Cardno Willing

Engineering the Future

Delatite Shire Council

Benalla
Floodplain Management Study

Final Report

October 2002

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Cover Photograph:
October 1993 flood at Benalla. The view is of the CBD and to the east along Bridge Street. The Broken River is in the foreground. Photo courtesy of DNRE.

FOREWORD

The Victorian Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State will consider subsidising flood mitigation works to alleviate existing problems and to provide specialist technical advice to assist councils in the discharge of their floodplain management responsibilities.

There are four basic sequential stages in the preparation and implementation of a floodplain management plan:

1. Flood Study - determines the nature and extent of the flood problem.

2. Floodplain Management Study - evaluates management options for the floodplain in respect of both existing and proposed development.

3. Floodplain Management Plan - involves formal adoption by the Minister known as an *Approved Scheme* under the Water Act, 1989.

4. Implementation of the Plan - construction of flood mitigation works to protect existing development.
   - use of the Victoria Planning Provisions (VPPs) to ensure new development is compatible with the flood hazard.

Stage 2 of the study comprises the Floodplain Management Study and hence constitutes the second stage of the management process for the Broken River catchment within the study area. The study has been prepared for the Delatite Shire Council to formulate and review structural and non-structural flood mitigation options.

The study was carried out as a priority measure to investigate the feasibility of various floodplain management strategies to alleviate existing flood problems and to quantify the impact of various development proposals which have been put to Council. The findings are based upon extensive consultation with the community, Council officers, the Goulburn Broken Catchment Management Authority, and the Department of Natural Resources and Environment.

This study should serve as an input to the formulation by Council of a management plan (The Water Management Scheme) for the Benalla floodplain. The Scheme should have the knowledge and support of the local community.

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ABBREVIATIONS

AAD	Average Annual Damages
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Aver Recurrence Interval
ARR	Australian Rainfall and Runoff (1987 edition)
BCC	The former Benalla City Council
BOM	Bureau of Meteorology
BRMB	Broken River Management Board
CBD	Central Business District
DNRE	Department of Natural Resources & Environment (the former Department of Conservation and Natural Resources)
DTC	Delatite Shire Council
FPMCC	Floodplain Management Consultative Committee
FPMP	Floodplain management plan
FPMS	Floodplain management study
GBCMA	Goulburn Broken Catchment Management Authority
ILAP	Integrated Local Area Plan
NPV	Nett Present Value
PTC	Public Transport Corporation
VICSES	Victorian State Emergency Services (VICSES)
VLine	State Rail Authority
VicRoads	Roads and Traffic Authority
XP-EXTRAN	Unsteady flood routing model
XP-RAFTS	Rainfall/runoff routing program

GLOSSARY

Annual Exceedance Probability (AEP)	refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be relatively large.
Average Recurrence Interval	refers to the long term average interval or average period between occurrences of a flood of a given size. The average recurrence interval does not imply that the flood of a given size will occur regularly.
Australian Height Datum (AHD)	a common national plane of level corresponding approximately to mean sea level.
catchment	the area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
design flood	a flood of known magnitude or probability of exceedance used for engineering design and planning purposes.
designated flood	(See flood standard)
✓development	the erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
discharge	the rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow which is a measure of how fast the water is moving rather than how much is moving.
flood	relatively high stream flow which overtops the natural or artificial banks in any part of a stream or river.
flood hazard	potential for damage to property or persons due to flooding.
flood liable land	land which would be inundated as a result of the standard flood.
floodplain	the portion of a river valley, adjacent to the river channel, which is covered with water when the river overflows during floods.
floodplain management measures	the full range of techniques available to floodplain managers.

Glossary (cont.)

floodplain management options	the measures which might be feasible for the management of a particular area.
flood standard (or designated flood)	the flood selected for planning purposes. The selection should be based on an understanding of flood behaviour and the associated flood risk. It should also take into account social, economic and ecological considerations.
flood storages	those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
floodways	those areas where a significant volume of water flows during floods. They are often aligned with obvious naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, the areas of deeper flow or the areas where higher velocities occur.
high hazard	possible danger to life and limb; evacuation by trucks difficult; potential for structural damage; social disruption and financial losses could be high.
hydraulics	the study of water flow; in particular the evaluation of flow parameters such as stage and velocity in a river or stream.
hydrograph	a graph which shows how the discharge changes with time at any particular location.
hydrology	the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
lag time	the term used to describe the time interval between the arrival of flood peaks from two or more tributary streams at a common location.
management plan	a document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, problems, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.

Glossary (cont.)

mathematical/computer models	the mathematical representation of the physical processes involved in runoff and stream flow. These models are usually run on computers due to the complexity of the mathematical relationships.
peak discharge	the maximum discharge occurring during a flood event.
probable maximum flood	the flood calculated to be the maximum which is likely to occur.
probability	a statistical measure of the expected frequency or occurrence of flooding. For a fuller ex-explanation see Annual Exceedance Probability.
runoff	the portion of rainfall which actually ends up as stream flow, also known as rainfall excess.
stage	equivalent to 'water level'. Both are measured with reference to a particular datum and location.
stage hydrograph	a graph which shows the variation in stage with respect to time. It must be referenced to a particular location and datum.

SUMMARY

S.1 Introduction

This report presents the results of the Benalla Floodplain Management Study. The study area extends from the Hume Freeway to the northern fringe of urban development approximately 1.5 km downstream of the railway viaduct. This study has been undertaken to investigate the impacts of a range of structural and non structural flood mitigation proposals. Three schemes comprising two or more structural measures plus a fourth scheme comprising of only non structural measures were initially investigated and reported in August 1996.

Each option was either identified or developed in consultation with the Floodplain Management Consultative Committee and from written submissions from the community. Where several variations of a measure where examined the most suitable was selected for inclusion in a scheme.

Following presentation of the draft report in 1996 the Floodplain Management Consultative Committee (FPMCC) undertook a further series of public meetings during 1997 with neighbourhood groups to clarify/confirm community expectations. Based on those meetings the FPMCC decided to examine four further schemes designed to provide structural works to protect the town from flooding against either a 2% AEP or a 5% AEP flood. These schemes were designated as E2, E5, F2 and F5 based on the level of flood protection afforded and were reported in October 1998.

Thereafter detailed discussions were held with a wide range of interest groups which included meetings with local neighbourhood groups who would be directly effected by the proposed structural measures. As a result of these discussions, comments by the GBCMA and further deliberations by the FPMCC an additional two schemes (Schemes H5 and J) were proposed and investigated. This report includes the findings relating to these two additional schemes as well as all other schemes previously reported.

Only the latest proposed schemes (H5 and J) and the "do nothing" option have been analyzed using the latest floor level survey that was undertaken as part of the Benalla Flood Warning System.

S.2 1% AEP Peak Flow Estimate and the Flood Standard

Initially the evaluation of various flood mitigation measures was undertaken using the 1% AEP flow estimated in Stage 1 of the study and reported in the Flood Study (Ref. 2). During the course of the second stage of this study (the Floodplain Management Study), a second estimate of the magnitude of the 1% AEP design flood was reported by HydroTechnology (Ref. 12). The HydroTechnology report suggested that the magnitude of the 1% AEP design flood was in the order of 1440 m^3/s. This is approximately 25% greater than the magnitude reported in the Flood Study (Ref. 2.) of 1150 m^3/s and 14.7% greater than the estimated 1250 m^3/s of the October 1993 flood.

In order to resolve the magnitude of the peak 1% AEP design flood flow, an independent assessment was undertaken which concluded that the 1995 estimate of the 1% AEP flood (Ref. 2) and the estimated peak flow in October 1993 were both within the acceptable range of peak flow estimates. On the basis of the independent assessment, the Floodplain Management Consultative Committee resolved to adopt the 1% AEP flood as the Flood Standard and to adopt a peak 1% AEP flood flow rate equal to the estimated peak flow for the October 1993 flood.

For planning purposes the extent of flooding is defined by the level of the Flood Standard. The extent of flooding indicated in this report is based on broad topographic information and is therefore only indicative. An accurate assessment of the flood liability of any individual property needs to be based on site specific survey data.

S.3 Impact of Flooding and Flood Hazard

Table S.1 shows the number of buildings which experience over floor flooding by various size floods. The majority of the residential buildings affected are south (upstream) of the Railway Viaduct.

TABLE S.1
NUMBER OF BUILDINGS EXPERIENCING OVER FLOOR FLOODING FOR VARIOUS DESIGN FLOODS

Flood	Residential	Non-Residential
10% AEP	8	4
5%AEP	36	21
2% AEP	361	138
1%AEP	877	208

To assess the degree of hazard across the floodplain reference was made to the procedures described in the Floodplain Development Manual (Ref 1). The maximum depth of water was estimated from the available survey of ground and floor levels at selected locations (Ref. 2). Where the estimated depth of floodwater is greater than one metre the area has been categorized as high hazard. In general the urban floodway has been provisionally equated to areas identified as high hazard excluding residential built-up land.

S.4 Flood Damages

Damages from flooding may be categorized typically as either financial or social in nature and are often referred to as tangible damages and intangible damages respectively. Generally, tangible damages are measurable in dollar values and they may be subdivided into direct and indirect damages.

Direct damages are those caused by the physical contact of flood water with damageable property. They include damages to commercial and residential building structures and contents, and infrastructure such as electricity, gas, water supply and sewerage reticulation. Direct damages also include damage to motor vehicles and other plant and equipment.

Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood.

Flood damages for this study were assessed using the model DAMAGE. The damage estimates derived using the DAMAGE model are for the tangible damages only. A separate estimate of secondary damages related to roads and public infrastructure, costs related to loss of business/trade, and costs associated with personal health attributable to flooding was included in the economic assessment. The estimated secondary costs were estimated as a percentage of the primary damage costs and for Benalla varied from 5.1% of the primary cost for the 10% AEP flood to 9.6% for the 1% AEP flood. The intangible costs included with the secondary costs are almost impossible to estimate accurately and while it is recognized that some assessments of intangible costs put the figure as high as 50% of the tangible costs the Study Team could not identify reliable data to support the higher figure. Guidance as to the sensitivity of the benefit cost ratio to increases in the secondary (and intangible costs) is reported.

The damage values shown below are therefore considered to be lower bound estimates when considering the total flood damage cost to the community.

TABLE S.2
ESTIMATED DAMAGE FOR VARIOUS FLOODS

Flood	Estimated Flood Damages
10% AEP	$0.34 million
5% AEP	$1.99 million
2% AEP	$13.0 million
1%AEP	$29.30 million
Extreme Flood	$260.90 million

Estimated flood damages are in 2001 dollars

The standard way of expressing flood damages is in terms of average annual damages (AAD). These are calculated by multiplying the damages which can occur in a given flood by the probability of the flood occurring in a given year and summing these annual damages across the range of floods beginning with the smallest flood which causes damage up to the Probable Maximum Flood (PMF). By this means, the smaller floods which occur more frequently are given a greater weighting than the rare catastrophic floods. The AAD for the study area is estimated to be $2,157,586.

S.5 Flood Mitigation Measures and Schemes

The study initially evaluated all flood mitigation measures and four schemes.
Based on the array of available structural measures, five alternative floodplain management schemes based on various structural measures in combination with non-structural measures were assembled and compared with a sixth scheme which is comprised only of non-structural measures.

The first 3 structural schemes (Schemes A, B and C) and the non-structural scheme (Scheme D) were developed and costed on the basis of their performance in the 1% AEP flood. This is equivalent to assessing the impact the scheme would have had if it had been in place during the October 1993 flood. Thus all levees have been costed on the basis that they would be constructed to the height of the 1% AEP flood plus 600 mm.

Thus all measures and the above schemes were presented on the basis that the community would be protected against the impacts of a flood of the same magnitude as the October 1993 flood.

Due to community concerns regarding the appearance and disruption to normal activities which would result from constructing levees to the required height for protection against a flood of similar magnitude as the 1993 flood the FPMCC proposed 2 further schemes (Schemes E and F). Schemes E and F were both analyzed and costed for the 2% AEP and 5% AEP design floods. These schemes have been reported as Schemes E2 and F2, and E5 and F5 for the 2% and 5% floods respectively. Subsequently two additional schemes (Scheme G5 and Scheme H5) were analyzed and costed for the 5% AEP flood only. An eighth scheme (Scheme J) contains only vegetation management measures and therefore applies across the full range of floods.

Structural Measures

Structural measures are designed to provide protection by limiting the extent of flooding or by lowering the level of floodwaters in a protected area. An initial list of possible structural measures was identified by the Floodplain Management Consultative Committee at the commencement of the study. Further possible structural measures were identified during the study including suggestions contained in written submissions from the community.

All the identified possible structural measures were examined but only some were included in potential schemes. The hydraulic impact of each structural measure and each scheme was assessed using the EXTRAN-XP hydraulic model assembled for the Flood Study and calibrated against the October 1993 flood.

The hydraulic impact of each measure was estimated for the 1% AEP flood. The impact of each scheme was estimated for the 10% AEP, 5% AEP, 2% AEP, 1% AEP floods and an extreme flood.

The structural and non-structural measures included in each alternative scheme are summarized in Table S.3. The structural measures included in the alternative schemes are:

Measure C Provision of additional culverts through the railway embankment between the river and the East Main Drain.

Measure D Clearing of understorey scrub and thinning of trees within the river, including the islands between Psaltis Parade and the confluence with Holland Creek, and downstream of Ackerly Avenue. Two levels of vegetation reduction were examined. The smaller reduction was included in Schemes A, B and C. The heavier reduction was included in Schemes E, F and G.

Measure F Construction of Levees 1 and 2 on the western side of the river from the railway to Bridge Street (Levee 1) and Bridge Street to upstream of Cowan Street (Levee 2).

Measure H Construction of Levee 7 on the eastern side of the river from Railway Place to the Yarrawonga railway branch line parallel to Gillies Street.

Measure I Construction of Levees 3A and 4 on the eastern side of the river from the railway to Bridge Street (Levee 4) and from Bridge Street to Willis Little Drive (Levee 3A).

Measure K Construction of a second lake (Arundel Lake) between Ackerly Avenue and the northern extension of Arundel Street together with a reduction of in-stream and bank trees/scrub between Arundel Street and Faithful Street.

Measure L3 Conversion of the area immediately upstream of the Hume Freeway into a flood retarding basin by reducing the waterway openings at the freeway crossings over the Broken River and its anabranch, Blind Creek and Holland Creek such that the impounded 1% AEP floodwaters would reach, but not overtop the lowest point along this section of the Hume Freeway.

Measure M Excavation of the mid-stream islands at the upstream end of Benalla Lake to a level no higher than RL 168m which is below the normal water level in the lake.

Measure NN Implementation of a vegetation management plan between the railway and Faithful Street which is designed to increase the available flood flow area by removing selected trees and woody understorey and providing compensating planting near the edge of the 1% AEP flood extent. A limited amount of channel excavation across a mid-stream island is included in this measure.

Measure VM Implementation of a vegetation management plan similar to Measure NN comprising environmentally sensitive vegetation management along waterways though Benalla including river islands and floodplain from the lake extending upstream to the extension of Cowan Street, downstream of the railway viaduct to Faithful street, the environs of the Lake Benalla weir and the Market Street floodway.

Non-Structural Measures

Non-structural measures including house raising, were considered in order to reduce the impact of flooding in areas where structural measures are not appropriate. In addition there are some non-structural measures applicable to all of Benalla such as flood warning system improvements and evacuation planning which are required to supplement both structural and non-structural measures.

All schemes include a range of non-structural measures to supplement the structural measures. For example, flood warning improvements, evacuation and contingency planning are still included where levees are provided (Scheme A) because it is not practical to protect all areas with levees and because of the residual flood risk associated with floods greater than the 1% AEP flood overtopping any levees that are provided.

Scheme A was found to have the greatest impact on flooding by providing protection up to and including the 1% AEP flood for all areas other than on the western side of the river north of the railway. Levees in this area are not considered practical. The construction of a lake downstream of Ackerly Avenue is the only identified structural measure which benefited properties in this area by reducing the extent of flooding. However it is estimated that a number of houses in this area would still experience over floor flooding in a 1% AEP flood.

TABLE S.3
SUMMARY OF ALTERNATIVE FLOODPLAIN MANAGEMENT SCHEMES

Scheme	A	B	C	D	E	F	G	H	J	K
Structural Measures										
C (Railway Culverts)		✓			✓	✓	✓[1]	✓		✓
Dm (Moderate Vegetation Management)	✓	✓	✓							
De (Extensive Vegetation Management)					✓	✓	✓	✓	✓	✓
F1 (Levees 1 and 2)	✓									
F5 (Landscaping, Road raising)					✓	✓	✓	✓		
H1 (Levee 7)	✓									
H5 (Floodwall, Landscaping,Levee)						✓	✓	✓		
I1 (Levees 3A and 4)	✓									
I5 (Landscaping ,Floodwall)					✓	✓	✓	✓		
K (Arundel Lake)			✓			✓	✓			
L3 (Freeway Retarding Basin)			✓							
M Excavation of river islands)					✓	✓				
NN (Vegetation management)					✓	✓		✓	✓	✓
VM (Vegetation management)										✓
Non Structural Measures										
House Raising	✓	✓	✓	✓						
Voluntary Purchase	✓[2]	✓	✓	✓						
Land Use Planning/Zoning	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Building and Development Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Improved Flood Warning	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Evacuation/Contingency Planning	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Public Education	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Improved Access	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Assembly Areas/Flood Refuges	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Note 1. Only the additional railway culverts between Duffy Street and the East Main Drain are included in Schemes G and H.
Note 2. One property recommended for purchase to facilitate construction of Levee 2 or free form landscaping. The cost of the purchase of a second property to facilitate construction of Levee 2 has not been included since it is not essential.

Scheme B offers only small reductions in the 1% AEP flood levels for most of Benalla although significant reductions in flood levels (up to 400 mm) are predicted locally in the vicinity of the proposed additional culverts through the railway embankment. Other areas which would derive the most benefit from Scheme B are houses in the immediate vicinity of works to reduce the amount of understorey vegetation and trees on the river islands and banks between Psaltis Parade and the Broken River confluence with Holland Creek. This includes properties in Arundel Street, Neill Avenue and surrounding streets.

Scheme C which includes a retarding basin upstream of the Hume Freeway provides a similar level of overall flood protection as Scheme B. If the flood level immediately upstream of the Hume Freeway is limited to the existing lowest point along the Hume Freeway there would only be a reduction of approximately 8% in the estimated peak flood flow which occurred in October 1993. As a consequence, reductions in the 1% AEP flood level are generally limited to no more than 100 mm although decreases of up to 300 mm are predicted where vegetation within the floodway upstream of Psaltis Parade is reduced.

Scheme C has the further disadvantage in that 6 houses upstream of the Hume Freeway will be affected by the impoundment of flood waters. Two of the houses not currently subject to over floor flooding would be inundated and three others would have less than the desirable freeboard of 600 mm.

Scheme D includes only non-structural measures such as raising house floor levels (non-brick buildings only) and flood proofing brick buildings. This scheme would not reduce the disruption or anxiety associated with major flooding in Benalla.

Scheme E includes smaller levees (Scheme E2) or landscaping, road raising and flood proof fencing (Scheme E5) plus a reduction in the extent and density of vegetation within and near the main river channel upstream of Psaltis Parade and downstream of Ackerly Avenue. Additional culverts through the railway embankment are also included to provide some localised flood alleviation when the flood waters overtop the roads, fences and landscaping. Elsewhere there would be no lowering of the 1% AEP flood level. Properties north of the railway on the western side of the river would receive the least benefit and only small decreases, generally less than 100mm, would be experienced.

Scheme F2 and F5 include the same measures as for Schemes E2 and E5 respectively but additionally include a lake or series of lakes downstream of Ackerly Avenue (Arundel Lake). In either Scheme flood protection is only afforded for floods up to and including the design flood and there would be no lowering of the 1% AEP flood level. Properties north of the railway on the western side of the river would receive the least benefit for floods up to and including the design flood (either 2% AEP or 5% AEP flood) but would experience decreases in flood levels for all floods up to and including the 1% AEP flood.

Scheme G5 is similar to Scheme F5 but excludes river excavation (Measure M) and the additional railway culverts proposed for the area near Nunn Street. The culverts proposed for the Duffy Street area provide the greatest benefit from the additional culverts and are therefore included. The benefits of the Scheme are similar to Scheme F5 but are achieved at a lower cost.

Scheme H5 differs from Scheme G5 only in that the second lake (Arundel Lake) proposed for the river reach between Ackerly Avenue and Arundel Street is replaced by a vegetation management plan extending from the railway to Faithful Street. Depending on the extent of tree removal and understorey clearing comparable reductions in flood levels can be achieved but at a substantially smaller cost.

Scheme J includes only vegetation management as the structural components (Measures De and NN).

Scheme K includes the vegetation management comprising environmentally sensitive vegetation management along waterways though Benalla including river islands and floodplain from the lake extending upstream to the extension of Cowan Street, downstream of the railway viaduct to Faithful street, the environs of the Lake Benalla weir and the Market Street floodway. The additional culverts through the railway embankment provide localized benefits to residential and commercial buildings.

An economic evaluation, or benefit-cost analysis, was undertaken to assess the performance of each scheme. The benefits and costs are measured in monetary terms, so that they can be readily compared. As most people prefer present goods and services to future ones, future costs and benefits are given less weight than present ones.

Benefit-cost analysis has been applied for many years to the evaluation of major infrastructure as part of the public sector's decision-making framework. It is applied in this instance to assist in the decision concerning strategies for flood management in Benalla.

Preliminary cost estimates were based on conceptual designs for each structural measure. For comparison with the cost of structural measures, the cost of raising and protecting all flood liable residential buildings under Scheme D was also estimated.

The net present value (NPV) of on-going maintenance costs were added to the capital cost of each structural measure included within each scheme to obtain the net present value of all structural measures in each scheme. The residual cost of the capital works after 20 years was deducted from the initial capital cost when estimating the benefit cost ratio. A summary of the key economic results for each Scheme is provided in Table S.4.

The number of buildings which would continue to experience overfloor flooding if only the structural measures in Schemes A, B, C, E, F, G. H, J and K are implemented is summarized in Table S.5. The commercial category includes retail and industrial buildings.

TABLE S4

SUMMARY PERFORMANCE OF FLOODPLAIN MANAGEMENT SCHEMES

SCHEME	Houses Protected	Houses Flooded	Commercial Bldgs Protected	Commercial bldgs Flooded	AAD Remaining	AAD Savings	Capital Cost ($ 000's)	Recurrent Cost ($ 000's)	Benefit/Cost Ratio	Capital Protection cost per Building	Capital Protection cost per House/Unit
Protection against 1% AEP Flood											
Do Nothing	**0**	**877**	**0**	**208**	**$2,157,586**	**0**	**0**		**NA**	**NA**	**NA**
Scheme A1 (Levees, Reduced River Vegetation near confluence)	832	215	241	2	$1,365,570	$792,016	9,042	177	1.19	$8,427	$10,868
Scheme B (Railway Culverts, Arundel Lake, Reduced River Vegetation near confluence)	299	578	0	208	$2,120,634	$36,952	3,180	9	0.97	$10,635	$10,635
Scheme C Retarding Basin, Arundel Lake, Reduced River Vegetation near confluence)	270	607	-3	211	$2,143,253	$14,333	7,380	168	0.30	$27,640	$27,333
Scheme D (House raising (weatherboard) and flood proofing (brick residences and suitable commercial properties)	877	0	243	0	$1,307,822	$849,764	27,906	279	0.48	$24,916	$31,820
Scheme J (Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street.)	**209**	**668**	**29**	**179**	**$1,788,064**	**$369,522**	**873**	**19**	**6.01**	**$3,668**	**$4,177**
Scheme K (Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street, additional railway culverts near Duffy Street - East Main Drain).	**258**	**619**	**32**	**176**	**$1,797,317**	**$360,269**	**1,968**	**29**	**2.58**	**$6,786**	**$7,628**
Protection against 2% AEP Flood											
Do Nothing	0	448	0	154	2351375	0	0	0	NA	NA	NA
Scheme A2 (Levees, Reduced River Vegetation near confluence)	389	59	152	2	$1,628,451	$529,135	6,276	128	1.25	$11,601	$16,134
Scheme E2 (Railway culverts, Levees, Reduced River Vegetation near confluence and downstream of Ackerly Ave., and excavation of islands in confluence area)	429	19	152	2	$1,381,354	$776,232	10,226	134	1.10	$17,601	$23,837
Scheme F2 (As for Scheme E2 plus Arundel Lake)	441	7	152	2	$1,374,859	$782,727	12,126	162	0.92	$20,449	$27,497
Protection against 5% AEP Flood											
Do Nothing	**0**	**36**	**0**	**21**	**$2,157,586**	**0**	**0**	**0**	**NA**	**NA**	**NA**
Scheme E5 (Railway culverts, Levees, Reduced River Vegetation near confluence and downstream of Ackerly Ave., and excavation of islands in confluence area)	29	7	21	0	$1,575,715	$581,871	9,005	109	1.00	$180,100	$310,517
Scheme F5 (As for Scheme E5 plus Arundel Lake)	32	4	21	0	$1,571,662	$585,924	10,905	138	0.82	$205,755	$340,781
Scheme G5 (Railway Culverts near Duffy St., Landscaping, Road raising, Flood proof Fencing, Reduced river vegetation near confluence and downstream of Ackerly Avenue, and Arundel Lake)	32	4	21	0	$1,556,678	$600,908	8,505	134	1.07	$160,472	$265,781
Scheme H5 (Railway Culverts near Duffy St., Landscaping, Road raising, Flood proof Fencing, Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street.)	**34**	**2**	**21**	**0**	**$1,882,813**	**$274,773**	**7,291**	**131**	**0.73**	**$132,564**	**$214,441**
Scheme J (Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street.)	**12**	**24**	**8**	**13**	**$1,788,064**	**$369,522**	**873**	**19**	**5.26**	**$43,650**	**$72,750**
Scheme K (Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street, additional railway culverts near Duffy Street - East Main Drain).	**12**	**24**	**8**	**13**	**$1,797,317**	**$360,269**	**1,968**	**29**	**2.58**	**$98,400**	**$164,000**

1. AAD is the Annual Average Damage cost of flooding in urban Benalla.
2. Under Scheme C, 2 additional houses would experience over floor flooding and 4 other houses would be seriously effected by impounding water behind the Hume freeway embankment.
3. All schemes include house raising or flood proofing where properties receive no other protection. In line with normal practice these costs, including those for flood proofing suitable commercial premises, have not been included when estimating the costs and benefits for each scheme (other than Scheme D.
4. Building numbers and cost estimates for "Do nothing", and Schemes H5 and J have been based on the updated floor level survey.
5. The BCR for Scheme H5 and Scheme J is based on 6% discount rate over 20 years. All others are based on 7% discount rate over 50 years with no residual.

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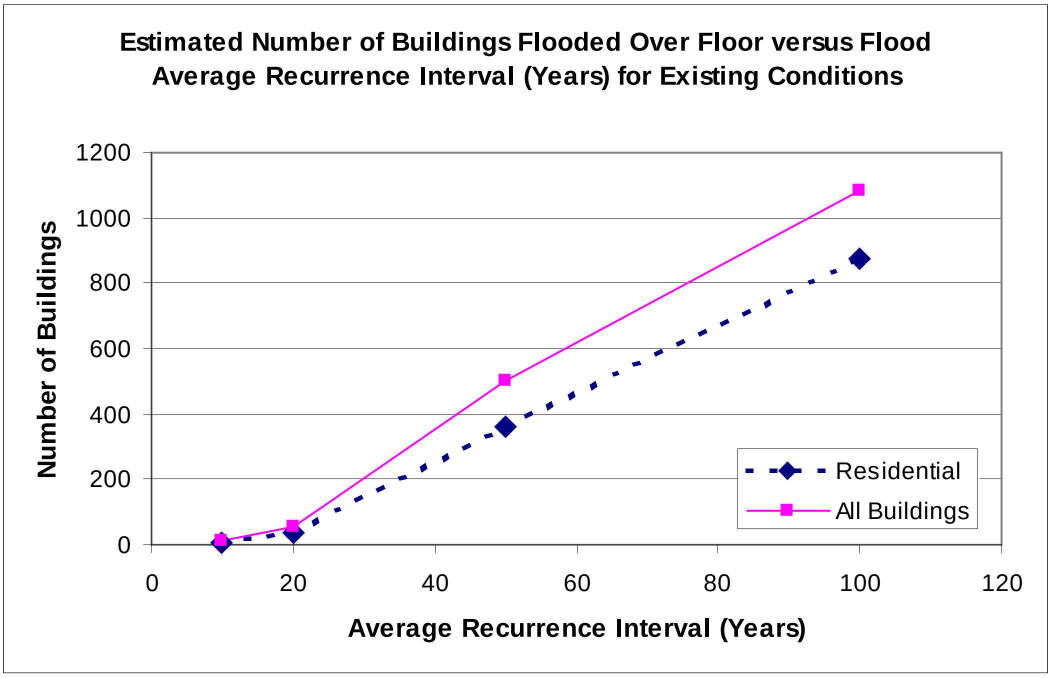
TABLE S.5
SUMMARY OF BUILDINGS FLOODED ABOVE FLOOR LEVEL

		5% AEP	2% AEP	1% AEP	Extreme[2]
Existing Conditions1	All buildings	57	499	1085	3230
	Residential	36	361	877	2856
Scheme A	All buildings	8	61	217	3298
	Residential	6	59	2152	2892
Scheme B	All buildings	219	402	786	3298
	Residential	159	261	578	2892
Scheme C	All buildings	155	234	440	3298
	Residential	110	164	297	2892
Scheme E2	All buildings	7	21	1290	3298
	Residential	7	19	1047	2892
Scheme E5	All buildings	125	588	1290	3298
	Residential	122	434	1047	2892
Scheme F2	All buildings	4	9	1290	3298
	Residential	4	7	1047	2892
Scheme F5	All buildings	4	588	1290	3298
	Residential	4	434	1047	2892
Scheme G5	All buildings	4	563	1212	3298
	Residential	4	398	957	2892
SchemeH51	All buildings	2	324	818	3230
	Residential	2	222	639	2856
Scheme J1	All buildings	37	344	847	3230
	Residential	24	242	668	2856
Scheme K	All buildings	37	354	795	3230
	Residential	24	245	619	2856

Note 1. Reported numbers for Existing, Scheme H5 and Scheme J are based on the updated floor level survey. The numbers for all other schemes are based on the Benalla Sewerage Authority mapping as reported in 1998 and beforehand.

Note 2. This is a lower bound estimate because additional properties significantly above the October 1993 flood and for which floor levels were not available have not been included in the property data base.

Note 3. All but a few properties subjected to overfloor flooding are located on the west side of the river north of the railway.



An environmental and social assessment of the various structural components of each Scheme was prepared based on five main factors. These are:

- amenity - whether the option will affect the social or physical amenity of Benalla, including accessibility to community facilities and services;
- aesthetic - whether the option will affect existing aesthetic qualities within the city, including views, vistas and impact on specific items or areas;
- land take - whether the option will involve the dedication of significant areas of land within the urban area;
- ecology - whether the option will cause disruption to the flora and fauna of the area and the extent to which this might be acceptable; and
- sensitivity - whether the option will affect sensitive uses, such as heritage items and whether general enjoyment of life will be compromised.

A summary of this assessment is provided in Table S.6.

TABLE S.6
SUMMARY OF ENVIRONMENTAL AND SOCIAL IMPACTS

Scheme	Amenity	Aesthetics	Land Take	Ecology	Sensitivity
Scheme A1					
Levee 1	L	L	L	L	L-M
Levee 2	M-H	H	M-H	M	H
Levee 3A	M-H	H	M-H	M	H
Levee 4	L	L	L	L	L
Levee 7	L	L	L	L	L-M
Vegetation reduction - confluence area	L	L	L	L	L
Overall Assessment	M	M	L-M	M	M
Scheme B					
Arundel Lake	L	L	L	H	H
Vegetation reduction - confluence area	L	L	L	H	L
Additional railway culverts	L	L	L	L	L
Overall Assessment	L	L	L	M-H	M
Scheme C					
Hume Freeway Retarding Basin	L	L	L	M	M-H
Vegetation reduction - confluence area	L	L	L	L	L
Arundel Lake	L	L	L	H	H
Overall Assessment	L	L	L	M	M-H
Scheme D					
House Raising & Floodproofing	L-M	L-H	L	L	M
Overall Assessment	L-M	M	L	L	M
Scheme A2					
Levee 1	L	L	L	L	L-M
Levee 2	M-H	M-H	M-H	M	H
Levee 3A	M-H	M-H	M-H	M	H
Levee 4	L	L	L	L	L
Levee 7	L	L	L	L	L-M
Vegetation reduction - confluence area	L	L	L	L	L
Overall Assessment	M	M	M	L-M	M

TABLE S.6 (cont.)
SUMMARY OF ENVIRONMENTAL AND SOCIAL IMPACTS

Scheme	Amenity	Aesthetics	Land Take	Ecology	Sensitivity
Scheme E2					
Levee 1	L	L	L	L	L-M
Levee 2	M-H	M	M-H	M	M-H
Levee 3A	M-H	H	M-H	M	H
Levee 4	L	L	L	L	L
Levee 7	L	L	L	L	L-M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Excavation of islands	L	H	L	H	M
Overall Assessment	L-M	L-M	L-M	M	M

Scheme	Amenity	Aesthetics	Land Take	Ecology	Sensitivity
Scheme E5					
Road raising - Area 1	L	L	L	L	L
Landscaping, Fencing - Area 2	M	M	M	M	M
Landscaping, Fencing - Area 3	M	M	M	M	M
Road raising - Area 4	L	L	L	L	L
Landscaping, fencing - Area 7	L	L	L	L	M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Excavation of islands	L	H	L	H	M
Overall Assessment	L-M	L-M	L-M	L-M	M
Scheme F2					
Levee 1	L	L	L	L	L-M
Levee 2	M-H	M	M-H	M	M-H
Levee 3A	M-H	H	M-H	M	H
Levee 4	L	L	L	L	L
Levee 7	L	L	L	L	L-M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Excavation of islands	L	H	L	H	M
Arundel Lake	L	L	L	H	H
Overall Assessment	L-M	M	L-M	M	M

TABLE S.6 (cont.)
SUMMARY OF ENVIRONMENTAL AND SOCIAL IMPACTS

Scheme	Amenity	Aesthetics	Land Take	Ecology	Sensitivity
Scheme F5					
Road raising - Area 1	L	L	L	L	L
Landscaping, Fencing - Area 2	M	M	M	M	M
Landscaping, Fencing - Area 3	M	M	M	M	M
Road raising - Area 4	L	L	L	L	L
Landscaping, fencing - Area 7	L	L	L	L	M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Excavation of islands	L	H	L	H	M
Arundel Lake	L	L	L	H	H
Overall Assessment	L	L	L-M	M	M
Scheme G5					
Road raising - Area 1	L	L	L	L	L
Landscaping, Fencing - Area 2	M	M	M	M	M
Landscaping, Fencing - Area 3	M	M	M	M	M
Road raising - Area 4	L	L	L	L	L
Landscaping, fencing - Area 7	L	L	L	L	M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Arundel Lake	L	L	L	H	H
Overall Assessment	L	L	L-M	L-M	M
Scheme H5					
Road raising - Area 1	L	L	L	L	L
Landscaping, Fencing - Area 2	M	M	M	M	M
Landscaping, Fencing - Area 3	M	M	M	M	M
Road raising - Area 4	L	L	L	L	L
Landscaping, fencing - Area 7	L	L	L	L	M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Vegetation management downstream of railway	L	L	L	L	L
Overall Assessment	L	L	L-M	L	M
Scheme J					
Vegetation reduction - confluence area	L	L	L	L	L
Vegetation management downstream of railway	L	L	L	L	L
Overall Assessment	L	L	L	L	L

TABLE S.6 (cont.)
SUMMARY OF ENVIRONMENTAL AND SOCIAL IMPACTS

Scheme K					
Vegetation management [VM]	L	L	L	L	L
"Duffy Street" area Culverts under Railway	L	L	L	L	L
Overall Assessment	L	L	L	L	L

S.6 Preferred Floodplain Management Scheme

The hydraulic, economic, social and environmental performance of each potential scheme was considered by the FPMCC taking into account information provided by the Study Team as discussed in this report and comments provided by the public during a series of meetings. Based on these considerations the preferred floodplain management strategy adopted by the FPMCC is

1. Environmentally sensitive vegetation management along waterways through Benalla with particular attention to –
   - On the river islands and floodplain from the lake extending upstream to the extension of Cowan Street
   - Downstream of the railway viaduct to Faithful Street
   - The environs of the Lake Benalla weir
   - The Market Street floodway
2. Provision of 5 culverts through the railway embankment near Duffy Street.
3. Provision of additional culverts at the East Main Drain

The scheme has been selected for the following reasons –

- Strong community support
- Excellent cost benefit ratio
- Significant reduction in the effects of flooding

The scheme does not provide protection from all floods and it is inevitable that flooding will reoccur in the future, however the effects of future flooding will be diminished. For floods in excess of the 5% AEP design flood occur the suite of non-structural measures outlined in Table S3 will be used to manage flooding and reduce exposure to flood related damages.

The estimated cost of the scheme is $1.97 million, plus $29,000 per annum for ongoing maintenance. The estimated monetary benefit of the preferred scheme is $360,269 per annum. The benefit cost ratio [BCR] of the scheme is 2.58.

A suite of "non-structural" measures as identified in Table S3 will be used to manage the flood and reduce the exposure to flood related damages historically experienced by the Benalla community

Of all the schemes examined, Scheme H5, provided the perceived best balance between visual impact, least overall disruption to the normal daily activities of the community while still providing a level of protection up to and including the 5% AEP flood with the exception of a small number of residential and commercial properties located between the river and the "levees" /floodwalls. This is a flood whose peak level would generally vary between about 600mm and 800mm lower than the October 1993 flood. Some reduction in flood risk would still be achieved for floods greater than the

5% AEP flood due to the vegetation management measures and the additional culverts under the railway in the Duffy Street area. However because of the continuing flood risk albeit a smaller risk it is imperative that adequate provision is made for flood warning, planning, training and evacuation procedures if potential damages and losses are to be kept to a minimum. These non-structural measures will need to be included in the Flood Sub-Plan and be regularly reviewed and updated as necessary.

The implementation program will be governed by funding, effectiveness of individual measures making up the scheme and the opportunity to implement the individual measures.

Some lower priority measures in terms of effectiveness may be implemented ahead of higher effective measures because of the lack of constraints such as the need for funding or the need to negotiate for the purchase of land.

The non-structural measures such as planning and building controls do not require special funding and the opportunity exists to begin the process for implementing the measures immediately and will limit any increases in future damages.

Of the structural measures designed to exclude floodwaters from designated areas the components of Measure H5 (flood walls and road raising) designed to offer protection in north east Benalla is likely to be the most easily implemented. No purchase of land is required and the works would have no effect on flooding for residential properties on the opposite side of the river in the Arundel Street-Boger Street area. There is however some opposition to these works and their implementation should probably be left till last.

Measures F5 (South west Benalla) and Measure I5 (south east Benalla) should be implemented simultaneously. It would however be acceptable to construct the components upstream of Bridge Street and downstream of Bridge Street as separate works packages providing the works on opposite sides of the river occurred simultaneously.

By adopting a structural system designed to provide flood protection against the 5% AEP flood rather than the 1% AEP flood the height of the structures (levees, flood walls etc) can be reduced in height by amounts ranging from 400mm to 800mm depending on the location. As a result of the reduced height requirement the land required (footprint area) is reduced, the potential for the obscuring of views to the river and parklands is minimized, and in numerous locations low form rolling grassed mounds and raising of roads can achieve the desired result without the need to construct masonry flood walls. The ecological impact is also reduced and in most cases there is only a minimal change in accessibility to the river.

Implementation of the vegetation management plans along the river (Measures De and NN) may occur at any time independent of any other works. Their effect on flood risk for floods smaller than the 5% AEP flood is however less than for Measures F5, H5 and I5 and they therefore been afforded a lower priority. However notwithstanding their relative lower priority both the implementation opportunity and economic benefit are high and because these measures are strongly favoured by the community they should be implemented first.

Construction of the additional railway culverts will only provide a benefit for floods greater than the 5% AEP flood and should therefore be afforded the lowest priority of all the structural measures.

Scheme J

During the final stages of this study further investigations were undertaken based on new floor level information. The revised floor levels resulted in a reduction in the number of buildings estimated to be subject to over floor flooding in a 5% AEP flood and as a consequence the Benefit Cost Ratio for Scheme H5 was lowered to an estimated 0.73 which is not considered cost effective.

In addition to the lowering of the estimated BCR for Scheme H5 to below 1.00 (the BCR break even value) the FPMCC acknowledged the continued noticeable lack of support for levees, and has therefore nominated a riparian vegetation management scheme as the preferred scheme. The preferred scheme has been identified as Scheme J in this report. Scheme J does not require the construction of any form of levee including road raising but relies on the implementation of a vegetation management program which is complemented by a range of non-structural measures. The vegetation management program will require an extensive but selective reduction in trees and woody understorey vegetation across the low lying ground in two areas:

1. from Lake Benalla upstream to the confluence of the Broken River and Holland Creek, and
2. from Ackerly Avenue to Faithful Street.

Scheme J has a relatively low capital cost for the estimated flood reduction benefits achievable and as a consequence has an estimated Benefit Cost Ratio of 5.26. A reduction in flood risk across the full range of flood frequencies is achievable with Scheme J. In comparison Scheme H5 provides flood reduction benefits primarily for floods equal to or smaller than the 5% AEP flood.

Scheme K

In order to protect a greater number of houses while still retaining an attractive cost benefit ratio it was decided to include additional culverts through the railway embankment in the vicinity of Duffy Street and the East Main Drain (Scheme K). Due to a redistribution of flows in the vicinity of the culverts an additional 3 commercial/industrial buildings would suffer overfloor flooding during a 1% AEP flood when compared to Scheme J but overall there would be an estimated 52 fewer buildings subjected to over floor flooding.

Scheme K has low capital cost for the estimated flood reduction benefits achievable and as a consequence has an estimated Benefit Cost Ratio of 2.58. A reduction in flood risk across the full range of flood frequencies is achievable with Scheme K. In comparison Scheme H5 provides flood reduction benefits primarily for floods equal to or smaller than the 5% AEP flood. Although the BCR is approximately half that achievable under Scheme J an additional 49 houses would be protected against over floor flooding during the 1% AEP flood and considering the BCR is still economically viable Scheme K has therefore been adopted by the FPMCC as the preferred scheme.

1 INTRODUCTION

1.1 Why a new Floodplain Management Strategy?

During the last decade, development in Benalla including the setting of floor levels, has been referenced to the estimated 1% AEP flood levels and flood extent estimated in 1984 by the then State Rivers and Water Supply Commission. The 1% AEP flood estimate was based on the available data at the time and included information on previous large floods.

The October 1993 flood surpassed the 1984 estimate of the 1% AEP flood and was the highest flow recorded this century at Benalla. Most residents were surprised by the magnitude of the flood and as a result a significant amount of potentially avoidable damage and suffering was experienced. As a result the former City of Benalla commissioned a study as part of program to develop a Floodplain Management Plan (The Water Management Scheme) for the Benalla urban area. Cardno Willing (formerly Willing & Partners) in association with ERM Mitchell & McCotter were commissioned by the then Benalla City Council to undertake a Flood Study and Floodplain Management Study to facilitate the preparation of a draft Floodplain Management Plan (The Water Management Scheme). The objective of the Water Management Scheme is to set out a preferred floodplain management strategy for urban Benalla which seeks to minimize the damage and trauma suffered as a result of major river flooding.

The now Delatite Shire Council, through its Floodplain Management Consultative Committee (FPMCC), is presently developing the Water Management Scheme.

In developing a Floodplain Management Plan (Water Management Scheme) the Victorian Government's floodplain management approach requires the determination of the nature and extent of the flood problem and the evaluation of the available floodplain management measures through a comprehensive flood study and floodplain management study respectively. This report draws on the Flood Study Report (Ref. 2) the findings of which were subsequently revised at the request of the Floodplain Management Consultative Committee (FPMCC) and reflects the Victorian Planning Provisions Practice Notes (Ref. 23).

The first stage of the floodplain management process requires the completion of a flood study. The Benalla Flood Study Report was completed in January 1995 and provided a series of flood profiles under present catchment conditions. At its meeting of 6th March 1996, the FPMCC resolved to adopt a revised estimate of the 1% AEP flood which in turn lead to the revision of the flood profiles given in Reference. 2. The XP-EXTRAN model of the floodplain which was developed during the Flood Study and subsequently enhanced during the Floodplain Management Study was used to evaluate the effects of various flood management options and their component structural measures on flood behaviour.

The Floodplain Management Study is the second stage in the process of developing a floodplain management plan. The purpose of the study is to define the nature of the flood hazards and identify and assess measures and options which can reduce the impact of flooding on both existing and future development on the floodplain.

This report presents the findings of the Floodplain Management Study.

The course of the Floodplain Management Study was guided by the Ministerial appointed Floodplain Management Consultative Committee (FPMCC). The Committee consists of Councillors and staff representatives of Delatite Shire Council, officers from the Department of Natural Resources and Environment, VicRoads, VLine, the State Emergency Service, the Broken River Catchment Management Authority and community representatives.

The floodplain management schemes assessed in this report were selected by the Floodplain Management Consultative Committee following an examination of a wide range of possible flood mitigation measures. A list of measures was initially identified by the Committee for investigation at the commencement of the study. Additional measures were identified and included for investigation during the course of the study.

Several of the additional measures investigated were as a direct result of suggestions put to the Committee by the public. Structural schemes comprising various combinations of measures were assessed using the hydraulic model of the floodplain.

1.2 History of the Study

The study commenced in June 1994 and has involved the following steps:

June 1994	Consultants commissioned to undertake a comprehensive flood study and floodplain management study.
July to November 1995	The collection, collation and analysis of historical flood data and hydrologic modelling of the Broken River catchment draining to Benalla and hydraulic modelling of the Broken River floodplain at Benalla was undertaken by the Consultant.
November 1994	A draft Flood Study Report was forwarded to the Floodplain Management Consultative Committee for review.
January 1995	Review of the draft Flood Study by the FPMCC completed.
February 1995	Flood Study Report finalised.
February 1995	Floodplain Management Study commenced.
July 1995	Consultants completed an initial assessment of floodplain management measures and schemes identified by the FPMCC including those contained in written submissions from the community.
September 1995	Hydro-Technology released a report on the October 1993 floods in north eastern Victoria and which provided a second and higher estimate of the magnitude of the 1% AEP design flood.
September to November 1995	Further analysis of suggested flood mitigation measures was undertaken by the Consultant.

January 1996	An independent review of the 1% AEP flood flow estimate was requested by the FPMCC and an invitation extended to the community to submit further ideas for flood mitigation in Benalla.
February 1996	The independent review of the 1% AEP flood estimate was presented to the FPMCC.
March 1996	Based on the independent review of the 1% AEP flood flow estimate the FPMCC adopted the peak estimated flow in October 1993 as equal to the 1% AEP design flood. Consultants completed a review of written submissions of flood mitigation measures and presented their findings to the FPMCC. A topographic survey was commissioned by the FPMCC to enable the option to construct a flood retarding basin immediately upstream of the Hume Freeway to be assessed. The FPMCC reviewed the effectiveness and practicality of all measures assessed by the Consultant and selected three combinations of measures to form 3 potential flood mitigation schemes which aim to reduce flood damages and the flood hazard posed to existing development
July 1996	A draft Floodplain Management Study report was presented to the FPMCC by the Consultants for review.
August 1996	A draft Final Floodplain Management Study report is prepared for public exhibition based on the FPMCC's review.
1997	Council conducted a series of neighbourhood meetings to discuss the findings of the August 1996 report in further detail. The views of the community expressed during the neighbourhood meetings were considered by the FPMCC and the Consultants asked to undertake further analyses of some structural measures and to revise the economic analysis.
June 1998	The results of the additional and revised analyses were presented to the FPMCC and on the basis of the information provided the FPMCC identified a preferred Floodplain Management Strategy. The preferred Floodplain Management Strategy is presented in this report.
1999 – 2000	The environmental and economic issues related to the second lake proposal were examined in further detail. This included a detailed tree survey within the affected area to identify the species, size and location. This provided the base information for assessing the potential for tree removal to improve flood flow capacity without unduly compromising the ecological value of the area.

March 2001	A series of neighbourhood meetings were held with residents who would be directly affected by the structural measures included in the preferred floodplain management strategy (Option G).
August 2001	The FPMCC instructed the consultants to finalize the Floodplain Management Report. This work included hydraulic modelling of two further options. Option J which was based on Option G but substituted the selective clearing of trees between Ackerly Avenue and Faithful Street in lieu of the second lake, and Option K which included only the vegetation management measures. The economic analysis of all previously reported options were updated using a more recent and extensive floor level survey and updated preliminary cost estimates for each measure.

2 BACKGROUND

2.1 The Study Area

The Broken River drains a catchment of approximately 1,450 km^2 upstream of Benalla, a major regional centre located some 200 km north of Melbourne. The catchment varies from mountainous, undeveloped areas with deeply dissected valleys in the upper reaches to mildly sloping areas between Benalla, Swanpool and Tatong. Approximately half of the catchment has been cleared for agricultural purposes, predominantly grazing (Ref 2).

Benalla is located on the Broken River floodplain and occupies an area of around 8 km^2. It has an urban population of around 9,500 persons. The Benalla CBD is located approximately 1.5 km downstream of the confluence of the Broken River and Holland Creek. Blind Creek joins the Broken River near the southern outskirts of the urban area.

The study area extends from the Hume Freeway approximately 3 km upstream of the Central Business district (CBD) to the outskirts of the urban area some 1.5 km downstream of the railway bridge (refer Figure 1)

Lake Nillahcootie is the major water storage on the Broken River. It is located some 36 km upstream of Benalla and commands a catchment of approximately 420 km^2. East of Benalla lies Lake Mokoan, an artificial lake fed by an offtake channel connected to both the Broken River and Holland Creek. (refer Figure 2). The outlet from Lake Mokoan rejoins the Broken River downstream of the urban area. The construction of Lake Benalla which is impounded by a low crescent weir immediately upstream of the railway bridge (Figure 1) significantly modified the Broken River through Benalla. The Lake extends past Bridge Street and the Civic Centre. Other works along the river which have modified river flood levels over time include:

- ❑ partial removal of the islands between Bridge Street and the railway,
- ❑ incremental increases in the river waterway area prior to 1968,
- ❑ increased waterway area past the Bridge Street bridge,
- ❑ replacement of the Ackerly Street bridge,
- ❑ construction of the Benalla Weir between 1968 and 1974, and the
- ❑ construction of the offtake channel for Lake Mokoan.

2.2 Social Context

Benalla is a regional city with approximately 9,500 people and is the third largest centre in the Goulburn-North-East region. It provides most major services and facilities for its population, as well as tourist attractions, such as the art gallery, wineries and the Winton Raceway.

Benalla is well linked to other main regional and sub-regional centres, being located at the intersection of the Midland Highway, linking to Mansfield and Adelaide, and the Hume Highway linking Melbourne to Sydney. The city is also on the Melbourne-Sydney rail line which provides for extensive freight and passenger transport.

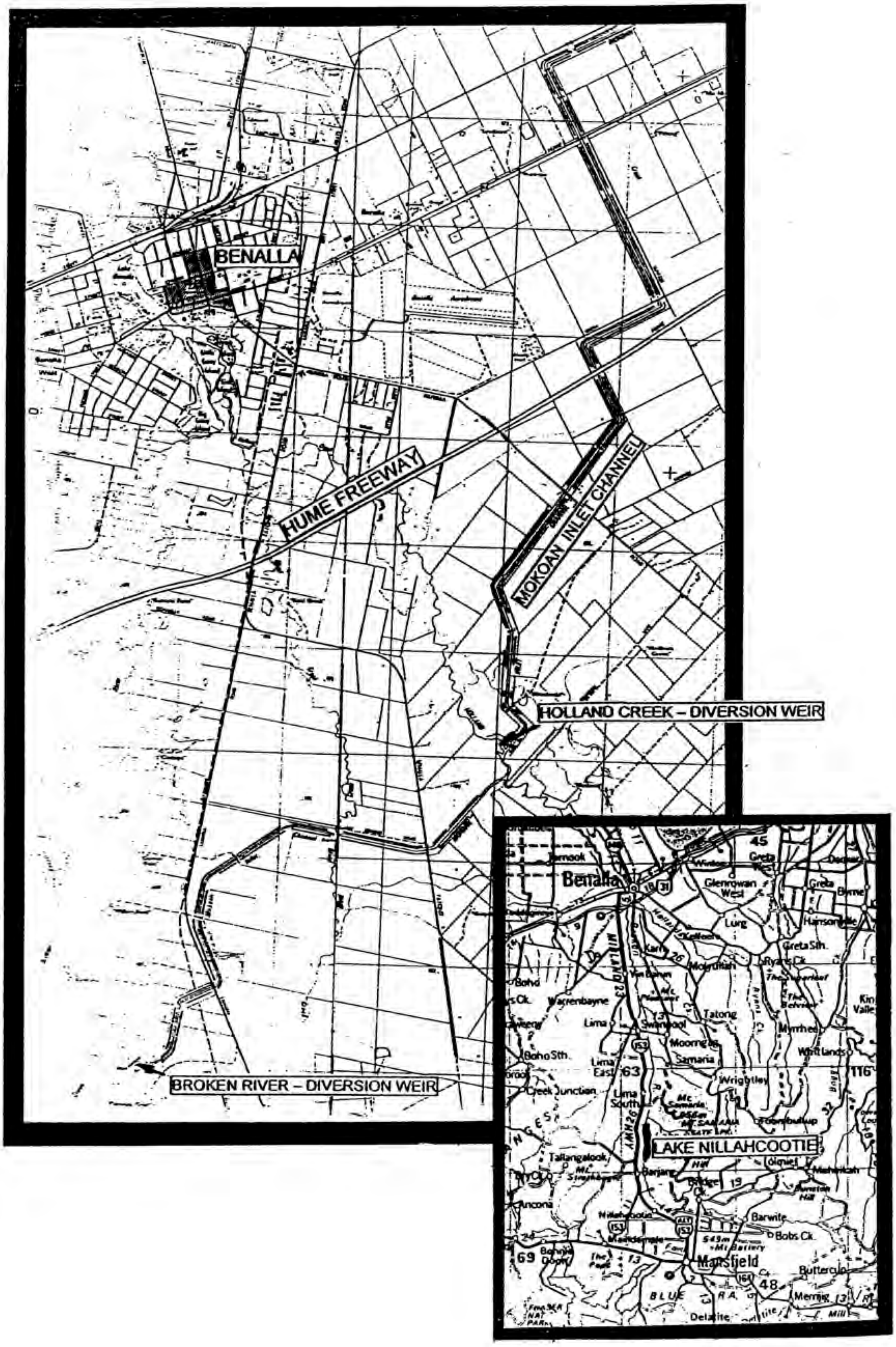


Figure 2 Regional Maps – Mokoan Inlet Channel and Lake Nillahcootie

As a regional centre, Benalla serves the administrative and agricultural needs of the region. This is reflected in the employment base shown in Table 1. The high proportion of persons employed within the wholesale and retail sector is important given the extent of flooding within the CBD where most retail premises are located.

Population growth in Benalla has been modest over the past ten years and is projected to increase by approximately 6,500 over the next 20 years. This represents an increase of almost 70% in the current population and as new housing areas are sought it will be imperative that adequate planning controls are in place to avoid developing areas with an unacceptably high risk of flooding.

TABLE 1
DISTRIBUTION OF EMPLOYMENT

Industry	Shire	City
Wholesale and Retail	13.3%	21.5%
Community Services	19.3%	18.9%
Agriculture	24.6%	Not applicable
Manufacturing	Not applicable	10.5%

Notes 1. Source of data is the Australian Bureau of Statistics, 1991
2. Data is presented for the former Shire of Benalla and the City of Benalla.

The structure of the population for the period 1986-1991, shows increases for both shire and city areas in middle age groups (40-49) and retirement ages (65-70 plus) and decreases in both areas for the 20-29 age group and 55-59 age group. Other age groups have experienced little change and are relatively stable in both areas. The percentage distribution of each age group in Benalla is fairly evenly spread, although the 50 plus age group is higher than other areas of north-eastern Victoria and the Goulburn census district.

With the development of the Australia Defence Industries (ADI) ammunition manufacturing plant employment could increase by several hundred, which in turn could have a multiplier affect of at least double this figure. This will also have repercussions in terms of demands on residential, commercial and community facilities and open space within Benalla.

2.3 Environmental Context

2.3.1 Physical

Benalla is located on the banks of the Broken River which bisects the urban area. Tributaries which flow into the Broken River on the southern edge of the urban area include Holland Creek and Blind Creek.

Areas immediately adjoining the Broken River are reasonably heavily vegetated with the exception of Lake Benalla which is fringed by open space including formal and informal planting. A walking circuit exists along the reaches of the Broken River and Lake Benalla within the urban area. This constitutes an important recreational facility and tourist attraction within the city centre.

Uses adjoining the Broken River vary from public open space (including the Botanical Gardens and Showgrounds), local government development (civic offices and swimming pool complex), residential, special uses (such as the Bowling Club) and rural development further downstream.

The main roads traversing the city are the Midland Highway, which crosses Lake Benalla on Bridge Street and the Sydney Road which links through to the Hume Freeway. Other roads through the centre are of a local nature although no designated hierarchy for these streets has been adopted.

A significant structure on the floodplain is the Melbourne-Sydney railway line which crosses the Broken River to the north of Lake Benalla and south of Ackerly Avenue. For the most part it is erected on an embankment which has been cited as being partially responsible for the build-up of floodwaters to the south and throughout the CBD during the October 1993 flood.

Peripheral areas of the city are in residential or rural residential use, although areas to the north and west tend to be more commercial in nature, including the aerodrome and the recently zoned Enterprise Park.

Land use within and immediately adjoining the Broken River is diverse. It encompasses most of the city's community, commercial and administrative functions. It also accommodates significant areas of open space utilised by both residents and visitors.

2.3.2 Flora and Fauna

Vegetation within the Broken River Catchment includes:

- tall forest;
- low forest;
- red gum woodland;
- grazing/broad acre cropping;
- swamps/marshes;
- irrigated land/intensive cropping; and
- plantations.

Of these, grazing and broad acre cropping cover by far the greatest percentage of area within the catchment, followed by irrigated land and low forest.

No detailed flora or fauna surveys were conducted within the floodplain area downstream of Ackerly Avenue.

A Streamside Re-vegetation Strategy (Ref. 8) provides a general description of the vegetation communities of the lower reach of the Broken River from Benalla to Shepparton and the Goulbourn River.

The vegetation community on the banks of the Broken River is Grey Box - Red Gum Woodland. River Red Gum (*Eucalyptus camaldulensis*) dominates the river banks in a continuous narrow band with greater concentrations generally found on the inside of river bends and around billabongs (Ref. 8). Other species forming the overstorey include Silver Wattle (*Acacia dealbata*), which is common, and Willows (*Salix spp.*) which are abundant. Much of the Grey Box (*E. microcarpa*) vegetation has been destroyed by clearing and the remnants have a high conservation significance.

The shrub layer is sparse due to unrestricted grazing and remaining remnants include River Bottlebrush (*Callistemon sieberi*) which dominate the water line.

The ground layer is dominated by introduced pasture grasses and weeds, with Tussock grass, (*Poa spp.*) and Common Reed (*Phragmites australis*) persisting.

A Management Plan for the Lake Benalla Bushland Area (Ref. 6) provides a description of the vegetation communities in this area. The two vegetation communities which were identified were classified as Riparian Zone and River Red Gum Zone.

The Riparian zone, which consists of Common Reed and Tall Flat-sedge (*Cyperus exaltatus*), is considered to be poor or degraded throughout the Broken River catchment (Ref. 6).

The River Red Gum zone is divided into two sub-zones based on the understorey species.

- River Red Gum/Weeping Grass Woodland confined locally to the Broken River floodplain and considered to be locally significant; and
- River Red Gum/ Silver Wattle/ Tussock grass occurring along the stream banks.

Two plant species that occur in this area are listed as rare in Victoria. These are Kangaroo Grass (*Themeda triandra*) and Australian Millet. Although these vegetation types are found within the lower reaches of the Broken River and within the Lake Benalla Bushland Area, the actual distribution of these communities in the study area is unknown.

No fauna surveys were conducted within the area downstream of Ackerly Avenue. However, both the former Department of Conservation and Natural Resources (Ref 9) and Drummond & Associates (Ref 10) suggest that the vegetation communities provide suitable habitat for a range of species including birds, mammals, reptiles and amphibians.

2.4 Flood History

Benalla has experienced a number of floods this century which have resulted in extensive flooding of the town. Reliable estimates of the peak flows during historical floods are only available for those floods which have occurred after the completion of the Benalla Weir works in 1973-74.

A summary of the major floods recorded at Benalla during the preceding 80 years is given in Table 2. The estimated peak flows for floods prior to 1973-74 are reproduced from Ref. 3.

The largest flood known to have occurred prior to 1916 was the flood of 1870. Newspaper reports at the time of the 1916 flood indicated that opinion was divided as to whether the 1916 flood was larger than the 1870 flood. One report from the Benalla Standard newspaper suggests that the balance of evidence was that the 1916 flood was a foot (0.3 metres) higher than the 1870 flood. This report should however in no way be considered conclusive.

TABLE 2
HISTORICAL FLOOD EVENTS AT BENALLA

Date	Peak Gauge Reading at Bridge Street Gauge (m AHD)	Estimated Peak Flow (m^3/s)
Pre Benalla Weir		
24/09/1916	170.55	850
07/06/1917	169.83	Unknown
20/10/1917	168.97	310
13/05/1918	169.89	Unknown
10/09/1921	170.67	700
26/08/1924	169.83	Unknown
01/09/1933	169.28	380
12/12/1954	169.43	500
07/07/1956	168.97	310
16/08/1958	169.56	650
14/12/1966	169.43	500
Post Benalla Weir		
17/05/1974	169.14	580
18/09/1975	168.64	420
22/07/1981	168.80	479
04/10/1993	170.36	1,250

Note: The rating table for the Bridge Street gauge was modified as a result of the Benalla Weir works completed in 1973-74. (ie. the gauge heights now correspond to higher flows than under pre-weir conditions).

The largest recorded flood flow this century was the flood of October 1993. The peak flow for this event was almost 50% higher than the next largest flood experienced in 1916. The 1993 flood was also significantly larger than the 1% AEP design flood flow of 850 m^3/s identified in the 1984 study (Ref. 3).

While the October 1993 flood was the largest recorded flood flow this century, the maximum gauge readings for the 1916 and 1921 flood events are higher than the peak gauge reading for the 1993 flood. This is attributed to a series of modifications to the floodplain by various works undertaken this century.

2.5 Social and Economic Impacts of Flooding

Social and economic impacts associated with flooding are categorised as either tangible or intangible, where tangible damages can be measured in monetary terms and intangible damages generally cannot.

Tangible damages include direct costs associated with flooding arising from the contact of floodwaters with a building or a physical asset. This includes damage to possessions, cars, crops and roads. Indirect tangible damages are consequential losses such as loss of trade, cost of evacuation and reinstatement, and the loss of man hours and trade arising from restrictions on travelling, loss of stock etc.

Intangible losses apply to the social disruption caused by a flood and include:

- inconvenience;
- isolation;
- disruption;
- psychological disturbances as a result of anxiety and trauma; and
- physical ill-health.

Social disruption is often considered to be the most significant effect on local communities and many urban flood mitigation options are justified by their reduction of this effect.

Social trauma often occurs amongst flood affected residents in situations where flooding is widespread, is greater than previously experienced or where damages are significant. The greater the flood the more significant the effect, whereby shock, disbelief, fear, anger, sickness and depression are often the main reactions. A proportion of residents can be emotionally affected by the flood and some will suffer a deterioration in health.

The latter results from increased stress and can be directly related to the flood. Emotional or psychological problems can be manifested as nervousness, irritability, nightmares, exhaustion, despair, depression and anxiety.

Isolation during and immediately after the flood event can occur where floodwaters present a barrier to through movement. This can lead to inconvenience and increased psychological stress. Isolation can also lead to substantial financial loss for retail and commercial premises.

Losses due to disruption, ill-health or time taken off work to clean-up may be considered in terms of lost time. Smith et al (Ref. 11) estimated the disruptive cost associated with ill-health by determining the percentage of the population who reported ill-health and the average number of work days lost per person.

In addition, the number of days of disability due to self reported ill health was estimated together with the average length of hospital stay. The same authors estimated that the lost time associated with clean-up operations could be as much as 100 person hours (14 days) for clean-up of houses that had been flooded above floor level.

Loss of life during flooding may result from accidents such as electrocution, drowning or death induced by flood-related stress (heart attacks). However, most flood-related deaths in Australia are a result of flooded roads, where a car is swept off the road into a flooded stormwater channel, creek or so on. Other deaths from drowning occur where people are swept away with rapidly rising waters or are trapped in a stormwater drain or creek.

2.5.1 Impacts of October 1993 Flood

The October 1993 flood exceeded the 1% AEP flood level, as defined in the 1984 Flood Study (Ref. 3), by approximately 0.7 metres. This resulted in major and unexpected flooding throughout Benalla which caused widespread devastation and significant social and economic costs to the community. The majority of the city was affected, including homes, commercial premises, community facilities and roads. The tangible and intangible costs of the 1993 flood are summarized below:

Tangible Costs

Tangible costs are the direct costs in economic terms of damage to property and possessions. In Benalla this included:

- ❑ business sector - damage to commercial premises, fittings, equipment, stock, industrial buildings and vehicles;
- ❑ residential sector - damage to houses, household fittings, equipment, appliances, personal effects, clothing, furniture, carpets, food, animals, and other durables;
- ❑ infrastructure - damage to roads, footpaths, kerbs, bridges, drains, water supply, fencing, recreation reserves, car parks and communications networks;
- ❑ agricultural - loss of stock, damage to fences and property and loss of crops; and
- ❑ other - damage to childcare and community facilities, art gallery, town hall and state and federal government buildings.

The estimated cost of these damages is summarized in Table 3. It should be noted that this is not a comprehensive list and costs are approximate only. While many of the costs in Table 3 have not been quantified, it is estimated that the total cost to the community of the October 1993 flood was between $30 - $50 million although some estimates are as high as $200 million.

Indirect Tangible Costs

The indirect tangible costs arising from the losses above are not so easily quantified and include:

- ❑ instant and continuing loss of income;
- ❑ closure of business;
- ❑ loss of man hours through isolation or health problems;
- ❑ loss of business, during and immediately and resulting from reduced household expenditure; and
- ❑ downturn in the local economy through loss of sales, loss of production, loss of wages and reduction in expenditure.

Intangible Costs

Most intangible costs are associated with trauma and ill-health, arising from damaged property and loss of employment. Specifically in Benalla this included:

- ❑ family trauma and personal trauma;

- cancellation of the Benalla Show;
- cancellation of the Benalla Races;
- cancellation of other social events;
- isolation and shock.

While no deaths directly related with the flood were reported (eg. drownings), ill-health arising from the disruption to the water supply and other related health problems was widespread.

TABLE 3
TANGIBLE COSTS OF OCTOBER 1993 FLOOD[1]

Location/Industry	Items	Estimated Cost
Shire of Benalla	Five (5) bridges	$250,000
	Road damages	$1,000,000
	Water supply, pipelines and sewerage system	$300,000
City of Benalla	1,200 homes water affected and 180 cars written off	
	Loss of commercial stock	$4,000,000
	Capital damage	$2,000,000
Rural	400 kilometres of fencing	$30,000,000
	Extensive damage to lupin and oat crops	
	Stock losses - 244 cattle, 4,200 sheep, 199 poultry	
Manufacturing	Extensive damage to Benalla Spinners and "Centique".	

Notes: 1. Source was the Benalla Ensign: Flood Special, October 1993

2.5.2 Disruption to Transport

The principal transport links between east and west Benalla are Bridge Street, Ackerly Avenue, Samaria Road and the railway viaduct. The Hume Freeway represents a further major route but is not designed to cater for local traffic. Under high flood conditions, Ackerly Avenue, Samaria Road and Bridge Street are all flooded making physical communication difficult and hazardous. The railway viaduct, while not being flooded , is not designed for road transport and anecdotal reports during the October 1993 flood suggest that the viaduct was vibrating significantly, thus raising fears of possible failure and unreliability. Substantial upgrading of the viaduct would be required even to allow emergency vehicles relatively safe passage.

The disruption to virtually all the transportation routes between east and west Benalla contributes substantially to the cost of flooding in Benalla since it poses valid arguments for the need to duplicate emergency services depots and equipment.

The Hume Freeway would provide a temporary link but it would be a time consuming indirect route between east and west Benalla. Furthermore, flood levels in Benalla can remain high for several days and the temporary use of the freeway for this time would severely disrupt transport along the main Melbourne - Sydney road link.

2.6 Data

2.6.1 Plans and Surveys

A variety of maps were obtained for the study and included;

- CMA 1:25,000 topographic maps
  - Benalla (8024-1-1)
  - Winton (8124-4-4)

- CMA 1:100,000 topographic maps
  - Dookie (8025),
  - Wangaratta (8125),
  - Euroa (8024),
  - Whitfield (8124).
  - Mansfield (8123).
  - Alexandra (8023).

- Flood Level Survey – Benalla Total flod Warning System Composite 1996 Flor Level survey and 100mm Contour Survey Plan (Plan No. 5000 026 – 31 sheets). LICS Pty. Ltd.

- Ground levels, floor levels and building type data derived from existing Benalla Sewerage Authority Maps.

- Aerial photography taken by VicRoads (Benalla),

- Survey commissioned by Willing & Partners during the Flood Study (Stage1) and by Delatite Shire Council during the Floodplain Management Study (Stage 2).

- Video of the 1993 flood supplied by the Insurance Council of Australia (ICA).

2.6.2 Survey Datum

All levels quoted in this report are consistent with the datum used for the Flood Study which are levels expressed in metres to Australian Height Datum (AHD). Levels recorded on the Benalla Sewerage Authority Maps were converted using the formula:

Level (m AHD) = (Imperial Level x 0.3048) - 0.306

2.6.3 Property Data

For the purposes of flood damage assessment, the use of each building (residential or commercial) was identified either by information supplied by Delatite Shire Council or from the Benalla Sewerage Authority plans. Additional information on building materials and floor heights for a number of properties was recorded during field reconnaissance work by the study team.

More recent floor level survey was carried out throughout Benalla as part of the Flood Warning System and this data was used in assessing the performance of the more recently suggested Schemes H and J.

2.7 Previous Key Studies

- STATE RIVERS AND WATER SUPPLY COMMISSION OF VICTORIA (1984) "Benalla Floodplain Management Study", *Final Report*, June.

- The report details similar investigations to the 1995 Flood Study report by Willing & Partners. The findings of the study were superseded as a result of the 1993 flood which greatly exceeded the 1% AEP flood estimate contained in the report.

- WILLING & PARTNERS (1995) "Benalla Floodplain Management Study", *Flood Study Report*, July.

- This report details the investigations and findings leading to a description of flood behaviour along the Broken River at Benalla and the estimation of the 5%, 2%, 1% AEP and extreme flood profiles. At its meeting of 6th March 1996, the FPMCC resolved to adopt a revised estimate of the 1% AEP flood which in turn lead to the revision of the flood profiles given in this report.

- HYDROTECHNOLOGY (1995) "*Documentation and Review of 1993 Victorian Floods, Broken River Catchment Floods, October 1993*", Volume 4, prepared for the Department of Conservation and Natural Resources, March.

- The report (which was released in August 1995) documents information collected from the 1993 flood in the catchment of the Broken River. It also aimed to determine flood discharges and flood levels, delineate the extent of flooding from aerial photography and to collate information available on flood damages. Other objectives included the identification of significant data deficiencies, a review of relevant previous flood studies and a review of the effectiveness of existing flood mitigation schemes and recommendations for further work which may be necessary.

- DELATITE SHIRE COUNCIL (1997), Benalla Total Flood Warning System.

3 STUDY APPROACH

This Floodplain Management Study has been carried out in accordance with Victorian Government policy as set out in *A Planning Guide For Land Liable To Flooding In Rural Victoria* (Ref 4), the *Victorian Planning Provisions*, and *State Flood Management Strategy* (NRE, 1999).

Since initiating the study the planning provisions have been coded into practice notes detailing the application of the flood provisions in planning schemes(Ref 23) and a guide for the application for a planning permit under the Flood Provisions (Ref 24).

The approach to a Floodplain Management Study usually involves the following steps:

- ❑ identification of principal issues,
- ❑ identification of available structural and non-structural measures,
- ❑ assessment of existing flood damages and the potential reduction in damages due to implementation of individual floodplain management measures,
- ❑ development of alternative floodplain management schemes using combinations of structural and non-structural measures,
- ❑ assessment of alternative schemes based on hydraulic, social, economic and environmental criteria, and the
- ❑ identification of a preferred floodplain management scheme.

3.1 Principal Issues

The principal issues addressed in the study cover:

- ❑ identification of the nature of the existing flood problem;
- ❑ review of the 1% AEP design flood levels;
- ❑ review of the Flood Standard;
- ❑ investigation of practical flood mitigation measures to reduce the impact of flooding on existing development and future development taking into consideration economic, social and environmental aspects;
- ❑ assessment of the consequences on flooding of a possible “Greenhouse Effect”; and
- ❑ review of existing flood warning as well as public awareness and evacuation program(s).

3.2 Available Measures

A variety of floodplain management measures are available. Typically, measures are classed as "structural" or "non-structural".

3.2.1 Structural Measures

"Structural" measures involve construction of capital works which are intended to reduce flood damages by either reducing flood levels or the lateral extent of flooding. Structural measures thus achieve benefits by changing flood behaviour over a wide area.

The major structural measures are:

- flood mitigation dams;
- flood retarding basins;
- by-pass floodways (channels);
- channel improvements; and/or
- levees,
- landscaped earthworks, and
- road raising.

Flood mitigation dams reduce downstream flooding by temporarily storing floodwaters. The flood mitigation effect of even large dams on major rivers is often very small because of the limited storage volume in relation to the overall flood volumes. Retarding basins operate in a similar fashion to flood mitigation dams although typically on a smaller scale. The benefits and costs of creating a large retarding basin by constricting the flow through the Broken River, Holland Creek and Blind Creek crossings of the Hume Highway was one measure which was investigated.

By-pass floodways and major channel improvements were also examined. In a natural channel, improvement of hydraulic capacity by dredging often has adverse effects on aquatic ecosystems and channel stability and may therefore not provide a straight forward effective long term measure.

Levees are probably the most common of the structural measures. They restrict the spread of floodwaters and/or lower the level of floodwaters in the protected area behind the levee. Levees provide protection up to a defined flood level, normally with an appropriate freeboard allowance. Drainage through levees is generally provided by pipes with flap gates to prevent backflow. Heavy rain may cause ponding within the protected area resulting in a need for retention basins and/or stormwater pumps to discharge local runoff in some cases.

Because of their construction cost, levee works are generally only feasible where large areas of existing development are to be protected from significant flooding or where a low levee is adequate. Precautions need to be taken in the design of levees to allow for possible overtopping and in the management of the areas which they protect. Levees do not remove the need for evacuation and contingency planning because there is always a residual risk of a flood overtopping the levee and quickly inundating "protected areas".

Other measures designed to exclude shallow floodwaters from an area include landscaped earthworks and raised road levels. In the latter case this may include the provision of a low height centre median.

3.2.2 Non-Structural Measures

"Non-structural" measures require the community to reduce flood damages by changing patterns of activity in flood-liable areas and or modifying the potential for flood damage. These measures include:

- do nothing;
- house-raising;
- building and development controls;
- voluntary purchase of properties;
- access improvements;
- flood warning systems;
- evacuation planning; and/or
- zoning.

Do nothing

The "do nothing" option provides no benefit to individuals or the community as no works are involved. It also imposes no implementation cost on the community. It does however incur costs as existing flood damages continue to accrue and damages may in fact increase with increased activity and value of infrastructure within the affected area. It is included in an analysis so as to provide a point of comparison with other measures and schemes.

House-raising

House-raising involves lifting all or part of a residence so that the floor level of habitable rooms is above a specified flood level. It is a common method of flood proofing though it is sometimes only considered for framed buildings with timber or sheet external cladding and timber floors. Brick houses or brick veneer houses which are slab on ground construction cannot be lifted. While brick veneer dwellings on stumps can be lifted in practice, it is unlikely that this would be undertaken because of the cost and inherent difficulties. Further investigation would be necessary to determine the number of houses which are brick, brick veneer and slab on ground. For new developments, houses can be built on earth mounds or on high base structures.

Although house-raising schemes provide protection to a certain level, floods higher than that level can still cause significant damage, especially if the occupants are complacent about the risks after the house-raising. Residents who raise their houses, tend to raise them a full storey height, but there is still a risk that occupants may be trapped in dangerous floodwaters if they remain in the perceived security of a raised house. With commercial buildings, raising is rarely feasible but provisions can usually be made for storage space to be provided above the 1% AEP flood level to minimise stock losses.

Building and Development Controls

This measure requires development to meet appropriate criteria such as minimum fill and floor levels or restricting the intensity of development.

Filling is not usually classified as a structural measure because it is primarily undertaken during new development rather than as a flood mitigation measure for existing development. However it does have the potential to alter flood behaviour and therefore any proposed significant areas of fill should be modelled to assess their effect on flood levels. This includes the cumulative effect of many small areas of fill.

Voluntary purchase

Voluntary purchase enables residents to move to a flood-free location. The cost of this measure can be high although subsidies are provided by government where the voluntary purchase of a property is part of an adopted floodplain management plan.

Voluntary purchase is normally used in "High Hazard" areas where other measures are not practical, with the ultimate aim of removing building development from the area concerned. The process however can take a considerable time to implement because of the times at which properties become available and the limits to funding. Furthermore, even with compensation, residents in high flood risk areas may not be able to afford to purchase property in area of negligible flood risk.

Access improvements

Improvements to access routes typically consist of reconstructing and raising sections of a road to eliminate dips and where possible provide a continuously rising route to high ground. Roadside flood markers are typically required to indicate the degree of submergence of roads.

Public information

This is seen as a public education process to:

- ❑ maintain general flood awareness within the community;
- ❑ explain flood warning and evacuation plans; and
- ❑ outline the basis of adopted floodplain management plans.

Flood warning and evacuation planning

These measures jointly help to reduce the damages suffered by individuals by enabling timely evacuation, removal of contents from properties and shifting of livestock to high ground. Costs are relatively minor, generally involving the establishment and operation of the flood warning system, training of VICVICSES and emergency personnel and transportation costs in flood periods.

Zoning

Land zoning is an appropriate means of limiting the potential for damage and the need to evacuate in flood-liable areas. Therefore it is important for Councils to consider the principles as outlined in the Victorian Planning Provisions.

In zoning flood liable land (and land which has the potential to affect flood behaviour) the following factors are important:

- whether the land is in a high hazard category;
- the potential for future development to have an adverse impact on flood behaviour and affect existing development;
- whether adequate access is available during floods; and
- whether certain types of development should be excluded because of additional or special risk to their users, eg. accommodation for aged people, hospitals, etc.

Generally the preferred management scheme for a particular area will often involve a combination of these measures as well as appropriate structural measures.

3.3 Assessment of Measures

A Floodplain Management Study concentrates principally on the hydraulic and flood damage aspects of various floodplain management measures with a preliminary benefit/cost analysis of selected measures and/or schemes. Relevant socio-economic and environmental issues have been addressed but only for particular measures and schemes. Fuller evaluation of the wider social-economic and environmental aspects of the preferred schemes may need to be addressed by Council at a later date.

The process of review consisted of the following steps:

- assess the number of buildings affected for a range of floods, with special attention to the Flood Standard (Designated Flood);
- assess the level of flood hazard;
- estimate the cost of flood damages;
- select appropriate measures;
- model selected structural measures to assess their likely impact on adjacent areas;
- estimate the costs of the measures for benefit/cost analysis, and
- assess the social and environmental aspects.

3.3.1 Buildings Affected by Various Floods

Information on ground and floor levels and building type used to estimate the number of flood liable properties and flood damages was derived initially from existing Benalla Sewerage Authority Maps. This information was supplemented by surveyed ground and floor levels where available and in some cases visual estimates of floor levels above ground level. Subsequent to this and as part of the improved flood warning system for the Broken River Catchment a comprehensive survey of floor levels in Benalla was undertaken in 1997 (Ref 27) and this data has been used to estimate the number of flood liable properties and buildings.

3.3.2 Flood Hazard

A preliminary flood hazard classification of the floodplain was undertaken based on peak 1% AEP flood levels and maximum flow velocities determined by the hydraulic model used for the Flood Study. The depth and extent of inundation were determined from a comparison of the peak flood levels with available contour mapping provided by Council.

3.3.3 Flood Damage Assessments

Flood damage estimates were prepared using estimated flood levels, estimated and/or surveyed floor levels and representative stage - damage curves. Flood damage estimates for existing conditions were derived for the 5%, 2%, 1% and Extreme floods. These estimates were used to determine the average annual damages (AAD) and the net present values (NPV) of the AAD for various discount rates over a design life of 50 years.

3.3.4 Selecting Appropriate Measures

Measures considered appropriate for further investigation and costing were identified in consultation with the Floodplain Management Consultative Committee with community input.

Where structural measures were not appropriate, non-structural alternatives were identified and costed. House-raising was costed as a possible alternative to levees in those areas where levees were considered.

Three alternative management schemes were selected from a number of schemes comprising different combinations of measures.

3.3.5 Hydrological Modelling

The hydrographs which were input into the floodplain model to determine flood levels in an extreme flood and the 1%, 2% and 5% AEP floods were initially taken from the Benalla Flood Study (Ref 2).

Following extensive discussions and consideration of an independent review (Ref. 6) the FPMCC decided, for the purposes of this study and the subsequent preparation of a Floodplain Management Plan, that the peak flow rate for the 1% AEP design flood estimated during the Flood Study should be revised and set equal to the estimated peak flow rate for the October 1993 flood. The hydrological model of the catchment was subsequently re-calibrated to give the specified peak 1% AEP flood flow in Benalla and re-run to identify any changes in the estimated peak flows for the 2% AEP and 5% AEP flood flows due to the re-calibration.

The extreme flood flow adopted for both the Flood Study and the Floodplain Management Study is 3,780 m^3/s. This is equivalent to 3 times the magnitude of the 1% AEP flood. Based on a flood frequency analyses for a large number of catchments in south eastern Australia it has been found that a peak flood flow rate 3 times larger than the design 1% AEP peak flow rate approximates a flood with an annual exceedance probability of around 0.02% (ie. 5,000 Year ARI).

3.3.6 Hydraulic Modelling

Hydraulic modelling was used to assess whether various measures would cause problems in nearby areas by raising the level of floodwaters. The hydraulic assessment was carried out using the XP-EXTRAN model, developed for the Flood Study (Ref. 2)

The levels for the majority of locations are the same as quoted in Appendix C of the Flood Study (Ref 2). The variations, primarily in the south eastern area, are due to further refinement of the hydraulic model as a result of additional flooding information provided by residents and the Delatite Shire Council since completion of the Flood Study.

Accuracy of Calculated Flood Levels

The design flood levels throughout the study area are considered to be reasonably accurate. A comparison of surveyed debris flood marks from the October 1993 flood with modelling results for 61 locations indicated a mean deviation from the observed flood mark of 0.11 m. At several locations variations of up to 0.37 m were noted but it is believed these are likely to be due to local factors and/or errors in assessing the true flood height from debris marks. Variations between actual flood heights and flood debris marks of ±0.25 m commonly occur when modelling historical floods. Flood marks indicated by coarse or heavy debris lines are frequently below the actual maximum flood level and lead to discrepancies of 200 to 300 mm. Notwithstanding the deviations between the predicted and observed flood levels for the October 1993 flood the accuracy obtained is considered to be within acceptable limits.

Accuracy of Predicted Impacts

In terms of the accuracy of the predicted impacts, ie. the difference between predicted flood levels with and without a measure in place, the model is considered to have an accuracy of ±0.01 m.

3.3.7 Cost Effectiveness

A cost estimate and benefit/cost ratio (BCR) was prepared for each alternative scheme. In the case of the levees, the cost estimate was based on the conceptual design of each levee which included any ancillary drainage works needed as a result of the levee.

3.3.8 Criteria for Assigning Priorities

The following criteria are proposed to identify the areas and the measures which should be given priority in implementing a preferred scheme:

- the degree of hazard to life and limb caused by flooding;
- the number of people affected;
- the comparative benefit/cost ratios of the various measures;
- cost of the scheme;
- impact on adjoining areas; and
- social and environmental impacts.

3.4 Flood Warning, Public Awareness, and Evacuation Planning

The existing flood warning system for the Broken River has been reviewed and is discussed in Section 7.8 along with issues relating to public awareness and evacuation planning.

3.5 Policy Issues and Related Matters

The potential impacts of the Greenhouse Effect including the selection of an appropriate freeboard and extreme flooding are discussed in Section 9.

4 THE FLOOD STANDARD

In Victoria the 1% AEP flood is the standard generally adopted for setting floor levels of habitable rooms. Although some exceptions do occur they usually involve adopting a higher (less frequent) flood than the 1% AEP flood, often as a direct result of recent community experiences involving a very large rare flood. This is consistent with the State Policy Planning Framework which recognizes that land affected by flooding is land inundated by the “1-in-100-year” flood or as determined by the floodplain management authority. The “1-in-100-year” flood is the same as the 1% AEP flood as discussed throughout this report

The Flood Standard provides the reference point for defining flood affected land and a basis for development restrictions and controls and to guide zoning changes. Selection of an appropriate flood standard should be based on an understanding of flood behaviour together with social, economic and environmental considerations, balancing short term savings against long term costs.

4.1 Review of Current Practice

By virtue of the requirements of the former Victorian Building Regulations, Delatite Shire Council has adopted the 1% AEP flood as the standard to be applied when considering planning, building and development proposals. However the controls exercised by Council were based on the 1984 estimates of the 1% AEP flood height (Ref. 3) which has since been shown to be seriously underestimated (Ref. 2). Therefore, this study reviewed the adoption of the 1% AEP flood as the Flood Standard to assess whether, in the light of the October 1993 flood, it was still appropriate and if not, what were the implications of changing to a higher or lower standard. The review was based on the consideration of a number of factors including:

- ❑ the 1984 estimate of the 1% AEP flood levels;
- ❑ flood behaviour, including the magnitude and timing of the flood peaks from Holland Creek and the Broken River;
- ❑ existing and predicted future landuse; and the
- ❑ impact of the revised estimate of the 1% AEP design flood and flood levels and the October 1993 flood.

Table 4 indicates the number of buildings in the urban area affected by the estimated 2% AEP flood (approximates to the 1984 estimate of the 1% AEP flood), and a design flood flow equal to the estimated peak flow in the October 1993 flood.

TABLE 4
HOUSES FLOODED AND ESTIMATED DAMAGE FOR VARIOUS FLOODS

Flood	No. of Houses Flooded Above Floor Level	Estimated Flood Damages (Includes External Damages)
5% AEP	36	$1.18 million
2% AEP	361	$5.23 million
1% AEP (Peak flow equal to October 1993 flood)	877	$13.75 million

Note: Estimated flood damages are in 2001 dollars and relate only to residential property and readily assessed tangible damages.

4.2 1% AEP Peak Flow Estimates

During the course of the study a second estimate of the magnitude of the 1% AEP design flood was reported by HydroTechnology (Ref. 12). The HydroTechnology report suggested that the magnitude of the 1% AEP design flood was in the order of 1440 m^3/s. This is approximately 25% greater than the magnitude reported in the Flood Study (Ref. 2.) of 1150 m^3/s and 14.7% greater than the estimated 1250 m^3/s of the October 1993 flood.

In order to resolve the magnitude of the peak 1% AEP design flood flow, an independent assessment was undertaken (Ref. 6). The independent assessment concluded that the 1995 estimate of the 1% AEP flood (Ref. 2) and the estimated peak flow in October 1993 were both within the acceptable range of peak flow estimates. The report further concluded that the higher estimate reported by HydroTechnology (Ref. 12) was outside the acceptable range of estimates.

It is understood that in the light of the independent assessment (Ref. 6) that HydroTechnology have reviewed their previously reported 1% AEP flood estimate and subsequently advised of a revised 1% AEP peak discharge at Benalla of 1170 m^3/s.

4.3 Recommended Flood Standard

On the basis of the:

- ❑ independent assessment of estimated 1% AEP flood flows (Ref. 6),
- ❑ the relatively small difference between the 1995 1% AEP design flood estimate (Ref. 2) and the October 1993 flood, and
- ❑ the large amount of recorded data for the October 1993 flood and the fact that the data represents the maximum known flood levels,

the Floodplain Management Consultative Committee resolved to adopt the 1% AEP flood as the Flood Standard (Designated Flood)and to adopt a peak 1% AEP flood flow rate equal to the estimated peak flow for the October 1993 flood.

The adoption of a flood of equal peak flow rate to the October 1993 flood as the Flood Standard, however, does not preclude the use of a lesser flood as the criteria for building floor levels and structural flood mitigation measures although the Flood Standard would normally be adopted for planning purposes.

For example, in Benalla, the use of a lesser flood for new and redeveloped retail and commercial properties, particularly in the main business area, may be appropriate when considering the overall disruption to the community, visual impact and economic viability of many businesses if they were raised significantly above the existing street level.

For structural flood mitigation measures, practical considerations might make a flood more frequent than the standard appropriate in a given situation. For example, a levee bank designed to cater for the flood standard might be too visually intrusive and therefore the adoption of a smaller and more frequent flood may be warranted when all factors are considered. On the other hand, some situations may warrant adoption of a higher design standard than the designated flood.

Not all residential properties in Benalla can be protected by a levee or other forms of food barriers including raising of roads. Therefore in the interests of providing a similar level of flood protection for all flood affected residents, it is normally recommended that where properties can be protected by a levee, that the levee affords a similar level of protection as house floor level raising. Any raising of house floor levels should be to a level above the Flood Standard plus an allowance for freeboard. Thus the preferred height for a levee should be to the height of the 1% AEP design flood plus freeboard. In some areas of Benalla this will require the height of the levee or floodwall to be in excess of 2 metres. Based on community comment received during a series of meetings conducted by Council in 1996 and 1997 the FPMCC have reported that some sections of the community were strongly opposed to a levee or floodwall which would rise 2 metres or higher where they were either in close proximity to their homes or where they would significantly obstruct existing views.

This report has evaluated all flood mitigation measures and three schemes on the basis of providing protection up to and including the 1% AEP design flood. Thus all measures and Schemes A1, B, C and D) are on the basis that the community would be protected against the impacts of a flood of the same magnitude as the October 1993 flood.

In addition two further schemes (Schemes E2, F2) nominated by the FPMCC following community consultation in 1996 and 1997, were evaluated for the 2% and 5% AEP floods, and one scheme (Scheme G5) was evaluated for the 5% AEP flood.

Following further community consultation between 1999 and 2001 an additional two schemes were nominated by the FPMCC were assessed. Scheme J was evaluated for the 5% AEP flood and Scheme K was evaluated against all floods up to and including the 1% AEP flood.

4.4 Adopted Peak Design Flows

The peak design flows adopted for this report are summarized in Table 5.

TABLE 5
ADOPTED PEAK DESIGN FLOWS (m^3/s)

Flood Frequency	Downstream of Bridge Street	Upstream of Bridge Street	Broken River at confluence	Holland Creek at confluence
1% AEP	1193	1259	659	736
2% AEP	965	1001	508	586
5% AEP	670	689	335	428

5 EXISTING FLOODING PROBLEMS

5.1 Flooding Categories

The damages and disruption caused by floodwaters depend on the extent and duration of flood inundation, and on the depth and the velocity of flow. The Victorian Planning Provisions (Ref. 23) provides for the classification of flooded areas taking account of the severity of flooding at specific locations. Three zones are defined which reflect the assessed relative flood risk for different parts of the floodplain. The three zones are:

- Urban Floodway Zone (UFZ),
- Floodway Overlay (FO), and
- Land Subject to Inundation Overlay (LSIO).

The mapping of each zone is based on a consideration of factors including flood depth, flood velocity, natural storage, flood frequency, and flood duration.

Mapping of each of the above three zones for Benalla was completed by the DNRE in 2000 using historical flood levels, aerial photography, ground level information and hydraulic modelling.

Urban Floodway Zones have been delineated so as to include:

- All of the main river channel and adjoining low lying ground along the Broken River from upstream of Cowan Street to Faithful Street,
- Holland Creek from the Broken river confluence to upstream of Samaria Road almost to Willis Little Drive,
- The anabranch bi-secting the residential area from near the intersection of Garden Street and Hair Crescent and extending to Arundel Street between Market Street and Maud Street,
- The West Main Drain from the Broken River to the railway, and
- The East Main Drain from the low lying land immediately upstream of the railway and east of Witt Street to the upstream side of the Benalla – Yarrawonga Railway.

The low lying corridor which functions as an anabranch during very high floods and extends downstream from near the intersection of Arundel Street and Shadforth Street has been included as rural (RUZ) rather than as part of the UFZ.

Disruption and damage from flooding in Benalla initially occurs for small floods with a relatively short duration and an average recurrence interval of approximately 10 years (10 Year ARI) and progressively worsens for larger floods. For large floods similar to those which occurred in 1981 and 1993 the duration of floods is significant and may last several days before receding. Flood impacts result in damage to both private and public property and the effects can last a considerable time while repairs to buildings, roads and public infrastructure is carried out.

As a general rule the Urban Floodway Zone and Flood Overlay areas reflect a greater flood risk and subsequent potential damage compared to the LSIO designated areas.

5.2 Extent of Flooding

For planning purposes the extent of flooding is defined by the level of the Flood Standard. To assess the flood liability of any individual property an accurate determination needs to be based on site specific survey data.

Table 6 shows the number of buildings which experience over floor flooding for various design floods. The majority of the residential buildings affected are south (upstream) of the railway viaduct.

TABLE 6
NUMBER OF BUILDINGS EXPERIENCING OVER FLOOR FLOODING

Flood	Residential	Non-Residential
5% AEP	36	21
2% AEP	361	138
1% AEP	877	208

Number of buildings flooded based on property and floor level survey undertaken in 1997.

5.3 Flood Damages Assessment

Damages from flooding may be categorized typically as either financial or social in nature and are often referred to as tangible damages and intangible damages, respectively. Generally, tangible damages are measurable in dollar values and they may be subdivided into direct and indirect damages (Ref. 11).

5.3.1 Tangible Damages

Direct damages are those caused by the physical contact of flood water with damageable property. They include damages to commercial and residential building structures and contents, and infrastructure such as electricity, gas, water supply and sewerage reticulation. Direct damages also include damage to motor vehicles and other plant and equipment (Ref. 7).

Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood (Ref. 7).
The estimated tangible damages suffered from the 1% AEP flood (=October 1993 flood) are given in Table 7.

TABLE 7
SUMMARY OF ESTIMATED TANGIBLE DAMAGES

Area	Building Type		Design Flood - Existing Conditions				
			10%	**5%**	**2%**	**1%**	**Extreme**
South East	Residential	Brick	0	0	68	242	775
		Weatherboard	0	0	54	187	543
		Total	0	0	122	429	1318
		Damage	$70,353	$112,599	$1,319,980	$6,015,341	$96,296,464
South East	Commercial	All	4	9	114	179	311
		Damage	$131,617	$364,501	$5,773,819	$12,704,399	$65,110,848
South West	Residential	Brick	0	9	89	145	521
		Weatherboard	2	7	104	193	425
		Total	2	16	193	338	946
		Damage	$74,330	$394,254	$3,012,921	$5,928,518	$63,104,472
South West	Commercial	All	0	6	8	8	34
		Damage	$0	$339,017	$623,356	$623,356	$4,508,077
North East	Residential	Brick	6	12	22	47	62
		Weatherboard	0	6	17	40	145
		Total	6	18	39	87	207
		Damage	$62,861	$342,152	$730,920	$1,393,152	$9,750,641
North East	Commercial	All	0	5	15	20	25
		Damage	$0	$221,864	$1,010,521	$1,781,161	$4,735,101
North West	Residential	Brick	0	2	5	18	191
		Weatherboard	0	0	2	5	194
		Total	0	2	7	23	385
		Damage	$1,006	$20,923	$162,393	$412,785	$17,085,090
North West	Commercial	All	0	1	1	1	4
		Damage	$0	$192,348	$363,587	$438,660	$309,736
Total Urban Area	Residential	Brick	6	23	184	452	1549
		Weatherboard	2	13	177	425	1307
		Total	8	36	361	877	2856
		Damage	**$208,550**	**$869,928**	**$5,226,214**	**$13,749,796**	**$186,236,667**
	Commercial	All	4	21	138	208	374
		Damage	**$131,617**	**$1,117,730**	**$7,771,283**	**$15,547,576**	**$74,663,762**
		Total damage	**$340,167**	**$1,987,658**	**$12,997,497**	**$29,297,372**	**$260,900,429**

Notes:
South East - refers to the area south (upstream) of the railway embankment and east of the Broken River.
South West - refers to the area south (upstream) of the railway embankment and west of the Broken River.
North East - refers to the area north (downstream) of the railway embankment and east of the Broken River.
North West - refers to the area north (downstream) of the railway embankment and west of the Broken River.
The number of buildings flooded and flood damage estimates are based on floor level, ground level and building type data base compiled from the survey undertaken in 1997 as part of the Total Flood Warning System (Ref 27).

5.3.2 Intangible Damages

Factors affecting intangible damages may include:

- inconvenience;
- isolation;
- disruption of family and social activities;
- anxiety, pain and suffering, trauma;
- physical ill-health; and
- psychological ill-health.

5.3.3 Damage Estimates

The damage estimates derived in this study are for the tangible damages only. While it is recognized that the various factors included in the intangible category may be significant, perhaps up to 50% of the tangible damages, these effects have not been quantified due to difficulties in obtaining data. The economic performance of each scheme has therefore been undertaken on the basis of tangible damages only and as such is consistent with normal practice. In doing so however the resulting benefit-cost ratios (BCR's) are likely to be an underestimate.

5.3.4 Potential Damages and Actual Damages

Damage estimates may be either potential or actual damage estimates. Potential damages are usually higher than actual damages because potential damage estimates make no allowance for the fact that some items may be evacuated before the flood provided sufficient warning time is available. Further, in estimating potential damages, many items are assumed to be destroyed and cannot be salvaged.

Tangible flood damages used are actual damages and were evaluated after considering the following components:

- direct residential damages;
- direct commercial damages;
- external damages;
- indirect damages and
- clean up after the flood.

In assessing the actual damages incurred from the October 1993 flood it is considered likely that the actual damages are close to the potential damages due to the unexpected magnitude of the flood, and the absence of a well documented, planned and rehearsed flood emergency response procedure which allowed for a flood greater than the previously highest recorded flood. As a consequence personal possessions and retail/commercial stock which could have been moved was not. Estimates of commercial stock losses have been quoted as $4 million (Ref 16, Benalla Ensign).

Improvements in flood warning lead times and the level of preparedness for evacuation by the community as a whole may significantly influence the extent of damage. For example, where sufficient warning is provided carpets and furniture may be removed from the reach of floodwaters.

The design of infrastructure to withstand temporary inundation or the location of services beyond the reach of flood waters can also substantially reduce damages arising from both the direct impact of flood waters and the time lost in restoring services.

It is difficult to accurately assess the avoidable damages in 1993 which may have resulted from a community which was well informed and prepared for such a flood. In flood affected areas where buildings are predominantly of brick or brick veneer construction damages to contents may represent as much as 50% of the damages sustained by each household. This proportion is likely to be lower where a significant number of buildings are timber clad and as a consequence are more susceptible to structural damage. This is the case in the older parts of Benalla and “contents damage” in these areas may only represent 20% to 25% of the total damage to each household. For residential areas in Benalla the overall damage attributable to contents and which is potentially avoidable is guestimated as 30%. The damage to stock in retail areas is likely to be considerably higher and a value of 70% has been adopted in this report.

Details of how flood damages are calculated are provided in Appendix A. Table 6 indicates the flood damage experienced for the 5%, 2% and 1% AEP flood. The estimated damage for the 1% AEP flood is lower than the damages reported by HydroTechnology (Ref. 12) for the October 1993 flood. The HydroTechnology damage estimate is considered high and the reasons for this are discussed in Appendix A.

Among other factors, damages are dependent on the depth of flooding and the materials used in the construction of the affected buildings. The economic analysis has been based on existing floor level and building data survey data recorded in 1997.

The standard way of expressing flood damages is in terms of average annual damages (AAD). These are calculated by multiplying the damages which can occur in a given flood by the probability of the flood occurring in a given year and summing these annual damages across the range of floods. By this means, the smaller floods which occur more frequently are given a greater weighting than the rare catastrophic floods. The AAD for the study area (urban Benalla) is estimated to be $2,157,586.

6 STRUCTURAL MEASURES

Structural measures are designed to provide protection by limiting the extent of flooding or by lowering the level of floodwaters in a protected area. An initial list of possible structural measures was identified by the Floodplain Management Consultative Committee at the commencement of the study. Further possible structural measures were identified during the study including suggestions contained in written submissions from the community.

Major structural measures such as levees can have adverse effects both upstream and downstream. For this reason it is essential to assess their impacts on flood behaviour before deciding if they are practical. This assessment was undertaken using the hydraulic model of the floodplain initially assembled for the Flood Study.

All the identified possible structural measures were examined. The various measures and their impact on flood behaviour are described below.

6.1 Removal of the Railway Embankment (Measure A)

There is widespread concern in the community regarding the impact the railway embankment has on flooding. To investigate the impact of the embankment on flooding the XP-EXTRAN hydraulic model was modified to simulate flood behaviour should the railway embankment be replaced with a continuous bridge or be removed altogether.

The railway embankment was found to increase flood levels immediately upstream of the embankment by up to 500 mm in the vicinity of the East Main Drain and lesser amounts elsewhere. In West Benalla the embankment was found to have a maximum impact of 440 mm next to the West Main Drain culvert.

Increases in flood levels of up to 160 mm are predicted for the area between the Railway and Racecourse Road if the embankment were to be removed or replaced with a continuous bridge. Similarly, increases of 70 mm are predicted in West Benalla between the Railway and Boger Street

The impact of the railway embankment on the 1% AEP flood is shown in Figure 3.

If the railway embankment was to be removed or replaced by a multi-span bridge there would be a net decrease of 149 residential properties and 33 commercial properties which experienced over floor flooding in a 1% AEP flood. Although the increases in the 1% AEP flood levels north of the railway embankment are relatively small it would be sufficient to cause a large number of residential properties currently estimated to have floor levels marginally below the 1% AEP flood level to be inundated above floor level (ie in part the flooding problem would be transferred downstream). A comparison of the estimated number of properties to experience over floor flooding with and without the railway embankment is given in Table 8.

Given the likely high cost for relatively little benefit this measure was not pursued further.

TABLE 8
PROPERTIES ESTIMATED TO EXPERIENCE OVER FLOOR FLOODING WITH AND WITHOUT THE RAILWAY EMBANKMENT FOR THE 1% AEP FLOOD

Locality	North East	North West	South East	South West
<u>Residential</u>				
With Railway Embankment	104	48	524	371
Without Railway Embankment	135	378	249	136
<u>Commercial</u>				
With Railway Embankment	18	0	207	18
Without Railway Embankment	18	0	189	3

Other less costly measures designed to achieve a similar impact as removal of the railway embankment were then examined. The alternatives measures were to widen the existing railway viaduct and to install culverts near Nunn Street and Duffy Street (Measure C).

6.2 Widening of the Railway Viaduct (Measure B)

The impact of the existing railway viaduct over the Broken River was investigated by modifying the XP-EXTRAN hydraulic model to include a viaduct 100 metres wider than the existing structure. The viaduct was assumed to extend over the right floodplain (eastern side of the river) and represents an increase in width of approximately 40%.

Small decreases in the 1% AEP flood level in the immediate upstream vicinity of the viaduct and the East and West Main Drains are predicted if the viaduct is widened by 100 metres. The decreases were generally about 100 mm and very localised. Widening the viaduct does not have a worthwhile impact on flood levels since approximately 90% of the total flow already passes beneath the viaduct. Increasing the viaduct width would not appreciably increase the amount of flow passing under the viaduct and therefore this measure was not pursued further.

6.3 Additional Railway Embankment Culverts (Measure C)

The hydraulic model was used to simulate the effect of providing 6 No. 4.2 metre wide x 1.2 metre high culverts through the railway embankment near Nunn Street and a further 5 culverts, each 4.2 m wide x 1.2 m high near Duffy Street. An additional 2.4 m wide x 1.5 m high box culvert was also added to the existing opening on the East Main Drain.

The location of the culverts immediately west of Nunn Street was chosen so that the culverts may discharge across the recreational area and away from residential properties. Should the culverts be constructed in this location then the construction of that part of Levee 7 between the railway and Roe Street should be considered to ensure flooding of residential properties north of the railway is not worsened. Preliminary investigations indicate that no additional properties would be flooded in the Maginess Street area and Levee 7 has therefore not been included at this stage. However although investigations indicate that no additional properties would experience over floor flooding small rises in peak flood levels in localized areas are nevertheless likely to occur and this matter will require further detailed analysis before implementation of Measure C.

Culverts installed between Duffy Street and the East Main Drain would discharge across vacant land and no supplementary measures are considered necessary.

Further flood culverts located between Nunn Street and Duffy Street were not investigated because the culverts would discharge opposite a developed residential area north of the railway line. This would lead to an increase in the flood risk for the area. For similar reasons, culverts on the west side of the river between Kent and Goodwin Streets have not been proposed.

At Nunn Street there is potential to re-construct the “at grade” road-railway crossing as a grade separated crossing by using 2 or possibly 3 of the proposed flood culverts as road culverts. This however would preclude heavy road transport from using the route because of the low clearance and a suitable bypass route would be required. A depressed road through the culverts to increase the clearance height is not recommended due to the need for additional drainage and the increase in flood risk for vehicles and pedestrians.

The predicted impact of providing the culverts is shown in Figure 4. An examination of Figure 4 indicates that the effect of the culverts is predominantly limited to the area between the railway and Church Street with the maximum effect occurring in the immediate vicinity of the culverts.

The effect quickly diminishes as the distance from the culverts increases. For properties upstream of Bridge Street there is no discernible lowering of the 1% AEP flood levels.

If the additional culverts are installed as described there would be a reduction of 83 residential buildings and 3 commercial buildings currently estimated to experience over floor flooding during the 1% AEP flood.

The preliminary estimated cost of installing an additional 12 culverts through the railway embankment is $3.5 million.

The environmental impact from the construction of these culverts is low and those in the vicinity of Duffy Street would provide the greatest benefit. The option to construct the culverts near Nunn Street were therefore discarded but those near Duffy Street were retained for inclusion in some of the schemes.

6.4 Vegetation Management in the River and on the Floodplain (Measure D)

The greatest potential for increasing river channel capacity by the selective removal of trees and snags from the river bed and floodplains is upstream of Parkview Parade and downstream of Ackerly Avenue. Any decision to clear the river channel and banks/floodplains should represent a balanced choice based on aesthetics, maintenance of river bed and bank stability and the desire to minimize the resistance to river flows and thereby reduce flood levels.

Apart from the environmental and aesthetic value of the trees any substantial clearance of trees in this area is likely to result in increased river flood velocities past Benalla which may lead to river destabilization and increased siltation. Initially, because of environmental concerns only a moderate thinning of vegetation was investigated but following discussions with the FPMCC a more drastic approach was considered which included excavation of the mid-stream islands to 168m which is approximately 1.5 metres above the normal level of Lake Benalla (Measure M).

The two vegetation reduction scenarios investigated corresponded to;

Measure Dm removal of most of the understorey growth and a 50% thinning of the trees from the river islands and floodplain opposite Parkview Parade, and extending the work upstream to the confluence of the Broken River and Holland Creek.

Measure De removal of all woody understorey growth and the selective removal of up to 75% of the trees from the river islands and floodplain opposite Parkview Parade, and extension of the work upstream to the confluence of the Broken River and Holland Creek. The selective removal of trees from critical flood areas would need to be compensated by planting in non-critical areas such as back water and flood fringe locations so that in the longer term their is no net decrease in the ecological value of the area.

Vegetation management as described for Measure Dm is predicted to lower the 1% AEP flood levels opposite Parkview Parade sufficiently to reduce the number of houses experiencing over floor flooding by 85. The majority of the benefiting properties would be in the vicinity of Arundel Street and Neill Avenue and are among the worst affected in Benalla.

A preliminary estimate for the initial clearing of scrub and thinning of trees is $54,000. An additional amount estimated to be about $3,500 would be required annually for maintenance slashing and removal.

Vegetation reduction as described for Measure De is predicted to lower the 1% AEP flood levels opposite Parkview Parade sufficiently to reduce the number of houses experiencing over floor flooding by 151. The majority of the benefiting properties would be in the vicinity of Arundel Street and Neill Avenue and are among the worst affected in Benalla. The effect of the measure is shown in Figure 5.

A preliminary estimate for the initial clearing of scrub and thinning of trees is $210,000. This estimate has been revised up based on Council's recent reported cost of $29,000 to remove an estimated 300 trees from near the river bank downstream of Ackerly Avenue. An additional amount estimated to be about $6,300 would be required annually for maintenance slashing and removal.

Vegetation management was found to be a cost effective measure in reducing the level of flooding and because of the implementation opportunities it has been included in several of the flood management schemes described in Section 8. It is imperative however that adequate areas for compensating planting are identified as part of this measure in order that, as a minimum the ecological “status quo” is maintained.

Following preparation of this section of the report it was decided to carry out an extensive tree survey and examine the impact of vegetation removal downstream of Ackerly Avenue in detail. The methodology and results of this evaluation is included in Section 6.11 and is the preferred vegetation management approach over Measures Dm and De.

6.5 Lowering Benalla Weir and De-silting of Lake Benalla (Measure E)

This measure would require the existing low embankment which dams the river and creates Lake Benalla to be replaced with a series of flood gates which may be opened prior to the arrival of a flood in Benalla. Opening the gates would create a larger waterway area for the flood to pass. Similarly de-silting of the lake would also create a slightly larger waterway area.

To estimate the impact of this measure on flooding, the hydraulic model was modified by lowering the weir crest to the level of the river bed immediately downstream of the weir. This change also simulates the effect of lowering the lake bed due to de-silting. Based on the hydraulic modelling results no change to the 1% AEP flood levels in built up areas is predicted. This result is consistent with anecdotal evidence gathered during the study which suggests that because the weir is a low structure it would be "drowned out" under peak 1% AEP flood conditions. This measure was therefore rejected.

6.6 Flood Exclusion Measures - Levees

6.6.1 Introduction

Measures designed to exclude floodwaters can take a variety of forms. Examples include levees, floodwalls, road embankments and raised landscaping. In the latter case where landscaping is used in existing developed areas it is most suited where the depth of flooding is shallow. Measures for individual buildings include shutters on doors and windows and solid fences. Where fences cross property entry points the fence opening is usually sealed during a flood with sandbags or drop boards.

For Benalla two broad alternatives for levees have been considered which are designed to provide protection against either the 5% AEP flood or the higher 1% AEP flood. Initially only levees designed to protect property against the 1% AEP flood were considered but following strong community opinion that the “cure was worse than the disease” a range of structural measures designed to provide protection against the 5% AEP flood were investigated. The height difference between the two alternatives is approximately 800mm and because of this difference the land required for construction, the type of levee, and the route of the levee, and therefore the environmental impact varies considerably.

Levees designed to provide protection against the 1% AEP flood would in some locations be in the order of 2 metres or more high once the freeboard requirement of 600mm was included. The areas required to construct an earthen embankment which could be grassed and mown or even planted with ground cover species would be considerable. For a levee height of 2 metres a strip of land at least 5 metres wide would be required if the levee was planted with ground covers, or 21 metres wide if grassed and mown. The alternative is flood proof walls constructed using either concrete or brickwork.

However where protection up to and including the 5%AEP flood only is required, low impact measures such as minor raising of the roads as part of re-surfacing works, and landscaping become viable measures in most locations. In some locations such measures could be suitably supplemented by masonry fences along either or both side and rear property boundaries but in all cases the masonry fences would be no higher than the fences they would replace. These measures are discussed further in Section 6.7.

The range of feasible measures identified in this report which would provide protection against the 5% AEP flood in Benalla include the raising of local roads “running parallel” to the river, free form landscaped / grassed earthen embankments and full or part replacement of existing timber or wire mesh fencing with masonry fencing of a similar or lower height. The consequences of the lower required height for these structures is a substantially reduced visual and ecological impact, minimal effect on current pedestrian and traffic movement, and lower capital costs.

The structures are located on both sides of the river upstream of the railway viaduct and in general follow the route of existing roads closest to the river. Downstream of the railway replacement flood proof fencing is proposed only for the eastern side of the river. On the western side of the river the height of any structures would be formidable even for the 5% AEP flood and as a consequence the community was generally opposed to the concept of levees in this area.

By contrast the impact of seven levees designed to provide protection against the 1% AEP flood were examined. The levees comprise either landscaped earthen embankments, masonry (brick) floodwalls, or raised median barriers along the centre of roads. In the majority of areas they would be fairly intrusive and cause significant permanent disruption to traffic and pedestrian movement close to the river as well as adversely affecting the ecology of the river corridor and the communities capacity to enjoy the river environs. The route recommended for the “5% AEP “ levees is not necessarily the same as for the “1% AEP” levees and significant deviations between the two optimum routes would occur.

In the case of the raised median barriers the breaks at road intersections would require sandbagging or the use of purpose built drop boards to seal the protected area during a flood. The use of aluminum drop boards is preferred due to the speed with they can be erected. The drop boards would need to be of a standard length (say 5 metres) to allow for interchangeability between road intersections. The boards would be held at each end by either a rebate set into the levee wall or an "H" section steel post seated into a preformed covered post hole located in the road. Dirt would be prevented from entering the preformed post holes by a screw cap.

Drop boards are often used as weirs in irrigation canals and drainage channels for the temporary impoundment of water. The hydrostatic force against the drop boards ensures a tighter seal as the depth of impounded water increases. Flexible seals around the edges of the drop boards would ensure a continuous watertight seal between individual boards.

It is envisaged that when using a drop board system, a 25 metre wide road intersection could be fully sealed by 3 or 4 persons in approximately 30 minutes.

However the use of purpose built systems which are not kept permanently in place and are only used once every 10 years or even less frequently can be easily misplaced or damaged and not repaired. In such circumstances the area for which they were provided would be left with insufficient or no protection against flooding. Systems or other arrangements designed to exclude floodwaters which are permanently in place and require little or no maintenance are preferable. Raising of local roads by small amounts and “free form” landscaping in parks to create usable continuous areas of higher ground would be types of permanent low maintenance flood exclusion systems.

The levees described in the following sections and suggested for various locations in Benalla are conceptual only and are designed to protect areas against the 1% AEP flood. A limited analysis was also undertaken with respect to levees designed to provide protection against the 2% AEP flood but in the majority of locations the differences in the environmental and social impacts was small.

If the community adopts a flood mitigation strategy based on a levee system it is envisaged that the final form and location of each levee would be based on a detailed site analysis and be subject to further public scrutiny. For example in several locations the height of the median levee with or without a plantation box may be reduced by raising the road part of the required amount. In the case of earthen levees where the landtake is considered unacceptable the embankment slope may be replaced by a vertical or near vertical retaining wall.

Levees are designed to protect property only. Wherever possible, residents in leveed areas should still evacuate since there is always a residual risk of the levee being overtopped by a flood greater than the design flood. Where levees are overtopped there can be a sudden rise in the depth of water creating a highly hazardous situation and making evacuation of residents both difficult and dangerous. In Benalla, overtopping of Levees 1 and 2 in some locations will result in flood waters behind the levee rising rapidly to depths of 2 metres or more and it is essential that residents in these areas are evacuated at the earliest opportunity.

The conceptual location of each levee examined is illustrated in Figure 7.

6.6.2 Levees 1 and 2 (Measure F)

The form that the levees take is dependent upon whether protection against the 5% AEP flood or the 1% AEP flood is required. The 5% AEP “levees” have a significantly lower impact compared with the 1% AEP levees because of their smaller scale.

Levee 1 for 1% AEP flood protection

This levee would be located along Arundel Street between Bridge Street and the railway. The suggested structure would comprise a raised road median barrier which could incorporate plantation boxes. The concept is illustrated in Figure 9. At road intersections gaps in the levee would allow for normal traffic movements. During a flood alert it is proposed that the gaps would be sealed using purpose built aluminum drop boards. To provide protection against the 1% AEP flood the levee would have an average height of 0.9 m and a maximum height of 1.05 m near at the intersection of Kent Street and Arundel Street. The levee height includes a freeboard allowance of 0.6 m.

Drainage of the area behind the levee is not expected to present any significant difficulties. The area is quite flat and it would appear that local drainage along east-west aligned streets can be re-graded as necessary to provide fall towards the West Main Drain.

This type of levee, if well designed and maintained can be visually attractive in a streetscape. However a major constraint is the need for a sufficiently wide road to allow safe movement of vehicles after construction of the levee. The road reserves where this type of levee has been proposed are all sufficiently wide to meet minimum road design criteria although in some instances conformance may necessitate the removal of some trees and/or reduction in footpath and "nature strip" widths. These are matters which would require further investigation during the design phase. For residents opposite the raised medians there would be increased inconvenience by restricting the direction in which vehicles can enter and leave properties.

Unless carefully designed this type of levee would may increase the risk of motor vehicle accidents due to reduced sight distances at road intersections. It is therefore recommended that where this type of levee is adopted the gap between levees at each road intersection should be approximately twice the intersection width. No accident statistics for this situation are available and therefore it has not been possible to quantify any increased risk.

A nominal "accident" allowance of $5,000 per intersection per year has been included in the cost-benefit analysis together with an annual allowance of $1,000 to account for increased travel times and costs to residents.

Levee 1 for 5% AEP flood protection

As an alternative to the levee described for protection against the 1% AEP flood it would be possible to provide protection against the 5% AEP flood by raising the road and thereby eliminate the need for the median flood structure. The road would need to be built up by a maximum of 400mm but generally less than this. From the railway to Kent Street the road would be raised 250mm but only 50mm near Wedge Street. Such an arrangement would have benefits in both reducing the need to seal road intersections during a flood and by providing improved sight distances at road intersections. Disadvantages would include increased difficulties in accessing some properties due to steeper "cross-overs" although a preliminary assessment indicates that at each property access an acceptable design is feasible.

Based on consultations with residents located on the river side of Arundel Street the FPMCC reports that works in this area, including road raising are not favoured and that it is likely that further discussions and preliminary design work would be required to show that residents concerns can be satisfactorily addressed.

Levee 2 for 1% AEP flood protection

This levee should be constructed in conjunction with Levee 1 to provide continuous protection for West Benalla upstream of the Railway line.

Where protection against the 1% AEP flood is required Levee 2 would be approximately 2,400 m long and extend from Bridge Street to Cowan Street. The suggested levee would be comprised of the following main elements;

- a masonry floodwall approximately 2.2 m high forming the rear boundary fence of Arundel Street properties between Bridge Street and Maud Street,
- a landscaped earthen embankment averaging 1.9 metres high along the western side of the Showgrounds between Maud Street and No 111 Arundel Street,
- a reinforced brick floodwall for approximately 100 m along the northern side boundary of 111 Arundel Street,
- a landscaped earthen embankment averaging 1.8 metres high across the rear portion of properties between 111 and 139 Arundel Street, and a 2.6 metre high embankment along the southern side of Neill Avenue,

- a reinforced brick floodwall at the rear of property on the corner of Neill Avenue and Benson Street,
- a landscaped earthen embankment averaging 2.4 metres high from Benson Street to Hair Crescent and,
- a landscaped “free form” embankment up to 1.6m high from Hair Crescent to opposite the intersection of Garden Street and Waller Street.

A 4m wide break in the levee would be required at the end of Arundel Street to allow access for maintenance vehicles and fire trucks to the low lying ground. The access point would need to be sealed with hinged flood gates or an equivalent arrangement. A further opening for fire access may also be required at Hair Crescent.

Construction of the levee near the corner of Arundel and Neill Streets would be greatly assisted by the purchase of the property at No. 139 Arundel Street. The recorded floor level of this property is below the 5% AEP flood height and purchase of this property is recommended as part of this measure if protection agains the 1% AEP flood is required. The alternative is to construct a flood proof masonry wall close to the property boundary however this may unduly affect the use of and access around the dwelling. Further detailed investigations of possible routes for a 1% AEP levee/flood wall would be required particularly for the protection of houses at the southern end of Arundel Street and along Neill Avenue.

This alternative was examined in some detail by the FPMCC who concluded that a flood wall was viable subject to the owners agreement. Purchase of the property on the southern corner of Neill Avenue and Benson Street (CP 107259) was initially considered an option to facilitate construction of the 1% AEP levee although upon further investigation by the FPMCC purchase of this property is now not considered to be warranted.

Hydraulic modelling of this levee indicates that flood levels on the opposite side of the river would increase by up to 150 mm in the 1% AEP flood. The increases would primarily affect properties in Parkview Parade, Riverview Parade, Kathyrn, Elizabeth, Short and Moore Streets. Some properties in Rebechhi Court and Psaltis Parade may also be affected. The extent of the impact is shown in Figure 8.

Drainage of local runoff collecting behind the levee will need to be either or both stored and pumped. There would be some opportunity to provide a small holding basin for local runoff on the Showgrounds and on vacant land near the end of Waller Street. Temporary storage would also be available in the anabranch which would not be carrying river flows. The creation of these storage areas would reduce the pump capacity required but not eliminate the need for some permanent pumping capacity. Peak flow estimates from local runoff are provided in Appendix B.

The estimated cost of the measure (Levees 1 and 2) to protect against the 1% AEP flood is estimated as $3.4M. The works would provide protection for an estimated 370 properties (354 residential buildings) in a 1% AEP flood.

Levee 2 for 5% AEP flood protection

Where protection is required only for flood up to and including the 5% AEP flood the length and height of the levee may be reduced. The works would be approximately 800mm lower than for the 1% AEP flood level and would extend over some 2200m long between Bridge Street and to the open ground opposite the Garden Street-Waller Street intersection. The extent of work allows for 600mm freeboard above the 5% AEP flood level. Along Neilll Avenue the levee could take the form of a masonry wall approximately 1 metre high and located immediately behind the kerb line. This arrangement would allow for the retention of trees lining the street and retain the parkland views for Neilll Avenue properties.

The flood wall would need to extend from the south east corner of No. 137 Arundel Street, along the southern side boundary of No 137 and then follow the rear and southern boundaries of No 139 Arundel Street.

The estimated cost of the measure (Levees 1 and 2) to protect against the 5% AEP flood is estimated as $2.03M . The works would provide protection for an estimated 22 properties (16 residential buildings) in a 1% AEP flood.

6.6.3 Levee 3A and Levee 4 (Measure I)

Levee 3A for 1% AEP flood protection

This levee would be designed to protect residential properties in East Benalla between Bridge Street and Samaria Road.

The levee would consist primarily of a “free form” landscaped continuous mounding extending from the rear of the Senior Citizens building, behind Lowry Place, then generally following Psaltis Parade, Parkview Parade and behind the Ascot Court subdivision as far as Samaria Road. A masonry floodwall would be used to replace existing boundary fences of affected properties on the northern side of Samaria Road and in Lowry Place, and between Psaltis Parade and Tower Road. To provide protection against the 1% AEP flood a levee would also be required to skirt the western side of properties in Rivergum Avenue and extend easterly to the high ground near Willis Little Drive.

The suggested form of levee along Fawckner Drive is a reinforced brick wall with screen planting along the southern side of the road. Entrances to the Civic Centre and carpark would need to be sealed with drop boards during a flood. The average height of the wall in front of the Civic Centre would be 1.6 metres including a freeboard allowance of 600 mm if protection against the 1% AEP flood was required (Figure 10)

The levee height to provide protection against the 1% AEP flood with the normal 600 mm freeboard would be approximately 1.9 m high along Psaltis Parade (Figure 11) and reducing to 0.6 m near Union Street. Further upstream the levee would generally be about 1.5 m high.

A levee of this height unless carefully landscaped would provide a formidable barrier to normal access into the riverside park and access to and from the park during normal activities needs to be addressed.

Drainage of local runoff collecting behind the levee will need to be pumped. Only limited opportunities exist for creating temporary storage areas behind the levee. An opportunity exists on vacant land south of Samaria Road but no opportunities to collect and store local runoff from the Psaltis Parade/Parkview Parade area were identified. Isolating a section of parkland by constructing the levee away from the edge of the Psaltis Parade would result in substantially greater levee construction costs and present less opportunities to blend the levee into the existing landscape.

Levee 3A for 5% AEP flood protection

Where protection against flooding up to and including the 5% AEP flood only is desired the height and length of works as described for the 1% AEP levee may be substantially reduced. All works south (upstream) of Samaria Road would not be required and elsewhere the height of all works could be reduced by 700mm to 800mm. The route of the levee would be the same as for the 1% AEP levee but considerably less intrusive because of the reduced height. Under this arrangement the landscaped mounding along Fawkner Parade would only be required up to a height of 400mm which would assist in resolving access difficulties to the Council offices and Senior Citizens premises.

Levee 4 for 1% AEP flood protection

This levee would be designed to protect development on the eastern side of the river between Bridge Street and the railway. The levee would comprise a raised road median barrier or general raising of the road along Mair, Church and Mitchell Streets and an earthen levee from Benalla Street to the railway along the edge of the parkland adjacent to Mitchell Street. The intersection of Mitchell Street and Mackellar Street would need to be raised to avoid the need to break the embankment. To provide protection against the 1% AEP flood plus freeboard the median would be about 300 mm high along Mair and Church Streets and 500 mm high in Mitchell Street. Each road intersection would be sealed with drop boards as described for Levee 1.

A landscaped earthen embankment averaging 1.4 m high would complete the levee between Benalla Street and the Railway line. The intersection of Mitchell and Mackellar Streets would need to be raised a similar amount.

Measure I would protect an estimated 516 residential buildings and 203 commercial premises which currently experience over floor flooding in the 1% AEP flood. The preliminary estimated cost to construct the levees and pumping system to protect against a 1% AEP flood is $5.05M.

Levee 4 for 5% AEP flood protection

Where protection against the 5% AEP flood only is desired the works may be reduced to the following:

- Lifting of the road parallel to the railway at the end of Sharpe Street,
- A masonry wall boundary fence north of Benalla Street,
- Raising of Mitchell Street south of Benalla Street, and
- Raising of Mair Street.

These works would include a 600mm freeboard allowance above the 5% AEP flood level.

Drainage of local runoff collecting behind the levee will need to be pumped. Runoff will tend to collect near the corner of Benalla and Mitchell Streets. To minimize the pumping required local drainage should be redirected where possible into existing or additional culverts under the railway embankment and floodgates provided where necessary. This may necessitate some upgrading of local drainage/floodways on the northern side of the railway. A detailed stormwater drainage investigation of this area would be required to determine the precise requirements.

Hydraulic modelling of Measure I indicated that increases of approximately 50 mm in the 1% AEP flood level would occur opposite Levee 3A. The small increase is because only 5% of the total flow is estimated to spill onto the eastern floodplain (Ref. 2). Although the increase is small it does impact on some of the worst flood affected properties in Benalla and should only be considered in conjunction with Levee 2. No discernible flood level increases attributable to Levee 4 are predicted in built up areas. The impact is shown in Figure 12.

If the community adopts a system of levees for flood mitigation it is envisaged that the final form of each levee would be based on a detailed analysis of community preferences and technical opportunities and constraints. Considerable has already occurred during the course of this study and to gain broad community acceptance of the principles for protection against the 5% AEP flood. However further discussions will be required with neighbourhood groups during the detailed design phase.

Measure I would protect an estimated 0 residential buildings and 9 commercial premises which currently experience over floor flooding in the 5% AEP flood. The preliminary estimated cost to construct the levees and pumping system to protect against a 1% AEP flood is $2.52M.

6.6.4 Levee 3B and Levee 4 (Measure J)

Levee 3B for 1% AEP flood protection

This levee was investigated as an alternative to a landscaped earthen levee as described for Levee 3A. The suggested alignment follows Fawckner Avenue, Coster Street, Samaria Road, the western boundary of Rivergum Avenue properties and then easterly to Willis Little Drive. The levee along Coster Avenue and Samaria Road would comprise a raised road median barrier as described for Levee 1. A reinforced brick flood wall with screen planting would be required along Fawckner Drive and a landscaped earthen embankment from Samaria Road to Willis Little Drive, both as described for Levee 3A.

The sections of the levee comprising a raised road median barrier would suffer from the same constraints and concerns as discussed for Levee 1. However an alternative form of the levee involving raising the road as described for Levee 1 is also applicable in this instance.

To provide protection against the 1% AEP flood the road median barrier would be up to 1.4 metres high along Coster Road between Psaltis Parade and Riverview Road. Construction of Levee 3B would also increase the difficulty of evacuation and the provision of clear access to the intersection of Coster Street and Samaria Road is considered essential.

A further problem with the levee is that it would leave a substantial number of properties unprotected and cause a rise of approximately 100mm in the 1% AEP flood level for properties in the Psaltis Parade area.

Levee 3B for 5% AEP flood protection

The option to construct a levee to provide protection against the 5% AEP flood is not applicable along this route as the areas it would protect are already above the 5% AEP flood level.

Levee 4 would be as described for Measure I.

Following discussions with the Floodplain Management Consultative Committee Measure J was rejected due to the required height of some parts of the wall, its failure to protect all residential properties in the area and extra the difficulties created with evacuation in the unprotected area. Therefore no further examination of the measure was undertaken.

6.6.5 Levee 7 (Measure H)

Levee 7 for 1% AEP flood protection

This levee would be designed to protect properties located in the Maginnes Street area on the right bank of the river north of the Railway line against either the 1%AEP or 2% AEP flood.
A reinforced masonry floodwall approximately 2 m high then would replace the rear boundary of properties between Ellen Street and Roe Street. This route has been chosen as the preferred alignment following discussion with residents even though 3 properties on the western side of Maginnes Street south of Ellen Street would not be protected.

At the end of Roe Street the levee wall would be approximately 900 mm high including a freeboard allowance of 600 mm.

The levee would then extend as an earthen embankment no more than 900 mm high parallel to and on the western side of the Midland Highway. The protected area drains to the north and the embankment would be extended along the Midland Highway a sufficient distance to prevent floodwaters returning around the end of the embankment and flooding the protected area. The protected area is above the 2% AEP flood level and based on available survey it appears feasible to provide local drainage with a discharge point at the northern end of the embankment thus avoiding the need to provide and maintain pumps.

Less than 1% of the total 1% AEP flood flow is estimated to flow across the Maginess/Roe Street area and as a consequence no rise in 1% AEP flood levels are predicted for areas beyond the levee.

The preliminary estimated cost to construct the levee to provide protection against the 1% AEP flood is $1.12M. The levee would protect an estimated 104 houses and 18 commercial premises which are currently estimated to experience over floor flooding in a 1% AEP flood.

Levee 7 for 5% AEP flood protection

The route and form that this levee would take is constructed to provide protection against the 5% AEP flood has been discussed in detail with the local residents.

The levee would include raising Maguiness Street from the railway embankment to Ellen Street which would tie in with a flood proof fence to replace existing side and/or boundary fences of properties as follows:

- the rear boundary fences of Nos 5 to 13 McIvor Street
- the western side boundary fence for Nos 13 and 14 McIvor Street,
- the rear boundary fence of No 2 Roe Street, and
- the western side boundary of Lot 2 Roe Street, and

a low (maximum 700mm high earthen embankment north of Roe Street for approximately 50m although the required distance would need to be confirmed by survey.

Based on existing survey information where protection against the 5% AEP flood only is desired works along the Midland Highway would not be required.

Four properties at Nos 21 to 27 Maguiness Street have been excluded from the “leveed” area following discussions with the residents.

This measure is considered to have a low environmental impact because for the most part it only requires the replacement of existing boundary fences with ones which are watertight and the fences would not be any higher than the existing. Raising of Maguiness Street between Ellen Street and the railway embankment would not appreciably affect access to properties nor disrupt current traffic movement in the vicinity.

6.7 Other Flood Exclusion Systems

Alternatives to levees which can also exclude floodwaters from certain areas include land fill, road raising and free form landscaped earthworks which provide usable areas of continuously high ground. Landfill is not feasible in established areas unless widespread re-development is occurring. However road raising and free form landscaped earthworks are feasible for retro fitting in established areas providing the depth of the floodwaters for the design flood is shallow.

Road Raising and Free Form Landscaping
A combination of road raising and free form landscaped earthworks in parkland is a feasible option for most parts of Benalla when designed to protect areas from events up to and including the 5% AEP flood. The works would in many cases follow the same or similar alignments as described for levees which are designed to protect against floods greater than the 5% AEP flood. In a small number of areas these works would need to be complemented by replacement of existing boundary fencing with brick fencing of a similar height. In other areas, however, no additional works would be required because of the lower design flood level. In general the 5% AEP flood is in the order of 600mm to 800mm lower than the peak flood level for the October 1993 flood (the 1% AEP flood).

A description of the elements of this measure together with all complementary measures is described in Section 10.

Landfill
The term landfill is generally applied to filling occurring generally over a wide area rather than as a narrow band as for levees. No opportunities have been identified in Benalla to use landfill as a means of protecting existing building development against major flooding.

Building Shutters
Flood proofing of individual buildings is usually categorized under non-structural measures although it may result in substantial physical changes to a building. Shutters are discussed further in Section 7.

Flood Proof Boundary Fencing
Flood proof boundary fences are useful where their construction would not look out of place and the required height is no greater than a normal fence height. A serious constraint to their usefulness occurs where the fence crosses a property entry point. At entry points sandbags or a system of drop boards is usually employed to seal the fence.

There is opportunity to construct several brick side or rear boundary fences in Benalla to complement other works such as road raising or free form landscaping to raise ground levels.

6.8 Arundel Lake (Measure K)

The impact of constructing a second lake downstream of Ackerly Avenue was investigated. The lake would have no value as a flood storage facility but would create a similar impact to clearing the floodplain of trees and scrub as outlined for Measure D. A conceptual layout for one possible configuration for the lake is shown in Figure 12.

The Lake however does have an potential additional advantage over vegetation clearing in terms of the value of residential properties overlooking the Lake. In other towns there is strong anecdotal evidence that the market value of residential property has risen significantly following completion of a large lake which is overlooked by residential areas. There is evidence of this occurring following completion of the Lillydale Lake project on Olinda Creek upstream of Lilydale, Victoria. Thus there may be opportunities for partly offsetting the cost of constructing Arundel Lake.

For the purposes of this study it has been assumed that an embankment would be constructed near the end of Arundel Street with some further thinning of trees and scrub between Arundel Street and Faithful Street. The construction of an embankment at Faithful Street sufficiently high to create a lake extending to upstream to Ackerly Avenue would result in flooding of developed land. It would however be possible to construct a second lake between Arundel Street and Faithful Street at a greater cost. Based on existing topographical maps it does not appear feasible to construct a single lake extending from Faithful Street to Ackerly Avenue without significantly inundating some nearby properties.

For analysis it was assumed that the fringes of the lake would be vegetated with trees and understorey vegetation for both aesthetic and environmental purposes.

A lowering of the 1% AEP flood levels by 250mm is predicted to occur at the Railway viaduct and lesser amounts elsewhere. Upstream of the railway decreases of approximately 150mm are estimated for properties near the river between the railway and Bridge Street.

The extent of the lake is illustrated conceptually in Figure 14 which also indicates the predicted impact on 1% AEP flood levels.

The preliminary estimated cost to construct the lake and environs is $1.9M (single lake option). Construction of the lake is estimated to reduce the number of residential buildings experiencing over floor flooding by 327 and the number of commercial buildings by 33 in a 1% AEP flood.

However notwithstanding the proposed re-vegetation a detailed survey of the trees which would need to be cleared highlighted the presence of a large number of mature trees including some which are providing habitat value in an otherwise fairly limited natural riparian vegetation corridor. Re-planting of even the same species would not replace lost habitat and this is considered a major impediment to the acceptance of the measure. As an alternative the careful selective thinning of trees as described for Measure NN (Section 6.11) has been shown to provide similar benefits in lowering of flood levels without the unwanted destruction of habitat and at a lower cost. For these reasons the option to construct a second lake was rejected.

6.9 Hume Freeway Retarding Basin (Measure L)

The potential to use the Hume Freeway embankment to create a flood retarding basin by reducing the bridge openings on each river and creek crossing was investigated using the hydrological model assembled for the Flood Study. Three scenarios were investigated as follows:

(i) restricting the freeway bridge opening across the Broken River and its anabranch only and assuming a design flood storage level of RL 174.0 m AHD (Measure L1);

(ii) restricting the freeway bridge opening across the Broken River and its anabranch, Blind Creek and Holland Creek and assuming a design flood storage level of RL 174.0 m AHD (Measure L2); or

(iii) restricting the freeway bridge opening across the Broken River and its anabranch, Blind Creek and Holland Creek and assuming a design flood storage level of RL 173.6 m AHD (Measure L3).

Measure L1
This would require an embankment along Samaria (Tatong) Road to prevent floodwaters spilling into the Blind Creek and Holland Creek catchments and overtopping the freeway at its lowest point of RL 173.6 m AHD between Blind Creek and Holland Creek.

The freeway embankment would need to be extended and raised by up to 1m for 760 metres to provide freeboard.

The stored floodwaters would inundate one (2) house and come within 400 mm of three others. A sixth house would have its floor level 870 mm above the design water level but would be near the basin outlet and surrounded by deep floodwaters.

Measure L2
This would allow floodwaters to pond to RL 174.0 m AHD and spill across Samaria Road. The freeway embankment would need to be extended and raised by up to 1 metre over 1900 metres to provide both the required storage and 600 mm freeboard.

Six houses would be effected with two subjected to over floor flooding. Three of the remaining four houses would have floor levels within 400mm of the design top water level.

Measure L3
This would allow floodwaters to pond to RL 173.6 m AHD in the Broken River, Blind Creek and Holland Creek valleys. The storage level equates to the minimum design profile level for the Hume Freeway. The freeway design level may not be the same as the constructed level and verification would be required as part of the design process. The freeway embankment would need to be extended and raised by up to 600mm over a total of 720 metres to provide freeboard of 600 mm.

Samaria Road would remain approximately 200mm or more above the design top water level. However the stored floodwaters would inundate 2 houses and isolate 4 others.

Measure L3 was chosen as the preferred flood retardation basin option because it provides the maximum possible flood storage volume using the existing freeway embankment height. Raising of the freeway embankment along the shoulder of the road is only required to provide freeboard.

The retarding basin is estimated to reduce the peak 1% AEP discharge by $106m^3/s$ (8% reduction) and the peak 2% AEP discharge by $30m^3/s$ (2% reduction).

The effect of the retarding basin (Measure L) is a modest reduction in the 1% AEP flood levels throughout Benalla. An estimated 220 homes and 20 businesses would be protected from over floor flooding but flood levels would remain above the 2% AEP design flood levels. The impact on flooding in Benalla and the area to be inundated upstream of the Hume Freeway is shown on Figures 16 and 17.

Preliminary advice received from Vicroads indicates that raising and extending the shoulder of the freeway embankment would create a number of difficulties involving road safety including the need for kerb and channel drainage, the re-routing of several cross over drains and the need for additional drains to efficiently disperse runoff from the road. While the difficulties created for drainage and other road safety aspects are not insurmountable they are likely to add significantly to the cost and the alternative of constructing a separate embankment immediately upstream of the freeway may be preferable.

The preliminary estimated cost to construct the retarding basin is $5.8M and would not solve flooding in Benalla and was therefore rejected.

6.10 River Islands Excavation (Measure M)

Measure M was proposed by the FPMCC after initially being rejected by the Study Team because of its severe aesthetic and environmental impact. However in absence of any effective alternative structural measure which had clear community support the FPMCC re-introduced the measure. Measure M requires the excavation of the mid-stream islands at the upstream end of Benalla Lake to a level no higher than RL 168m which approximately 1.5m above the normal water level in the lake. In addition the existing low lying ground from opposite Neill Street upstream towards Samaria Road would be heavily cleared leaving only a relatively small number of trees along the edge of the main river channel.

Although some further lowering of flood levels was predicted in localized areas close to the river over and above those predicted as a result of vegetation clearing there was no further reduction in the estimated number of houses likely to experience over floor flooding in the 1% AEP flood.

The combined effect of vegetation reduction (Measure De) and excavation within the river is shown in Figure 6.

The preliminary estimated cost to undertake the excavation and vegetation clearing is $995,000 with a potential annual maintenance cost to keep the low ground clear of trees is between $4,500 and $5,500.

The measure is a severe one with a potentially high ecological cost and is therefore not favoured.

6.11 Vegetation Management Downstream of the Railway (Measure NN)

6.11.1 Background

This measure was proposed after extensive investigations for providing either a wide flood channel between Ackerly Avenue and Faithful Street (Refer Section 6.12.6) or a second lake (refer Section 6.8, Measure K) both of which were considered by the DNRE and GBCMA as being likely to result in unacceptable degradation of the aquatic and terrestrial ecosystems.

The measure is closely related to Measure D (Section 6.4) proposed for areas upstream of Benalla Lake and would involve the selective removal of trees in order to allow flood waters to move downstream more quickly while still retaining the ecological integrity of the area. Along this river reach it has been estimated that approximately 80% of the treed area is either on Crown land or land reserved for public purposes.

During 1993 the area was thickly vegetated with new and established trees and substantial woody scrub species. The plants include both native and exotic species and in several critical areas trees have become established sufficiently close together to reduce flood capacity in their own but which also have the potential to further reduce flood capacity by trapping flood debris and forming a barrier across the path of the flood.

In general to provide a significant improvement in the food flow capacity downstream of the railway viaduct the following management guidelines should be implemented:

- Allow one tree with trunk diameter greater than 100mm every 80 to100m^2,

or

- Allow trees at a closer spacing but be restricted to narrow stands orientated with the expected direction of flood flow. Stands of trees should however retain a minimum 10m clear distance between adjacent stands lateral to the direction of flow,
- No low hanging branches below the estimated 1% AEP flood level, and
- No understorey woody species which remain upright during floods.

Extensive mapping of the river's upper terrace and trees over a 19ha area was undertaken prior to developing a preliminary vegetation management plan for this river reach. The survey defined:

- Single/groups of trees under 300mm diameter (typically saplings),
- Single/groups of trees 300mm to 600mm diameter (typically 25 to 100 years old),
- Single/groups of trees over 600mm diameter (typically older than 100 years), and
- Single habitat trees identified as providing nesting or other significant habitat value.

6.11.2 Hydraulic Modelling

This measure was investigated to estimate the maximum likely flood mitigation benefit from a reduction in the density of the trees and scrub flanking the river between Ackerley Avenue and Faithful Street.

The measure was originally modelled by reducing the hydraulic roughness from the calibrated value for existing conditions (0.08 to 0.085) to 0.05 to 0.06.

An hydraulic roughness of 0.06 on flat to gently undulating ground is equivalent to a floodplain with scattered trees (say 1 large tree/80-100m^2) and no understorey or alternatively trees spaced closer together but remaining in narrow stands orientated with the expected direction of overland flow. The stands of trees would need to be at least 15 metres apart.

Furthermore all low branches would need to be above the estimated design flood level. In this area the lowest tree branches would need to be about 2.5 metres above the ground when allowing for the 1% AEP flood.

An hydraulic roughness of 0.05 adopted for the main floodway is equivalent to gently undulating ground, no tight river meanders, and only scattered trees. It was further assumed that the heaviest reductions in vegetation would occur between Ackerley Avenue and Arundel Street.

Based on the above modelling assumptions it has been estimated that a reduction in the 1% AEP flood level similar to that achieved with the Lake Concepts 1 or 2 is possible but at a greatly reduced cost.

The maximum reduction in the 1% AEP flood level was estimated to be approximately 400mm near Ackerly Avenue. Reductions of up to 300mm were estimated for residential areas in north western and north eastern Benalla. The flood mitigation benefits also extend to properties upstream of the railway and close to the river. Unlike the lake proposal (Measure K, Section 6.8) and the floodcut proposal (Section 6.12.6) there are no estimated increases in flood levels in residential areas between Arundel Street and Faithful Street.

The estimated mean velocity of flood flows during the 1% AEP flood along the existing alignment of the river is in the range 1.4m/s to 1.9m/s. Similar mean velocities were estimated for smaller floods. The estimated mean velocities under existing conditions range from 0.7m/s at Ackerly Avenue to 1.3m/s midway between Ackerley Avenue and Arundel Street.

The maximum river velocity usually occurs at or near bank full conditions and is often 50% higher than the mean velocity for the same flow. Thus velocities for a 10% AEP flow maybe in the order of 2.5 m/s and over a prolonged period may result in bank erosion. Some consideration may therefore need to be given to increasing bank stability (eg battering and grassing) if this measure is to be adopted. An allowance has been made in the cost estimates for bank stability work to be undertaken in critical locations.

Lesser amounts of clearing such as reducing the allowable clear spacing between trees trunks, or groups of trees to 10 metres rather than 15m would be expected to result in smaller reductions in flood levels.

6.11.3 Vegetation Management Recommendations

Based on the survey, hydraulic modelling of this measure, and a detailed analysis of the area by the GBCMA the following vegetation management plan is recommended throughout the floodplain within the study area:

- Habitat trees are given first priority for retention,
- Trees with trunks greater than 600mm diameter are given second priority for retention,
- Trees with trunks greater between 300mm and 600mm diameter are given third priority for retention.
- Generally aim to provide a ten metre clear spacing between tree trunks measured perpendicular to the general flood flow direction. This spacing may be reduced in order to retain habitat trees and trees greater than 600mm diameter but in any case the clear spacing should not be less than 8 metres and in such cases nearby wider spacings should be provided such that the average spacing is not less than 10 metres. This is especially important close to the main river channel where flood flows are deeper and where normally where the greatest percentage of the flood flow would occur.

- No low hanging branches below the estimated 1% AEP flood level.
- The 1993 aerial flood photographs may be used to assist in determining the flood flow direction,
- Compensatory re-vegetation should be undertaken near or beyond the fringe of the 1% AEP flood extent to satisfy the Government's net gain principles.

This methodology forms part of sensitive vegetation management measure VM.

6.11.4 Complementary Excavation

A complementary adjunct to vegetation management in this area was identified during the tree survey and associated inspections by the FPMCC and involves the partial excavation across a 35m band of the mid-stream island downstream of Ackerly Avenue. The western side of the island would be excavated down to within approximately 1m of the existing river bed. Tree cover in this area is predominantly exotic species and excavation would not result in any significant.

Separate hydraulic modelling to estimate the effect of excavating the western side of the island has not been undertaken, however it is expected that the net benefit to lowering the 1% AEP flood would small unless the increased waterway area being provided is extended downstream towards Arundel Street. The excavated channel has however been included in Option K which includes vegetation management (Measure NN) as part of the floodplain management strategy.

6.11.5 Preliminary Estimated Cost

The preliminary estimated cost to implement the vegetation management plan for this reach of the river is $709,000. This includes an amount of $180,000 for excavation of the western side of the island. The annual maintenance cost has been estimated as 3% of the capital cost of clearing ie $9,600 although in practice maintenance work may only occur every 3 to 5 years. The indicative area to which the management plan would apply closely approximates the area of Arundel Lake (Measure K) as shown conceptually in Figure 14.

6.12 Other Measures

A number of other possible structural measures were examined but discarded because they were either impractical and/or expensive or had negligible impact on flood levels. These measures included:

6.12.1 Levee 5

Levee 5 was investigated as a part alternative to Levee 2. It would follow the western bank of the anabranch which extends from near Hair Crescent and discharges across Arundel Road in the vicinity of Maud Street. The levee would comprise a landscaped earthen embankment and, depending on the final alignment at least portion of Nos. 28, 30 and 33 Market Street would need to be acquired. The levee would not protect the worst flood effected properties and would cause disruption to the daily movements of residents.

6.12.2 Levee 6

Levee 6 would be a raised road median barrier along Shadforth, Cook Street and Boger Streets. Properties on the eastern side of Cook Street between Shadforth and Boger Streets would not be protected and an alternative measure such as house raising would be required. The levee height would be 1.5 m high near the corner of Arundel and Shadforth Streets and 1.8 m high at the corner of Cook and Boger Streets. The height is impractical and following discussions with the FPMCC this measure was discarded.

6.12.3 Holland Creek Diversion to Lake Mokoan

The existing diversion channel has a design capacity of 28 m^3/s or approximately 2% of the total estimated peak flow to occur at Bridge Street in October, 1993. The measure investigated the cost of increasing the diversion channel capacity to 220 m^3/s. This was achieved by both increasing the channel dimensions and providing a continuous levee along the northern side of the channel sufficient to allow the floodwaters to flow 1 metre deep on the floodplain. The new channel would need to be 4 metres deep and have a base width of 57 metres. Owing to the very flat terrain in this locality the channel flow width would be approximately 1 km wide and likely to effect a number of farm houses. The resulting 1% AEP flood levels in Benalla would still be above the existing 2% AEP flood levels and in view of the estimated $20 million cost to upgrade the channel and associated road, rail and syphon crossings the Floodplain Management Consultative Committee discarded this measure.

The location of the Mokoan Inlet Channel diversion weir on Holland Creek is shown in Figure 2.

6.12.4 Additional Flood Storage Capacity at Lake Nillahcootie

Lake Nillahcootie was designed and constructed as a water supply facility on the recommendations contained in a 1963 parliamentary report (Ref 24). The report did not identify any flood control requirement as part of the Lake Nillahcootie project and no such allowance was made in its design.

Notwithstanding this the provision of flood storage at Lake Nillahcootie was examined during the Flood Study (Ref. 2). It was found to be ineffective in reducing flooding in Benalla. A reduction of only 40 m^3/s could be achieved even if the lake was empty at the commencement of rainfall. This amount represents approximately 3% of the total 1% AEP flood flow at Benalla and is insufficient to translate into cost effective reductions in the level of flooding.

The location of Lake Nillahcootie in relation to Benalla is shown in Figure 2.

6.12.5 River Bank Re-Vegetation

The impact of river bank re-vegetation programmes being implemented in the upper catchment, such as along reaches of Sam Creek, were estimated by modifying the hydrological model of the catchment. The effect of increased stream bank vegetation is to reduce the rate of runoff entering the tributary streams, slow the stream velocity and hence increase the time taken to reach the flood peak.

The impact of increasing both in-stream and bank vegetation on both the timing and peak height of the flood is very difficult to estimate but is expected to be small based on the normal extent of re-vegetation undertaken of which the projects on Sam Creek and Watchbox Creek are considered fairly typical.

To estimate the possible effect of slowing the arrival of flood peaks at Benalla the channel travel times in the hydrologic model were adjusted by 10%, 15% and 20% on selected tributaries. The maximum reduction in peak 1% AEP flows at Benalla was estimated to be approximately 4.5%. However, under other scenarios examined the peak flows increased. The effect of re-vegetation programmes is therefore considered to be an unreliable flood mitigation measure.

6.12.6 Floodcut Downstream of Ackerly Avenue

The floodcut was proposed as an alternative to constructing a lake. The proposal was to excavate a floodcut approximately parallel to the river and located generally between 50m and 80m from the eastern bank of the main channel.

The location and extent of the floodcut is shown conceptually in Figure 12. The floodcut required excavation of the bank of the eastern most river channel immediately downstream of Ackerly Avenue and past the tennis courts before connecting with a 80m wide channel excavated approximately 2m below the existing floodplain between the river and north eastern Benalla.

This measure would require a reduction in the number of trees close to the river between Ackerly Avenue and the tennis courts but would allow a strip of land adjacent to the river and up to 80m wide and all existing vegetation thereon to be retained.

The estimated 1% AEP flood levels were lowered by a maximum of approximately 100mm on the eastern side but the reductions on the western side in the vicinity of Arundel Street, Cook Street etc were much less. In addition small rises in the 1% AEP flood levels are predicted in the vicinity of Faithful Street due to the increase efficiency in the delivery of floodwaters to this location.

As a consequence this Measure was not examined further.

6.13 Social and Environmental Assessment

The social and environmental assessment of each measure is detailed in Appendix C.

7 NON STRUCTURAL MEASURES

Non-structural measures including house raising, were considered in order to reduce the impact of flooding in areas where structural measures are not appropriate. In addition there are some non structural measures applicable to all of Benalla such as planning controls, (building and development controls), flood warning system improvements and evacuation planning which are required to supplement both structural and non-structural measures. This section identifies the non-structural measures examined and which are considered appropriate for Benalla.

The non structural measures examined included;

- planning controls;
- flood proofing;
- flood warning and emergency procedures;
- voluntary land purchase;
- public education and information; and
- flood insurance.

Field inspections undertaken during the study determined the practicability of structural measures and of alternative measures such as house raising or other flood protection/risk minimisation strategies for individual buildings. As a result of these assessments some structural works measures were eliminated as being either impracticable on social and environmental grounds or not cost-effective.

It was therefore necessary to carry out detailed investigations into the costs, benefits and social acceptability of a range of alternative measures as outlined above. These works are commonly classified as non-structural although some measures may in fact have structural components.

The effect of non-structural measures is to:

- reduce the susceptibility of new development to damage and disruption from floods by means such as zoning, development and building controls,
- ensure that new development does not worsen the flood problems experienced by existing development, and
- reduce the impact of flooding on existing development through the use of flood warning systems, evacuation planning, public awareness programmes and the like.

Land use planning and zoning are two of the most effective means of reducing flood risk for undeveloped land. However in Benalla the opportunities for minimizing existing flood risks using zoning controls are limited and generally building controls offer a more practical alternative.

Flood-proofing is usually included in the non-structural category of management measures although it may involve very substantial costs and involve physical changes to properties.

Voluntary purchase should only be considered in terms of acquiring properties in high hazard areas where a reduction in the hazard rating cannot be achieved by other economically justifiable means. In the case of Benalla a voluntary purchase option on a large scale is considered inappropriate. Voluntary purchase of properties has only been considered for areas close to the river between the railway and Samaria Road.

7.1 Land Use Planning

Land use planning and development control are major non-structural methods of mitigating the effects of a flood. Under Section 4 of the Victoria Planning and Environment Act, 1987 (Ref. 15) Councils are required to implement certain objectives. A number of these are particularly relevant to floodplain management and include at Section 6, the need to regulate or prohibit any use or development in hazardous areas or in areas which are likely to become hazardous areas.

Planning options are the main form of land use regulation. Under the Policy Section of the Victoria Planning Provisions (Ref 23) land use and development controls are considered necessary to:

- minimize the risk to life, health and safety;
- preserve the natural function of floodplains, including the inherent wetland values;
- complement catchment management strategies; and
- minimize the potential for flood damage.

This Policy also recognizes that there are significant economic and social benefits from clearly delineating land development constraints for future urban areas, within the urban floodplain and major regional centres.

The insertion of appropriate planning controls in local planning options is preferred because it enables a broader range of land use matters to be taken into account. However, before appropriate planning controls are formulated several steps are identified. The first is concerned with identifying the land liable to flooding and assessing the flood hazard as discussed in Section 5.3.

The next step is deciding the appropriate use and development of floodplains. This involves balancing the developed use of the floodplain, against its environmental and wetland values.

Several principles are outlined, which provide a guide to deciding whether development is appropriate in areas liable to flooding:

- except in special circumstances, subdivisions are inappropriate in floodways;
- development that requires low level access across a floodway is inappropriate;

- building in floodways should be avoided, although development on land adjoining main floodways might be appropriate provided the equivalent of the provisions of the Victoria Building Regulations, 1983 are complied with;

- building envelopes for houses must provide adequate effluent disposal areas;

- land use in floodplains should be managed to reduce run-off: uses such as sewerage treatment and pumping works, intensive animal industries and sanitary landfill depots should be avoided;

- flood mitigation works should only be permitted to protect existing development at risk of flooding, or where there is a critical shortage of flood free land in the area, to facilitate development on land liable to flooding; and

- works that obstruct flows or reduce natural flood storage should be avoided.

Planning options are one of the most effective methods of limiting the development of flood liable land which apply to both developed and undeveloped areas. Zoning controls should reflect the prevailing flood behaviour and hazard. Although not essential, it is preferable that the name given to the zone reflects the flood liable nature of the land. Terms such as open space, when applied to an area considered to form part of a floodway may be misleading and result in inappropriate development, including tree planting which may obstruct floodwaters and result in an increased flood risk to adjoining areas.

These principles have to a large extent now been incorporated into the Draft Amendments for the Shire of Delatite (Refer Appendix F). The draft amendments cover:

- The Municipal Strategic Statement (Clause 21)
- Policy Section, (Floodplain Management ,Clause 22)
- Floodway Overlay (Clause 44.03)
- Land subject to Inundation Overlay (Clause 44.04),
- Local Floodplain Development Plan,
- General Requirements for Precincts, and
- Special Requirements for Precincts.

The stated objectives for floodplain management throughout the Shire are:

The detailed provisions of this policy, and its application to Benalla is considered in the recommendations below.

7.2 Zoning

7.2.1 Preamble

The following discussion and recommendations were prepared prior to 1998 and have not been reviewed in detail following more recent action by Council to introduce a range of planning controls designed to provide a uniform and logical approach to development of flood prone land and more particularly by land below the 1% AEP flood level. The recommendations contained in the discussion are now reflected in either the draft planning amendments or in the Emergency Sub-Plan which deals with flooding. In the latter case detailed information relating to the operation of the flood warning system is contained in references 25 and 26.

7.2.2 Land Zoning

Land zoning is an effective and long lasting means of containing growth in flood damage. It is therefore important for Council to continue to give priority consideration to the effects of flooding in local planning options and/or development control plans. In zoning flood liable land and land which has the potential to affect flood behaviour the following factors are important:

- ❑ whether the land is in the high hazard or floodway category,
- ❑ potential for future development to have an adverse impact on flood behaviour and thereby on existing development,
- ❑ whether adequate access is available during floods, and
- ❑ whether certain classes of development should be excluded because of additional or special risk to their users, eg. accommodation for aged people, hospitals and the like.

7.2.3 Existing Statutory Provisions

Prior to the introduction of the new format planning scheme (VPPs), the Benalla (City) Planning Option did not include any specific policies for the control of development in floodprone areas. It does, however, zone certain land within the high hazard flood category for purposes other than floodway. Significantly these include:

- ❑ land bounded by Arundel Street, Neill Avenue, Market Street and some areas north of Kitson Court, for residential (zone R2) use;
- ❑ an area east of Arundel Street, south of railway line and north of Deas Street for residential (zone R1) use;
- ❑ several areas for public purposes, including the art gallery and civic centre;
- ❑ rural uses (zone RU1);
- ❑ public open space (POS), including the Showgrounds, botanical gardens and islands linked to the river walkway and cycle track; and
- ❑ the Bowling Club, a special use zone (SU2).

Within each of these zones and in adjoining zones falling within the low hazard flood category, there are no specific provisions relating to their location within a flood zone. Where subdivision is proposed within zone R2, section 46-4 requires the consent authority to consider the relationship of the subdivision to the terrain and other physical characteristics of the land. However, this is a coincidental reference whereby the characteristics of that land should be considered. This is not required for residential development on existing subdivided land.

Following the 1993 flood, Council adopted October 1993 flood levels to determine floor levels in new development, as recommended by the Department of National Resources and the Environment (DNRE). This requires floors to be a minimum of 300 mm above the October, 1993 flood level.

The standard for non-habitable buildings depends on the damage potential of that use and varies from the one per cent flood level plus 300 mm or one per cent flood level with flood proofing up to the one per cent flood level plus 300 mm (the Nominal Protection Level NPL). Generally construction of other uses in floodprone areas such as recreational, health clubs and theatres are considered on their merits in relation to the damage potential of each and the proposed construction materials, for example, floor tiles versus carpet, steel and brick construction versus timber construction.

7.2.4 Existing Non-Statutory Provisions

Council have recently adopted the provisions of an Integrated Planning Study (ILAP, Ref. 18) which was prepared in December, 1994. While this has not been the subject of public exhibition, it sets out a strategy and recommendations for the future development of the city including proposed amendments to the Benalla Planning Option.

The ILAP study proposes specific areas of the city for future residential, commercial, retail industrial development. Generally this conforms with the existing development and land use pattern throughout the centre although some proposals will require rezoning. This includes the possibility of developing a discount department store to the rear of Bridge Street on land currently zoned for public purposes (car park PP8). Retail intensification is proposed in certain areas of the CBD currently zoned for commercial use.

Industrial zones are generally proposed in a new Urban Development Zone located to the north and west of the city and in proximity to existing industrial development. Most of this area does not fall within the floodprone area.

The ILAP study nominates several new areas for residential release. While new development is encouraged to continue within or immediately adjoining existing residential areas, such as at the River Gums Estate and north of Cowan Street, two further main areas are proposed:

- ❑ land south of Cowan Street, east of the Midland Highway, which is already zoned as residential (zone R2); and
- ❑ north-west Benalla, including land west of Coish Street (zoned residential, R1) and land north of Goomalibee Road on the western fringe of the Broken River (currently unzoned).

Further land for long-term residential development is also proposed, despite existing modest forecasts for housing land demand over the next 20 year period. The three areas are:

- ❑ south from Hair Street to the Freeway;
- ❑ west of the Midland Highway, opposite Cowan Street and north of the golf course; and
- ❑ to the north-west of the Broken River north of Goomalibee Road.

The latter has been chosen primarily due to the large amount of high lying land, and the fact that it falls within a low flood risk category. However it should be noted that at least portion of each of these areas are outside the study area and flood mapping for them has not been undertaken. These areas will require further scrutiny before allowing development to proceed.

7.2.5 Planning Provisions for Flood-Prone Areas

Initially a draft policy was developed in May 1996 by the Floodplain Management Section of the Department of Natural Resources and the Environment which sought to redress previous practice within Victoria by providing a single policy statement, with model provisions to be used in relation to land subject to flooding. The draft policy has now been superceded by the Victorian Planning Provisions and the floodplain management Practice Notes.

The current planning documents and related policies are the most effective way of limiting the growth and future damage, and ensuring that economic, social and environmental benefits arise from the introduction of flood controls into the land use planning process.

Essentially the goals of overall floodplain management remain the same as the 1996 documents which are to:

- ensure potential loss of life, health and damaged property are minimized;
- preserve the natural function of the floodplain to convey and store flood waters; and
- protect the inherent values of wetland and preserve floodplain areas of environmental significance.

However, in the preparation of this policy, it was found that the single overlay approach to managing flooding was not adequate and that there is a need for a floodway zone to recognize that the primary role of some land is to convey flood waters. In addition, flood risk must be considered when preparing planning schemes and making decisions about the use and development of land.

The VPPs and Floodplain Management Practice Notes propose three main features:

- Urban floodway zone which establishes that the primary purpose of the land in the zone is to convey floodwaters;
- Floodway overlay zone (FO), and
- Land Subject to Inundation Overlay (LSIO).

The rural floodway zone defined under the draft policies has not been included in the adopted VPPs.

Within each of the zones or overlays a set of provisions apply which control land use planning within them. The policy therefore relates to non-structural measures of control, rather than structural. A summary of the provisions is set out below.

Urban Floodway Zone (UFZ)

The purpose of the urban floodway zone is to ensure that development within it maintains the free passage and temporary storage of floodwaters and that land uses within it are compatible with flood hazard. Table 9 sets out uses of land within this zone which are appropriate.

In addition there are provisions relating to various categories of development including buildings and works, subdivision and replacement or extensions to existing dwellings. These provisions are incorporated in the recommended policies for undeveloped and developed areas.

Land Subject to Inundation Overlay (LSIO)

The purpose of this area is to ensure that development maintains a free passage and temporary storage of floodwaters and does not cause a significant rise in flood levels or flow velocity. This generally applies to areas liable to inundation by overland flow, sheet flooding, or flood fringe areas for the 1% AEP flood.

Requirements in relation to development for this area relate to buildings, works and subdivision. Further guidelines for the granting of permits are also provided.

The policy does not therefore, seek to offer advice on the suitability of structural flood control measures, rather it seeks to provide a range of policies which would be incorporated as part of local planning schemes as a means of controlling future development within the various flood liable areas.

In summary, rezoning, as a non-structural flood mitigation measure, would seek to achieve the following:

- ❑ Removal of the possibility of future inappropriate developments occurring within the floodway or flood fringe areas. This would limit flood damage to those existing buildings and limit any adverse impacts on flood behaviour,

- ❑ Restrictions on development of specific land parcels that are particularly at risk,

- ❑ Ensure that any flood-liable land has adequate egress during a flood, and

- ❑ Ensure that essential community services are not developed within flood liable land.

The Local Planning Policy actively seeks to discourage:

- ❑ New buildings and works in FO areas,
- ❑ Small lot sub-divisions within LSIO areas,
- ❑ Large building extensions below the nominal flood protection level, land fill in areas subject to flooding (other than for building envelopes),
- ❑ Levees in areas regarded as important for flood conveyance, flood storage, and environmental values.

In the urban area the Local Planning Policy encourages buildings to be designed to withstand flooding with nil or minimal damage, and including floors which are above the nominal flood protection level.

TABLE 9
APPROPRIATE LAND WITHIN URBAN FLOODWAY ZONE

Permissibility	Land Use
Permit not required	Agriculture
	Mineral Stone or Soil Extraction
	Public Open Space
Permit Required	Leisure and Recreation
	Road
	Utility Installation
Prohibited	Any use not listed above

7.3 Building and Development Controls

Under the performance provisions of the Building Code of Australia, a building must be constructed such that surface water having an average recurrence interval of 100 years cannot enter the building however no direction is given as to what freeboard if any is to be applied. In respect to freeboard Council has continued to apply the provisions of the Victorian Building Regulations by requiring all flood levels of habitable rooms to be at least 300 mm above the 1% AEP flood level. This requirement is also reflected in the VPP Practice Notes.

Furthermore in 2001 the 1% AEP (100 Year ARI) flood levels were declared under the provision of the Water Act (1989) by the GBCMA (Plan No 540214).

To contain the growth in flood losses, conditions would be imposed on new developments and re-developments consistent with the Victorian Planning Provisions to ensure that they do not add significantly to the overall level of flood damage. Typically, buildings should be flood proofed, as discussed in Section 7.5.

Building and development controls are an effective measure of flood damage mitigation. They have the advantages of being selective in their application, low-cost and able to limit damage to both the property to which the controls are applied and surrounding properties. However the effectiveness of the controls is limited by the fact that they can only apply to new developments or re-developments. In areas where currently there is little or no building activity it is considered that building and development controls will be of benefit to flood damage mitigation as a long term strategy.

The floor height requirements of the existing building controls adopted by Council are currently set at 300 mm above the estimated 1% AEP flood level although for minor extensions to commercial development floor levels may be set at the existing level. Floor levels for major extensions to commercial development are required to be at or above the 1% AEP flood level with further flood proofing as appropriate. The adopted 1% AEP flood level is based on the estimates contained in the 1984 Flood Study (Ref. 7) which have been superseded as a result of the 1993 flood and the subsequent decision by the FPMCC to adopt the estimated peak October 1993 flow as the 1% AEP design flow. The required floor levels for habitable rooms in all new residential development and new development areas should be revised to reflect the recommended 1% AEP flood.

7.3.1 Landfill and Fencing

Fencing

For purposes of assessing the likely impact on flooding, development should be defined so as to include all fencing and other permanent or semi-permanent structures, fixtures etc. Therefore in assessing the impact of a proposed development on flooding both boundary and internal fencing should be considered as part of the works including the cumulative effect from fencing a large number of smaller developments. Where the cumulative effect of fencing small allotments is deemed significant an area policy on fencing should be defined. In some cases this may necessitate fencing to be set back from the title boundary and/or special provisions, such as frangible floodgates, made to allow floodwaters to pass virtually unimpeded through the fence.

Landfill

In some cases of re-development it may be appropriate to achieve the required minimum floor levels by filling the flood liable site. This is likely to be most appropriate where large scale re-development is occurring or where it might reasonably be expected that wide scale re-development would occur within a relatively short time frame, say 10 to 15 years. However in all such cases checks on the effect of the filling on flood behaviour on the surrounding area needs to be carefully considered. The acceptance criteria for filling should be the same as discussed in Section 7.3.2 for floor levels.

In the case of new sub-divisional development the flood liable land should be filled to at least the 1%AEP flood level and building lots to 300mm higher. By raising the building lots 300mm above the 1% AEP flood level slab on ground construction can occur and still achieve floor levels which are the recommended minimum 500mm above the 1% AEP flood level. All roadways within the subdivision should be at or above the estimated 1% AEP flood level and be linked to areas beyond the estimated extent of flood liable land in order to facilitate evacuation.

Before approving landfill Council must be satisfied that the filling will not adversely effect the flood risk for the surrounding area. As a minimum the criteria discussed in the context of floor levels in Section 7.3.3 should be satisfied.

Irrespective of the above no landfill should be permitted in areas considered Floodways.

The recommended floor level requirements may be summarised as follows:

7.3.2 Re-development.

- ❑ Residential floor levels to be a minimum of 300mm and preferably 500 mm above the 1% AEP flood level. The historic amount of 300mm is considered inadequate for long term provision taking into account hydrologic uncertainties, wave action, localised variations in flood levels and likely long term climatic changes. The amount of 500mm brings the freeboard closer to the freeboard allowance of 600mm for public structural mitigation works such as levees, floodwalls, landscaping, and road raising.

- ❑ Commercial/Retail floor levels to be at or above existing floor levels for minor extensions. At present applications are assessed on a case by case basis but given the extensive damage caused to the retail/commercial sector in the October 1993 flood, and in order to introduce some guidance for applicants the following is strongly suggested.

Minor extensions would be classed as a "one off" extension equal to 10% of the footprint area below the 1% AEP flood level up to a maximum of 50 m^2. Where these levels are less than 300 mm above the 1% AEP flood level provision must be made to protect the building and contents from damage using appropriate means approved by Council. Appropriate means would include measures such as using flood shutters and reflux valves, using flood damage resistant materials and in the case of retail premises providing shelving which may be raised at least 300 mm and preferably 500mm above the 1% AEP flood level. In the cases where stock cannot be stored on shelves a permanent reliable stock removal and evacuation procedure which does not rely on emergency service resources must be demonstrated to the satisfaction of Council. For major re-development floor levels should be no lower than the 1% AEP flood level with flood proofing up to at least 300 mm and preferably 500mm above the 1% AEP flood level. However where it can be demonstrated to the satisfaction of Council that compliance with the floor level requirements is likely to affect the commercial viability of the re-development the requirements may be relaxed. However any relaxation of floor level requirements should still ensure that a minimum of 70% of the footprint area below the 1% AEP flood level is raised above the 1% AEP flood level to allow the temporary re-location and storage of stock above floodwaters.

- Industrial floor levels would be the same as for commercial buildings and with specific reference to the storage of hazardous goods. Dangerous chemicals and similar substances should not be stored in positions where they can be washed away by floodwaters or their containers damaged by floodwater.

7.3.2 New Development

- Residential floor levels to be a minimum of 300mm and preferably 500 mm above the 1% AEP flood level for the same reasons as discussed for re-development.

- Commercial/Retail floor levels to be a minimum of 300mm and preferably 500 mm above the 1% AEP flood level except in special circumstances where it can be demonstrated to the satisfaction of Council and floodplain management authority that compliance with the floor level requirements is likely to affect the commercial viability of the development. In these circumstances any relaxation of floor level requirements should still ensure that a minimum of 70% of the footprint area below the 1% AEP flood level is raised above the 1% AEP flood level to allow the temporary re-location and storage of stock above floodwaters.

- Industrial floor levels to be a minimum of 300mm and preferably 500 mm above the 1% AEP flood level and with specific reference to the storage of hazardous goods.

The following sections outline the controls which are typically applied for each of the zones and which are recommended for adoption in Benalla.

7.4 Voluntary Purchase

Voluntary purchase of properties is an option which is used in isolated cases and usually only when property occurs on land classified as a floodway or where flood waters are deep and evacuation is difficult. Generally this would be land zoned as either Urban Floodway Zone (UFZ) or Flood Overlay

(FO). Normally land classified as LSIO would not justify implementing a voluntary purchase scheme. Land may however be acquired to facilitate the implementation of a structural option such as a levee.

Voluntary purchase is a measure which has been considered for properties affected by the 5% AEP flood and which are located between the river and its anabranch in the vicinity of Neill Avenue and Garden Street and north of the railway between the river and Commercial Road. However above floor flooding does not occur in many of these cases for the 5% AEP flood and therefore voluntary purchase is more difficult to justify.

Up to three properties would need to be acquired for the construction of levees designed to provide protection against the 1% AEP flood if the community adopts such a strategy although in this case purchase of the properties would be negotiated and therefore they would not be classified under a voluntary purchase scheme. No property purchase is considered essential to facilitate the construction of a levee system designed to provide protection against the 5% AEP flood.

Construction of Levee 2 is likely to require the purchase of No. 139 Arundel Street. Although not essential levee construction would also be assisted with the purchase of property on the southern corner of Neill Avenue and Benson Street (CP 107259).

In order to provide free form landscaping to protect the Arundel Street South area from the 5% AEP flood it would appear that only the purchase of No. 139 Arundel Street is warranted. There would however be a need for an easement or some form of caveat on title to protect the integrity of the system where the raised land traversed private properties or where boundary fencing formed part of the protective system.

7.5 Flood Proofing

Flood proofing can be a viable measure for both commercial and residential development in flood affected areas where flood depths are less than about 1 metre. It may be achieved by several means including:

- ❑ providing bunds or floodwalls for each building,
- ❑ flood shutters and water proof seals around all openings, and
- ❑ floor level raising

Although simple in principle, the flood proofing of buildings has a number of practical difficulties. In the case of commercial buildings, raising of floor levels can make access for delivery vehicles and customers difficult. Raising floor levels and/or the use of flood walls is not considered to be appropriate where flooding depths approach one metre or more. Furthermore, unless floor raising can be restricted to small amounts, say less than approximately 500 mm, floor level raising is not considered appropriate for the Benalla CBD since it would cause on-going inconvenience during normal business operations.

7.5.1 Floodwalls and Bunding

Construction of flood proof fences or walls to protect individual buildings, whether commercial or residential, would only be feasible on the flood fringe areas where the depth of flooding is less than about 600 mm and where flood flow paths would not be adversely affected. They are in effect ring levees for either individual or a small group of buildings and as such can be included as a structural measure.

7.5.2 Flood Shutters and Water Proof Seals

Examples exist in Australia of flood proofing using shutter systems fitted to windows, doors and other openings and the provision of reflux valves on sewerage fittings to protect against flood waters entering the building. The system is considered best in areas where flooding depths are less than one metre and where a low flood hazard category is applicable. Therefore such a system may be worth considering for some commercial and retail premises in Benalla.

A major disadvantage with this type of measure is that maintenance of the system, and in particular the ensuring that seals are in good condition, would rest with the property owner and therefore no guarantees can be provided as to the efficiency of the system when it is needed. An on-going programme to ensure all owners and occupiers are aware of the frequency and extent of flooding will be a crucial element in such a strategy. In this regard it is envisaged that the VICVICSES would have a role in educating and providing advice in relation to the maintenance and installation of flood sealing systems.

Where flood sealing is adopted the floodplain management plan will need to provide for on-going education of the community and appropriate levels of funding for the VICVICSES. It is envisaged that Council's property system notes could be use to advise all new owners/occupiers of flood liable property of the relevant details of the floodplain management plan and any other particular flood related matters.

The cost of providing aluminum shutters with neoprene seals is in the order of $600/m^2 of window area. Shutter systems designed for large retail stores such as supermarkets can typically cost about $30,000.

Generally the environmental and social impacts of flood sealing buildings using shutter systems is low. The environmental impacts are limited to the minor visual intrusion of solid masonry fences and small bunds used to protect properties. Where these are of a relatively low height and the materials used are common, the change to the visual environment and therefore the impact is minimal. Flood shutters used to protect commercial and residential properties are only used when a flood is imminent and so have no permanent visual impact.

The social limitations relating to flood shutters and seals relate to its effectiveness over time. The effectiveness of this measure in the Central Business District is limited by the mechanical means of flood proofing being available and in working order during a flood. For various reasons this may not happen. Business owners may neglect to store flood shutters so that they can be quickly and easily retrieved or, if a flood proofed building were to change ownership there is a possibility that the new owners would be unaware of the existence of flood shutters or the procedure for installation.

There is also the possibility that business owners would rely on the flood shutters as their sole response to a flood situation. Normal procedure of moving stock and evacuating people may be left until it is too late. Owners may also be tempted to remain in the building and run the risk of the need for a hazardous rescue should the shutter or flood proofing system fail. Again a property system operated by Council could be useful in both recording property specific information and reminding owners of the need to maintain flood proofing devices etc. Such information could be forwarded to owners annually with rates notices.

Flood proofing of buildings in Benalla is an attractive mitigation measure when compared to structural options such as levees which have a higher level of social and environmental impact. Due to the predicted relatively low depth of 1% AEP flooding a strategy to flood proof commercial and retail premises using flood shutters and reflux valves is considered a technically viable measure.

An alternative adopted in other flood liable centres throughout south eastern Australia for minimising retail stock losses is to provide shelving which may be raised above the flood standard. In known examples, shelving is attached to mechanical pulley systems which enables stock to be quickly raised above flood waters. Shop fittings and floor coverings are chosen which are not susceptible to flood damage. In view of the relatively shallow depth of flooding throughout the CBD this option is also considered worthy of serious consideration as part of any non-structural option.

7.5.3 Floor Level Raising

For residential buildings, raising of floor levels either by building on earth mounds or by using high base structures would be the most effective method of flood proofing. These methods have been widely used in south eastern Australia and several examples exist in Benalla.

For existing houses in low flood hazard areas, house raising is the most practicable form of flood proofing. However, the biggest obstacle to house raising is the cost, which is borne fully by the property owner although government grants are available for approved options. A light-framed small to medium sized home (timber or fibro) can cost about $35,000 to raise. There are understood to be satisfactory techniques available for raising brick veneer houses and some examples exist but the cost is upwards of $60,000 or more and hence the technique is generally restricted to timber or sheet clad buildings. Raising of brick properties constructed with a slab-on-ground is not viable and such homes which cannot otherwise be viably protected are often included in a voluntary purchase option. Flood prone properties in Benalla are a mixture of both brick and weatherboard clad houses. Some of the advantages and disadvantages of house-raising are listed below.

Advantages

- major reduction of tangible flood damage,
- lessening of intangible costs, eg. stress and anxiety,
- under-house space available for garage, storage etc.,
- enhanced re-sale value for property, and
- reduction of afflux (ie. flood levels are lowered due to less obstruction to flows).

Disadvantages

- house significantly above ground; steps inconvenient, difficult for the elderly,
- house isolated at times of flood; some intangible costs remain,

- over-floor flooding may still be possible in extreme events,
- need to ensure that under-house space is cleared in times of flood,
- enhanced re-sale price does not generally cover costs of raising,
- house more exposed to high winds,
- increased maintenance costs, and
- a false sense of security.

House raising is eligible for government subsidies where it is included in an adopted Floodplain Management Plan as a cost effective flood mitigation option. House raising options are available at Commonwealth and State Level.

The National Landcare Program generally provides finance at the rate of $2 from the Commonwealth, $2 from State funds and $1 from the local Council. State assisted Options comprise $2 from the State for each $1 from Council. For a house raising option a portion of the Council contribution could be funded by the owner of the property.

The economics of house raising often does not compare favourably in situations where alternative flood control strategies are available. Where a large proportion of the houses requiring raising are of brick construction, the high cost of raising them to effect flood damage savings cannot normally be economically justified.

7.6 Flood Insurance

Flood insurance is not a measure that can effectively be introduced in a single catchment area. In 1993 the only known area where a flood insurance option exists for householders is with one insurance company which operates only in the Northern Territory. However in recent years following major flooding in Katherine (NT), Townsville (Qld) and Wollongong (NSW) other insurance companies now offer flood insurance. Notwithstanding that flood insurance is now more widely available the fundamental difficulty is that flood insurance does not reduce the physical and economic risks of development, but merely redistributes them throughout the community. Nor does flood insurance properly compensate for the trauma and anxiety related health problems commonly expereinced by flood victims.

7.7 Other Measures

There are several further measures which are worthy of consideration.

7.7.1 Location of Emergency Services

The securing of standing arrangements to use an appropriate building as a communications and operations centre. The building should be accessible during all floods including the designated flood and preferably an extreme flood. In the long term it would be preferable for both the Benalla VICVICSES operations to be relocated into a building(s) which are not located on flood liable land. The Regional Headquarters located in Wedge Street was not flooded during October 1993.

In Benalla this will probably mean locating the centre on the outskirts of the existing development on ground that is at least above the 1993 flood. It is also worth considering the provision of a second building for housing some essential basic items including communications equipment on the opposite side of the river. Benalla VICVICSES volunteers cited increased operational difficulties during the 1993 flood because the river divided the town. As an alternative, modification of the railway viaduct was considered for use by emergency road vehicles but the Public Transport Corporation (PTC) have indicated that modification of the bridge would be expensive and would not necessarily provide an appropriate level of safety for road vehicles. In addition, there would be on-going difficulties in preventing unauthorised use of the bridge during both floods and normal weather conditions. The PTC have road/rail trucks and utilities fitted with rail wheels which could be utilised for carrying personnel or equipment during floods. However during major flooding, it is likely that the vehicles would be used for the protection of PTC assets and would not necessarily be available for emergency services use. It is understood that during the 1993 flood the railway viaduct was only used by pedestrians.

Ideally all emergency services and especially the Police and CFA should be located on high ground. However this is likely to prove disruptive to normal activities and is not considered practical for Benalla.

7.7.2 Sandbagging Machines

It is understood that current arrangements rely upon the availability of privately owned concrete agitator trucks and sand supplies to be available for the filling of sand bags. The trucks would not necessarily be available during working hours and the supply of sand may not be sufficient. While this arrangement may not have led to difficulties in the past either the Council or VICVICSES are urged to consider ensuring that at least one agitator truck is always available or that a purpose built sand bagging machine is acquired.

Purpose built machines with a practical capability of filling about 1200 bags/hour are available at a cost of less than $10,000. The machine is filled directly from a truck or front end loader both of which could presumably be provided by Council. The practical capacity of the sand bagging machine is limited by the number of handlers who can be located around it to tie and distribute the filled bags.

A sand bagging machine is considered a worthwhile investment both in the short term and the long term irrespective of the which floodplain management measures are adopted.

If the community decides to adopt a levee system as described in this report it is recommended that the road intersections are sealed using a system of aluminum drop boards to allow quicker sealing with less manpower than would be required with sandbagging. However there would still be a need for limited sandbagging in non-leveed areas, thus the acquisition of a machine and the stockpiling of a minimum amount of sand is strongly recommended to ensure supplies are available when required.

Alternatively clip-on attachments designed to be installed on *Flocon* trucks are reportedly used by some Councils. It is understood that the device is relatively cheap and simple to operate however hand tying of the bags is still required. The capacity of the device is not known but is likely to compare favourably with purpose built sand bagging machines.

7.7.3 Development of a GIS Linked Flood Model

One initiative which the Steering Committee may wish to consider is the further development of the calibrated hydraulic model developed for the Flood Study and used to assess the impact of the structural floodplain management measures described in this report. The technology exists to input rainfall and stream level data directly into an hydraulic model which would then be used in real time to predict flood heights at strategic locations throughout Benalla. Where a GIS system is available the predicted flood levels are input to the GIS system allowing the properties/buildings at risk to be quickly identified.

The existing Flood Study hydraulic model, takes approximately 30 minutes to run on a "586" PC. This is considered to be well within limits of acceptability for flood forecasting in Benalla. However with ever increasingly more powerful and faster computers this time is likely to be reduced even further.

In the interim, the production of a series of flood maps produced by undertaking multiple design runs could be produced and used to identify the progressive inundation of urban areas and hence identification of priority areas for sandbagging and/or evacuation. During a flood the progressive rainfall and stream height gauge readings would be compared with the design runs and the appropriate flood map used to update the risk to identified areas. The inclusion of building floor levels on the flood maps would enable selective targeting of properties for protection/evacuation.

7.8 Flood Warning, Evacuation Planning and Public Information

This section of the report was prepared as part of the first draft and contains valuable information on the response to 1993 flood. Subsequently an extensive flood warning and public information network has been installed.

The purpose of a flood warning system is to warn a community of an impending flood. The purpose of evacuation planning is to make people aware of when and how they should evacuate themselves and their possessions in the event of flooding. Evacuation planning is particularly important in the case of wide spread flooding such as occurs along the Broken River and its tributaries.

The public should be made aware of flood liable areas and alerted to possible dangers, particularly where roads are flooded. The majority of fatalities in floods of recent years has arisen from motorists or motor cyclists attempting to cross flooded sections of road. Flood warning signs have been found most useful for this purpose. Signs should be displayed which indicate the nature of the site and warn that floodwaters can rapidly rise to inundate the given area.

For convenience, flood warning systems can be divided into three major components. They are the hardware and formulation of the warning (forecast), dissemination of the forecast and the response of the flooded community.

An effective warning system requires at least the following:

- reliable and representative catchment monitoring and modelling,

- reliable and accurate flood height predictions,
- effective dissemination of these predictions,
- a knowledgeable community that will respond correctly to these predictions, and
- an informed and involved relief and emergency system.

It is necessary that the flood forecast is provided in a form that can be easily translated to the areas at risk. Post flood surveys of flood affected communities often identify resident difficulty in translating river gauge heights into meaningful flooding depths at their own properties. This type of problem can seriously diminish the value of an otherwise excellent warning system and is considered crucial when planning and evaluating the effectiveness of the system.

7.8.1 The October 1993 Flood

Problems in several of these areas were highlighted during discussions of the 1993 flood with the VICSES personnel and Council officers although it is understood that some of these have since been addressed. Identified problems which occurred in 1993 can be broadly grouped under communication, education and experience. The problems included the following:

- A flood warning system had been documented but was based on a smaller flood than what occurred notwithstanding that the documented flood was previously considered to be a 1% AEP flood
- The initial flood warning (warning of a minor flood) for the Broken River forwarded to the North East region of the VICSES by facsimile was delayed by 3 hours for reasons unknown. The minor warning was followed by a major flood warning less than 6 hours later. No intermediate warning of a moderate flood was given.
- The alarm was first raised locally by residents in the Baggadinne/Winton area contacting the Benalla VICSES for assistance to cope with stormwater flooding,
- No communications centre is available. In 1993 the Police Station acted as the operations and communications centre during the flood. It is understood that the second floor of the Police Station, which housed the Department of Agriculture, is being considered as the permanent operations centre.
- No formal procedures were in place to notify the public of flood warnings,
- Problems were experienced with the media. Many of the radio and television stations are networked and there is little or no local (Benalla) content. It is therefore difficult to convince duty managers of the seriousness of a flood situation in Benalla and thereby gain their co-operation in broadcasting warnings.
- There appears to have been a lack of co-ordination in the early stages (Sunday afternoon and evening) eg. The CFA were involved independently early Sunday evening.
- Many operations are made more difficult because the town is divided by the river, (The railway viaduct was used for pedestrian traffic only)

- Concern with contacting and evacuating residents in rural areas.

- Some local emergency service personnel did not appear to understand how the local DISPLAN operates,

- Many residents do not understand what the flood warnings mean to them,

- Some local emergency service personnel had not experienced flooding in Benalla and did not realize the seriousness of a given flood warning (river stage height),

- Police were initially unaware of the evacuee registration forms and their purpose because of no prior flood experience. The emergency service personnel who were aware of procedures were, in many cases, also victims of the flooding and consequently not necessarily immediately available to assist,

- Difficulties in getting assistance to fill sandbags because many residents did not understand the significance of the flood warning and as a consequence reacted slowly,

- The BARC hall in Samaria Road was set up as an evacuation centre but was subsequently flooded.

7.8.2 Response to October 1993 Flood

Following the October, 1993 flood Council established a Flood Response Committee and a Flood Warning Sub-Committee to investigate ways of improving the level of preparedness for future floods. The Flood Study, this report, and the preparation of a draft Floodplain Management Plan form part of the investigations into minimizing the exposure to future flood risk and flood damage in Benalla.

Early investigations of the committees identified a need for substantial improvements to the flood warning capability for the Broken river catchment. The Victorian Flood Warning Consultative Committee, chaired by the Bureau of Meteorology, has prepared a 5 Year Plan for state wide improvements. The Plan gave high priority and a substantial funding allocation to improving flood warning facilities in Benalla. Contracts for the improved warning system which includes an extensive rainfall and river height monitoring network have been let and installation is now complete.

In addition a detailed Benalla Flood Alerting Operations Procedure (Ref 24) has been prepared together with a Flood Information Providers Manual (Ref 25) clearly identifies the roles, responsibilities and prioritized actions of the various agency staff and volunteers in the period prior to an impending flood.

The relevant issues relating to flood warning, evacuation planning and public information are discussed in the following sections.

7.8.3 Flood Warning

Flood warnings for Benalla are issued by the VICSES to Delatite Shire and other authorities. These warnings are based on rainfall and river height information collected by the Bureau of Meteorology (BOM) who provide “official” flood warnings and flood predictions to the VICSES, media, police and other relevant organizations (Ref 25).

In the case of Benalla flood warnings are issued to the North East Regional office which, since 1993, has been relocated from Wodonga to Benalla. The regional VICSES office then forwards the warnings to the relevant local VICSES headquarters.

For the Broken River catchment the BoM has relied on both rainfall and stream height data transmitted via the Public Service Telephone Network (PSTN) and as such suffers from all its inherent problems. In many communities rainfall data used in flood warning systems can be supplemented by calibrated radar measurements of rainfall intensities. Unfortunately Benalla is on the extreme limit of the Melbourne based radar system and therefore this is not a viable option for the Broken River catchment. It is understood however that funding is to be made available for a new radar facility at Yarrawonga which would assist in providing early warning of exceptionally heavy rainfall over the catchment.

The severe floods of October 1993 highlighted significant network deficiencies which adversely impacted on the Bureau's ability to provide accurate quantitative flood warnings for Benalla. These deficiencies consisted of a number of different factors which included:

- The extreme nature of the rainfall causing "flash" flooding in many parts of the catchment,
- Absence of rainfall and river level telemetry in the catchment areas upstream of Kelfeera on the Holland/Ryans Creek System and a lack of rainfall telemetry (Moorngag only) in the remainder of the Broken River catchment,
- Communication problems inherent to the Public Switched Telephone Network (PSTN), and
- Overtopping of a PSTN telemetered river gauges.

In order to address these problems and to provide the community with a flood warning system that satisfies the majority, if not all, of their requirements the Bureau of Meteorology (BOM) proposed a number of options for upgrading the system in the Broken River catchment and as a result an ALERT based system has been installed.

ALERT is a relatively inexpensive system for collecting and processing information used in the provision of an operational flood warning system. In general terms ALERT involves the transmission of a radio signal from a field station to a base station each time an "event" occurs. An event is defined as a preset change in either the rainfall or stream level depending on which is being monitored. Once the data has been received at the base station it is stored for future use. The primary use of the data is for input to a hydrological/hydraulic model of the catchment that predicts future river levels.

The system which has been installed includes 10 telemetry rain gauge stations and 7 telemetry river gauge stations upstream of Benalla and will provide a very significant improvement in the ability to provide timely flood warnings for Benalla. Further details of the flood warning data collection system are provided in Appendix E.

For maximum benefit it will be essential that the new flood warning system is regularly checked by conducting trials and undertaking periodic reviews to ensure all components of the system are functioning correctly and all relevant personnel have an adequate awareness and appreciation of the system.

7.8.4 Response to Flood Warning

Under current arrangements flood warnings are issued by the BOM and issued via faxstream to the responsible regional VICSES offices. The north east regional headquarters of the VICSES, which is responsible for the Broken River catchment is located in Benalla. On receipt of the warning either the Regional Director or the Duty Officer forwards the warning to the Benalla unit. The local unit then responds in accordance with the Flood sub-plan (Ref 25) which forms part of the local DISPLAN.

The documented operations procedure covers the standing arrangements for command control and the identification of known hazards and their management in detail. The procedure defines the action steps of a flood alert plan, trigger river height values for minor, moderate and major flooding, and the roles and responsibilities of:

- Residents and landholders,
- Flood Information Providers,
- Bureau of Meteorology,
- Victoria State Emergency Service (VICSES),
- Delatite Shire,
- Victoria Police,
- Victorian Farmers Federation,
- Country Fire Authority,
- Community Recovery Committee,
- Department of Human Services, Victoria,
- Department of Natural Resources and Environment,
- Volunteer Groups and Service Clubs,
- Goulburn Broken Catchment Management Authority,
- North East REgion Water Authority, and
- Goulburn Murray Water.

One of the criticisms raised in the aftermath of the October 1993 flood was the role of the army. In particular, concern was raised that the assistance provided was withdrawn after 24 hours and subsequently the army had to return.

It needs to be clearly understood that there are strict guidelines covering Defence Forces involvement in emergencies and these are spelt out in the "Defence Assistance to the Civil Community" policy (Ref 19). Broadly, emergency assistance can be provided under 3 categories:

Category 1 covers local emergencies which pose a direct threat to life and/or property. This is short term assistance which is reviewed after 24 hours. Approval is made by the local commander and assistance is provided from within local resources,

Category 2 refers to general emergencies with direct threat to life and/or property and where resourcing may come from beyond the local area. Assistance can only be provided following an approach from state authorities and approval is required from Head Quarters Australian Defence Forces (HQADF) in Canberra.

Category 3 deals with ongoing emergencies with no direct threat to life and/or property. Approval arrangements are the same as for Category 2.

The provision of assistance is guided by the following considerations:

- Defence Assistance to the Community is an exception and not a rule,
- assistance will be provided only if no alternative assistance is available,
- Defence forces are intended for defence only,
- benefits to defence can be demonstrated,
- assistance does not establish a precedent for future support, and
- the aims of the requesting organisation are identified.

In considering whether to provide assistance, the availability of alternative civil assistance beyond the local area will be made. Therefore, notwithstanding that the army base is located in the region, the support of the Australian Defence Forces cannot be guaranteed and any flood emergency response plan should not rely upon such assistance.

7.8.5 Dissemination

The process by which flood warnings are issued and the dissemination of the information is critical to the success of flood emergency response planning. The dissemination of flood information and the response to a flooding situation is the responsibility of the VICSES. The Benalla VICSES chairs the flood sub-plan committee which has the responsibility to prepare a flood emergency response plan as part of the Municipal Plan.

Concern has been raised during the study that several factors were evident during the 1993 flood which hampered the efficiency and effectiveness of the dissemination of information and subsequent evacuations. The factors identified were:

- unfamiliarity with flooding in Benalla,
- unfamiliarity with flood response procedures, and
- the significance of river gauge heights.

A concerted education and training program will be required to adequately address these issues .

The development of a flood emergency plan which clearly defines the role of council, VICSES and other emergency services personnel is essential. Responsibility for co-ordination of the development of the flood-plan is with the VICSES and this has been implemented recently.

The use of flood maps developed for the Benalla Flood Study and updated as part of this study form part of the operations procedure and have been designed to assist emergency service personnel to appreciate the extent of flooding which can occur in Benalla and to prioritize the evacuation of residents should it become necessary. The introduction of brief, but regular familiarization training sessions conducted by the VICSES will allow new VICSES volunteers, police, relevant Council officers and others who have recently located to Benalla to understand the procedures that are in place for dealing with floods, identification of the likely hazards and the priority areas.

Training exercises conducted at regular intervals, but not less frequently than every 2 years, could provide a valuable opportunity for emergency service personnel to familiarize themselves with the operational procedures and may highlight unforeseen difficulties which could then be addressed prior to a real flood. It is understood that the warning system is to be tested each August and this would be the logical time to familiarize new personnel. Training exercises are recommended even if the community adopts a floodplain management strategy based on the construction of levees as there will always be a residual risk of a flood overtopping the levees. There are several documented cases where such a situation has arisen and the damage toll has been significantly greater than would have otherwise been the case because residents have not taken the appropriate contingency measures.

The critical need is for the flood forecast to be disseminated in a manner that is clear to individual households. Forecasts distributed by the media that refer to moderate or severe flooding are of minimal value, ie. the recipients have little idea of what such terms mean for their property. Approaches which have been tested in other flood prone areas involves some or all of the following:

- placement of historical flood markers in prominent locations throughout the flood liable area,
- warnings broadcast over the radio and television,
- fixed and mobile street siren systems,
- warning buzzers inside flood liable houses, and
- setting up of a warden system to assist in door knocking and on-going education.

Historical Flood Markers

Where the height of significant historical floods have been surveyed the heights are recorded on distinctive plaques which are permanently attached to street power poles or similar. This then allows flood warnings to refer to predicted flood heights which are referenced to the historical flood height.

Since Benalla has recently experienced one of the largest, if not the largest recorded flood in the town it presents an ideal opportunity to fix permanent 1993 flood height markers at each affected street intersection. This measure is recommended even in areas where levees are proposed because of the continued risk of a greater flood overtopping the levee system.

Warnings Broadcast over Radio and Television

Difficulties with radio and television based warnings have already been identified where the broadcasts are emanating from areas which may be outside the flood affected community. In these cases it is often difficult for Duty Managers to appreciate the urgency or seriousness of the situation and warnings may be given a lower than required priority. ie. Instead of being broadcast immediately the warnings may be held over until the next news service or at some other convenient break in programming.

In an effort to avoid the possibility of warnings not being afforded an appropriate priority by the media initial facsimile messages are followed up with a telephone call. This has been standard practice since 1992. After the initial warning and telephone call all subsequent warnings identify when an update will be forwarded. Any dramatic change to the warning is handled by telephone. It is strongly recommended that this practice should continue.

In Benalla a community radio broadcasting on the FM band with a range of 25km can be accessed by the Delatitie Shire and would be activated during a flood alert.

Sirens

In recent years several different warning sirens are known to have been trialed as a means of alerting the community of an impending flood. Of particular concern was the need for the sirens to be sufficiently loud and distinguishable from other emergency services sirens during the night under heavy rainfall conditions.

One of the more promising systems known to have been trialed was a system with sirens fixed to street power poles and powered by solar batteries. Generally a siren would need to be no further than approximately 500 m from a property. Purchase and installation of a fixed system is estimated to cost about $5,000 per siren. If the system is installed the community will need to be regularly reminded of the meaning of the siren. However technology exists to allow an electronic voice chip to be included which would direct residents to tune to a particular radio or television station for further details. However, it is also considered necessary to have a system involving direct personal contact by telephone or door to door in the event of failure of the siren(s) to operate. In fact it is considered appropriate that siren systems be considered as a supplement to door knocking rather than the primary means of warning. It is understood that, for a variety of reasons, in U.S. cities where siren systems have been installed they are now being replaced by door knocking as the primary warning method. Nevertheless a fixed siren warning system remains a potential measure for Benalla.

A mobile system broadcast from vehicles moving through the streets is also a valid system and is envisaged as a potential adjunct to door knocking.

Warning Buzzers

This system is similar in principle to a siren except that the buzzers are installed in houses and business premises identified as being at risk from flooding. It is understood that the system has been used in Australia although its success is largely unknown. The system costs approximately $150 per installation.

Some of the difficulties with a buzzer system include both maintenance and education. It is far more difficult to ensure an adequate level of maintenance for such a system when compared with public warning systems. To guard against power failure a battery back up power source would be required. Therefore an internal buzzer system is not regarded as a long term reliable solution and a door knock approach would still be required.

Wardens

An approach adopted in other flood prone areas involves setting up warden systems for sub-areas of the flood prone community. The flood warden system revolves around an individual, who does not have other responsibilities during a flood emergency, being responsible for a group of properties. It is usually the job of the warden to receive warnings and flood predictions and then to inform and translate these for the residents in the area for which they are responsible.

Typically the wardens would receive the warnings and projected peak heights and times from the VICSES and would then inform the residents in their areas of responsibility what the warnings mean in relation to them and their property. Out of flood time, the wardens could assist the VICSES in public education and awareness and the reporting of damaged or lost street flood markers.

Much of the wardens role is viewed as reinforcing information broadcast during an emergency and maintaining residents awareness of the relevance of the flood risk. However it is likely that Benalla, in common with most flood affected communities, will experience waning interest in flood preparedness as time since the last flood increases. This will be a constant problem and is one which will need to be addressed carefully and particularly where a strategy involving levees is adopted since these can invoke a false sense of security.

Although no specific warden position has been established as part of the Benalla flood warning system the operations procedure identifies a role for residents and landholders to be self sufficient and to advise neighbours wherever possible.

7.8.6 Evacuation

Existing Development

The development of an appropriate evacuation strategy depends on a number of factors, including:

- ❑ the establishment of and access to a satisfactory early flood warning system, and

- ❑ the emergency evacuation plan. Whilst the existence of the evacuation strategy, for which the police are responsible, is recognized as an emergency backup, provision for self evacuation should be made if at all possible.

New Development

It is most important that appropriate evacuation strategies, commensurate with the flood risk, be in place for all new development on floodprone land. There is always the possibility that a flood of greater magnitude than the design flood will occur, increasing the depths of floodwaters and overtopping areas previously expected to be above flood levels, increasing velocities and creating floodways in areas previously considered to be safe. Additionally, although some occupants may choose to remain in their premises during a flood, many will wish to be evacuated, particularly when services become inoperable, in times of medical emergency, in times of extended flood periods or the like.

For all new developments control policies should require applications to demonstrate that a satisfactory evacuation strategy will be available to service a proposed new development. The application should address the following issues:

- ❑ the ability of residents or occupants of the proposed development to have access to the flood warning system;

- ❑ the role of the development in the police emergency evacuation strategy. Whilst this strategy is recognized as an emergency backup, all new developments should demonstrate the ability for residents/occupants to evacuate without adding to the burden that already exists on the emergency services;

- the means of evacuation from the proposed development to an area of negligible flood risk and which has ready vehicular access to a communal flood refuge/assembly area. The application should include details of the depth, velocity of flow and distance to be travelled through flood waters.

Evacuation by boat is dangerous and slow. Hidden snags and other submerged obstacles make navigation of a swollen river a difficult task and many accidents have been reported in Australia and overseas. Fortunately in the Benalla the majority of homes are located in areas accessible by high wheel based vehicles and the need for evacuation by water craft is minimal.

Inherent in any wading route determined to be "safe" is the necessity for clearly marked routes with stable even submerged surfaces which minimize the potential for loss of foothold for evacuees.

The recently completed detailed floor level survey and flood height mapping has allowed the VICSES to identify preferred evacuation routes and the prioritized evacuation of residents. It is recommended that these routes be clearly identified to the public in an appropriate manner.

7.8.7 Access Improvements

Risks to both life and property can be minimized with the implementation of an effective evacuation plan. An integral element of an effective evacuation plan is the provision of clearly defined and publicized evacuation routes which also serve as access for emergency vehicles and personnel.

A typical concern in rural areas especially is the isolation of many residences and the vulnerability to flooding of many of the evacuation routes.

Typically access route improvements consist of reconstruction and raising of sections of a road so as to eliminate low points and to provide a continuously rising vehicular route by which to escape to high ground in the event of flooding. While it is preferable to complete all evacuations prior to flooding it is inevitable that some evacuations will be required after roads and access routes have become flooded.

In order to maximize the safety of all rescue personnel and residents, roads which are known to be subject to flooding should be clearly defined by markers on each side to enable evacuation by high wheel based road transport to continue in relative safety in the event that evacuations have not been completed prior to the road becoming flooded. This need was highlighted in 1993 following reports of several instances of vehicles, including trucks, running off the roads. Evacuation/access roads may form part of a levee system. Where the escape route includes bridge crossings the bridges must be designed to a flood standard greater than the approach road.

One area of principle concern in Benalla is the residential area bounded by the Broken River and its anabranch near the Showgrounds. The depth of water flowing along the anabranch during the height of a 5% AEP flood is estimated to be approximately 1.3 metres and approximately 2 metres during a 1% AEP flood.

Residents in this area are considered to be at greatest risk and access improvements are strongly recommended irrespective of the adopted floodplain management scheme.

The preferred evacuation route is via Benson Street and west along Maud Street. The low point occurs in Benson Street between Garden and Maud Streets where the depth of flow across the road in a 5% AEP flood is an estimated 1.3 m. Raising of the road to above the 5% AEP flood level and the provision of concrete box flood culverts with capacity to pass the estimated 5% AEP flow is recommended as a priority measure unless Levee 2 is constructed as part of the adopted flood mitigation strategy. This will allow access to Maud Street west of Benson Street where the road rises and would remain navigable for vehicles even though it would be overtopped during the 1% AEP flood. The anabranch conveys an estimated 141 m^3/s and 53 m^3/s for the 1% AEP and 5% AEP floods respectively The design for the raised road will need to include sufficient waterway area to pass at least the 5% AEP flow and to allow overtopping during the 1% AEP flows without significantly raising upstream flood levels.

In many cases improvements to road surfaces and grades may be undertaken over several years by filling of local low points as opportunities arise during normal road maintenance. Any evacuation route should be on a continuously rising grade away from the floodplain and should be an all weather surface to minimize potential washouts.

7.8.8 Assembly Areas/Flood Refuges

The 1993 flood highlighted some difficulties in respect of "safe" assembly areas where evacuees may be registered and provided with food and shelter.

The BARC hall on the airport precinct was nominated as the official evacuation centre. However during the height of the 1993 flood the hall was flooded and the evacuees required to relocate to other areas. Both the High School and Technical Schools were used as full evacuation centres where evacuees were fed and housed. However it is understood the schools were not ideal for the purpose and some improvements in basic facilities would be required if they are to be used as assembly/refuge areas in the future.

In the absence of any other suitable buildings standing arrangements with the schools and Department of Education to use the facilities should be sought and funding obtained to provide the basic requirements for the temporary housing of evacuees.

In rural communities thought should be given to artificially creating areas of public land for stock refuges where no local readily accessible high ground exists.

8 ALTERNATIVE MANAGEMENT SCHEMES

Based on the array of available structural measures, seven alternative floodplain management schemes based on various structural measures in combination with non-structural measures were assembled and compared with an eighth scheme which is comprised only of non-structural measures.

Three of the structural schemes (Schemes A, B and C) and the non-structural scheme (Scheme D) were developed initially and costed on the basis of their performance in the 1% AEP flood. This is equivalent to assessing the impact the scheme would have had if it had been in place during the October 1993 flood. All levees have been costed on the basis that they would be constructed to the height of the 1% AEP flood plus 600 mm.

Following the analysis and reporting of the above schemes in 1996 the FPMCC undertook a further round of discussions with the local community and subsequently proposed 2 further schemes (Schemes E and F). Schemes E and F were both analyzed and costed for the 2% AEP and 5% AEP design floods. For comparison, Scheme A (the Levee scheme) was also analyzed for the 2% AEP and 5% AEP floods.

These schemes were then subjected to further public scrutiny and further options were developed which included a lake downstream of the railway viaduct. Notwithstanding the superior economic performance of schemes which included a second lake compared to other schemes the economic and ecological viability of the second lake was questioned and an alternative vegetation management plan was developed in lieu of the second lake.

Two additional schemes were then proposed (Schemes H5 and K). Scheme H5 included a system of flood walls, road raising and levees to provide protection against the 5% AEP flood. Scheme K did not include the levees or the additional flood culverts under the railway.

Improvements to the East and West Main Drains recommended in the *Review of East and West Main Drains at Benalla* (Ref. 20) have not been included in assessing the schemes because preliminary investigations indicated that they did not have any impact on peak flood levels. However the implementation of the recommendations are supported because the works will assist in the more efficient draining of flood waters after the flood has peaked and in the case of schemes which include levees or some other form of flood exclusion system will assist in the efficient dispersal of local runoff as the flood recedes.

8.1 Alternative Floodplain Management Schemes

The structural and non-structural measures included in each alternative scheme are summarized in Table 10 and overviewed as follows.

8.1.1 Structural Measures

Each of the structural measures discussed in Section 6, except for free form landscaping and road raising, was assessed based on its impact on 1% AEP flood levels and its economic, social and environmental performance. Free form landscaping and road raising was assessed based on its effect on the 1% AEP, 2% AEP and 5% AEP flood levels, plus its economic, social, and environmental performance.

TABLE 10
SUMMARY OF ALTERNATIVE FLOODPLAIN MANAGEMENT SCHEMES

Scheme	A	B	C	D	E	F	G	H	J	K
Structural Measures										
C (Railway Culverts)		✓			✓	✓	✓[1]	✓		✓
Dm (Moderate Vegetation Management)	✓	✓	✓							
De (Extensive Vegetation Management)					✓	✓	✓	✓	✓	✓
F1 (Levees 1 and 2)	✓									
F5 (Landscaping, Road raising)					✓	✓	✓	✓		
H1 (Levee 7)	✓									
H5 (Floodwall, Landscaping,Levee)						✓	✓	✓		
I1 (Levees 3A and 4)	✓									
I5 (Landscaping ,Floodwall)					✓	✓	✓	✓		
K (Arundel Lake)			✓			✓	✓			
L3 (Freeway Retarding Basin)			✓							
M Excavation of river islands)					✓	✓				
NN (Vegetation management)					✓	✓		✓	✓	✓
VM ((Vegetation management)										✓
Non Structural Measures										
House Raising	✓	✓	✓	✓						
Voluntary Purchase	✓[2]	✓	✓	✓						
Land Use Planning/Zoning	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Building and Development Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Improved Flood Warning	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Evacuation/Contingency Planning	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Public Education	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Improved Access	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Assembly Areas/Flood Refuges	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Note 1. Only the additional railway culverts between Duffy Street and the East Main Drain are included in Schemes G and H.
Note 2. One property recommended for purchase to facilitate construction of Levee 2 or free form landscaping. The cost of the purchase of a second property to facilitate construction of Levee 2 has not been included since it is not essential.

The structural measures included in the alternative schemes included:

Measure C Provision of additional culverts through the railway embankment between the river and the East Main Drain.

Measure D Vegetation management comprising clearing of understorey scrub and thinning of trees within the river, including the islands between Psaltis Parade and the confluence with Holland Creek, and compensatory tree planting in nearby areas.

Measure F Construction of Levees 1 and 2 on the western side of the river from the railway to Bridge Street (Levee 1) and Bridge Street to upstream of Cowan Street (Levee 2).

Measure H Construction of Levee 7 on the eastern side of the river from Railway Place to the Yarrawonga railway branch line opposite Doherty Street.

Measure I Construction of Levees 3A and 4 on the eastern side of the river from the railway to Bridge Street (Levee 4) and from Bridge Street to Willis Little Drive (Levee 3A).

Measure K Construction of a second lake (Arundel Lake) between Ackerly Avenue and the northern extension of Arundel Street together with a reduction in "in-stream and bank trees/scrub between Arundel Street and Faithful Street.

Measure L3 Conversion of the area immediately upstream of the Hume Freeway into a flood retarding basin by reducing the waterway openings at the freeway crossings over the Broken River and its anabranch, Blind Creek and Holland Creek such that the in a 1% AEP flood the floodwaters would reach, but not overtop the lowest point along this section of the Hume Freeway.

Measure M Excavation of the mid-stream islands at the upstream end of Benalla Lake to a level no higher than RL 168m which is below the normal water level in the lake.

Measure NN Vegetation management downstream of the railway viaduct to Arundel Street and part excavation of the western side of the midstream island downstream of Ackerly Avenue.

Measure VM Implementation of a vegetation management plan similar to Measure NN comprising environmentally sensitive vegetation management along waterways though Benalla including river islands and floodplain from the lake extending upstream to the extension of Cowan Street, downstream of the railway viaduct to Faithful street, the environs of the Lake Benalla weir and the Market Street floodway.

8.1.2 Non-Structural Measures

All of the measures discussed in Section 7 are utilized to some extent in all of the schemes. For example, flood warning improvements, evacuation and contingency planning are still included even where levees are provided because it is not practical to protect all areas with levees and because of the residual flood risk associated with floods greater than the 1% AEP flood overtopping any levees that are provided. Similarly areas behind free form landscaping and road raising would only be protected by floods up to and including the 5% AEP design flood and a repeat of the 1993 flood would still inundate “protected” areas.

8.2 Hydraulic Performance of Alternative Schemes

The hydraulic performance of Schemes A, B and C was assessed for the 5%, 2% and 1% AEP floods using the hydraulic model of the floodplain. The impact of the Schemes on 1% AEP flood levels is shown in Figures 17, 19 and 20. The impact of Scheme A on the 2% AEP flood in shown in Figure 18.

The hydraulic performance of Schemes E and F was assessed only for the 5% and 2% AEP floods using the hydraulic model of the floodplain. The impact of the Schemes on the 2% and 5% AEP flood levels is shown in Figures 24 to 27.

Scheme A was found to have the greatest impact on flooding by providing protection up to and including the 1% AEP flood for all areas other than on the western side of the river north of the railway. Levees in this area are not considered practical. The construction of a lake downstream of Ackerly Avenue (Arundel Lake – Measure K) and vegetation management (Measure NN) are the only identified structural measures which benefited properties in this area.

The levees confine flood flows and in the absence of compensating measures would cause an increase in flood levels between Bridge Street and Samaria Road. The reduction in stream vegetation upstream of Bridge Street reduces this risk and no discernible increase in flood levels upstream of the levee system are anticipated if the amount of vegetation covering the low lying ground upstream of Benalla Lake is reduced. Downstream of the railway the levee proposed on the eastern bank under Scheme A would redirect less than 1% of the total peak 1% AEP flow back into the river. Therefore only very small increases in flood levels immediately downstream of the levee system are anticipated. For rural properties downstream of Benalla no change in flood behaviour following implementation of the levee system is expected.

Scheme B offers only small reductions in the 1% AEP flood levels for most of Benalla although significant reductions in flood levels (up to 600 mm) are predicted in eastern Benalla immediately south of the railway and particularly in the vicinity of the proposed additional culverts through the railway embankment. Other areas which would derive the most benefit from Scheme B are houses in the immediate vicinity of works to reduce the amount of understorey vegetation and trees on the river islands and banks between Psaltis Parade and the Broken River confluence with Holland Creek (Measure Dm – Moderate Vegetation Management).

Scheme C which includes a retarding basin upstream of the Hume Freeway provides only a marginal increase in the overall flood protection when compared with Scheme B. If the flood level immediately upstream of the Hume Freeway is limited to the existing lowest point along the Freeway then there would only be a reduction of 106 m^3/s in the peak 1% AEP flow at Benalla. This represents approximately an 8% decrease in the estimated peak flood flow for the October 1993 flood. As a consequence reductions in the 1% AEP flood level are generally limited to no more than 100 mm although decreases of up to 300 mm are predicted where vegetation within the floodway upstream of Psaltis Parade is removed (see Figure 20). Scheme C has the further disadvantage that 6 houses upstream of the Hume Freeway will be affected by the impoundment of flood waters. Two of the houses not currently subject to over floor flooding would be inundated and three others would have less than the desirable freeboard of 500 mm.

Schemes E and F were proposed and analyzed to ascertain whether flood exclusion systems other than the levees as identified for other schemes would be practicable. Hydraulically the system of raising roads, free form landscaping and short sections of flood walls consistent with existing walls/fence locations and heights was shown to provide the same level of protection as the levees for floods up to and including the 5% AEP flood. For greater floods, the height to which roads must be raised, fences constructed, and ground levels raised was becoming unacceptably high in several locations such as opposite Psaltis Parade and along Neilll Avenue. In most areas works designed to provide protection against the 5% AEP flood would need to be raised at least a further 500 mm.

Scheme G is closely related to Scheme F differing only in that excavation within the river is not included nor are the additional railway culverts proposed near Nunn Street. In the latter case the Nunn Street culverts were shown to be largely ineffective in reducing 1% AEP flood levels except in a very localized area near the entrance to the culverts.

Scheme H provides similar flood level reduction benefits as Scheme G but at a substantially lower cost due to the low capital cost of implementing the vegetation management plan (Measure NN) compared to the cost of constructing a second lake (Measure K).

Scheme J includes only the vegetation management measures (Measures De and NN). Measure NN includes some excavation across along the western portion of the mid-stream island downstream of Ackerley Avenue to increase available flood waterway area. The excavation is considered to have minimal environmental impact.

Scheme K differs from Scheme J in that the additional culverts under the railway proposed for the Duffy Street area (Measure C) are included. As a result there is a reduction in the estimated 1% AEP flood level for properties upstream of the railway embankment in the vicinity of the East Main Drain compared with Scheme J.

The number of buildings which would continue to experience overfloor flooding if only the structural measures in Schemes A, B, C, E, F, G, H, J and K are implemented is summarized in Table 11. Buildings include residential, retail, commercial and industrial buildings. The numbers in brackets are the estimated number of residential buildings estimated to experience over floor flooding. Note however that the building numbers reported for Existing conditions and Schemes H, J and K only are based on the revised floor level survey. All others are based on the original survey based on the Benalla Sewerage Authority mapping supplemented by other more recent data taken from sub-divisional plans.

8.3 Economic Analysis of Alternative Schemes

Economic evaluation, or benefit-cost analysis, aims to estimate the net benefit (defined as total benefits less total costs) of alternatives. Benefits and costs are measured in monetary terms, so that they can be readily compared. As most people prefer present goods and services to future ones, future costs and benefits are given less weight than present ones.

In practice, it is usually not possible to quantify and value all benefits and costs. In these cases the evaluation should make clear the scope of the benefit-cost exercise and the major items that have not been quantified. Benefits and costs that have been quantified in this benefit-cost analysis are distinguished from those which have not been quantified in the discussion regarding flood damages and economic analysis also in Appendix A.

Benefit-cost analysis has been applied for many years to the evaluation of major infrastructure as part of the public sector's decision-making framework. It is applied in this instance to assist in the decision concerning strategies for flood management in Benalla.

8.3.1 Preliminary Cost Estimates

Preliminary cost estimates were based on conceptual designs for each structural measure. Details of the estimates are provided in Appendix A.

Building floor level and ground level information was based on recent survey commissioned by the former Delatite Shire Council. Ground level survey for properties was supplemented in some cases by spot height and/or contours shown on the Benalla Sewerage Authority maps. Surface area and volume estimates for the Arundel Lake were taken from available regional mapping and limited additional topographic survey provided by the former Delatite Shire Council. Earthworks quantities for the retarding basin were based on the Hume Freeway retarding basin survey specifically commissioned as part of this study.

TABLE 11
SUMMARY OF BUILDINGS FLOODED ABOVE FLOOR LEVEL

		5% AEP	2% AEP	1% AEP	Extreme[2]
Existing Conditions[1]	All buildings	57	499	1085	3230
	Residential	36	361	877	2856
Scheme A	All buildings	8	61	217	3298
	Residential	6	59	215[2]	2892
Scheme B	All buildings	219	402	786	3298
	Residential	159	261	578	2892
Scheme C	All buildings	155	234	440	3298
	Residential	110	164	297	2892
Scheme E2	All buildings	7	21	1290	3298
	Residential	7	19	1047	2892
Scheme E5	All buildings	125	588	1290	3298
	Residential	122	434	1047	2892
Scheme F2	All buildings	4	9	1290	3298
	Residential	4	7	1047	2892
Scheme F5	All buildings	4	588	1290	3298
	Residential	4	434	1047	2892
Scheme G5	All buildings	4	563	1212	3298
	Residential	4	398	957	2892
SchemeH5[1]	All buildings	2	324	818	3230
	Residential	2	222	639	2856
Scheme J[1]	All buildings	37	344	847	3230
	Residential	24	242	668	2856
Scheme K	All buildings	37	354	795	3230
	Residential	24	245	619	2856

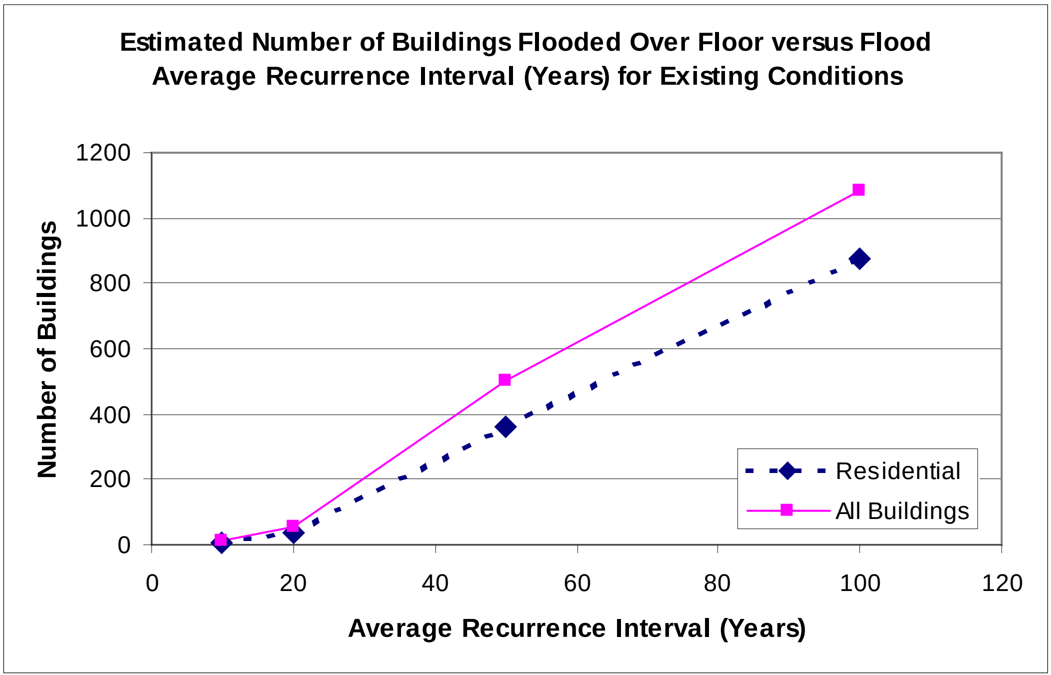
Note 1. Reported numbers for Existing, Scheme H5 and Scheme J are based on the updated floor level survey. The numbers for all other schemes are based on the Benalla Sewerage Authority mapping as reported in 1998 and beforehand.

Note 2. This is a lower bound estimate because additional properties significantly above the October 1993 flood and for which floor levels were not available have not been included in the property data base.

Note 3. All but a few properties subjected to overfloor flooding are located on the west side of the river north of the railway.

Unit costs and rates were based on both local information and published estimating data (Ref. 21). Property values were based on advertised 1998 market rates in Benalla.

For comparison with the cost of structural measures, the cost of raising all suitable flood liable residential buildings under Scheme D was also estimated.



The net present value (NPV) of on-going maintenance costs were added to the capital cost of each structural measures within each scheme to obtain the net present value of all structural measures in each scheme.

8.3.2 Flood Damages

Flood damage estimates were prepared as described in Appendix A for existing conditions. Flood damage estimates were derived for the 5%, 2%, 1% AEP floods and an extreme flood. These estimates were used to determine average annual damages (AADs) and the net present value of the AAD based on discount rates of 4%, 7% and 10% over 20 years for schemes A to G inclusive. Schemes H, J and K which were added in the latter stages of the report have been assessed using discount rates of 3%, 6%, and 9% to reflect the generally lower interest and inflation rates in recent years. Under direction from the FPMCC Schemes A to G were not recalculated as these Schemes had already been rejected.

In estimating the damages savings following the implementation of an upgraded flood warning system, public education campaign and well planned and rehearsed flood response plan a 35% reduction in the potential damages is considered reasonable. In the October 1993 flood the actual damages suffered are considered to be close to the potential damages because of a number of factors including the unexpected size of the flood and the lack of preparedness by the majority of the community.

8.3.3 Benefit/Cost Ratios

Benefit/Cost Ratios (BCRs) were calculated as the ratio of the Net Present Value (NPV) of AAD avoided to the NPV of structural measures.

A summary of the key economic results for each Scheme is provided in Table 12. Further details are provided in Appendix A.

8.4 Environmental and Social Assessment

An environmental and social assessment of the various structural components of each Scheme was been prepared based on six main factors. These are:

- ❑ amenity - whether the option will affect the social or physical amenity of Benalla, including accessibility to community facilities and services;
- ❑ aesthetic - whether the option will affect existing aesthetic qualities within the city, including views, vistas and impact on specific items or areas;
- ❑ land take - whether the option will involve the dedication of significant areas of land within the urban area;
- ❑ ecology - whether the option will cause disruption to the flora and fauna of the area and the extent to which this might be acceptable; and
- ❑ sensitivity - whether the option will affect sensitive uses, such as heritage items and whether general enjoyment of life will be compromised.

This assessment includes reference to other non-structural measures which are part of each Scheme. Although improvements to the East and West Main Drains identified previously (Ref. 20) have no impact on peak flood levels they will assist in the more efficient draining of flood waters and so were included in the social and environmental assessment.

The impacts were also ranked according to their affect on the environmental and social qualities of the community. The assessment is summarized in Table 13. Further details are provided in Appendix C.

TABLE 12

SUMMARY PERFORMANCE OF FLOODPLAIN MANAGEMENT SCHEMES

SCHEME	Houses Protected	Houses Flooded	Commercial Bldgs Protected	Commercial bldgs Flooded	AAD Remaining	AAD Savings	Capital Cost ($ 000's)	Recurrent Cost ($ 000's)	Benefit/Cost Ratio	Capital Protection cost per Building	Capital Protection cost per House/Unit
Protection against 1% AEP Flood											
Do Nothing	**0**	**877**	**0**	**208**	**$2,157,586**	**0**	**0**		**NA**	**NA**	**NA**
Scheme A1 (Levees, Reduced River Vegetation near confluence)	832	215	241	2	$1,365,570	$792,016	9,042	177	1.19	$8,427	$10,868
Scheme B (Railway Culverts, Arundel Lake, Reduced River Vegetation near confluence)	299	578	0	208	$2,120,634	$36,952	3,180	9	0.97	$10,635	$10,635
Scheme C Retarding Basin, Arundel Lake, Reduced River Vegetation near confluence)	270	607	-3	211	$2,143,253	$14,333	7,380	168	0.30	$27,640	$27,333
Scheme D (House raising (weatherboard) and flood proofing (brick residences and suitable commercial properties)	877	0	243	0	$1,307,822	$849,764	27,906	279	0.48	$24,916	$31,820
Scheme J (Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street.)	**209**	**668**	**29**	**179**	**$1,788,064**	**$369,522**	**873**	**19**	**6.01**	**$3,668**	**$4,177**
Scheme K (Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street, additional railway culverts near Duffy Street - East Main Drain).	**258**	**619**	**32**	**176**	**$1,797,317**	**$360,269**	**1,968**	**29**	**2.58**	**$6,786**	**$7,628**
Protection against 2% AEP Flood											
Do Nothing	0	448	0	154	2351375	0	0	0	NA	NA	NA
Scheme A2 (Levees, Reduced River Vegetation near confluence)	389	59	152	2	$1,628,451	$529,135	6,276	128	1.25	$11,601	$16,134
Scheme E2 (Railway culverts, Levees, Reduced River Vegetation near confluence and downstream of Ackerly Ave., and excavation of islands in confluence area)	429	19	152	2	$1,381,354	$776,232	10,226	134	1.10	$17,601	$23,837
Scheme F2 (As for Scheme E2 plus Arundel Lake)	441	7	152	2	$1,374,859	$782,727	12,126	162	0.92	$20,449	$27,497
Protection against 5% AEP Flood											
Do Nothing	**0**	**36**	**0**	**21**	**$2,157,586**	**0**	**0**	**0**	**NA**	**NA**	**NA**
Scheme E5 (Railway culverts, Levees, Reduced River Vegetation near confluence and downstream of Ackerly Ave., and excavation of islands in confluence area)	29	7	21	0	$1,575,715	$581,871	9,005	109	1.00	$180,100	$310,517
Scheme F5 (As for Scheme E5 plus Arundel Lake)	32	4	21	0	$1,571,662	$585,924	10,905	138	0.82	$205,755	$340,781
Scheme G5 (Railway Culverts near Duffy St., Landscaping, Road raising, Flood proof Fencing, Reduced river vegetation near confluence and downstream of Ackerly Avenue, and Arundel Lake)	32	4	21	0	$1,556,678	$600,908	8,505	134	1.07	$160,472	$265,781
Scheme H5 (Railway Culverts near Duffy St., Landscaping, Road raising, Flood proof Fencing, Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street.)	**34**	**2**	**21**	**0**	**$1,882,813**	**$274,773**	**7,291**	**131**	**0.73**	**$132,564**	**$214,441**
Scheme J (Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street.)	**12**	**24**	**8**	**13**	**$1,788,064**	**$369,522**	**873**	**19**	**5.26**	**$43,650**	**$72,750**
Scheme K (Reduced river vegetation in confluence/ Casey islands area and between Ackerly Avenue and Arundel Street, additional railway culverts near Duffy Street - East Main Drain).	**12**	**24**	**8**	**13**	**$1,797,317**	**$360,269**	**1,968**	**29**	**2.58**	**$98,400**	**$164,000**

1. AAD is the Annual Average Damage cost of flooding in urban Benalla.
2. Under Scheme C, 2 additional houses would experience over floor flooding and 4 other houses would be seriously effected by impounding water behind the Hume freeway embankment.
3. All schemes include house raising or flood proofing where properties receive no other protection. In line with normal practice these costs, including those for flood proofing suitable commercial premises, have not been included when estimating the costs and benefits for each scheme (other than Scheme D.
4. Building numbers and cost estimates for "Do nothing", and Schemes H5 and J have been based on the updated floor level survey.
5. The BCR for Scheme H5 and Scheme J is based on 6% discount rate over 20 years. All others are based on 7% discount rate over 50 years with no residual.

TABLE 12
SUMMARY OF PERFORMANCE OF FLOODPLAIN MANAGEMENT SCHEMES

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TABLE 13
SUMMARY OF SOCIAL AND ENVIRONMENTAL IMPACTS

Scheme	Amenity	Aesthetics	Land Take	Ecology	Sensitivity
Scheme A1					
Levee 1	L	L	L	L	L-M
Levee 2	M-H	H	M-H	M	H
Levee 3A	M-H	H	M-H	M	H
Levee 4	L	L	L	L	L
Levee 7	L	L	L	L	L-M
Vegetation reduction - confluence area	L	L	L	L	L
Overall Assessment	M	M	L-M	M	M
Scheme B					
Arundel Lake	L	L	L	H	H
Vegetation reduction - confluence area	L	L	L	H	L
Additional railway culverts	L	L	L	L	L
Overall Assessment	L	L	L	M-H	M
Scheme C					
Hume Freeway Retarding Basin	L	L	L	M	M-H
Vegetation reduction - confluence area	L	L	L	L	L
Arundel Lake	L	L	L	H	H
Overall Assessment	L	L	L	M	M-H
Scheme D					
House Raising & Floodproofing	L-M	L-H	L	L	M
Overall Assessment	L-M	M	L	L	M
Scheme A2					
Levee 1	L	L	L	L	L-M
Levee 2	M-H	M-H	M-H	M	H
Levee 3A	M-H	M-H	M-H	M	H
Levee 4	L	L	L	L	L
Levee 7	L	L	L	L	L-M
Vegetation reduction - confluence area	L	L	L	L	L
Overall Assessment	M	M	M	L-M	M

TABLE 13 (cont.)
SUMMARY OF ENVIRONMENTAL AND SOCIAL IMPACTS

Scheme	Amenity	Aesthetics	Land Take	Ecology	Sensitivity
Scheme E2					
Levee 1	L	L	L	L	L-M
Levee 2	M-H	M	M-H	M	M-H
Levee 3A	M-H	H	M-H	M	H
Levee 4	L	L	L	L	L
Levee 7	L	L	L	L	L-M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Excavation of islands	L	H	L	H	M
Overall Assessment	L-M	L-M	L-M	M	M

Scheme	Amenity	Aesthetics	Land Take	Ecology	Sensitivity
Scheme E5					
Road raising - Area 1	L	L	L	L	L
Landscaping, Fencing - Area 2	M	M	M	M	M
Landscaping, Fencing - Area 3	M	M	M	M	M
Road raising - Area 4	L	L	L	L	L
Landscaping, fencing - Area 7	L	L	L	L	M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Excavation of islands	L	H	L	H	M
Overall Assessment	L-M	L-M	L-M	L-M	M
Scheme F2					
Levee 1	L	L	L	L	L-M
Levee 2	M-H	M	M-H	M	M-H
Levee 3A	M-H	H	M-H	M	H
Levee 4	L	L	L	L	L
Levee 7	L	L	L	L	L-M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Excavation of islands	L	H	L	H	M
Arundel Lake	L	L	L	H	H
Overall Assessment	L-M	M	L-M	M	M

TABLE 13 (cont.)
SUMMARY OF ENVIRONMENTAL AND SOCIAL IMPACTS

Scheme	Amenity	Aesthetics	Land Take	Ecology	Sensitivity
Scheme F5					
Road raising - Area 1	L	L	L	L	L
Landscaping, Fencing - Area 2	M	M	M	M	M
Landscaping, Fencing - Area 3	M	M	M	M	M
Road raising - Area 4	L	L	L	L	L
Landscaping, fencing - Area 7	L	L	L	L	M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Excavation of islands	L	H	L	H	M
Arundel Lake	L	L	L	H	H
Overall Assessment	L	L	L-M	M	M
Scheme G5					
Road raising - Area 1	L	L	L	L	L
Landscaping, Fencing - Area 2	M	M	M	M	M
Landscaping, Fencing - Area 3	M	M	M	M	M
Road raising - Area 4	L	L	L	L	L
Landscaping, fencing - Area 7	L	L	L	L	M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Arundel Lake	L	L	L	H	H
Overall Assessment	L	L	L-M	L-M	M
Scheme H5					
Road raising - Area 1	L	L	L	L	L
Landscaping, Fencing - Area 2	M	M	M	M	M
Landscaping, Fencing - Area 3	M	M	M	M	M
Road raising - Area 4	L	L	L	L	L
Landscaping, fencing - Area 7	L	L	L	L	M
Vegetation reduction - confluence area	L	L	L	L	L
Additional railway culverts	L	L	L	L	L
Vegetation management downstream of railway	L	L	L	L	L
Overall Assessment	L	L	L-M	L	M
Scheme J					
Vegetation reduction - confluence area	L	L	L	L	L
Vegetation management downstream of railway	L	L	L	L	L
Overall Assessment	L	L	L	L	L

TABLE 13 (cont.)
SUMMARY OF ENVIRONMENTAL AND SOCIAL IMPACTS

Scheme K					
Vegetation management [VM]	L	L	L	L	L
"Duffy Street" area Culverts under Railway	L	L	L	L	L
Overall Assessment	L	L	L	L	L

For Scheme J and all other schemes which include a reduction in the existing riparian vegetation the potential adverse effects on the ecology would be further reduced where supplementary planting can be undertaken near and beyond the fringe of the 1% AEP flood.

8.5 Land Use Planning under Schemes

Land use planning is a key non-structural component of all the alternative Schemes. The following Policies for Undeveloped and Developed Areas should be included in any adopted Scheme and during the course of this study have been embodied in the Victorian Planning Provisions, the Practice Notes, and Local Planning Policy.

8.5.1 Policy for Undeveloped Areas

Formulating an appropriate policy for undeveloped areas is quite complex and should be based on the following principles:

- recognition that virtually all flooding causes significant damages in urban areas and is difficult and expensive to mitigate;
- notwithstanding the above, recognition of the fact that the risk of damages and opportunities for safe development varies considerably across the floodplain; and
- that in areas within the catchments of existing infrastructure, under-utilization of the infrastructure would be a considerable opportunity cost.

It is apparent that the undeveloped floodplain cannot be treated homogeneously, rather the following principles should be considered:

- high flood hazard areas should remain free of building development because of the risks to life and property and the high costs of dealing with frequency flooding. Development may be appropriate in certain flood fringe or flood storage areas if spare capacity exists in existing infrastructure in the subject locality;
- all areas of the floodplain where there is no significant infrastructure and which are outside the catchments of existing major facilities should be given low priority for development when alternatives are available. Major facilities include water supply reservoirs, sewerage treatment works and high schools or hospitals.

In circumstances where flood free land is not readily available and there is a demand for additional urban land, alternative strategies involving higher densities, avoidance of worst areas, appropriate conditions for development and structural mitigation measures should be considered. However, the recent ILAP strategy prepared for Council does not indicate any requirement for the expansion of the urban area with the exception of the residential areas identified above. There will therefore be no requirement to adopt these alternative provisions.

While the extent to which land use categories are incorporated into local planning options is at Councils discretion, the following rules of thumb generally apply:

- Residential - this is a sensitive use, highly susceptible to flood damage. Its location within flood prone land should therefore be avoided.

- Commercial/Industrial - consideration needs to be given to potential damage to such premises in high hazard areas. Non-structural measures can usually be implemented to reduce this.

- Open Space - generally this land use is flood compatible. Where club houses are proposed, appropriate methods to reduce flood impacts should be included.

- Rural/Non-Urban - this refers to land used for activities such as market gardening, plantations, orchards, etc. Any residential development proposed within this area should be treated on the same basis as for normal residential, in relation to flood proofing measures.

- Special Uses - this includes, schools, hospitals, public halls, churches, telephone exchanges, water and sewerage works, etc. These are all essential during times of flood and their continued operation during and after such an event is often critical in reducing social disruption. Therefore, such uses are most appropriately located beyond the flood zone.

In relation to Councils ILAP study, which nominates certain areas for the expansion of residential, commercial and industrial development, the following comments are made:

- The existing and proposed commercial area falls within the one per cent low hazard flood category, and therefore appropriate non-structural measures for new development within this area will need to be taken in accordance with the guidelines for LSIO areas.

- New industrial zones do not fall within the floodprone area, therefore other than existing policy relating to floor levels and potential damages, no further policies are considered necessary.

- None of the proposed residential areas fall within a flood affected area. In these terms, it is considered that residential development of these areas is appropriate.

8.5.2 Policy for Developed Areas

In higher density urban areas, the scope for reduction in high flood loss is less. As an overriding principle, a reduction in the intensity of development or, at worst, not increasing it at all, should be pursued. In these circumstances, the main mitigation measure is usually of a structural nature however other alternatives as discussed elsewhere in this report are potentially available.

This includes:

- ❑ raising floor levels for habitable rooms only, to a level at least 300 mm and preferably 500mm above the 1% AEP flood level;

- ❑ flood proofing of buildings - usually appropriate for retail, commercial and industrial buildings, and comprising shutters to prevent the entry of debris, or raising storage areas above the 1% AEP flood level;

- ❑ voluntary purchase - only normally used where urban land is exposed to a very high flood hazard and where structural solutions are not viable (none voluntary purchase scheme is considered warranted in Benalla and therefore none has been recommended);

- ❑ flood warning and evacuation planning - to make people aware of when and how they should evacuate and where to go when a flood eventuates. This might also include contingency plans for sealing off specific roads or buildings with sand bags or other equivalent means.

8.5.3 Provisions from the State Policy on Floodprone Areas Model Planning Scheme Flood Provisions

The policy for flood prone areas is quite prescriptive in its application of provisions to be incorporated as part of local planning schemes. The 1998 draft of this report recommended that the Benalla City planning scheme be amended to incorporate their provisions when the policies had been finalized and this has now occurred. Appropriate provisions have been included in the draft amendments for the Shire which recognize the existence of waterways, major flood paths, drainage depressions and high hazard areas within Benalla. These have been identified with Floodway Overlays (shown on planning scheme map as FO) and Land Subject to Inundation Overlay (shown on the planning scheme as LSIO).

In addition a Local Floodplain Development Plan has been developed for the precinct of the Broken River.

Uses permissible within such a zone are noted in Section 7.3. This should be supplemented by the need for a permit to carry out buildings and works, subdivision or to replace or extend existing dwellings.

Within the land subject to inundation area the overlay to the planning scheme should identify land liable to inundation by overland flow, sheet flooding or areas within the flood fringe from the 1% AEP flood.

These provisions essentially cover all flood liable areas within Benalla and should be incorporated as part of the Planning Scheme in conjunction with other appropriate structural as discussed in this report.

9 FLOOD POLICY ISSUES

9.1 Greenhouse Effect

In recent years the likely impact of a change in climate resulting from the increase of Greenhouse gas emissions to the atmosphere (Greenhouse Effect) has been widely accepted. The scope of changes likely to occur and the time scale for such changes are not well defined and could encompass both general change in weather patterns (storminess) and a change in mean sea level.

At present, there is insufficient data available to allow predictions to be made of the effect with any great degree of confidence. Estimates of the impact from global warming have been reduced during the past decade as observations have not supported original estimates. There is however more recent evidence which is still to be firmly quantified that the extremes in weather patterns are likely to become more pronounced. The severity of periods of drought are expected to increase as will the intensity of high rainfall events.

In Benalla, the impacts would be experienced through higher and more intense rainfall although at this stage the amount cannot be quantified. Recent advice from the Bureau of Meteorology indicates that there is no intention at this time to revise design rainfalls to take into account the Greenhouse Effect because the possible mechanisms are unclear although the matter is under regular review by agencies including the CSIRO. Nonetheless the consequences of future climatic change for floodplain management at Benalla are to introduce additional uncertainties into the flood level estimates with the expectation that the frequency of future events with the same rainfall intensity as historical events are likely to increase. It is therefore recommended that, at the present state of engineering knowledge, the most practical solution is to adopt an adequate freeboard on all structural works and house raising proposals and to include an additional allowance for "greenhouse effects". In Benalla freeboard which includes approximately an additional 200 mm allowance is considered sufficient.

9.2 Freeboard

Freeboard for floor levels and levee works is required to allow for hydrological uncertainty, differences in water level across the floodplain, wave action and the effect of any subsequent infill development. In addition there are advantages in having adequate freeboard to reduce the likelihood of sewer surcharges in buildings. Hydrological uncertainty covers both uncertainties introduced as part of the hydrological modelling procedures and climatic uncertainty including greenhouse effects.

Historically, 300 mm has been adopted as the minimum freeboard for floor levels throughout Benalla. This is in accordance with the provisions contained in the Victorian Building Regulations (Ref. 13). However State Government policy for community flood protection works, such as levees, has required a freeboard allowance of 600 mm.

An allowance of 600 mm has generally been considered sufficient and compares favourably with practice in other states such as NSW where historically 500 mm freeboard has been considered acceptable. However in the aftermath of recent floods such as at Nyngan, NSW government policy now requires a minimum freeboard of one metre for all levee schemes unless there are justifiable reasons for adopting a lesser amount.

The additional allowance for community flood protection works has arisen through concern that provision of levees have engendered a false sense of security and as a result communities have been unprepared when levees have been overtopped.

In Benalla, because of the flat terrain, an extreme flood would be required to overtop any levees with one metre of freeboard and therefore any amount greater than 600 mm is considered excessive.

In the light of the 1993 flood which exceeded previous estimates of the 1% AEP flood there is an argument for increasing the freeboard to 500 mm or 600mm for individual buildings not otherwise protected. In Benalla levees included as part of a scheme would offer protection against the 1% AEP flood while maintaining freeboard of 600 mm. In both cases the adoption of 500 mm as the freeboard allowance would be considered to include an allowance of approximately 200 mm for climatic uncertainty as discussed in Section 9.1.

The minimum floor level for new housing development in areas protected by levees may be lower than houses in "unprotected" areas if the levee is designed to provide protection against the 1% AEP flood. The levees are primarily to protect existing development and the temptation to allow floor levels of new housing development to be set below the 1% AEP flood level should be avoided. It has been found that where house floor levels are set at or very close to ground level in "leveed" areas problems with flooding due to local drainage can still occur. However it would seem reasonable to take some advantage of the levee to reduce building costs and therefore it is suggested that the minimum floor level for new housing development in "leveed" areas be set at the height of the 1% AEP flood (ie there would be no freeboard allowance) but only if the levees are constructed higher than the 1% AEP flood level plus a freeboard allowance of 600mm (equal to the freeboard adopted for public flood mitigation works). Floor levels set at the 1% AEP flood level would ensure that should the “1% AEP” levee be breached or overtopped flood damage would be minimized.

In areas where levees are designed to provide protection against floods smaller than the 1% AEP flood (eg 5% AEP Levees in Benalla) no consideration should be given to relaxing floor level requirements in “leveed” areas. In the case of Benalla all floor levels for new development should be above the 1% AEP flood level.

9.3 Extreme Flood

There is always the possibility of an extreme flood event occurring which exceeds the Flood Standard. This would affect substantial areas of Benalla which were not affected by the October 1993 flood. Furthermore, those areas which were flood affected in October 1993 would experience greater depths of flooding and a greater hazard.

Even those areas which may in the future be protected by levees, will experience a residual risk of flooding in the event of floods which overtop the levees. Effective strategies should be put in place to cater for the range of flood events, including extreme events.

The implications of a flood substantially greater than the October 1993 flood (the Flood Standard) will require recognition in any emergency plan. The potential impacts of an extreme flood should be recognized in planning for the location of essential services.

10 COMMUNITY CONSULTATION

During the study meetings have been conducted at both a community wide and neighbourhood level.

The initial consultation was conducted during the period up until mid 1998 and included:

- public meetings (3), both of which were announced in the local press,
- invitations to complete questionnaires relating to flooding and flood management issues,
- invitations to forward written submissions including suggestions for possible flood management measures, and
- regular meetings with the Community Consultative Steering Committee which included representatives from the community, Council and other government agencies.

As part of the investigation the complete range of flood management measures investigated were explained to the FPMCC and thereafter to the community at each of the public meetings. The meetings were used as a forum to receive immediate feedback on community attitude towards the floodplain measures investigated and to consider any further suggestions put forward. All measures suggested by the community were considered and have been discussed in this report.

Two major considerations for flood management arose from the initial consultation phase. These were:
The community generally did not approve of levees designed to protect areas subject to flooding by the 1% AEP flood, but gave cautious support to a scheme which included flood walls, road raising and similar initiatives designed to provide protection against the 5% AEP flood, and
Strong support was given to the option of constructing a second lake between Ackerley Avenue and Faithful Street.

As a consequence the Community Consultative Steering Committee included a second lake and a range of measures designed to physically prevent flood waters entering onto developed land south of the railway line as part of the then preferred floodplain management option (Option G).

During the next two years a further and more detailed assessment of the environmental ramifications and economic benefit of constructing the second lake was undertaken and a comprehensive communications strategy was developed by Socom Public Relations.

The communications strategy was based on several assumptions which included that the memory of the 1993 floods had dimmed in many people's minds and complacency had occurred given that the upgraded flood warning system has been implemented.

The objective of the strategy was to assist the Benalla community to:

- be fully informed about the Water Management Scheme being proposed by the FPMCC,
- understand the level of flood protection that is being proposed,
- accept that the solution that has been reached is a fair trade off between:
- a reasonable level of protection (5% AEP flood)
- an acceptable level of cost,
- a fair distribution of that cost,

- a technical solution (levees, lake and vegetation management) that will enhance the recreational and lifestyle opportunities within the town, and
- accept that the "do nothing" option is not an option.

The communications strategy was divided into 4 phases which included:

Phase 1 Pre-launch – local residents.
The phase included small consultative group discussions with residents directly affected by the proposed measures with the aim of seeking their involvement in the design and/or approval of the proposals. Other actions included a public display of drawings of the proposals and meetings with politicians, Council staff, landholders adjacent to the Arundel Lake site, newspaper editors and key opinion leaders.

Phase 2 The Launch
This phase involved a media conference and advertizing of the location of displays and the availability of information, and an invitation to comment on the proposals.

Phase 3 Consultative Period
This phase included briefings to community service groups, church groups, etc,; a flood warning trial, a display of a computer based model of a flood simulation, and media briefings.

Phase 4 Close of Submissions

Actions during Phase 4 included the preparation of a media release giving details of the number of submissions, the issues raised and the timetable for the consideration of the submissions / decisions by other levels of government.

As part of Phase 1 of the strategy a series of ten neighbourhood meetings were held in areas that would be directly affected by implementing the preferred scheme (Option G). The purpose of the neighbourhood meetings was to enable residents to examine the effect the preferred floodplain management option would have on the local area and discuss with CCSC members any concerns regarding the proposals. The meetings were held during March 2001 in the following areas:

- Arundel Street: North of the railway line (the North West sector),
- Arundel Street: Railway to Bridge Street (part South West sector),
- Arundel Street: Bridge Street to Neilll Avenue (part South West sector),
- Neil Avenue: (part South West sector),
- Neil Avenue to McConnan Street (part South West sector),
- Midland Highway – McIvor Street – Ackerly Avenue (North East sector),
- Railway to Bridge Street (Mitchell Street, part South East sector),
- Bridge Street to Tower Road (part South East sector),
- Tower Road – Parkview Road – Samaria Road (part South East sector),
- Samaria Road to Willis Little Drive (part South East sector).

A summary of discussions held with residents during the neighbourhood meetings has been included in Appendix D which also includes a review of all written submissions received during the initial community consultation period.

11 PREFERRED FLOODPLAIN MANAGEMENT STRATEGY

11.1 Description of the Preferred Scheme

The hydraulic, economic, social and environmental performance of each potential scheme was considered by the FPMCC taking into account information provided by the Study Team as discussed in this report and comments provided by the public during a series of meetings. Based on these considerations the preferred floodplain management strategy adopted by the FPMCC is Scheme K.

Scheme K includes:

1. Environmentally sensitive vegetation management along waterways through Benalla with particular attention to:
   - ❑ On the river islands and floodplain from the lake extending upstream to the extension of Cowan Street
   - ❑ Downstream of the railway viaduct to Faithful Street
   - ❑ The environs of the Lake Benalla weir
   - ❑ The Market Street floodway

2 Provision of five culverts through the railway embankment near Duffy Street.

3 Provision of additional culverts at the East Main Drain

The scheme has been selected for the following reasons –

- ❑ Strong community support
- ❑ Excellent cost benefit ratio
- ❑ Significant reduction in the effects of flooding

The scheme does not provide protection from all floods and it is inevitable that flooding will reoccur in the future, however the effects of future flooding will be diminished. For floods in excess of the 5% AEP design flood occur the suite of non structural measures outlined in Table 10 will be used to manage flooding and reduce exposure to flood related damages.

The estimated cost of the scheme is $1.97 million, plus $29,000 per annum for ongoing maintenance. The estimated monetary benefits of the preferred scheme is $360,269 per annum. The benefit cost ratio [BCR] of the scheme is 2.58.

A suite of “non-structural“ measures as identified in Table 10 will be used to manage the flood and reduce the exposure to flood related damages historically experienced by the Benalla community

11.2 Consideration of other schemes

Detailed consideration has been given to a number of alternative schemes. The discussions on these schemes has been retained in the report to provide an understanding of alternative measures considered.

Scheme G5 avoids the need for an obtrusive network of levees but still provides a structural system of providing protection against floods up to and including the 5% AEP design flood. However following further detailed discussion with the GBCMA and DNRE the ecological effect of the loss of native riparian vegetation was considered too severe.

Due to the ecological damage that would be caused by construction of the lake and the estimated similar benefits in flood level reduction at a substantially lower cost offered by a vegetation management plan over the same area the FPMCC adopted Scheme H5. Scheme H5 differs from Scheme G5 only in that the proposed lake is replaced by a vegetation management plan covering the same area.

Prior to March 2001 Scheme H5 was the FPMCC's preferred scheme. This decision was based amongst other things, on an estimated cost effectiveness of the scheme.

During the final stages of this study further investigations were undertaken based on new floor level information. The revised floor levels resulted in a reduction in the number of buildings estimated to be subject to over floor flooding in a 5% AEP flood and as a consequence the Benefit Cost Ratio for Scheme H5 was lowered to an estimated 0.73 which is not considered cost effective.

In addition to the lowering of the estimated BCR for Scheme H5 to below 1.00 (the BCR break even value) the FPMCC acknowledged the continued noticeable lack of support for levees, and has therefore nominated a riparian vegetation management scheme as the preferred scheme.

The structural components of Scheme H5 include:

- landscaping to create linked areas of ground which is above the estimated 5% AEP flood level,
- flood proof fencing,
- road raising,
- implementation of a vegetation management plan which involves the selective removal of many of the trees and woody understorey vegetation covering the mid-stream islands at the upper end of Lake Benalla, the low lying ground from Parkview Parade to the confluence with Holland Creek, and between Ackerly Avenue and Faithful Street, combined with
- the implementation of a tree planting program in nearby non-critical flood area to ensure the continued long term integrity of the vegetation community, and
- additional culverts through the railway embankment in the vicinity of Duffy Street.

The vegetation management measures (De and NN) should provide the greatest economic benefit and the two measures combined represent the structural measures included in the preferred scheme (Scheme J).

A detailed description of the specific structural measures included in Scheme H5 follows:

South East Benalla

Landscaped earthworks would be used to create a "free from" continuous area of higher ground along the edge of the river parkland and generally following Fawckner Drive, Psaltis Parade, Parkview Parade and to the rear of properties in the Ascot Court area. Where appropriate brick fencing of a normally expected height appropriate to the building it bounds could be used in lieu of, or to supplement the landscaping. Such areas may include areas in front or to the side and rear of the public buildings fronting Fawckner Street. The height of landscaping and/or fencing along Fawckner Street would need to be no more than approximately 850mm above the road level.

The rear fence of factories in Lowry Place would be most appropriately replaced with a solid brick wall designed to withstand the force of floodwaters. Although no surveyed levels are available it would appear that this wall would not need be higher than the existing corrugated iron/paling fencing. Brick flood fencing would also be required between the end of Psaltis Parade and Tower Road, and along the southern boundary of properties in Samaria Road between the river and Stacey Street.

Free form landscaping would be used to create a line of higher ground near the western side of Psaltis Parade, Tower Street, and Parkview Parade. The higher ground which could be between or behind most trees lining the roads would need to be no more than about 1.3 metres above the level of Psaltis Parade and about 1.4 metres above Parkview Parade.

All of the new residential allotments created in the Shawbrook Estate on the eastern side of Samaria Road have been filled sufficiently to create areas at or above the estimated 1% AEP flood level. These levels are approximately 1.2 metres above the 5% AEP level and thus no further works are required between Samaria Road and Willis Little Drive in order to provide protection against the 5% AEP design flood. However should further development occur between the Shawbrook Estate and Willis Little Drive it is recommended that only areas which marginally encroach into the 1% AEP flood extent be considered for development and that such areas should be filled to at least the estimated 1% AEP flood height plus 300mm. This would allow for slab on ground construction without the need for further mounding under the buildings.

The intersection of Samaria Road and Shawbrook Avenue is above the 5% AEP flood level but part of the intersection is approximately 400mm below the 1% AEP flood. The future raising of Samaria Road should be included so that the intersection is above the 1% AEP flood level thus allowing increased safety during any future evacuation.

On the northern side of Bridge Road and east of the river protection against the 5% AEP design flood can be provided by;

- raising a short section of Mair Street by a maximum of approximately 300mm to eliminate a low point immediately north Bridge Street,
- raising Mitchell Street from approximately midway between Church Street and Benalla Street by a maximum of 400mm (at the Benalla Street corner),
- raising Mitchell Street and portion of the adjacent parkland between Benalla Street and the railway by a maximum of 1.5 metres.

No works are required at the western end of Church Street to protect against the 5% AEP design flood.

Additional railway culverts are to be provided between Duffy Street and the East Main Drain. The additional culverts will provide benefit for floods greater than the 5% AEP flood by noticeably lowering the flood levels in a radius of approximately 200m upstream of the culverts, and by assisting the more rapid dispersion of flood waters as the flood recedes.

South West Benalla

Works in south west Benalla that are required to provide protection against the 5% AEP design flood include:

- Landscaping along the edge of the recreational area adjacent to Arundel Street south of Bridge Street to create a ridge of higher ground, replacement of the side boundary fence of No. 111 Arundel Street with a fence of the same height.

- "Free form" mounding across the rear of Nos. 111 to 137 Arundel Street and a masonry flood wall along rear and southern side of No 137 and No 139 Arundel Street. Depending on the location the wall would be between 1.5 and 1.8 metres high adjacent to the house.

- The section of Neill Avenue between Arundel Street and Benson street is the worst area affected by flooding. In order to maintain the present vistas from houses in Neill Avenue as far as possible the proposed flood exclusion system is for a brick wall located behind the kerb line. This will allow the trees lining the road to be retained and the views of the parkland from the existing houses would be retained. A 4m wide gap in the wall would be required to provide maintenance and fire truck access tot he parkland. The gap would require a flood gate to be installed to maintain continuity of the flood wall. It is envisaged that the flood gate would be hinged and self sealing under the pressure of flood water. The embankment/wall would extend from the corner of Arundel Street and Neill Street to Hair Street..

- From Hair Street to the eastern end of Waller Street "free form" landscaped mounding would be located on the open space.

- North of Bridge Road the preferred measure is to raise part of Arundel Street. Commencing at Wedge Street, the level of Arundel Street would be gradually raised to a maximum of 350mm above the existing level at the intersection with Kent Street. At the Deas Street intersection the road would be 400mm higher than at present.

Some modifications to the street drainage system are also likely to be required to allow runoff to drain towards the West Main Drain during high river levels.

North Benalla

On the eastern side of the river the road would be raised from the Nunn Street railway crossing to Ellen Street. From Ellen Street to Roe Street the existing rear boundary fences of properties in Maginness Street and McIvor Street would be replaced with brick fencing of the same height. Fences of this height would be sufficient to protect properties from the adopted 5% AEP flood. The fencing would be continued across the end of McIvor Street and extended to Roe Street. The western end of Roe Street is above the 5% AEP flood and the road would need to be raised by approximately 200mm only to provide 600mm freeboard against the 5% AEP flood. Flood protection would be completed with low level mounding along Commercial Road within the road reserve as required.

The area can be drained by a gravity system under 5% AEP peak flood level conditions.

On the western side of the river there is no practical barrier system of preventing flood waters entering this area. Flood levels can however be lowered by implementing a vegetation management plan for the river reach between the railway and Arundel Street. The vegetation management plan would require the creation of clear overland flow paths a minimum 10 metres wide between the trees while retaining those trees critical for habitat and the general ecological sustainability of the riparian corridor. The part excavation along the western side of the midstream island downstream of Ackerly Avenue is a complementary measure which would provide an additional small benefit by creating additional localized flood capacity. The area which would be excavated supports predominantly exotic trees species or native trees of low habitat value.

Replacement planting of appropriate native species would be required on the fringes of the 1% AEP flood extent and beyond to compensate for the loss of vegetation within the main flood flow path.

11.3 Hydraulic Performance

11.3.1 Scheme H5

Scheme H5 will have no adverse effect on the 2% AEP, 1% AEP or greater floods. The components of the scheme designed to prevent flood waters entering given areas would cause a small increase in the 5% AEP flood level in some areas but the proposed removal of a significant amount of the obstructing trees and understorey growth occurring on the river flats near the confluence of Holland Creek and the river will compensate for the possibility. Downstream of the railway viaduct the vegetation management plan is estimated to reduce 1% AEP flood levels by up to 210mm near Ackerly Avenue and lesser amounts for smaller floods. The effect of the vegetation management plan extends upstream towards Bridge Road although the effect diminishes as the distance upstream increases.

South of the railway viaduct all residential and commercial properties will be protected against the 5%AEP design flood with the exception of a small number of properties adjacent to the river. Unprotected properties include two in Samaria Road near Holland Creek, those on the eastern side of Arundel Street north of Bridge Street, and on the western side of Mair Street and Mitchell Street.

North of the railway unprotected buildings would include 3 residential properties on the south side of Maginess Street, the sports and leisure centre complex and a small group of buildings north west of the intersection of Roe Street and Commercial Road.

Properties west of the river and north of the railway would benefit from lower flood levels for all floods equal to or greater than the 5%AEP flood.

11.3.2 The Preferred Scheme (Scheme K)

Scheme K will provide overall benefits by lowering flood levels within the urban areas across the full range of floods up to and including the 1% AEP flood. The largest decreases in the 1% AEP flood will be in the vicinity of the East Main Drain immediately upstream of the railway where localized decreases of more than 300mm can be expected. Elsewhere the decrease in the 1% AEP flood will be smaller and generally limited to a maximum of 200mm close to the river. Downstream of the railway decreases in the 1% AEP flood level will generally be no more than 100mm. A small increase in the level of the 1% AEP flood (approximately 50mm) is expected near the end of Faithful Street due to the greater hydraulic efficiency of the river following the selective clearing of vegetation.

A summary of the effect on the number of properties following implementation of the structural components of the preferred scheme are given in Table 14.

11.4 Social and Environmental Impacts

Schemes H5, J and K have been designed to cause the least disruption to the community. Scheme H5 however requires the creation of areas of higher ground within existing parkland and which will generally be of a height which can be readily blended with existing facilities and uses. The newly created areas of higher ground will be below eye level and would not be expected to block or severely disrupt existing views. In a number of cases rear and/or side boundary fences, some of which are in poor condition, would be replaced with permanent brick fencing no higher than the existing fence and thus would be expected to add to the property value.

Where roads require raising the generally wide road reserves would allow all or much of the required height to be achieved by increasing the cross fall on the road. Re-grading of private driveway crossings are likely to be required in some instances but none are expected to appear intrusive or otherwise cause appreciable disruption to existing patterns of movement.

The preferred Scheme (Scheme K) does not include road grading or the creation of areas of higher ground. The visual impact would be restricted to a small thinning of mature trees and a reduction in understorey vegetation in critical areas close to the river channel. In each instance the reduction in vegetation would be compensated by further planting in areas non critical with respect to flooding.

TABLE 14
SUMMARY OF PROPERTIES FLOODED ABOVE FLOOR FOR SCHEME K

Locality	5% AEP		2% AEP		1% AEP	
	Existing	Scheme K	Existing	Scheme K	Existing	Scheme K
<u>Residential</u>						
South East	0	0	122	56	429	273
South West	16	6	193	148	338	267
North East	18	17	39	36	87	56
North West	2	1	7	5	23	23
<u>Commercial</u>						
All areas	21	13	138	109	208	176

11.5 Economic Aspects

11.5.1 Scheme H5

Scheme H5 is considered economically viable for all discount rates of 6% or less. In the current low inflation environment a maximum discount rate of 6% is considered appropriate. Under this scenario the preferred scheme has a benefit cost ratio (BCR) of 0.77. This rate is higher for lower discount rates (eg. BCR = 1.26 for a discount rate of 3%). The flood damage estimate used to calculate the BCR is expected to represent a lower value than the actual due to the difficulty in quantifying some damages including intangible damages. An attempt has been made to quantify the secondary costs which include damage to roads and infrastructure as well as loss of trade, and the cost of personnel health issues attributable to flooding. These costs were assessed as a percentage of the direct damages (damage to residential and commercial buildings, loss of household items, stock, clean up). The secondary costs have been estimated as varying between 5.1% for the 10% AEP flood to 9.6% for the 1% AEP flood. Details of the assessment of secondary costs are included in Appendix A. There is some anecdotal evidence that intangible damages may be higher than the figures suggest but no reliable data is known to the Study Team and has therefore not been included. If a nominal allowance of 33% is made then the BCR is increases to 1.56 when calculated at a discount rate of 6%.

Among the individual measures included in Scheme H5 the vegetation management measures (D_e and NN) provide the greatest economic return (Refer Scheme J). The BCR for implementing Measures D_e and NN only has been estimated as 6.01 at a discount rate of 6%. Vegetation management alone however does not provide protection against the 5% AEP flood to the same large number of properties that would benefit from implementing Scheme H5.

11.5.2 Preferred Scheme (Scheme K)

Scheme K includes 3 of the most economically attractive measures (Measures VM – vegetation management, and Measure C – Duffy Street Railway culverts).

As a consequence the economic performance of Scheme K is high. The cost benefit ratio being an estimated 2.58 based on a discount rate of 6% over 20 years. The monetary benefit (reduction in annualized flood damages) is an estimated $360,269

11.6 Further Recommendations

It is noted that since the first draft of this study was prepared in 1996 many of the following recommended controls have been incorporated into draft local planning and building development controls.

11.6.1 Building and Development Controls

The recommended floor level requirements may be summarized as follows:

Re-development

- ❑ Residential floor levels to be a minimum of 300mm and preferably 500 mm above the 1% AEP flood level.

- ❑ Commercial/Retail floor levels to be at or above existing floor levels for minor extensions. Minor extensions would be classed as a "one off" extension equal to 10% of the footprint area below the 1% AEP flood level up to a maximum of 50m^2. Where these levels are less than 600 mm above the 1% AEP flood level provision must be made to protect the building and contents from damage using appropriate means approved by Council. In the cases where stock cannot be stored on shelves a permanent reliable stock removal and evacuation procedure which does not rely on emergency service resources must be demonstrated to the satisfaction of Council. For major re-development floor levels should be no lower than the 1% AEP flood level with flood proofing up to at least 300 mm and preferably 500mm above the 1% AEP flood level. However where it can be demonstrated to the satisfaction of Council that compliance with the floor level requirements is likely to affect the commercial viability of the re-development the requirements may be relaxed. Any relaxation of floor level requirements however should still ensure that a minimum of 70% of the footprint area below the 1% AEP flood level is raised above the 1% AEP flood level to allow the temporary re-location and storage of stock above floodwaters.

- ❑ Industrial floor levels would be the same as for commercial buildings and with specific reference to the storage of hazardous goods.

New Development

- ❑ Residential floor levels to be a minimum of 300mm and preferably 500 mm above the 1% AEP flood level.

- ❑ Commercial/Retail floor levels to be a minimum of 300mm and preferably 500 mm above the 1% AEP flood level except in special circumstances where it can be demonstrated to the satisfaction of Council that compliance with the floor level requirements is likely to affect the commercial viability of the development. In these circumstances any relaxation of floor level requirements should still ensure that a minimum of 70% of the footprint area below the 1% AEP flood level is raised above the 1% AEP flood level to allow the temporary re-location and storage of stock above floodwaters.

- ❑ Industrial floor levels to be a minimum of 300mm and preferably 500 mm above the 1% AEP flood level and with specific reference to the storage of hazardous goods.

Development to Include Fencing and Landfill

For purposes of assessing the likely impact on flooding, development should be defined so as to include all fencing and other permanent or semi-permanent structures, fixtures etc. Where the cumulative effect of fencing small allotments is deemed significant an area policy on fencing should be defined.

In some cases of re-development it may be appropriate to achieve the required minimum floor levels by filling the flood liable site. In all such cases checks should be made by a suitably qualified and experienced engineer that the filling will have no discernible adverse impact on flood levels or velocities for the surrounding areas. The checks should be carried out for at least the 5% AEP and 1% AEP floods.

In the case of new sub-divisional development the flood liable land all access routes should be filled to at least the 1%AEP flood level and building lots to 350mm higher. By raising the building lots 300mm above the 1% AEP flood level slab on ground construction can occur and still achieve floor levels which are the recommended minimum 600mm above the 1% AEP flood level.

The following sections outline the controls which are typically applied for each of the zones and which are recommended for adoption in Benalla.

11.6.2 Voluntary Purchase

One property is recommended for voluntary purchase although based on our understanding of recent survey of this property and discussions with the owners that a masonry flood wall constructed along the rear and southern side boundaries is both feasible and acceptable to the owner.

11.6.3 Flood Warning System

Infrastructure

Installation of an upgraded system has recently been completed which has the potential to provide Benalla with sufficient warning times to mobilise a planned emergency response which includes the progressive evacuation of residents as necessary. No further field infrastructure work is considered necessary at this time.

It is understood that the production of flood inundation maps is in progress. Such maps should identify priority areas and evacuation routes. It is recommended that ultimately the information provided by the maps should be incorporated into a GIS which can be directly linked to a hydrological – hydraulic model used to predict flood levels. It is envisaged that the GIS would include property addresses and floor levels to assist the emergency services in evacuating residents. The technology for a linked system is available and should be pursued.

Flood Emergency Response Plan, Dissemination of Warnings and Public Education

A Flood sub-plan has recently been completed and which is to be subjected to periodical review. This is in accordance with earlier recommendations contained in the 1998 Draft Floodplain Management Study Report. In addition there is a planned test of the system in August of each year. The Flood sub-plan should not rely on the assistance of Defence Forces personnel.

The critical need is for the flood forecast to be disseminated in a manner that is clear to individual households. A vigorous and sustained education campaign will be required to ensure as far as practicable that all residents are familiar with the flood risk relevant to their locality and the procedures to be adopted during an impending flood. It is recommended that as part of the public awareness program that;

Flood height markers indicating the level of the 1993 flood be located at convenient locations throughout the town. Flood warnings issued to the community can then be described relative to this flood.

In an effort to avoid previous difficulties with flood warnings issued via the media it is strongly recommended that the practice of following up initial flood warnings via the telephone and advising of when updates will be provided should continue.

A system of direct door knocking by trained personnel should be established. This may include the use of a warden system.

Typically the wardens would receive the warnings and projected peak heights and times from the VICSES and would then inform the residents in their areas of responsibility what the warnings mean in relation to them and their property. Out of flood time, the wardens could assist the VICSES in public education and awareness and the reporting of damaged or lost street flood markers. Much of the wardens role is viewed as reinforcing information broadcast during an emergency and maintaining residents awareness of the relevance of the flood risk.

A mobile system broadcast from vehicles moving through the streets is also a valid system and is an acceptable alternative for Benalla.

11.6.4 Evacuation

<u>New Development</u>
It is most important that appropriate evacuation strategies, commensurate with the flood risk, be in place for all new development on flood prone land as there is always the possibility that a flood of greater magnitude than the design flood will occur.

For all new developments control policies should require applications to demonstrate that a satisfactory evacuation strategy will be available to service a proposed new development. The application should address the following issues:

- ❑ the ability of residents or occupants of the proposed development to have access to the flood warning system;

- ❑ the role of the development in the police emergency evacuation strategy. Whilst this strategy is recognized as an emergency backup, all new developments should demonstrate the ability for residents/occupants to evacuate without adding to the burden that already exists on the emergency services;

- ❑ the means of evacuation from the proposed development to an area of negligible flood risk and which has ready vehicular access to a communal flood refuge/assembly area. The application should include details of the depth, velocity of flow and distance to be travelled through flood waters.

Evacuation by boat is dangerous and slow and should not be contemplated as an evacuation strategy for new development.

Inherent in any wading route determined to be "safe" is the necessity for clearly marked routes with stable even submerged surfaces which minimize the potential for loss of foothold for evacuees.

<u>Existing Development</u>

For existing development improved efficiency and safety associated with evacuation can be achieved by:

- ❑ the effective dissemination of a flood warning using the measures described elsewhere in this report,

- ❑ the emergency evacuation plan. Whilst the existence of the evacuation strategy, for which the police are responsible, is recognized as an emergency backup, provision for self evacuation should be made if at all possible. Evacuation will be assisted by improved and/or clearly marked access routes and assembly areas/refuges.

Access Improvements

In order to maximize the safety of all rescue personnel and residents, roads which are known to be subject to flooding should be clearly defined by markers on each side to enable evacuation by high wheel based road transport to continue in relative safety in the event that evacuations have not been completed prior to the road becoming flooded. Dips in roads identified as part of an evacuation route should be eliminated and preferably be constructed so that the road/route rises continuously to the refuge/assembly point.

One area of principle concern in Benalla is the residential area bounded by the Broken River and its anabranch near the Showgrounds. The depth of water flowing along the anabranch during the height of a 5% AEP flood is estimated to be approximately 1.3 metres and approximately 2 metres during a 1% AEP flood.

Residents in this area are considered to be at greatest risk and access improvements are strongly recommended. The preferred evacuation route is via Benson Street and west along Maud Street. The low point occurs in Benson Street between Garden and Maud Streets where the depth of flow across the road in a 5% AEP flood is an estimated 1.3 m. Raising of the road to at least the 5% AEP flood level and the provision of concrete box flood culverts with capacity to pass the estimated 5% AEP anabranch flow is recommended as a priority measure. This will allow access to Maud Street west of Benson Street where the road rises. The route would remain navigable for vehicles even though it would be overtopped during the 1% AEP flood. The raised road and culvert must not cause discernible increases in flooding upstream private properties.

In many cases improvements to road surfaces and grades may be undertaken over several years by filling of local low points as opportunities arise during normal road maintenance. Any evacuation route should be on a continuously rising grade away from the floodplain and should be an all weather surface to minimize potential washouts.

11.6.5 Assembly Areas/Flood Refuges

The 1993 flood highlighted some difficulties in respect of "safe" assembly areas where evacuees may be registered and provided with food and shelter.

In 1993 the High School and Technical School were used as full evacuation centres where evacuees were fed and housed. However the schools improvements in basic facilities would be required if they are to be used as assembly/refuge areas in the future. Ideally the evacuation centres should be significantly above the 1993 flood level but no suitable large facility(s) in such a location has been identified. Should council consider the provision of a multi-purpose community centre/hall in the future it is recommended that it be sited on land at least 1 metre above the 1993 flood level and have direct land connections to areas outside Benalla. Given that the river bisects the town there is an arguable case for two such facilities, one on either side of the river.

In the absence of any other suitable buildings standing arrangements with the schools and Department of Education to use the facilities should be sought and funding obtained to provide the basic requirements for the temporary housing of evacuees.

11.6.6 Relocation of Emergency Services

During any future planning for emergency services consideration should be given to relocating the services in areas beyond the 1993 flood extent. Where this is not practical and new multi-purpose community centre(s) are built as discussed above, the new facilities should include provision for the temporary re-location of the services to part of these buildings during a flood emergency.

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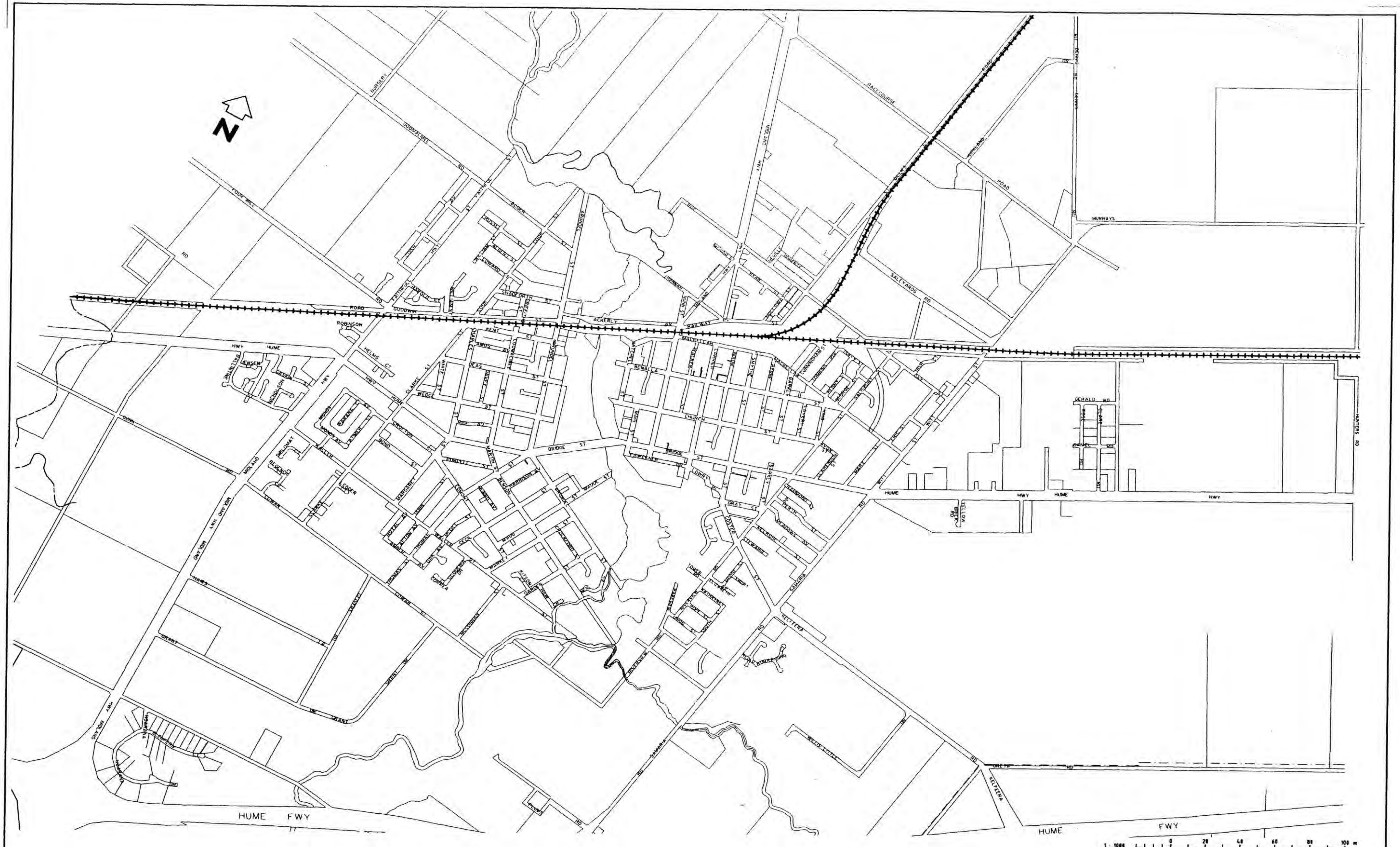

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FOR
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BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE
STUDY AREA

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FIGURE 1

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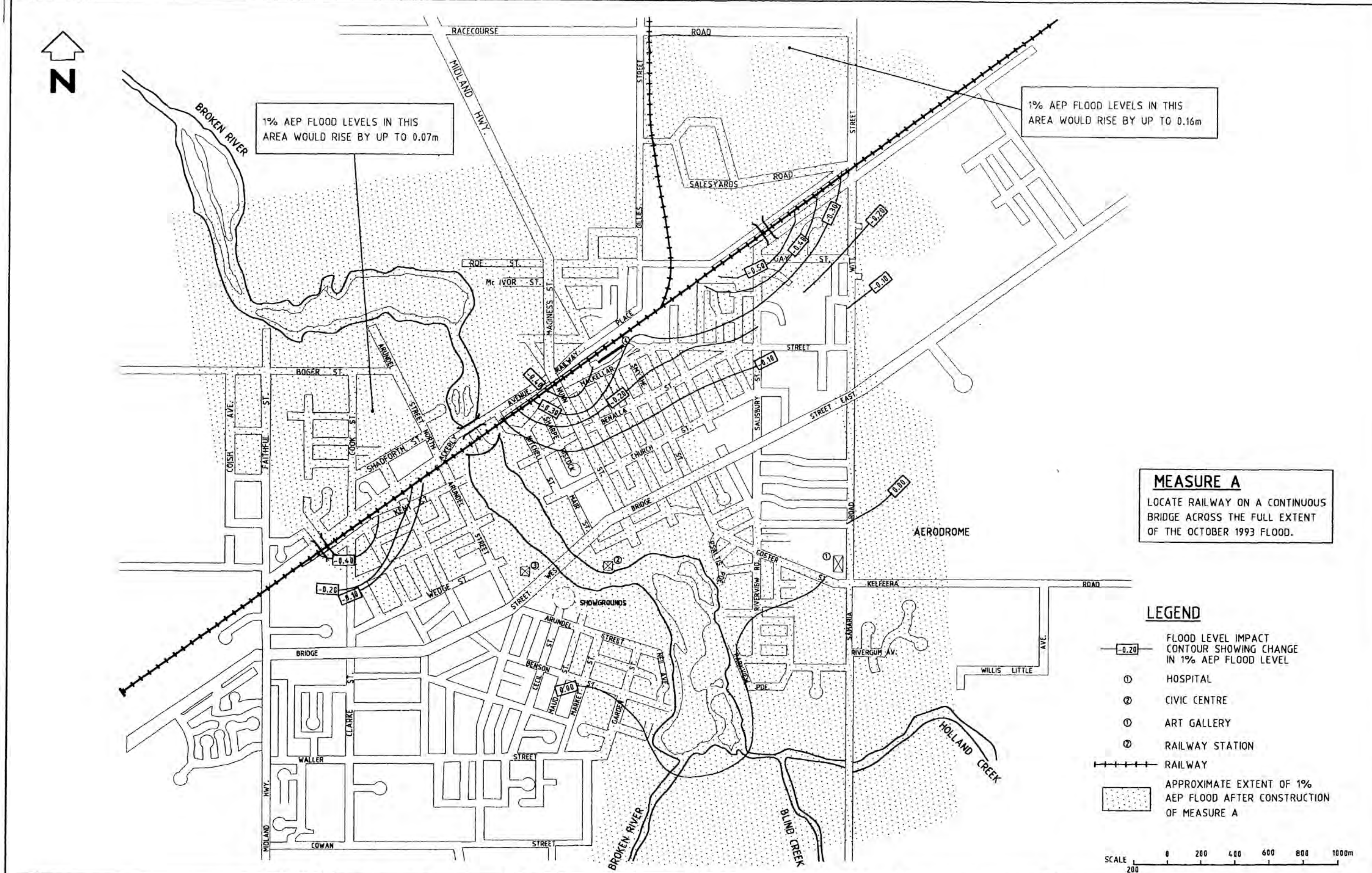

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IMPACT ON 1% AEP FLOOD LEVELS MEASURE A

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FIGURE 3

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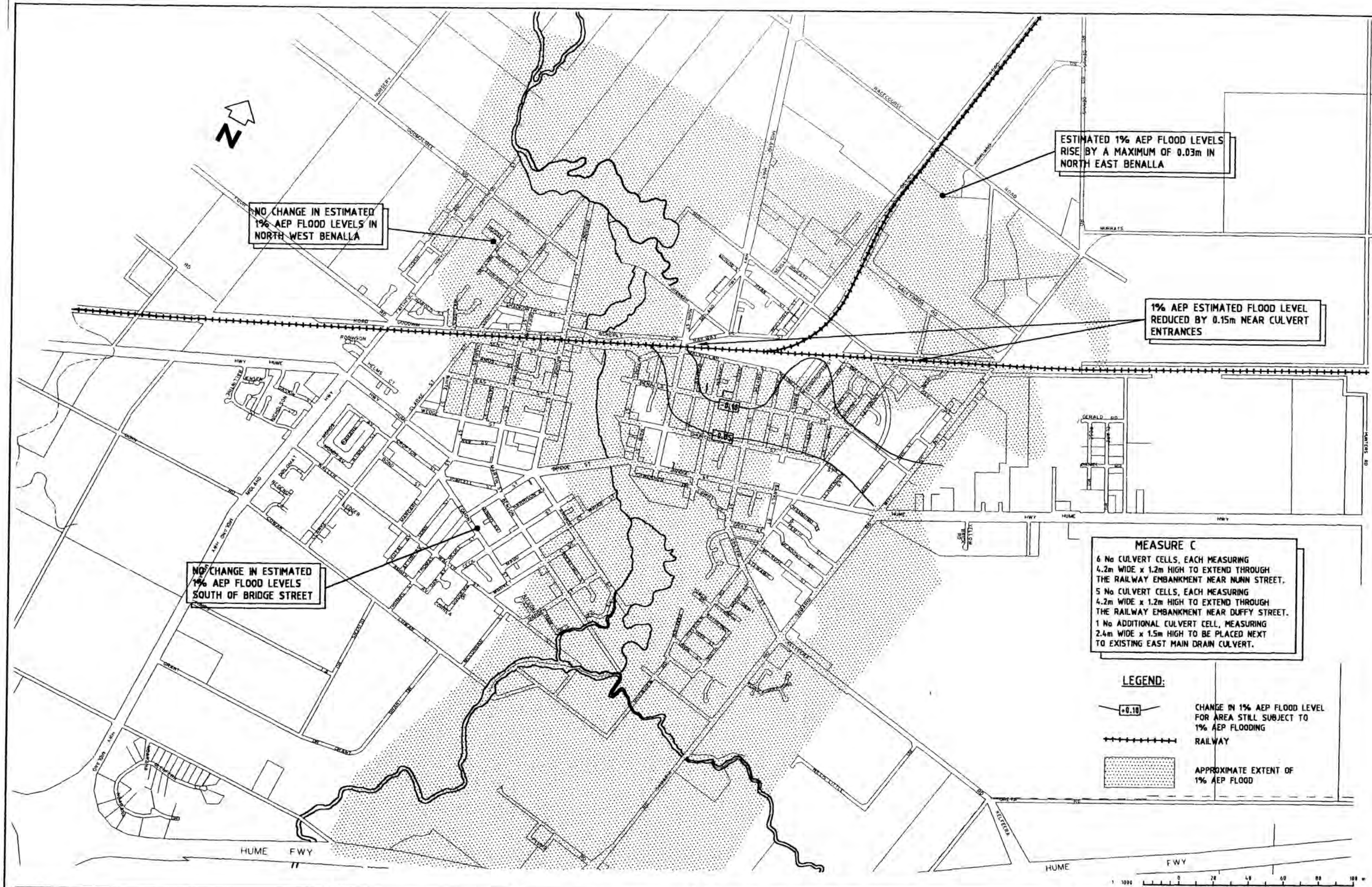

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TITLE: IMPACT ON 1% AEP FLOOD LEVELS MEASURE C

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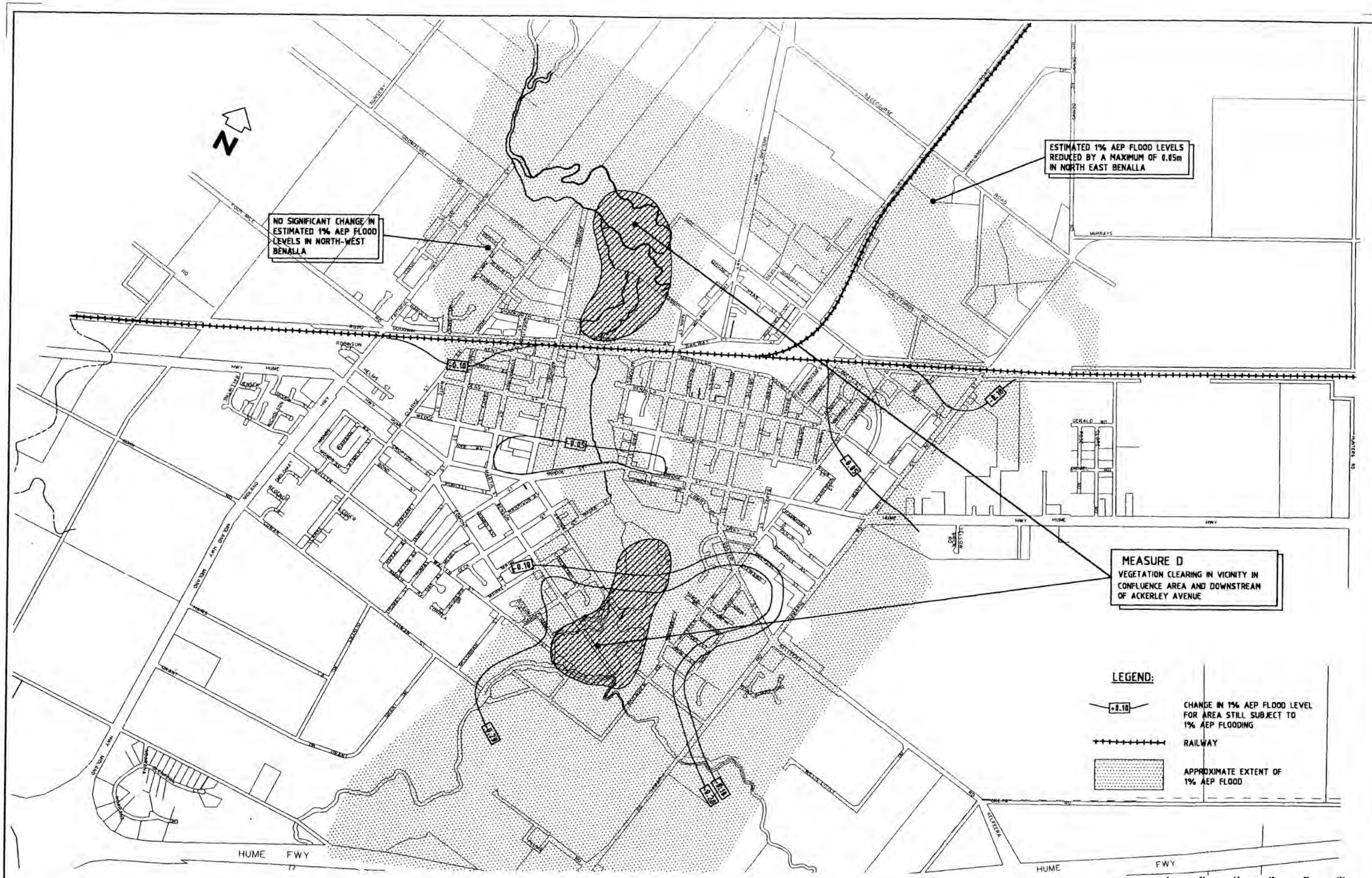

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BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE
IMPACT ON 1% AEP FLOOD LEVELS MEASURE De

FIGURE 5

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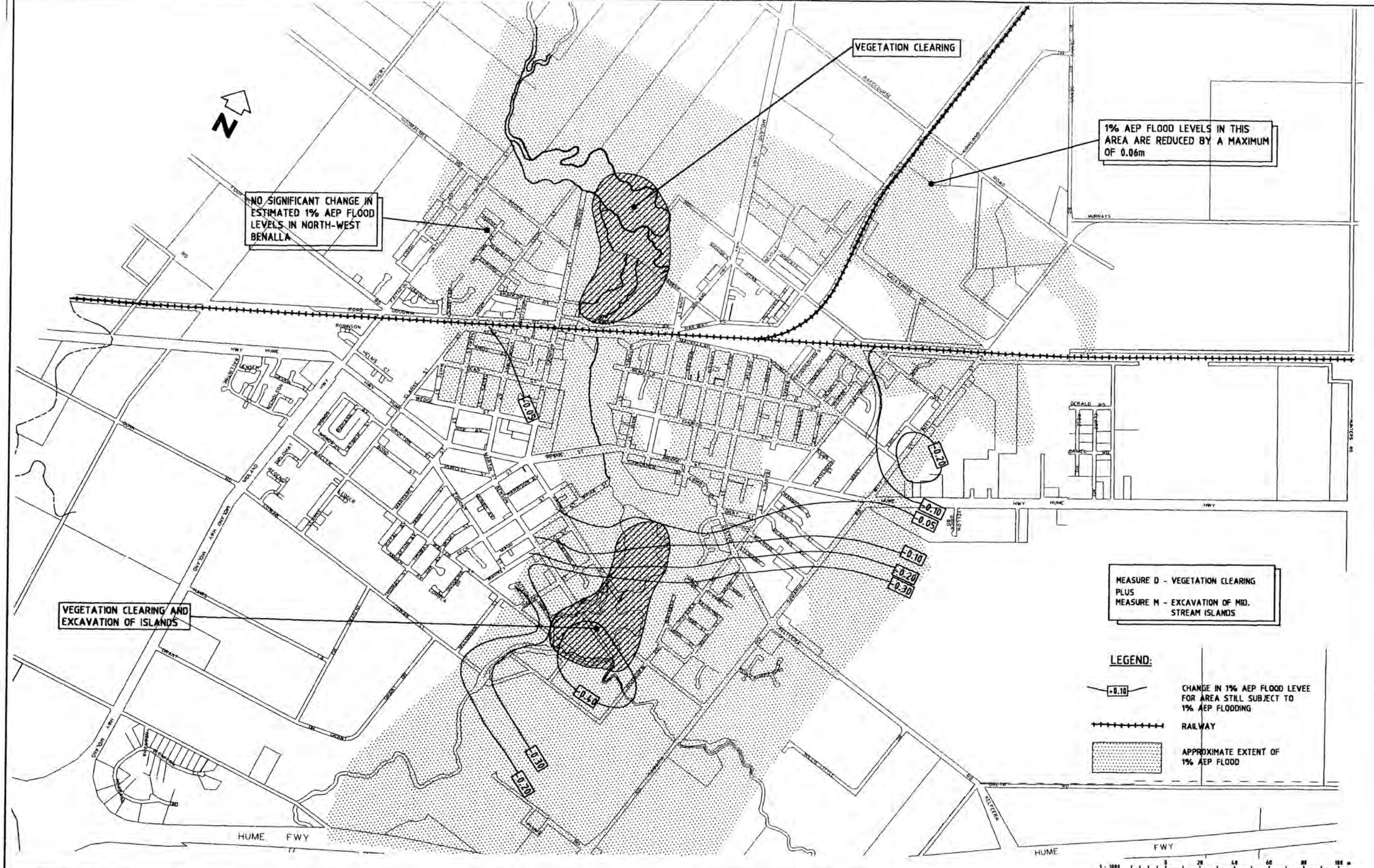

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IMPACT ON 1% AEP FLOOD LEVELS MEASURE De & M

FIGURE 6

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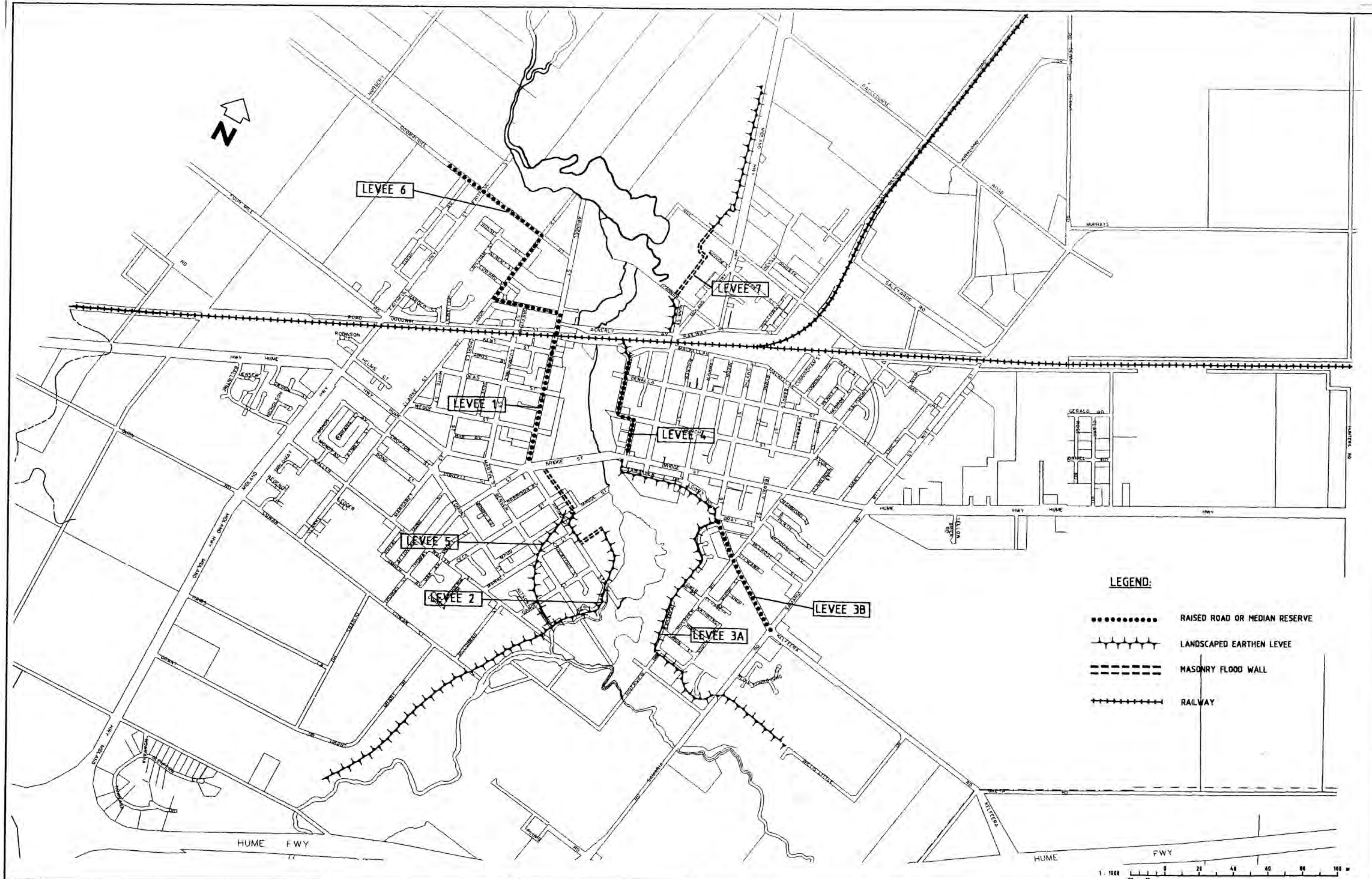

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BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE
LOCATION OF LEVEES

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FIGURE 7

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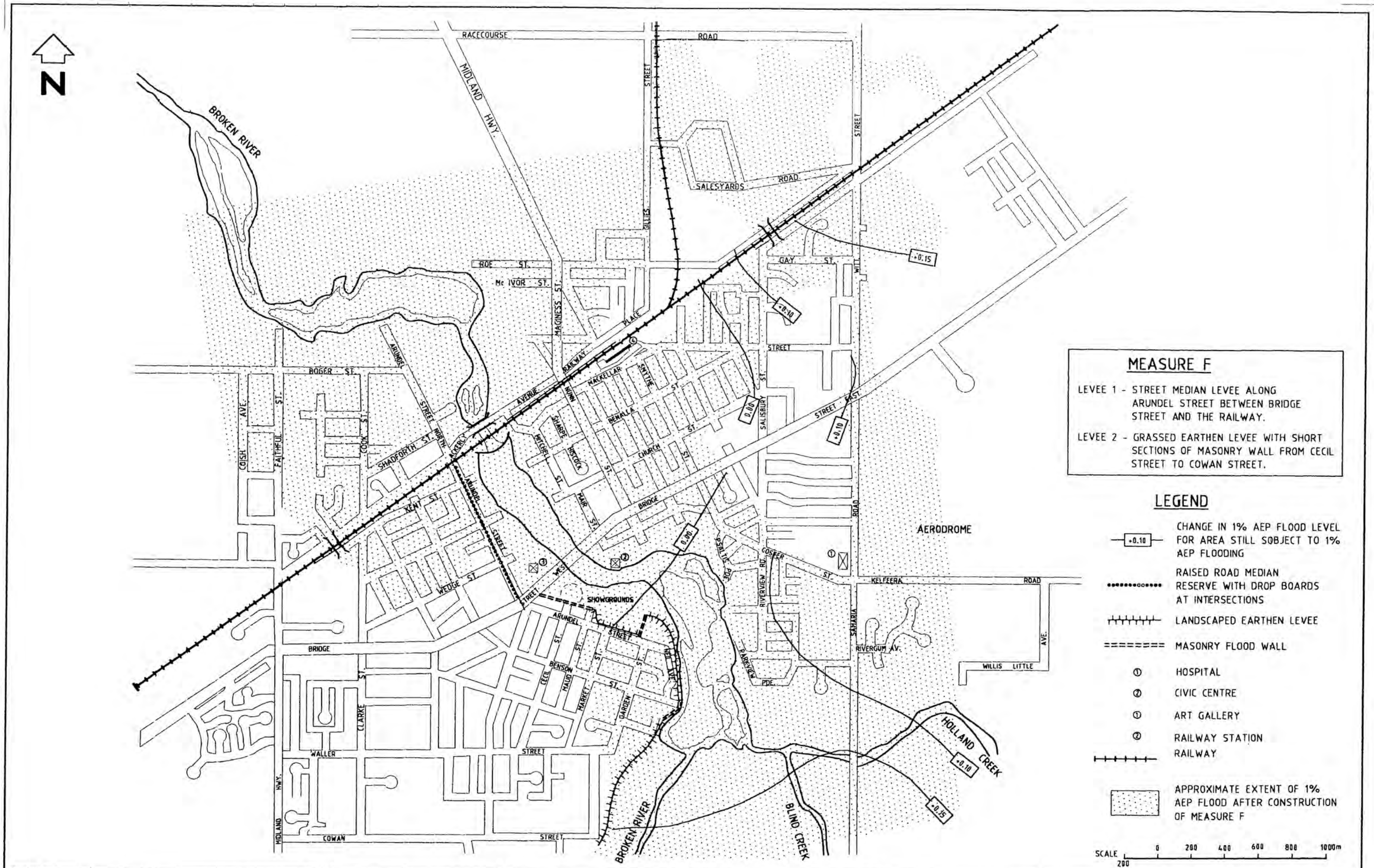

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PROJECT: BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE: IMPACT ON 1% AEP FLOOD LEVELS MEASURE F

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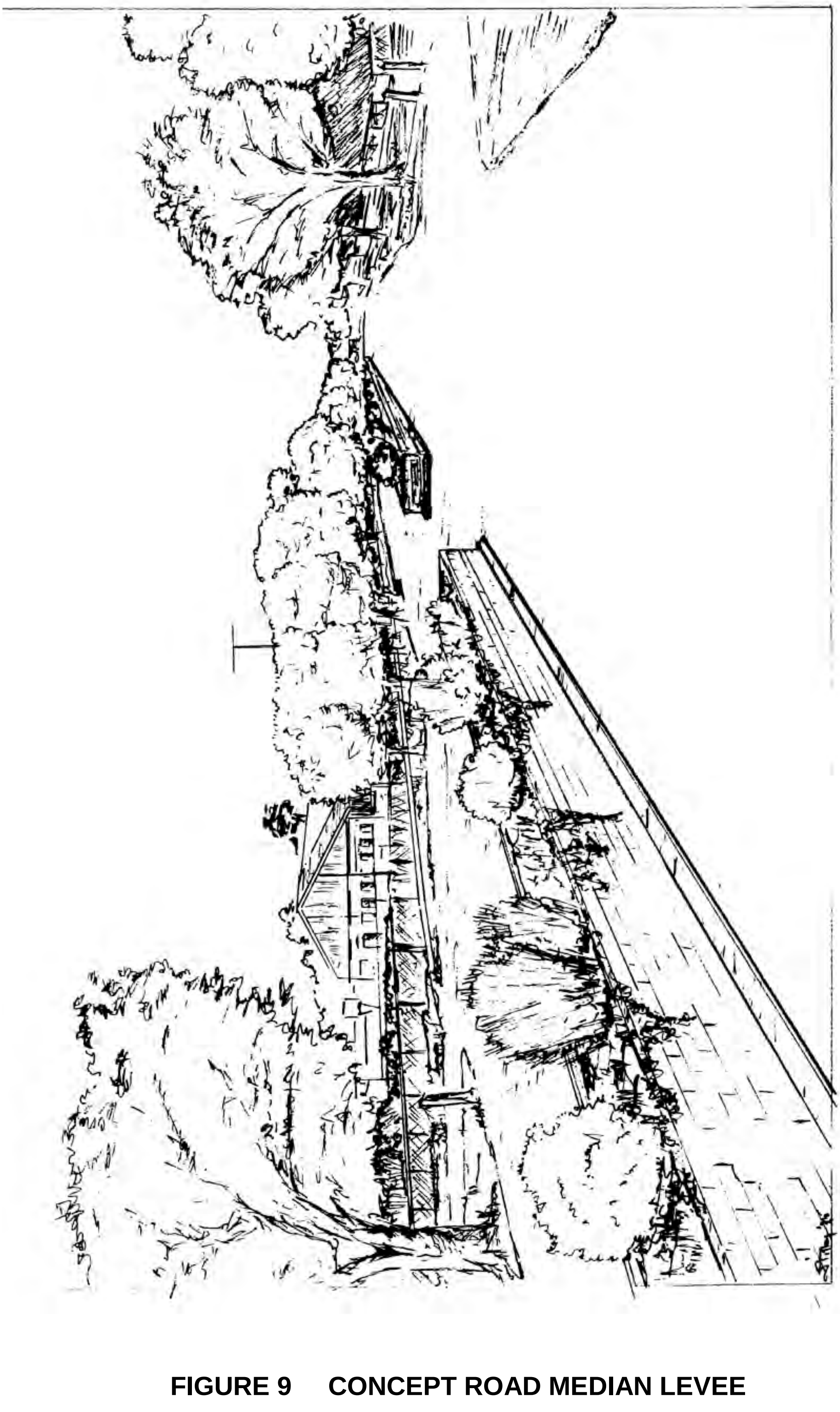


FIGURE 9 CONCEPT ROAD MEDIAN LEVEE

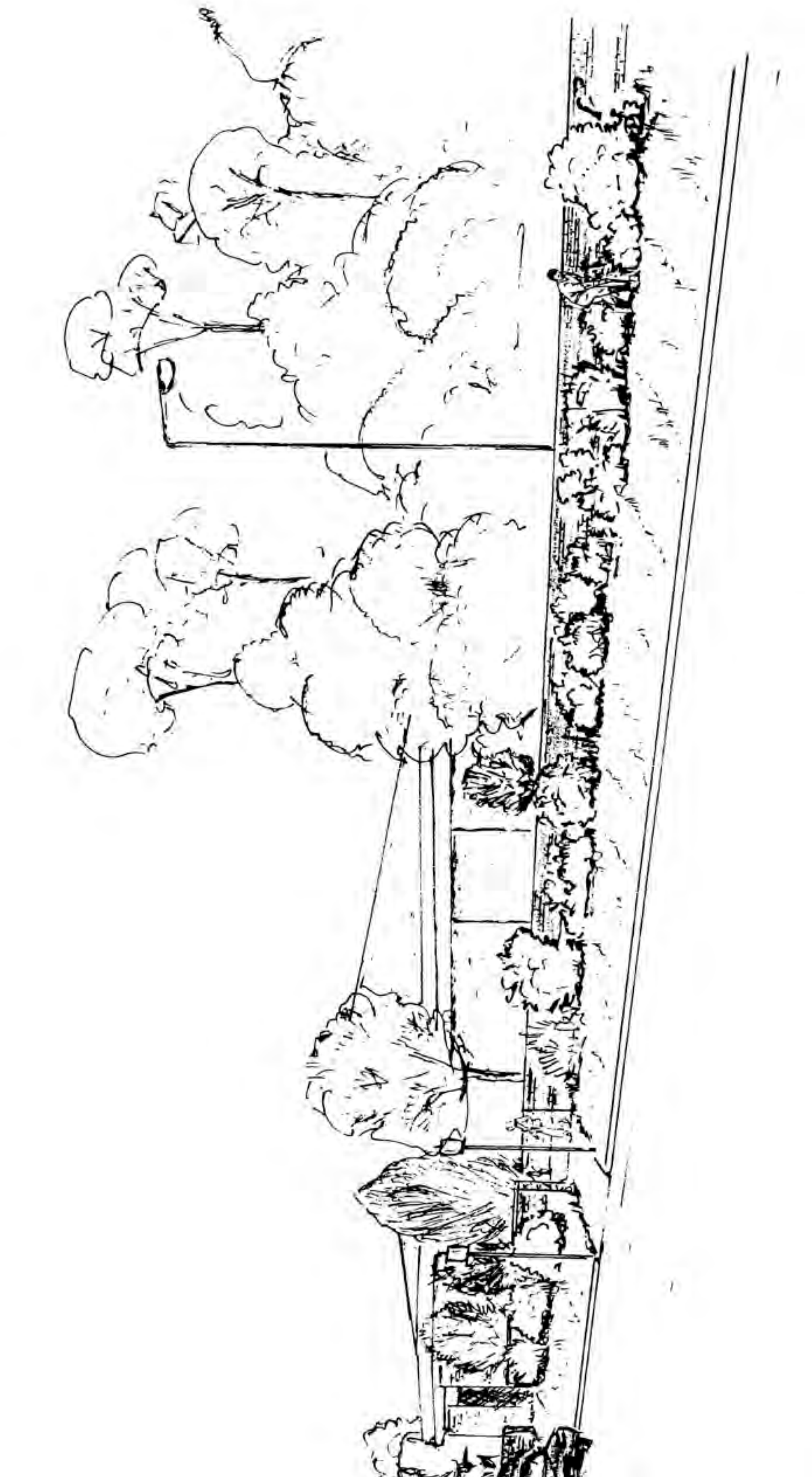


FIGURE 10 MASONRY FLOODWALL WITH SCREEN PLANTING

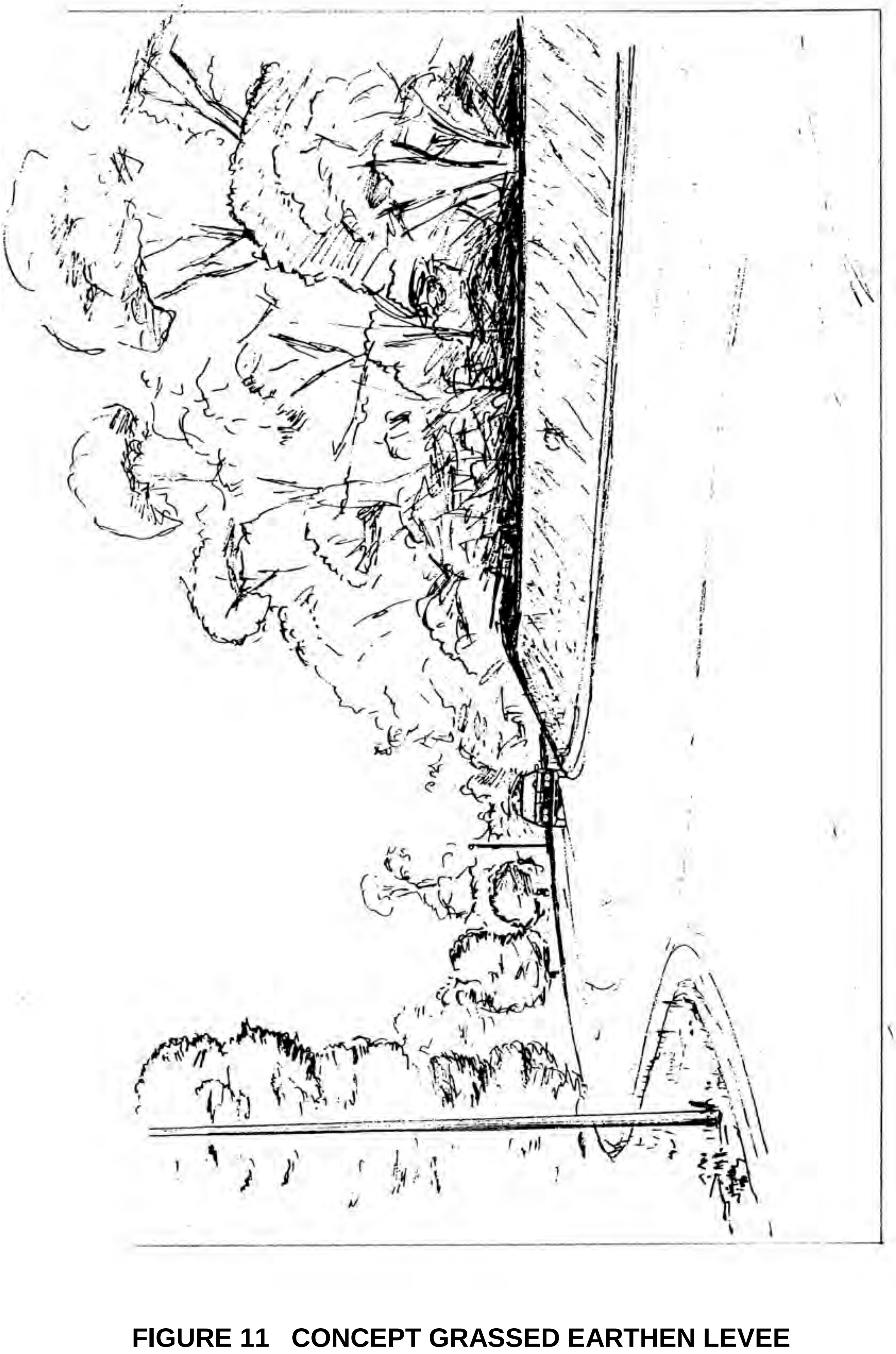


FIGURE 11   CONCEPT GRASSED EARTHEN LEVEE

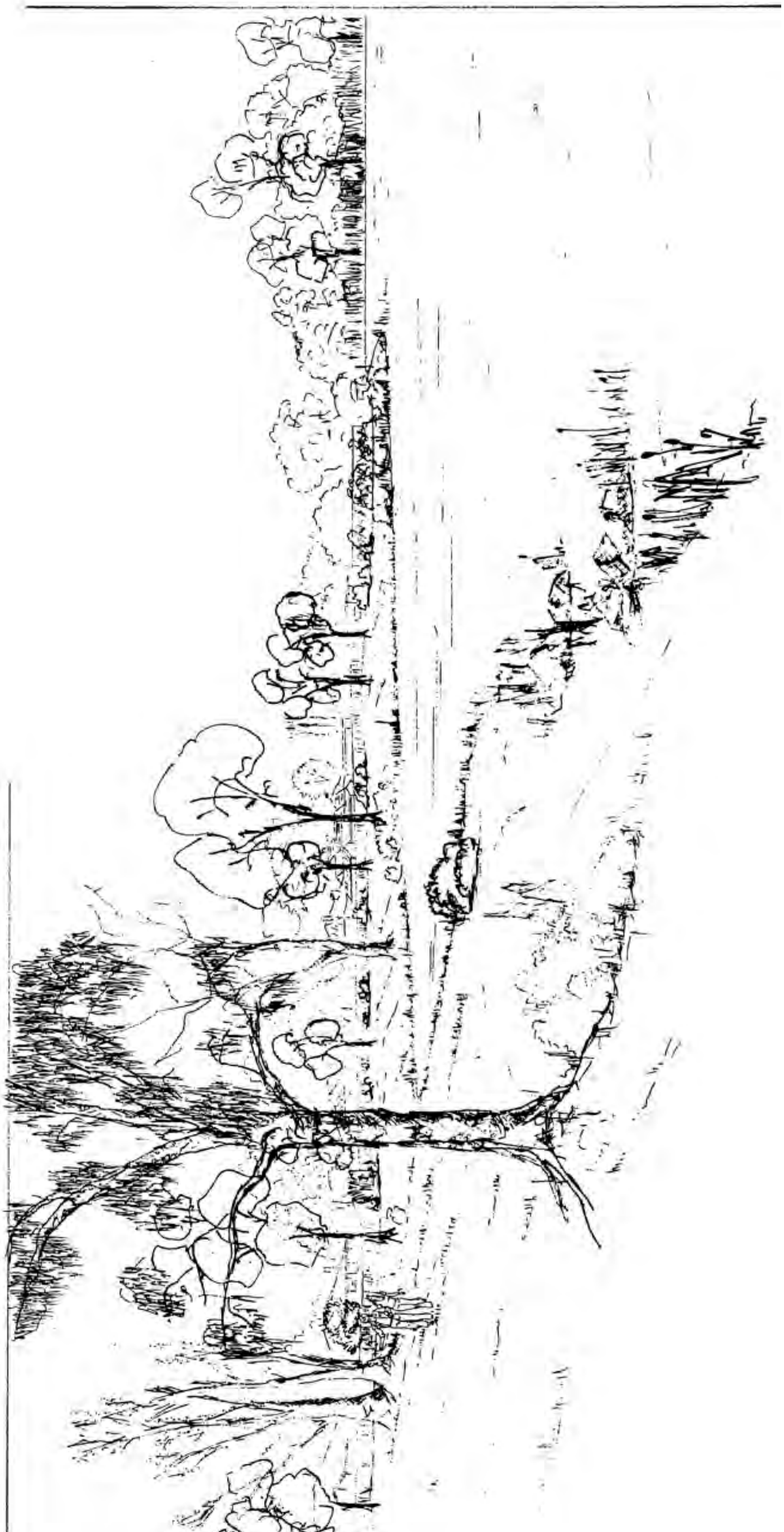
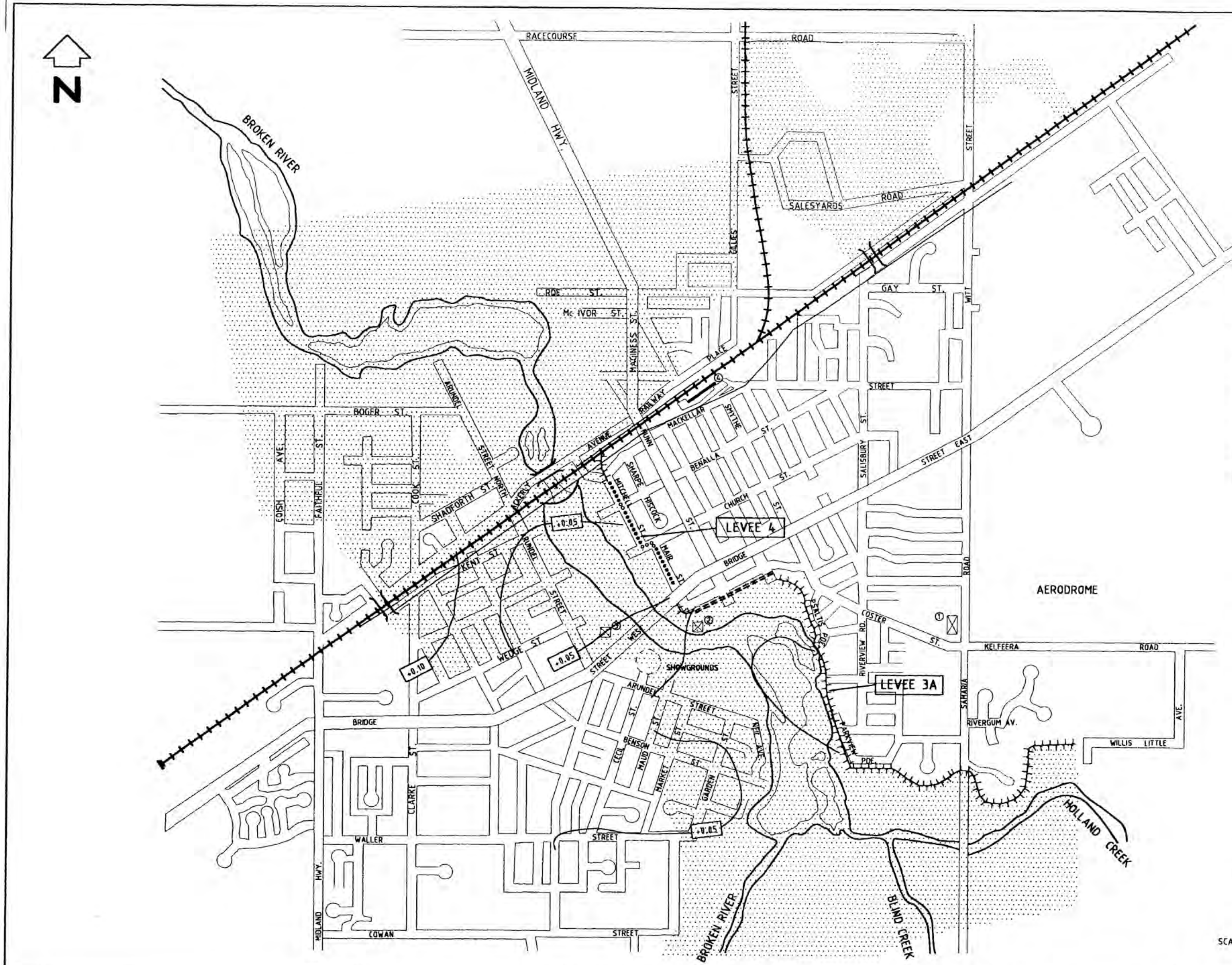


FIGURE 12 CONCEPT ARUNDEL LAKE



MEASURE I

CONSTRUCTION OF LEVEES ALONG THE RIGHT RIVER BANK FROM THE RAILWAY EMBANKMENT TO WILLIS LITTLE DRIVE.

THE LEVEES WOULD INCLUDE SECTIONS OF ROAD MEDIAN LEVEES, MASONRY FLOOD WALLS LANDSCAPED EARTHEN EMBANKMENT.

LEGEND

- [+0.10] CHANGE IN 1% AEP FLOOD LEVEL FOR AREA STILL SUBJECT TO 1% AEP FLOODING
- RAISED ROAD MEDIAN RESERVE WITH DROP BOARDS AT INTERSECTIONS
- LANDSCAPED EARTHEN LEVEE
- MASONRY FLOOD WALL
- ① HOSPITAL
- ② CIVIC CENTRE
- ① ART GALLERY
- ② RAILWAY STATION
- RAILWAY
- APPROXIMATE EXTENT OF 1% AEP FLOOD AFTER CONSTRUCTION OF MEASURE I

SCALE 200 0 200 400 600 800 1000m

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FOR DELATITE SHIRE COUNCIL

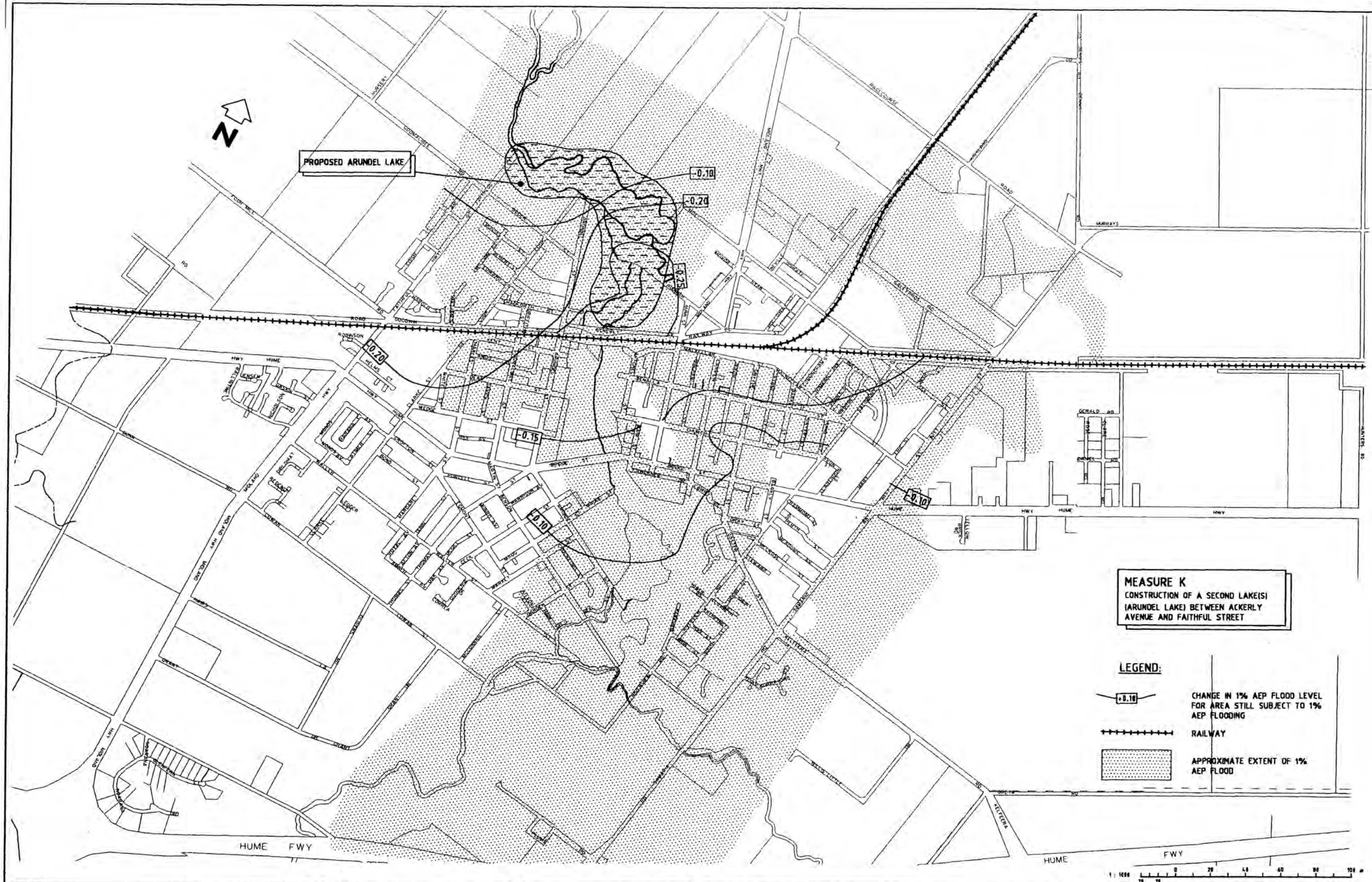
PROJECT: BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE: IMPACT ON 1% AEP FLOOD LEVELS MEASURE I

DRAWING No: FIGURE 13

on original A1

CAD ref: \3307\3307-F12.DWG, PLOT SCALE:1:1, DRAWN:T.T., DATE:29/09/98, AutoCAD r13, international.



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CO-ORDINATE SYSTEM	HEIGHT DATUM
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TITLE
IMPACT ON 1% AEP FLOOD LEVELS MEASURE K

DRAWING No
FIGURE 14

ISSUE No

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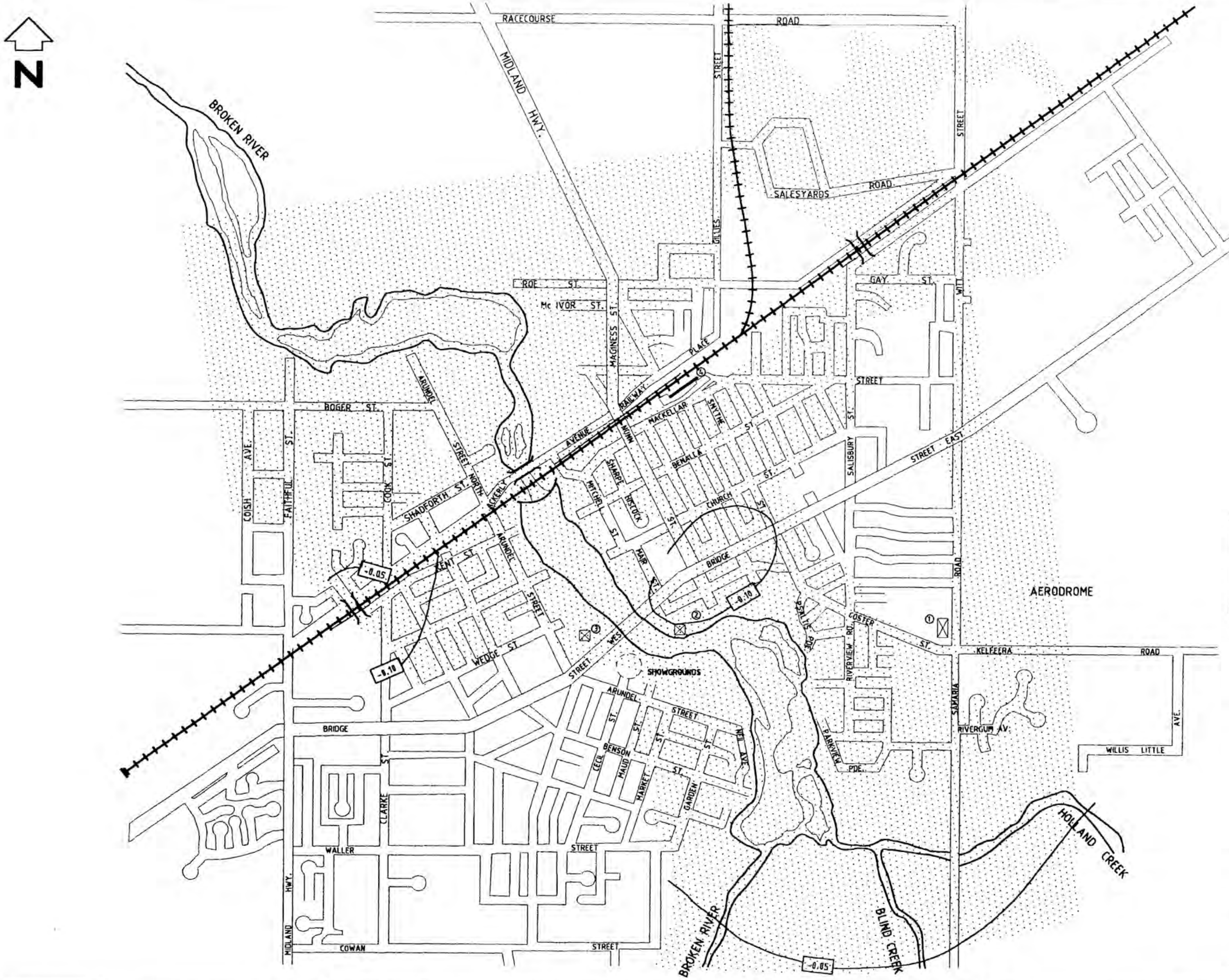

MEASURE L

RETARDING BASIN CONSTRUCTED UPSTREAM OF HUME FREEWAY ON THE BROKEN RIVER, BLIND CREEK AND HOLLAND CREEK.

LEGEND

- [-0.10] CHANGE IN 1% AEP FLOOD LEVEL FOR AREA STILL SUBJECT TO 1% AEP FLOODING
- ① HOSPITAL
- ② CIVIC CENTRE
- ① ART GALLERY
- ② RAILWAY STATION
- RAILWAY
- APPROXIMATE EXTENT OF 1% AEP FLOOD AFTER CONSTRUCTION OF MEASURE L

SCALE 200 0 200 400 600 800 1000m

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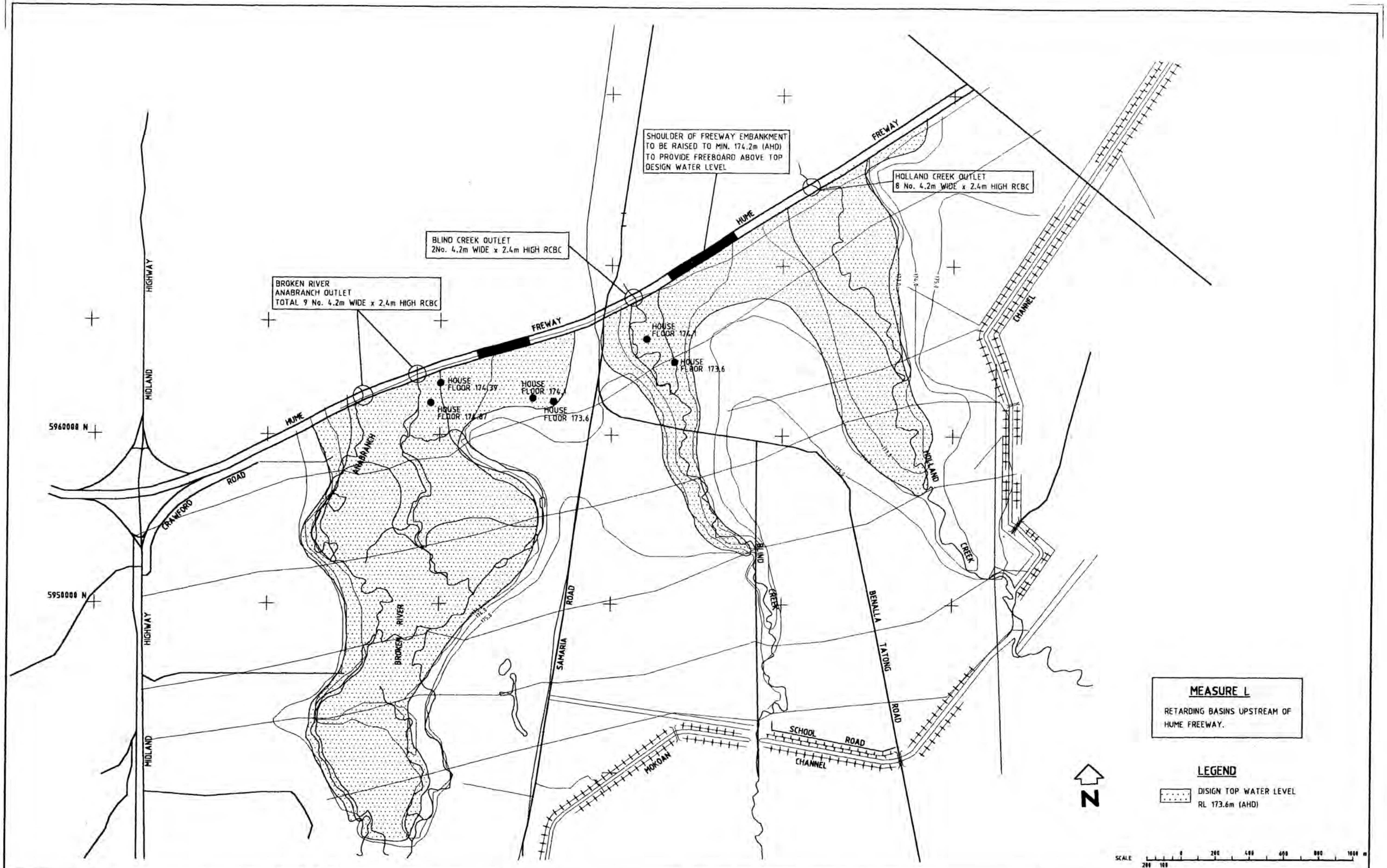
TITLE: IMPACT ON 1% AEP FLOOD LEVELS MEASURE L3

DRAWING No: FIGURE 15

on original A1

CAD ref: \3307\3307-F14.DWG, PLOT SCALE:1:1, DRAWN:T.T., DATE:28/09/98, AutoCAD r13. International.



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PROJECT

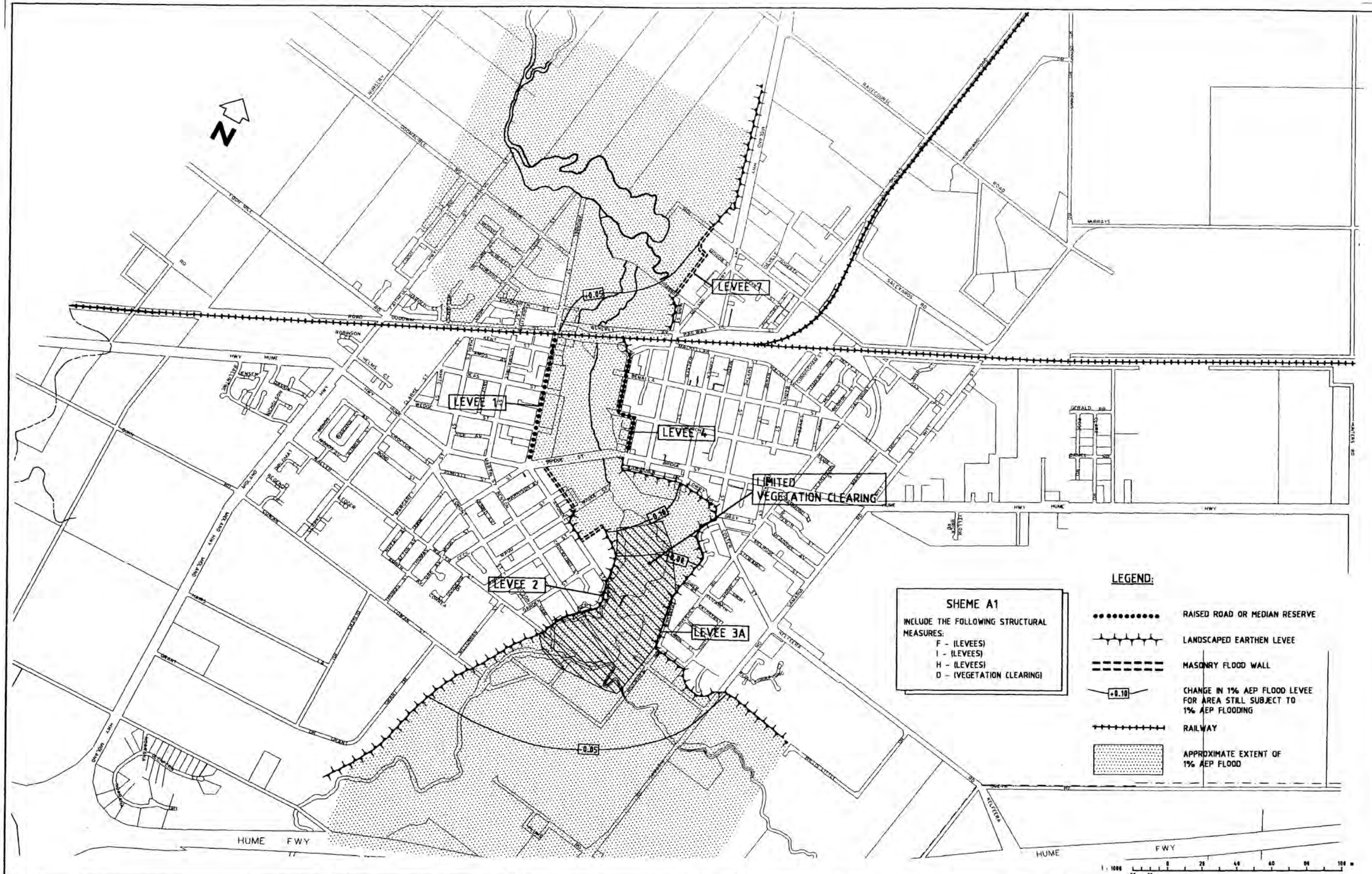
BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE

FREEWAY RETARDING BASIN
MEASURE L3
AREA OF INUNDATION

FIGURE 16

CAD ref: \3307\3307-F16.DWG, PLOT SCALE:1:1, DRAWN:T.T., DATE:29/09/98, AutoCAD r13. International.



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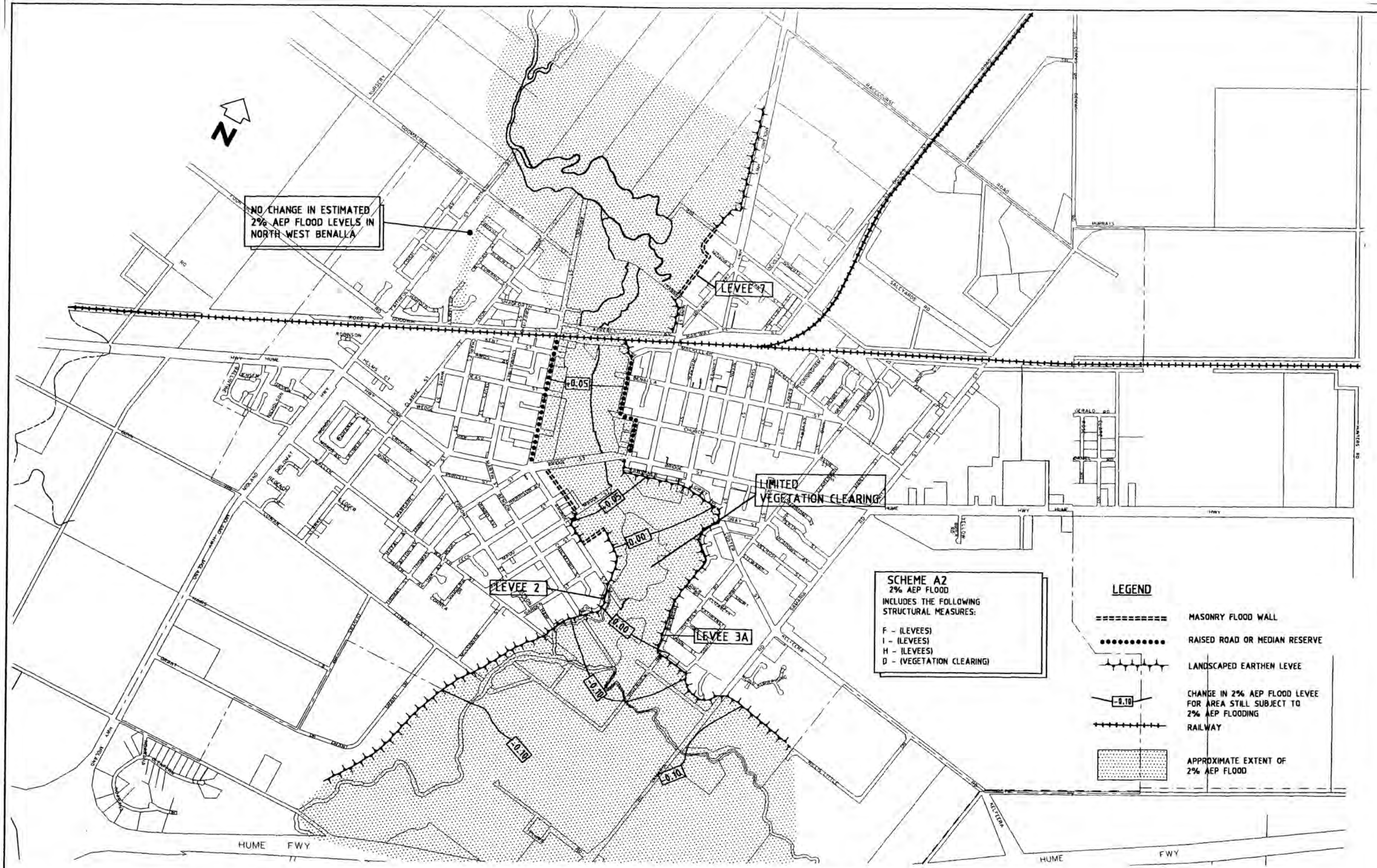
BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE
IMPACT ON 1% AEP FLOOD LEVELS SCHEME A1

DRAWING No
FIGURE 17

ISSUE No.

CAD ref: \3307\3307-F16.DWG, PLOT SCALE:1=1, DRAWN:T.T., DATE:23/09/98, AutoCAD r13. International



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BENALLA FLOODPLAIN MANAGEMENT STUDY

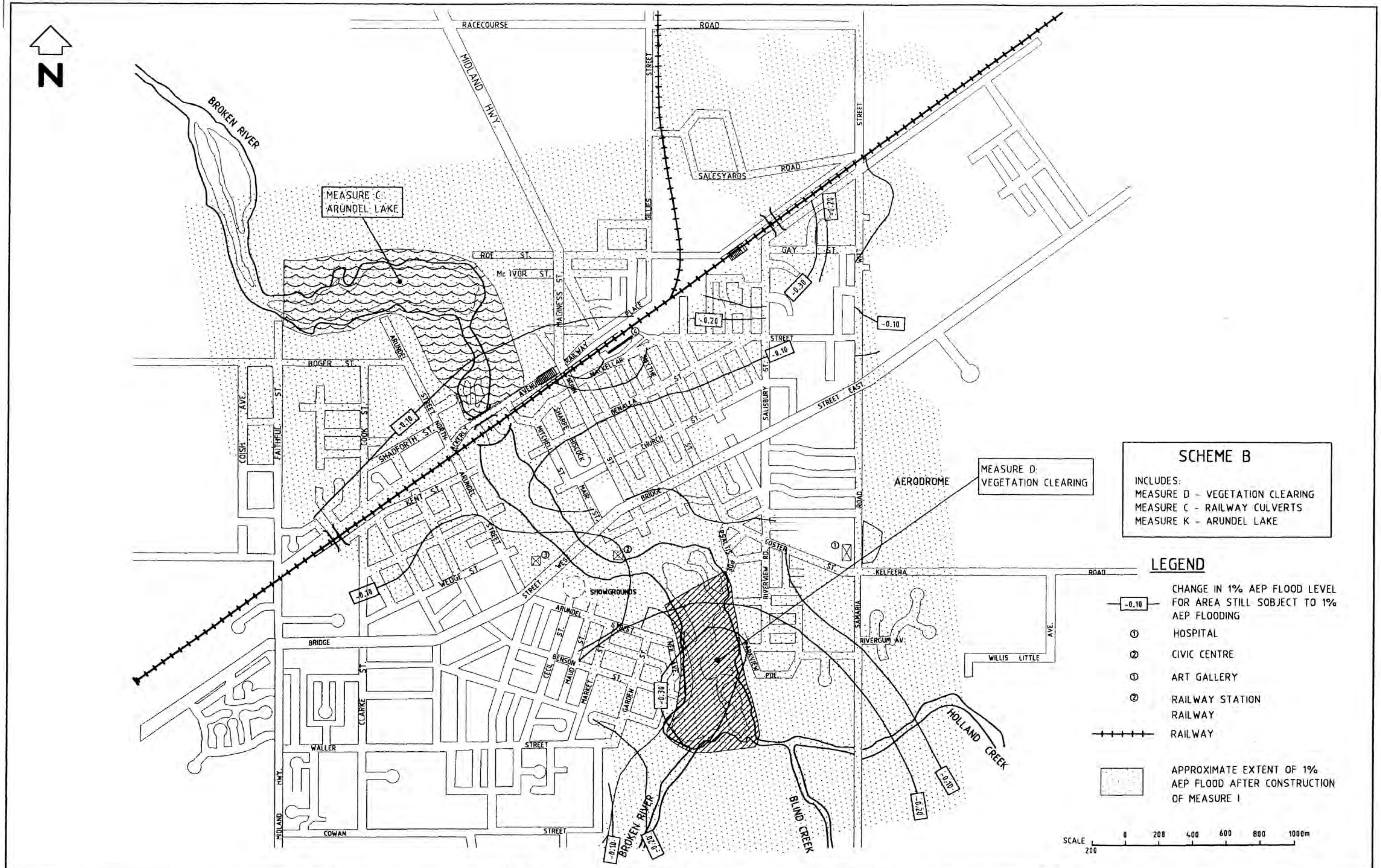
TITLE
IMPACT ON 2% AEP FLOOD LEVELS SCHEME A2

DRAWING No
FIGURE 18

ISSUE No

on original A1

CAD ref: \3307\3307-F17.DWG, PLOT SCALE:1=1, DRAWN:T.T., DATE:25/09/98, AutoCAD r13, International



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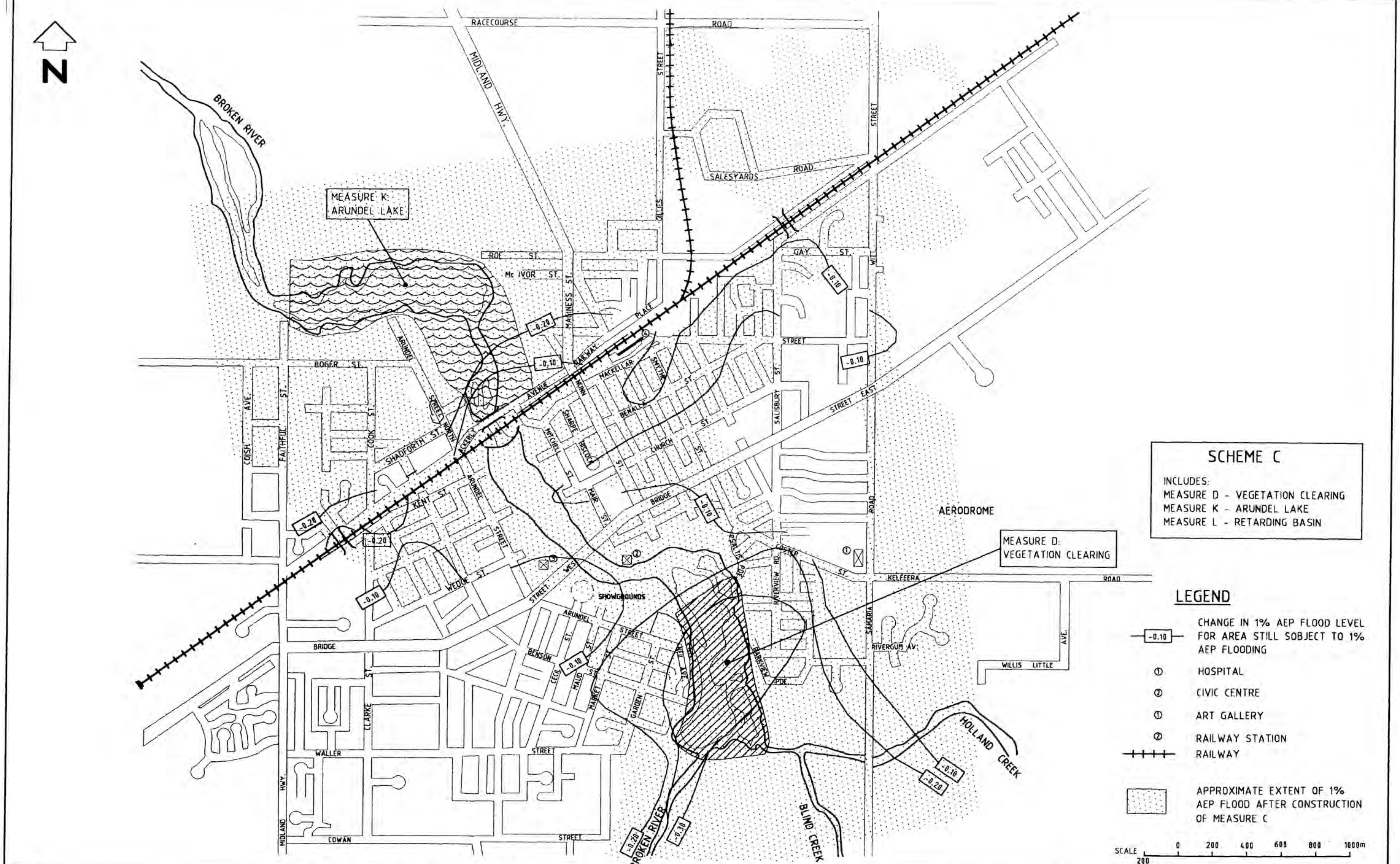
TITLE: IMPACT ON 1% AEP FLOOD LEVELS SCHEME B

DRAWING No: FIGURE 19

CAD ref: \3307\3307-F18.DWG, PLOT SCALE:1:1, DRAWN:T.T., DATE:29/09/98, AutoCAD r13. International.



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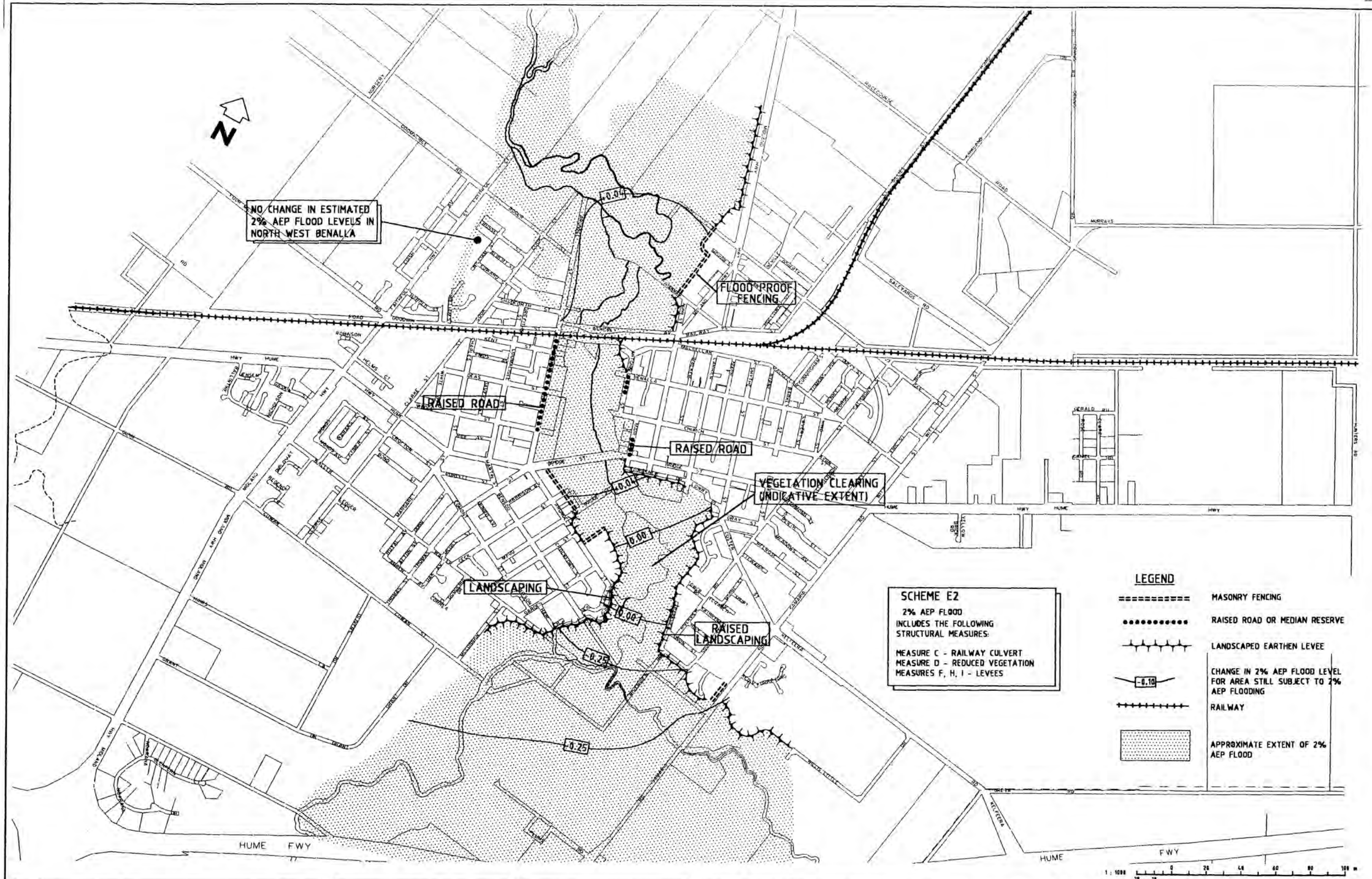
TITLE: IMPACT ON 1% AEP FLOOD LEVELS SCHEME C

DRAWING No: FIGURE 20

CAD ref: \3307\3307-F19.DWG, PLOT SCALE:1=1, DRAWN:T.T., DATE:29/09/98, AutoCAD r13. International.



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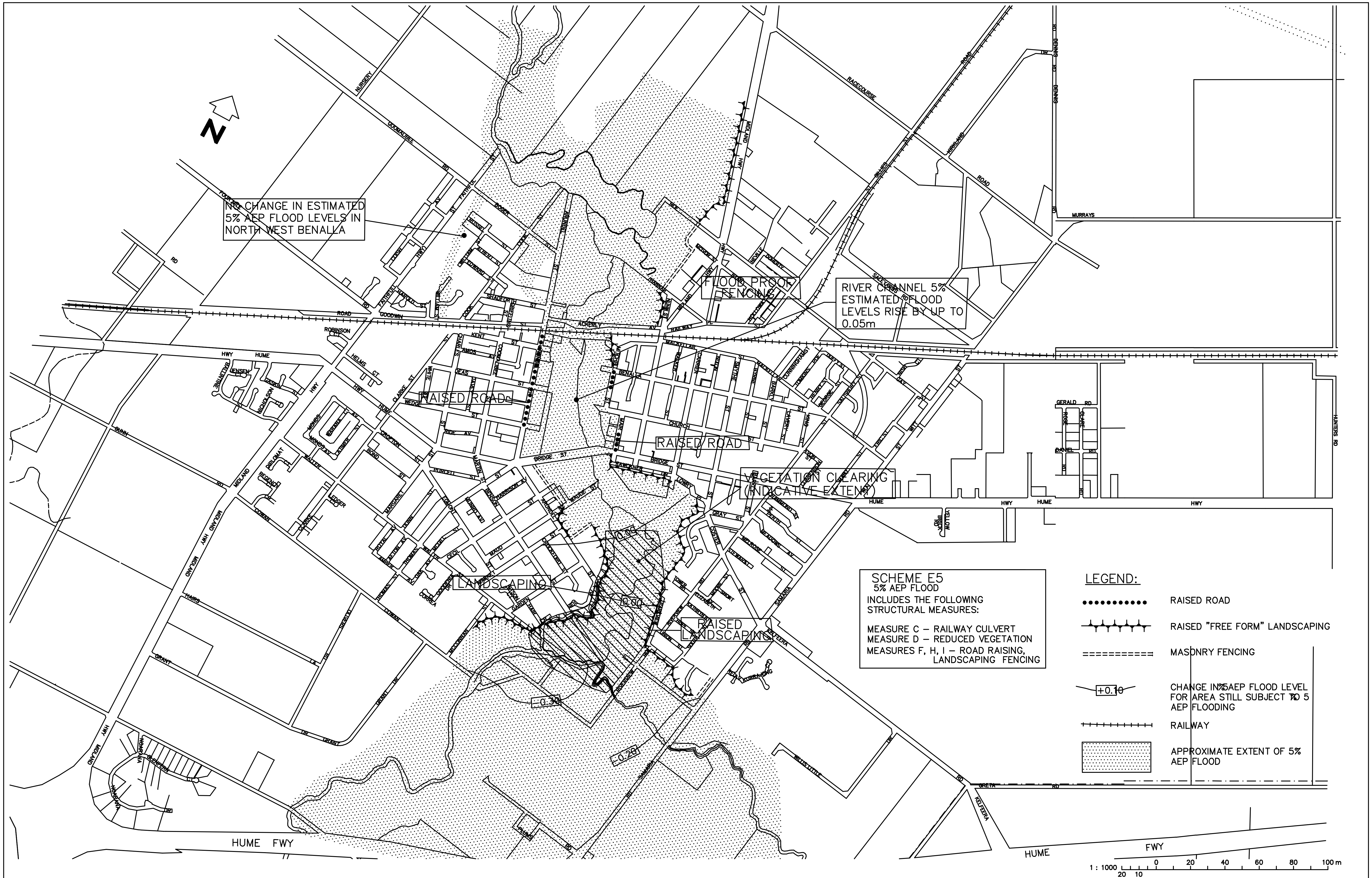
TITLE: IMPACT ON 2% AEP FLOOD LEVELS SCHEME E2

DRAWING No: FIGURE 21

CAD ref: \3307\3307-F22.DWG, PLOT SCALE:1:1, DRAWN:T.T., DATE:29/09/98, AutoCAD r13, International.



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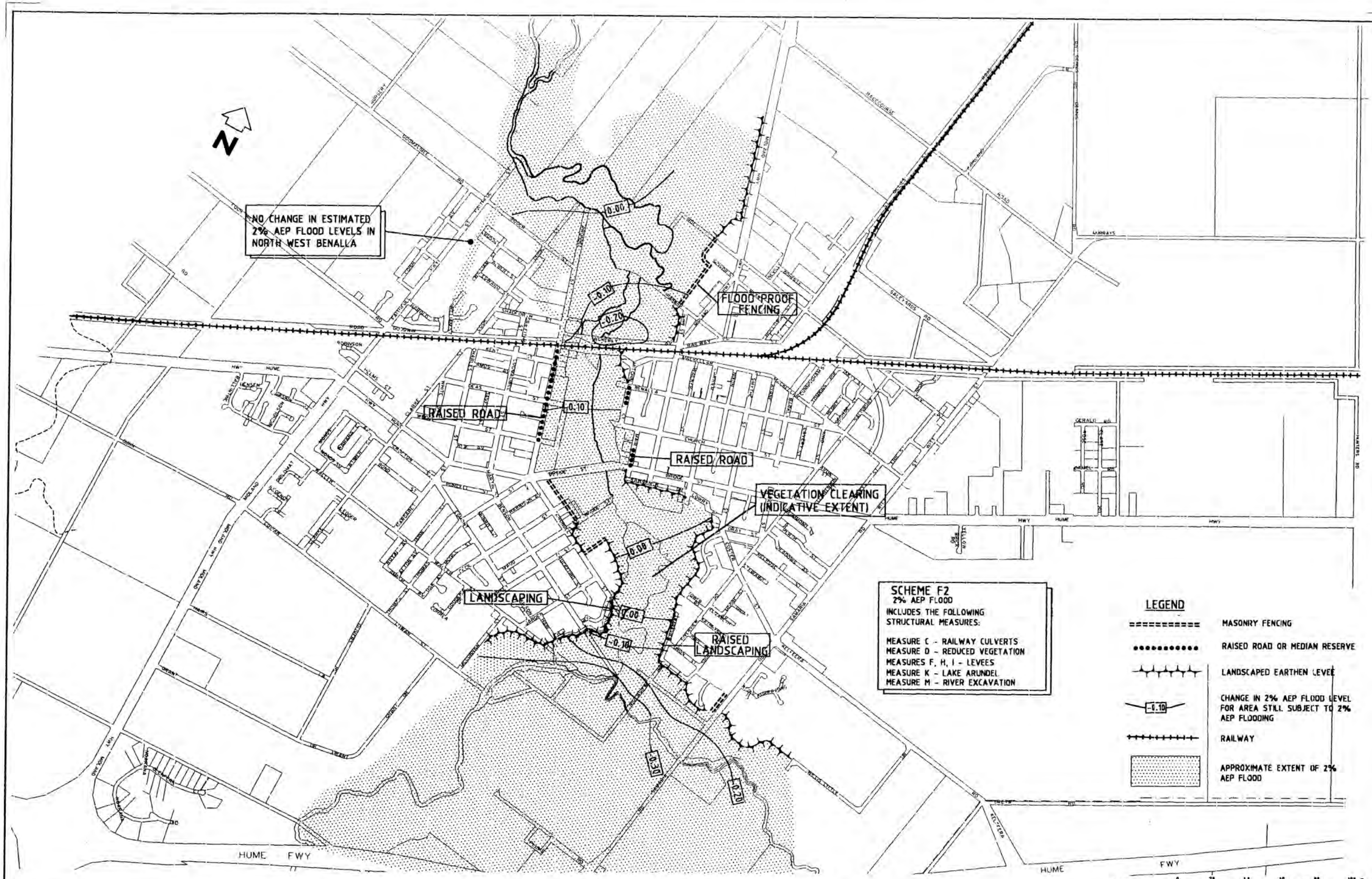
TITLE: IMPACT ON 5% AEP FLOOD LEVELS SCHEME E5

DRAWING No.: FIGURE 21

ISSUE No.:

0 10 20 30 on original A1

CAD ref: \3307\3307-F21.DWG, PLOT SCALE:1=1, DRAWN: T.T., DATE: 29/09/98, AutoCAD r13. International.



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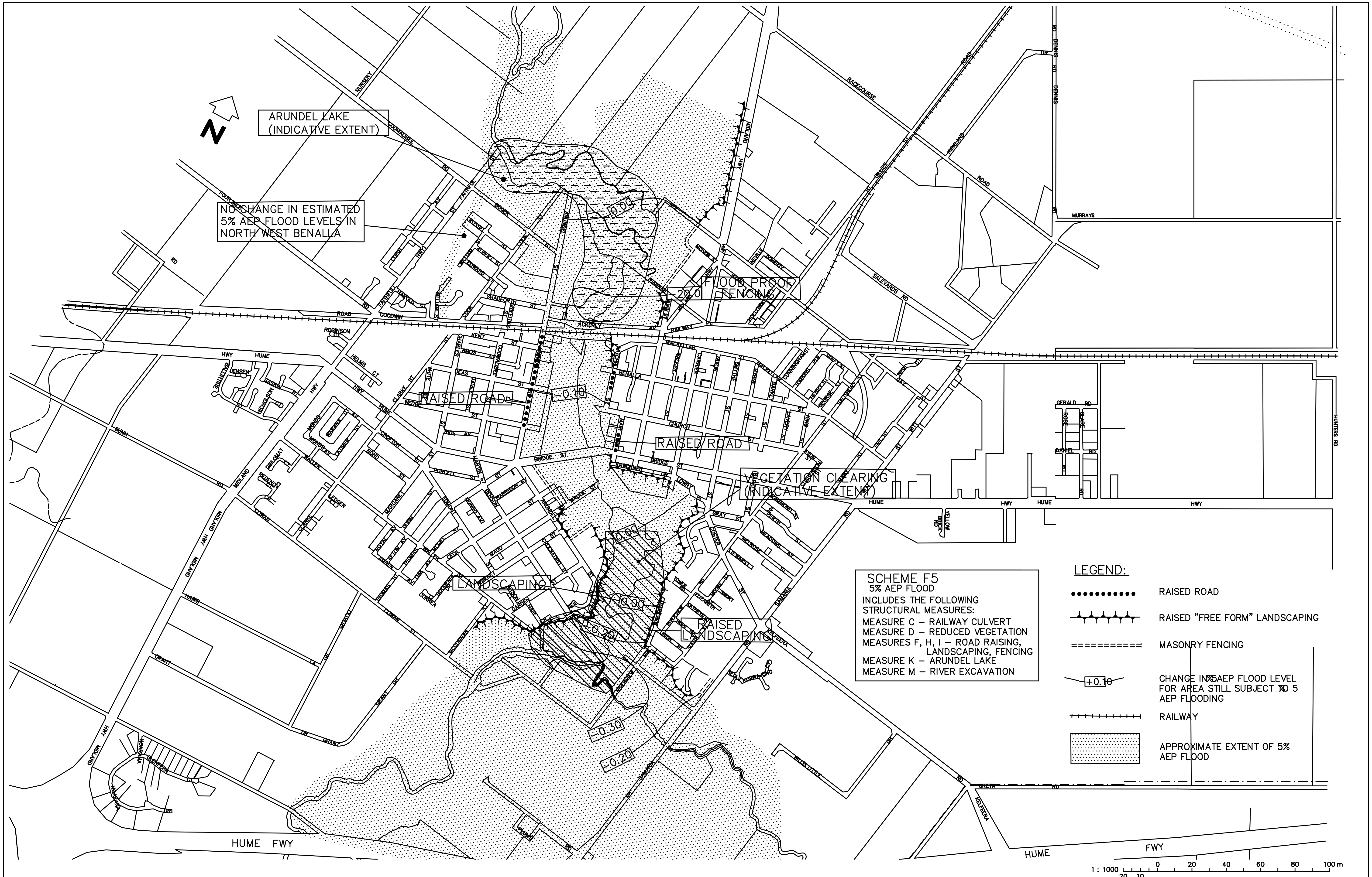
BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE
IMPACT ON 2% AEP FLOOD LEVELS SCHEME F2

DRAWING No
FIGURE 23

on original A1

CAD ref: \3307\3301-F22.DWG PLOT SCALE:1:1, DRAWN:T.T., DATE:29/09/98, AutoCAD r13 International.



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PROJECT: BENALLA FLOODPLAIN MANAGEMENT STUDY

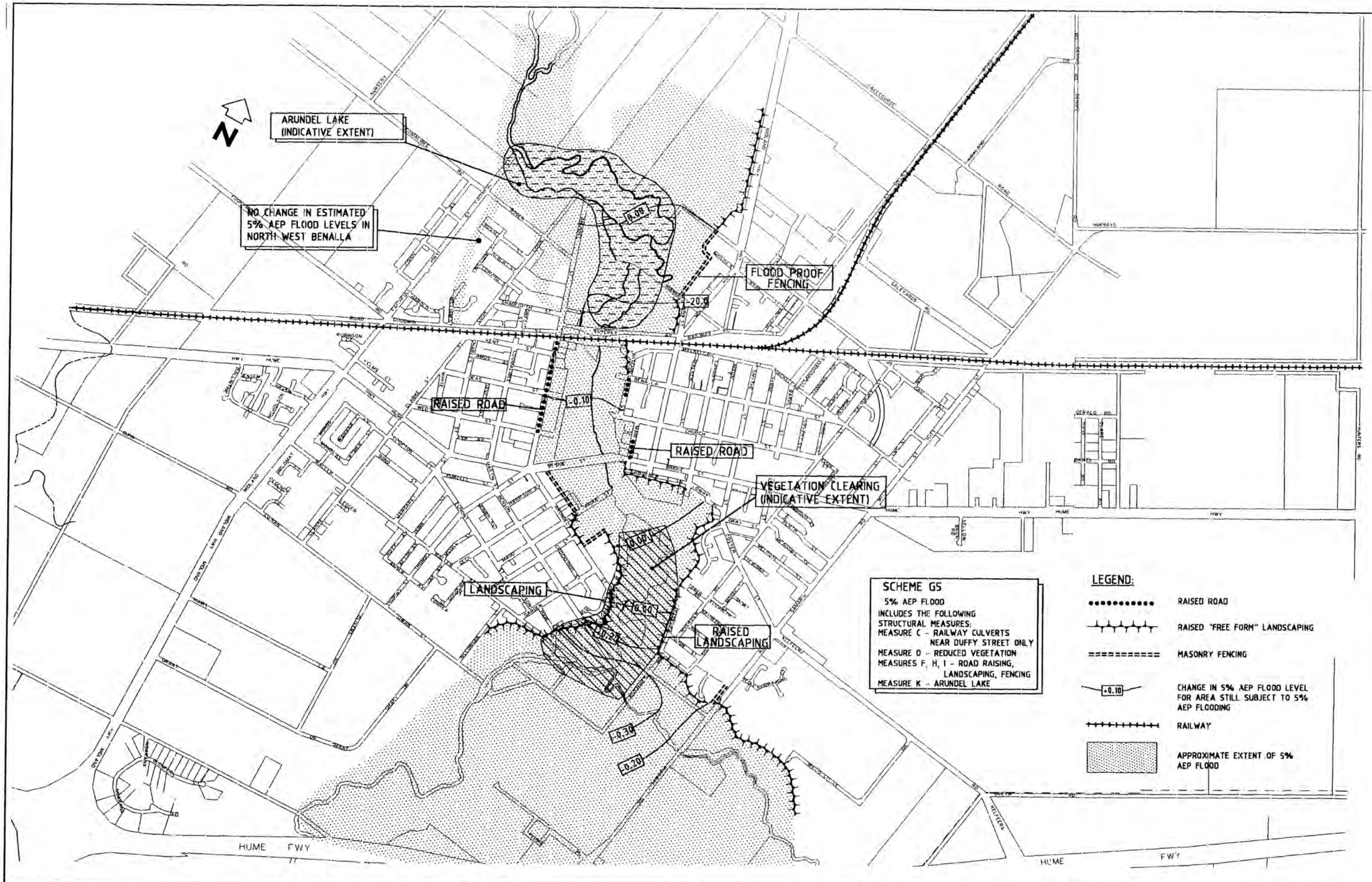
TITLE: IMPACT ON 5% AEP FLOOD LEVELS SCHEME F5

DRAWING No.: FIGURE 24

ISSUE No.:

0 50 100 150 200 300 on original A1

CAD ref: \3307\3307-F21.DWG, PLOT SCALE: 1=1, DRAWN: T.T., DATE: 29/09/98, AutoCAD r13. International.



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PROJECT BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE IMPACT ON 5% AEP FLOOD LEVELS SCHEME G5

DRAWING No. FIGURE 25

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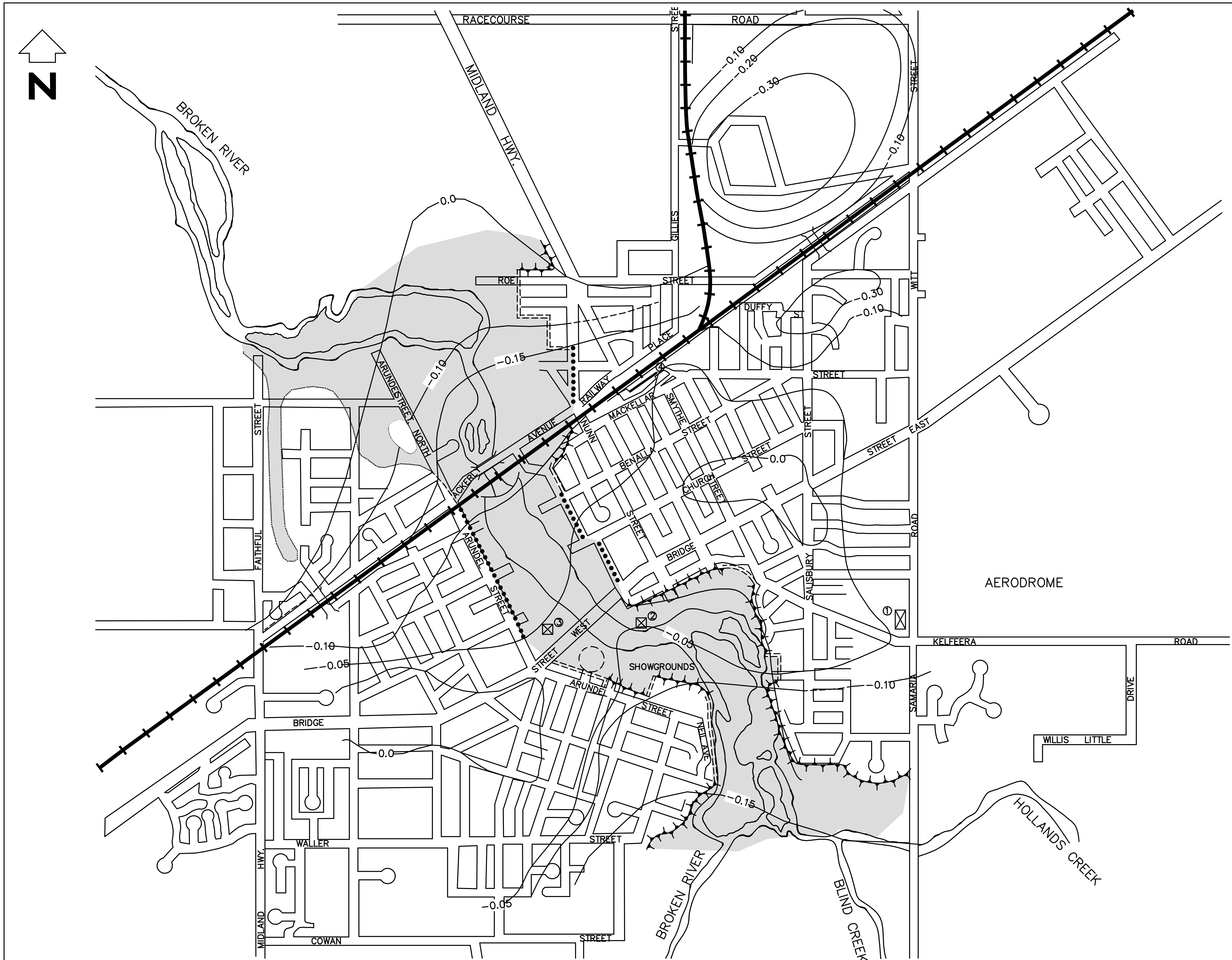

SCHEME H5

INCLUDES THE FOLLOWING STRUCTURAL MEASURES:

MEASURE De: VEGETATION CLEARING NEAR CONFLUENCE AREA

MEASURES F5, H5, 15: ROAD RAISING, LANDSCAPED LEVEES, FLOOD PROOF FENCING FOR 20 YEAR ARI FLOOD PROTECTION

MEASURE Cd: ADDITIONAL RAILWAY CULVERTS IN DUFFY STREET AREA

MEASURE NN: VEGETATION MANAGEMENT DOWNSTREAM OF THE RAILWAY

LEGEND:

- RAISED ROAD
- RAISED "FREE FORM" LANDSCAPING
- MASONRY FENCING
- +0.10 CHANGE IN 5% AEP FLOOD LEVEL FOR AREA STILL SUBJECT TO 5% AEP FLOODING
- RAILWAY
- APPROXIMATE EXTENT OF 5% AEP FLOOD

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PROJECT: BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE: 5% AEP FLOOD IMPACTS SCHEME H5

SHEET X OF X

ISSUE No. A

DRAWING No. FIGURE 26

0 50 100 150 200 300 original A1

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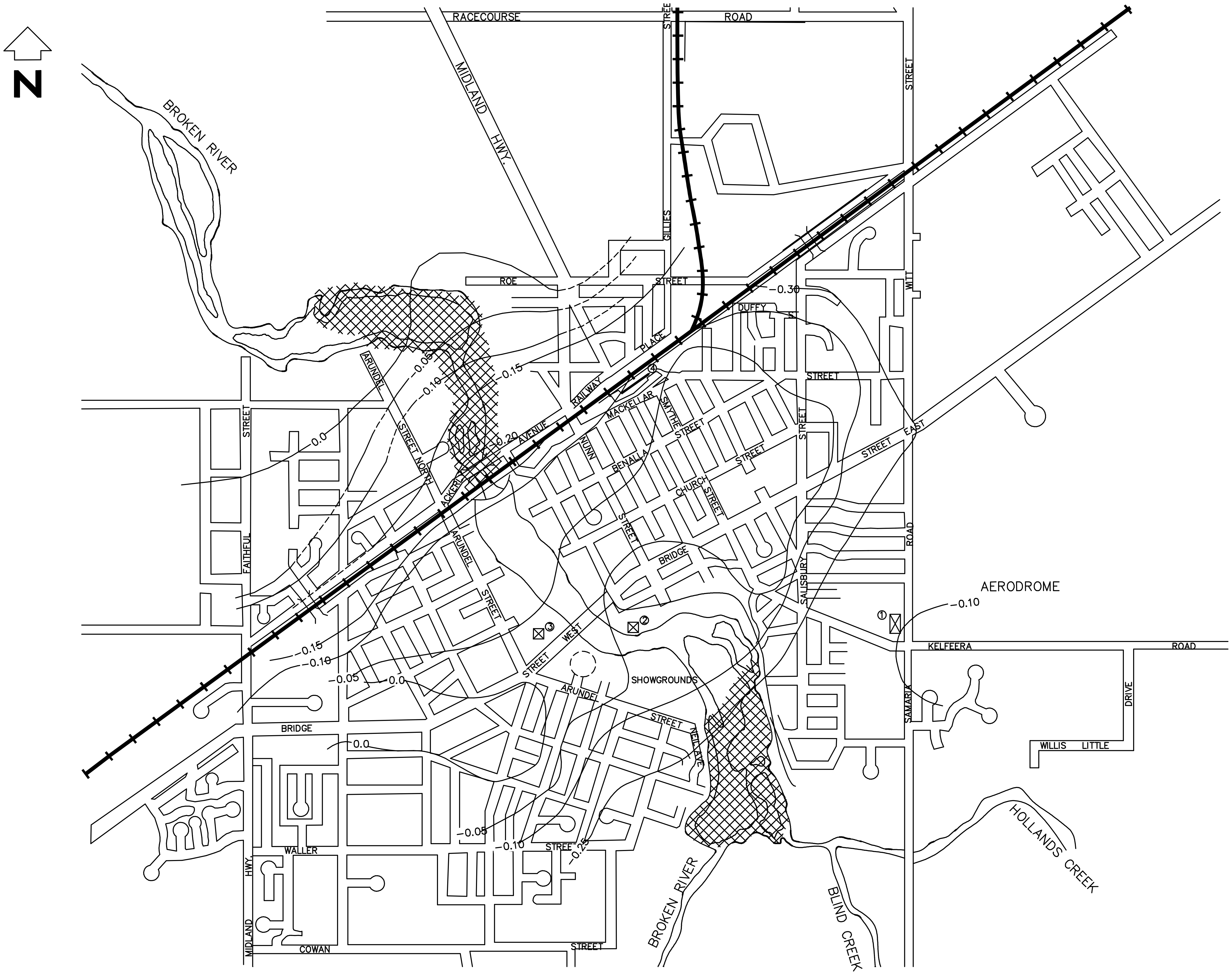

SCHEME J
includes:

MEASURE VM: VEGETATION MANAGEMENT BETWEEN COWAN STREET AND FAITHFUL STREET

LEGEND:

+0.10 CHANGE IN 1% AEP FLOOD LEVEL.

RAILWAY

VEGETATION MANAGEMENT.

AMDT.	DESCRIPTION	DATE	INIT.
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BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE
1% AEP FLOOD IMPACTS
SCHEME J

SHEET 1 OF 1
DRAWING No. FIGURE 27
ISSUE No. A

0 50 100 150 200 300 on original A1

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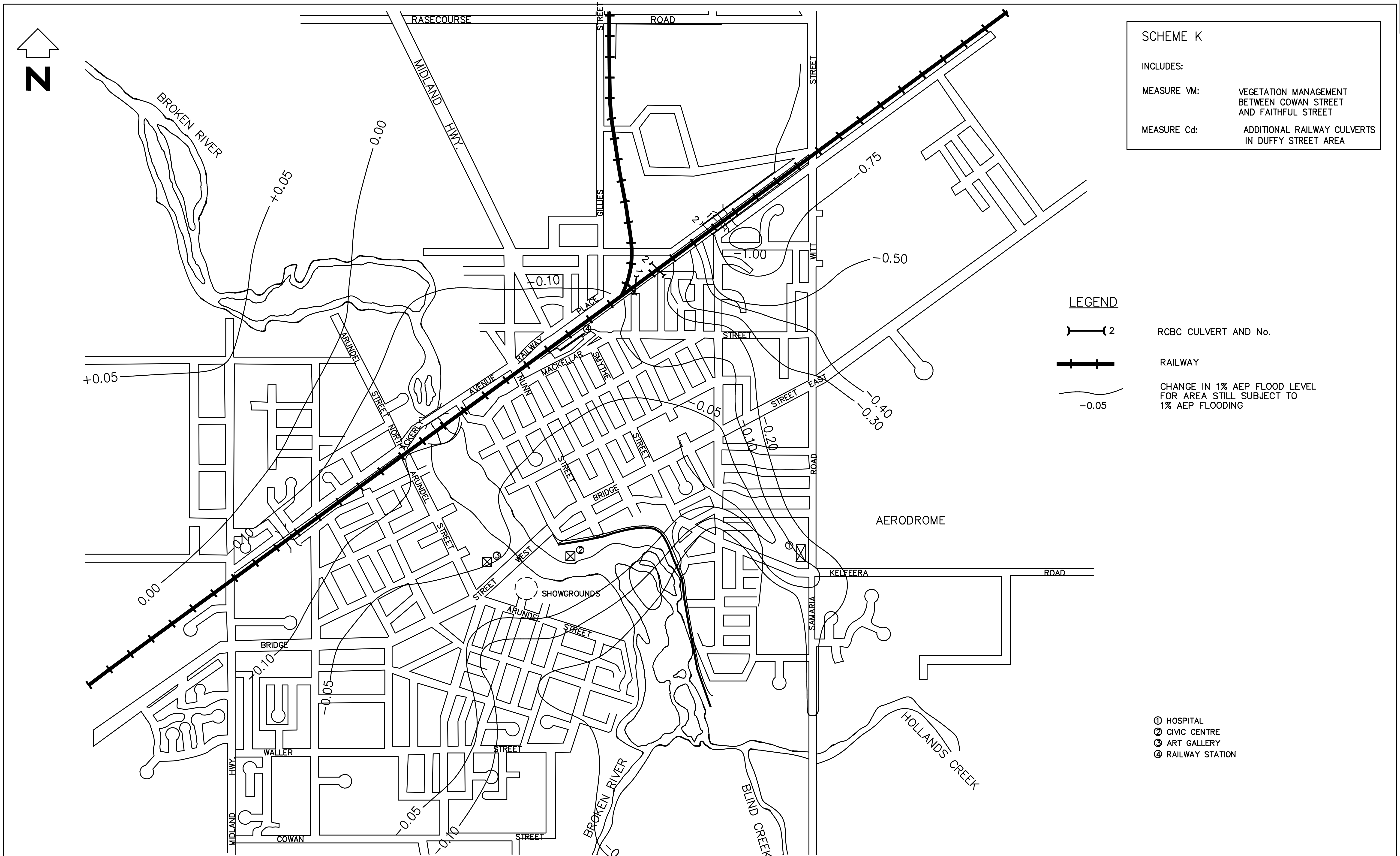

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PROJECT: BENALLA FLOODPLAIN MANAGEMENT STUDY

TITLE: 1% AEP FLOOD IMPACTS Scheme K

SHEET X OF X — ISSUE No. A

DRAWING No. FIGURE 28

0 50 100 150 200 300 original A1

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APPENDIX A

Economic Analysis

APPENDIX A ECONOMIC ANALYSIS

The economic analysis for Schemes G, H, J, and K have been undertaken in accordance with the methodology described in the Victorian Department of Treasury and Finance publication " Investment Evaluation and Policy Guidelines". The economic analysis of Schemes A, B, C, D, and E were undertaken with reference to the NSW Treasury document "Guidelines for Economic Appraisal". The two approaches are essentially the same but the analysis of Schemes A to E have not been revised in accordance with instructions from the Steering Committee based on the community's previous rejection of these schemes.

A.1 Flood Damages

It is usual practice to divide flood damages into two major categories, tangible and intangible. The former is further subdivided into direct and indirect damage components.

Direct damage results from the action of floodwaters together with associated sediment and debris. In broad terms, such losses include the direct impact of floods upon a range of man-made structures. In this study the direct damages are limited to those that would occur to buildings and their contents. The estimated depth of inundation of each building was based on a floor level and ground survey undertaken in 1997. In many instances this survey revealed significant differences in floor levels when compared with information shown on the Benalla Sewerage Authority plans. The 1997 survey also provided substantial additional information in relation to new developments and re-developments in both residential and commercial/retail areas. The direct damages to other forms of the built environment such as roads, bridges and other aspects of infrastructure are estimated separately.

Indirect damage, the other component of tangible damage, results from the disruption caused by flooding. It includes the costs of alternative accommodation for the residential sector and loss of trading profit for commercial enterprises and services, together with the additional costs of transport due to the destruction of bridges etc.

Tangible losses are capable of expression in direct monetary terms. The remaining class of damage is termed 'intangible' and is difficult, or impossible, to assess in this way. Major components of intangible damage would include stress and inconvenience experienced by the flooded community.

Flood damages can also be classified as 'actual' or 'potential'. Potential damage represents the situation where the damages are not mitigated, ie. No allowance is made for items lifted or removed from properties to lessen flood damages. Actual damage is an estimate of the damages after action has been taken to reduce them. The difference between potential and actual damage is sometimes referred to as 'avoidable damage'. A major factor in the size of 'avoidable damage' is the flood warning lead time and the level of preparedness of the community for possible evacuation. The upgraded flood warning system recently implemented for the Broken River catchment will substantially improve the timeliness and accuracy of flood warnings and would be expected to lead to significant increases in the amount of 'avoidable damage'.

A.1.1 Indirect Damages

In the past flood damage estimation procedures were generally restricted to the estimation of direct damage to buildings and contents. Indirect damage, the other component of tangible loss, is more difficult to assess and if included was usually guestimated or some nominal allowance was made. The methods used in earlier studies in Australia assumed indirect damage to be a set proportion of direct damage. For example, the indirect losses for the residential sector are often taken to be 5% to 15% of direct costs, and for the commercial sector 55%. Following recent large scale and severe flooding in northern and eastern Australia several studies have attempted to quantify various other categories of damage such as "clean up" costs. The revised Damage model used to upgrade the Benalla flood damage estimates now includes an allowance for clean up.

A.1.2 Intangible Losses

Detailed assessment of this aspect of flood damage is not practicable within the ambit of this report. However, the property database, and related survey provides background information. The most significant factors are loss of trade for businesses, sickness, and the possibility of loss of life.

The size of the death toll is heavily dependent on the length of the warning time, the efficacy of transmitting such a warning and finally, upon the response of those at risk. For planning purposes this is compounded by the differing forms the flood could take.

There must remain serious doubt as to the possibility of a complete evacuation of the area subject to inundation. A day-time emergency would be likely to lead to road chaos as several thousand workers and shoppers in vehicles tried to flee the area at the same time as the police and emergency services were closing the bridges and roads. This is especially pertinent since the majority of flood deaths in Australia are vehicle-related. The alternative scenario of awakening residents in the middle of the night and persuading them to flee at a few minutes' notice is equally difficult.

A.1.3 Stage-Damage Curves

These describe the average losses to each class of property recognized in the property survey for differing depths of overfloor flooding. In this study three residential stage-damage curves were used. These were for small, average and large properties, based on external inspection. The effect of velocity on the structures was examined separately and it was considered highly unlikely that any property would suffer structural failure up to and including the 1% AEP flood. These stage-damage curves also contained a component for under house damage, damage to grounds, and post flood "clean up".

The stage-damage curves include both contents and structural damages. The contents component includes all furniture, clothing etc, while structure refers to damage to walls and floors, decoration, fitted furniture, electrical wiring, doors, etc.

The residential stage-damage curves used in this study are in terms of actual damage, not potential damages. The data for these curves was derived from studies in eastern Australia. These studies included detailed assessment of various property types that experienced overfloor flooding by a team of loss adjustors.

Due to the more complex nature of the commercial sector, the commercial stage-damage curves are in terms of potential damages. These curves (15 in all) were also derived from studies in eastern Australia in the last 15 years. The damage values used in this study and have been indexed using published CPI data. Further verification of the data was attempted based on damage estimates for Benalla in October 1998. Enquiries to the insurance industry indicates the cost for Benalla to be in the order of $13 million. However given the then widely adopted insurance policy clause which excluded payouts for flood damage, the $13 million would represent the cost of stormwater damage only and is therefore likely to be a lower bound value of the actual damage to buildings and contents.

A.1.4 Flood Data

For each analysis zone, flood levels corresponding to the design 1% AEP, 2% AEP, 5% AEP, 10% AEP and the extreme flood were determined and input into the DAMAGES model. The flood damage analysis was then performed on a zone by zone basis. Four zones were used;

1. South east — the area east of the river and south of the railway,

2. South west — the area west of the river and south of the railway,

3. North east — the area east of the river and north of the railway, and

4. North west — the area west of the river and north of the railway.

A.1.5 Average Annual Damages (AAD)

Average annual damages (AAD) is derived by integrating the area under the curve of damages against probability of flood occurrence. AADs are useful for cost benefit analysis. On an individual property basis the AAD corresponds to a direct break-even insurance premium.

The average annual direct damage for properties in the study area is $2,157,586 per annum.

A.2 Flood Damage Estimation Procedure

The flood damages were estimated using the DAMAGES model which was compared against the number of houses reported as having experienced over floor flooding in October 1993. The survey conducted shortly after the October 1993 flood reported a total of approximately 491 properties as having being flooded above floor level compared with the DAMAGES model which predicts that 877 houses would be flooded by the 1% AEP flood. The numbers predicted by the model are considered to be reasonably reliable and there is no apparent explanation for the discrepancy other than that the survey may not have covered all effected areas. A report prepared by HydroTechnology (Ref 12) independently estimated the number of residential properties effected by flooding in 1993 as 1400. This estimate compares with the modelling results which estimate that almost 3000 residential properties were effected of which 877 would have experienced over floor flooding.

The estimated flood damage for urban Benalla in a 1% AEP flood is $32.28 million (1999 dollars). This estimate is based on damage curves derived from previous studies. In assessing the damages for the retail sector the majority of premises were assessed as having medium or high value which corresponds with the damage estimates based on a survey reported by HydroTechnology (Ref. 12).

The damage estimate is lower than the $37.96 million reported by HydroTechnology in its 1995 report entitled "Documentation and Review of 1993 Victorian Floods, Broken River Catchment Floods, October 1993", Volume 4. The $37.96 million represents approximately $42.2 million in 1999 costs based on changes to the Melbourne CPI since 1993.

The difference in the two estimates is primarily attributable to the estimated average damage per residential property. For residential properties the HydroTechnology estimate was based on an average depth of overfloor flooding taken from a limited sample of properties. The depths of over floor flooding were based on assumed floor levels prior to the 1997 floor level survey. The floor level survey revealed significant differences in floor levels for a large number of properties the majority of which had floor levels higher than the previously adopted level. In some cases this is due to re-development.

For the business sector the total flood damage estimates are very similar. The HydroTechnology report estimated the total urban business flood damages as $18.7 million in 1999 costs ($16.8 million in 1993) compared the $17.3 million (1999 costs) estimated for this study.

Secondary damages were estimated using procedures similar to those adopted for other recent flood studies in Victoria where losses are estimated as a percentage of direct damage costs. The secondary damages were estimated as 9.6% of the direct damage cost for a 1% AEP flood (equal to the estimated peak discharge of the October 1993 flood). For the economic analysis the estimated secondary damages for the 1% AEP flood were rounded up to 10% of the estimated $29.342 million in direct damages. The same percentage was adopted for flood of other magnitudes.

The secondary damages included allowances for the following:

- Repair of roads,
- Repair of utilities (electricity, gas water, telephone),
- Business trading days lost,
- Health and related productivity losses,
- Recovery services (households and businesses), and
- Loss of life (for floods greater than the 1% AEP flood).

The above losses are notoriously difficult to estimate and although a survey of businesses was conducted in the aftermath of the October 1993 flood (Hydrotechnology, Ref . 12) the secondary losses should only be regarded as preliminary estimates. Notwithstanding the uncertainty in secondary damage estimates an allowance of 10% of the direct damage costs appears reasonable based on the information available from Benalla and surveys of more recent flood affected communities in eastern Australia.

A.3 Benefit Cost Analysis

A.3.1 General Principles

Economic evaluation, or cost-benefit analysis, aims to estimate the net benefit (defined as total benefits less total costs) of alternatives. Benefits and costs are measured in monetary terms, so that they can be readily compared. As most people prefer present goods and services to future ones, future costs and benefits are given less weight than present ones.

Benefit-cost analysis has been applied for many years to the evaluation of major infrastructure as part of the public sector's decision-making framework. It is applied in this instance to assist in the decision concerning strategies for flood management in Benalla.

A.3.2 Method

The benefit-cost analysis is undertaken for each scheme against the base case of do nothing. This analysis includes:

- Estimating the cost of the base case, which for both areas was to 'do nothing'. The cost involved was the annual average damage costs in the occurrence of a flood.
- Estimating the benefits and costs of each of the schemes in relation to the base case (the net benefits and costs).
- Discounting the benefits and costs to the present value.
- Calculating the net present value, benefit cost ratio and internal rate of return.

These are accepted criteria for the evaluation of investment decisions on capital projects and can be defined as follows:

Net present value (NPV) is the sum of the discounted project benefits less discounted project costs. Under this decision rule a project is potentially viable if the net present value is greater than zero.

Benefit cost ratio (BCR) is the ratio of the present value of benefits to the present value of costs. A project is potentially viable if its benefit cost ratio is greater than one.

Costs and benefits are estimated for schemes A to E inclusive were for each of the 50 years from 1999 to 2048. In accordance with Treasury guidelines the latter schemes to be considered (Schemes G5, H5, J and K were assessed over 20 years with the residual cost included as a cash benefit). The net benefits are then calculated relative to the base case and then transferred to the discounted cash flow analysis for each Scheme.

Discounted cash flow analysis was carried out under Victorian Department of Treasury and Finance Guidelines (Ref 26). The discount rates originally adopted and used to evaluate Schemes A to E were based on three discount rates: seven percent (the central case), four percent (sensitivity test number l) and ten percent (sensitivity test number 2). However for the latest schemes lower discount rates have been used in line with the lower annual inflation during recent years. The revised discount rates used are: six percent (the central case), three percent (sensitivity test number l) and nine percent (sensitivity test number 2).

A.3.3 General Assumptions

The following general assumptions apply to this revised economic evaluation:

- The costs and benefits are assessed over a 20 year period. This allows for 20 years of operation from the earliest time when some alternatives can be in operation.

- Residual costs were included as a cash benefit after 20 years.

- Costs and benefits are estimated in 2001 dollars for Schemes H, G, J and K. All others are assessed in 1999 dollars.

- The construction of levees and retarding basin was assumed to occur over a 3 year period with a proportional saving in the annual average damages during the first 3 years.

- House raising has been assumed to occur over a 3 year period with a proportional saving in the annual average damages over the first 3 years.

The following benefits and costs were not quantified although they form part of the qualitative assessment:

- Social cost of flooding including death, injury, anxiety, disease etc., (economic costs were included),
- Disruption to daily social lives,
- Visual intrusion of structural schemes,
- Effect on flora and fauna.

A.3.4 Conclusion

Several schemes may be regarded as economically viable and include the levee schemes (A1, A2 and A5), Schemes E2 and E5 (combination of additional railway culverts, levees, road raising, and river vegetation management), Scheme G5 which includes Arundel Lake, Scheme J which is based entirely on an overall reduction and on-going management of in-stream and floodplain vegetation, and Scheme K which differs from scheme J only in that it also includes additional railway culverts in the Duffy street- East Main Drain area.

A summary of the results is outlined in Tables A.1 and A.2. The findings of this analysis are as follows:

- At all discount rates the ranking of the schemes is constant. The net present value and the benefit cost ratio of Scheme A2 exceeds that of other levee schemes and similarly Scheme A2 has a higher BCR (1.25) than the other levee schemes. These BCR's are based on the original analysis using discount rates of 4%, 7% and 10% and have not been revised in accordance with the Steering Committee's direction based of the rejection of the community of the high levee concepts and the development of subsequent schemes based on extended community consultation between 1998 and 2001.

- Scheme G5 has been evaluated for both Arundel Lake concepts. The BCR and NPV estimates for Scheme G5 presented in Table A.1a are based on a the original simplistic Arundel Lake concept with an estimated cost of $1.9M. The corresponding estimates presented in Table A.1b are for the updated Arundel Lake concept 2 with an estimated cost of $4.2 million. Both Arundel Lake concepts are as described in the Benalla Floodplain Management Study Supplementary Report (Willing & Partners, October 1999).

- Schemes H5, J and K which do not include the construction of Arundel Lake have a clear superior economic performance compared to all other schemes. These schemes have been evaluated using 2 sets of discount rates. The original discount rates of 4%, 7%, and 10% applying over 50 years with no residual cost have been included to allow a direct comparison with earlier evaluations of previously reported schemes. Both schemes were then re-evaluated using the revised lower discount rates (3%, 6%, and 9%) applied over a 20 year period with the residual costs included as a cash inflow after 20 years. For the latter evaluation the BCR for Scheme J is estimated as 5.28 which more than twice the estimate for Scheme H5 (BCR=2.08). The difference in the economic performance is due to the relatively poorer economic return for the structural measures which are included in Scheme H5. A BCR of 2.58 is estimated for Scheme K which is Scheme J plus the additional railway culverts near Duffy Street. Notwithstanding the reduced cost benefit caused by the inclusion of the railway culverts a significant additional number of homes are protected against over floor flooding.

- The estimated cost of vegetation management could double and Scheme J and Scheme K would still remain more cost effective than other schemes.

TABLE A.1a
SUMMARY OF BENEFIT COST ANALYSIS FOR EACH SCHEME
(Based on discount extending over 50 years with no residual value)

	Benefit Cost Ratio (BCR)			Net Present Value (NPV)		
Discount Rate	**4%**	**7%**	**10%**	**4%**	**7%**	**10%**
Scheme A1	1.66	1.19	0.91	$12,913,899	$11,517,262	$10,812,777
Scheme A2	1.74	1.25	0.95	$9,058,625	$8,054,901	$7,548,607
Scheme A5	1.44	1.04	0.79	$7,306,421	$6,494,308	$6,084,666
Scheme B	1.49	0.97	0.70	$3,368,162	$3,300,290	$3,266,054
Scheme C	0.41	0.30	0.23	$11,023,603	$9,709,315	$9,046,367
Scheme D	0.71	0.48	0.36	$32,069,702	$30,002,934	$28,960,425
Scheme E2	1.57	1.10	0.82	$13,478,426	$12,315,339	$11,728,661
Scheme E5	1.44	1.00	0.75	$11,736,266	$10,763,693	$10,273,112
Scheme F2	1.31	0.92	0.69	$16,205,034	$14,743,781	$14,006,702
Scheme F5	1.17	0.82	0.62	$14,462,875	$13,192,134	$12,551,153
Scheme G5	1.46	1.02	0.83	$11,309,137	$10,349,633	$9,984,837
Scheme H5	1.29	0.92	0.70	$10,146,095	$9,116,320	$8,596,886
Scheme J	5.84	4.30	3.34	$1,384,192	$1,199,799	$1,106,789
Scheme K	3.43	2.20	1.62	$1,466,094	$1,789,291	$1,956,676

TABLE A.1b
SUMMARY OF BENEFIT COST ANALYSIS FOR EACH SCHEME
(Based on discount extending over 20 years with the residual value included
as a cash inflow after 20 years)

	Benefit Cost Ratio (BCR)			Net Present Value (NPV)		
Discount Rate	**3%**	**6%**	**9%**	**3%**	**6%**	**9%**
Scheme G5	1.33	0.96	0.71	$13,412,422	$12,849,222	$12,454,429
Scheme G5a[1]	1.44	1.05	0.79	$13,762,284	$13,183,679	$12,778,086
Scheme H5	3.39	2.08	1.49	$5,199,430	$6,593,772	$7,313,306
Scheme J	8.34	5.28	3.85	$677,077	$831,921	$909,446
Scheme K	4.41	2.58	1.81	$1,241,464	$1,653,756	$1,873,580

Note 1. Scheme G5a is the same as Scheme G5 except the cost of road raising and levees is reduced due to a lowering of the crest height by 300mm. For Scheme G5a the available freeboard for the design 5% AEP flood is thus reduced from 600mm (Scheme G5) to 300mm.

TABLE A.2
SUMMARY OF ESTIMATED FLOOD DAMAGES BY PROPERTY TYPE AND AREA

Area	**Building Type**		**Design Flood - Existing Conditions**				
			10%	**5%**	**2%**	**1%**	**Extreme**
South East	Residential	Brick	0	0	68	242	775
		Weatherboard	0	0	54	187	543
		Total	0	0	122	429	1318
		Damage	$70,353	$112,599	$1,319,980	$6,015,341	$96,296,464
South East	Commercial	All	4	9	114	179	311
		Damage	$131,617	$364,501	$5,773,819	$12,704,399	$65,110,848
South West	Residential	Brick	0	9	89	145	521
		Weatherboard	2	7	104	193	425
		Total	2	16	193	338	946
		Damage	$74,330	$394,254	$3,012,921	$5,928,518	$63,104,472
South West	Commercial	All	0	6	8	8	34
		Damage	$0	$339,017	$623,356	$623,356	$4,508,077
North East	Residential	Brick	6	12	22	47	62
		Weatherboard	0	6	17	40	145
		Total	6	18	39	87	207
		Damage	$62,861	$342,152	$730,920	$1,393,152	$9,750,641
North East	Commercial	All	0	5	15	20	25
		Damage	$0	$221,864	$1,010,521	$1,781,161	$4,735,101
North West	Residential	Brick	0	2	5	18	191
		Weatherboard	0	0	2	5	194
		Total	0	2	7	23	385
		Damage	$1,006	$20,923	$162,393	$412,785	$17,085,090
North West	Commercial	All	0	1	1	1	4
		Damage	$0	$192,348	$363,587	$438,660	$309,736
Total Urban Area	Residential	Brick	6	23	184	452	1549
		Weatherboard	2	13	177	425	1307
		Total	8	36	361	877	2856
		Damage	**$208,550**	**$869,928**	**$5,226,214**	**$13,749,796**	**$186,236,667**
	Commercial	All	4	21	138	208	374
		Damage	**$131,617**	**$1,117,730**	**$7,771,283**	**$15,547,576**	**$74,663,762**
		Total damage	**$340,167**	**$1,987,658**	**$12,997,497**	**$29,297,372**	**$260,900,429**

Notes:

South East - refers to the area south (upstream) of the railway embankment and east of the Broken River.

South West - south refers to the south (upstream) of the railway embankment and west of the Broken River.

North East - refers to the area north (downstream) of the railway embankment and east of the Broken River.

North West - refers to the area north (downstream) of the railway embankment and west of the Broken River.

The commercial category includes retail and industrial buildings as surveyed in 1997.

TABLE A.3
PRELIMINARY ESTIMATES FOR LEVEE 1

LEVEE 1 (1% AEP) - Road Raising

Length 720m

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	3,000.00	1	$3,000.00
Prepare Site	m^2	0.40	7200	$2,880.00
Provision for traffic	item	10,000.00	1	$10,000.00
Break out existing bitumen	m^2	7.00	7200	$50,400.00
Construct new carriageway	m	320.00	720	$230,400.00
Import embankment fill and compact	m^3	30.00	9000	$270,000.00
Draiange Alterations	item	160,000.00	1	$160,000.00
Sub Total				$736,680.00
Clean-up		2.50%		$18,417.00
Sub Total				$755,097.00
Contingencies		20.00%		$151,019.40
Levee Total				**$906,116.40**
Design and Prepare Contract		7.50%		$67,958.73
Total				**$974,075.13**

LEVEE 1 (2% AEP) - Road Raising

Length 720m

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	3,000.00	1	$3,000.00
Prepare Site	m^2	0.40	7200	$2,880.00
Provision for traffic	item	10,000.00	1	$10,000.00
Break out existing bitumen	m^2	7.00	7200	$50,400.00
Construct new carriageway	m	325.00	720	$234,000.00
Import embankment fill and compact	m^3	30.00	7000	$210,000.00
Draiange Alterations	item	160,000.00	1	$160,000.00
Sub Total				$680,280.00
Clean-up		2.50%		$17,007.00
Sub Total				$697,287.00
Contingencies		20.00%		$139,457.40
Levee Total				**$836,744.40**
Design and Prepare Contract		7.50%		$62,755.83
Total				**$899,500.23**

LEVEE 1 (5% AEP) - Road Raising

Length 720m

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	3,000.00	1	$3,000.00
Prepare Site	m^2	0.40	7200	$2,880.00
Provision for traffic	item	10,000.00	1	$10,000.00
Break out existing bitumen	m^2	7.00	7200	$50,400.00
Construct new carriageway	m	325.00	720	$234,000.00
Draiange Alterations	item	160,000.00	1	$160,000.00
Sub Total				$470,280.00
Clean-up		2.50%		$11,757.00
Sub Total				$482,037.00
Contingencies		20.00%		$96,407.40
Levee Total				**$578,444.40**
Design and Prepare Contract		7.50%		$43,383.33
Total				**$621,827.73**

TABLE A.3 (cont.)
PRELIMINARY ESTIMATES FOR LEVEE 1

LEVEE 1 (1% AEP) - Planted Median Strip Along Arundel Street

Length 720m

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	3,000.00	1	$3,000.00
Prepare Site	m^2	0.40	720	$288.00
Provision for traffic	item	5,000.00	1	$5,000.00
Break out existing bitumen	m^2	5.00	720	$3,600.00
Excavate and pour RC strip footings	m^3	300.00	389	$116,700.00
Construct double leaf brick retaining wall	m^2	115.00	1160	$133,400.00
Import embankment fill and compact	m^3	30.00	670	$20,100.00
Shrubs/mulch	m	22.50	720	$16,200.00
Draiange Alterations	item	160,000.00	1	$160,000.00
Sub Total				$468,288.00
Clean-up		2.50%		$11,707.20
Sub Total				$479,995.20
Contingencies		20.00%		$95,999.04
Levee Total				$575,994.24
Design and Prepare Contract		7.50%		$43,199.57
Total				**$619,193.81**

LEVEE 1 (2% AEP) - Planted Median Strip Along Arundel Street

Length 720m

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	3,000.00	1	$3,000.00
Prepare Site	m^2	0.40	720	$288.00
Provision for traffic	item	5,000.00	1	$5,000.00
Break out existing bitumen	m^2	5.00	720	$3,600.00
Excavate and pour RC strip footings	m^3	300.00	389	$116,700.00
Construct double leaf brick retaining wall	m^2	115.00	780	$89,700.00
Import embankment fill and compact	m^3	30.00	455	$13,650.00
Shrubs/mulch	m	22.50	720	$16,200.00
Draiange Alterations	item	160,000.00	1	$160,000.00
Sub Total				$418,138.00
Clean-up		2.50%		$10,453.45
Sub Total				$428,591.45
Contingencies		20.00%		$85,718.29
Levee Total				$514,309.74
Design and Prepare Contract		7.50%		$38,573.23
Total				**$552,882.97**

LEVEE 1 (5% AEP) - Concrete Median Strip Along Arundel Street

Length 720m

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	5,000.00	1	$5,000.00
Setting out survey	item	1,000.00	1	$1,000.00
Provision for traffic	item	3,000.00	1	$3,000.00
Break out existing bitumen	m^2	5.00	360	$1,800.00
Construct double mountable kerb median	m^2	44.00	720	$31,680.00
Draiange Alterations	item	160,000.00	1	$160,000.00
Sub Total				$202,480.00
Clean-up		2.50%		$5,062.00
Sub Total				$207,542.00
Contingencies		15.00%		$31,131.30
Levee Total				$238,673.30
Design and Prepare Contract		5.00%		$11,933.67
Total				**$250,606.97**

TABLE A.4

PRELIMINARY ESTIMATES FOR LEVEE 2

LEVEE 2 (1% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	20,000.00	1	$20,000.00
Setting out survey	item	10,000.00	1	$10,000.00
Prepare Site	m^2	0.40	20000	$8,000.00
Remove/replace topsoil	m^3	16.50	10000	$165,000.00
Masonry Wall (540m)				
Excavate and pour RC strip footings	m^3	300.00	200	$60,000.00
200 Wide reinforced Blockwork wall	m^2	120.00	1050	$126,000.00
Landscaped Earthem Embankment				
Import embankment fill and compact	m^3	30.00	35500	$1,005,000.00
Hydromulch embankments	m^2	0.30	20000	$6,000.00
Shrubs	m^2	1.00	20000	$20,000.00
Draiange Alterations	item	50,000.00	1	$50,000.00
Pumping supply and installation	item	175,000.00	2	$350,000.00
Sub Total				$1,880,000.00
Clean-up		2.50%		$47,000.00
Sub Total				$1,927,000.00
Contingencies		20.00%		$385,400.00
Levee Total				$2,312,400.00
Design and Prepare Contract		5.00%		$115,620.00
Total				$2,428,020.00
Property Purchase including legal fees	item	155,000.00	1	$155,000.00
Total				$2,583,020.00

LEVEE 2 (2% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	20,000.00	1	$20,000.00
Setting out survey	item	10,000.00	1	$10,000.00
Prepare Site	m^2	0.40	17500	$7,000.00
Remove/replace topsoil	m^3	16.50	9000	$148,500.00
Masonry Wall (540m)				
Excavate and pour RC strip footings	m^3	300.00	170	$51,000.00
200 Wide reinforced Blockwork wall	m^2	120.00	950	$114,000.00
Landscaped Earthem Embankment				
Import embankment fill and compact	m^3	30.00	28000	$840,000.00
Hydromulch embankments	m^2	0.30	17500	$5,250.00
Shrubs	m^2	1.00	17500	$17,500.00
Draiange Alterations	item	50,000.00	1	$50,000.00
Pumping supply and installation	item	175,000.00	2	$350,000.00
Sub Total				$1,613,250.00
Clean-up		2.50%		$40,331.25
Sub Total				$1,653,581.25
Contingencies		20.00%		$330,716.25
Levee Total				$1,984,297.50
Design and Prepare Contract		5.00%		$99,214.88
Total				$2,083,512.38
Property Purchase including legal fees	item	155,000.00	1	$155,000.00
Total				$2,238,512.38

LEVEE 2 (5% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	20,000.00	1	$20,000.00
Setting out survey	item	10,000.00	1	$10,000.00
Prepare Site	m^2	0.40	13500	$5,400.00
Remove/replace topsoil	m^3	16.50	6750	$111,375.00
Masonry Wall (540m)				
Excavate and pour RC strip footings	m^3	300.00	125	$37,500.00
200 Wide reinforced Blockwork wall	m^2	120.00	710	$85,200.00
Landscaped Earthem Embankment				
Import embankment fill and compact	m^3	30.00	15500	$465,000.00
Hydromulch embankments	m^2	0.30	13500	$4,050.00
Shrubs	m^2	1.00	13500	$13,500.00
Draiange Alterations	item	50,000.00	1	$50,000.00
Pumping supply and installation	item	175,000.00	2	$350,000.00
Sub Total				$1,152,025.00
Clean-up		2.50%		$28,800.63
Sub Total				$1,180,825.63
Contingencies		20.00%		$236,165.13
Levee Total				$1,416,990.75
Design and Prepare Contract		5.00%		$70,849.54
Total				$1,487,840.29
Property Purchase including legal fees	item	155,000.00	1	$155,000.00
Total				$1,642,840.29

TABLE A.5
PRELIMINARY ESTIMATES FOR LEVEE 3A

LEVEE 3A (1% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	15,000.00	1	$15,000.00
Setting out survey	item	8,000.00	1	$8,000.00
Prepare Site	m^2	0.40	27500	$11,000.00
Remove/replace topsoil	m^3	16.50	13750	$226,875.00
Masonry Wall (540m)				
Excavate and pour RC strip footings	m^3	300.00	170	$51,000.00
200 Wide reinforced Blockwork wall	m^2	120.00	950	$114,000.00
Landscaped Earthern Embankment				
Import embankment fill and compact	m^3	30.00	47000	$1,410,000.00
Hydromulch embankments	m^2	0.30	27500	$8,250.00
Shrubs	m^2	1.00	27500	$27,500.00
Draiange Alterations	item	100,000.00	1	$100,000.00
Pumping supply and installation	item	175,000.00	3	$525,000.00
Sub Total				$2,496,625.00
Clean-up		2.50%		$62,415.63
Sub Total				$2,559,040.63
Contingencies		20.00%		$511,808.13
Levee Total				$3,070,848.75
Design and Prepare Contract		5.00%		$153,542.44
Total				$3,224,391.19

LEVEE 3A (2% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	15,000.00	1	$15,000.00
Setting out survey	item	8,000.00	1	$8,000.00
Prepare Site	m^2	0.40	24250	$9,700.00
Remove/replace topsoil	m^3	16.50	12125	$200,062.50
Masonry Wall (540m)				
Excavate and pour RC strip footings	m^3	300.00	170	$51,000.00
200 Wide reinforced Blockwork wall	m^2	120.00	950	$114,000.00
Landscaped Earthern Embankment				
Import embankment fill and compact	m^3	30.00	30000	$900,000.00
Hydromulch embankments	m^2	0.30	24250	$7,275.00
Shrubs	m^2	1.00	24250	$24,250.00
Draiange Alterations	item	100,000.00	1	$100,000.00
Pumping supply and installation	item	175,000.00	3	$525,000.00
Sub Total				$1,954,287.50
Clean-up		2.50%		$48,857.19
Sub Total				$2,003,144.69
Contingencies		20.00%		$400,628.94
Levee Total				$2,403,773.63
Design and Prepare Contract		5.00%		$120,188.68
Total				$2,523,962.31

LEVEE 3A (5% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	15,000.00	1	$15,000.00
Setting out survey	item	8,000.00	1	$8,000.00
Prepare Site	m^2	0.40	18000	$7,200.00
Remove/replace topsoil	m^3	16.50	9000	$148,500.00
Masonry Wall (540m)				
Excavate and pour RC strip footings	m^3	300.00	30	$9,000.00
200 Wide reinforced Blockwork wall	m^2	120.00	120	$14,400.00
Landscaped Earthern Embankment				
Import embankment fill and compact	m^3	30.00	21200	$636,000.00
Hydromulch embankments	m^2	0.30	18000	$5,400.00
Shrubs	m^2	1.00	18000	$18,000.00
Draiange Alterations	item	100,000.00	1	$100,000.00
Pumping supply and installation	item	175,000.00	3	$525,000.00
Sub Total				$1,486,500.00
Clean-up		2.50%		$37,162.50
Sub Total				$1,523,662.50
Contingencies		20.00%		$304,732.50
Levee Total				$1,828,395.00
Design and Prepare Contract		5.00%		$91,419.75
Total				$1,919,814.75

TABLE A.6
PRELIMINARY ESTIMATES FOR LEVEE 4

LEVEE 4 (1% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	3,000.00	1	$3,000.00
Prepare Site	m^2	0.40	19000	$7,600.00
Remove/replace topsoil	m^3	16.50	1500	$24,750.00
Median				
Break out existing bitumen	m^2	5.00	1400	$7,000.00
Excavate and pour RC strip footings	m^3	300.00	140	$42,000.00
Construct double leaf brick retaining wall	m^2	115.00	740	$85,100.00
Import fill and place	m^3	30.00	344	$10,320.00
Shrubs/mulch	m	22.50	1400	$31,500.00
Road Raising				
Break out existing bitumen	m^2	7.00	9000	$63,000.00
Construct new carriageway	m	325.00	740	$240,500.00
Import embankment fill and compact	m^3	30.00	7400	$222,000.00
Landscaped Earthern Embankment				
Import embankment fill and compact	m^3	30.00	5000	$150,000.00
Hydromulch embankments	m^2	0.30	3000	$900.00
Shrubs	m^2	1.00	3000	$3,000.00
Draiange Alterations	item	75,000.00	1	$75,000.00
Pumping supply and installation	item	175,000.00	1	$175,000.00
Sub Total				$1,150,670.00
Clean-up		2.50%		$28,766.75
Sub Total				$1,179,436.75
Contingencies		20.00%		$235,887.35
Levee Total				$1,415,324.10
Design and Prepare Contract		5.00%		$70,766.21
Total				$1,486,090.31

LEVEE 4 (2% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	3,000.00	1	$3,000.00
Prepare Site	m^2	0.40	16000	$6,400.00
Remove/replace topsoil	m^3	16.50	1250	$20,625.00
Median				
Break out existing bitumen	m^2	5.00	1400	$7,000.00
Construct double mountable kerb median	m^2	44.00	720	$31,680.00
Road Raising				
Break out existing bitumen	m^2	7.00	5000	$35,000.00
Construct new carriageway	m	325.00	500	$162,500.00
Import embankment fill and compact	m^3	30.00	7000	$210,000.00
Landscaped Earthern Embankment				
Import embankment fill and compact	m^3	30.00	5000	$150,000.00
Hydromulch embankments	m^2	0.30	2500	$750.00
Shrubs	m^2	1.00	2500	$2,500.00
Draiange Alterations	item	75,000.00	1	$75,000.00
Pumping supply and installation	item	175,000.00	1	$175,000.00
Sub Total				$889,455.00
Clean-up		2.50%		$22,236.38
Sub Total				$911,691.38
Contingencies		20.00%		$182,338.28
Levee Total				$1,094,029.65
Design and Prepare Contract		5.00%		$54,701.48
Total				$1,148,731.13

LEVEE 4 (5% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	7,500.00	1	$7,500.00
Setting out survey	item	1,000.00	1	$1,000.00
Prepare Site	m^2	0.40	2000	$800.00
Remove/replace topsoil	m^3	16.50	1000	$16,500.00
Landscaped Earthern Embankment				
Import embankment fill and compact	m^3	30.00	2000	$60,000.00
Hydromulch embankments	m^2	0.30	2000	$600.00
Shrubs	m^2	1.00	2000	$2,000.00
Draiange Alterations	item	75,000.00	1	$75,000.00
Pumping supply and installation	item	175,000.00	1	$175,000.00
Sub Total				$338,400.00
Clean-up		2.50%		$8,460.00
Sub Total				$346,860.00
Contingencies		20.00%		$69,372.00
Levee Total				$416,232.00
Design and Prepare Contract		5.00%		$20,811.60
Total				$437,043.60
Total				$437,043.60

TABLE A.7
PRELIMINARY ESTIMATES FOR LEVEE 7

LEVEE 7 (1% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	7,500.00	1	$7,500.00
Prepare Site	m^2	0.40	10000	$4,000.00
Remove/replace topsoil	m^3	16.50	5000	$82,500.00
Masonry Wall (490m)				
Excavate and pour RC strip footings	m^3	300.00	240	$72,000.00
200 Wide reinforced Blockwork wall	m^2	120.00	1150	$138,000.00
Landscaped Earthern Embankment				
Import embankment fill and compact	m^3	30.00	14500	$435,000.00
Hydromulch embankments	m^2	0.30	10000	$3,000.00
Shrubs	m^2	1.00	10000	$10,000.00
Draiange Alterations	item	50,000.00	1	$50,000.00
Sub Total				$812,000.00
Clean-up		2.50%		$20,300.00
Sub Total				$832,300.00
Contingencies		20.00%		$166,460.00
Levee Total				**$998,760.00**
Design and Prepare Contract		5.00%		$49,938.00
Total				**$1,048,698.00**

LEVEE 7 (2% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	7,500.00	1	$7,500.00
Prepare Site	m^2	0.40	9000	$3,600.00
Remove/replace topsoil	m^3	16.50	4500	$74,250.00
Masonry Wall (540m)				
Excavate and pour RC strip footings	m^3	300.00	200	$60,000.00
200 Wide reinforced Blockwork wall	m^2	120.00	1075	$129,000.00
Landscaped Earthern Embankment				
Import embankment fill and compact	m^3	30.00	11200	$336,000.00
Hydromulch embankments	m^2	0.30	9000	$2,700.00
Shrubs	m^2	1.00	9000	$9,000.00
Draiange Alterations	item	50,000.00	1	$50,000.00
Sub Total				$682,050.00
Clean-up		2.50%		$17,051.25
Sub Total				$699,101.25
Contingencies		20.00%		$139,820.25
Levee Total				**$838,921.50**
Design and Prepare Contract		5.00%		$41,946.08
Total				**$880,867.58**

LEVEE 7 (5% AEP) - Landscaped Embankment / Floodwall

Description	Unit	Rate	Qty	Cost ($)
Establishment	item	10,000.00	1	$10,000.00
Setting out survey	item	7,500.00	1	$7,500.00
Prepare Site	m^2	0.40	8200	$3,280.00
Remove/replace topsoil	m^3	16.50	4100	$67,650.00
Masonry Wall (540m)				
Excavate and pour RC strip footings	m^3	300.00	180	$54,000.00
200 Wide reinforced Blockwork wall	m^2	120.00	980	$117,600.00
Landscaped Earthern Embankment				
Import embankment fill and compact	m^3	30.00	8000	$240,000.00
Hydromulch embankments	m^2	0.30	8200	$2,460.00
Shrubs	m^2	1.00	8200	$8,200.00
Drainage Alterations	item	50,000.00	1	$50,000.00
Sub Total				$560,690.00
Clean-up		2.50%		$14,017.25
Sub Total				$574,707.25
Contingencies		20.00%		$114,941.45
Structure Total				**$689,648.70**
Design and Prepare Contract		5.00%		$34,482.44
Total				**$724,131.14**

TABLE A.8
PRELIMINARY ESTIMATES FOR RIVER EXCAVATION AND RAILWAY CULVERTS

River Island Excavation

Description	Unit	Rate	Qty	Cost ($)
Establishment	Item	20000.00	1	$20,000.00
Setting Out Survey	Item	7500.00	1	$7,500.00
Clear Vegetation	m^2	0.40	54750	$21,900.00
Remove/replace topsoil	m^3	16.50	16500	$272,250.00
Excavate to create min. depth	m^3	6.00	75000	$450,000.00
Sub-total				$771,650.00
Clean-up		2.50%		$19,291.25
Sub-total				$790,941.25
Contingencies		20.00%		$158,188.25
River Excavation Total				**$949,129.50**
Design and Prepare Contract		5.00%		$47,456.48
Total				**$996,585.98**

Railway Culverts

	Unit	Rate	Qty	Cost ($)
Nunn Street Culverts				
Establishment	Item	20000.00	1	$20,000.00
Setting Out Survey	Item	6000.00	1	$6,000.00
Supply 6 No 4.2m x 1.5m RCBC	m	1400.00	240	$336,000.00
Install culverts	m	3500.00	240	$840,000.00
Sub-total				$1,202,000.00
Clean-up		2.50%		$30,050.00
Sub-total				$1,232,050.00
Contingencies		20.00%		$246,410.00
Nunn Street culverts total				**$1,478,460.00**
Design and Prepare Contract		5.00%		$73,923.00
Total				**$1,552,383.00**
Duffy Street Culverts				
Establishment	Item	20000.00	1	$20,000.00
Setting Out Survey	Item	5000.00	1	$5,000.00
Supply 5 No 4.2m x 1.5m RCBC	m	1400.00	150	$210,000.00
Install culverts	m	3500.00	150	$525,000.00
Clean-up				$760,000.00
Sub-total		2.50%		$19,000.00
Contingencies				$779,000.00
Duffy Street culverts total		20.00%		$155,800.00
Design and Prepare Contract				$934,800.00
		5.00%		$46,740.00
Total				
				$981,540.00
Additional East Main Drain Culvert				
Establishment	Item	20000.00	1	$20,000.00
Setting Out Survey	Item	1000.00	1	$1,000.00
Supply 1 No 2.4m x 1.5m RCBC	m	1135.00	20	$22,700.00
Install culverts	m	2270.00	20	$45,400.00
Clean-up				$89,100.00
Sub-total		2.50%		$2,227.50
Contingencies				$91,327.50
Additional East Main Drain Culvert total		20.00%		$18,265.50
Design and Prepare Contract				$109,593.00
		5.00%		$5,479.65
Total				$115,072.65

TABLE A.9

PRELIMINARY ESTIMATE FOR HUME FREEWAY RETARDING BASIN

Hume Freeway Retarding Basin				
Description	**Unit**	**Rate**	**Qty**	**Cost ($)**
Establishment	Item	40000.00	1	40,000
Setting out survey	Item	12000.00	1	12,000
Sub Total				52,000
Broken River Anabranch				
Prepare site	m^2	0.35	3775	1,321
Remove/replace topsoil (1000mm)	m^3	12.20	3775	46,055
Construct Earthen Embankment	m^3	10.00	6680	66,800
Embankment Scour Protection	m^2	0.30	3880	1,164
Spillway (Reinforced Grass)	m^2	20.00	570	11,400
Normal Outlet (4 No. 4.2 mx 2.4 m RCBC)				
Supply	m	160.00	1790	286,400
Installation	m	120.00	3580	429,600
Sub Total				842,740
Broken River				
Prepare site	m^2	0.35	4550	1,593
Remove/replace topsoil (1000mm)	m^3	12.20	4550	55,510
Construct Earthen Embankment	m^3	10.00	6900	69,000
Embankment Scour Protection	m^2	0.30	4680	1,404
Spillway (Reinforced Grass)	m^2	20.00	855	17,100
Normal Outlet (5 No. 4.2 mx 2.4 m RCBC)				
Supply	m	175.00	1790	313,250
Installation	m	175.00	3580	626,500
Sub Total				1,084,357
Blind Creek				
Prepare site	m^2	0.35	1690	592
Remove/replace topsoil (1000mm)	m^3	12.20	1690	20,618
Construct Earthen Embankment	m^3	10.00	3000	30,000
Embankment Scour Protection	m^2	0.30	1740	522
Spillway (Reinforced Grass)	m^2	20.00	260	5,200
Normal Outlet (4 No. 4.2 mx 2.4 m RCBC)				
Supply	m	80.00	1790	143,200
Installation	m	80.00	3580	286,400
Sub Total				486,532
Holland Creek				
Prepare site	m^2	0.35	9030	3,161
Remove/replace topsoil (1000mm)	m^3	12.20	9030	110,166
Construct Earthen Embankment	m^3	10.00	14000	140,000
Embankment Scour Protection	m^2	0.30	7500	2,250
Spillway (Reinforced Grass)	m^2	20.00	960	19,200
Normal Outlet (4 No. 4.2 mx 2.4 m RCBC)				
Supply	m	320.00	1790	572,800
Installation	m	320.00	3580	1,145,600
Sub Total				1,993,177
Raise Freeway Shoulder				
Earthworks	m^3	10	620	6,200
Stabilisation	m^2	0.3	3200	960
Sub Total				7,160
Retarding Basin sub-total				4,413,965
Clean up @2.5%				110,349
Sub Total				4,524,314
Contingencies @ 20%				904,863
Design & Prepare Contract @ 6.0%				264,838
Sub Total				4,678,803
Raise/Relocate 6 houses	Item	70000.00	6	420,000
TOTAL				5,098,803

TABLE A.10
PRELIMINARY ESTIMATE FOR ARUNDEL LAKE

Arundel Lake				
Description	Unit	Rate	Qty	Cost ($)
Establishment & enviro. Ctrls	item	40,000.00	1	$40,000.00
Setting out survey	item	10,000.00	1	$10,000.00
Prepare site, clear & grub trees	ha	2,100.00	30	$63,000.00
Remove & stockpile topsoil (300mm)	m^3	10.00	30000	$300,000.00
Excavate to create min. depth	m^3	7.00	25000	$175,000.00
Construct Embankment (2 No.)	m^3	30.00	6000	$180,000.00
Embankment rip-rap	tonne	30.00	1600	$48,000.00
Spillway (2 no.)	item	60,000.00	2	$120,000.00
Filling and shaping of lake near Maginess St	m^3	7.50	10500	$78,750.00
Stread topsoil & trim	m^3	4.50	30000	$135,000.00
Hydromulch/seed to stabilize perimeter	ha	3,000.00	10	$30,000.00
Landscaping (incl. Trees, shrubs)	ha	30,000.00	10	$300,000.00
Sub Total				$1,479,750.00
Clean-up		2.50%		$36,993.75
Sub Total				$1,516,743.75
Contingencies		20.00%		$303,348.75
Levee Total				**$1,820,092.50**
Design and Prepare Contract		5.00%		$91,004.63
Total				**$1,911,097.13**

TABLE A.11
SUMMARY OF PRELIMINARY ESTIMATED CAPITAL AND RECURRENT COST FOR FLOODPLAIN MEASURES

Code	Description	Capital	Recurrent
C_{NUNN}	Railway Culverts near Nunn St.	2350000	11750
C_{DUFFY}	Railway Culverts near Duffy Street	1095000	5475
D_E	Vegetation Management near confluence.	210000	10500
F1	Levees 1 & 2	3426140	68523
F2	Levees 1 & 2	2986370	59727
F5	Levees 1 & 2	2026580	40532
H1	Levee 7	1122430	16836
H2	Levee 7	942670	18853
H3	Levee 7	774680	15494
I1	Levee 3A & 4	5040770	100815
I2	Levee 3A & 4	2700680	54014
I3	Levee 3A & 4	2521990	50440
K	Lake Arundel	2033000	30495
M	River Island Excavation.	909500	1364
L	Retarding Basin upstream of Hume Frreway	5778000	144450
NN	Vegetation Management downstream of Ackerley Ave.	663000	13000

APPENDIX B

Hydrological Analysis

APPENDIX B HYDROLOGICAL ANALYSIS

B.1 Pumping and Storage Requirements

For the satisfactory functioning of Levees 1, 2, 3A, 4, and 7 either or both pumping and the temporary storage of local runoff from behind the levees will need to be considered. The area behind Levee 1 can be re-directed towards the West Main Drain and therefore pumping would not be required. In the case of Levee 7 pumping would be required for floods greater than the 2% AEP flood.

For all other levees there are only limited opportunities to provide temporary storage. The potential areas identified include undeveloped land near the end of Waller Street and the Broken River anabranch between Hair Street and Maud Street both of which are behind Levee 2. Potential storage areas have been identified south of Samaria Road behind the alignment for Levee 3A but nowhere else unless the Levee 3A is constructed within the open parkland opposite Psaltis Parade. No potential storage areas in the area protected by Levee 4 were identified.

An analysis of the volume of runoff and peak flow occurring behind the levees was undertaken using the RAFTS-XP rainfall/runoff model. Rainfall loss rates were identical to those adopted in the Flood Study for the Benalla urban area. The hydrographs presented in Tables B.1 to B.4 are for the 1% AEP, 18 hour duration storm which is the critical event for flooding in the Broken River at Benalla.

The estimated peak local runoff rates for long term storms when the river level is high and local runoff from behind the levee cannot discharge under gravity are within the capacity of available submersible pumps. Pumps with capacities of 2000 l/s are readily available at a cost of about $75,000. A permanent housing, either above or below ground would be required together with a reliable mains power supply.

FIGURE B.1
HYETOGRAPH AND PEAK FLOW HYDROGRAPH FOR AREA BEHIND LEVEE 1

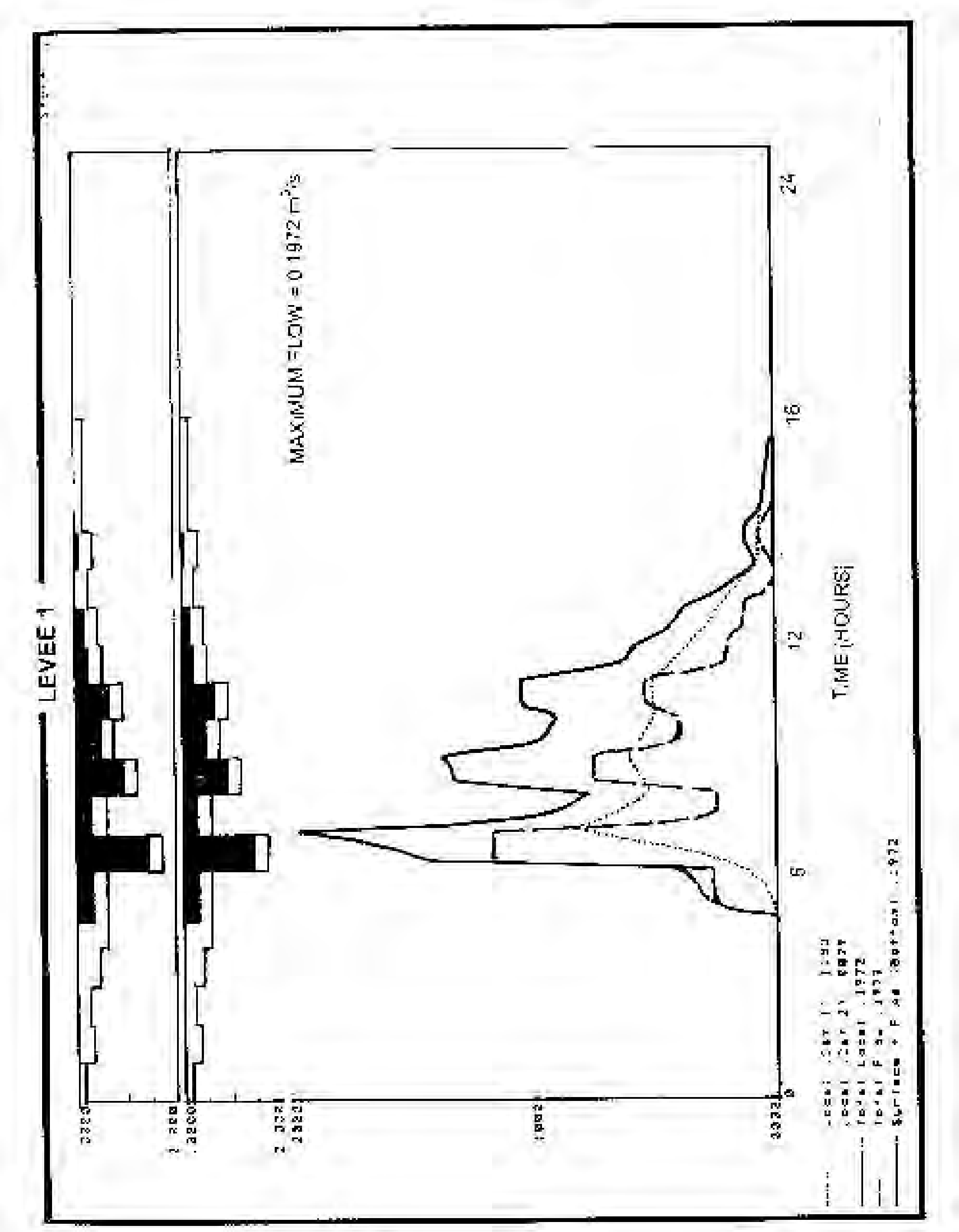


FIGURE B.2
HYETOGRAPH AND PEAK FLOW HYDROGRAPH FOR AREA BEHIND LEVEE 2

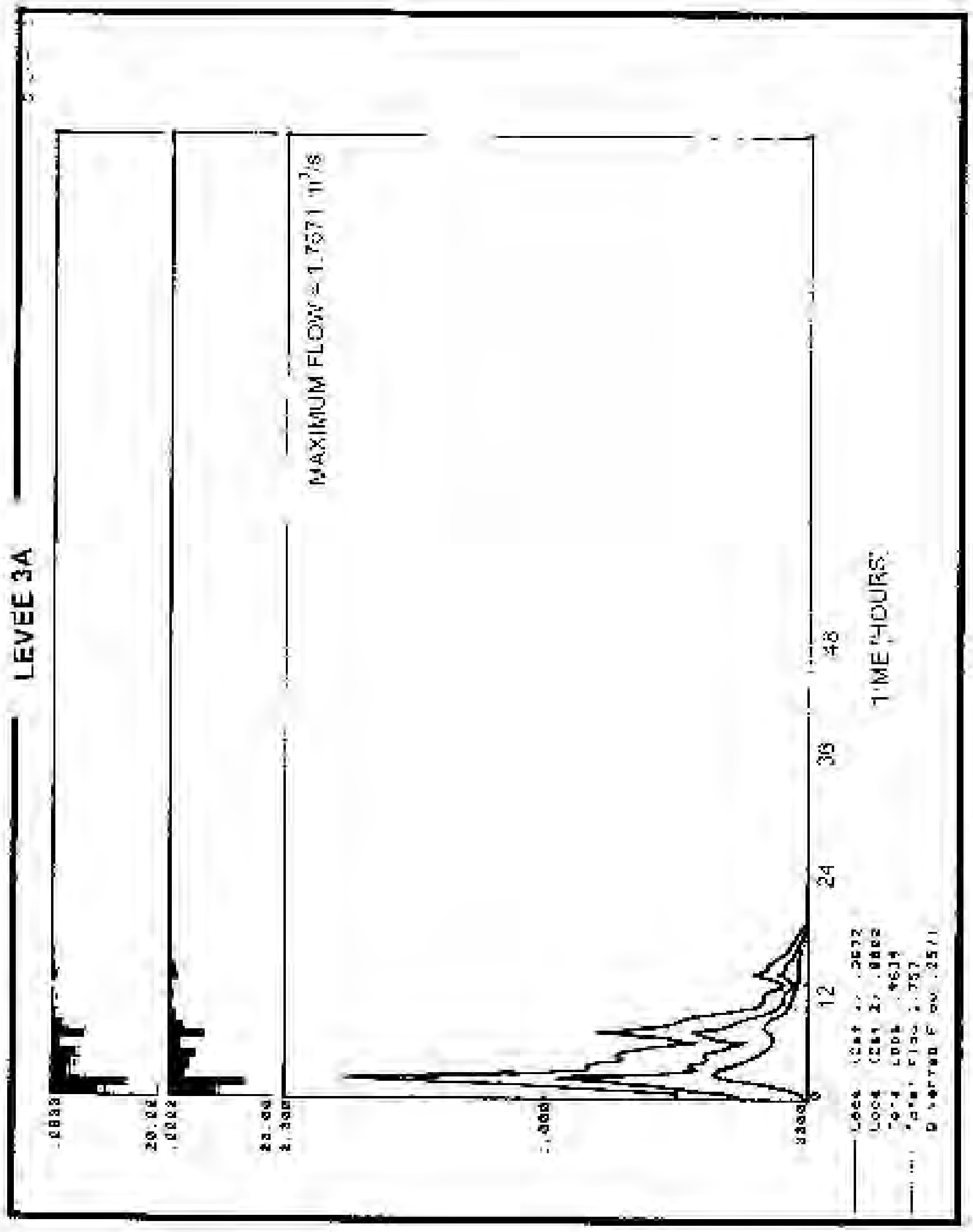


FIGURE B.3
HYETOGRAPH AND PEAK FLOW HYDROGRAPH FOR AREA BEHIND LEVEE 3A

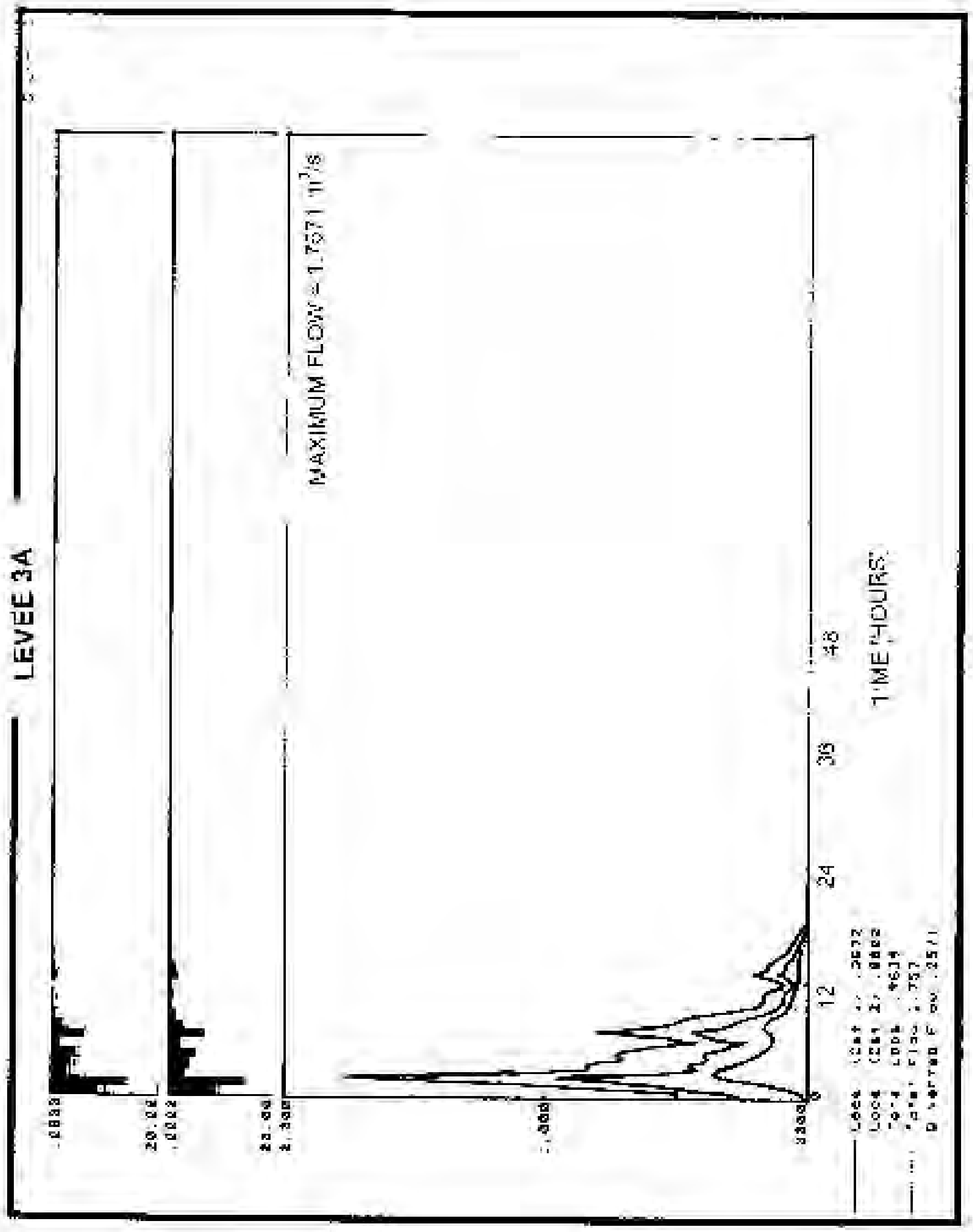
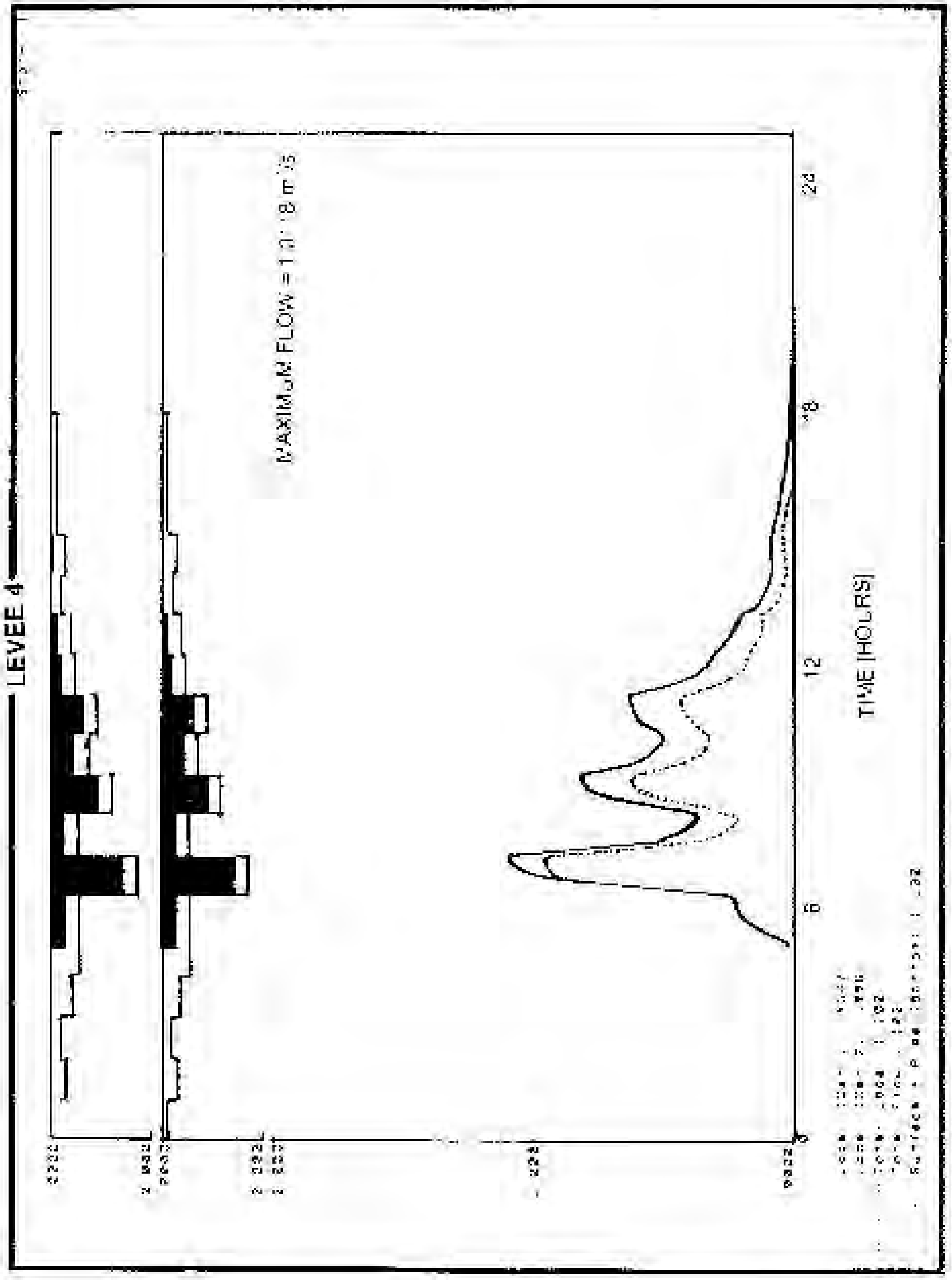


TABLE B.4
PEAK FLOW HYDROGRAPH FOR AREA BEHIND LEVEE 4



APPENDIX C

Environmental and Social Assessment

APPENDIX C ENVIRONMENTAL & SOCIAL ASSESSMENT

C.1 Heritage Items

Of importance to Benalla are the significant number of Heritage items, some of which are located within or immediately adjacent to the floodway. A list of these and their current heritage status is presented in Table C.1.

TABLE C.1
BENALLA: HERITAGE ITEMS WITHIN OR ADJACENT TO FLOODWAY

Planning Option Reference	Item	Historic Building Register[2]	National Estate Register	Planning Option
1	Rail Bridge over Broken River		✓	
15	Faithful Massacre Site and Memorial		✓	✓
12	Benalla Gardens			✓
11	Showground			✓
9	*Sunningdale*, Benson Street			✓
17	Former Mechanics Institute and free library		✓	✓
20	*Wooleen*, (Garden and trees only, Mitchell Street)			✓
8	Former *Moira* House, Benalla Street		✓	✓
6	Ombu Tree, adjacent to 21 Arundel St.			✓

Notes:
1. Source was Benalla (City) Planning Option
2. None listed on the Register

The main purpose of the policy in relation to these items is to consider whether any proposed development will alter the character and appearance of the building or place. Many of the non-structural measures are therefore not appropriate in relation to such items, such as floor raising and flood proofing. Structural measures proposed should therefore take account of the location and importance of such items to ensure that every effort is made to protect heritage items in times of flood.

C.2 Environmental and Social Assessment

C.2.1 Introduction

An environmental and social assessment of the various structural options has been prepared based on six main factors.

These are:

- amenity - whether the option will affect the social or physical amenity of Benalla, including accessibility to community facilities and services;
- aesthetic - whether the option will affect existing aesthetic qualities within the city, including views, vistas and impact on specific items or areas;
- land take - whether the option will involve the dedication of significant areas of land within the urban area;
- ecology - whether the option will cause disruption to the flora and fauna of the area and the extent to which this might be acceptable; and
- sensitivity - whether the option will affect sensitive uses, such as heritage items and whether general enjoyment of life will be compromised.

This assessment includes reference to other non-structural measures which will be required to supplement options in each instance. Impacts are then tabled and ranked according to their affect on the environmental and social qualities of the community.

C.2.2 Assessment

Common to all options are improvements to the East and West Main Drains which were reported to Council in July, 1994. They include widening existing easements, channel regrading, bed profile modification and road crossing upgrades. These are limited to existing reservations, and provided development within, over or under these easements does not affect their carrying capacity, there are no major impacts imposed by this particular component.

Nevertheless, it is recommended that only flood compatible uses such as open space, should be permitted within each easement. The 1994 report also recommended that consideration be given to rezoning the East and West Main Drain to a stream (zone S1), although as previously identified, under the draft State Policy on Floodprone Areas and Model Planning Scheme Flood Provisions an Urban Floodway Zone would be applicable. Zones which identify the flood liable area only as open space place the wrong emphasis on the primary reason for prohibiting certain types of development.

It is intended that the improvements to the main drains be supplemented by other initiatives, such as raising the level of bridge structures crossing the channel (eg. immediately downstream of Bridge Street) on the east main drain. This will prevent intrusion into the waterway and consequently allow capacity of the main drain to be maximised.

Another non-structural measure associated with this component, is the need to prevent vegetation and weed infestation within the drain, by enforcing weed spraying at appropriate intervals throughout the year. This would need to be carefully monitored to ensure that there is no contamination arising from this within and downstream of the drains.

Scheme A

This Scheme involves the construction of five levees, ie. Levees 1, 2, 3A, 4 and 7 in addition to improvements to the East and West Main Drains and a reduction in the amount and extent of vegetation along and within the river between Psaltis Parade and Holland Creek. The levees comprise a mixture of raised road median barriers with planter boxes, landscaped earthen levees and masonry flood walls. The extent and location of these is shown in Figure 15. They are designed to reduce flood damage for floods equal to or smaller than the 1%AEP flood (equivalent to a flood with a peak flow the same as the October 1993 flood).

Levee 1 comprises a raised road median barrier with a continuous planter box between road intersections located in Arundel Street between Ackerly Avenue and Bridge Street. The height of this will be approximately 700 mm for and this will be supplemented at street intersections by contingency sealing using drop boards fitted to slots in the end of each levee. It is proposed that the reserve provide for planting of appropriate species and creepers, to provide a landscaped finish. Since this part of Arundel Street is visually sensitive, due to the presence of two major heritage items and much pleasing turn of the century architecture, appropriate landscaping would be necessary. Arundel Street is wide enough to accommodate the reserve which will also bring the scale of the street down to a human level, by breaking up the expanse of the road. Since the median reserve will only be of limited height and does not require any additional land for its construction, it will have a low impact on all social and environmental factors considered.

The concept of the median reserve is the same for **Levee 4**, which will vary in height from 300 mm along Mair Street to 1000 mm at the intersection of Mitchell and Benalla Streets. The levee would be supplemented by drop boards at intersections as for Levee 1. Implementation of the levee will have a low impact, provided planting maintenance and management is enforced.

Construction of **Levee 2** would require the acquisition of residential premises at 139 Arundel Street. The floor level of this property is below the 5% AEP flood. To reduce land take, that part of levee 2 located to the east of Neil Avenue would take the form of a timber crib retaining wall adapted to accommodate ground cover species to make it more visually acceptable. The levee would prevent access onto Arundel Street from the walking/cycle track. An alternative location for the track would need to be found or access redesigned for incorporation into the levee. One option might be inclusion of a steel hinged gate. This would maintain access to the track but would be visually intrusive.

Levee 2 is constructed for the most part along the rear boundary of an existing residential area in a relatively unexposed area. The remainder of the levee extending south from Neil Avenue will not have a significant adverse impact upon the amenity or aesthetic value of the area with the exception of developed property (CP 107259) at the corner of Neil Avenue and Benson Street where a retaining wall (masonry or timber crib) may be required to provide balance between the height of the wall (up to 2.6 metres depending on its alignment along the river bank) and the amount of land required.

There are a number of trees located in this area and there is potential for ecological impacts where the levee involves the removal of trees. However, landscaping and replanting where appropriate, should ensure that this is reduced to a minimum.

This levee is considered to be in a sensitive location, due to its exposure from the showground and Bridge Street and to other public open space areas along Arundel Street, especially adjoining the special use zone (SU1), where several heritage items are located. The use of a reinforced masonry wall along the rear boundary of properties between Bridge and Maud Streets will help reduce the visual impact as well as minimising the landtake.

Where reinforced masonry walls are proposed, such as along the rear of properties between Bridge and Maud Streets and the side boundary of 111 Arundel Street, in lieu of a ramped earthen embankment the privacy of the occupants will be protected.

Levee 3A would comprise a masonry wall with screen planting along Fawckner Parade in front of the Civic Centre and Senior Citizens Centre. Openings to both the buildings and car park area would need to be sealed with drop boards during a flood. The levee would then continue upstream as either a reinforced masonry wall or earthen embankment behind property in Lowry Place and a landscaped embankment generally following Psaltis Parade, Parkview Parade South Street, behind properties in Ascot Court and then on towards Willis Little Drive. A break in the levee at Samaria Road would need to be sealed with drop boards as described for Levee 1 during a flood.

From Psaltis Parade to Willis Little Drive the levee would be located on a mixture of public open space, rural and local government land. The roads are wide enough in these locations to not cause an immediate impact on residential properties, in terms of overshadowing or loss of privacy. There may be some disruption of views from properties along Psaltis Parade and Parkview Parade towards the river, although much of this is quite heavily vegetated and most views limited. Many of the residences also have extensive planting to the front of their properties which effectively obscure views into and out of the premises.

There is sufficient land to provide a landscaped earthen levee along and upstream of Psaltis Parade. Much of the area is within the floodway and there would be no loss of development land. A potential exists for this levee to reduce access to the river, both informal and via the river walk. This is especially so to the north of Parkview Parade, where the existing walk and network of tracks is accessed. Access may be maintained by providing a ramp over the levee at this location.

As with Levee 2, there is potential for ecological disturbance from the construction of this levee, due to the floodway being reasonably well vegetated. If pursued, this option should involve the replacement and location of any trees removed to minimise any potential long term effects. Further detailed comment is provided in this regard under discussions concerning Measure D which requires significant reductions in understorey vegetation and a thinning of existing trees to approximately half their existing number opposite Psaltis Parade and upstream to Holland Creek.

Since Levee 3A is located on rural zoned land to the rear of properties in Ascot Court, impacts will be minimised, and indeed the levee might serve to screen properties from any adjoining developments. However, due to significant exposure of parkland to the rear of Fawckner Drive this levee impinges heavily upon a sensitive area of open space which is a main focus of the city. The levee would segregate the river from the open space and be visually intrusive in this location

Levee 7 comprises a brick flood wall to the rear of residential premises in Maginnes and McIvor Streets, up to a height of two metres (including freeboard) and an earthen levee to the west of Nunn Street. Sealing the breaks in the levee across Ackerly Avenue and Hannah Street would be required during times of flood.

While reasonably high, this levee would be located in land zoned as public open space (POS) and Rural A (RU1) where development density is minimal. In addition, that part of the levee proposed as a flood wall would be to the rear of properties and would not be intrusive. Impacts on the amenity and aesthetic values of the location of the levee in this area are therefore low.

The floodwall along Roe Street, Neville Street and Doherty Streets would be no more than 900 mm high (including 600 mm freeboard) and may be readily disguised as boundary fencing. A low sloping earthen embankment between Gillies street and the railway would complete the levee.

Land take would also be limited due to the majority of the levee being a wall and the earthen part being located within a large area of public open space.

Access to the recreational reserve would be impeded from Nunn Street although it is considered to have sufficient exposure to Ackerly Avenue not to have an adverse affect. Impacts on the ecological values of this area cannot be fully determined in the absence of available information.

However, it is unlikely that any wildlife corridors exist through this area, due to the presence of residential property immediately east. The flood wall requires minimum land take. Where the earthen levee is proposed and where this involves the removal of any significant items of vegetation, this should be replaced within the immediate vicinity.

There are no items of any particular sensitivity which this levee would affect.

Scheme A also involves clearing all understorey vegetation (except grass) and thinning trees to 50% of the existing provision immediately downstream from the confluence of Broken River, Blind Creek and Holland Creek to opposite Psaltis Parade. While this important recreational resource is not removed by taking this action, the character of this area will be severely altered whereby it would resemble formal rather than informal open space.

The area would be much more visible, and views especially during winter would be possible across the river from Neil Avenue to Parkview Parade either side of the river.

The area of land under this measure is zoned POS (Public Open Space). This measure would therefore modify this area rather than remove it. and would not reduce in any way the amount of land available for development within the city.

The ecology of the area has previously been documented in the Lake Benalla Bushland Area (Ref. 9). At the confluence of the Broken River and Holland Creek relatively undisturbed bushland remains. This bushland area consists of two vegetation zones, River Red Gum Woodland and Riparian. The River Red Gum zone is comprised of two vegetation communities:

(i) River Red Gum/Silver Wattle/Tussock-grass along the stream banks, and

(ii) River Red Gum/Weeping Grass on the higher ground.

The river red gum/weeping grass woodlands are confined locally to the Broken River floodplain. This vegetation type is considered locally significant as most of it has been modified by agriculture. Two grass species, kangaroo grass and Australian millet, occurring in small patches, are listed as rare in Victoria. It is considered that kangaroo grass was once more widespread around Benalla (Ref. 9).

The management plan (Ref 9) did not involve a fauna survey. Fauna habitats in the area consist of woodland and riparian zones. Rare mammal species recorded for the Broken River include the Brush-tailed Phascogale and Squirrel Glider (Ref 8). The woodland area provides habitat for gliders, including the Squirrel Glider which is listed as rare and restricted in Victoria and is also listed under the Flora and Fauna Guarantee Act. This area also provides habitat for birds which are largely dependent on the bushland area and other nearby remnant stream side vegetation. Suitable habitat for owls and parrots such as the Grass Parrot and Eastern Rosella exists. The Regent Honeyeater has been recorded for the Broken River (Ref 8) and may occur in this location. The woodland area also provides important habitat for reptiles and small mammals (Ref 9).

The Riparian zone also supports an array of fauna. Riparian vegetation is important for the long term stability of waterways and provides habitat for fauna such as mammals, birds and amphibians. The azure kingfisher, a regionally significant species with numbers thought to be declining, also occurs in this area. Other species which are present include frogs, the Platypus, Water Rats and pardalotes.

Twelve bat species have been recorded in the Benalla area and may of these are likely to be found in the bushland area. One of these species. the large-footed myotis, is listed as vulnerable in Victoria (Ref.9)

Species of significance which do or may occur within the study area will be impacted by this option which will reduce what little bushland vegetation remains in the floodplain.

As such, ecological impacts of partly clearing this area are potentially significant. Before this measure is pursued further, it is would be strongly advisable to undertake detailed flora and fauna investigations. It is likely that any such surveys would be a requirement as part of preparing an environmental impact statement for the works should this be deemed necessary.

This Scheme will significantly reduce the risk of flooding for the majority of Benalla residents to a negligible amount. Only those residents on the west side of the river north of the railway will not be protected by a levee. However significant visual impacts and potentially disruption to pedestrian and traffic movement would be incurred.

Scheme B

This Scheme includes construction of a second lake downstream of Ackerly Avenue, a reduction in vegetation along and within the river between Psaltis Parade and Holland Creek and the provision of additional culverts through the railway embankment near Nunn Street and Duffy Street.

It is anticipated that formulation of a lake as part of this option, would be similar to Lake Benalla. The area proposed for this purpose is currently zoned as a stream (S1), Rural A (RU1) and public open space (POS). The creation of a lake would be compatible with this zoning and the amenity of the area would not be compromised in any way. The lake would also contribute to the visual amenity of the area for adjoining residential development.

Since the lake would be located within the existing floodway, where development for any use other than that zoned is unlikely, land take would be minimal, and constrained by the branches of the Broken River.

The lack of information of the flora and fauna of the area proposed for the lake make it difficult to assess the ecological impacts of this component. However, information made available at the time of the creation of Lake Benalla, further upstream, suggest that there may be some locally significant vegetation communities and rare plant species present in this part of the Broken River Catchment. It is almost certain that there will also be requisite fauna present in this area.

As such, ecological impacts of the creation of a lake are potentially significant. Before this measure is pursued further, it is recommended that further detailed flora and fauna investigations be conducted.

Comments made in respect to reducing the amount of vegetation within and along the river between Psaltis Parade and Holland Creek for Option A are equally applicable for Scheme B.

The additional culverts proposed for the railway would involve temporary disruption to the community during their construction, particularly those near the Nunn Street. The culverts near Nunn street would discharge across a plantation reserve parallel to the railway embankment and are likely to require the removal of recently planted trees. This impact is considered small and may be minimised by landscaping around the culverts and the planting of new trees. The culverts would not be considered as detracting from any visual aspects of the area to the south of the railway.

The culverts proposed near Duffy Street are isolated from existing building development on both sides of the railway and any visual impact is considered negligible.

Scheme C

This Scheme comprises improvements to the East and West Main Drains, the formulation of a lake, similar to Lake Benalla on that part of the Broken River between Ackerly Avenue and Faithful Street, a reduction in vegetation along and within the river between Psaltis Parade and Holland Creek and a retarding basin upstream of the Hume Freeway.

Comments on the impact of a second lake are the same as discussed above for Scheme A. Similarly the comments made in respect to reducing the amount of vegetation within and along the river between Psaltis Parade and Holland Creek for Scheme A are equally applicable for Scheme C.

A significant impact of this option is the provision of a Retarding Basin upstream of the Hume Freeway designed to reduce the peak 1% AEP flow on the Broken River and its anabranch, Blind Creek and Holland Creek. Six houses located on rural land would be severely affected by the temporary impoundment of flood waters during the 1% AEP flood. Two houses would experience over floor flooding and three other would have less than the desirable 500 mm freeboard. All houses would be surrounded by an increased depth of floodwaters and ideally should be re-located.

The repercussions of this Scheme on most of the urban area of Benalla is a reduction in flood levels of approximately 0.1 m for the 1% AEP flood although reductions of 0.2 m for residential areas opposite the river vegetation reductions work are predicted. The exception is an area north-west of the proposed lake and within the existing floodway, which will experience a slight increase of up to approximately 0.05 metres.

This Scheme would be insufficient to protect the majority of houses effected by overfloor flooding in October 1993 and consideration should be given to raising floor levels of unprotected properties to 500 mm above the 1% AEP flood level. Properties where this should occur will be identified in the Floodplain Management Plan, if this option is pursued.

Scheme E

Scheme E substitutes the levees of Scheme A for less prominent means of excluding flood waters from designated areas. The formal regular mounding associated with grassed levee systems would be replaced by the creation of irregular or “free form” areas of linked higher ground. The higher areas would form part of the usable park area and when properly designed and landscaped would become an integral feature rather than a presenting an obstacle to accessing and using the park.

In built areas there is opportunity to readily increase the height of the crown of the road, or the whole carriageway by up to 300mm or even 400mm without causing any significant disruption to existing patterns of vehicular movement or access to properties. Some of this work could be undertaken as part of normal road maintenance or as part of a periodic road re-construction program.

In several cases it maybe more appropriate to replace existing timber fencing with a brick fence of similar height. In locations such as at the rear of properties in Maginess Street the fences would not need to be any higher than the existing boundary fences and no additional landtake would be required nor would existing patterns of movement be effected.

To complete the protection of north east Benalla Scheme E would include a grassed embankment within the grassed road reserve and extending north along Commercial Road north of McIvor Street. The embankment height would be well below eye level and would be clear of all residential properties therefore its environmental and social impact is considered minimal.

The heavy reduction in vegetation proposed from the upper end of Benalla Lake to the confluence of Holland Creek and Broken River will have severe ecological ramifications. The issues are the same as those discussed for Scheme A but assume an even greater importance as the extent of clearing is increased. Although not included in the economic analyses prepared for this report consideration should be given to seed collection and the re-establishment of a compensatory area of forest. The compensatory area would need to be located where possible increases in flood levels associated with increase in vegetation in the riparian zone will not be significant.

The most readily implemented form of Scheme E is Scheme E5 which is designed to offer flood protection only for floods up to and including the 5% AEP flood. For this reason the extent and height to which the various components of Scheme E5 need to be constructed will be significantly less than that required to protect against the 2% AEP flood (Scheme E2). The height to which some of the components would need to be constructed to protect against the 1% AEP flood is not considered viable and the social and environmental effects would in many locations be similar to those as assessed for Scheme A.

Scheme F

Scheme F is similar to Scheme E except that the Scheme also includes construction of Lake Arundel. The assessment of the social and environmental impact for the two forms of this Scheme (F2 and F5, to protect against the 2% AEP and 5% AEP flood respectively) are identical to those discussed for Schemes E2 and E5.

It is anticipated that formulation of a lake as part of this option, would be similar to Lake Benalla. The area proposed for this purpose is currently zoned as a stream (S1), Rural A (RU1) and public open space (POS). The creation of a lake would be compatible with this zoning and the amenity of the area would not be compromised in any way. The lake would also contribute to the visual amenity of the area for adjoining residential development.

Since the lake would be located within the existing floodway, where development for any use other than that zoned is unlikely, land take would be minimal, and constrained by the branches of the Broken River.

The lack of information of the flora and fauna of the area proposed for the lake make it difficult to assess the ecological impacts of this component. However, information made available at the time of the creation of Lake Benalla, further upstream, suggest that there may be some locally significant vegetation communities and rare plant species present in this part of the Broken River Catchment. It is almost certain that there will also be requisite fauna present in this area.

As such, ecological impacts of the creation of a lake are potentially significant. Before this measure is pursued further, it is recommended that further detailed flora and fauna investigations be conducted.

Similarly the heavy clearing of vegetation contemplated as part of this Scheme will be significant and the need for the establishment of compensatory areas as discussed for Scheme E warrants careful consideration. Depending on the final configuration adopted for Lake Arundel there may be opportunities for some replacement planting near the lake otherwise areas beyond the township will need to be considered.

Scheme G5

Scheme G5 differs only from Scheme F5 in that the additional culverts through the railway embankment in the vicinity of Nunn Street would not be included.

The provision of the additional railway culverts is not considered to have an adverse social or environmental effect and therefore the assessment made for Scheme F5 is equally applicable to Scheme G5.

Scheme H5

Scheme H5 includes road raising and raised landscaping options to provide protection against the 5%AEP flood plus vegetation management between Lake Benalla and the Samaria Road, and downstream of Ackerley Avenue. The raised landscaping would cause a minor to moderate inconvenience to the resident movement near the river. Vegetation management will require a thinning of vegetation, especially understorey species in certain areas. The negative ecological effect of this can be overcome by compensatory planting in other nearby areas that are not critical to flood management.

Scheme J

Scheme J includes only vegetation management between Lake Benalla and the Samaria Road, and downstream of Ackerley Avenue. As for Scheme H5 vegetation management will require a thinning of vegetation, especially understorey species in certain areas. The negative ecological effect of this can be overcome by compensatory planting in other nearby areas that are not critical to flood management.

Scheme K

Scheme K includes the vegetation management as for Scheme J plus additional culverts under the railway embankment near Dufy street and the East Main Drain. The ecological issues and net effect associated with vegetation management will be the same as for Schemes H5 and J. The additional railway culverts will allow flood waters to dissipate onto land north of the railway more readily but rises in flood levels are expected to be very small and as a consequence any adverse flooding impact downstream of the railway has been assessed as low.

Other Structural Measures Not Included in Schemes

Levee 3B comprises a raised road median barrier incorporating a planter box along Coster Street and Samaria Road, a masonry floodwall on land to the south of Lowry Place and along the southern side of Fawckner Drive in front of the Civic Centre and Senior Citizens Centre.

A landscaped earthen embankment would complete the levee from Samaria Road to Willis Little Drive as described for Levee 3A.

The height of Levee 3B varies considerably, from 700 mm along the median reserve in Coster Street to 1.3 metres for the masonry wall to the south of Fawckner Drive and 2.5 metres for the masonry wall on land to the south of Lowry Place.

The main issue arising from the construction of this levee is the segregation of the open space areas associated with the river, from the defined commercial and residential areas adjoining. In particular, the earthen embankment, which would be over 2 metres high will be located in a visually prominent location and will disrupt some views from commercial and residential areas to the river. Access to and from the foreshore will also be impeded. Since this is one of the major open space areas within the city, this component is considered to have a relatively high impact in terms of amenity and aesthetic values.

Aesthetically, the construction of a brick wall along the southern boundary of Fawckner Street would benefit from planting in the same way proposed for the median reserves.

Comments relating to the median strip are applicable here, as they were for Levees 1 and 4. Adverse social and environmental impacts will result from increased travel times for residents together with an increased risk of accidents at road intersections.

That part of Levee 3B accommodated east of Samaria Road is earthen. This is located within a proposed subdivision where residential development is to be located. This provides an opportunity to include open space as part of the new development which could act as a buffer. As the site has been cleared, there will be no ecological impact. Due to the height of Levee 3B, the land take for this component of Scheme B, would be quite considerable. However because of its location within the high hazard area, on an existing open space zone where other forms of development are inappropriate, this is not considered to have a significant impact.

Levee 5 would be formed by a landscaped earthen levee following the line of the anabranch between Hair Street and Maud Street. A masonry wall from Maud Street to Bridge Street within the Showgrounds as discussed for Levee 2 would complete the levee. A majority of this levee is located within a proposed public open space zone (R3). This area is characterised by occasional informal planting, and grassed areas maintained by Council. The construction of an earthen levee in this location to the required height of approximately 2 metres would disrupt access across these areas and be visually intrusive.

Construction of the levee may involve the removal of some established trees which could provide habitat for local fauna. However, given the number of other nearby trees and the fact that the location is essentially urban, any displaced fauna will likely relocate to other nearby trees. Precise impacts of the removal of any vegetation will need to be considered when details of the location of the levee are established.

This levee would involve the purchase of up to three properties (dependent on precise design) at 28, 30 and 33 Market Street, which would reduce the volume of fill required in this location. Due to the height of the levee across Garden Street, there may be a requirement to close the road, as temporary sealing (sandbagging or drop boards) to this height would not be appropriate. This would have implications on traffic circulation in this location which would need to be assessed in more detail if this levee is included within any of the options. Both of these factors are detrimental in terms of the social impact of this option.

Another problem associated with Levee 5 is the disruption of access to the showground from Cecil Street. It might be that there will need to be some contingency sand bagging along this part of the levee and probably raised access to the showgrounds if existing access is to be retained. Otherwise, alternative access will need to be sought. The levee will also interfere with views travelling east along Arundel Street towards the existing playing field.

Furthermore this levee while blocking overland flows in residential streets draining towards the West Main Drain it does not reduce the level of flooding for the more severely flood affected properties in this area.

The overall social and environmental impact of Levee 5 is considered to be high.

Levee 6 would be in the form of a raised road median reserve, extending north of Ackerly Avenue, to the junction with Shadforth Street and along Boger Street from west of Coish Avenue to the junction with Cook Street. An area of landfill is also proposed as part of this levee in the area extending south of Boger Street and west of Arundel Street. While quite an extensive area, development is low density, most of which is zoned for rural purposes (zone RU1). However, as part of the site proposed for infill, a small area is zoned as residential (zone R1). A heritage item (the Ombu tree) as identified in Councils planning option is also located within this area adjacent to 21 Arundel Street. For this reason that part of the levee considered for landfill is located in a reasonably sensitive location and the impact of this is reflected in the assessment.

The height of the median reserve varies from 300 mm to approximately 1.8 m for the 1% AEP flood when 600 mm freeboard is included. The road reservation is wide enough to accommodate the levee but is considered impractically high. Although the density of residential development in parts of this area are low at present the levee would not have a severe adverse impact in terms of amenity and aesthetics. The impact would be greatest near the corner of Shadforth and Arundel Streets and along Boger Street between Cook Street and the West Main Drain crossing. The area of possible landfill along the alignment of the anabranch is used for grazing with a minimal number of trees and as a consequence there is not considered to be any ecological impact.

The overall social and environmental impact of Levee 6 is considered to be medium to high.

C.2.3 Conclusions

The assessment of flood mitigation measures is summarised and presented in Table C.2. This shows the relative social and environmental impacts of each measure and the overall assessment of each Option containing structural components. It should be noted that this does not take account of the need to supplement the structural measures with non-structural measures nor does it take account of the extent of areas likely to experience a reduction, or otherwise, in flood levels.

It shows that from a purely environmental and social perspective, Scheme B has least overall impact on the urban area, although there are concerns regarding the ecological implications of the construction of the lake and the reduction in vegetation along and within the river upstream of Psaltis Parade. Resolution of these implications would require a more detailed flora and fauna survey. The survey would be required as part of an environmental impact statement should this be necessary. The main reason for Scheme B having the least impact is also that it has least direct effect on residential areas and works can largely be undertaken within the confines of existing easements and the Broken River channel.

Scheme A1 has the highest impact because of the extensive earthen levees proposed. One reason for this is their overall height and the implications this has on visual intrusion, access to the river and community severance. However, from a social perspective, Scheme A provides the highest reduction in flood levels for the worst affected areas. Schemes E, F, and G seek to eliminate the many of the more severe aesthetic and social ramifications of Scheme A but at the cost of a lower standard of flood protection. Consequently the final decision must be one of balance between the benefits provided by an option in terms of a reduction in flood levels against the long term environmental and social impacts of the presence of such a option.

APPENDIX D

Review of Written Submissions

APPENDIX D REVIEW OF WRITTEN SUBMISSIONS

D.1 Introduction

The Benalla Floodplain Management Consultative Committee has on several occasions invited submissions and/or comments from stakeholders on issues of concern regarding past, existing and future management of the Broken River floodplain at Benalla. The most recent invitation to the stakeholders, which includes the community of Benalla, was extended after the meeting held on Monday 29th January 1996.

In response to these invitations a number of submissions/comments have been received from a variety of stakeholders. These include submissions/comments received from the following:-

1.	D. Haines	82 Witt Street, Benalla	(Ref. DSC1)
2.	M. Richards	Chairman, Benalla Floodplain Management Consultative Committee	(Ref. DSC2)
3.	D. Runge	Broken River Management Board	(Ref. DSC3)
4.	R. Sullivan	11 North Salisbury St, Benalla	(Ref. DSC4)
5.	N. Grubb	Community Representative,Benalla Floodplain Management Consultative Committee	(Ref. DSC5)
6.	I. Barry	VicRoads	(Ref. DSC6)
7.	M. Chapman	Department of Conservation & Natural Resources	(Ref. DSC7)
8.	J. Onas	Department of Conservation & Natural Resources	(Ref. DSC8)
9.	G. Jessop	Shire of Delatite	(Ref. DSC9)
10.	K. Perry	State Emergency Service	(Ref. DSC10)
11.	A. Baker	Bureau of Meteorology (2)	(Refs. DSC11, DSC12)
12.	J. Ross	2/5 Perth Street, Benalla	(Ref. DSC13)
13.	H. Rose	15 Tomkins Parade, Benalla (including petition signed by residents of 22 homes in Tomkins Pde)	(Ref. DSC14)
14.	N. Lemin	10 Garrett Street, Euroa	(Ref. DSC15)
15.	R. Bain	8 Walker Street, Benalla	(Ref. DSC16)
16.	N. Lewis	8 Nish Court, Benalla	(Ref. DSC17)
17.	A. Ford	126 Faithful Street, Benalla	(Ref. DSC18)
18.	F. Saunders/ R. Ball	19 Hair Crescent, Benalla	(Ref. DSC19)
19.	N. Fear	No address given	(Ref. DSC20)

A breakdown of the issues of concern expressed by the stakeholders is given in the accompanying Table D.1. Comments on each of the major issues of concern are provided in Section D.2.

To assist the Consultative Committee in its review of the identified range of structural and non-structural measures a separate table entitled "Summary of Performance of Floodplain Management Measures" was also prepared. This table is included at the end of Section D.2 and is referred in the discussion of a range of possible measures.

D.2 Issues of Concern

D.2.1 Flood Study

Design Flood Estimates

On 16 October 1995, the Consultative Committee requested that the magnitude of the 1%, 2%, 5% and 20% AEP design floods be urgently re-assessed for a number of reasons.

A response to this request was forwarded to the Consultative Committee on 19 October 1996. It outlined the approach which was used to estimate the 1% AEP design flood and lesser floods (ie. 2%, 5%, 10% and 20% AEP floods) which were presented to the Consultative Committee at a full Committee meeting held on 29 November 1994.

This issue was further discussed at the Consultative Committee meeting held on 29 January 1996. As a result of these discussions, Willing & Partners commissioned an independent review of the 1% AEP flood estimate. This review, which was undertaken by Dr J.L. Irish, is reproduced in Appendix A.

Flood Mapping

The issue of flood maps provided in the Flood Study was raised and discussed at the Consultative Committee held on 29 January 1996. As a result of these Delatite Shire Council is investigating the availability of superior base maps. The resolution of the issues surrounding the design flood estimates may also require a further review of the flood maps for the major floods.

D.2.2 Structural Measures

Floodgates on Benalla Weir

Suggestions have been made that either the Benalla weir should be lowered or that flood gates be installed in the weir to allow the lake level to be lowered when a flood is imminent.

The effect of installing flood gates would be the same as removing the weir. Flood behaviour under this situation was investigated by modifying the hydraulic model and re-running the design 1% AEP flood. No other changes were made to the hydraulic model. The impact on 1% AEP flood levels was found to be very small and localised near the river banks opposite the weir. It was concluded therefore that either lowering the weir or installing floodgates would not lead to a reduction in the number of properties considered to be at risk from flooding.

Levees and Landfill

Virtually all comments received from Consultative Committee members referred to one or more aspects of the levee options.

Level of Flood Protection

Comments in relation to the level of flood protection afforded by each combination of levee has been noted and will be clarified in the draft Final Report.

As a result of earlier discussions with Council officers, the working draft Report focused on levees with a crest height of 600 mm above the estimated 2% AEP flood level. Although in many cases the finished levee crest level would be higher than the October 1993 flood level the levee could not be guaranteed nor should be relied upon to provide protection for a flood greater than a design 2% AEP flood. The 600 mm freeboard is an allowance which is designed to cater for uncertainties including variations in river flow and flood height estimates, wave action and possible settlement of the levee.

Seven possible levees were identified but some of the levees would not provide sufficient protection unless constructed in combination with others. Only Levees 6 and 7 would provide benefits when constructed in isolation. Both Levees 6 and 7 are located downstream of the Melbourne - Sydney railway. However Levee 6 is not considered to be either environmentally or socially acceptable due to its excessive height and was included only at the request of the Chairman of the Consultative Committee and the former Group Services Manager to the Shire of Delatite. Furthermore, Levee 2, which would be on the western side of the river between the Showgrounds and Cowan Street, would cause an increase in the flood levels in the Parkview Parade area and therefore should only be considered in conjunction with Levee 3A which follows the eastern river bank upstream of Psaltis Parade.

Levee 1 (along Arundel Street between Bridge Street and the Railway Line) and Levee 4 on the opposite bank would provide only minimal benefits unless levees are also constructed on the respective sides of the river upstream of Bridge Street.

On this basis the following combinations of levees have been summarised in the accompanying Table.

Levee Measure A	Levees 1, 2 and 3A and 4 combined
Levee Measure B	Levees 4 and 3A combined
Levee Measure C	Levees 4 and 3B combined
Levee Measure D	Levee 6 only
Levee Measure E	Levee 7 only

Cost estimates and benefits have been identified for levee heights designed to provide protection against both the design 2% AEP flood and a re-occurrence of the October 1993 flood with full freeboard of 600 mm. These are summarised in the accompanying Table. Full details including cost estimates will be provided in the draft Final Report.

Local Drainage behind Levees

Several comments were made in relation to an allowance for pumping and where available, temporary storage of local runoff from areas behind a levee.

An allowance for pumping was included in the working draft Report however the opportunity has been taken to update these costs. Potential areas for the temporary storage of local runoff which would allow the use of smaller pumps will be clarified in the draft Final Report.

Only Levee 1 and Levee 7 will not require pumping to disperse local runoff when the river is in high flood. Levee 7, located on the eastern side of the river and north of the Railway Line may be constructed with a gravity drain and avoid the risk of "local" flooding during a 1% AEP flood. The ground levels between Arundel Street North and the West Main Drain are sufficient to allow the local drainage system behind Levee 1 to be modified to allow gravity discharge of runoff towards the West Main Drain.

Sandbagging of Levees at Road Openings

Concerns have been raised with respect to closing the openings provided in the levees where a levee alignment crosses a road intersection. The concerns relate to the ability of the State Emergency Service (SES) to close the openings in the available time, the availability of sand bags and/or sand and the resources to fill the bags.

The use of sandbags represents only one possible approach. A viable alternative which has been considered and will be included in the draft Final Report makes use of purpose-built drop boards which may be fitted into preformed slots at the end of each levee. The drop boards would be constructed of aluminium and typically would be capable of spanning 5 to 6 metres. Each board would be the same size and each levee opening a multiple of the drop board length thus allowing full interchangeability. Use of this arrangement would allow each intersection to be closed in a matter of minutes and will eliminate the need for resources to fill and tie sandbags.

An improved flood warning system would be also expected to both improve the accuracy of flood forecasts and to provide a longer warning time than is currently available. It is envisaged that a Benalla Flood Sub-Plan would clearly identify the intersection which would need to be "closed" and the order of closure of intersections based on the predicted flood levels. The increased warning times would allow any such closure to be undertaken in a timely manner prior to the expected arrival of the flood peak.

Overtopping of Levees

All levees which have been considered for Benalla could be overtopped by a flood greater than the design flood. Therefore adequate precautions must be included in the design to protect the structural integrity of the levee under overtopping. The risk of overtopping is referred to as the residual risk of flooding and is normally dealt with in a Contingency Plan. It is important that an adequate flood warning system be operating to allow the timely evacuation of residents to higher ground in the event that the overtopping of levees is imminent. In all cases where levees have been considered in Benalla there is the opportunity to evacuate residents to higher ground using the existing road network.

If levees are overtopped then the lowering of flood levels behind levees on the falling limb may occur more slowly since this may only occur via pumping and gravity drainage through pipes located beneath the levees. For many locations in Benalla, floodwaters would also drain via the East and West Main

Drains. In locations where levee openings have been closed using drop boards then these boards could be also removed as the river level recedes to allow floodwaters which have collected behind the levee to drain away more rapidly.

While the increased duration of flooding on the rare occasion a levee is overtopped may lead to marginal increases in flood damage the risk is very small and there would be an overall reduction in flood risk and damage for areas protected by levees.

Environmental Aspects

Comments on the environmental and social impacts of levee construction have been noted and will be expanded on in the draft Final Report for all levees schemes which are deemed feasible by the Consultative Committee.

Landfill in North West Anabranch Area

Landfill has only been proposed for this area in combination with compensating river works such as clearing of the woody vegetation downstream of Ackerly Avenue or construction of a lake between Ackerly Avenue and Arundel Street or further to Faithful Street.

If compensating river works are not undertaken then rises in the estimated 1% AEP flood level of less than 0.05 metres would be experienced across most of the developed urban area. However larger increases would be expected to occur in local areas near the West Main drain where it passes under the railway embankment and along the main river channel immediately downstream of Ackerly Avenue. However, decreases in the 1% AEP flood level would be experienced by properties between Cook Street and Coish Street. The relatively small change in flood levels is attributed to the small proportion of the total flow which discharges along the high level anabranch.

River Straightening

Straightening of a Broken River would steepen the river grade and lead to increased flow velocities. While this would increase the flood carrying capacity of the river it would also greatly increase the risk of both bank and river bed erosion. Where this type of work has been undertaken in other areas it has frequently been accompanied by long periods of river destabilisation. Destabilisation may be manifested as a deepening of the river in the upstream direction as the steepened river bed section moves upstream. This would result in an increased silt load which would be deposited downstream and at least initially result in a reduced waterway area and flood carrying capacity. The only opportunity for straightening the Broken river near Benalla is downstream of Faithful Street and this would not provide any tangible benefit for most of the flood liable houses in Benalla.

Removal of the river bend where the Showgrounds are located could be undertaken to increase the waterway area. However this area forms part of the lake and in times of flow increased sedimentation is likely to occur and would require periodic removal to prevent the river returning to its existing condition. In both cases, however, a detailed investigation including an on-going monitoring program would be required to predict the likely morphological changes in the river.

The impact of removing the river bend on flood levels is expected to be very small and would not provide any tangible benefit to most residents. Conversely the risk of environmental damage and long term adverse consequences are substantial.

D.2.3 Impact of Railway Embankment

Additional Culverts

Modelling was undertaken to ascertain the likely effect of increasing the available waterway area in the area between Duffy Street and Witt Street to supplement the existing culvert on the East Main Drain. Four additional culverts, each 4.2 m (W) x 2.4 m (H) located in the vicinity of Duffy Street were investigated and the results reported to the Consultative Committee in September 1995.

The impact of providing 10 No. additional culverts, each 4.2 m (W) x 2.4 m (H) west of Nunn Street was also investigated and the findings reported to the Committee in September 1995.

In both cases the investigations indicated that the effect of the culverts is localised with the maximum impact occurring in the immediate vicinity of the culverts, and that for properties east of the river and south of Bridge Street there is no discernible lowering of the 1% AEP flood levels.

We have estimated that if all culverts are installed (12 No.) there would be a reduction of 83 residential buildings and 3 commercial properties subject to overfloor flooding in the 1% AEP flood.

The preliminary estimated cost of installing 14 No. culverts through the railway embankment is $3.1 million.

Widening of Existing Viaduct

Further investigations have been undertaken to estimate the effect of increasing the width of the railway viaduct opening by approximately 40% from 230 metres to 330 metres. This would be sufficient to extend the viaduct on the eastern bank to opposite the rear of properties on the western side of Sharpe Street. The impact of this option is summarised in the accompanying Table.

The above investigations were further extended to estimate the impact of the railway on flooding by re-running the 1% AEP design flood assuming the Melbourne - Sydney railway embankment had been completely removed. The railway embankment is estimated to raise the 1% AEP flood levels primarily in east Benalla between the Railway Line and Church Street. No increases in flood levels south of Church Street are attributed to the Railway Line. Increases in the 1% AEP flood level in West Benalla are generally less than 0.1 m.

D.2.4 Retarding Basins and Diversions

Diversion to Lake Mokoan

Suggestions have been made during the study that the diversion of floodwaters around Benalla be also considered. One option which has been investigated would be to undertake works to increase the capacity of the diversion channel from Hollands Creek to Lake Mokoan to cause the peak 1% AEP flow passing Benalla to be reduced ideally to the equivalent of the 5% AEP flow at which only the lowest houses experience overfloor flooding. The required channel capacity to achieve this aim would be around 430 m^3/s. The existing capacity of the diversion channel is 28 m^3/s which has no discernible impact on flooding in Benalla.

A conceptual channel design which uses the excavated material to form a levee on the northern side of the channel was prepared. It was established that such a channel would be large enough to convey 210 m^3/s ie. sufficient to reduce the peak 1% AEP flow to the equivalent of the peak 2% AEP flow. The estimated cost is $20 million which includes the cost of widened road and rail bridges but makes no allowance for modifications to the outlet of Lake Mokoan or the waterway to transfer floodwaters back to the Broken River downstream of Benalla.

A summary of the estimated impacts is provided in the accompanying Table.

Lake Nillahcootie Retarding Basin

Flood retarding basins are used to reduce the maximum flow along the river and thereby lower the level of flooding.

The possibility of modifying Lake Nillahcootie to allow the temporary storage of flood waters was examined. It was found however that any such works at Lake Nillahcootie would only have a small impact due its distance upstream of Benalla. Such works would not result in a significant lowering of flood levels. A more realistic option is the provision of a retarding basin immediately upstream of the freeway.

Freeway Retarding Basin

Two alternatives have been examined. Both alternatives would utilise the existing Freeway road embankment. The existing bridge openings would be reduced such that in the 1% AEP flood the peak water level would rise to the level of the existing road surface.

This would require the upstream side of the Freeway embankment to be raised at least 600 mm to provide freeboard.

The effect of the retarding basin would be to reduce the peak design 1% AEP flood flow passing Benalla by approximately 7%. The resulting peak flow would still be greater than the estimated 2% AEP peak flow.

A second alternative which was investigated was to increase the maximum storage level by a further 600 mm. This would require the Freeway embankment to be widened on the upstream side and raised to a level at least 1.2 metres above the existing road surface. The effect of increasing the available flood storage was to reduce the peak design 1% AEP flood flow passing Benalla by approximately 10%. The resulting peak flow would approximate the estimated 2% AEP peak flow.

In both cases, provision would need to be made to reduce the waterway area beneath the Freeway to throttle flood flows up to the 1% AEP event. During a 1% AEP flood when the retarding basin nears its capacity it may be necessary to close the Freeway with the attendant disruption and costs associated with traffic and transport delays.

Both retarding basin options would inundate farmland and a number of houses and farm buildings. Supplementary embankments may also be required along Samaria Road to limit the extent of inundation.

D.2.5 Local Drainage Issues

Several issues were raised by the public in relation to the East Main Drain upstream of the railway embankment. The concerns relate primarily to:

(i) the capacity of the existing culvert under the railway,
(ii) removal of portion of the embankment forming part of the abandoned Tatong railway,
(iii) the need for general improvements to increase the capacity of the East Main Drain including the construction of the Witt Street Retarding Basin, and

Local Drainage in East Benalla

Modelling was undertaken to ascertain the likely effect of increasing the available waterway area in the area between Duffy Street and Witt Street to supplement the existing culvert on the East Main Drain. Four additional culverts, each 4.2 m (W) x 2.4 m (H) located in the vicinity of Duffy Street were investigated and the results reported to the Consultative Committee in September 1995.

Tatong Railway Embankment

The issue of the Tatong River Embankment was addressed in a letter response to Council following a representation from Mr D. Haines of 82 Witt Street.

The issue is considered to be a local stormwater drainage issue. Local drainage issues have been previously investigated and summarised in our previous report entitled *East and West Main Drain Investigations* dated 1994. The removal of the Tatong railway embankment would be expected to result in an overall improvement to local drainage for the area.

Witt St Retarding Basin

The construction of the Witt Street Retarding Basin has been proposed to mitigate the impact on flooding of proposed future urban development east of Witt Street. The retarding basin is downstream of existing flood liable development and would have no impact on flooding due to the break out of floodwaters from either the Broken River or Holland Creek.

D.2.6 Environmental Issues

Arundel Lake

The construction of a second (Arundel) lake along downstream of the Railway Line has been investigated.

The investigations indicated that the lake would be expected to lower flood levels by a maximum of approximately 300 mm at the Railway Line. The reduction in flood levels would decrease both with distance upstream of the Railway Line and with distance from the river bank. No reductions in the 1% AEP design flood levels are expected upstream of Bridge Street.

Vegetation Management

Several comments have been made on the effect of the heavy vegetative growth immediately downstream of Ackerly Avenue. Anecdotal evidence from the October 1993 flood suggests that flood waters were raised due to the inability of floodwaters to move freely downstream.

The impact of clearing the river and floodplain of all trees and other woody vegetation between Ackerly Avenue and Faithful Street would be similar to the construction of a second lake along this reach. Due to the increase in waterway area the lake would be expected to give the greatest reduction in flood levels ie. any reduction in flood levels due to the removal or thinning of vegetation would be less than would result from the construction of the second lake.

The selective removal of vegetation near the existing lake has also been suggested. The impact of thinning the established woody vegetation has been investigated by reducing the assumed floodplain roughness adopted for the hydraulic model by approximately 10%. The estimated 1% AEP flood levels were lowered only slightly and only in areas adjacent to the river. The impact is summarised in the accompanying Table.

Desilting of Lake Benalla

Desilting of Lake Benalla could be undertaken to increase the waterway area. However subsequent deposition would require periodic removal to prevent the river returning to its existing condition. The impact of desilting Lake Benalla on flood levels is expected to be small and is not expected to provide any tangible benefit to most residents. A detailed investigation including an on-going monitoring program would be required to predict the likely morphological changes in the river due to desilting the lake.

D.2.7 Non-structural Measures

Planning & Zoning Controls

Issues relating to flood hazard mapping and adoption of floodway zones were raised by the Department of Conservation and Natural Resources. The use of zoning controls can be an effective method of preventing future inappropriate development which would otherwise add to the flood damage risk and cost. Zoning controls however do not reduce flood damages for existing properties. Structural or non-structural measures are needed to address the problems of existing properties..

Mapping of draft floodway zones is to be included in the draft Final Report.

Contingency Planning

All levees which have been considered for Benalla could be overtopped by a flood greater than the design flood. Therefore adequate precautions must be included in the design to protect the structural integrity of the levee under overtopping. The risk of overtopping is referred to as the residual risk of flooding and is normally dealt with in a Contingency Plan. It is important that an adequate flood warning system be operating to allow the timely evacuation of residents to higher ground in the event that the overtopping of levees is imminent. In all cases where levees have been considered in Benalla there is the opportunity to evacuate residents to higher ground using the existing road network.

Flood Warning & Evacuation

The purpose of a flood warning system is to warn a community of an impending flood. The purpose of evacuation planning is to make people aware of when and how they should evacuate themselves and their possessions in the event of flooding. Evacuation planning is particularly important in the case of widespread flooding such as can occur on the Broken River floodplain.

The public should be made aware of flood liable areas and alerted to possible dangers, particularly where roads may be flooded. It is important that any flood forecast be provided in a form which can be easily understood in the areas at risk.

Flood warnings for Benalla are issued by the Bureau of Meteorology (BoM) in Melbourne to the Regional SES office in Benalla. The Regional SES office then forwards the warning to the relevant local SES headquarters.

In the case of the Broken River catchment, the BoM relies on both rainfall and stream height data transmitted via the Public Service Telephone Network (PSTN). In some communities rainfall data from gauges can be supplemented by radar measurements which can indicate rainfall intensities. Unfortunately, Benalla is on the extreme limit of the Melbourne wether radar system and can therefore cannot add to data collected locally during storms.

The flood of October 1993 highlighted significant network deficiencies which adversely impacted on the BoM's ability to provide accurate quantitative flood warnings for Benalla. In particular, the absence of rainfall and river level telemetry (Moorngag only) in the remainder of the Broken River catchment curtailed the issuing of early and accurate flood warnings.

In order to address these problems and to provide the community with a flood warning system that meets the majority if not all their requirements, the BoM has proposed a range of options to upgrade the flood warning system for Benalla which are currently under active consideration. The draft Final Report will reflect the state of these deliberations at the time of finalising the draft Final Report.

D.2.8 Reporting

The remaining comments primarily relate to the consistency between Tables in the working draft Final Report, the provision of place names on maps when referred to in the text and other editorial matters. All comments have been noted and the relevant sections will be amended in the draft Final Report.

APPENDIX E

Flood Warning System
Data collection Upgrading

APPENDIX E FLOOD WARNING SYSTEM DATA COLLECTION UPGRADING

E.1 Overview

The severe floods of October 1993 highlighted significant deficiencies in the availability of data which seriously hampered the Bureau of Meteorology's ability to provide accurate and timely flood warnings for parts of the Broken River catchment.

The deficiencies were caused by a number of factors which included;

- the extreme nature of the rainfall causing "flash" flooding in many parts of the catchment,
- the absence of rainfall and river level telemetry in the catchment areas upstream of Keelfeera in the Holland/Ryans Creek catchment and lack of rainfall telemetry in the remainder of the Broken River catchment,
- communications problems inherent to the Public Switched Telephone Network (PSTN), and
- Flooding of PSTN telemetred river gauges.

As a result of this the Victorian Flood Warning Consultative Committee (VFWCC), representing agencies involved in flood warning in Victoria, initiated an upgrading of the flood warning system for the Broken River.

Funding for the project is being provided through the National Landcare Program with agency and local contributions.

The upgraded flood warning system for the Broken River Catchment consists of:

- an expanded network of river and rain gauge stations,
- development and implementation of improved flood forecast techniques,
- development and promulgation of flood inundation maps,
- refinement of local flood warning response plans, and
- implementation of flood awareness/education programs to raise community awareness.

Installation of the upgraded data collection system is now complete and its primary purpose will be to collect rainfall and river level data from the Broken River and its tributaries for input to a hydrological (rainfall-runoff) model of the catchment which can then be used to predict river levels at key locations.

The network is being developed to provide a co-operative solution to data needs of Delatite Shire, Bureau of Meteorology, Ovens Water and Goulburn-Murray Water.

The data collection system includes;

- rainfall and river level measuring stations at existing and new sites,
- an Event Reporting Radio Telemetry System (ERRTS) network to transmit the data to a master stations at Benalla and Lake Mokoan,
- computer master stations using ALERT software at the Sate Emergency Service Regional Headquarters in Benalla and The Goulburn Murray Water Office at Lake Mokoan,
- Remote links from the master stations using the Public Switched Telephone Network (PSTN) to the Bureau of Meteorology, Victorian Office in Melbourne.

E.2 Rainfall and River Level Gauge Stations

Details of the locations of each station are provided in Table E.1

TABLE E.1
SUMMARY OF RAINFALL AND RIVER LEVEL GAUGES FOR ERRTS NETWORK

Station	Rain Gauge Type	River Level Gauge Type
Broken River at Caseys Weir	None	ISE
Broken River at Benalla	TBRG	DPT
Broken River at Broken Weir	TBRG	ISE
Broken River at Moorngag	TBRG	DPT
Broken River at Bridge Creek	TBRG	DPT
Holland Creek at Keelfeera	TBRG	ISE
Holland Creek at Wrightley	TBRG	DPT
Ryans Creek at Loombah Reservoir	TBRG	DPT
Charnwood (formerly Lima East)	TBRG	Not applicable
Tatong	TBRG	None
Archerton	TBRG	None
Warrenbayne	TBRG	None
Mt. Tabletop	TBRG	None
Lurg	TBRG	None

TBRG Tipping Bucket Rain Gauge
ISE Incremental Shaft Encoder with counter
DPT Dry Pressure Transducer

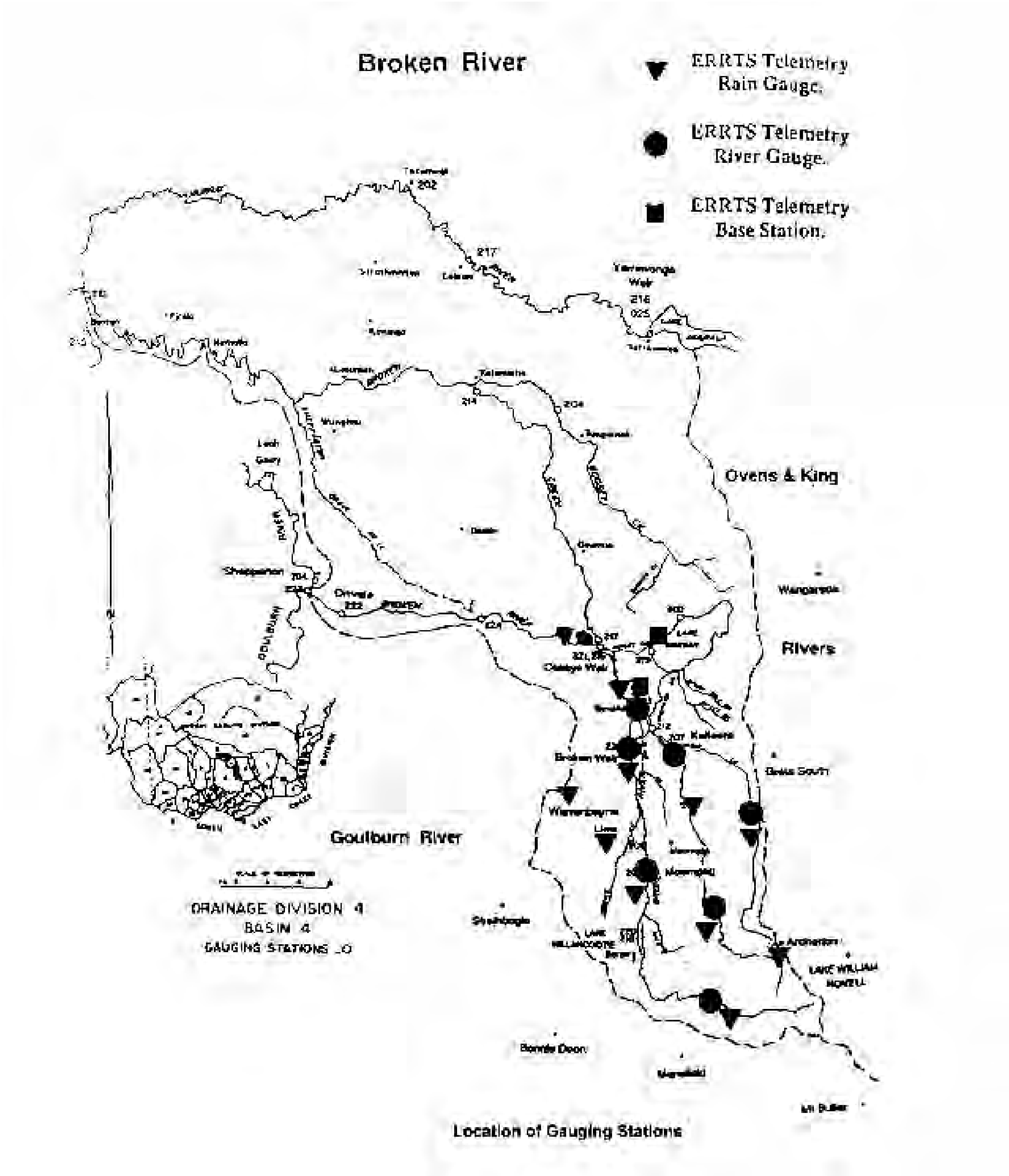


Figure E1 Location of Gauging Stations

APPENDIX F

Draft Planning Amendments for the Shire of Delatite

APPENDIX F DRAFT PLANNING AMENDMENTS FOR THE SHIRE OF DELATITE

ADOPTED FLOODPLAIN MANAGEMENT PERFORMANCE CRITERIA WITHIN THE DELATITE SHIRE COUNCIL

[Proposed Amendments for the Delatite Planning Scheme]

Municipal Strategic Statement (Clause 21: VPP Insert into environmental section)

Flooding imposes substantial costs on individuals and the community. While significant costs are incurred by direct damage to public and private property, indirect costs to the community such as loss of productivity, displacement of residents, closure of roads, trauma and ill health are also significant. Equally, use and development of land in flood prone areas can have serious implications on the natural hydraulic and environmental functions of floodplains within the municipality.

Notwithstanding the significant impacts on existing infrastructure, individuals and the community, natural flooding of floodplains and their associated wetlands provide essential breeding habitats for bird and aquatic species, and promotes the health of rivers and floodplains. A healthy, functioning floodplain system keeps rivers clean and provides native flora and fauna with the necessary food, habitat and breeding resources for their survival. Microorganisms on the floodplain remove pollutants from waterways, without which human and animal diseases may flourish. If managed correctly, floodplain ecosystems provide clean and living river systems. Floodplains are natural wildlife corridors and refuges within the Australian landscape providing healthy ecosystems and fertile land, and therefore are seen as high priority areas for conservation. As a natural phenomenon flooding will continue as it has in the past, and where possible should naturally continue to do so.

In order to minimise future flooding risks and damage costs it is critical for the municipality and community to utilise the suite of available floodplain management tools. Key measures such as flood warning, emergency response planning, community education, and the careful planning of land use and development on the floodplain will minimise the impacts of flooding.

POLICY SECTION (CLAUSE 22: VPP Insert as a stand alone sub-clause)

FLOODPLAIN MANAGEMENT

Policy Application

This policy applies to all land within the Urban Floodway Zone, Floodway Overlay or Land Subject to Inundation Overlay of the Delatite Planning Scheme or any other area known to be subject to inundation by flooding.

Policy Basis

The catchments of the various rivers and streams within the municipality include significant areas of flood prone land, where flooding has historically caused substantial damage to the natural and built environment. Floods are naturally occurring events and the inherent functions of the floodplains to convey and store floodwater should be recognised and preserved if increases in the long term flood risk to floodplain production, assets and communities are to be minimised. Natural flooding, long term productivity of flood prone land, river and wetland health are all closely linked and inappropriate development on the floodplain can lead to the deterioration of environmental values and reduced agricultural production.

It is evident that the impact of floods is increasing due to land use and vegetation changes. In particular:

- raised earthworks (including but not limited to roadworks, levees and farm channels) have reduced natural flood storage, obstructed and/or redistributed flood flows, and increased flow velocities and levels;
- urban expansion has occurred in floodplains, reducing flood storage, obstructing flood flows and increasing the risk to life, health and safety to occupants of the floodplain;
- irrigation and drainage infrastructure has extensively modified natural drainage patterns; and
- significant flood paths have been blocked off, leading to flow re-distributions.

Sound floodplain management in the municipality is the critical means by which the economic, social and environmental risks associated with floodplain use and development can be minimised.

In the past there has been a number of dwellings constructed within floodplain areas below flood level. It is recognised throughout the municipality that there is a genuine need for dwelling extensions. However, to manage future flood damage, dwelling extensions may match existing floor levels if they are no larger than 50% of the average sized dwelling.

In urban centres, it is policy to recognise the need for subdivisions and buildings within infill areas, ie those areas of land surrounded by existing buildings on at least three sides.

Objectives

- To coordinate and manage land use and development in floodplain areas throughout the municipality effectively.
- To implement measures to reduce the impact of flooding within the municipality.
- To minimise inappropriate development in the floodplains.
- To cooperate with the floodplain management authority to coordinate and manage floodplains within the municipality.

Local Planning Policy

It is policy to:

- minimise the adverse impacts of land use and development proposals with regard to the likelihood of any increase in flood risk and any individual or cumulative effects downstream;
- discourage new buildings and works in FO areas;
- discourage small lot subdivisions within LSIO;
- discourage large building extensions below the nominal flood protection level;
- encourage buildings designed so that flooding will cause minimal damage to the structure and its contents including raising floor levels, using water resistant materials and raising electrical fittings and wiring above the nominal flood level protection;
- discourage land fill in all areas subject to flooding other than for building envelopes;
- recognise the natural flood carrying capacity of rivers, streams and floodways and the flood storage function of floodplains;
- discourage levees in areas regarded by the floodplain management authority as important for conveying flood flow, flood storage and environmental values, except to protect existing dwellings and their immediate curtilage;
- minimise the adverse impacts of laser grading or land forming on downstream flooding along floodplains by encouraging flood and environmentally sensitive designs including compensatory or ameliorative works such as farm recycling dams.

Policy References

- Goulburn Broken Catchment Management Authority Catchment Strategy.
- Goulburn Broken Catchment Management Authority Regional Floodplain Management Strategy.
- Delatite Shire Municipal Emergency Management Plan – Flood Sub Plan.
- Victoria Planning Provisions Practice Notes Applying for a Planning Permit under the Flood Provision.
- Victoria Planning Provisions Practice Notes Applying the Flood Provision in Planning Schemes.
- Best Practice Guidelines for Flood Management in Australia.
- The Victoria Flood Management Strategy.
- The Manual of Best Management Principles and Practices for Flood Management in Victoria (in preparation).

URBAN FLOODWAY ZONE (CLAUSE 37.03)

Schedule to the Urban Floodway Zone

Not applicable

SCHEDULE TO THE FLOODWAY OVERLAY

Shown on the planning scheme map as **FO** or **RFO**

1.0 Permit Requirement

A permit is not required to construct or carry out the following buildings or works:

2.0 Buildings

- a non-habitable building (other than industrial, retail and office) with a floor area less than 100 m^2 and located on land outside an identified depression;
- an extension to a non-habitable building, provided that the total ground floor area of the building is less than 100 m^2 and located on land outside an identified depression;
- a dwelling (other than a replacement dwelling) located on land outside an identified depression where the 100-year ARI flood depth is less than 0.5 metres above the natural surface level, and is less than 0.8 metres along a defined access route to the dwelling site for rural areas, or 0.5 metres for urban areas, with a floor level set at least 300 mm above the 100-year ARI flood level;
- a replacement dwelling where the floor level is at least 300 mm above the 100-year ARI flood level and where the additional floor area is not greater than 84 m2 or 50% of the existing floor area;
- a single or multiple dwelling extensions where the combined floor area is less than 84 m^2 or 50% of the ground floor area of the original dwelling, which ever is the greater. Where a dwelling extension (or multiple extensions) is greater than 20 m^2 and below the nominal flood protection level the owner must:
    - enter into an agreement with Council under Section 173 of the *Planning and Environment Act 1987,* acknowledging that the floor level is below nominal flood protection level which will lead to possible flood damages for floods less than the nominal flood protection level.
    - use water resistant materials that are designed for flood proofing and any possible flow velocity impacts.
- a pergola, veranda, carport, or swimming pool associated with an existing dwelling; and
- a telecommunication tower.

2.0 Works

- a protective wall or levee bank around an existing dwelling and its curtilage, providing it protects an area (including the foot print of the protective wall and levee bank) less than 500 m^2; and
- a sports ground without grandstands or raised viewing areas, golf course, play ground, picnic shelter or barbecue.

SCHEDULE TO THE LAND SUBJECT TO INUNDATION OVERLAY

Shown on the planning scheme map as **LSIO**

1.0 Permit Requirement

A permit is not required to construct or carry out the following buildings or works:

2.0 Buildings

- a non-habitable building (other than industrial, retail and office) with a floor area less than 130 m^2 and located on land outside an identified depression;
- an extension to a non-habitable building (other than industrial, retail and office), provided that the total ground floor area of the building is less than 130 m^2 and located on land outside an identified depression;
- an extension to industrial, retail or office building, provided that the additional floor area of the building is less than 100 m^2. Where an extension (or multiple extensions) is greater than 20 m^2 and below the nominal flood protection level the owner must:
  - enter into an agreement with Council under Section 173 of the *Planning and Environment Act 1987*, acknowledging that the floor level is below nominal flood protection level which will lead to possible flood damages for floods less than the nominal flood protection level; and
  - use water resistant materials that are designed for flood proofing and any possible flow velocity impacts.
- a new industrial, retail or office building located on land outside an identified depression where the 100-year ARI flood depth is less than 0.5 metres above the natural surface level, with the floor level set at least 300 mm above the 100-year ARI flood level;
- a dwelling (other than a replacement dwelling) located on land outside an identified depression where the 100-year ARI flood depth is less than 0.5 metres above the natural surface level, and is less than 0.8 metres along a defined access route to the dwelling site for rural areas, or 0.5 metres for urban areas, with the floor level set at least 300 mm above the 100-year ARI flood level;
- a replacement dwelling where the floor level is at least 300 mm above the 100-year ARI flood level and where the additional floor area is not greater than 84 m^2 or 50% of the existing floor area;
- a single or multiple dwelling extensions where the combined floor area is less than 84 m^2 or 50% of the ground floor area of the original dwelling, which ever is the greater. Where a dwelling extension (or multiple extensions) is greater than 20 m^2 and below the nominal flood protection level the owner must:
  - enter into an agreement with Council under Section 173 of the *Planning and Environment Act 1987*, acknowledging that the floor level is below nominal flood protection level which will lead to possible flood damages for floods less than the nominal flood protection level; and
  - use water resistant materials that are designed for flood proofing and any possible flow velocity impacts.
- a pergola, veranda, carport, or swimming pool associated with an existing dwelling;
- a telecommunication tower; and
- a fence in residential, business and/or industrial zones.

3.0 Works

- a protective wall or levee bank around an existing dwelling and its curtilage, providing it protects an area (including the foot print of the protective wall and levee bank) less than 500 m^2; and
- a sports ground without grandstands or raised viewing areas, golf course, play ground, picnic shelter or barbecue.

LOCAL FLOODPLAIN DEVELOPMENT PLANS

[To be an Incorporated Document within the Schedule to Clause 81]

Preamble

A local floodplain development plan has been prepared for the precinct of the Broken River which provides a performance-based approach for decision making that reflect local issues and best policy and practice in floodplain management.

PRECINCT OF THE BROKEN RIVER

Application

This local floodplain development plan applies Broken River floodplains as shown on the attached plan and which is within either the Urban Floodway Zone, Floodway Overlay or Land Subject to Inundation Overlay of the Delatite Planning Scheme or any other area known to be subject to inundation by flooding.

Flood History

In the twentieth century, major floods occurred on Broken River in 1916, 1921, 1966, 1981 and 1993. In October 1993, widespread flooding in the area is estimated to have cost at least $50 million. The 1993 flood is believed to be representative of the 100-year ARI flood. Similar floods occurred in 1916 and 1870.

Flood Information

The extent of flooding has been determined from flood mapping completed in 2000 by the Department of Natural Resources and Environment. The project made use of historic flood levels documented in past flood events, aerial flood photography, ground level information and hydraulic modelling. FO and LSIO areas are based on the relative flood risk assessed for different parts of the floodplain, considering factors such as flood depth, velocity, natural storage, flood frequency and flood duration.

The Broken River floodplain is relatively well confined until just upstream of Benalla where it broadens out considerably. Catchment boundaries are not well defined and flooding is characterised by a combination of spills from the Broken River and its tributaries and local storm runoff. Flood depths and velocities can be significant. At Benalla, the gauge reached 5.05 metres in October 1993 – 2 metres higher than the minor flood levels which are experienced in most years.

The duration of flooding can also be significant for major floods, taking one or two days for floodwaters to recede. A comprehensive flood warning system was recently installed at Benalla, providing state of the art flood warning dissemination.

Flood Impacts

Flood impacts in the area are significant, resulting in road closures, loss of access for residents, property isolation, risks to emergency personnel during sand bagging and evacuation operations and damage to buildings constructed below flood level. During major floods, there are also likely to be substantial rural and infrastructure flood damages.

In the October 1993 flood, more than 1,000 residents of Benalla were evacuated from their homes, telephone communications were severely disrupted and water supplies were contaminated for several weeks.

Flood impacts for UFZ and FO areas are generally greater than LSIO areas, as the velocities, depths and frequency of flooding are generally greater.

REQUIREMENTS FOR PRECINCTS

An application must be consistent with the relevant development requirements contained in the General Requirements for Precincts and any other additional requirements contained in the Special Requirements for Precincts. Where both the General and Special Requirement covers the same issue the Special Requirements takes precedence.

GENERAL REQUIREMENTS FOR PRECINCTS

Development Requirements for FO or RFO

Buildings

- any buildings do not obstruct natural flow paths or drainage lines;
- the construction of any new dwelling, including a replacement dwelling, is sited on the highest available ground (unless the applicant can demonstrate to the satisfaction of the responsible authority that an alternative site is more suitable);
- the construction of any new dwelling (other than a replacement dwelling) is sited on land where the 100-year ARI flood depth is less than 0.5 metres above the natural surface level, and is less than 0.8 metres along the defined access route to the dwelling site for rural areas, or 0.5 metres for urban areas, unless a lot, which may require land consolidation, is greater than 80 hectares;
- the floor level of any new dwelling, including a replacement dwelling, is set at least 300 mm above the 100-year ARI flood level;
- there are no new commercial or industrial buildings; and
- any non habitable buildings are aligned so that their longitudinal axis is parallel to the predicted direction of flood flow.

Works

- any earthworks do not obstruct natural flow paths or drainage lines;
- any earthen land fill at the site of a new or replacement dwelling, or a building extension is restricted to its immediate curtilage;
- there are no new caravan parks or residential villages; and
- any works that are designed to protect the immediate surrounds of existing habitable dwellings do not enclose an area of more than 500 m^2 including the footprint area of works.

Subdivision

- any subdivision (including realignment of lot boundaries) does not increase the number of lots; and
- any subdivision located partly within **FO** or **RFO** is structured so that:
  - new lot boundaries (other than existing and/or realignment of lot boundaries) are sited on land where the 100-year ARI flood depths are less than 0.5 metres; and
  - each lot contains land for a building envelope where the 100-year ARI flood depths are less than 0.5 metres, and is accessible via a defined access route where the 100-year ARI flood depths are less than 0.8 metres for rural areas, or 0.5 metres for urban areas.

Development Requirements for LSIO in Rural Areas

Buildings

- any buildings do not obstruct natural flow paths or drainage lines;
- the construction of any new dwelling, including a replacement dwelling, is sited on the highest available ground (unless the applicant can demonstrate to the satisfaction of the responsible authority that an alternative site is more suitable);
- there are no new commercial or industrial buildings sited on land where the 100-year ARI flood depth in more than 0.5 m above the natural surface level;
- the construction of any new dwelling (other than a replacement dwelling) is sited on land where the 100-year ARI flood depth is less than 0.5 metres above the natural surface level, and the 100-year ARI flood depth is less than 0.8 metres along defined access route (unless the applicant can demonstrate to the satisfaction of the responsible authority and the floodplain management authority that an alternative site is more suitable);
- the floor level of any new dwelling, including a replacement dwelling, is set at least 300 mm above the 100-year ARI flood level;
- the floor level of any new commercial or industrial building, including a replacement building, is set at least 300 mm above the 100-year ARI flood level unless the applicant can demonstrate to the responsible authority and the floodplain management authority that a lower floor level is more suitable;
- any non habitable buildings are aligned so that their longitudinal axis is parallel to the predicted direction of flood flow; and
- there are no fences other than replacement fences or open post and wire fences.

Works

- any earthworks do not obstruct natural flow paths or drainage lines.
- any earthen land fill at the site of a new or replacement dwelling, or a building extension is restricted to its immediate curtilage;
- any works that are designed to protect the immediate surrounds of existing habitable dwellings do not enclose an area of more than 500 m^2 including the footprint area of works; and
- no new caravan parks or residential villages on land where the 100-year ARI flood depth is more than 0.5 metres above the natural surface level.

Subdivision

- there are no new lots less than 40 hectares in area (other than to realign the boundaries of existing lots) unless for the purposes of a lot excision agreed to by the responsible authority; and
- any subdivision located partly within **LSIO** is structured so that:
  - new lot boundaries (other than existing and/or realignment of lot boundaries) are sited on land where the 100-year ARI flood depths are less than 0.5 metres; and
  - each lot contains land for a building envelope where the 100-year ARI flood depths are less than 0.5 metres, and is accessible via a defined access route where the 100-year ARI flood depths are less than 0.8 metres for rural areas, or 0.5 metres for urban areas.

SPECIAL REQUIREMENTS FOR PRECINCTS

Development Requirements for UFZ

Buildings

- there are no new dwellings (other than replacement habitable dwelling) or new commercial or industrial buildings;
- the ground floor area of replacement dwellings must not exceed 20 m^2 than the original floor area;
- the combined ground floor area of one-off or subsequent extensions does not exceed 20 m^2 over the life of the building;
- the floor level of any replacement dwelling is set at least 300 mm above the 100-year ARI flood level; and
- any buildings do not obstruct natural flow paths or drainage lines.

Works

- any earthworks do not obstruct natural flow paths or drainage lines.

Development Requirements for LSIO in Residential, Industrial and Business Zones for Benalla

An application is consistent with the Local Floodplain Development Plan if:

Buildings

- any buildings do not obstruct natural flow paths or natural drainage lines;
- any new dwelling is constructed on land where the 100-year ARI flood depth is less than 0.5 metres above the natural surface level, and is less than 0.5 metres along a defined access route to the dwelling site unless the site is surrounded by existing dwellings within 50 metres on at least three sides.
- the floor level of any new dwelling, including a replacement dwelling, is set at least 300 mm above the 100-year ARI flood level; and
- the floor level of any new commercial or industrial building, including a replacement building, is set at least 300 mm above the 100-year ARI flood level unless the applicant can demonstrate to the responsible authority and the floodplain management authority that a lower floor level is more suitable.

Works

- any earthworks do not obstruct natural flow paths or natural drainage lines.

Subdivisions

- land is subdivided to realign the boundaries of existing lots unless the site is surrounded by existing buildings (dwelling, industrial or commercial) within 50 metres on at least three sides.

APPENDIX G

Properties Estimated to be Flooded Overfloor by a 5% AEP Flood Following Implementation of Scheme H5

APPENDIX G PROPERTIES ESTIMATED TO BE FLOODED OVERFLOOR BY A 5% AEP FLOOD FOLLOWING IMPLEMENTATION OF SCHEME H5

- 36 Arundle St (North)
- 40 Arundle St (North)