GOVERNMENT OF WESTERN AUSTRALIA

Moore River Flood Management Plan

Bidaminna

Water Resource Management Series

Water and Rivers Commission Report WRM 7

1997

Water and Rivers Commission

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Summary

The flooding problems of the Moore River in the Bidaminna area are complex and have been developing over more than three decades. In July 1995 these flooding problems were exacerbated by a large flood which caused major bank and floodplain erosion, siltation, economic loss and major inconvenience to landowners on the Moore River floodplain.

The aims of this study were to investigate the flooding issues and to develop flood management and implementation strategies for the Bidaminna area of the Moore River .

The catchment area of the Moore River to the Bidaminna area is over 13,000 km^2. However the runoff is relatively low and major floods are rare. The flood that occurred in July 1995 had an average recurrence interval of 50 years.

The current waterway management problems of the Moore River in the Bidaminna area are considered to include:

- severe bank erosion at numerous locations along the river;
- scour and erosion of the river bed;
- extensive flooding and land erosion as a result of the July 1995 flood;
- unco-ordinated construction of levees on the floodplain; and
- degradation of the health of the river including sedimentation of pools.

As part of the development of strategies to alleviate the impacts of flooding along this section of Moore River, a Steering Committee was established with representatives from the Shire of Gingin, Gingin Land Conservation District Committee, Water and Rivers Commission, Agriculture Western Australia, and Main Roads WA.

The principles which have been used to evaluate possible strategies for the flooding problem on the Moore River were:

- Flooding is a natural and regular occurrence;
- Agricultural production and environmental health are both valid land and water uses;
- Management strategies are developed to ensure overall community benefit;
- Development of management strategies is based on community consultation;
- Levee banks are recognised river management works with their merits assessed in relation to their impact on flooding;
- Acknowledge that it may not be possible to return to pre-1960 conditions of the river; and
- Flood management measures are to incorporate environmental values wherever possible.

The impacts of major river flooding can be alleviated by the setback of levee banks and the use of flood relief channels. Flood relief channels provide additional waterway capacity during the larger river flows.

The major components of the Flood Management Plan are:

- Component 1 - Levee repairs on Loc 2 & Loc 1456;
- Component 2 - Replace diversion banks on Loc 2840 channel with low weirs;
- Component 3 - Setback of levees;
- Component 4 - Lowering of transverse levee on Loc 491;
- Component 5 - Construction of low weirs;
- Component 6 - Bank restoration and protection works;
- Component 7 - Setback of levees; and
- Component 8 - Fencing and revegetation.

The Flood Management Plan will be implemented by:

- negotiated agreement;
- land planning process; and
- legal direction.

The Flood Management Plan should be funded by:

- joint funding by Federal, State and Local Government and landowners; and
- beneficiaries and creators pay.

In order of priority the following components of the Flood Management Plan are recommended to be implemented:

1. ***Component 1*** - levee repairs on Loc 2 and Loc 1456.
2. ***Component 6*** - bank restoration and protection works on Loc 922 and Loc 2296.
3. ***Component 5*** - construction of low weirs at Loc 2744 and Loc 2784.
4. ***Component 3*** - setback of levees on properties downstream of Bennies Road.
5. ***Component 2*** - replace diversion banks with low weirs on Loc 2840.

1. Introduction

The development of a flood management plan for the Moore River in the Bidaminna area arose from a request by the then Minister for the Environment to investigate the flooding problems of the Moore River.

1.1 Study aims

The aims for this study were to:

- investigate the flooding issues of the Moore River in the Bidaminna area;
- develop and evaluate flood management strategies; and
- recommend an implementation strategy.

The extent of the study is the Bidaminna area of the Moore River and, in particular, the area from Gungawah Pool to Greenwood Road centring on Bennies Road (see Figure1). The scope of the study was focussed on flood management issues, however, the broader river management aspects were incorporated where possible.

1.2 Background

Flooding is a natural phenomenon. Periodically rain causes rivers to rise and streams and lakes to overflow their banks and onto adjacent land areas. These areas, known as floodplains, have been carved out by floods for the specific purpose of carrying excess floodwaters. However, since times of settlement, little regard has been given to the purpose and function of floodplains.

The lower reaches of the Moore River are quite sluggish and, because of the flat grades, the river floods readily. Over many years landowners in the area have constructed levees to reduce flooding on their properties. The levees have been built on an *ad hoc* basis with each landowner looking after his own interests. The interference with the waterway has been exacerbated by the subdivision of rural lots with smaller landowners more affected by flooding than the larger landowners.

In 1979 the landowner of Loc 2840 constructed a channel to divert the Moore River around a sluggish section of the river in order to reduce flooding on his property. The majority of this work was carried out on his own property but some work was located in the river reserve. Subsequently the channel scoured severely and became the preferred path for the low river flows. This was primarily due to the bed of the new channel now being lower than the bed of the old river course. During major flooding the flow is distributed between the old river course and the excavated channel in Loc 2840.

In 1979 the Public Works Department requested the landowner of Loc 2840 to *"undertake whatever works may be necessary to return the River to its original course"*. However, this action was unsuccessful. Prosecution of the landowner was then considered but a successful prosecution was not considered possible due to the delay in taking legal proceedings.

In 1987 the landowner of Loc 2840 carried out further works to improve his excavated channel and to prevent water flowing down the old river course. Based on the RWI Act the Water Authority requested the landowner to carry out restoration works. However the Crown Solicitor's Office subsequently advised that the diverted portion of the river was not covered by the RWI Act.

In March 1993 a Soil Conservation Notice under the Soil and Land Conservation Act (1982) was served on the landowner of Loc 2840 directing him to construct a levee designed by the Water Authority to divert river flows back to the original course of Moore River and to carry out restoration works to the river bank. The diversion levee was constructed in late 1993 with the bank protection works not being carried out.

In June 1995 the Deputy Commissioner of Soil and Land Conservation initiated the development of a Flood Management Plan for the Moore River in the Bennies Road area. In July 1995 significant flooding occurred in the Moore River. Most of the flow was diverted down the original river course but a proportion was diverted into the excavated channel through Loc 2840. There is still some dispute amongst landowners in the area as to which of the river courses is the natural one for flooding in the Moore River.

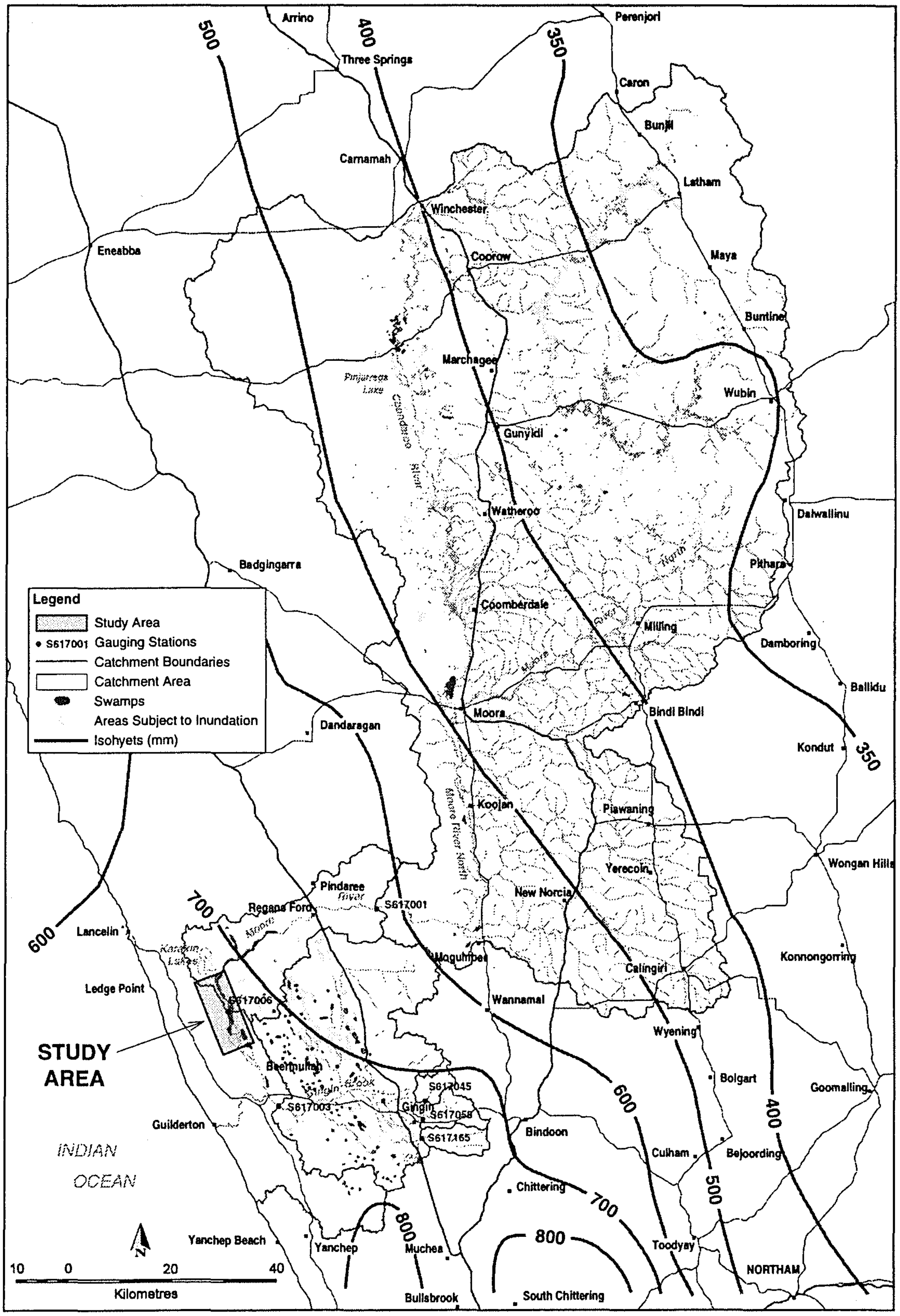

Figure 1. Catchment plan for the Moore River

2. Moore River catchment

2.1 Description

The catchment of the Moore River extends from Latham and Dalwallinu at the headwaters of the river to Guilderton at the mouth (see Figure 1). The major tributaries of the Moore River are the Coonderoo River and Moore River North. Gingin Brook flows into the Moore River downstream of the study area. At the foot of the Darling Scarp the river flows south through Moora to Mogumber, where it turns west, crosses the southern tip of the Dandaragan Plateau, descends the low Gingin Scarp near Regans Ford, then winds south-west across the sandy coastal plain to the Moore River estuary at Guilderton (Olsen and Skitmore 1991). Approximately half of the river's catchment on the coastal plain is cleared.

Due to the extensive clearing in its upper catchment and the salt lakes which can discharge into it, the Moore River is saline when it flows in winter. Loss of fringing vegetation and bank erosion are common problems along sections of the river subject to grazing.

The vegetation of the catchment ranges from banksia low woodland on the coastal plain to York gum and wandoo and then to mallee and casuarina thickets with distance from the coast. The major natural vegetation within the study area are banksia low woodland with scattered trees and patches of jarrah-marri forest.

2.2 Hydrology

The catchment area of the Moore River to Bennies Road is 13,200 km^2 with the catchment area to the upstream gauging station being 12,400 km^2.

The mean annual rainfall ranges from less than 350 mm in the north-east of the catchment to slightly over 700 mm in the study area. The runoff from the catchment is very low, with an annual average of only 4 mm, which is about 1% of the catchment rainfall.

The observed annual peak discharges for the Moore River at the Quinns Ford gauging station are shown on Figure 1. The largest flows were observed in 1983 and 1995 with intermediate flows in 1974, 1975 and 1988. The largest observed peak discharge of 320 m^3/sec is low compared to other observed peak discharges in the south-west of the State for the size of the catchment of the Moore River. In general terms the annual peak discharges as shown on Figure 2 occur in July and August over 70% of the time. Over the 25 years of annual peak discharges only one has occurred in summer.

As an indication of the longer term context of heavy rainfall associated with flood runoff, the maximum monthly rainfall for the Moora rainfall station is shown on Figure 3. The high July 1995 rainfall should be noted in the context of low maximum monthly rainfall for the last 25 years. However the 23 years from 1945 to 1968 show five years with high maximum monthly rainfall.

The flood frequency curve for the Moore River at Quinns Ford (refer Figure 4) shows that the July 1995 event had a recurrence interval of approximately 1 in 50 years. Flood recurrence intervals are difficult to predict for the Moore River at Bidaminna due to the short period of hydrologic record, the lack of hydrologic data within the study area, and the changing land use within the Moore River catchment.:

Extension of the streamflow by using the longer data set (1898 to 1996) of maximum monthly rainfall data shown in Figure 3 does not significantly change the annual recurrence interval of the July 1995 event.

The July 1995 flood hydrograph is shown on Figure 5 and highlights the two main peaks which occurred on 13 July and 22 July 1995.

The floodprone zone of the Moore River is shown in Figure 6. The area in blue represents a potential floodprone zone based on topography and the geomorphology of the Moore River in this area.

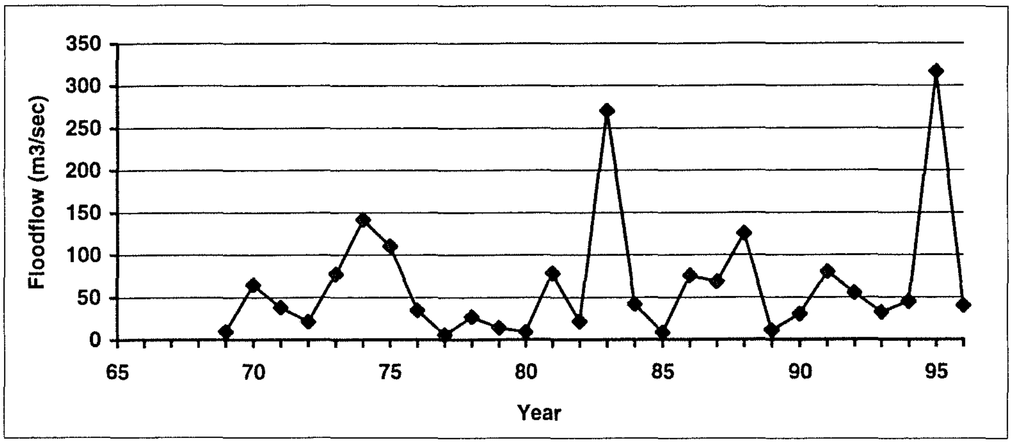

Figure 2. Peak annual discharge for Moore River at Quinns Ford

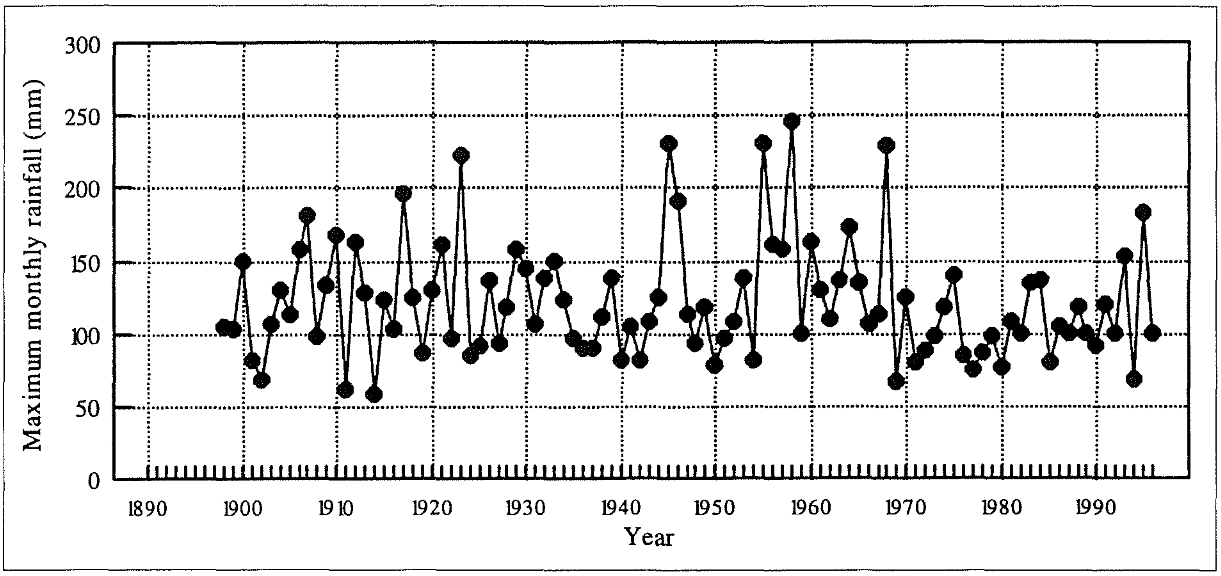

Figure 3. Maximum monthly rainfall Moora

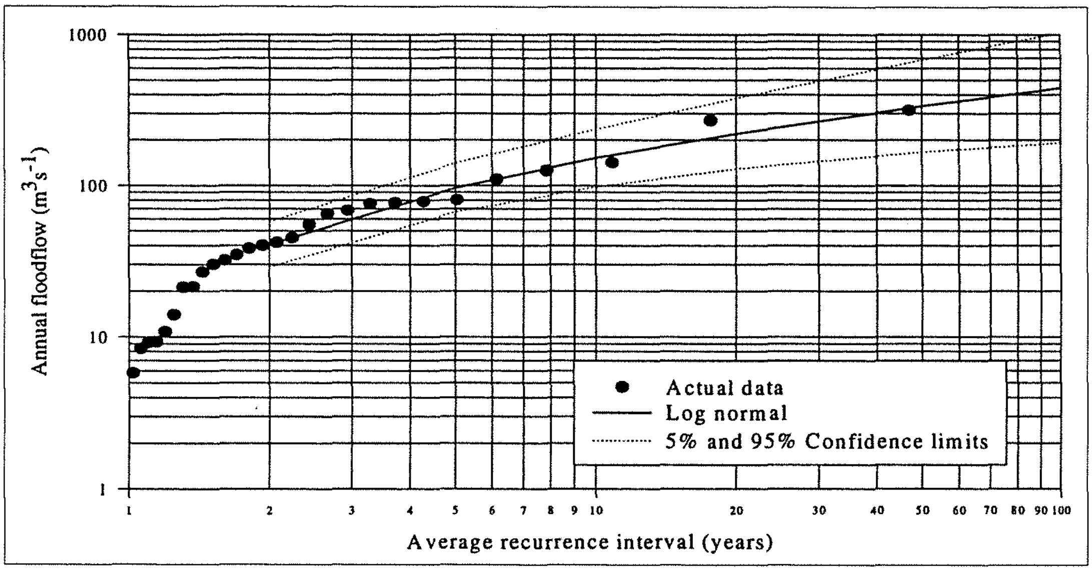

Figure 4. Flood frequency curve for Moore River at Quinns Ford

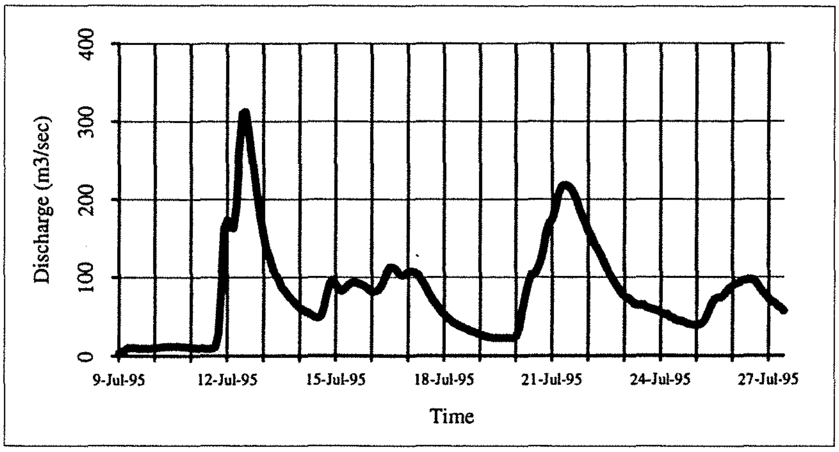

Figure 5. July 1995 streamflow for Moore River at Quinns Ford

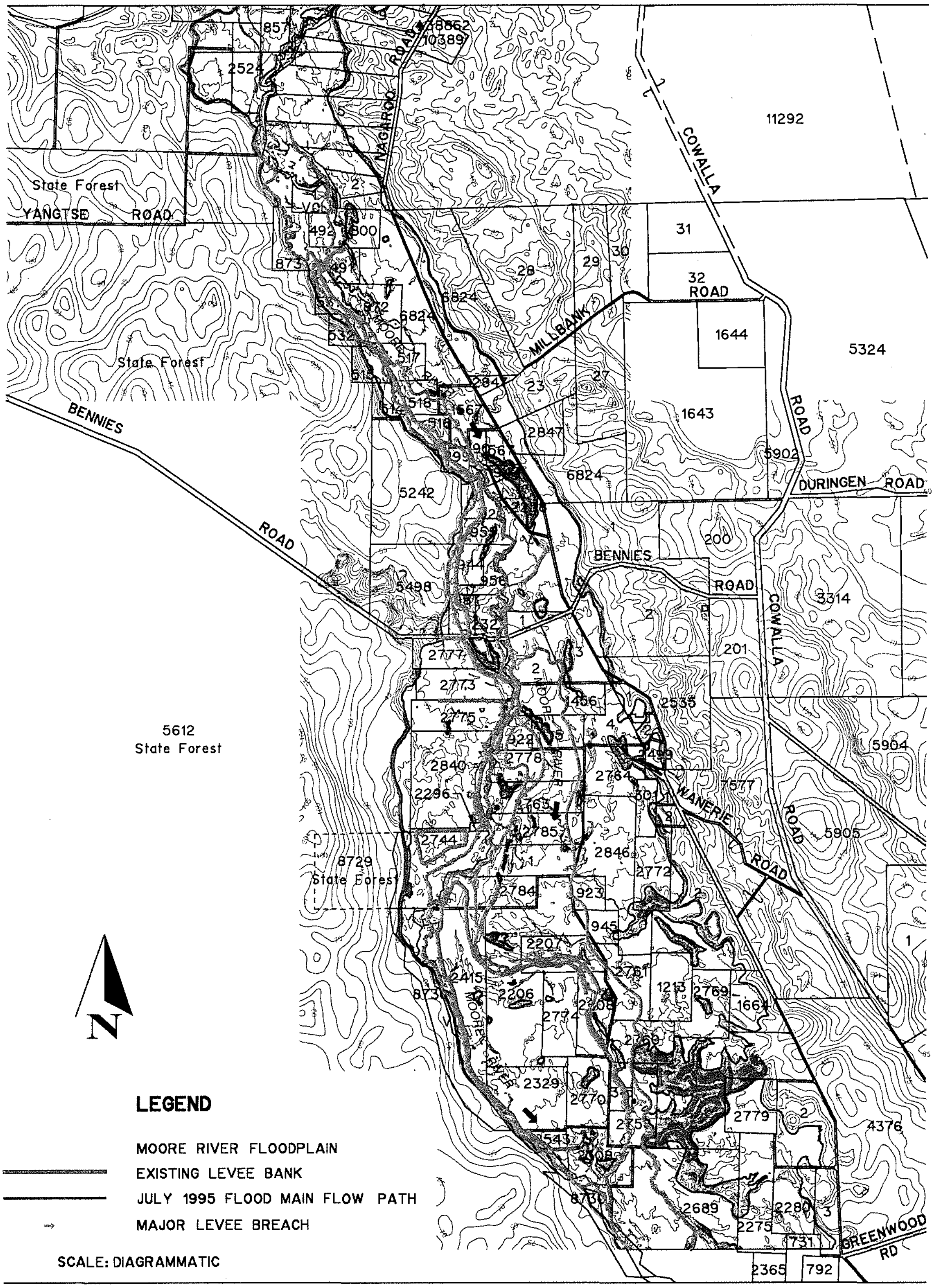

Figure 6. Floodprone zone for Moore River

3. Flood management problems

The current waterway problems of the Moore River are:

- severe bank erosion at numerous locations along the river;
- scour and erosion of the river bed;
- extensive flooding and land erosion as a result of the July 1995 flood;
- unco-ordinated construction of levees on the floodplain; and
- degradation of the health of the river including sedimentation of pools.

3.1 Primary causes of flood management problems

This Section incorporates some of the theory developed by the Standing Committee on Rivers and Catchments, Victoria, (1991) and the guidelines for stream management by the Department of Water Resources, New South Wales, (1993).

3.1.1 Bed lowering

Bed lowering is the process by which the bed of a stream is eroded to a new lower level at a much faster rate than occurs naturally. The bed of the channels through Loc 2840 and Loc 2744 both show accelerated rates of bed lowering. The lowering of a stream's bed can initiate extensive bank erosion as the height of the banks relative to the bed is effectively increased, leaving them more susceptible to collapse.

Activities which directly alter a stream channel and which can initiate upstream progressing bed lowering include:

- channel straightening;
- excavation of drainage lines through on-creek swamps;
- excessive extraction of sand and gravel; and
- excessive desnagging and removal of vegetation from within the channel.

3.1.2 Bank erosion

There are various factors which cause bank erosion and include:

Streamflow
The flow of water within a channel is a major factor in causing bank erosion. The potential for bank erosion generally increases with flow velocity, turbulence and secondary currents.

Channel alignment
The potential for bank erosion can be significantly affected by the alignment of a bank relative to the direction of flow. Abrupt changes in the alignment of the channel cause flow to hit a bank at a more direct angle and induce more turbulence than that which occurs along a relatively smooth and even bend.

Stream bed lowering
Lowering of a stream bed effectively increases the relative height of a bank. This may induce bank erosion as the bank adjusts to a more stable slope.

Obstructions to streamflow
Obstructions to the flow of water in a stream can cause bank erosion by increasing local turbulence and directing flow towards a bank.

Livestock
Stock grazing on banks may remove or damage vegetation and break the soil surface leaving banks prone to erosion.

3.1.3 Floodplain siltation

Deposition occurs when the velocity of sediment bearing flow decreases to a point where it can no longer carry its load. This commonly occurs where the flow expands over a broad area such as a floodplain. Sediment deposition often occurs in the form of levees or sediment sheets. The flooding along the Moore River in July 1995 left a number of major sediment sheets on the floodplain. Levees form along the top of stream banks as a result of secondary currents operating within the channel during an overbank full flow.

The deposition of sediment sheets can occur anywhere over a floodplain and their formation is usually of the greatest concern to floodplain landholders.

Some common causes of sediment sheet formation include:

- a reduction in the capacity of the channel to carry flow;
- clearing of shrubs and trees from the adjacent floodplain;
- flow over the floodplain entraining sediment from exposed surfaces;
- erosion of the floodplain surface resulting from concentration of the flow; and
- erosion of adjacent hillslope land.

3.1.4 Floodplain erosion

Erosion of the surface of the floodplain occurs when the velocity of the flow over it is greater than the resisting strength of the floodplain material and vegetation.

Floodplain erosion can be localised to a specific site along a stream or be part of much larger changes in a stream. Scour often occurs along depressions in the floodplain. Some common causes of floodplain erosion include:

- clearing of vegetation from a floodplain allows more water to move across it with a higher velocity;
- obstructions to the flow in a stream can reduce the capacity of the channel to carry flows;
- an influx of sediment into a stream can also reduce the capacity of the channel;
- construction of weirs can alter a stream's flow regime in such a way that smaller floods which move sediment deposited by tributary flows no longer occur. Excessive vegetation growth may further constrict the channel so that when a major flood does occur the channel capacity is insufficient; and
- breaches in a levee bank may allow new flow paths to form across a floodplain.

3.2 Potential management strategies

3.2.1 Bed control

Bed control strategies may take the form of techniques which aim to:

Control of erosion head
Head control employs techniques such as rock chutes, grass chutes and drop structures that will prevent the upstream progression of an erosion head.

Reduce the effective channel grade
Grade reduction incorporates similar techniques to head control but applies them over longer lengths of channel. Grade reduction structures will normally form small weirs above the channel bed.

Increase resistance to flow
An important component of most bed control strategies is to increase channel flow resistance upstream of head control structures. Increased channel resistance is most readily obtained by encouraging vegetation within the channel, particularly by stock exclusion.

Increase stability of bed material
Vegetation and bed seeding can also act to reduce the susceptibility of bed material to movement.

3.2.2 Bank protection

Bank protection strategies are those which aim to physically protect the bank material from the action of flowing water. Typical bank protection techniques include rock riprap, brushing, concrete block mattresses, and vegetation.

3.2.3 Alignment training

Alignment training strategies influence stream behaviour by selectively introducing resistance to parts of the channel. Increased resistance causes decreased velocities, hence deposition of sediment, followed generally by re-vegetation.

Resistance is usually introduced using some form of retard or groyne structure, or by disturbing the patterns of flow in a bend using vane dykes. Alignment training has its principle application in the control of meander processes, but can also be an effective component of strategies to treat other stream processes such as creating an alignment more favourable to an eroding bank; controlling the width of a stream or inducing channel deepening by constriction.

Elements of successful alignment training strategies can include:

- some form of retard, groyne, or vane structure to provide the initial increase in resistance to flow; and

  re-vegetation by natural or artificial means to provide a long term increase in flow resistance and a spread of increased resistance between or beyond the initial structure.

3.2.4 Increased channel capacity

Common techniques for increasing channel capacity include:

- de-snagging to remove obstructions to flow;
- widening of floodplain by relocating levees;
- excavation of the stream channel;
- straightening of the channel by meander cutoff;
- floodways across meander bends to increase flood capacity;
- banks or blocks to prevent or control overbank flows; and
- removal of in-channel vegetation.

3.2.5 Influencing catchment landuse

Many of the causes of channel change stem from events outside the river channel. An effective flood management plan must consider a broader viewpoint and introduce strategies which relate to all the area which drain to a river system.

4. Process in developing strategies

As part of the development of strategies to alleviate the impacts of flooding along this section of Moore River, a Steering Committee was established with representatives from:

- Shire of Gingin;
- Gingin Land Conservation District Committee;
- Water and Rivers Commission;
- Agriculture Western Australia; and
- Main Roads WA.

In consultation with the Steering Committee and affected landowners the Commission:

- defined the extent of the study;
- defined the river management problems;
- determined the events that caused the flooding problems;
- developed river management strategies to alleviate these problems;
- developed an agreed Flood Management Plan which incorporates river management strategies; and
- identified responsibilities for the implementation of the Flood Management Plan.

4.1 Principles for developing solutions

The following principles have been used to evaluate possible strategies for the flooding problem on the Moore River:

- Flooding is a natural and regular occurrence on the Moore River floodplain with the river spreading over the floodplain during major flows.
- Agricultural production and environmental health are both valid land and water uses which need to be balanced.
- Management strategies are developed to ensure overall community benefit. For effective flood management a community view needs to be taken as flood management measures may be necessary on specific properties to provide an overall benefit to the area.
- Development of management strategies is based on community consultation.
- Levee banks are recognised river management works with their merits assessed in relation to their impact on flooding.
- Acknowledge that it may not be possible to return to pre-1960 conditions of the river. This may not be possible and, in some circumstances, not desirable. It is natural for rivers on the coastal plain to move their channel alignment with time with these changes typically occurring during major flooding. There has been significant landuse change and development in the Bennies Road area including the recently constructed Bennies Road culverts and floodway.
- Flood management measures are to incorporate environmental values wherever possible.

Levee Banks

Levee banks are acceptable river management works as they protect landowners from the more frequent nuisance flooding. However, during major flooding, there are significant implications of floodwaters being channelled through levee bank systems and not flowing naturally across the natural floodplain. They include:

- flood levels increasing upstream of the levee system and exacerbating problems for upstream landowners;
- flood levels increasing within the levee system and creating considerable hydraulic pressure on the banks
- water velocities significantly increasing and thereby increasing potential erosion; and
- providing a false sense of security as levee banks are susceptible to breaching during major flooding.

Levee failures or breaches can bring additional problems. If the levee bank is overtopped or breached a large volume of water rushes through the opening at a high velocity contributing to increased flood damage.

Once a levee has been breached water is often retained behind the levee making it difficult for water to return to the river. In many instances it may take weeks for floodwaters to return to the main river channel.

Scouring and deposition is another consequence of levee failure. When a levee breaches water moves with a high velocity and erodes material from the surrounding area before spreading out and depositing the material on the floodplain.

Another concern is the changing environmental conditions that can significantly alter the hydrologic regime of a river. For example, an increase in clearing and agricultural drainage within a river basin can lead to increased flood discharge and flood levels and thereby reduce the level of protection offered by the levees.

4.2 Goals of the Flood Management Plan

The goals of the Flood Management Plan are to:

- reduce flooding risks on the floodplain;
- minimise the impact of those risks when they occur;
- mitigate damages caused by floods when they occur; and
- protect and enhance the natural environment.

5. Floodplain modelling

5.1 Background

Due to the extensive earthworks that have been carried out by landowners on the floodplain in the study area, such as the levee bank system and an excavated channel, a detailed hydraulic assessment of these flood mitigation works was considered necessary to fully understand their impact on major flooding.

Detailed aerial photography and contour mapping of a 16 kilometre section of river in the Bennies Road area was completed so that the July 1995 flood could be hydraulically modelled. The modelling (Bretnall 1996) was used to examine the impact of the levee banks and assess various options to reduce the impact of major flooding.

Using a computer based hydraulic backwater program, the 13 July 1995 flood was modelled using surveyed cross-sectional data and recorded peak flood levels. A schematic diagram of the modelled flow paths with peak flows is shown on Figure 7. Recognised values of Manning's n were used for the floodplain and varied from 0.035 for the main river channel to 0.110 for the heavily vegetated areas.

A high degree of confidence was achieved in the modelling of the 1995 flood due to the large number of modelled flood levels comparing favourably with the recorded peak flood levels. Of the 22 recorded peak flood levels obtained, 16 were modelled to within 0.07 metre of the recorded flood level. The locations of the overtopped levee banks were also modelled and only reinforced the realistic nature of the calibrated 1995 flood hydraulic model.

The following significant points arise in the modelling of the 1995 flood:

Attenuation of peak flows

A peak river flow of 310 m^3/sec was recorded at the Quinns Ford gauging station which is located approximately 50 kilometres upstream of Bennies Road. Modelling of the recorded peak flood levels indicates a peak flow of 270 m^3/sec through the study area with the lower peak flow being attributed to attenuation of flow along the river. Further attenuation of the flow is expected at the numerous levee breaches due to the significant volume of available storage behind the levee system in the Bennies Road area.

Major levee breaches

There are four major levee breaches and an overtopped levee in the study area which are considered significant in the 1995 flood.

Two levee breaches and an overtopped levee bank are located upstream of Bennies Road. The size of the breaches controls the outflow capacity and this information is then used in the flood modelling.

The two major levee breaches located upstream of Bennies Road on Loc 872 and Loc 516 appear to be permanent type openings in the levee bank system with floodwaters being directed onto the eastern side of the levee system. Overtopping of the levee bank between these two breaches also occurred. During the 1995 flood an estimated flow of 130 m^3/sec of the total of 270 m^3/sec was directed away from the main watercourse and onto the eastern side, however, the flow returned to the main river system at Bennies Road.

The two major levee breaches located downstream of Bennies Road at Loc 1456 and Loc 2 (just south of Bennies Road) direct floodwaters away from the main watercourse. However, the floodwaters from the Loc 1456 breach returns to the river at Loc 1 (east of Loc 2744). The two levee breaches divert about 110 m^3/sec of the total flow of 270 m^3/sec away from the river, however the levee breach at Loc 1456 is considered to be the major breakout with an estimated outflow of 80 m^3/sec.

The aerial photograph of the Moore River flooding dated 28 July 1995 confirms the significant amount of flow breaking out from the levee breaches.

Excavated channel - Loc 2840

The two constructed diversion banks at the northern and southern ends of the Loc 2840 excavated flood relief channel generally direct floodwaters eastwards.

However, in the July 1995 flood, the Loc 1456 levee breach has more effect on flooding in the Loc 1 area (east of Loc 2744) than these two diversion banks.

It is considered that the diversion banks have more impact in directing flow eastwards in the smaller river flows than in the larger type flows.

The northern diversion bank was designed to divert flows into the old river course in events up to the 1 in 10 year flow with larger flows overtopping the diversion bank and flowing across the floodplain as it normally would in such large flows. The northern diversion bank was also designed and constructed assuming there was no diversion bank at the southern end of the excavated channel.

During the July 1995 flood there was a significant breakout of flow around the western side of the northern diversion bank. This breakout caused extensive floodplain erosion through Loc 2840 and reduced the potential overtopping and failure of the northern diversion bank.

Information of the July 1995 flood showing flow paths, flow rates and levee breaches is shown on Figure 7 with more detailed hydraulic information shown on Water and Rivers Commission drawings 1969-1-1, -2-1/2/3.

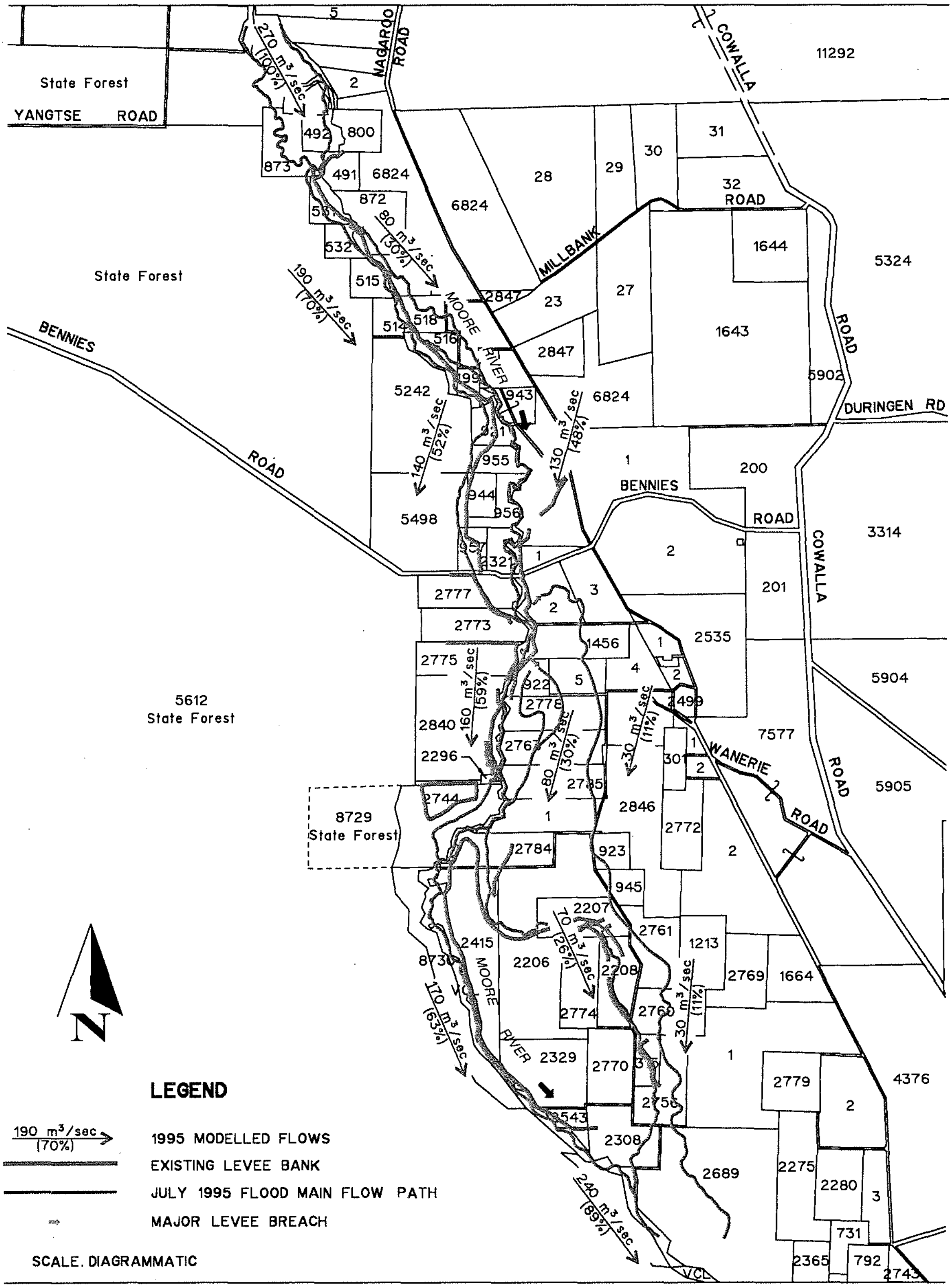

Figure 7. Modelled flow paths and flow rates for July 1995 flood

6. Recommended strategy

6.1 Flood Management Plan

6.1.1 Principles

The following principles, as previously outlined in Section 4.1, provide guidance in the development of the Flood Management Plan:

- minimise the impacts of flooding;
- no obstructions to river flow in the main channel of the Moore River; and
- current and future landuse requires to be balanced with historical river flooding.

The impacts of major river flooding can be alleviated by:

Setback of levee banks
To increase the waterway capacity of the channel the setback of existing levee banks should be increased to 100 metres from the main river channel and 25 metres from the flood relief channels. The setback levees will not need to be as high as levees that are located nearer to the river.

Flood relief channels
Flood relief channels provide additional waterway capacity during the larger river flows. There are four significant flood relief channels in the study area:

- channel on the eastern side of the floodplain north of Bennies Road;
- channel through Loc 2840;
- channel through Loc 2744; and
- channel that commences in Loc 2784 and traverses southwards.

6.2 Detailed description of Flood Management Plan

The Components of the Flood Management Plan are shown on Figure 8 with more detailed information for the Bennies Road area shown on Figure 9.

Components 1, 2, 3, 4, 7 and 8 have their main impact on major river flows with Components 5 and 6 having their main impact on the more frequent low river flows.

6.2.1 Component 1 - Levee repairs on Loc 2 and Loc 1456

The levee breaches on Loc 2 and Loc 1456 require proper repair to withstand major flooding. The repair of these levee breaches will significantly reduce the flooding risk on these properties and other properties further downstream.

6.2.2 Component 2 - Replace diversion banks on Loc 2840 channel with low weirs

The excavated channel in Loc 2840 is to act as an efficient flood relief channel during major flooding. The two existing diversion banks on the channel have been constructed to the levels shown in Table 1.

Replacing the 4 metre high northern diversion bank with a 1.5 metre high diversion weir will direct low flows eastwards into the old watercourse but will also allow flow into the excavated flood relief channel during major flows each winter.

Replacing the 4 metre high southern bank with a 1.2 metre high weir will allow some ponding of river flow in the channel and but, more importantly, will also allow major flows to pass without significant obstruction.

Both diversion banks need to be designed to withstand substantial overtopping and it is envisaged that extensive rock protection will be required.

Extensive erosion protection works will also be necessary along the entire length of the Loc 2840 flood relief channel in order to provide sustainable banks and channel for the long term.

6.2.3 Component 3 - Setback of levees

The floodplain just south of Bennies Road is severely constricted due to the existing levee bank system adjacent to the main river channel. The existing waterway requires to be widened on these properties by relocating the levees away from the watercourse.

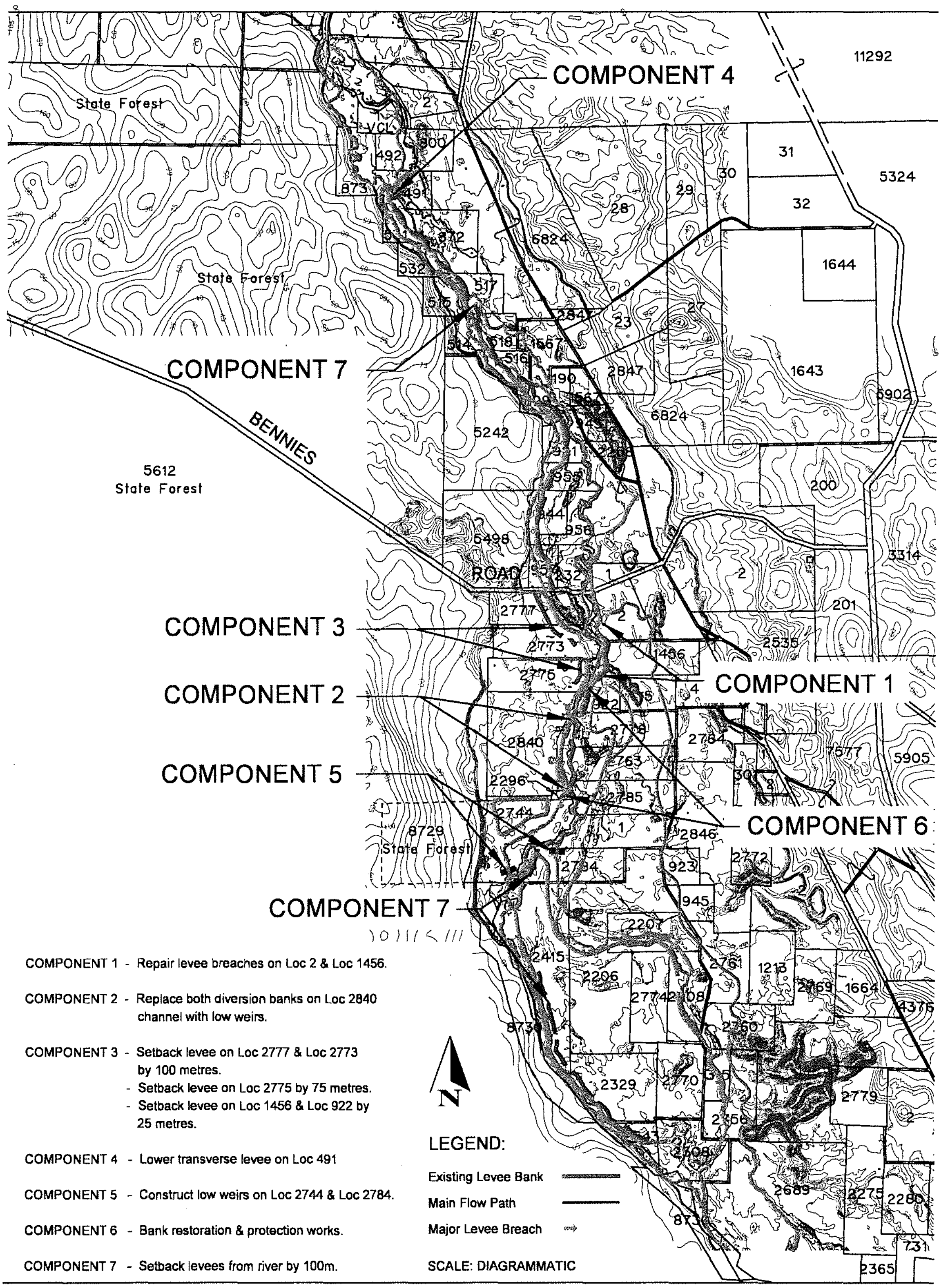

Figure 8. Flood management strategies for Moore River - Bidaminna

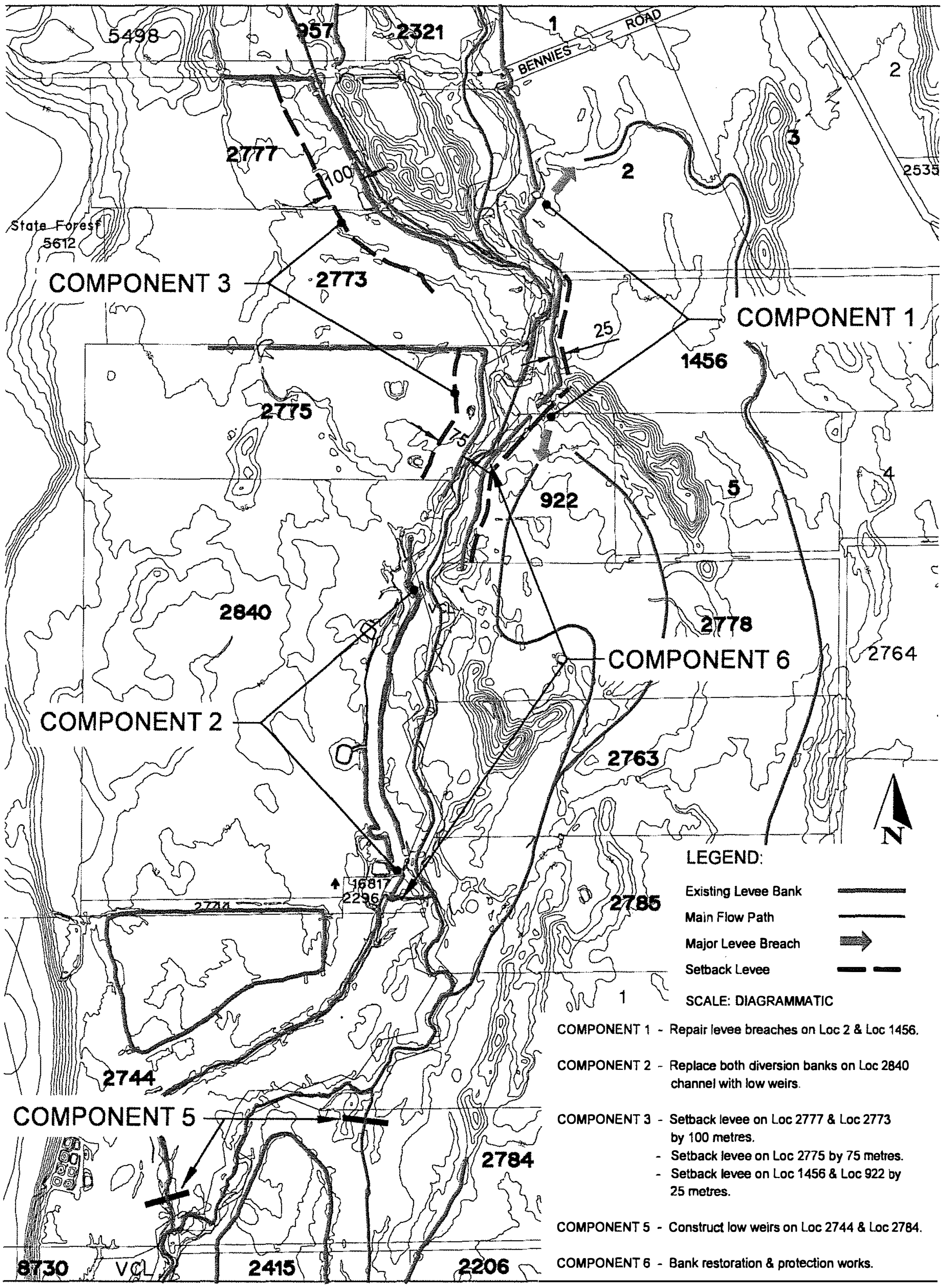

Figure 9. Detail of flood management strategies downstream of Bennies Road

The setting back of the levees will lower water levels and decrease water velocities and thereby lessen the potential for severe erosion and levee breaches.

The levees and their setbacks are:

- 100 metres setback on Loc 2777 and Loc 2773;
- 75 metres setback on Loc 2775; and
- 25 metres setback on Loc 1456 and Loc 922.

6.2.4 Component 4 - Lowering of transverse levee on Loc 491

The transverse levee on Loc 491 needs to be lowered to allow a portion of the floodwaters to be directed in a controlled manner onto the eastern side of the Moore River floodplain.

As shown in the 1995 flood, the main watercourse of the Moore River upstream of Bennies Road does not have the capacity to contain large flows as the levee system breached on Loc 872 and Loc 516 with approximately 50% of the flow being diverted onto the eastern side of the floodplain.

If the transverse levee at Loc 491 is not lowered then uncontrolled breakouts of the levee system are again expected to occur during major flooding.

6.2.5 Component 5 - Construction of low weirs

Low weirs need to be constructed on Loc 2744 and Loc 2784 to maintain low river flows in the main channel. However, during major flooding, the weirs will be overtopped and allow floodwaters into the flood relief channels. The required heights of these weirs are estimated to be 1.2 metres and 0.7 metres respectively.

Vehicle access across the weirs should be incorporated into the design.

6.2.6 Component 6 - Bank restoration and protection works

Major erosion areas on the banks adjacent to Loc 922 and Loc 2296 require suitable repair and protection against further erosion. These areas are considered the worst cases of bank and channel erosion of the river in the study area and require immediate repair.

6.2.7 Component 7 - Setback of levees

As a general guideline existing levee banks in the study area are recommended to be setback at least 100 metres from the main river channel as this will increase the waterway capacity and reduce the likelihood of levee breaches during major flooding.

The construction of new levee banks, such as along the flood relief channel in Loc 2744, is acceptable provided they are located at least 25 metres from the adjacent flood relief channel or 100 metres from the main river channel.

6.2.8 Component 8 - Fencing and revegetation

Uncontrolled stock access to riparian land can lead to excessive runoff, bank erosion, loss of productive land and important habitat and damage to in-stream ecosystems. It is not necessary to permanently exclude animals from riparian land but it is important to control their movement and to manage grazing pressure.

The location of fencing on the floodplain requires careful planning as major flooding causes a continual threat to conventional fence-lines.

The regeneration of fringing vegetation on the floodplain is also encouraged as it is very important for sustainable agriculture. Stock grazing on floodplains is acceptable provided overgrazing of the land does not occur.

6.3 Implementation of Flood Management Plan

The Flood Management Plan will be implemented by:

- negotiated agreement;
- land planning process; and
- legal direction.

Implementing the plan will initially be based on negotiation with individual landowners

The use of the land planning process is considered important for the long-term implementation of the Flood Management Plan. However, it may be necessary to resort to legal direction if a negotiated agreement cannot occur and the land planning process is considered too long-term.

Until the Flood Management Plan is implemented there should be restrictions on landuse changes or intensification of existing landuse due to the significant flooding risk. Full implementation of the Flood Management Plan is expected to take at least three years.

The Flood Management Plan should be funded by:

- joint funding by Federal, State and Local Government and landowners; and
- beneficiaries and creators pay.

"*Beneficiaries and creators pay*" means that the beneficiaries of flood management works should contribute to the cost of the implementation. In addition, if landowners in their flood or land management practices create or exacerbate flooding then these landowners should contribute to the cost of flood mitigation works.

6.3.1 Scheduling and Costing of Flood Management Plan

In order of priority the following Components of the Flood Management Plan are recommended to be implemented:

1. ***Component 1*** - levee repairs on Loc 2 and Loc 1456
2. ***Component 6*** - bank restoration and protection works on Loc 922 and Loc 2296
3. ***Component 5*** - construction of low weirs at Loc 2744 and Loc 2784
4. ***Component 3*** - setback of levees on properties downstream of Bennies Road
5. ***Component 2*** - replace diversion banks with low weirs on Loc 2840
6. ***Components 4, 7*** and ***8*** are considered a lower priority and are recommended to be implemented in the medium to long term.

Preliminary cost estimates for the various flood management components are outlined in Table 2.

Table 1. Existing and proposed bank heights for diversion weirs in Loc 2840 flood relief channel

Bank	*Top of bank (m AHD)*	*Toe of bank (m AHD)*	*Existing bank height (m)*	*Proposed bank height (m)*
Northern	36.0	32.0	4.0	1.5
Southern	35.0	31.0	4.0	1.2

Table 2. Estimated costs for the implementation of the flood management strategies

Component		*Estimated Cost*
1	**Repair levee breach on Loc 2 & Loc 1456**	$ 20,000
6	**Bank restoration and protection works on Loc 922 and Loc 2296**	$ 40,000
5	**Construction of low weirs on Loc 2744 and Loc 2784**	$ 40,000
3	**Set back levee on Loc 2777 & Loc 2773 by 100 metres** **Set back levee on Loc 2775 by 75 metres** **Set back levee on Loc 1456 & Loc 922 by 25 metres** - Total length of levee to be relocated is 2000 metres. - Total volume of earthworks is 24 000 cubic metres.	$120,000
2	**Replace diversion banks on Loc 2840 channel with low weirs** - Two diversion weirs with rock protection. - Erosion protection of Loc 2840 channel.	$300,000
	TOTAL	$520,000

7. References

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