powered Machines

Type (specify)	Number	Model	Capacity	Age	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Agricultural Implements

Type (specify)	Number	Model	Capacity	Age	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Soil and Harvest Damage

Type / Classification	Grazing land		Dryland		Irrigation land		Vineyards / Orchard		*Other* (farmstead & waste)		*Total Estimated* Repair or Replacement Cost (R)	Insured (Yes / No)	*Total Actual* Repair or Replacement Cost (R)
	ha.	R/ha.	ha.	R/ha.	ha.	R/ha.	ha.	R/ha.	ha.	R/ha.			
Soil :													
Repairable													
Irrepairable*													
*** Use market value of land as indicator of damage**													
Damage to harvest (Specify Crop)	**ha.**	**R/ha.***	**ha.**	**R/ha.***	**ha.**	**R/ha.***	**ha.**	**R/ha.***	**ha.**	**R/ha.***			

* Value of yield loss (R) means savings in harvesting cost, due to smaller yield

Crop Damage

Specify Crop	Area that should be Restablished (ha.)	Crop Age (years)	Normal Production Cost (R / ha.)	Establishing Cost (R / ha.)	Estimated Crop Damage (R)	Insured (Yes / No)	Actual Crop Damage (R)

Livestock Losses / Damage

Specify Livestock Type	Dead & Lost				Veterinary & Medicine (R)		Production Losses (R)		Total Estimated Loss (R)	Insured (Yes / No)	Total Actual Loss (R)
	Grade		Stud		Grade	Stud	Grade	Stud			
	Number	Market Value (R)	Number	Market Value (R)							

Annexure 6-16

Damage to Fixed Improvements

Type	Numbers (w.a.)	Length (m) (w.a.)	Height (m) (w.a.)	Estimated Repair Cost (R)	Insured (Yes / No)	Actual Repair Cost (R)
Soil Conservation						
Border fences patially destroyed						
Border fences totally destroyed						
Interior fences patially destroyed						
Interior fences totally destroyed						
Reservoirs						
Stock waterpipelines destroyed						
Troughs						
Earth dams						
Area contoured lands damaged						
Waterways damaged						
Erosion works						
Boreholes						
Windmills						
Other water pumping equipment						

w.a. = when applicable

Annexure 6-17

Damage to Fixed Improvements (continued)

Type	Numbers (w.a.)	Length (m) (w.a.)	Height (m) (w.a.)	Estimated Repair Cost (R)	Insured (Yes / No)	Actual Repair Cost (R)
Irrigation Works						
Dams partially damaged						
Dams damaged :						
Walls higher than 5 m						
Walls lower than 5 m						
Irrigation equipment						
Pumps						
Systems						
Pipes etc.						
Irrigation boreholes						
Chanals :						
Earth						
Concrete						
Furrows :						
Earth						
Concrete						
Levees						
Drainage works (Specify) :						

w.a. = when applicable

Damage to Fixed Improvements (continued)

Type	Numbers (w.a.)	Length (m) (w.a.)	Height (m) (w.a.)	Estimated Repair Cost (R)	Insured (Yes / No)	Actual Repair Cost (R)
Bridges and Roads						
Farm roads						
Farm bridges						
Other (Specify)						

w.a. = when applicable

Annexure 6-19

Agricultural Other Damages / Losses *

Type (Specify)	Estimated Damage (R)	Insured (Yes / No)	Actual Loss (R)

* E.g. detours, or any other indirect losses.

Annexure 6-20

Residential : General Information

Person ID :	
Language Preference :	
Surname :	
Name :	
I.D. :	
Name of Farm :	
Deed of Transport :	
Magisterial District :	
Postal Address :	
Street Address :	
Telephone Number (Home) :	
(Work) :	
(Cellular) :	
(E-mail) :	
Name of Interviewer :	
Date of Interview :	

THE INFORMATION WILL BE TREATED CONFIDENTIALLY

Annexure 6-21

Residential Buildings : Owners House

Floor Area (m²) :		Depth of inundation (m) :	
Type / Classification	**Estimated Repair or Replacement Cost (R)**	**Insured Yes / No**	**Actual Repair or Replacement Cost (R)**
Structural Damage :			
Finishing :			
Electrical :			
Sewerage :			
Plumbing :			
Other :			
Total :			
Content Damage :			
Lounge			
Kitchen			
Bedrooms			
Dining rooms			
Bath rooms			
TV room			
Study			
Other :			
Total :			
Outdoor Damage :			
Garden (soil included)			
Swimming pool			
Garage			
Garden structure			
Other :			
Total :			
GRAND TOTAL			

Annexure 6-22

Residential: Buildings (Other)

Type / Classification	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)
Structure			
Content (Specify)			
Total			

Residential : Vehicles

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)
Motors								
Trucks								
Tractors								
Self powered machines								
Implements								
Other								

Annexure 6-24

Residential Other Damages / Losses *

Type (Specify)	Estimated Loss (R)	Insured (Yes / No)	Actual Loss (R)

* E.g. detours, or any other indirect losses.

Annexure 6-25

Commercial : General Information

Person ID :	
Language Preference :	
Surname :	
Name :	
I.D. :	
Name of Farm :	
Deed of Transport :	
Magisterial District :	
Postal Address :	
Street Address :	
Telephone Number (Home) :	
(Work) :	
(Cellular) :	
(E-mail) :	
Name of Interviewer :	
Date of Interview :	

THE INFORMATION WILL BE TREATED CONFIDENTIALLY

Annexure 6-26

Commercial Buildings

Floor Area (m^2) :		Depth of inundation (m) :	
Type / Classification	**Estimated Repair or Replacement Cost (R)**	**Insured (Yes / No)**	**Actual Repair or Replacement Cost (R)**
Direct Damage			
Structural Damage :			
Finishing :			
Electrical Works :			
Sewerage :			
Plumbing :			
Other :			
Total :			
Content Damage :			
Stock :			
Specify :			
Equipment :			
Other :			
Total :			
Indirect Damage			
Loss in Turnover :			
Net profit as a percentage of turnover :			
Total :			
Other (specify)			
Evacuation :			
Flood Fighting :			
Other (Indirect) :			
Total :			

Annexure 6-27

Commercial buildings : Other damages

Type / Classification	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)
Structure			
Content (Specify)			
Total :			

Commercial Vehicles : motor cars and motor bikes

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Commercial Vehicles : Trucks

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Commercial Vehicles : Tractors

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Self Powered Machines

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Commercial Vehicles : Other

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Annexure 6-31

Commercial Other Damages / Losses *

Type (Specify)	Estimated Loss (R)	Insured (Yes / No)	Actual Loss (R)

* E.g. detours, or any other indirect losses.

Annexure 6-32

Industrial : General Information

Person ID :	
Language Preference :	
Surname :	
Name :	
I.D. :	
Name of Farm :	
Deed of Transport :	
Magisterial District :	
Postal Address :	
Street Address :	
Telephone Number (Home) :	
(Work) :	
(Cellular) :	
(E-mail) :	
Name of Interviewer :	
Date of Interview :	

THE INFORMATION WILL BE TREATED CONFIDENTIALLY

Annexure 6-33

Industrial Buildings

Floor Area (m²) :		Depth of inundation (m) :	
Type / Classification	**Estimated Repair or Replacement Cost (R)**	**Insured (Yes / No)**	**Actual Repair or Replacement Cost (R)**
Direct Damage			
Structural Damage :			
Finishing :			
Electrical Works :			
Sewerage :			
Plumbing :			
Other :			
Total :			
Content Damage			
Raw Material and Unfinished goods			
Specify :			
Plant and equipment (buildings excluded)			
Specify :			
Finished Goods			
Specify :			
Total :			
Indirect Damage			
Loss in Turnover			
Net profit as a percentage of turnover			
Evacuation			
Transport :			
Manpower :			
Storage :			
Other :			
Clean-up			
Specify :			
Flood Fighting			
Specify :			
Total:			

Annexure 6-34

Industrial buildings : Other damages

Type / Classification	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)
Structure (Specify)			
Content (Specify)			
Total:			

Industrial Vehicles : motor cars and motor bikes

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Industrial Vehicles : Trucks

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Industrial Vehicles : Tractors

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Self Powered Machines

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Industrial Vehicles : Other

Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)

Annexure 6-38

Industrial : Other Damages / Losses *

Type (Specify)	Estimated Loss (R)	Insured Yes / No	Actual Loss (R)

* E.g. detours, or any other indirect losses.

Annexure 6-39

Informal Settlements : General Information

Person ID :	
Language Preference :	
Surname :	
Name :	
I.D. :	
Name of Farm :	
Deed of Transport :	
Magisterial District :	
Postal Address :	
Street Address :	
Telephone Number (Home) :	
(Work) :	
(Cellular) :	
(E-mail) :	
Name of Interviewer :	
Date of Interview :	

THE INFORMATION WILL BE TREATED CONFIDENTIALLY

Annexure 6-40

Informal Settlements : Owners House

Floor Area (m²) :		Depth of inundation (m) :	
Type / Classification	**Estimated Repair or Replacement Cost (R)**	**Insured (Yes / No)**	**Actual Repair or Replacement Cost (R)**
Structural Damage :			
Finishing :			
Electrical :			
Sewerage :			
Plumbing :			
Other :			
Total :			
Content Damage :			
Lounge			
Kitchen			
Bedrooms			
Dining rooms			
Bath rooms			
TV room			
Study			
Other :			
Total :			
Outdoor Damage :			
Garden (soil included)			
Swimming pool			
Garage			
Garden structure			
Other :			
Total :			
GRAND TOTAL			

Annexure 6-41

Informal Settlements : Buildings (Other)

Type / Classification	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)
Structure (Specify)			
Content (Specify)			
Total :			

Informal Settlements : Vehicles

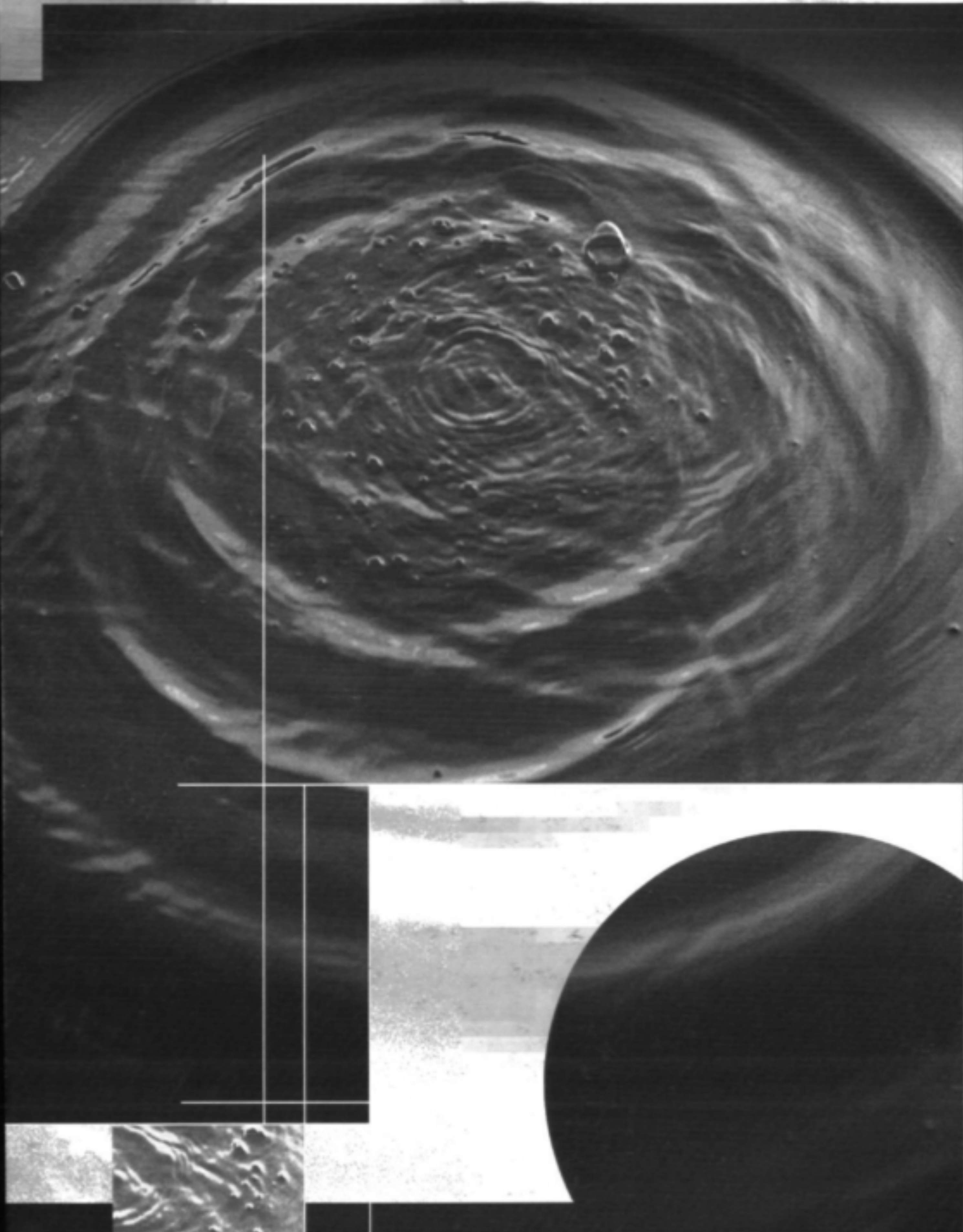
Type (specify)	Number	Model	Capacity	Age (year)	Market Value (R)	Estimated Repair or Replacement Cost (R)	Insured (Yes / No)	Actual Repair or Replacement Cost (R)
Motors								
Trucks								
Tractors								
Self powered machines								
Other								

Annexure 6-43

Informal Settlements : Other Damages / Losses *

Type (Specify)	Estimated Loss (R)	Insured (Yes / No)	Actual Loss (R)

* E.g. detours, or any other indirect losses.



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