Wyong Shire Council
CENTRAL COAST

LOWER WYONG RIVER FLOODPLAIN RISK MANAGEMENT STUDY

Final Report
July 2010

Paterson Consultants Pty Limited

WYONG SHIRE COUNCIL

LOWER WYONG RIVER
FLOODPLAIN RISK MANAGEMENT STUDY

FINAL REPORT

July 2010

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TABLE OF CONTENTS **PAGE NUMBER**

TABLE OF CONTENTS CONT. **PAGE NUMBER**

TABLE OF CONTENTS CONT. **PAGE NUMBER**

TABLES

TABLE OF CONTENTS CONT. **PAGE NUMBER**

TABLES (Cont)

FIGURES

TABLE OF CONTENTS CONT. **PAGE NUMBER**

APPENDICES

FOREWORD

The NSW Government's Flood Prone Land Policy recognises that flood-liable land is a valuable resource and should not be sterilised by unnecessarily precluding its development. The Policy also recognises the benefits flowing from the use, occupation and development of floodprone land. Accordingly, the Policy requires that all development proposals be treated on their merits.

The merit approach requires that flooding issues be considered along with other planning and environmental factors. Specifically, the merit approach seeks to balance social, economic, environmental and flood risk parameters to ascertain whether a particular development or use of the floodplain is appropriate and sustainable.

The prime responsibility for local planning and land management rests with local government. The study area falls under the administrative responsibility of Wyong Shire Council.

The first Floodplain Development Manual (Ref 1) was released in 1986 and introduced the merit based approach. The first Floodplain Development Manual created a floodplain management process similar to that shown on Figure A1 in Appendix A, with a number of subtle differences. Revised versions of the Floodplain Development Manual in 2001 and 2003 led to the current Floodplain Development Manual of 2005 (Ref 23). Broad changes to the Manual between 1986 and 2005 covered:

- explicit consideration of the full range of floods up to and including the Probable Maximum Flood (PMF);

- recognition of existing future and continuing flood risks on a strategic basis rather than an ad-hoc individual basis;

- enabling local Council to obtain State support to manage local overland flooding in a manner similar to riverine flooding;

- promotion of the preparation and adoption of local flood plans to address flood readiness, response and recovery;

More subtle changes in the progression from the 1986 Manual to the 2005 Manual were:

- the introduction of risk management concepts;
- the deletion of "Interim Flood Policies";
- deletion of an encompassing Flood Standard;
- adoption of Flood Planning Levels (FPLs);
- changes to reflect structural changes in the NSW Government departments with responsibility for administration of government policy.

The New South Wales Floodplain Development Manual (Manual) (Ref. 23) has been prepared to assist councils in the development of management plans for flood-liable lands. The principal objective of the floodplain management process is to reduce the impact of flooding and flood liability on individual owners and occupiers and to reduce private and public losses resulting from floods.

The Floodplain Risk Management process comprises the following activities:

- establishment of a Floodplain Management Committee;
- data collection;
- completion of a Flood Study;
- preparation of a Floodplain Risk Management Study;
- adoption of a Floodplain Risk Management Plan; and
- implementation of the Floodplain Risk Management Plan.

The Floodplain Risk Management process is presented schematically on Figure A1 in Appendix A, which has been derived from the Manual.

The Lower Wyong River Floodplain Risk Management Study has been prepared by Paterson Consultants Pty Limited on behalf of Wyong Shire Council. The work has been jointly funded by Wyong Shire Council and DECCW on a 1:2 basis under State Floodplain Management Program

GLOSSARY - Terms and Abbreviations

Note: A more extensive glossary is available in the 2005 Floodplain Development Manual. An extract from the Glossary of the Floodplain Development Manual, giving a fuller description of floodways, flood storages and flood fringe, appears in Appendix H.

Floodplain Management

Manual or *Floodplain Development Manual*: The New South Wales Government publication "Floodplain Development Manual", 2005.

Australian Height Datum (AHD): a common notional plane of level corresponding approximately to mean sea level.

Reduced Level (RL): a measured height above Australian Height Datum.

Full Supply Level (FSL): The level of a water supply storage which corresponds to the full storage capacity.

Flood Probability

Annual Exceedence Probability (AEP): the probability of an event (say a flood) occurring or being exceeded in any one year.

Average Recurrence Interval (ARI): the long-term average number of years between the occurrence of a flood as big as or larger than the selected event.

Probable Maximum Precipitation (PMP): (see description under "Flood Behaviour")

Probable Maximum Flood (PMF): (see description under "Flood Behaviour")

Flood Damages

Direct Damage: damage caused by contact with floodwater eg. structural damage to building, water damage to furniture or house contents or damage caused by silt and debris.

Indirect Damage: damage caused by flooding though not directly eg. loss of trade, cost of alternative accommodation or loss of wages.

Tangible Damage: damage that can be quantified in monetary terms, includes direct and indirect damages.

Intangible Damage: damage that occurs but is difficult to quantify eg. increased stress in the community or disruption to community life.

Potential Damages: an estimate of the flood damage that represents the maximum damage loss if no action is taken to reduce the damage.

Actual Damage: an estimate of the flood damage that makes allowance for any action taken to reduce the damage.

Mean Annual Damage: an estimate of the annual average damage from the full range of floods. It is obtained by summation of the product of damage and probability over the full range of flooding likely to occur.

Economic Factors

Capital Cost: total construction cost of project, including land acquisition, survey, investigation and design.

Amortization: annual interest and redemption payments over the economic life of the project.

Economic Life: period during which a works item remains in a satisfactory working condition before being replaced.

Recurrent Cost: annual cost for maintenance and operation eg. power, fuel.

Annual Cost: sum of amortization, operation and maintenance cost for a year.

Nett Present Value: the sum of money which, if invested today at the adopted interest rate, would be sufficient to fund all annual costs of the project over the economic life.

Nett Present Value-Capital Cost Ratio: ratio of nett present value of annual costs of a project to the capital cost. This ratio reflects the relativities of capital and recurrent costs of a project.

Benefit-Cost Ratio: ratio of the monetary benefits of a project to the cost of a project. This ratio can be determined on an annual cost basis or nett present value basis.

Relative Cost Effectiveness: ratio of the relative benefit for a project to the relative cost of the project. This ratio enables a variety of projects which provide different benefits to be compared. It is also equal to the ratio of the benefit-cost ratio for a project to the benefit-cost ratio for the reference project.

Emergency Management

emergency management: a range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

disaster plan (DISPLAN): a step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency

operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

flood plan (local): A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.

flood awareness: Awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

flood readiness: Readiness is an ability to react within the effective warning time.

minor, moderate and major flooding: both the SES and the BoM use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

> *minor flooding*: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.
>
> *moderate flooding*: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.
>
> *major flooding*: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

<u>*Flood Behaviour*</u>

flood prone land: land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.

Flood risk: potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in the Floodplain Development Manual is divided into 3 types, existing, future and continuing risks as below:

> *existing flood risk*: the risk a community is exposed to as a result of its location on the floodplain.
>
> *future flood risk*: the risk a community may be exposed to as a result of new development on the floodplain.
>
> *continuing flood risk*: the risk a community is exposed to after floodplain risk management measures have been implemented.

Floodway areas: those areas of the floodplain where a significant discharge of water occurs during floods.

flood storage areas: those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.

flood fringe areas: the remaining area of flood prone land after floodway and flood storage areas have been defined.

discharge: the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (cu m/sec).

probable maximum precipitation: the PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probable maximum flood: the PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions.

stage: equivalent to water level (both measured with reference to a specified datum).

stage hydrograph: a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.

Development

Development: is defined in Part 4 of the EP&A Act.

Development types (in this study):

Infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land.

New development: refers to development of a completely different nature to that associated with the former land use.

Redevelopment: refers to rebuilding in an area as urban areas age.

Flood planning levels (FPL): are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.

Freeboard: provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided.

flood planning area: the area of land below the FPL and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.

SUMMARY

The Lower Wyong River Floodplain Risk Management Study draws on the results of a number of previous studies of flooding in the Wyong River and nearby Mardi Creek. Information derived from these previous studies together with additional data collected for the Floodplain Risk Management Study was used to assess a range of feasible floodplain management options.

The study area comprises the floodplain of the Wyong River downstream of Woodbury's Bridge and the Old Maitland Road, some 2.5 kilometres west of the town of Wyong towards Tuggerah Lakes. The downstream boundary of the study area has been set approximately 1.4 kilometres upstream of Tuggerah Lakes, as beyond this point, the flood levels are controlled by Tuggerah Lakes. Floodplain Management around Tuggerah Lakes will be the subject of a separate floodplain risk management study, currently underway.

The floodplain extends over approximately 16 square kilometres and includes Mardi Creek, which is located at the southern limit of the study area. The study area is shown on Figure 1.

Significant areas of residential development at Tacoma, Tacoma South and eastern Wyong as well as the Tuggerah Straight Industrial Area are located on the floodplain. Approximately 4 square kilometres of the floodplain is included (for land use planning) within the Zone 7(g) Environmental Protection - Wetland Management Zone, as shown on Figure 15.

The floodplain is traversed by the Sydney-Newcastle Freeway and the Pacific Highway-Main Northern Railway transport corridors.

Flooding within the study area is caused primarily by runoff in the Wyong River with runoff in Mardi Creek having localised flooding effect. Flooding of the lower Wyong River floodplain can also be influenced by flood levels in Tuggerah Lakes and by flood overflows from Ourimbah Creek, which is located 1.5 to 2 kilometres south of the study area.

Reports of flooding in the Wyong River are available from 1867, with the highest recorded flood occurring in June 1949. It is reported in the 1983 flood study (Ref 2) that the entrance to Tuggerah Lakes was closed when this flood occurred. Extensive flood level data is available only for the January 1964 flood which was 0.15 metres lower than the 1949 flood at the railway bridge over the Wyong River. This event is generally considered to be the second largest recorded flood.

The most recent significant flood on the Wyong River occurred in June 2007, when the Wyong River peaked at the Wyong Railway Bridge at RL 2.63 m AHD after daily rainfalls over the catchment of approximately 235 millimetres in 24 hours on the eastern part of the catchment, falling to 200 millimetres in 24 hours in the western part. At Wyong Weir, a 24 hour total of 335 millimetres was recorded, indicating a highly localised storm event.

The last recorded, significant flood in the Wyong River prior to June 2007 occurred in 1977 when extensive flooding followed daily rainfalls of 120 to 200 millimetres on a catchment which had received significant rainfall over the preceding 48 hours.

In examination of the historical background to this study, three periods of floodplain management activity are evident, namely:

- prior to 1986;
- 1986 to 1995; and
- 1995 to 2005.

The most significant action, in terms of continuing development of flood liable lands, is Council's adoption of a Flood Prone Land Development Policy in 1986. This development has continued within the lower Wyong River catchment with:

- some 40 new residences and 85 renovations and extensions to domestic building completed over the period 1995 to 2009;

- an additional 53 industrial buildings in the Tuggerah Straight Industrial Area over the same period;

- development of the "Kooindah" sub-division;

- development of the Tuggerah Business Park.

Floor level survey indicates that 404 houses on the floodplain have habitable floors located below the 1 percent Annual Exceedence Probability (1% AEP) flood level, while 147 commercial and light industrial premises are located below the 1% AEP flood level. The approximate extent of land inundated in the 1% AEP flood is shown on Figure 4.

The estimated mean annual, direct and indirect flood damages to residential, commercial and light industrial properties on the lower Wyong River floodplain is $8.46 million of which approximately 82% of the damages is sustained by the commercial and light industrial properties. The estimated mean annual flood damages to public utilities is $893,000, equivalent to 11% of the total damages with the remaining 7% of total damages incurred by residential properties.

The study area is zoned under Wyong Shire Local Environment Plan 1991, as shown on Figure 15. The principal change in land use zoning between 1996 and 2005 is the creation of Zone 7(g) “Wetlands Management Zone”.

Wyong Shire Council has been applying development controls within the flood liable areas of Wyong River via the Flood Prone Land Development Policy. The allowable development is set out in a matrix format involving:

- High and Low Flood Hazard;
- Floodway, Flood Storage and Flood Fringe Hazard categories; and
- Development types as “New Development”, “Non-Urban Zones”, and “Urban Zones”.

The Flood Prone Land Development Policy adopts the 1% AEP flood for planning purposes generally, with the exception of the Tuggerah Straight Industrial Area, where the 2% AEP flood was adopted as the "Designated Flood" (the flood standard for planning purposes). This area is indicated on Figure 1. The extent of the Tuggerah Straight Industrial Area is identified as located west of the Pacific Highway, east of Gavenlock Road, north of Anzac Road and south of Macphersons Road..

Wyong Shire Council has been applying the Flood Prone Land Development Policy, 1986, for development on flood liable land. The application of the Policy has allowed further building on the Wyong River floodplain, and hence has not met the objective "to minimise the financial and emotional cost to the community due to flooding". Wyong Shire Council is currently developing a DCP covering flooding.

The Wyong River has a flood warning system in place, which is operated by the Bureau of Meteorology, with flood warning issued to the SES. The system uses five rainfall gauges and three river level gauges, connected by a telemetric system, to collect field data. The field data is converted to flood warnings using a relatively simple hydrologic model. To date, the system has not been tested in a large flood event.

In 2005, the NSW Government released the 2005 Floodplain Development Manual, as an update to the 1986 Manual. The 2005 Manual introduced:

- concepts of existing flood risk, future flood risk and continuing flood risk;
- concepts of flood risk management measures as flood modification measures, property modification measures, and response modification measures;
- concepts of Flood Planning Levels applicable to separate development types.

Council's current flood planning level through the Study area generally, is 1% AEP flood plus 0.3 m freeboard, with the exception of the Tuggerah Straight Industrial Area, where a 2% AEP flood with zero freeboard has been adopted.

On review, there is little benefit to varying the design flood adopted to serve as "flood planning levels". The current freeboard allowance of 0.3 metres is considered inadequate and is recommended to be increased to 0.5 metres.

A variety of flood mitigation works and schemes have been examined in the previous studies of flooding in the Wyong River and Mardi Creek. The proposed works comprised of levee works, channel works, and house raising, and included channel improvements to Mardi Creek between Gavenlock Road and the Pacific Highway and augmentation of the culvert at Gavenlock Road.

The initial assessment of feasible floodplain management options for existing development indicated the above channel improvements and augmentation of the Mardi Creek culverts under the Pacific Highway and Main Northern Railway as the most effective and acceptable flood mitigation works. More detailed assessment of the Mardi Creek culvert options indicated that the benefits from the work were not as large as originally indicated and hence the culvert option has been discarded. The channel works have been included in the adopted strategy for Mardi Creek and were carried out during the course of this study.

Raising of the Pacific Highway bridge over the Wyong River is considered to be marginally desirable, though this option is ranked below the `Status Quo' option. The high capital cost of this option implies that it is unlikely to proceed on the basis of floodplain management benefits alone.

Raising of flood-liable houses is also ranked below the `Status Quo' option and is not considered to be worthy of implementation by Council due to the large number of houses potentially affected and the low benefit/cost ratio. However, this is considered to be an appropriate option for individual landowners to implement.

Increasing the opening size of Tuggerah Lake to the ocean at The Entrance was examined in 1994. The examination showed that increasing the entrance opening would have little flood mitigation benefits, incur high maintenance cost and create major environmental changes in Tuggerah Lake through an increased tidal variation of water levels.

A broad environmental examination of the flood liable area has been undertaken to identify any environmental constraints that may affect any flood mitigation works.

The floodplain risk management options mitigate existing flood risk and have been compared on the basis of:

- flood mitigation performance;
- environmental impacts;
- social impacts;
- economic performance.

The overall ranking and economic costs of these works options means maintaining the “status quo” is the most attractive option for floodplain management of the Lower Wyong River.

Works along Mardi Creek were ranked highly in the 1995 draft study (Ref. 10) and have since been constructed.

Additional culverts for Mardi Creek under the Pacific Highway and Main Northern Railway Line are attractive to reduce flood levels, although investigations in 2008 indicate costs will be significantly higher than anticipated and benefits significantly lower. However, the gradual re-development of the Tuggerah Straight Industrial Area with filling of remaining blocks reduces the need of these works.

In management of future and continuing flood risk, changes to Council’s Flood Policy by way of changes to the controls matrix and creation of a DCP covering floodplain risk management or alternatively creating a DCP which incorporates the allowable development control simply in text form is the best alternative for Wyong Shire Council to improve floodplain management in the Lower Wyong River.

1. INTRODUCTION

The Wyong River has a catchment area of 439 square kilometres and discharges into Tuggerah Lake on the Central Coast of New South Wales. Tuggerah Lake is the largest of three interconnected coastal lakes which enter the Pacific Ocean via a single entrance at The Entrance.

The total catchment of Wyong River to Pacific Highway is some 442 sq kilometres. The major tributaries to this point are:

- Wyong River: 283 sq km
- Jilliby Jilliby Creek: 100 sq km
- Porters Creek: 58.7 sq km

The smaller catchments are:

- Deep Creek: 5.4 sq km
- Mardi Creek: 8.8 sq km

The Lower Wyong River Floodplain Risk Management Study area extends over an area of 16 square kilometres downstream of the Old Maitland Road and Woodbury's Bridge to a point 1.4 kilometres upstream of Tuggerah Lake. Beyond the downstream limit, flood levels are principally controlled by Tuggerah Lake. The study area also includes the floodplain of Mardi Creek, a small tributary stream located at the southern edge of the study area.

The study area is shown on Figure 1.

The Wyong River floodplain is crossed by three major transport routes:

- the Sydney-Newcastle Freeway;
- the Pacific Highway; and
- the Main Northern Railway.

The Sydney-Newcastle Freeway is located near the upstream boundary of the study area, while the Pacific Highway and Main Northern Railway form a single corridor which is located near the centre of the study area.

The Wyong River floodplain can be divided into two major sub-areas:

- the upper Wyong River floodplain, located upstream of the Pacific Highway/railway corridor; and

- the lower Wyong River floodplain, located downstream of the Pacific Highway/railway corridor.

Flooding within the study area is caused primarily by runoff in the Wyong River with runoff in Mardi Creek having a localised flooding effect. However, flood behaviour in the lower Wyong River floodplain can also

be influenced by flood levels in Tuggerah Lake and by flood overflows from Ourimbah Creek to the south of the study area.

Particular reference in this study is made to a number of areas on the floodplain, namely:

- Wyong itself;
- Tuggerah Straight Industrial Area bounded by Pacific Highway, Anzac Road and Gavenlock Road (see Figure 1);
- Commercial/industrial sub-division known as "Tuggerah Business Park", located east of Main Northern Railway Line and south of Wyong Road;
- Fishermans Co-operative;
- Wyong Nursing Home, located between Wyong River and McPherson Road, west of the Pacific Highway;
- "Kooindah" development;
- Supa Centre developments and others north and south of Lake Road.

Local roads north of the Wyong River and east of the Main Northern Railway line:

- Panonia Road;
- Warner Avenue;
- Boyce Avenue;
- Golding Grove.

Local Roads south of the Wyong River and east of the Main Northern Railway line:

- Wyong Road;
- Lake Road;
- Bryant Drive.

Local roads in the Tuggerah Straight Industrial Area:

- Gavenlock Road;
- Anzac Road;
- Mildon Road.

Local roads, west of the Main Northern Railway line (excluding the Tuggerah Straight Industrial Area):

- McPherson Road;
- Old Maitland Road;
- Mardi Road.

The Business District of Wyong is located on the northern bank of the Wyong River on an elevated ridge adjacent to the Pacific Highway and railway line. The Tuggerah Straight Industrial Area is located immediately upstream of the highway, south of the Wyong River, and extends from Mardi Creek to the Wyong River.

The lower floodplain is used for cattle grazing and turf farming, with some isolated houses. There is extensive residential development of both banks of the Wyong River in Tacoma and Tacoma South. This development is confined to riverfront properties. There is also an area of residential development on the foreshore of Tuggerah Lake, a short distance north of the river entrance.

There is recent light industrial development along Lake Road, with some isolated residences.

The primary objective of the Lower Wyong River Floodplain Risk Management Study is to determine appropriate floodplain management measures for the preparation of a cost-effective Floodplain Risk Management Plan for the study area.

The study addresses flooding caused by runoff in the Wyong River and Mardi Creek and does not address flooding caused by elevated water levels in Tuggerah Lakes independent of river flooding. Floodplain management for Tuggerah Lakes flooding is currently being addressed in a separate study.

This Floodplain Risk Management Study reviews flood behaviour and evaluates a range of management options which aim to reduce and control the impact of flooding on existing and future development within the study area.

2. HISTORICAL DEVELOPMENT OF THIS STUDY

This Study and Plan have had a long development period to reach the current position.

A historical sequence of periods of activity can be identified as:

- Prior to the issue of the 1986 Floodplain Development Manual;
- Application of NSW 1986 Manual;
- Period 1995 to 2010.

The activities within each period are described below. The descriptions have been derived from the documents provided by Wyong Shire Council and from the consultant's personal knowledge.

Prior to 1986

Residential development on the Wyong River floodplain appears to have commenced in the early 1900's. Wyong Shire information in 1996 listed historical sites within the floodplain area as:

- Woodbury Inn site, Woodbury's Bridge, built circa 1866;
- Old Tuggerah Jetty, Lake Road, built 1901;
- "Strathaven", Boyce Avenue, built 1912-1913.

Several flood investigations were conducted between 1983 and 1985 with the aim of identifying flood levels and flow velocities over the floodplain. Attention was also directed to assessment of the impact of construction of the Sydney-Newcastle freeway.

Period 1986 to 1995

Over this period, Wyong Shire Council undertook a series of activities to comply with the 1986 Floodplain Development Manual. These activities involved:

- development of the Flood Prone Land Development Policy which essentially created a matrix of allowable site development scenarios against flood hydraulic categories. The development matrix is still used by Wyong Shire Council and is addressed in Chapter 7.

- completion of flood studies for the "Upper Wyong River", "Lower Wyong River" and Mardi Creek;

- completion of draft floodplain management studies for the Lower Wyong River. These studies were never placed on public exhibition or adopted by Council.

At that time, the floodplain management studies reviewed structural floodplain management options (physical works) and non-structural options (land use planning and the like). There was no pressure on the part of Wyong Shire Council to change the Flood Prone Land Policy that was in place.

Period 1995 to 2010

The principal floodplain management activities and issues dealt with on-going development on the Lower Wyong River floodplain, in particular:

- renovations and re-building of the residential housing stock;
- in-fill development of residential land;
- in-fill development of the Tuggerah Straight Industrial Area;
- commercial areas, identified as "Tuggerah Industrial Area", located east of the Main Northern Railway line and north of Wyong Road. This area contains the "Supa Centre" development sites.
- "Kooindah" development;
- Tuggerah Business Park development;
- raising of the Main Northern Railway embankment;
- development in the Tuggerah Industrial Area near Bryant Drive (the "Supa Centre) and south of Lake Road;
- on-going concern of the evacuation planning for the Wyong Nursing Home.

In this period, Council undertook further investigation of floodplain management works along Mardi Creek, together with channel improvement works upstream of the Pacific Highway.

Building development changes and updated flood damage estimates were undertaken in late 2006.

The relative magnitude of on-going development (as of 2006) has been deduced by inspection and comparison of available aerial photography, Council's development approvals, and the house floor level data base as follows.

Building approvals for 147 buildings (both residential and commercial/industrial) have been issued since 1995.

Wyong Shire Council's house floor level data base indicates there are about 799 residences below the one percent Annual Exceedence Probability (1% AEP) flood level. Comparison between the 1995 floor level data base and site inspection in August 2006 shows some 116 new buildings have been constructed. Ground survey indicates that:

- there have been 40 new residences built on lots within the study area inundated by the 1% AEP, while there have been a further 22 replacements of building stock.

- the difference of 85 residences between Council approvals (147 off) and ground surveyed changes (62 off) has been viewed as involving renovations and extensions to existing buildings.

Within the Tuggerah Straight Industrial Area, the number of buildings has increased from 188 in 1995 to 241 in 2006. The measured roof area (as an indicator of floor area) has increased by about 45 percent from the 1995 estimate to about 186,000 sq metres.

The Tuggerah Business Park (formerly identified as "Meridian Development") has created some 60 industrial/commercial lots south of Wyong Road. This development is protected by flooding from Ourimbah Creek by a constructed earth levee along its southern boundary. The development controls applied in this area set building floor levels at the 1% AEP flood level in Wyong River but with no freeboard.

It is noted that the 2010 Wyong council heritage register changed since 1996 in that it has:

- deleted the Woodbury Inn Site and the old Tuggerah Jetty, Lake Road;
- changed the “Strathaven name to “Hakone”;
- added All Saints Anglican Church, Anzac Road, and Pioneer Dairy.

Ongoing floodplain risk management issues relate to the Main Northern Railway and Wyong Nursing Home, as well as Wyong Shire Council’s development policies.

The Main Northern Railway crosses the Wyong River and its floodplain, virtually perpendicular to the flood flow directions. The railway is founded on a raised embankment. The openings through the embankment are:

- Bridge crossing of Wyong River channel near Wyong;
- Culverts below the embankment for Mardi Creek;
- Other culverts opposite Johnson Road in the Tuggerah Straight Industrial Area.

The railway has been overtopped by flooding in the past (in 1927 and 1949). The railway line has been re-ballasted since the overtopping events. The railway line is founded on an earth embankment with crushed rock (the rail ballast) between the top of the embankment and the rails. The work “re-ballasting” involves replacement and addition to the ballast and usually involves lifting the rails. Thus, the critical point for overtopping is the “top of rail” levels. If the “top of rail” levels are raised, there will be a commensurate increase in flood levels upstream. In this instance, further re-ballasting or changes to the “top of rail” levels have the potential to increase the flood levels through the Tuggerah Straight Industrial Area.

The Wyong Nursing Home, located immediately upstream of the Pacific Highway bridge over the Wyong River is also a source of on-going concern for floodplain risk management and flood evacuation. The buildings in the Nursing Home are elevated, though located on a high knoll with floor levels above the 1% AEP flood levels. However, access to the Nursing Home is cut early in a flood, at approximately the 20% AEP (once in 5 year ARI) flood, giving rise to increased evacuation difficulties, given the number of elderly patients and their lack of mobility.

The St Peters Catholic School on Gavenlock Road reported evacuation difficulties from the school to Gavenlock Road and along Gavenlock Road in the June 2007 flood. The school buildings are located to the western end of the block. Access to Gavenlock Road is easterly from the School buildings. This access crosses the floodways between Mardi Creek and Wyong River. Access to the west appears to be blocked by the residential development adjacent to the School.

3. STUDY APPROACH

The approach to this floodplain risk management study is slightly different to a normal procedure under the NSW Floodplain Development Manual. This difference follows:

- the substantial work on the flood studies and floodplain management studies completed up to 1995 under the guidelines outlined by the 1986 Floodplain Development Manual;

- a draft floodplain management study was completed in July 1996, which had undergone internal review by Wyong Shire Council staff, but was not placed on public exhibition, nor subsequently formally adopted by Council;

- the 1996 draft Floodplain Management Plan recommended a range of non-structural works, namely:

    - improved flood evacuation planning;

    - improved flood warning;

    - community education program;

    - amplification of the Mardi Creek culverts under both the Pacific Highway and Main Northern Railway;

    - encouragement for individual house owners to raise their dwellings;

    - changes to Council's Flood Prone Land Development Policy to increase the freeboard allowance from 0.3 metres to 0.5 metres;

    - changes to Council's Flood Prone Land Development Policy to change assessment of floodways and flood fringes from "usually permitted" to "considered on merit";

    - no further filling and development between Mildon Road and Boswell Close to limit flood level increases and increased flood damages.

- further detailed investigations in 1997 into the Mardi Creek culverts beneath the Pacific Highway and the Main Northern Railway indicated the culvert works did not yield the expected benefits, and thus the culvert proposals were discarded;

- the limited changes to the floodplain management process introduced by the 2005 Floodplain Development Manual.

It is normal practice in flood studies to use a hydrology model to identify flood flows (discharges) and a riverine hydraulic model to identify flood behaviour (flood levels, flows and flow velocities).

The original flood studies of Wyong River, to identify flood levels, used a computer program, generically identified as CELLS, for hydraulic model, while WBNM was used for the hydrology model.

WBNM is currently used in New South Wales. There have been minimal changes to WBNM software from 1995. The main changes have been to the user interfaces for the software, while the underlying theories and concepts remain the same.

CELL type models have fallen into disuse since 1995 and have been superceded by more sophisticated two dimensional models using finite difference or finite element solution techniques to identify flood behaviour. The data input and output is also more sophisticated and graphical with the later two dimensional models.

In essence, CELLS divides the floodplain into a series of compartments ("cells") where flood volume is conserved in each cell and transferred between cells based on friction losses.

In the fully two dimensional models, the floodplain is divided into a series of squares (for finite difference methods) or a series of rectangles and triangles (for finite element analysis). Flood volume is conserved for each square (or rectangle or triangle) with flow between each square (or rectangle or triangle) controlled by momentum, comprising of friction forces and acceleration forces (known as convective terms).

In river flood flows, the friction terms dominate the convective terms, while in tidal flows (where the flood direction reverses), the convective terms dominate the friction terms.

In the Lower Wyong River situation, given a careful layout of the flood model, CELLS can be expected to give reasonable results.

Further, the development application for the "Kooindah" development created a two dimensional finite element model of Lower Wyong River and its floodplain downstream of the Main Northern Railway line using RMA-2 software. Using the same hydrograph inputs as the CELLS model at the Main Northern Railway Line, the RMA-2 model produced water levels generally within 0.12 metres of the CELLS model. The comparison between the two models is addressed in the following chapter.

Two study approaches were available to complete this study and to prepare the floodplain risk management plan for Lower Wyong River.

The first approach involves complete revision of the flood study using the most recent two dimensional software, followed by review of floodplain risk management options and preparation of the risk management plan. This process would take 2 to 3 years to complete.

The second approach involves building on the previous work (the flood studies and floodplain management studies) updating the work as applicable to current conditions, whilst achieving compliance with the 2005 Floodplain Development Manual.

The second approach above was considered the best alternative, given:

- the time required to reach completion by following the first approach;
- the financial cost of the first approach, given it is essentially re-working of existing information;
- considerable funds have already been expended getting the existing flood studies and floodplain management studies to their virtual completion stage;
- the time pressure to have the floodplain risk management plans adopted by Council;
- the lack of any large floods (with the exception of June 2007) to create an adequate data base for verification and calibration of the hydraulic model for any new flood studies.

The work on the second approach was commenced in 2006, however, there have been delays (from 2007 to 2010) to enable this study and its recommendations to pass through Wyong Shire Council's internal assessment procedures.

Thus, the study approach used has been essentially extending the existing flood and floodplain management studies, particularly:

- developing conformance with the 2005 NSW Floodplain Development Manual;
- estimation of PMP flood behaviour in the study area;
- identification of flood hydraulic categories (floodways, flood storage and flood fringe area) and flood hazard categories (high hazard and low hazard);
- updating flood damage estimates by inclusion within the building data base of buildings constructed over the period 1995 to 2006;
- updating flood damage and works cost estimates by use of the Consumer Price Index (CPI) over the period 1995 to 2006;
- further adjustment of damage figures from 2007 to 2010 using Consumer Price Index changes;
- introduction of the concepts of flood risk, in accordance with the 2005 Floodplain Development Manual;
- review of the works and measures proposed in the 1995 Floodplain Management Study;
- drawing of conclusions from the current study and the experience of application of the 1995 study over the period 1995 to 2008 as a "development policy".

4. EXISTING FLOOD BEHAVIOUR

4.1 Overview

Although reports of flooding in the Wyong River date back to 1867, reliable flood level data is available for few of these events. An extensive coverage of flood level data is available only for the June 1964 event. This event is the second highest recorded flood in the Wyong River.

The recorded flood level data is distributed over a wide area with no single location having a complete record of the historical flood events. A ranked listing (in decreasing size) of historical floods for which information is available is presented in Table 2.1.

Table 4.1

Recorded Floods - Wyong River at Railway Bridge

Rank	Date	Peak Flood Level (m AHD)
1	June 1949	4.15 (Est.)
2	June 1964	4.06
3	June 1930	3.19
4	April 1927	3.79
5	1977	3.60

Notes: (Est.) - estimated

With respect to Table 4.1, it should be noted that:

- the floods represented occurred before 1978;
- floods probably occurred in 1988, 1989 and 1990 (based on general flooding occurring along the NSW coastal areas). It appears there are no flood level readings or records available for these events or alternatively, flooding did not occur.
- the flood warning system in the Wyong River catchment started in 1992, and since that time, no significant floods have occurred other than June 2007;
- the June 2007 flood peaked at RL 2.63 m AHD at the Wyong Railway Bridge. It was thus about 1 metre lower than the 1977 flood.

It is reported in the 1983 Flood Study (Ref.2) that the entrance to Tuggerah Lake was not open to the ocean when the 1949 flood occurred and a pilot channel was excavated by hand to enable the lake to break

out. Peak flood levels for this event were generally less than 0.15 metres higher than the 1964 flood levels upstream of the railway bridge. The peak flood levels downstream of the railway bridge through to Tacoma at the mouth of the Wyong River were typically 0.4 metres higher than the 1964 flood levels, reflecting the higher water level in Tuggerah Lake due to the closed entrance.

The estimated design flood levels at various key locations within the study area are presented in Table 4.2.

The data for the design 20%, 5%, 2% and 1% AEP flood events has been extracted from flood studies undertaken for the Wyong River, Mardi Creek and Tuggerah Lake (Ref. 5, 8 and 14) and are based on design rainfall and hydraulic modelling.

The PMF flood levels have been derived by:

- determination of PMP discharges from the WBNM hydrology model;
- determination of the PMP flood levels from the CELLS model established in the earlier flood studies.

This process for derivation of the PMF flood behaviour is detailed in Appendix B.

There is not sufficient recorded flood level data available for a full flood frequency analysis to be undertaken using historical flood levels.

Table 4.2

Design Flood Levels

AEP (%)	Flood Level (m AHD)		
	Wyong River Upstream Rail Bridge	**Mardi Creek Upstream Pacific Highway**	**Tuggerah Lake**
20	3.8	4.7	1.36
5	4.6	4.9	1.8
2	5.0	5.0	2.05
1	5.35	5.1	2.23
PMP	7.6	6.6	Not calculated

4.2 Previous Studies

There have been a number of investigations of flooding in the Wyong River undertaken since 1983. A brief summary of each of these investigations is given below.

1. "Wyong River Flood Study", Sinclair Knight & Partners, May 1983, (Ref. 2). Design flood discharges were estimated using synthetic unit hydrographs with design rainfall data and input to a HEC-2 steady-state, hydraulic model to determine design flood levels for the lower Wyong River floodplain.

2. "Upper Wyong Physical Model Study", New South Wales Public Works, Jan. 1985, (Ref. 3). A physical model of the upper Wyong River was used to determine design flood levels, velocities and flow directions. The model had originally been used to investigate the impact of the Sydney-Newcastle Freeway on flood behaviour of the Wyong River.

3. "Lower Wyong River Model Investigation", New South Wales Public Works, Oct. 1985, (Ref. 4). Flood levels, velocities and flow directions on the lower Wyong River floodplain were determined by physical modelling. The modelled flood levels were found to be in general agreement with the numerical model results of the previous study.

4. "Upper Wyong River Flood Study", Webb McKeown & Associates, Feb. 1988, (Ref. 5). A Watershed Bounded Network Model (WBNM) rainfall-runoff model of the total catchment was established and calibrated and used with design rainfall data determined in accordance with the 1987 edition of Australian Rainfall and Runoff to determine design flood discharge hydrographs for input to a CELLS unsteady-flow, hydraulic model to determine design flood levels for the upper Wyong River floodplain. The estimated 1% AEP design flood discharge was approximately two times the peak discharge adopted for the 1983 study.

5. "Upper Wyong River Flood Study - Compendium of Data", New South Wales Public Works Department, Feb. 1988, (Ref. 6). This compendium was prepared as a companion document to the study report. The compendium presents all the rainfall and flooding data available for historical flood events.

6. "Lower Wyong River Flood Study Review 1991", Webb McKeown & Associates., Jun. 1992, (Ref. 7). The 1983 flood study was revised to take account of new design rainfall data available from the 1987 edition of Australian Rainfall and Runoff and revised design flows determined for the 1988 study, and additional topographic survey of the floodplain.

7. "Mardi Creek Flood Study", Webb McKeown & Associates, Jun. 1992, (Ref. 8). Design flood levels for Mardi Creek were determined using a WBNM rainfall-runoff model to determine design flood hydrographs for input to a RUBICON hydraulic model of Mardi Creek between the Sydney-Newcastle Freeway and the lagoon near the Tuggerah Power Station.

8. "Wyong River Floodplain Management Study", Webb McKeown & Associates, Jun. 1992, (Ref. 9). The effectiveness of a range of structural flood mitigation options was assessed by hydraulic modelling. The impact of future development on the floodplain was also assessed by modelling. Non-structural flood mitigation strategies were reviewed.

9. "Flood Investigation Report, Wyong River Floodplain Modelling", Webb McKeown & Associates, Jun. 1993, (Ref. 10). This report details the modelling undertaken to assess the impact of possible filling on the floodplain in a number of locations.

10. "Wyong Railway Embankment - Effect of Track Lifts on Flooding", Webb McKeown & Associates, Aug. 1995, (Ref. 11). This study determined the changes in 1% AEP flood levels caused by proposed raising of the railway line by approximately 160 millimetres.

11. "Wyong River Floodplain Management Study - Exhibition Report", July 1996, Paterson Consultants Pty Ltd (Ref. 24). This study combined the previous flood studies and examined a range of structural works and non-structural measures to reduce flood damages. The study was consistent with the 1986 Floodplain Development Manual in that it considered environmental and land use planning considerations as well as the general structural issues.

The study recommended a floodplain management plan be adopted involving:

- no construction of structural works;
- changes to Council's floodplain development matrix to restrict development in existing urban areas to move from "developments to be usually permitted" to "developments to be considered on their merits";
- adoption of additional controls for development conditions for buildings in floodways and flood fringe categories within existing urban areas;
- changes to Council's freeboard allowance as included in the Flood Prone Land Development Policy.

12. "Mardi Creek, Tuggerah, Investigation and Concept Design of Flood Mitigation Works", Webb McKeown, 1997 (Ref. 33) This report deals with the possible hydraulic benefits, concept design and costing of works in Mardi Creek, namely, improvements to the Main Northern Railway culverts and the Pacific Highway, channel improvements along Mardi Creek and a series of retarding basins in the Mardi Creek catchment near the Freeway.

13. "Tuggerah Lakes Estuary Process Management Study, 2005", Wyong Shire Council (Ref. 25). This study was prepared under NSW Governments Estuary Management Policy and was viewed as providing "a managerial framework as a pre-cursor to the development of an Estuary Management Plan". The study concentrated on six core principles and associated objectives as guidance for management of the estuary.

The Estuary Management Study is primarily concerned with the ecology of Tuggerah Lake and its foreshores and adopts a "whole of catchment" approach to estuary management.

Consideration of the contents of both the Tuggerah Estuary Management Study (2005) and the Wyong River Floodplain Management Study (1996, Ref. 24, Item 11 above) does not indicate any conflicts in the recommendations of both studies to achieve their management outcomes (that is, estuary management floodplain risk management).

14. Individual Development Investigations

There have also been several site-specific investigations carried out for proposed developments on the floodplain, including:

- *"Wyong River: Freeway Model Investigations"*, New South Wales Public Works, Apr. 1974 (Ref. 12);
- *"Proposed Golf Course, Warner Avenue"*, Webb McKeown & Associates, Nov. 1993 (Ref. 13);
- *"Estimates and Preliminary Designs of Components of Westfield's Scheme B"*, Sinclair Knight and Partners, Apr. 1994 (Ref. 14);
- *"Wyong River Floodplain Management Study - Benefit/Cost of House Raising on the North Bank of the Wyong River"*, Webb McKeown & Associates, Jul. 1994 (Ref. 15);
- *"Lake Road, Tuggerah: Review of Drainage Options"*, Paterson Consultants Pty Limited, Jun. 1995 (Ref. 16);
- *"Kooindah Resort, Wyong - Flood Impact Assessment"*, July 2002, Patterson Britton & Partners (Ref. 28).

The last report, ("Kooindah Resort, Wyong - Flood Impact Assessment") is a significant document for this study. The report was prepared to support the development of the "Kooindah" development between Pollock Avenue and Warners Road on the floodplain north of the Wyong River. The development involves major filling of the floodplain areas.

The "Kooindah" report established a full two dimensional hydraulic model of Wyong River on its floodplain, east of the Main Northern Railway Line using RMA-2 finite element software. The model was based on available ground survey (and thus has a better topographical base than the CELLS model).

The CELLS model comprises of 150 cells distributed as:

- 8 cells are "dummy" cells and form no part of the calculation. It was common practice with CELLS to insert “dummy” cells where there was a possibility of extension of the model, to reduce the effort involved in changes to the model data coding.
- 5 cells represent Tuggerah Lake, where flood levels are specified (not calculated in the model);
- 75 cells are located west of the Pacific Highway;

The report presents a comparison between the CELLS model and the RMA-2 model using the same inflow hydrographs as:

- 63 active cells are located east of the Pacific Highway;
- flood level increases between the RMA-2 model and the CELLS model at 7 cells are shown as greater than 100 millimetres, but this difference is due to different tailwater levels in Tuggerah Lake used in the model tests.
- flood level differences are reported at 56 of the remaining 63 cells. At 44 cells, the change in flood levels is reported as less than 120 millimetres (increase or decrease);
- the only large increase in predicted flood levels was at the south eastern abutment of the Main Northern Railway Bridge across the Wyong River. The RMA-2 model predicts an increased flood level by 270 millimetres, which is considered reasonable, given the topography and the comparison of the surrounding points in the CELLS models. It should be noted that the 1% AEP flood contour map produced in Reference 24 shows some anomalies in the expected flood contours at this point.
- the RMA-2 model showed significant reductions in flood levels on Mardi Creek immediately downstream of the Main Northern Railway Line. This is seen as partly due to the model configurations used by both models.

Overall, the RMA-2 finite element model produced flood level estimates similar to the CELLS model and within the expected order of accuracy of such models when those models are without calibration.

This conclusion is also viewed as justifying the approach used in this study to proceed with the Floodplain Risk Management Plan on the basis of the existing flood data (from CELLS) as opposed to complete re-commencement of the flood study process.

4.3 Constructed Flood Mitigation Works

The earlier studies proposed that a number of flood mitigation works be carried out in the Lower Wyong River catchment, particularly along Mardi Creek. The only works constructed to date have been on Mardi Creek.

The Mardi Creek channel upstream of Gavenlock Road was improved in 1993 with the construction of a concrete invert to the earth channel. The culvert at Gavenlock Road was replaced and the creek channel between Gavenlock Road and the Pacific Highway was widened and concrete lined in 1995-6 as part of the drainage strategy adopted by Wyong Shire Council.

The locations of these flood mitigation works are shown on Figure 2.

As part of the Floodplain Management Program, Wyong Shire Council has installed and maintains a series of "ALERT" rainfall and water level gauges throughout the Wyong River catchment. These are addressed later in this report and indicated diagrammatically on Figure 17.

4.4 Flood Extent and Flood Levels

The approximate extent of land inundated in the 1% AEP design flood is shown on Figure 4. This figure also shows the estimated 1% AEP flood contours which have been compiled from References 5, 8 and 14.

Figures 3, 5 and 6 show the same information (flood contours and approximate flood extents) for the 5% AEP flood, the 0.5% AEP flood and the Probable Maximum Flood (PMF). The information in Figure 4 provides an overview of flood behaviour as follows:

- The inundated area is approximately 1.6 kilometres wide upstream of the Porters Creek confluence, rapidly reducing to 0.8 kilometres wide downstream of the Deep Creek confluence and expanding to approximately 2.4 kilometres between Gavenlock Road and the Pacific Highway.

- Downstream of the Pacific Highway and Main Northern Railway, the inundated area extends 3.5 to 4.0 kilometres northwards from Lake Road and some 0.5 km south of Lake Road.

- There is an isolated knoll of dry land in Tacoma South.

Flood flow directions will be approximately perpendicular to the flood contours on Figure 4, thus, flood flow is shown:

- from Wyong River across McPherson Road to the Tuggerah Straight Industrial Area;

- Mardi Creek will partly flow into the Tuggerah Straight Industrial Area;

- flood water will pond in the Tuggerah Straight Industrial Area, west of the Main Northern Railway Line;

- floodwaters from the Wyong River will break out from downstream of the Main Northern Railway Line towards Pollock Avenue;

- floodwater will break from the Wyong River, direct to Tuggerah Lake across the land between the flood free knoll at Tacoma South and Lake Road.

It should be noted that the above appreciation occurs at the peak of the flood (as indicated by the peak flood level contours on Figure 4). During the rise of the floodwaters, some backwater flooding (that is, floodwaters moving upstream) can be expected before the flood changes to its behaviour at peak. Such backwater flooding has been reported by residents on the northern floodplain away from the natural levee that has been formed on the northern "top of bank" of the Wyong River adjacent to Panonia Road, Boyce Avenue and Golding Grove. The existing development on the northern floodplain is essentially along this natural levee area.

Flood levels downstream of the Fishing Co-operative (see Figures 1 and 4) in the Wyong River can be influenced by the water level in Tuggerah Lake. The influence of the tide and Tuggerah Lake flood levels is effectively damped out by the Wyong River floods upstream of the Fishing Co-operative.

4.5 Flood Hazard Assessment

The Floodplain Development Manual urges an assessment of development activity on flood liable lands by, firstly, consideration of flood behaviour and secondly, by consideration of the flood hazard to development created by flooding.

The Floodplain Development Manual recognises three categories of flood-liable land, related to flood behaviour, as summarised below.

1. ***Floodways*** - those areas where a significant volume of water flows during floods which, even if only partially blocked, would cause a significant redistribution of flood flow and significant increase in flood levels.

2. ***Flood Storage*** - those areas which provide temporary storage of floodwaters during passage of a flood. Flow velocities are generally low.

3. ***Flood Fringes*** - those areas of the floodplain not included in floodways or flood storage areas.

The Floodplain Development Manual also recognises two categories of flood hazard, as follows:

1. ***High Hazard*** - where floodwaters present a danger to personal safety, could cause structural damage to buildings and where the resultant social disruption and financial losses could be high.

2. ***Low Hazard*** - where floodwaters do not present a danger to personal safety and flood damages would be low.

It should be noted that the flood behaviour categories (floodway, flood storage and flood fringe) and the flood hazard categories (high hazard and low hazard) can be expected to change with differing magnitudes of floods. For example, an area may be a flood storage area in a 5% AEP flood (perhaps flooded by backwater) yet become an active floodway in a 1% AEP flood. With specific reference to the Lower Wyong River floodplain, flood hazard is a measure of the overall impact of flooding. The assessment of flood hazard includes consideration of the depth and velocity of floodwaters, effective warning and evacuation time and evacuation difficulties.

The initial assessment of floodways, flood storage and flood fringe was based on:

- identifying flood fringe where flood depths on the periphery of the flood liable areas were less than 300 millimetres;

- identifying floodways as carrying high volumes of flow (as measured by high discharges per unit width across the floodplain);

The flood fringes shown by this preliminary identification were shown to be very small in the Lower Wyong River floodplain and thus could be treated as "Flood Storage".

The identification of floodways using flood discharges was partly successful, indicating:

- only small differences in the floodways over the range of floods tested (5% AEP, 1% AEP and PMF events);

- the indicated floodways were not joined to form a network and thus not within the intentions of the Floodplain Development Manual in defining floodways.

Given the above, the floodplain was divided into "floodway" and "flood storage" areas on the basis of:'

- the numerical results from the CELLS model (using the 5% AEP, 1% AEP and PMF events);

- review of recent aerial photography;

- site inspection of ground levels;

- site inspection after the recent June 2007 flood for signs of flooding, eg erosion, debris lines.

Figure 7 indicates the "floodway" and "flood storage" derived by the above process for the 1% AEP Flood event..

A preliminary assessment of hazard is generally determined on the basis of the depth and velocity of floodwaters. This preliminary assessment may be revised following a review of other relevant factors, including warning times, flood awareness, rate of rise of floodwaters and evacuation considerations to develop the true flood hazard.

The preliminary assessment of hazard is determined with reference to Figure A2 which shows the provisional flood hazard categories as defined in the Manual.

Figures 8, 9, 10 and 11 show the preliminary flood hazard for the design 5% AEP, 1% AEP, 0.5% AEP and PMF events. Two preliminary hazard categories are used (High Hazard and Low Hazard) as per the Floodplain Development Manual.

Review of Figures 8, 9, 10 and 11 shows that the flood extent and the extent of "high hazard" area increase significantly with flood magnitude.

Wyong Shire Council's current Flood Prone Land Development Policy (see Section 7.1) relies on the definition of "high hazard" and "low hazard" categories with hydraulic categories of "Flood Fringe", "Flood Storage" and "Floodway".

The adopted or true flood hazard for the Lower Wyong River floodplain appears on Figure 12, which was derived from:

- Figure 7 for floodways and flood storage;
- Figure 9 for preliminary flood hazard for the 1% AEP flood event;
- Adjustment of flood hazard from "Low" to "High" in situations where an evacuation route to flood free land (defined by the PMF flood extent) passed through a floodway.

There are approximately 35 lots in Tacoma South, located immediately downstream of the Fishing Co-operative bend, where the depth of floodwaters in the 1% AEP flood is 0.5 to 0.8 metres. This area is classified as `Low Hazard' on the basis of depth and velocity of floodwaters.

However, these lots, along with the remaining lots in Tacoma South are completely isolated by floodwaters and, as a result, it is appropriate to upgrade the hazard classification to `High Hazard' due to the difficulty of evacuation. This provides a uniform hazard classification for the Tacoma South residential area.

It is clear, from the projections on climate change, that an increase in mean sea level and increases in total anticipated rainfall are likely. With the anticipated climate change scenarios, the flood hazard categories on the lower Wyong River floodplain are likely to worsen, that is, become more hazardous.

These impacts would need to be investigated in future flood study revisions of the Wyong River and Tuggerah Lakes, due to the interaction between Wyong River and Tuggerah Lakes.

5. FLOOD DAMAGES ASSESSMENT

5.1 Overview

5.1.1 Flood Damages

It is recognised that floods cause damage to the human environment (including individuals) when they occur. Conversely, excluding floodwater from particular areas can cause additional damage in other areas and ecological damage through drastic changes to the environment. Accordingly, a realistic assessment of flood damages is required for:

- overall economic assessment of any future floodplain works and measures;

- a considered compromise between competing demands for funds (for example, for expenditure on other infrastructure) and balancing other community expectations.

Further, flood damages are treated as losses that are suffered by the community, (as a sum of individual losses) as opposed to individuals.

Damages caused by flooding can be divided into tangible damages, which can be quantified in monetary terms, and intangible damages which cannot be quantified in monetary terms.

Tangible flood damages can be subdivided as follows:

(a) direct damages - repair or replacement of buildings and contents damaged or destroyed by floodwaters; and

(b) indirect damages - cost incurred in clean-up, evacuation, temporary accommodation and loss of income.

Intangible damages reflect the effect of flooding on the health and psyche of the community and can be very real and significant. These damages typically take the form of anxiety, depression, trauma and general deterioration in well-being of those affected by flooding and are difficult to quantify in monetary terms. Assessment of intangible damages is beyond the scope of this study.

Potential direct damages represent the damages which would occur during a flood if no action is taken to reduce damages. In general, residents can be expected to take some action to reduce flood damages. Such action would include the following:

- placing moveable items on higher levels, such as tables or cupboards;
- moving contents to upper floor levels;
- use of sandbags to seal doorways; and
- removal of vehicles to higher ground.

The above actions enable residents to reduce the actual damages suffered in a flood event. The savings in flood damages which can be achieved is dependent on a number of factors, including:

- flood warning lead times;
- flood awareness and preparedness;
- availability of upper level floors; and
- access conditions and evacuation considerations.

Considerable reduction in damages can be achieved with adequate warning and appropriate response.

5.1.2 Application to Lower Wyong River

The direct flood damages have been assessed using the ANUFLOOD flood damages model which was developed at the Centre for Resource and Environmental Studies at the Australian National University (Ref. 17). The model assesses the potential direct damage to property only and does not provide estimates of indirect damages. Accordingly, indirect damages have been assessed on the basis of historical flood damages recorded at Nyngan and Inverell (References 18 and 19 respectively), as outlined in Section 5.2.3. Further, the intangible damages, which are also relevant in floodplain management, are not assessed by the model.

The Wyong River has a catchment area of approximately 450 square kilometres and responds to storm durations of 9 to 24 hours. Thus, residents on the floodplain generally have a reasonable amount of time to carry out some measures to reduce individual flood damages. Such measures would include relocation of furnishings to upper floors or onto tables, benches etc and relocation of vehicles to higher ground.

Mardi Creek, which enters the floodplain at the southern edge of the study area has a much smaller catchment area of only 8 square kilometres and thus responds very rapidly to rainfall. The critical duration is approximately 6 hours. As such, there is insufficient time for residents adjacent to Mardi Creek to take effective measures to reduce damages caused by local flooding.

The flood damages survey carried out following the Nyngan flood (Reference 18) indicates that actual damages to buildings and contents may be 10% less than the potential damages. The Nyngan survey found that the major saving in external property damages is achieved by relocation of vehicles to higher ground.

Direct property damages for the Lower Wyong River catchment have been based on the potential direct damages to buildings and contents. It has been assumed that all vehicles can be relocated to higher ground prior to the Wyong River floodwaters cutting the roads. This assumption may underestimate flood damages, as these actions require some flood evacuation awareness by the residents and business owners. This is discussed further in Section 11

The most recent work on flood damages is the Department of Natural Resources document "Residential Property Damage" (Draft), 2004 (Reference 26). This document highlights:

- there is not a single "correct answer" with respect to flood damages;

- insurance paid out appears to be considerably higher than actual damage;

- consideration of insurance paid out as a measure of damage is higher than damage restoration costs;

- the damage costs used in this study (based on recorded damages at Nyngan and Inverell) are about 60 percent of the flood damages based on insurance paid out, and thus represent a lower bound of damages.

5.2 Damages Model

The ANUFLOOD model uses three sets of input data as follows:

- a property database;

- a stage-damages relationship which specifies the estimated potential direct damage sustained at differing depths of flooding for different categories of properties; and

- a design flood level probability distribution for the study area.

5.2.1 Property Database

The information for the property database was obtained by ground survey in 1995 for all properties which are located less than 0.5 metres above the estimated 1% AEP flood levels in the study area. The data collected for residential properties included location, ground level, lowest habitable floor level, elevated or non-elevated construction, building materials and damage class required for estimation of flood damages and other data required for floodplain management considerations. In damage classes, ANUFLOOD uses three damage classes (High, Medium and Low) to reflect the direct damage in differing socio-economic areas.

There have been a number of changes to the development of the flood liable area of the Lower Wyong River since 1995. These can be described as:

- infill development or replacement of buildings in the residential zones;

- infill development in the Tuggerah Straight Industrial Area;

- extension of the Woodbury Park development area north from Mardi Creek towards McPherson Road and west of Gavenlock Road;

- construction of new dwellings as part of the "Kooindah" development;

- construction of new buildings as part of the Tuggerah Business Park development;

- construction of new buildings and fill platforms in Tuggerah Industrial Area.

With regard to site inspection in 2006, comparing buildings against the 1995 floor level data base and review of Wyong Shire Council's building approvals indicated an additional 85 buildings had been built. Of these, only 64 represented new buildings, while the remainder (11 houses) appear to be replacement of earlier buildings.

With regard to the "Kooindah" development, minimum floor levels have been set by Wyong Shire Council at RL 2.95 m AHD, 0.3 metres above the design 1% AEP flood. Site inspection in July 2006 indicated that, at that time, 32 two storey residences had been constructed within the "Kooindah" development. These buildings have been treated as 32 "high value" flood damage buildings (for ANUFLOOD) with floor level set at RL 2.95 m AHD.

Data, similar to the residential data, was collected in 1995 for the commercial and light industrial properties, with the inclusion of size of the property, as damage estimates are based on floor area. Infill development has occurred in the Tuggerah Straight Industrial Area since 1995. Site inspection in July 2006 indicated that 53 new developments on the existing sub-division have occurred since 1995. The site inspection also indicated that the new developments could be considered as commercial/light industrial, consistent with the development as existed in 1995.

Examination of available aerial photography and building counts indicate that the building floor areas in the Tuggerah Straight Industrial Area approximated 163,100 sq metres in 1995, which increased to some 186,000 sq metres in 2006. The new developments will have been constructed with floor levels at the 2% AEP flood level. These recent developments have been represented in the property data base by introduction of 22,900 sq metres of floor space, set at RL 4.75 m AHD.

The Tuggerah Business Park, located south of Wyong Road, was not developed for the 1995 Floodplain Management Study. The development is protected from overflows from Ourimbah Creek in flood events up to the design 1% AEP flood by a levee along the southern boundary. The development would, however, be affected by the PMF event on Wyong River and accordingly, it has been included in the property data base. Analysis of existing aerial photography shows the total floor area constructed by 2006 was approximately 83,400 sq metres. The property data base has been modified to include 83,400 sq metres at RL 4.0 m AHD for flood damage estimation purposes.

In general, the flood damages assessment has been an extension of the 1995 flood damages survey (Ref. 24) and up-dated by:

- adjustment of damage curves using Consumer Price Index (CPI) figures from 1995 to 2007;
- inclusion of building developments over the period 1995 to 2007; and
- further adjustment of damage figures from 2007 to 2010 using Consumer Price Index changes.

Building floor levels vary throughout the floodplain, generally dependant on ground level at the individual properties and the particular building styles adopted. The property data base includes either surveyed floor levels or minimum floor levels based on Wyong Shire Council's individual development controls. The precise location of each building is not recorded in the data base. Given that the flood damage estimate

relies on a relationship between flood depth over individual floor levels versus damage, a "precinct" approach has been used such that a single flood level is used in each precinct (and sub-precinct areas).

Flood damage has been assessed on a "precinct" basis for comparison between flood level and building floor levels. The study area was divided into eight (8) precincts, based on locality and/or source of flooding and a reference location assigned to each precinct as shown on Table 5.1. The "reference location" is used to describe a point where flood levels have been defined, for later adjustment to each precinct as described below. The precinct boundaries are shown on Figure 13. Precincts 1 to 6 were utilised in the 1996 study (Ref. 24). Precincts 7 (Tuggerah Business Park) and Precinct 8 ("Kooindah") represent the major developments within the flood liable areas surrounding the lower Wyong River since 1995.

Table 5.1

ANUFLOOD Precincts and Reference Locations

Precinct	Locality	Reference Location
1	Tacoma - Wyong east of railway	Railway Bridge
2	Wyong, rural areas, Freeway to Pacific Highway	Railway Bridge
3	Rural areas upstream of Freeway	Freeway
4	Tuggerah Straight Industrial Area	Joule Place
5	Mardi Creek, southern end of Tuggerah Straight Industrial Area	Pacific Highway
6	Tacoma South - East of railway	Railway Bridge
7	Tuggerah Business Park	Reliance Drive / Wyong Road
8	"Kooindah" development	Development Site

Each of the precincts was sub-divided into sub-areas based on similar flood levels. Flood level adjustment factors equal to the difference in flood level at the centroid of the sub-area and at the reference location were then used to modify the ground level and floor level survey data for each property in the sub-area to allow for the spatial variation in flood level throughout the precinct.

5.2.2 Stage-Damages Relationships

There has not been any flooding of major significance in the Wyong River in recent years except for the June 2007 floods. It was considered appropriate to base damages estimates on the results of flood damages surveys from other towns rather than to undertake a fresh survey of residents in the Wyong area.

Detailed flood damages data was collected following the April 1990 flood in Nyngan and the February 1991 flood in Inverell (Refs 18 and 19). The data collected included potential direct damage to buildings and contents, external property damages (including vehicles) and indirect damage estimates for evacuation, temporary accommodation, clean-up and loss of income.

Thus, in the draft 1996 Floodplain Management Study (Ref. 24), the stage-damages relationships for residential properties from the Nyngan and Inverell data, adjusted to 1995 dollar values, has been adopted for residential properties on the lower Wyong River floodplain. The adopted stage-damages relationships for residential properties adopted in 1996 is summarised in Table 5.2 below.

The ANUFLOOD model assesses damages sustained by inundated houses and industrial/commercial buildings. The model does not assess damages sustained to the grounds of properties which may be inundated. Thus, the damages estimates are limited to structure and contents damages only.

As noted earlier, DECCW has prepared flood damage curves based on insurance paid out, which includes indirect damage (as discussed in the following section). Thus Table 5.2 provides a comparison between:

- flood damage estimates derived for the 1996 study (Ref. 24);
- flood damage estimates for 2007 derived by adjustment of the 1996 figures by CPI changes;
- a "total flood damage" including both direct and indirect damages based on the updated 1996 figures;
- estimated damage data as derived by DECCW from insurance paid out;
- further adjustment from 2007 values to 2010 values using CPI figures.

The conversion of flood damages from 2007 to 2010 follows from the last assessment of damages in 2007 to the adoption date of the Floodplain Risk Management Plan in 2010. Given the extent of damage data involved, assessment of flood damage values have been kept to 2007 values with update of the total damages to 2010 for the purpose of summary and conclusion.

It is noted that the 1996 figures adjusted to 2007 are approximately 60 percent of the DECCW figures, principally because of the differing approaches to basic damages figures. It is accepted that the updated 1996 figures are a lower bound of likely flood damages.

Table 5.2

Potential Direct Damages For Residential Properties

Depth of Flooding (m)	Damages ($) per Property Structure and Contents		Comparative Total Damage [1]	DECCW Data [2]
	$ per Property 1996	$ per Property 2007	$ per Property 2007	$ per Property 2007
0	3,300	4,712	5,655	7,477
0.5	18,700	26,705	32,044	52,975
1.0	25,850	36,914	44,296	73,785
1.5	27,500	39,270	47,124	74,596
2.0	30,000	42,840	51,408	84,406

Notes: 1. Total damage includes direct and indirect damages
2. See Reference 26

The Wyong River has an operational flood warning system. Thus, the damages used in Table 5.2 do not include motor vehicles which are presumed to be relocated to high ground prior to arrival of the flood. Flood damages data had been collected for commercial and light industrial premises following the Nyngan and Inverell floods (Refs 18 and 19). The damages data collected highlighted that flood damages to non-residential properties can be widely variable.

In an effort to `standardise' the damages data, the damages were reduced to a `per square metre value' and plotted against depth of floodwaters, as shown on Figure 14. This data was still highly variable. Interviews of a sample of 18 properties in the Tuggerah Straight Industrial Area in 1996 were carried out in an effort to improve the usefulness of the previously collected data.

The averaged damages data is summarised in Table 5.3 and is also plotted on Figure 14.

Table 5.3

Estimated Flood Damages for Non-Residential Properties (Tuggerah Straight Industrial Area Sample)

Depth of Floodwaters (m)	Estimated Direct Damages ($ per square metre, 1995)		Estimated Direct Damages ($ per square metre, 2007)	
	Typical Value Contents	"High" Value Contents	Typical Value Contents	"High" Value Contents
0.3	120	430	171	614
0.9	280	470	400	671
1.5	360	490	514	700

Flood damages sustained by electrical and furniture retail outlets and other `high' value premises are up to three times the `typical' damages at low depths of flooding. This is due to goods being effectively destroyed even before being covered by floodwaters.

The critical depth of flooding, when maximum damage is sustained varies from about 0.3 metres for premises where stock is stored at floor level to about 1.5 metres where stock is stored on shelving.

As part of the Gloucester Floodplain Management Study (Reference 27), an interview survey of 41 businesses in the retail/commercial area of Gloucester was undertaken to determine potential flood damages. The potential flood damages included:

- building damage;
- fittings and fit-out damage;
- stock damage;
- clean up;
- loss of trade.

The total damage information for Gloucester, reduced to "per square metre" base also appears on Figure 14.

The Gloucester data on Figure 14:

- excludes two very high damage values that appear to be outliers;
- includes three types, namely:

    - Type 1, where stock is vertically distributed;
    - Type 2, where stock is essentially stored at floor level;
    - Type 3, where the enterprise did not involve retail stock.

The average data obtained from the Tuggerah Straight Industrial Area survey is considered to be consistent with the scatter of individual damages collected at Nyngan and Inverell and the scatter of potential flood damages from Gloucester, as illustrated by Figure 14.

The damages data adopted for commercial and light industrial properties as of 1996 and 2007 is presented in Table 5.4.

Table 5.4

Potential Direct Damages
Commercial and Light Industrial Properties

Depth of Flooding (m)	Value of Contents ($ per square metre, 1995)			Value of Contents ($ per square metre, 2007)		
	Low	Average	High	Low	Average	High
0	10	20	100	14	29	143
0.3	40	120	330	57	171	471
0.6	70	200	370	100	286	528
0.9	90	280	410	129	400	585
1.2	110	320	450	157	457	643
1.5	120	360	490	171	514	700
2.0	130	400	540	186	571	771

5.2.3 Indirect Damages

Analysis of the data collected at Nyngan and Inverell indicated that the indirect costs associated with flooding (in 2007 dollars) comprise:

- clean-up $3,810/property
- evacuation, temporary accommodation and loss of wages $ 800/household/day
- loss of trade $4,750/day

For short duration floods, the indirect damages above are equivalent to 20% of potential damages for residential and commercial/light industrial properties for a typical depth of flooding of 0.5 metres. The indirect damages for Inverell were estimated to be 20% of potential direct damages for residential properties and 16 to 24% of potential direct damages for commercial and light industrial properties.

The owners/lessees interviewed in the Tuggerah Straight Industrial Area estimated that indirect losses due to flooding would be $50 000 to $120 000 per premises. This was found to be equivalent to 40% of the estimated direct damages for major flood events.

It is noted that the DECCW guideline (Ref. 26) outlines higher damages than the Nyngan and Inverell data, but adopts an indirect damage of about 8 percent of the direct damage. This may follow because the DECCW data base is based on insurance paid out, as opposed to actual damage. Such insurance pay-out would presumably have no indirect damages included.

Indirect flood damages have been assessed as being 20% of the direct flood damages for residential and 40% for commercial/light industrial properties.

5.2.4 Design Flood Level Probability

The design flood level probability distributions adopted for each of ANUFLOOD Precincts were based on the design flood level probabilities listed in Table 2.2 and the relevant flood studies.

The Tuggerah Straight Industrial Area is susceptible to flooding from the Wyong River to the north or from Mardi Creek to the south, or from both sources. The estimated design flood level probability distributions for various sites within the industrial area are presented in Table 5.5. The data presented in Table 5.5 is based on the results of hydraulic modelling of flood behaviour of Mardi Creek and the Wyong River (Refs 5, 8 and 10).

Table 5.5

Design Flood Levels (m AHD), Tuggerah Straight Industrial Area

AEP (%)	Wyong River Upstream Pacific Highway	Mardi Creek Upstream Pacific Highway	Joule Place	
			Wyong River	Mardi Creek
20	3.8	4.7	3.25	4.5
5	4.6	4.9	4.5	4.7
2	5.0	5.0	4.8	4.8
1	5.35	5.1	5.0	4.9
PMP	7.6	6.7	6.7	6.7

The data presented in Table 5.5 indicates that Mardi Creek poses a greater flooding risk to the Tuggerah Straight Industrial Area than does the Wyong River for floods smaller than the 2% AEP event.

A composite design flood level probability distribution was adopted for Precinct 4. The flood probability distribution for flooding from Mardi Creek was used for flood smaller than the 2% AEP event, while the flood probability distribution for flooding from the Wyong River was used for floods larger than the 2% AEP event.

The design flood levels adopted for the reference locations for each ANUFLOOD precinct and used in the damages estimation are presented on Table 5.6.

Table 5.6

Design Flood Levels Adopted for Damages Assessment

Precinct	Reference Location					
	Wyong River Upstream Rail Bridge	Wyong River Upstream Freeway	Joule Place	Mardi Creek Upstream Pacific Highway	Wyong Road/ Reliance Drive	"Kooindah"
	1, 2, 6	3	4	5	7	8
AEP (%)	Flood Level (m AHD)					
20	3.8	5.9	4.5	4.7	NC	NC
10	4.2	6.0	4.6	4.8	NC	NC
5	4.6	6.1	4.7	4.9	3.75	2.10
2	5.0	6.25	4.8	5.0	3.9	2.45
1	5.35	6.45	5.0	5.1	4.2	2.65
0.01	7.6	9.24	6.7	6.7	6.54	6.35

Notes: NC = Not Calculated

As noted in Section 5.2.1, the flood levels at the “reference points” were adjusted by flood slope to give above floor flooding depths for buildings within sub-areas of each precinct.

5.3 Residential Properties

The distribution of habitable floor levels for the residential properties relative to the 1% AEP flood level in each Precinct is presented in Table 5.7. This data has been verified by comparison of the 1% AEP flood profile and the surveyed floor levels.

Table 5.7

Distribution of Residential Floor Levels

Flood Level	Total Number of Houses Below Flood Level							
	Precinct							
	1	2	3	4	5	6	8	Total
1.2 m below 1% AEP	9	-	4	2	-	2	0	17
0.9 m below 1% AEP	31	14	6	2	1	5	0	59
0.6 m below 1% AEP	83	18	6	6	1	13	0	127
0.3 m below 1% AEP	193	22	11	10	2	30	0	268
1% AEP	285	27	15	28	5	44	0	404
0.3 m above 1% AEP	399	41	18	41	28	54	30	611
0.6 m above 1% AEP	444	47	23	52	48	57	30	701

The data presented in Table 5.7 shows that there are 404 houses with habitable floor levels at or below the 1% AEP flood level and 207 additional houses with habitable floors at or less than 0.3 metres above the 1% AEP flood level.

Some 90% of the flood-liable houses are located between the Main Northern Railway Line and Tuggerah Lake. Part of this area is also prone to flooding from Tuggerah Lake.

High water levels in Tuggerah Lake generally occur in response to flood runoff in the Wyong River, Ourimbah Creek and other tributaries. Thus, flooding caused by runoff or high lake levels can, in general, be considered to be related. Properties can be flooded by high lake levels or flood runoff from individual tributaries. Care is required in assessing flood damages and numbers of flood liable properties to ensure that "double-counting" of properties affected by lake flooding, tributary flooding or interaction of tributary flooding does not occur. To avoid this confusion, the study limit has been set approximately 1.4 km upstream of Tuggerah Lakes, between the outfall of Wyong River to Tuggerah Lakes and the Fishermans Co-operative.

The estimated potential direct flood damages sustained by residential properties for a range of flood probabilities is presented in Table 5.8.

Table 5.8

Potential Direct Flood Damages
Residential Properties
($ 2007)

AEP (%)	Precinct								TOTALS
	1	2	3	4	5	6	7 [1]	8 [2]	
20	10,880	33,100	217,200	56,300	67,900	76,100	0	0	461,480
10	136,500	175,400	244,400	62,900	87,100	87,800	0	0	794,100
5	802,000	366,700	281,200	68,500	109,500	128,640	0	0	1,756,540
2	2,628,700	548,400	327,100	72,000	127,400	338,300	0	0	4,041,900
1	5,782,800	727,200	408,400	85,600	149,400	724,800	0	1,600	7,879,800
PMP	22,286,400	1,946,400	1,234,200	158,000	2,744,000	3,365,600	0	1,402,900	33,137,500
Mean Annual Damage (2007)	301,900	61,700	60,000	13,400	29,300	50,600	0	78	517,000
Mean Annual Damage (2010)	329,100	67,300	65,400	14,600	31,900	55,200	0	85	564,000

Notes:
1. Tuggerah Business Park
2. "Kooindah"

In comparison with the 1995 assessment of flood damages, the differences occur through:

- inflation (measured by changes in Consumer Price Index (CPI) or other inflation indices);
- growth in the number of buildings in the area;
- a reduction in the number of buildings in the area examined by exclusion of the residences surrounding Tuggerah Lake, but unaffected by Wyong River flooding.

Growth in residential damages from 1996 to 2007 is a multiplier of 1.72, while inflation (measured by CPI increases) accounts for a multiplier of 1.48, indicating that the growth in flood damages is due to new buildings, not inflation..

5.4 Commercial and Light Industrial Properties

The major commercial and light industrial areas of the Lower Wyong River floodplain comprise:

- the Tuggerah Straight Industrial Area; and
- the Tuggerah Industrial Area (including Lake Road); and
- the Tuggerah Business Park.

The Tuggerah Straight Industrial Area is bounded by the Pacific Highway, McPherson Road, Gavenlock Road and Cobbs Road. It comprises almost 241 premises with limited potential expansion new development will consist of re-development of sites.

The entire industrial area is located on the Wyong River floodplain and stretches from the Wyong River, in the north, to Mardi Creek, in the south.

The area between Mildon Road and the lower Wyong River is included in Precinct 4 for flood damages assessment, while the southern end of the area is included in Precinct 5.

The Tuggerah Business Park has been in the study area for completeness. The ground levels in the Business Park are of the order of RL 5.1 m AHD, and thus above the 1% AEP flood level in Wyong River, but below the PMF flood level. It, however, should be noted that the Business Park is protected from inundation from Ourimbah Creek by a levee constructed to the 1% AEP flood level along Ourimbah Creek.

There are a small number of commercial and light industrial properties in the other urban precincts. There are no commercial or light industrial properties in Precinct 3 which is located upstream of the Sydney-Newcastle Freeway and is essentially rural in character.

The distribution of floor levels for commercial and light industrial properties relative to the 1% AEP flood level in each Precinct, is presented in Table 5.9.

Table 5.9

Distribution of Commercial and Light Industrial Floor Levels

Flood Level	Total Number of Premises Below Flood Level						
	Precinct						
	1	2	3	4	5	6	Total
1.2 m below 1% AEP	-	2	-	33	2	-	37
0.9 m below 1% AEP	-	4	-	39	12	-	55
0.6 m below 1% AEP	-	6	-	42	35	-	83
0.3 m below 1% AEP	-	7	-	65	62	1	135
1% AEP	3	7	-	71	65	1	147
0.3 m above 1% AEP	5	8	-	98	92	1	204
0.6 m above 1% AEP	6	10	-	98	92	1	207

The data presented in Table 5.9 shows that there are 148 commercial and light industrial premises which have floor levels below the estimated 1% AEP flood level. Only 11 of these premises are located outside the Tuggerah Straight Industrial Area (Precincts 4 and 5).

Analysis of the floor level data for the Tuggerah Straight Industrial Area indicates that 127 premises are located below the 2% AEP flood level. This flood has been adopted in the current Flood Policy as the Designated Flood event for the area.

The estimated potential direct damages to commercial and light industrial properties for a range of flood probabilities is presented in Table 5.10.

Table 5.10

Potential Direct Flood Damages
Commercial and Light Industrial Properties
($ 2007)

AEP (%)	Precinct								Totals
	1	2	3	4	5	6	7 [1]	8 [2]	
20	0	148,600	0	0	810,100	0	0	0	958,700
10	0	226,600	0	0	10,560,000	0	0	0	10,786,600
5	0	626,600	0	0	11,870,000	0	0	0	12,496,600
2	0	1,200,700	0	161,258,000	13,492,000	411,800	0	0	176,362,500
1	234,200	1,527,000	0	18,394,600	15,010,600	1,078,400	0	0	36,244,800
PMF	2,704,100	2,819,000	0	48,839,800	26,714,000	3,021,200	54,260,000	0	138,358,100
Mean Annual Damages 2007	16,930	113,132	0	2,767,353	2,027,000	36,200	2,713	0	4,963,328
Mean Annual Damages 2010	18,450	123,300	0	3,016,400	2,209,400	39,500	2,960	0	5,392,000

Notes:
1. Tuggerah Business Park
2. "Kooindah"

The flood damages analysis for Precinct 4 has been based on a composite flood probability distribution, as discussed in Section 5.2.4. The flood probability distribution for flooding from Mardi Creek was used for floods smaller than the 2% AEP event, while the flood probability distribution for flooding from the Wyong River was used for the floods larger than the 2% AEP event. As shown in Table 5.5, the dominant source of flooding in Precinct 4 changes from Mardi Creek to the Wyong River when floods exceed the 2% AEP event.

The estimated mean annual damages to commercial and light industrial properties on the lower Wyong River floodplain (rounded to the nearest thousand, $ 2010) is $5,392,000 of which $5,226,000 is sustained by properties within the Tuggerah Straight Industrial Area (Precincts 4 and 5).

5.5 Public Utilities

The extent of inundated land in the 1% AEP flood is shown on Figure 4. Some 1,575 hectares of urban/rural land is covered by floodwaters in this event.

Public utility works which are located within the inundated area include:

- roads;
- parklands;
- underground water and sewerage services; and
- underground power and communication services.

Public utilities damages comprise the replacement or repair of assets damaged by floodwaters, the costs of clean-up of debris deposited by floods, as well as the disposal of clean-up material from private property. Public utility services encompasses all public sector assets, excluding buildings which are included in the commercial and light industrial properties damages assessment.

Analysis of public utility damages incurred in the Nyngan and Inverell floods indicates that utility damages are $8,750 to $10,322 per hectare of inundated land (Refs 18 & 19). The higher damages estimate was reported at Nyngan and is possibly due to the longer duration of the flood.

The flood clean-up and repair costs in parks and gardens in Grafton (pers. comm.) after the 2001 flood were some $9,800 per hectare (in 2007 dollars).

Public utilities damage in Kempsey (pers. comm.)in 2001 comprised:

- roads, parks and gardens: $7,750 per hectare (in 2007 dollars)
- water supply and sewer: $15,500 per hectare (in 2007 dollars)

Given the above data suggests a range of values for differing scenarios, public utility damages have been assessed at $10,500 per hectare of inundated land, equivalent to the damages estimate for Inverell (compared using $ 2007).

There are extensive wetland areas on both sides of the Wyong River downstream of the railway, as shown on Figure 15. The wetland area extends over 340 hectares, or 22%, of the flood-liable land. These areas as well as the undeveloped areas have been excluded for the assessment of public utility damages.

The estimated damages to public utilities for a range of flood probabilities based on the nett inundated area and the adopted damages rate is presented in Table 5.11.

The estimated mean annual damages to public utilities is $892,500 ($ 2007).

Table 5.11

Public Utilities Damages
($ 2007)

AEP (%)	Damages ($)
20	-
10	4,312,000
5	8,624,000
2	9,122,000
1	9,622,000
0.01 (PMF)	10,710,000

5.6 Total Tangible Flood Damages

The total mean annual tangible flood damages for the lower Wyong River floodplain in 2010 comprises:

-	direct damages to residential properties	$ 563,500
-	indirect damages to residential properties (20% of direct damages)	$ 112,700
-	direct damages to commercial and light industrial properties	$5,392,000
-	indirect damages to commercial and light industrial properties (40%)	$2,164,000
-	public utilities damages	$ 972,800
	TOTAL	$9,205,000

The estimated mean-annual indirect damages to residential and commercial/light industrial properties has been assessed at 20% and 40% of the estimated direct damages respectively.

It is noted that 82% of the total tangible flood damages is sustained by the commercial and light industrial properties, while only 7% of the total tangible flood damages is sustained by residential properties. The damages sustained by public utilities is equivalent to 11% of the total tangible flood damages.

6. ENVIRONMENTAL ISSUES

The object of this section is to present an overview of environmental issues as they affect the floodplain risk management process.

It is intended to provide a background such that floodplain risk management options are considered, mindful of environmental impacts.

6.1 Vegetation

The vegetation on the upper Wyong River floodplain is classified as Tall Open Forest, while the lower floodplain is Melaleuca Swamp Forest or low-lying sedgeland.

The Tall Open Forest comprises *Eucalyptus longfolia, E. pilularis* and occasionally *E. robusta.* The understorey consists of a moderate to dense cover of herbs and graminoids. Melaleuca species dominate the understorey adjacent to drainage lines.

There has been extensive clearing of the upper floodplain of the study area between the Pacific Highway and the Sydney-Newcastle Freeway to allow urban development. Regrowth species in this area comprises pasture grasses, weeds and isolated trees.

Vegetation types present on the lower floodplain (downstream of the Pacific Highway) include wetlands of various types to inundation areas of *Eucalyptus robusta* forest and remnant riparian forest of *Casuarina glauca* along the banks of the Wyong River.

Melaleuca armillaris and *M. biconvexa* occasionally occur in the remnant riparian forest. There is little native understorey in this area, with lantana and privet infestation apparent.

Extensive clearing of the lower floodplain has been carried out to provide pasture for grazing. The vegetation in these cleared areas now consists of low open grasslands.

The species *Melaleuca biconvexa*, which occurs within the remnant riparian forest, is considered to be of local significance as it has been adversely affected by lowland development in the Central Coast region.

The presence of *Eucalyptus robusta* is also considered to be of local significance as a keystone species of Wyong Shire. It is one of the few winter flowering species of the region and provides valuable habitat and food source for several Schedule 12 species. The *E. robusta* is generally restricted to the wetland areas and river fringes.

6.2 Fauna

No fauna survey has been carried out of the lower Wyong River floodplain for this study. However, the site inspection indicates that the river and surrounding vegetation potentially provide fauna habitat. As stated above, the presence of *E. robusta* provides a winter food source and habitat for several species of birds and mammals.

The riverbanks and wetland areas also provide nesting hollows such as old tree trunks and logs. The dense understorey and ground cover, the variety of flowering and seed producing grasses and shrubs and the periodic inundation of the area provides suitable conditions for a variety of fauna.

The casuarina forest and melaleuca wetland areas on the lower floodplain provide better quality habitat as they are less disturbed and provide a greater diversity of habitat.

The shallow water and seagrass beds of Tuggerah Lake and the adjacent freshwater swamp areas are important feeding areas for a variety of waterbirds. The area is important for migratory waders and other birds.

6.3 Wetlands

There are a number of wetlands designated under State Environmental Planning Policy No. 14 within the study area.

The Tuggerah Oxbow lies on the floodplain south of the Wyong River. It is designated as Wetland No. 900 under State Environmental Planning Policy No. 14 and is situated on land currently owned by the Crown. The site is the only large oxbow wetland with freshwater remaining on the Wyong River floodplain. The Pioneer Trust Board was appointed trustee of the Reserve pursuant to Section 92 of the Crown Lands Act 1989.

Prior to 1990, anecdotal evidence indicates that the oxbow was in relatively natural condition and free of weed. Following this period, Mardi Creek was diverted via a constructed channel to drain into the wetland. Since that time, the main open water body has become infested with Water Hyacinth *Eichhornia crassipes*.

No regular water quality analysis has been carried out on the wetland, however, ecological investigations indicate that this increase in runoff volumes may have caused a reduction in water quality in the system. Mardi Creek currently receives runoff from rural, urban and industrial development in the western and central catchment. Originally this runoff may have drained into Wyong River and, subsequently, the Tuggerah Lakes and undergone significant dilution. Draining into the small enclosed waterbody of the oxbow the dilution is reduced, leading to a concentration of nutrients in the system.

Proposals to control Water Hyacinth in the oxbow primarily involve the use of a selective herbicide. However, the possibility of redirecting the existing channel away from the wetland may also be considered. Preliminary observations indicate that an improvement in water quality as a consequence may allow the re-establishment of native species in the lagoon and, consequently, control Water Hyacinth in the future.

It will also be necessary to control Water Hyacinth in the upper reaches of Mardi Creek, particularly in the waterholes on the old abattoir site, in order to prevent Water Hyacinth being carried into the wetland by runoff in Mardi Creek.

SEPP 14 Wetland 901 is located adjacent to Tuggerah Lake at the end of Lake Road.

Pioneer Dairy Trust and Council have commenced works on construction of one of two proposed wetlands in the reserve area. This wetland aims to provide water quality treatment for flows generated from the Tuggerah Straight catchment, prior to discharge to the Wyong River.

The second wetland, currently under design, aims to provide water quality treatment for flows generated from the Lake Road Industrial area that ultimately discharge to the SEPP 14 wetland.

There are other wetland areas in the study extents. These have been zoned by Council as "7(g) - Wetland Management Zone". The wetland areas are shown on Figure 15.

6.4 Soil Conditions

Reference to the Sydney 1:250 000 Geological Series Sheet indicates that the Wyong River catchment is underlain in elevated areas by the Triassic aged Clifton Sub-group and Patonga Claystone and in the low-lying areas by Quaternary aged alluvial deposits. The Clifton formation is a sub-group of the Narrabeen Group and generally consists of claystones and shale. The floodplain areas are dominated by Quaternary alluvium gravels, sands, silts and clays.

Information available from the Department of Natural Resources (now DECCW) and previous studies of the Wyong River catchment indicate that the area under study contains two major soil mapping units, yellow podzolic (Wyong Alluvial Soil Landscape) and peaty loams to gleyed plastic clays (Tacoma Swamp Soil Landscape). The Wyong yellow podzolic soils are the dominant soil type particularly around the main drainage lines of Mardi Creek and Wyong River.

The Wyong Soil Landscape is formed on Triassic sediments comprising claystone, siltstone and shale. The Tacoma Swamp Soil Landscape is typical of swampy floodplains and closed depressions on Quaternary sediments, particularly adjacent to Tuggerah Lakes. These soil types are characteristic of wetland areas in this region. Soils associated with this landscape are deep (greater than two metres) acid peats and humic gleys. The term Gley is used to describe the green or greenish grey colouration found in soils. It is often produced under conditions of poor drainage, which give rise to chemical reduction of iron and other elements.

Long periods of waterlogging cause a low rate of organic matter breakdown. Consequently, Tacoma Swamp soils have a significant organic matter content incorporated into the dark surface horizons.

Despite the high organic content of soils in the low-lying areas of the catchment, they generally have low fertility due to low soil pH. The relative availability of nutrients to vegetation is reduced under conditions of low pH.

Available water holding capacities are moderate to high and soils, particularly those in low-lying areas, are generally poorly drained and seasonable waterlogging is common. Topsoils tend to be hard setting when dry.

Acid sulphate soils contain iron pyrite (FeS_2) which occurs naturally in estuarine sediments. It is chemically unstable in the presence of oxygen and decomposes to form ferrous ions and sulphuric acid and creates acidic soils. Current literature refers to both *actual acid sulphate soils* and *potential acid sulphate soils.*

Potential acid sulphate soils contain iron pyrite sediments which have not been exposed to oxygen, while *actual acid sulphate soils* have been oxidised and are strongly acidified.

The relatively restricted conditions under which acid sulphate soils form, limit their location to low-lying areas of coastal plains such as creeks, rivers, floodplains and wetland areas, including the eastern Wyong River catchment.

The Department of Natural Resources (now DECCW) has prepared maps of potential acid sulphate soil (PASS) risk for the New South Wales coast to identify broad-scale risks and provide an indication of requirements for site specific soil investigation. The mapping was undertaken at 1:25 000 scale using topography and geomorphology to identify three primary risk classes:

- high probability of occurrence;
- low probability of occurrence; and
- no known occurrence.

The PASS risk maps covering the study area indicate that the potential for acid sulphate soils ranges from `no known occurrence' in the upper floodplain, with the lower floodplain classed as a `high probability of occurrence'. The depth of acid sulfate material in the lower floodplain ranges from less than 1 metre to between 1 and 3 metres.

Recent investigations carried out in the Pioneer Dairy site indicate significant areas of actual Acid Sulphate Soils (ASS) in the lower Wyong River floodplain.

6.5 Summary

Extensive clearing of the floodplain has been carried out for urban development and to provide pasture for dairy cattle. Remnant riparian forest of casuarina and melaleuca occurs along the riverbanks while extensive areas of the lower floodplain comprise melaleuca swamp forest and sedgelands.

The lower floodplain and riverbank region are considered to provide suitable habitat for a variety of fauna. The foreshore areas of Tuggerah Lake and adjacent freshwater wetland areas provide important feeding areas for a variety of waterbirds.

Studies carried out by the Department of Natural Resources have identified the lower floodplain as having a high probability of occurrence for acid sulphate soils.

The Wyong River floodplain contains extensive areas of environmental significance and value.

Construction of flood mitigation works could result in significant impacts, including:

- loss of vegetation and fauna habitat;
- impact on significant wetland areas; and
- possible exposure of acid sulphate soils.

7. PLANNING CONSIDERATIONS

7.1 Zoning and Planning Controls

There are four main levels of land use planning controls. As a hierarchy, they are:

1. State reservations, strategies and policies
2. Regional plans and strategies
3. Local land use strategy, and zonings under a Shire-wide Local Environment Plan
4. Local policies and specific planning controls under Development Control Plans

There are four State Environmental Planning Policies (SEPPs) directly relevant to the study area in relation to floodplain risk management. These are:

- SEPP 14 - Coastal Wetlands
- SEPP 26 - Littoral Rainforest
- SEPP 44 - Koala Habitat
- SEPP 17 - Coastal Protection

There are two designated SEPP 14 wetlands (No. 900 and No. 901) within the study area.

These wetland areas are protected by the policy and require management which retains their conservation values. Any works related to flood mitigation affecting these areas would be designated development under the Environmental Planning & Assessment Act (1979) and require an environmental impact statement (EIS) prior to any works.

The study area is currently zoned under the Wyong Shire Local Environmental Plan 1991. The current zonings are reproduced on Figure 15. The flood liable area within the study area is zoned under the categories of:

- Rural 1(c)	Non Urban constrained lands zone
- Residential 2(a)	Residential zone
- Business 3(b)	Centre Support zone
- Industrial 4(a)	General Industrial zone
- Industrial 4(b)	Light Industrial zone
- Special Uses 5(a)	Special Uses zone
- Special Uses 5(b)	Railway zone
- Open Space 6(a)	Open Space and recreational zone
- Open Space 6(b)	Regional open space zone
- Open Space 6(c)	Proposed open space and recreation zone
- Environmental Protection 7(c)	Scenic Protection, Small Holdings
- Environmental Protection 7(g)	Wetlands Management zone

The Local Environment Plan, although dated 1991, is not static and has numerous amendments. The total number of amendments to date is thought to be in the order of 170.

The land use zoning in 1995 is shown on Figure 16 for comparison purposes.

The most significant changes in the land use zoning between 1995 and 2010 is the creation of the "Wetlands Management Zone 7(g)" from the "Rural Zone 1(c)" and "Open Space/Recreation Zone 6".

The objectives of Wetlands Management Zone 7(g) zoning are to protect and conserve critical wetland habitats and to limit development which is likely to have a detrimental effect on the ecological sustainability of wetland functions and values.

Extensive areas of the floodplain are thus now affected by the LEP zonings and the provisions of Council's current Development Control Plan (DCP) "No. 30 - Wyong Shire Wetland Area".

7.2 Council's Flood Policy

The Wyong Shire LEP - 1991 only briefly mentions flood liable land to the extent that Council may fix building floor levels and consider the flood impact of development on surrounding properties.

There is currently no DCP covering development of flood liable land.

Wyong Shire Council has a development policy for flood liable land, which is applied as a condition of development consent. The original Flood Prone Land Development Policy was adopted in 1986.

The stated objectives of Wyong Shire Council's current policy for development of flood prone lands are reproduced as:

"OBJECTIVES

The following objectives have been developed with the primary objective of reducing the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods using ecologically positive methods wherever possible.

1. *To reduce the risk to property and to life of the residents and those involved in rescue operations during floods and to minimise the financial and emotional burden on the community due to flooding.*

2. *To reduce flood losses that may result from development and redevelopment by the application of sustainable planning and development controls.*

3. *To limit development and redevelopment that may reduce the ability of the floodplain to carry water and so increase the flood hazard.*

4. *To limit incremental development within the floodplain by considering the cumulative impacts on flooding.*

5. *To ensure that developments within the floodplain are assessed using a merits based decision making approach which considers social, economic and ecological factors, as well as flooding considerations.*

6. *To ensure that development within a floodplain considers extreme events greater than the designated flood(s) and the Probable Maximum Flood (PMF) is quantified for the purposes of emergency/disaster management.*

7. *To ensure that any developments on flood prone land are designed and constructed to withstand the likely stresses of floods. "*

The policy also recognises that flood-prone land is a valuable resource and should not be sterilised unnecessarily by precluding its development. However, it is essential that any new development be designed and constructed in such a way that will minimise the risk to life and property without adversely affecting flood conditions on other properties.

In order to achieve the objectives of the flood policy, Wyong Shire Council has adopted a response to proposals for differing types of development within the various flood hazard categories defined in the 1986 Floodplain Development Manual, in the form of a matrix as set out in Table 7.1.

Table 7.1

Assessment of Development Applications For Flood-Prone Lands

Type of Development	Flood Hazard Categories					
	Low Hazard			High Hazard		
	Flood Fringe	Flood Storage	Floodway	Flood Fringe	Flood Storage	Floodway
New Development	Usually permitted	On merits	Prohibited	Prohibited	Prohibited	Prohibited
Non-Urban Zones	Usually permitted	Usually permitted	On merits	On merits	On merits	On merits
Urban Zones	Usually permitted	Usually permitted	Usually permitted	Usually permitted	Usually permitted	Usually permitted

The following restrictions also apply:

- for all high hazard areas and for low hazard floodways, no rezoning of the land will be permitted except to rezone the land as floodway, special use drainage or for open space purposes;

- for low hazard flood fringe and flood storage areas, no rezoning of the land will be permitted except to rezone the land to a zoning that permits a lesser density usage (eg. rezoning from Residential to Rural);

- with the exception of small subdivision (usually 2 or 3 lots) within a developed area, all residential land in new subdivisions must be at or above the Designated Flood level, although public roadways, service corridors etc may be at a lower level. In small subdivisions (usually of 2 or 3 lots) within a developed area, filling of the whole of the land to the Designated Flood level will not be required if it causes drainage problems to adjoining properties. In such cases, only partial filling may be required, together with measures to prevent runoff onto the adjoining properties;

- in industrial and business zonings, the buildings envelope within each land parcel is to be at or above the Designated Flood level. Other areas, including buffer areas, roadways, service corridors etc may be at a lower level;

- any caravan park or mobile home park development, whether for short-term use, long-term use or a combination of both and whether development of an entirely new facility or extension to an existing facility is to be considered `New Development' for the purposes of the policy; and

- tourist related development involving accommodation, whether development of an entirely new facility or extension to an existing facility, is to be considered `New Development' for the purposes of the policy.

- Any development or building approval given in accordance with the policy will be subject to conditions, including (but not limited to) the following:

  · Habitable Rooms

    The floor level for all habitable rooms is required to have a minimum freeboard (generally 300 millimetres) above the Designated Flood level.

    The level of minor additions (ie. an addition increasing the existing floor area by no more than 20 square metres) may remain at the same level as the existing building. For major additions, the floor levels will be required to be in accordance with the preceding paragraph (ie. generally 300 millimetres above the Designated Flood).

  · Industrial and Commercial Developments

    The minimum floor levels for industrial and commercial buildings is usually set at the Designated Flood level, with no requirement for freeboard.

Where non-flood compatible materials or equipment are to be stored outside the building, provision shall be made to permanently store these materials or equipment at a level not less than the height of the 1% AEP flood level.

Machinery and electrical installations that are non-flood compatible are to be placed at a minimum of 500 millimetres above the height of the 1% AEP flood.

Where a structure is used for the storage of toxic or pollutant substances or other products that could cause pollution, all sections of the structure that are subject to the force of water or debris are to be designed to resist the stresses induced by the flood, including buoyancy, overturning and sliding forces. All forces exerted by the Designated Flood are to be increased by a factor of 1.5 before use in structural calculations.

Where buildings and structures are subject to immersion by floodwaters, flood-compatible materials shall be used.

The Designated Flood is the flood standard selected for planning purposes. The Designated Flood within Wyong Shire is the 1% AEP flood, except for the Tuggerah Straight Industrial Area (Wyong River) where the Designated Flood is the 2% AEP flood.

For developments within or adjacent to the storage area of detention basins, the Designated Flood level is 0.3 metres above the level of the spillway weir crest.

8. FLOOD WARNING AND EMERGENCY RESPONSE

The catchment area of the Wyong River is approximately 450 square kilometres, with a critical storm duration of 24 to 36 hours. This should enable flood warnings to be issued to residents with a lead time of 6 hours.

The Bureau of Meteorology advised that it provides a flood warning service for Wyong River comprising:

- confidential flood advice providing 24 hour or longer outlook of possible floods;
- quantitative river level predictions for Wyong River at the Pacific Highway when the river level is expected to exceed a level of 2.7 metres AHD (considered a minor flood level); and
- quantitative lake level predictions for Tuggerah Lake when the level is expected to exceed 0.9 metres AHD.

Mardi Creek has a catchment area of approximately 6 square kilometres and a critical storm duration for flooding of 6 hours. Due to the short response time of the catchment, typically less than 3 hours, it is not possible to provide flood warnings with an effective lead time to enable residents to implement flood protection measures to reduce the damages caused by flooding.

A computer-based flood warning system for the Tuggerah Lakes system has been established by the Bureau of Meteorology. Physically, the rainfall and water level gauges were installed by Wyong Shire Council and the Bureau has the expectation that Council will maintain the installed gauges.

Data from seven (7) rainfall and four (4) river height gauges is radio telemetered to a computer in the Council office block in Wyong and by radio repeater stations to the Bureau of Meteorology Flood Warning Centre. The location of the rainfall and river level gauges used appears on Figure 15. These rainfall and river height gauges operate on ALERT technology and transmit data throughout a rainfall and runoff event.

There are two (2) rainfall and three (3) combined rainfall and river height ALERT gauges located within the Wyong River catchment. The remaining gauges are located in the Ourimbah Creek catchment at the southern end of Tuggerah Lake.

Additional data can be derived from the DECCW system of river height gauges and tide gauges (via Manly Hydraulics Laboratory).

The flood warning system provides flood forecasts for the Tuggerah Lakes, the Wyong River downstream of the Pacific Highway and Ourimbah Creek downstream of the Pacific Highway.

The rainfall and river height data is input to a hydrologic model to produce flood level forecasts using the real-time data. Specifically, the telemetered rainfall data is converted into runoff discharge using a simple hydrologic model. The calculated flood levels are compared with the telemetered river heights and the hydrologic computation is modified to account for the differences between the calculated and observed flood levels. A forecast is then produced on the basis of predicted rainfall and ocean water level conditions.

Flood forecasts are thus based on tidal predictions adjusted for storm surge, real-time rainfall and river height information and forecast rainfall and storm surge.

It is anticipated that reliable flood forecasts with lead times of up to 6 hours will be able to be provided by the system.

The real-time river height data and forecasts are available to the State Emergency Service Controller and Wyong Shire Council for assistance in the preparation and implementation of appropriate flood emergency procedures.

"Flood combat" responses are identified by legislation, as the responsibility of the SES. A new Local Flood Plan for Wyong was drafted in December 2007. This plan revised earlier versions of the Wyong Flood Plan with information from the June 2007 flood event in Wyong Shire.

The 2007 Wyong Local Flood Plan (Ref. 22) identifies the areas at risk of flooding and details the procedures to be implemented during a flood event. However, critical river flood level thresholds for implementation of the various procedures have not been identified.

Thus, the plan contains details of how the procedures are to be implemented and by whom, and where evacuees are to be accommodated but no details as to when such actions are to be initiated.

The identification of those critical flood height thresholds requires considerable investigation and assessment of historical flood behaviour, for which there is limited recorded data available, supplemented by analysis of synthetic or `design' floods based on hydrologic and hydraulic modelling. It is the consultant's experience that such investigation takes some time to complete and the results require regular review, particularly following flood events, in order to `fine tune' the process. Nevertheless, the identification of threshold levels is considered to be possible.

The current study provides information on flood extents and depth of flooding which will assist in the identification of high risk properties and evacuation and access difficulties for a range of flood events. However, additional investigation is required to successfully link the floodplain management and emergency management processes.

9. COMMUNITY CONSULTATION

Community consultation was undertaken during the Floodplain Management Study process via three mechanisms, namely:

- formal correspondence with government and other bodies;
- community workshop;
- public requests for formal submission; and
- Wyong Shire Council's Estuary, Coastal and Floodplain Management Committee.

Details of the above processes are outlined below.

As noted in Chapter 2, this Floodplain Risk Management Study has had a long gestation period.

The 1995 consultation results are indicated below, as well as responses to the 2007 Public Exhibition of this report for completeness.

9.1 Formal Correspondence - 1995

Formal requests for input to the floodplain management study were forwarded to 17 government bodies and 20 community groups. Replies were received from:

- Bureau of Meteorology;
- City Rail;
- National Parks and Wildlife Service;
- National Trust;
- New South Wales Fisheries;
- Pacific Power;
- Roads and Traffic Authority;
- State Forests; and
- Sydney Electricity.

A summarised list of the replies appears in Appendix E.

The Bureau of Meteorology also queried the preparedness of the local community to deal with flooding and saw such preparedness as limiting the effectiveness of the flood warning system.

National Parks and Wildlife Service raised specific issue that the Wyong River floodplain contains significant wetland area with endangered fauna species and regionally significant flora.

City Rail simply noted previous flood studies and floodplain management studies have identified all issues to be addressed.

Council forwarded correspondence with the State Rail Authority (SRA) relating to the proposed raising of the Main Northern Railway across the Wyong River floodplain and the resultant changes in flood behaviour. These matters were investigated in Reference 11. SRA had advised that sections of the railway had been partly raised between 1979 and 1982.

Four formal submissions were received from the general public. The issues raised involved:

- construction of a permanent entrance of the Tuggerah Lakes and the entrance channel;
- control of siltation and pollution in Tuggerah Lake;
- dredging of Wyong River;
- damage to property caused by motor vehicles driving through floodwaters; and
- continued filling on the floodplain.

9.2 Community Workshops - 1995

A community workshop was held on 24 June 1995 at Wyong RSL Club.

The workshop was attended by:

- 34 members of the public
- two representatives from the consultants; and
- one Councillor and one officer from Wyong Shire Council.

The format of the workshops followed:

- an outline of the floodplain risk management process by the consultants; and
- discussions of issues by the workshop.

The issues raised by the workshop are outlined below.

- Residents noted that in the McDonagh Road and Golding Grove areas, flooding commenced by backwater flooding from downstream prior to overtopping of the river banks upstream.

- Residents expressed concern on filling of the floodplain and the impact of filling on flood behaviour.

- Council outlined proposed drainage improvements through Tuggerah Straight Industrial Area for Mardi Creek.

- Residents raised the issue of improvement of the Tuggerah Lake opening to the sea to reduce flood levels. This is to be addressed in the Tuggerah Lake Floodplain Management Study.

- Several residents raised dredging and clearing of Wyong River as a means to reduce flood levels. Reference 5 indicates that reduced channel roughness could lower flood levels by approximately 0.2 m in the 1% AEP event.

- Residents queried if on-site detention of runoff was viable. In discussions, it was accepted that the Wyong River catchment is too large for small on-site detention systems to be effective in reducing flooding.

- Residents queried if the study area (the Wyong River floodplain downstream of Maitland Road) would be affected by mine subsidence and if such mine subsidence would affect flood levels and flood damages. Subsequent enquiries have revealed that the study area is not subject to current mine subsidence though it is covered in the long-term as a mining investigation area.

  The proposed Wallarah2 coalmine proposes to mine under Jilliby Jilliby Creek, one of the main tributaries of the Wyong River. That section of Wyong River is outside the study area of this report.

- During the workshop, Council noted that:

  - Tuggerah Straight Industrial Estate floor levels were set at 2% AEP level; and

  - City Rail had been requested to outline plans to raise the rail levels and to amplify existing culverts.

9.3 Public Exhibition of Risk Management Study - 2009

A draft Lower Wyong River Floodplain Risk Management Study and Plan were placed on public exhibition at the end of 2009. The report and plan were placed on Wyong Shire Council's website for viewing or download; copies placed in Council's library at Tuggerah, and Council's customer service counter in the Council Chambers. Both electronic and hardcopies were made available at these locations.

Several of the CD's were taken by the general public. Council received one phone call from a local resident indicating support of the Plan, however, no written submissions were received during the exhibition period.

10. APPLICATION OF THE 2005 FLOODPLAIN DEVELOPMENT MANUAL

10.1 Overview

The New South Wales Flood Prone Land Policy is outlined by the Floodplain Development Manual, April 2005 and the Direction of January 2007 (issued under Section 117 (2) of the EPA Act). The April 2005 Manual is an extension of the 1986 Flood Development Manual, which introduced the concepts of a "merit based" approach to the development of flood prone lands.

Given that current floodplain management practices, in essence, revolve on the communities' acceptance of uses of land, primary responsibility for the management of flood liable lands sits with local councils, by virtue of their control of the land use and development policies in their administrative areas.

The 2005 Floodplain Development Manual introduces the concept of risk management. Three categories of risk are identified specifically:

- "existing risk" relating directly to existing population and development within flood prone areas;

- "future risk" identifies with planned (or unplanned) development of flood prone areas and the potential population affected by such future developments;

- "continuing risk" relates to the concept that, even though a variety of floodplain risk measures might be introduced, there will remain property and communities potentially affected by flooding and that this risk also needs to be managed, generally through flood warning, flood emergency planning and community education programs.

The 2005 Manual also introduces the concepts of three floodplain risk management types, namely:

- flood modification measures (that is, measures to change flood behaviour, such as levees), which were previously identified as "structural" measures;

- property modification measures (that is, changes at an individual property level that seek to reduce flood damage by reducing flood damage potential). These measures were previously classified as "non-structural" measures.

- response modification measures relate principally to management of "continuing flood risk".

The 2005 Floodplain Development Manual also introduced the concepts of:

- flood prone land being defined as land being inundated by the Probable Maximum Flood (PMF). It must be noted that this requirement was superceded in 2007 by the NSW Department of Planning – Planning Circular PS-07-03, that stated “unless there are exceptional circumstances, Councils should adopt the 100 year flood as the FPL for residential development”.;

- Flood Planning Levels (FPL) as replacement of the "Flood Standard".

The Flood Planning Levels (FPL) represent a major departure, and approach the issue of development controls on the basis of:

- FPL based on an adopted flood event (design or historical) **plus** an appropriate freeboard;
- different FPL's can be applied to different areas and land zonings;
- different FPL's could be applied to different land uses within a single land use zoning.

10.2 Appropriate Flood Planning Levels

The 2005 Floodplain Development Manual outlines the factors to be addressed in considering the Flood Planning Level as:

- Council's duty of care;
- risk to life for floods up to the Flood Planning Level;
- risk to life for floods greater than the Flood Planning Level;
- flood behaviour (for example, flood depths reached, flood flow velocities, flood hazard, rate of rise of floodwater);
- social issues;
- land availability;
- existing level of development;
- current "Flood Standard" (under the 1986 Manual) or current FPL;
- land values and social equity;
- duration of flooding;
- economic factors;
- future development (specifically, the ability of the community and individuals to recover from flood events);
- appropriate flood mitigation works;
- environmental issues;
- cultural issues;
- freeboard.

In summary, the assessment of Flood Planning Levels is to be consistent with the overall objective of minimising the potential for property damage and risk to life from flooding, while not sterilising flood prone land from development unnecessarily.

Many Councils have adopted the 1% AEP design flood plus 0.5 metres freeboard as their Flood Planning Level, either through the Floodplain Risk Management process or simple extension of their earlier practice for planning and development purposes.

The 1% AEP design flood is a hypothetical event which produces flood levels and discharges which would be exceeded, on average, once in 100 years. It is frequently determined on the basis of design rainfall which

has been derived from analysis of rainfall data collected at sites which may be some distance removed from the study area. Occasionally, the 1% AEP design flood corresponds to a recorded flood event.

It should be noted that there is a 50% chance of a person experiencing a 1% AEP event over a 70 year period (say, during their lifetime). The chance of experiencing two floods of 1% AEP magnitude within a 70 year period is 17 percent.

The 2005 Manual indicates that the Flood Planning Levels for new residential development should be set at 1% AEP flood level **plus** a freeboard (typically 0.5 metres).

Continuation of Wyong Shire Council's current Flood Policy implies:

- the Flood Planning Level (with the exception of the Tuggerah Straight Industrial Area) as the 1% AEP flood level plus 0.3 metres freeboard;

- the Flood Planning Level in the Tuggerah Straight Industrial Area as the 2% AEP flood level with no freeboard.

Thus, while the flood level component of Wyong Shire Council's current policy is in accordance with the Floodplain Development Manual, the freeboard allocated is not.

The June 1949 flood is the highest recorded flood in the Wyong River. The estimated 1% AEP flood level at the railway bridge over the Wyong River is approximately 1.15 metres above the 1949 flood level. The estimated 2% AEP flood level is approximately 0.8 metres above the 1949 flood level.

Thus, the implied Flood Planning Levels, created by Wyong Shire Council's Flood Prone Land Development Policy, for the Tuggerah Straight Industrial Area and the remainder of the Wyong River floodplain provide protection for floods which are significantly larger than any previously experienced in the Wyong River, downstream of the Pacific Highway.

The criteria for selection of Flood Planning Levels above include assessment of economic criteria. The adoption of a Flood Planning Level affects damages sustained by future development and the economic assessment of any proposed flood mitigation works.

As discussed in Section 5.2, increasing the freeboard by 0.2 m was found to reduce mean annual direct flood damages to residential properties by approximately $65 per property. This was found to have a benefit-cost ratio (on a marginal measurement) of 0.4 for tangible benefits alone.

It has been assumed that the intangible benefits associated with building at a higher level are at least equal to the tangible benefits, thus providing an overall marginal benefit-cost ratio approaching 1.0.

Based on that analysis, it is concluded that amendment of the Designated Flood level also has a marginal benefit-cost ratio approaching 1.0. The marginal benefit-cost ratio decreases with increasing level.

Thus, it is concluded that the 1% AEP flood is appropriate for adoption as the Designated Flood Event for residential properties on the lower Wyong River floodplain.

A review of the distribution and magnitude of flood damages in Section 5.6 indicates that the bulk of flood damage is likely from the commercial/industrial sector, confined principally to the Tuggerah Straight Industrial Estate.

An examination of the Designated Flood adopted in the Tuggerah Straight Industrial Area is warranted given some further development in this area is possible.

Adoption of the 1% AEP flood as the Designated Flood Event for the Tuggerah Straight Industrial Area would result in increased filling of the area for new buildings which would significantly increase flood damages to existing development in the area.

Reference 9 states that filling of the remaining vacant land in the central section of the Tuggerah Straight Industrial Area to 1% AEP flood level would increase flood levels between the Wyong River and Mardi Creek by 0.15 to 0.32 m. Additional hydraulic modelling undertaken in 1995 indicates that filling of the vacant land (in 1995) to the 2% AEP flood level would result in 1% AEP flood levels being increased by less than 0.1 m.

Therefore, it is considered that retention of the 2% AEP flood as the Designated Flood Event for the Tuggerah Straight Industrial Area is appropriate.

11. FLOODPLAIN RISK MANAGEMENT OPTIONS - GENERAL

This chapter provides a general overview of the various floodplain risk management options which can be used for floodplain management. Detailed analysis of the feasible options for the study area is provided in following chapters.

The Floodplain Development Manual outlines a variety of risk management measures which can reduce the impact of floods and achieve the objectives of the Floodplain Risk Management Plan.

The options are discussed in general terms below. Some of the options are simply not applicable for the Wyong River system and discarded on the basis of:

- not practical;
- not feasible (either technically or financially);
- very limited benefits;
- significant flood impacts.

Practical options are discussed in detail in Chapter 12 and illustrated on Figure 18.

11.1 Flood Modification Measures

Structural flood mitigation measures reduce the impact of flooding by modifying flood behaviour ie. the extent, depth and velocity of floodwaters and frequency of flooding. These measures include:

- flood mitigation dams and/or detention basins;
- levees;
- bypass floodways; and
- channel improvements.
- detention basins;
- various combinations of the above.

A locally specific option raised was changing the behaviour of the Tuggerah Lake opening at The Entrance. The community has frequently raised this option. Accordingly, the entrance opening has been addressed in Chapter 12 and will be discussed in greater detail in the Tuggerah Lakes Floodplain Risk Management Study underway.

Flood mitigation dams and detention basins perform essentially the same function, though on vastly different scales. The former is applicable for large rivers and catchments, whereas, the latter is most suitable for small streams which respond quickly to rainfall and/or stormwater flooding.

The Wyong River catchment can be divided into three major sub-catchments (see Figure 17):

- the upper Wyong River, upstream of the Sydney-Newcastle Freeway;
- Jilliby Jilliby Creek; and
- the lower Wyong River.

Jilliby Jilliby Creek has a catchment area of 100 square kilometres and joins the Wyong River approximately 3 kilometres upstream of the freeway. The catchment area of the upper Wyong River is 255 square kilometres, giving a catchment area above the freeway of 355 square kilometres. The catchment area of the lower Wyong River is approximately 90 square kilometres.

Thus, approximately 80% of the total catchment area of the Wyong River is located upstream of the study area.

The majority of the upper Wyong River and Jilliby Jilliby Creek catchments is native forest on steep to undulating country. The valley floors and floodplains have been extensively cleared for cattle grazing and agriculture.

Achieving a measurable reduction in flood levels in the Lower Wyong River (of say 0.2 metres) would require a storage of some 3.25 Gigalitres. A dam of this magnitude is a significant undertaking.

It may be possible to construct a flood mitigation dam on the upper Wyong River. However, such a dam would require acquisition of extensive areas of farming land and deviation of the road to Yarramalong as well as causing significant social and environmental impacts.

The construction of a flood mitigation dam on the upper Wyong River has been deemed to be not feasible due to the high capital cost and perceived unacceptable social and environmental impacts.

The construction of detention basins in the Mardi Creek catchment has been proposed in a previous study (Ref. 33). It should be noted that, at present, the freeway embankment and culverts provide a degree of flood mitigation for Mardi Creek.

Further, part of Mardi Dam could be left unfilled as part of the water supply operational procedures. This unfilled part provides some flood mitigation of floods down Mardi Creek.

A number of features of detention basins require careful evaluation when assessing this option, for example:

- area of land required;
- public safety;
- effectiveness in long duration or multi-peaked storms; and
- maintenance costs
- detailed design measures.

Levees are an effective means to protect development from flooding in frequent to moderately rare events. The height of the levee is determined by economic factors and site conditions in addition to flood behaviour. Therefore, in general, levees do not provide protection against all floods.

Issues to be considered in the levee proposals include:

- probability of overtopping and failure;
- consequences of overtopping or failure;

- the threat to life caused by levee overtopping and failure;
- drainage of land within the levee; and
- adverse impacts at other locations.

Construction of a levee across the northern edge of the Tuggerah Straight Industrial Area to protect the industrial properties has been proposed in a previous study. Similarly, the construction of a riverbank levee to protect residential development on the northern floodplain, downstream of the railway has also been proposed. These proposals are addressed in detail in Chapter 12.

Bypass floodways provide an additional outlet or flowpath for floodwaters. Construction of bypass floodways is limited by the topography of the area, environmental considerations and the availability of land.

During major floods, there is a significant flow which leaves the Wyong River at the Charlton Island bend and flows overland to Tuggerah Lake. Construction of a bypass floodway along this route is considered to be a feasible flood mitigation option for the Wyong River study area. The channel excavation is likely to expose acid sulphate soils and could have significant environmental impacts.

It has been suggested that a flood channel could be constructed from Mardi Creek to Tuggerah Lake along the route indicated on Figure 18. The channel would be located close to the Mardi sub-station and crosses SEPP 14 Wetland 901 on the foreshore of the lake. Construction of the channel is likely to expose acid sulphate soils as well as having a significant impact on the wetland areas.

Based on results obtained by hydraulic modelling of channel improvements in Mardi Creek between the railway and the lagoon (Ref. 9), the flood channel could provide only a minor reduction in flood levels upstream of the railway embankment for Mardi Creek flood events. The channel would provide negligible reduction in flood levels for Wyong River floods which inundate the full width of the floodplain.

Thus, it is considered that construction of a flood channel from Mardi Creek to Tuggerah is not feasible due to significant environmental impacts caused by the construction and the minimal flood mitigation which can be derived from the works.

Channel improvements increase the capacity of a stream to discharge floodwaters. The effect of channel improvements is to reduce the overbank flow and, hence, depth of flooding. Channel improvements are unlikely to have a significant effect in areas where flooding is dominated by tide levels or where there is extensive overbank flow.

The channel of Mardi Creek has been significantly improved upstream of the Pacific Highway. The channel reach between Gavenlock Road and the Pacific Highway was widened in early 1995. Augmentation of the culverts under the Pacific Highway and railway are additional improvements which are considered feasible for Mardi Creek.

Flooding in the adjacent industrial development is controlled by the restricted capacity of these culverts. Duplication and re-alignment of the two culverts could reduce flood levels by 0.3 to 0.5 metres in the industrial area for Mardi Creek floods. The culvert and channel improvements would have a much lesser effect on Wyong River floods. Further analysis of the duplication and re-alignment option indicated the

reduction in flood levels was not as great as originally thought. Any future works must consider recent works carried out by the RTA in this area.

It is unlikely that extension of the channel improvements downstream of the railway will provide any additional reduction in flooding in the industrial area. In major flood events, the bulk of the flood discharge is conveyed over the floodplain and channel improvements are unlikely to be effective in lowering flood levels.

Factors to be considered in the assessment of channel improvements include:

- impacts on ecology of the stream;
- visual impacts; and
- maintenance requirements.

The embankment for the Main Northern Railway traverses the full width of the Wyong River floodplain. This embankment is some 1.2 to 2.0 metres higher than the natural ground levels. There are only two major culverts under the embankment, located at Mardi Creek and approximately 550 metres south of the Wyong River. Thus, the railway embankment presents a major obstruction to floodwaters.

The estimated 1% AEP flood levels in the Tuggerah Straight Industrial Areas, immediately upstream (west) of the railway, are some 0.9 metres higher than on the floodplain immediately downstream (east) of the railway. Additional hydraulic modelling (Ref. 11) indicates that any change in the level of the railway embankment will produce an equivalent change in flood levels immediately upstream.

Thus, removal of the railway embankment would significantly lower flood levels upstream and reduce flood damages. Flood levels on the lower floodplain would be increased by a lesser amount. The lower floodplain is not intensively developed so the resultant increase in flood damages would be relatively minor.

However, removal of the railway is not a feasible option. Similarly, replacement of the embankment with a viaduct is not considered to be economically viable.

Therefore, it is considered that it is not economically feasible to undertake works on the railway embankment which will substantially lower Wyong River flood levels in the Tuggerah Straight Industrial Area.

Initial indications (Ref. 33) were that flood levels in Mardi Creek, upstream of the Pacific Highway, could be lowered by 0.2 m for Mardi Creek flooding and by less than 0.1 m for Wyong River flooding if the capacity of the culverts under the highway and railway was doubled.

These works have been proposed as part of the drainage strategy for Mardi Creek, but are not likely to be constructed, given more recent Council investigations show the reduction in flood levels to be substantially less.

The Flood Modification Measures which are considered to be feasible for the lower Wyong River study area are:

- detention basins;
- levees;
- bypass floodway; and
- channel improvements.

The locations of the Flood Modification works which are feasible and evaluated are shown on Figure 18.

11.2 Property Modification Measures

Property Modification Measures reduce the impact of flooding on existing development and reduce the risk of damage caused by flooding for future development. These measures include:

- floodproofing of buildings;
- land use controls;
- building and development controls; and
- voluntary purchase.

The commercial considerations of flood insurance are such that this options is only available on a restricted basis for commercial properties. A de-facto form of flood insurance is available to residential property owners in the form of disaster relief.

Flood-proofing of buildings and voluntary purchase of flood-liable properties can reduce the impact of floods on existing development, while land use planning controls and building and development controls are applied in order to minimise the impact of floods on future development within the flood-liable area.

11.3 Response Modification Methods

The Response Modification Methods listed by the Floodplain Development Manual encompasses:

- Community Flood Awareness and Readiness;
- Flood Warnings;
- Emergency Response Planning for floods.

Flood warning and disaster planning enable people and possessions to move out of the way of an approaching flood. In general, the flood warning available for small catchments is inadequate for flood-affected persons to initiate evacuation procedures. Thus, flood warning is feasible for Wyong River flooding but not for Mardi Creek flooding.

Public education raises the level of awareness of flooding issues so that residents will accept and act on flood warnings and adopt appropriate safeguards in the design of new building construction.

12. EXISTING FLOOD RISKS - FLOOD MODIFICATION MEASURES - WYONG RIVER FLOODING

The effectiveness of feasible flood modification measures for improved protection of existing development from Wyong River flooding is discussed below. Options for Mardi Creek flood modification options are discussed in the following chapter. The detailed comparison of all options is discussed in Chapter 15.

The flood modification works options are shown on Figure 18.

12.1 Entrance Opening

There is a general community perception that physical improvements to the opening of Tuggerah lake to the sea will significantly reduce flood levels and improve flood characteristics.

The floodplain management of Tuggerah Lakes is currently underway as a separate floodplain risk management study. The subject of changes to the entrance opening is generally beyond the scope of this study, but the following comments are given as background information.

Flood runoff from the Wyong River and adjacent catchments which drain into the Tuggerah Lake system is discharged to the ocean through the Tuggerah Lakes entrance. The entrance is normally open to allow tidal flow in the lake but has closed in the past.

The entrance controls the rate of discharge of floodwaters to the ocean and, hence, controls lake flood levels.

Changes to the Tuggerah Lakes entrance cannot be considered for flooding alone because of the major interactions with the estuarine processes of Tuggerah Lakes that will occur after entrance changes.

A feasibility study (Ref. 15) into establishment of training walls at The Entrance was completed in 1994 and covered a range of entrance management options from prevention of closure to provision of a permanent navigable entrance.

Under existing conditions, the entrance opening of Tuggerah Lakes to the sea is affected by:

- flood occurrences;
- coastal processes; and
- particular site conditions.

During floods, a wide and relatively deep channel is scoured through the entrance shoals and sand spit at the entrance. The magnitude of scouring is dependent on the flood height in Tuggerah Lakes, prevailing ocean water levels and wave climate and the actual volume of sand contained within the entrance area.

After floods scour the entrance, tidal flows, wave action and wind action move more sand (on average) into the scoured entrance than is removed under ebb tide conditions. The sand spits thus gradually build up, throttling ebb tide flows which, in turn, creates a gradual entrance closure. The process is rejuvenated by the next flood which breaks through the sand spit.

The construction of a permanent entrance with training walls would have significant impacts. The training walls should be spaced such that the tidal exchange in Tuggerah Lakes is sufficient to prevent coastal littoral processes creating sand bars in the entrance. Achievement of this objective requires narrowly-spaced training walls, however, to achieve a reduction in flood levels, widely spaced training walls are required. Thus, it appears to be technically difficult to achieve both objectives of a permanent entrance opening and a reduction in flood levels.

Hydraulic modelling results undertaken for the 1992 Floodplain Management Study (Ref. 9) indicate that a doubling of the width of the entrance to Tuggerah Lakes would provide a maximum reduction in lake flood levels of 0.15 metres. The results indicated that there was a negligible lowering of flood levels upstream of the Fishing Co-operative in the Wyong River.

Further opening of the Tuggerah Lakes' entrance will increase the tidal range within the lake itself and thus ecological changes can be expected.

Wyong Shire Council completed the Tuggerah Lakes Estuary Management Study (Reference 25) in 2005. It examined the entrance opening proposals in a qualitative sense. Whilst the Estuary Management Study does not draw firm conclusions on a permanent entrance opening, it is clear from the Management Study that a permanent entrance opening would not be a favoured option from an estuary management perspective.

In summary of the above, widening of the Tuggerah Lakes entrance was found to provide a relatively small reduction in flood levels around the foreshores only and was ineffectual in reducing flood levels on the Wyong River floodplain beyond the foreshore area.

12.2 Panonia Road Levee

The route for this proposed levee commences downstream of the railway bridge and runs along the northern bank of the Wyong River for a distance of 2.4 kilometres, as shown on Figure 19.

The purpose of this levee is to protect the existing residential development from floodwaters spilling onto the northern floodplain downstream of the rail bridge. This area is flooded to depths of about 1 metre in the 1% AEP design flood with average flow velocity of 0.3 to 0.6 metres per second.
Thus, the area is classified as being `High Hazard - Flood Storage' and `High Hazard - Flood Fringe' in accordance with the Floodplain Development Manual, due to the depth and velocity of floodwaters.

The riverbank levee will prevent direct flooding of the area from the Wyong River. However, floodwaters will spill onto the floodplain beyond the downstream limit of the levee. The 1% AEP flood level at this location is some 1.2 metres lower than the 1% AEP flood level immediately downstream of the rail bridge. Backwater flooding from the northern floodplain could be prevented by the construction of a lower rear levee, as shown on Figure 19.

There are some 145 houses between the railway and McDonagh Road which are located within the 1% AEP flood extent. These houses are within the area enclosed between the Panonia Road section of the riverbank levee and the rear levee.

There are 45 houses in Boyce Avenue, Riverview Drive and Golding Grove which would be protected from direct river flooding by the downstream section of the riverbank levee. These houses are located in a `High Hazard - Flood Fringe' area.

Floodwaters spilling around the end of the riverbank levee would produce backwater flooding levels some 0.4 m lower than the flood level in the Wyong River.

As a result, an additional 10 houses in this area would then be outside the 1% AEP flood extent. Thus, a total of 155 houses would be protected against the 1% AEP flood by the proposed levee scheme.

Flood levels on the northern floodplain would be reduced by 0.1 to 0.2 metres as a result of the proposed levee due to the reduced spill of floodwaters onto the northern floodplain.

However, flood levels on the southern floodplain would be increased by up to 0.35 metres as more floodwater would be diverted onto the southern floodplain and flow overland to Tuggerah Lakes.

There are two houses on the southern floodplain which would experience an increase of approximately 0.1 metres in the 1% AEP flood level. The houses at Tacoma South would be unaffected by the proposed levee scheme.

12.3 Tuggerah Straight Industrial Area Levee

The route of this possible levee runs westward from the Pacific Highway along McPhersons Road to Gavenlock Road, then southward along Gavenlock Road for 200 metres and thence westward over open land to higher ground, as shown on Figure 20.

The levee would be approximately 3.5 metres high at the Pacific Highway and up to 4.5 metres high on the floodplain, with a crest level of 0.3 metres above the resultant 1% AEP flood level.

Construction of this levee would prevent floodwaters from the Wyong River spilling onto the southern floodplain upstream of the Pacific Highway and railway. The levee would thus protect the Tuggerah Straight Industrial Area against flooding from the Wyong River. However, the area could still be flooded by runoff from the local catchment and Mardi Creek at the southern edge of the industrial area.

Flood levels in the Tuggerah Straight Industrial Area would be reduced by 2.5 metres at the northern end and 1 metre at the southern end as a result of the floodwaters being contained by the proposed levee.

However, flood levels in the Wyong River and on the floodplain would be increased by 0.8 metres immediately upstream of the rail bridge and by 0.4 to 0.5 metres at the Sydney-Newcastle Freeway.

There are some 40 houses and a nursing home between the Freeway and the Pacific Highway which would suffer significantly higher flood levels as a result of the proposed levee. There are also 30 houses upstream of the freeway which would suffer minor increases in flood level.

Flood levels downstream of the railway bridge would be increased by 0.1 m, causing 30 additional houses in the Panonia Road area to be inundated in the 1% AEP flood.

The possibility of construction of a southern levee to protect the industrial area from Mardi Creek flood has been investigated. However, a site inspection of the Tuggerah Straight Industrial Area adjacent to Mardi Creek indicated that a suitable route for construction of a southern levee could not be located. Even if a levee could be constructed to protect the industrial area from Mardi Creek flooding, the resultant loss of temporary flood storage would cause significant increases in flood levels in Mardi Creek, possibly affecting Woodbury Park residential area and the car park areas of Westfields shopping complex.

12.4 Flood Channel From Charlton Island to Tuggerah Lake

This option comprises the excavation of a bypass floodway some 150 metres wide from the bend in the Wyong River immediately downstream of Charlton Island, across the southern floodplain to discharge into Tuggerah Lake 1.2 kilometres south of the river entrance (see Figure 18). The invert of the channel would be 0.3 metres above mean high water level in Tuggerah Lake.

Construction of the bypass floodway would reduce flood levels downstream of the rail bridge by 0.1 to 0.15 metres in the 1% AEP flood.

12.5 Replacement of Pacific Highway and Railway Bridges

The Pacific Highway and Main Northern Railway bridges over the Wyong River provide the major waterway area for the passing of Wyong River floods. The railway embankment across the southern floodplain blocks off most of the flow over the floodplain.

The rail bridge is approximately 1 m higher than the highway bridge and is located immediately downstream. The highway bridge was the previous rail bridge before the railway was raised and the current railway bridge constructed in the late 1960's.

The deck of the highway bridge is approximately 0.6m above the 1% AEP flood level. However, the underside of the bridge beams is more than 2 m below the 1% AEP flood level. Thus, the highway bridge provides a significant obstruction to the flood discharge in the Wyong River channel in major flood events.

The estimated afflux at the highway and rail bridges in the 1% AEP flood exceeds 1.5 m. By comparison, the difference in 1% AEP flood levels across the railway embankment on the southern floodplain is 0.9 m.

It is estimated that flood levels upstream of the bridges could be lowered by 0.1 m by raising the highway bridge to the same level as the rail bridge (Ref. 9). Preliminary advice received from the Roads and Traffic Authority (RTA) is that the highway bridge is considered to be structurally sound and is unlikely to be replaced in the short or mid-term future.

However, continuing upgrading works on the Pacific Highway suggest an additional bridge will be required in the near future (from 2010) to match expanded road networks.

It is not considered feasible to raise both bridges above the 1% AEP flood level, as this would require raising of railway line across the southern floodplain. State Rail Authority drawings prepared in 1984 show a proposal to raise the railway by 0.15 to 0.2 metres over the floodplain. Hydraulic modelling (Ref.11) indicates that 1% AEP design flood levels in the Tuggerah Straight Industrial Area, immediately upstream of the railway, will be increased by up to 0.15 metres as a result. In fact, a shorter length of the Railway across the southern floodplain was raised by approximately 0.12 metres circa 1982 .The flood models showed this work would increase flood levels by 0.05 metres in the Tuggerah Straight Industrial Area.

Thus, additional raising of the railway associated with raising the bridge over the Wyong River would offset some of the reduction in flood levels achieved by the raising of the bridge.

The effectiveness of raising of the highway and railway bridges over the Wyong River is limited by the obstruction of floodwaters flowing over the floodplain which is caused by the railway embankment. There is a 0.9 metre difference in flood levels across the rail embankment in the 1% AEP event. Replacement of the bridges would provide a minimal reduction in this difference in flood levels, typically less than 0.1 m.

12.6 Comparison of Flood Modification Measures

The flood mitigation effectiveness of the various works options investigated for Wyong River flooding are summarised in Table 12.1. This table shows that reduction in the number of premises flooded and the resultant reduction in mean annual damages for each of the works options. The full economic analysis of options is presented in Chapter 15.

Table 12.1

Comparison of Flood Modification Measures for Wyong River Flooding

Flood Modification Measure	Reduction in Premises Flooded in 1% AEP Flood	Reduction in Mean Annual Damages ($)
Panonia Road Levee	155	59,800
Industrial Levee	Increased 31	-203,500
Flood Channel	1	23,600
Raise Highway Bridge	1	179,500
Widen Tuggerah Lakes Entrance	10	11,400

The data presented in Table 12.1 shows that the Industrial Levee option results in significant increase in the number of premises flooded in the 1% AEP flood and an increase in the mean annual damages.

The Tuggerah Straight Industrial Area can be flooded from Mardi Creek as well as from the Wyong River (Refer Table 3.5). The proposed Industrial Levee will reduce the damages caused by Wyong River flooding of the industrial area. However, the levee will not affect flooding from Mardi Creek. Thus, the

Industrial Area will be protected from Wyong River flooding but not Mardi Creek flooding. The estimated reduction in mean annual flood damages in the industrial area is $33 000. The low benefit reflects the partial protection provided against all floods (Wyong River and Mardi Creek) in the Industrial Area.

However, the proposed levee will increase flood levels and, hence, the number of premises flooded and flood damages upstream of the Pacific Highway bridge and in the Panonia Road area.

Replacement of the Pacific Highway bridge was found to provide the greatest reduction in mean annual damages, although the reduction in the number of residential premises flooded in the 1% AEP flood was limited to a single property. The reduction in damages results from a reduction in depth of flooding of some 370 houses and 80 commercial and industrial premises.

House raising has the potential to provide the greatest reduction in the number of premises flooded. The estimated reduction in mean annual flood damages is equivalent to $590 per house raised.

The Panonia Road levee option provides the second greatest reduction in the number of premises flooded. This option provides an estimated reduction in mean annual flood damages of $415 per property protected.

The flood channel option and Tuggerah Lakes entrance widening option provide minimal reduction in the number of premises flooded and mean annual flood damages.

13. EXISTING FLOOD RISKS - FLOOD MODIFICATION MEASURES - MARDI CREEK FLOODING

The effectiveness of feasible flood modification measures for improved protection of existing development from Mardi Creek flooding is discussed below.

The flood modification measures works options are shown on Figure 18. The works options discussed in this chapter were investigated in Reference 9.

The changes in flood behaviour produced by the various works options and schemes discussed below are related to 1994 conditions as the base case.

It is noted that channel improvements have been completed on Mardi Creek between Gavenlock Road and the Pacific Highway.

13.1 Upgrade Culverts Under Pacific Highway and Railway

The proposed augmentation of these culverts is included in the drainage strategy for Mardi Creek.

The culverts under the Pacific Highway and the railway provide a major restriction on the flood discharge in Mardi Creek. The difference in 1% AEP flood levels upstream of the highway to downstream of the railway exceeds 0.5 metres.

The culvert under the Pacific Highway comprises a twin cell 3.6 x 2.4 metre box culvert with invert level at RL 2.0 m AHD and road level at RL 4.8 m AHD. The culverts are prone to partial blockage by silt and debris accumulation.

The culvert under the railway is a twin cell 4.3 x 2.5 metre box culvert with invert level at RL 2.0 m AHD. The rail level is approximately RL 5.5 m AHD.

The two sets of culverts are approximately 20 metres apart and the creek channel between the culverts is heavily overgrown.

Hydraulic modelling for site conditions prior to recent RTA road-works along Tuggerah Straight indicates that duplication of the existing culverts and realignment and clearing of the intervening channel would reduce 1% AEP flood levels by approximately 0.2 metres at the Pacific Highway and by less than 0.02 metres at Gavenlock Road.

The culverts underneath the Pacific Highway have recently been upgraded by the RTA as part of their suite of works to widen the Pacific Highway between Wyong Road and Wyong River. Works included:

- Widening of the carriageway by approximately 10 metres;
- Construction of a roundabout at Mildon Road
- Traffic lights at Johnson Road;
- Raising of the median along the centerline of the full length of road widening between 0.15m to 0.39m;

- Wire rope median
- Tree planting along the centre median;
- "Type F" crash barriers at Mildon Road
- Importation of approximately 10,000 m3 of fill over 25,000m2 area.

The exact impact of these roadworks and drainage works has on the hydraulic capacity of Mardi Creek and the wider Wyong River floodplain is unknown. The RTA completed a Flood Impact Assessment (Ref 34) for the concept design of these works in 2004, which was later updated in 2006 (Ref. 35). It appears however, that the finished surface levels differ to those indicated in the Flood Impact Assessment (Ref. 34.)

The construction of the amplification of the culverts under the railway was deferred due to the cost and perceived limited benefits of the works. Agreement from Railcorp NSW is also required for works under the railway line. As this line is the main north-south railway line and therefore important for rail freight, preliminary discussions between Railcorp and Council have indicated Railcorp reluctance to close the line for a period of time long enough that would enable such works to be carried out.

13.2 Mardi Dam Works

Mardi Dam is an off-stream storage used for water supply purposes and is operated by the Gosford-Wyong Council's Water Authority. Water is pumped from Lower Wyong River weir, Ourimbah Creek weir and Mangrove Creek to the dam for treatment and distribution. Mardi Dam has a catchment area of 1.7 square kilometres, equivalent to 30% of the catchment area of Mardi Creek above the Pacific Highway.

The temporary flood storage available in Mardi Dam provides a nominal flood mitigation benefit under existing conditions.

As part of the Gosford-Wyong Councils Water Authority's Mardi-to-Mangrove pipeline project, there are plans to raise the dam embankment levels by approximately 2 metres, so as to improve the water storage capacity of Mardi dam, and the water supply security for the area.

Previous studies of Mardi Creek (Ref. 33) investigations were carried out in to reducing the full supply level (FSL) of Mardi Dam and the impact this would have on flood levels further downstream. The outcomes of these investigations have been nullified with the "Mardi to Mangrove" pipeline project, which is raising the dam wall height and storage capacity of Mardi Dam.

Due to the relatively small catchment area controlled by the dam and the rapid response of the remainder of the Mardi Creek catchment, it is not considered feasible to pre-release from the dam or to attempt to operate the dam for flood mitigation purposes.

13.3 Cobbs Road Detention Basins

Mardi Dam and the Freeway embankment provide significant informal detention benefits for Mardi Creek.

Two potential sites for retarding basins were identified upstream of the Freeway (nominated F3 North Arm Detention Basin and F3 South Arm Detention Basin). One further site was identified downstream of the Freeway, on the southern side of Cobbs Road, upstream of Tonkiss Street.

The Cobbs Road southern site is located on the old abattoir site and is cleared pasture. Construction of a detention basin on the site would reduce flood levels between Gavenlock Road and the Pacific Highway by approximately 0.05 metres.

The initial investigations (see Reference 33) indicated the potential basin on the abattoir site as the most effective. The basins upstream of the freeway were less expensive to construct, however there are significant implications with using the freeway as an embankment. The RTA provided a stringent set of design and construction conditions early in 2002 if this work was to proceed.

The basin on the old abattoir site was determined to be the most beneficial and appropriate considering the existing land use constraints of all of the options. The detail design of this basin was put on hold when Westfield (the land-holder of the abattoir site) indicated their plans to expand their development into this site circa 2006.

Further detailed investigation of these options is "on hold" while the full land use potential of the surrounding areas is determined.

13.4 Channel Improvements Downstream of Railway

The existing Mardi Creek channel downstream of the railway culvert is heavily vegetated with an invert some 2 metres below the general floodplain level. In a 1% AEP Mardi Creek flood, floodwaters extend some 300 metres over the floodplain. The depths of floodwaters on the floodplain in the 1% AEP flood exceeds 1 metre. The flood discharge is evenly split between the creek channel and the floodplain.

Excavation of a grass lined, hydraulically improved channel with a base width of 40 meters between the railway embankment and the SEPP 14 wetland approximately 1 km downstream has been investigated. Initial investigations (Ref. 9) reported significant reductions in flood levels downstream of the railway with these works. Subsequent studies (Ref. 33) reviewed these initial investigations, and reduced the scale of channel works in accordance with cost constraints and environmental impacts. The resultant hydraulic benefit of these latter works were greatly reduced downstream of the railway, with negligible impacts upstream of the railway.

13.5 Proposed Schemes

A number of schemes, comprising combination of the individual works options, have been proposed for flood mitigation along Mardi Creek, as outlined in Reference 9. These schemes and their effectiveness were reviewed and updated or discarded in the1996 – 1997 investigation (Ref 33).

Scheme 1 comprises channel improvements downstream of the railway, channel improvements between Gavenlock Road and the Pacific Highway and upgrading of the Gavenlock Road culvert. The estimated reduction in flood levels between Gavenlock Road and the Pacific Highway is 0.2 to 0.3 metres. This work was completed in 1997.
Scheme 2 comprises the Scheme 1 works plus duplication of the culverts under the Pacific Highway and the railway. The estimated reduction in flood levels between Gavenlock Road and the Pacific Highway was 0.6 to 0.75 metres. Recent RTA road works in this area impact these results, however the extent of the

impacts is currently unknown.

Scheme 3 comprises the Scheme 1 works plus lowering of the Mardi Dam FSL by 0.2 metres. The estimated reduction in flood levels between Gavenlock Road and the Pacific Highway is 0.36 to 0.4 metres. This scheme is no longer considered viable with the "Mardi to Mangrove" pipeline project currently under construction.

Scheme 4 comprises the Scheme 3 works plus construction of a detention basin south of Cobbs Road. The estimated reduction in flood levels between Gavenlock Road and the Pacific Highway is 0.45 to 0.6 metres. As noted above in Scheme 3, recent works on the Mardi Dam as part of the "Mardi to Mangrove" work impact these results, making the option no longer valid.

13.6 Comparison of Works and Schemes

The effectiveness of the various works and schemes investigated for Mardi Creek (measured by reduction in flood levels, reduction in number of premises flooded and reduction in mean annual damages) are summarised in Table 13.1. This table shows the estimated lowering in flood levels at Gavenlock Road and the Pacific Highway as well as the reduction in the number of premises flooded in the 1% AEP and 2% AEP flood events. The latter flood event was adopted by Wyong Shire Council as the Flood Planning Level for the Tuggerah Straight Industrial Area. The estimated reduction in mean annual flood damages for each works and scheme is also presented in Table 13.1.

The flood mitigation benefits to be derived from the combinations of works included in the various schemes are not necessarily equal to the sum of the individual benefits. This is due to possible changes in the timing of runoff hydrographs. Channel improvements lower flood levels but increase flow velocities, thereby increasing flood discharges downstream.

The flood mitigation benefits are dependent on the relative timing of the inflows from the catchment sub-areas.

Review of the effectiveness of each proposed scheme and the individual works indicates that the bulk of the flood mitigation benefits are derived from duplication of the culverts under the Pacific Highway and railway and channel improvements between Gavenlock Road and the Pacific Highway. These works were estimated to provide an estimated lowering of flood levels between Gavenlock Road and the Pacific Highway of 0.5 to 0.6 metres.

These works have been included in the drainage strategy adopted for Mardi Creek. The adopted strategy comprises:

- channel improvements between Gavenlock Road and Pacific Highway (constructed 1995);
- upgrading of Gavenlock Road culvert (constructed 1995-96)

Table 13.1

Comparison of Works and Schemes Options For Mardi Creek Flooding

Works Option	Reduction in Flood Level (m)		Reduction in Number of Premises Flooded		Reduction in Mean Annual Damages	
	Gavenlock Rd	Pacific Hwy	1% AEP	2% AEP	($ 2007)	% of Existing
1. Channel improvements Gavenlock Road to Pacific Hwy (already completed)	0.20	0	25	25	696,300	13%
2. Duplicate culverts at Pacific Hwy and Railway	< 0.02	0.20	6	26	674,900	12.5%
3. Upgrade Gavenlock Road culvert	< 0.02	0	-	-	-	-
4. Cobbs Road Detention Basin	0.05	0.05	6	22	261,600	4.5%
5. Channel improvements downstream Railway	< 0.02	0.15	6	22	269,300	5%
6. Scheme 2	0.60	0.75	62	81	3,146,300	58%
7. Scheme 3 [1]						
8. Scheme 4 [1]						

Notes: 1 Schemes 3 and 4 have been discarded from further investigation due to recent works at Mardi Dam and Pacific Highway, which effectively eliminate these scheme options.

The remaining works provide marginal flood level reduction of 0.1 to 0.2 metres.

Scheme 2 provides the greatest reduction in the number of premises flooded as well as the greatest reduction in mean annual flood damages. This scheme has been adopted as the drainage strategy for Mardi Creek circa 1996.

The bulk of the benefits derived from this scheme are attributable to the channel improvements between Gavenlock Road and the Pacific Highway and the duplication of the culverts under the Pacific Highway and railway with the other works providing a marginal benefit only.

14. EXISTING FLOOD RISKS - PROPERTY MODIFICATION MEASURES

14.1 House Raising - Wyong River

One of the most effective means of reducing flood damages to residential properties is to raise habitable floor levels above flood level. This is not economically feasible for slab-on-ground or brick/brick veneer forms of construction.

The NSW Government's Flood Policy provides for a subsidy of the cost of voluntary house raising where this is found to be more cost-effective than other floodplain management measures. House raising is generally subsidised at a rate of 2:1 where two thirds the cost is met by NSW Government and the remaining third as a local contribution from either Council, the property owner, or a combination of these parties.

Analysis of the floor level survey data for the lower Wyong River floodplain indicates that 215 of the 372 flood-liable houses are of timber framed construction and are potentially suitable for raising. There are 61 additional houses which have less than 0.3 metres freeboard above the 1% AEP flood level.

The distribution of houses potentially suitable for raising is presented in Table 14.1.

Table 14.1

Houses Suitable for Raising

Precinct	Number of Houses with Habitable Floors	
	Below 5% AEP Flood	Less Than 0.3 m Above 1% AEP Flood
1	170	43
2	14	-
3	3	1
4	1	1
6	27	16
Total	215	61

Precinct 7 (Tuggerah Business Park) and Precinct 8 ("Kooindah" development) are not included in Table 14.1 above, as these precincts contain no houses suitable for house raising.

14.2 Voluntary Purchase - Wyong river

An alternative means of reducing flood damages is to purchase flood-liable properties. The houses may then be demolished or relocated to flood-free land and the site used for open space or may be re-developed above flood level. The high cost of this option and the social disruption caused, generally restricts the viability of this option to small localised areas of residential development which are located in high hazard floodways where there is serious risk to life and no alternative option is practicable.

Figure 12 shows that the bulk of the floodplain of the Wyong River upstream of the Pacific Highway can be classified as `High Hazard - Floodway'. Table 5.7 shows that there are 31 houses located below the 1% AEP flood level on this section of the floodplain (Precincts 2 and 3).

There are three (3) houses upstream of the Freeway (Precinct 3) where the depth of floodwaters in the 1% AEP flood exceeds 0.9 m. Two (2) of these houses are of brick or brick veneer construction while the third house is timber framed.

The upper floodplain is rural in character with houses separated by distances of hundreds of metres. Construction of isolated ring levees around the houses or raising of houses, where practicable, are considered to be more appropriate than voluntary purchase.

There are a number of houses located in a `High Hazard - Flood Fringe' area in the Riverview Drive area on the lower floodplain. Eight (8) of these houses would be inundated by floodwaters in excess of 0.9 m deep in the 1% AEP flood. However, the velocity of the floodwaters is unlikely to result in structural damage in these houses.

Voluntary purchase of flood-liable properties is not considered to be an appropriate option for the lower Wyong River floodplain as alternative options are available or the risk to life is not considered sufficiently great as to warrant this measure.

14.3 House Raising - Mardi Creek

In 1995, there were five houses in Anzac Road which were located below the 1% AEP flood level and which could have been raised above flood level. By 2007, these buildings were demolished and the land ready for re-development.

15. ASSESSMENT OF FLOODPLAIN RISK MANAGEMENT OPTIONS - EXISTING FLOOD RISKS

The aims of floodplain management are to reduce the impact of flooding and flood liability on individuals and to reduce private and public losses resulting from flooding.

The general thrust of floodplain management options involving capital works is directed to protection/mitigation for existing developments. Future development is best addressed through planning strategies. This chapter addresses the floodplain measures applicable to existing development.

The favourable impacts of floodplain management are the reduction in tangible and intangible damages caused by flooding. However, flood management measures may also have an impact on the environment.

The "merits approach" outlined in the NSW Government Flood Policy requires that flooding factors be considered along with planning, social, environmental and economic factors.

Therefore, it is necessary to assess floodplain management options by consideration of a number of relevant criteria. These criteria can be classified under the following:

- function - a reduction in tangible and intangible flood damages;
- economics - assessment of costs, benefits and affordability of the option;
- environment - assessment of the impact of the option on the natural and man-made environment; and
- social issues - assessment of the intangible factors relevant to the option.

The assessment of the floodplain management options relative to the above criteria is discussed in the following sections.

15.1 Reduction in Damages

Flood damages sustained by existing development can be reduced by the construction of flood protection works or by relocation of flood-liable premises to above flood level or to flood-free areas. Flood damages to future development can be minimised by ensuring that such development does not take place in flood-liable areas or that such development is located above the flood planning level.

The estimated reduction in direct flood damages to existing development for the various management options investigated for the Wyong River study area are summarised in Table 15.1.

The results presented in Table 15.1 show that the mean annual flood damages to existing development can be reduced by up to $202,000 for lower Wyong River flooding and by up to $3,430,000 for Mardi Creek flooding. These reductions in mean annual damages represent a reduction of almost 60% in the estimated direct damages to existing residential, commercial and light industrial properties within the study area.

The industrial levee option has been discarded from the assessment as this option was found to produce an increase in the flood damages for other areas, particularly between the Freeway and Pacific Highway.

Table 15.1

Reduction in Potential Direct Damages - Existing Development

Option	Reduction in Mean Annual Damages		Precincts Benefitting
	($ 2007)	($ 2010)	
WYONG RIVER MANAGEMENT OPTIONS Panonia Road Levee	59,800	65,200	1
Flood Channel	23,600	25,700	1
Replace Highway Bridge	179,500	195,700	2, 4
Widen Tuggerah Lakes Entrance	11,400	12,400	1, 6
House Raising (Wyong River)	125,400	136,700	1 - 4, 6
MARDI CREEK MANAGEMENT OPTIONS Culvert Duplication Pacific Highway and Railway	674,900	735,600	4, 5
Cobbs Road Detention Basin	261,600	285,100	4, 5
Channel Improvements Downstream Railway	269,300	293,600	4, 5
Mardi Creek Scheme 2 [1]	3,146,300	3,429,500	4, 5

Note: 1 Adopted in current Mardi Creek drainage strategy. These works must be reviewed in incorporate recent RTA road works at the Pacific Highway.

15.2 Economic Assessment of Options

The economic assessment process analyses all the tangible costs and benefits associated with alternative management options. The process provides information for decision makers and for the formulation of capital works programmes.

Intangible costs and benefits are difficult to quantify in monetary values and are excluded from the economic assessment. The intangible costs and benefits are discussed in Section 15.4 - Social Impacts.

The basic feature of the economic assessment is the systematic examination of all advantages and disadvantages of alternative means of meeting an objective ie. improved flood protection. This is achieved by determination of the monetary value of the costs and benefits associated with each option.

Cost-benefit analysis is the most widely used of the economic assessment techniques. However, the nature of benefits derived from alternative flood management options can be widely variable. Therefore, the economic assessment includes an assessment of the relative cost-effectiveness of the floodplain management options. Definitions of the economic parameters are provided in the Glossary.

The tangible benefits derived from floodplain management are reduced direct and indirect damages.

For areas subject to flooding from Mardi Creek, direct damages have been assessed on the basis of one hundred percent of potential damages to buildings and contents . This is considered reasonable, given the relatively short response time of the Mardi Creek catchment and absence of a warning system for this catchment.

It was noted in Section 5.3 that a computer-based flood warning system for the Wyong River has been established in recent years. The system is yet to be tested in a real-time flood event due to the lack of flood producing rainfall. However, it is anticipated that, when operational, the system will enable more accurate forecasts of flooding to be provided to the public with a greater lead time. Thus, residents and occupiers on the Wyong River floodplain will have greater opportunity to prepare for flooding in the future. Such preparation could include sandbagging of doorways, relocation of furniture and contents to higher levels as well as improved safety for evacuation.

Therefore, it has been assumed that, as a result of improved flood warnings, the actual damages suffered in lower Wyong River floods will be less than the potential damages.

The direct damages in areas subject to flooding from the lower Wyong River have been assessed on the basis of estimated actual damages to buildings and contents. The estimated actual damages have been assessed at 95% of the potential direct damages. This is considered reasonable given that residents should have approximately 6 hours warning of major flooding.

Indirect damages for residential and commercial/light industrial properties have been assessed respectively as 20% and 40% of the direct damages, based on experience elsewhere and sample interviews as discussed in Section 5.2.2.

The estimated capital costs of structural works has been based on current construction rates. It has been assumed that the Nett Present Value of construction programmes is equivalent to the current estimated cost ie. future cost increases have been assumed to be equal to the general inflation rate. The annual operation and maintenance costs for the structural works options have been assessed at 2% of capital cost.

The annual cost of the options comprise the annual operation and maintenance costs as well as amortization costs over an economic life of 50 years.
The works in the Mardi Creek catchment are included for comparative purposes, though investigations (2007) indicate that the detention basins upstream of the Freeway will be incorporated into any works proposed on the old “abattoir site”, immediately downstream of the freeway..

A standard discount rate of 7% per annum was adopted for the economic analysis with sensitivity testing using discount rates of 4% and 10% per annum.

The economic analysis of the floodplain management options is summarised in Table 15.2.

The economic assessment of the floodplain management options shows that the recently completed channel improvements to Mardi Creek between Gavenlock Road and the Pacific Highway is the most cost-effective flood mitigation option.

The most cost-effective option for the lower Wyong River was found to be raising of the Pacific Highway bridge over the Wyong River, with a benefit/cost ratio of 0.50. The remaining options for Wyong River flood mitigation have benefit/cost ratios less than 0.4.

The economic analysis in Table 15.2 is based on 2007 values, when the analysis was undertaken. The changes to flood damages from 2007 to 2010 have been assumed to be simply CPI adjustments and thus, the comparative values in Table 15.2 are unchanged by the base date used.

Table 15.2

Economic Assessment of Floodplain Management Options ($ 2007)

	Wyong River Options				
	Panonia Road Levee	Flood Channel	New Highway Bridge	Widen Tuggerah Lakes Entrance	House Raising
Capital Cost	2,856,000	2,142,000	4,800,000	714,000	7,818,300
Annual Maintenance	57,100	42,800	96,000	142,800	-
Capital Amortization @ 7%	207,100	155,400	348,100	51,800	566,900
Annual Cost 7%	264,200	198,200	444,100	194,600	552,600
Nett Present Value	3,643,800	2,733,900	6,568,200	2,684,600	7,818,300
Nett Present Value/Capital	1.276	1.276	1.276	3.76	1.000
Capital Amortization @ 10%	297,000	244,900	484,800	72,100	789,700
Annual Cost 10%	345,600	267,800	580,800	214,900	789,700
Nett Present Value	3,421,500	2,566,100	5,750,300	2,127,900	7,818,300
Nett Present Value/Capital	1.198	1.198	1.198	2.98	1.00
Capital Amortization @ 4%	132,800	99,700	223,200	33,300	363,600
Annual Cost 4%	189,900	142,500	319,200	176,100	363,600
Nett Present Value	4,084,400	3,064,800	6,864,600	3,786,500	7,818,300
Nett Present Value/Capital	1.43	1.43	1.43	5.30	1.00
Direct Damages Reduction *	56,800	22,400	170,800	10,900	135,200
Indirect Damages Reduction	11,400	4,400	66,800	2,300	27,100
Public Damages Reduction	29,400	-	-	-	-
Total Damages Reduction	97,700	26,800	237,300	13,100	162,400
Benefit/Cost @ 7%	0.37	0.14	0.53	0.067	0.29
Benefit/Cost @ 10%	0.28	0.10	0.41	0.060	0.20
Benefit/Cost @ 4%	0.51	0.19	0.74	0.074	0.45
Relative Cost Effectiveness @ 7%	0.02	0.01	0.029	0.003	0.013

*Note: Direct damages reduction for Wyong River flooding assumed equal to 95% of potential direct damages reduction listed in Table 15.1 due to flood-warning enabling actual damages to be less than potential damages.

Table 15.2 (CONT.)

Economic Assessment of Floodplain Management Options
($ 2007)

	Mardi Creek Options			
	Culvert Duplication	**Cobbs Road Detention Basin**	**Channel Works Downstream Railway**	**Scheme 2**
Capital Cost	1,142,400	714,000	714,000	2,599,000
Annual Maintenance	5,700	14,300	14,300	52,000
Amortization @ 7%	82,800	51,800	51,800	188,500
Annual Cost 7%	88,500	66,100	66,100	240,500
Nett Present Value	1,221,200	911,900	911,900	3,317,000
Nett Present Value/Capital	1.069	1.277	1.277	1.277
Amortization @ 10%	115,400	72,100	72,100	262,500
Annual Cost 10%	121,100	86,400	86,400	314,400
Nett Present Value	1,198,900	855,400	855,400	3,113,300
Nett Present Value/Capital	1.05	1.198	1.198	1.198
Amortization @ 4%	53,100	33,300	33,300	122,200
Annual Cost 4%	58,800	47,600	47,600	174,200
Nett Present Value	1,265,200	1,022,600	1,022,600	3,746,600
Nett Present Value/Capital	1.11	1.43	1.43	1.44
Direct Damages Reduction*	674,900	261,600	269,300	3,146,300
Indirect Damages Reduction	268,300	103,800	107,700	1,253,400
Public Damages Reduction	-	-	-	-
Total Damages Reduction	943,200	365,400	377,000	4,399,700
Benefit/Cost @ 7%	10.65	5.53	5.70	18.3
Benefit/Cost @ 10%	7.79	4.23	4.36	13.99
Benefit/Cost @ 4%	16.03	7.68	7.93	25.25
Relative Cost Effectiveness @ 7%	0.577	0.30	0.31	0.99

*Note: Direct damages reduction for Mardi Creek flooding equal to 100% of potential Direct Damages listed in Table 15.1 due to insufficient floodwarning time for damage reduction.

The benefit-cost ratios for all the Mardi Creek flood mitigation options are greater than unity and range

between 5 and 18 for a 7 percent discount rate.
The relative cost-effectiveness of the options is based on the estimated costs and benefits of each option relative to the costs and benefits of the option having the greatest benefit-cost ratio. This enables options which provide differing benefits to be compared. Thus, the relative merits of flood mitigation works for lower Wyong River and Mardi Creek can be compared.

This comparison shows that the community receives a significantly greater benefit from investment in Mardi Creek flood mitigation works than from investment in lower Wyong River flood mitigation works.

Raising the Pacific Highway bridge over the Wyong River was found to be the most cost-effective works option for lower Wyong River flooding with a benefit-cost ratio of 0.5. However, the estimated capital cost of this option is almost 3 times that of the channel improvements to Mardi Creek, which has a benefit-cost ratio of 18.42.

15.3 Environmental Impacts

Current proposals for flood mitigation works on the lower Wyong River floodplain include channel improvements along Mardi Creek, levee construction, bridge and culvert replacement, construction of a detention basin on Mardi Creek, excavation of a bypass flood channel and widening of the entrance of Tuggerah Lakes.

The nature of the environmental impacts expected to result from construction of the proposed works are reviewed below. This review is based on the general extent of works to be carried out for each of the conceptual designs, as identified in Reference 9.

15.3.1 Panonia Road Levee

The site of the Panonia Road levee is proposed on private land immediately adjacent to Wyong River. This levee adversely affects the visual quality of the river foreshore and adjoining properties by reducing the extent of the view and removing existing waterfront improvements. Along the Wyong River foreshore, there is little land available for development and it would require the acquisition of private land. Administration of such a programme will involve some complexities in terms of purchase costs, obtaining owner agreements and coordinating works to minimise visual impacts.

Depending on the design of the levee and the exact location it could result in some limited loss of foreshore vegetation, although this impact is likely to be minimal as the area is predominantly cleared for residential development.

15.3.2 Floodway Channel from Charlton Island to Tuggerah Lakes

The construction of the proposed floodway channel from Charlton Island to Tuggerah Lakes will have several impacts on the vegetation and fauna habitats in the immediate vicinity of development. Although the area identified for the establishment of the channel is partially cleared, there will be some loss of vegetation within the wetland area. Access to the site for development will also result in the destruction of vegetation by trucks and other equipment entering the site during construction. The area to be affected has been identified as a `significant' wetland area by Council and is subject to Council's DCP No. 30. Thus, the

criteria and controls identified within the DCP should be considered in the review of development options for the channel.

The site for the channel is also near SEPP 14 Wetlands Number 900 and 901. While the construction will not impact directly on these areas, any changes in hydrology as a result of the channel may result in a change in the local ecology. This has potential implications for the wetland areas identified in Council's DCP and, to a lesser extent, the SEPP 14 wetlands adjacent.

The vegetation to be removed may be habitat to several species of amphibians, mammals and birds and may involve the removal of some winter flowering species, including *E. robusta*. Any loss of this vegetation may affect fauna habitat, including fauna identified under Schedule 12 of the National Parks and Wildlife Act, 1974. However, further assessment will be required to determine this.

Prior to resolution of channel design, a site specific vegetation assessment will be required to determine the implications for vegetation community structures and specific species loss. A Fauna Impact Statement may also be required.

Studies carried out by the Department of Land and Water Conservation have identified the potential risk of acid sulphate soils throughout the Wyong region. These studies, although not site specific, indicate that the area identified for development of the floodway channel has a high probability of acid sulphate soils and that these soils are likely to be located between 1 to 3 metres from the surface. Given the potential localised nature of acid sulphate soils, a more detailed geotechnical testing regime is required prior to completion of any design, as the depth and location may be affected.

15.3.3 Raising of Pacific Highway Bridge

This action will result in only minor alterations to bridge design with minimal environmental impact on the system, although there may be minor damage to foreshore vegetation and disturbance of benthic material during the construction period.

15.3.4 Upgrade Channel From the Railway Line to Tuggerah Oxbow Wetland

Tuggerah Oxbow (also known as Pioneer Dairy wetland) currently falls under SEPP 14 - Coastal Wetlands. Any proposed works within the SEPP 14 wetland area will require an Environmental Impact Statement to identify any significant environmental effects on the wetland and approval from the Department of Environment, Climate Change and Water (DECCW) prior to works commencing.

It is unlikely that channel improvements will extend more than about 200 m downstream of the railway and will end some 800 m upstream of the SEPP14 area.

Any construction works associated with channel upgrading will also need to address the provision of Council's DCP No. 30. Primarily, the loss of vegetation adjacent to the existing creek line will need to be assessed by a site specific vegetation survey to determine the extent of loss.

The impact of this option on water quality should also be assessed and consideration made of the proposal to redirect this channel to bypass the lagoon entirely.

15.3.5 Detention Basins on the Southern Side of Cobbs Road

The basin site has been identified on the original abattoir site. This site is largely cleared and thus the establishment of the basin will result in little or no loss of vegetation. This site is currently under the control of Department of Planning as a "State Significant Site". Given private ownership of the site, use of the land for catchment based flood mitigation purposes is unlikely without land acquisition.

15.4 Social Impacts

Construction of a levee along the northern bank of the Wyong River, downstream of the railway, is likely to produce a variety of social impacts. The owners of the riverfront properties will suffer disruption during the construction period and a perceived loss of amenity following construction of the levee.

The resultant benefits of the levee scheme may not be considered to be commensurate with the impacts.

Landowners remote from the immediate vicinity of the works are likely to react more favourably to the levee construction

The proposed excavation of a flood bypass channel from Charlton Island to Tuggerah Lakes is likely to be opposed by the wider community on environmental issues.

Replacement of the Pacific Highway bridge over the Wyong River is likely to cause significant disruption during the construction period. In the longer-term, it is expected that this option would be received favourably by the community.

It is anticipated that duplication of the Mardi Creek culverts under the Pacific Highway and railway would produce similar social impacts to those produced by the replacement of the bridge over the Wyong River.

House raising can have an impact on the lifestyle of property owners, particularly when access to the house is significantly altered. Such access difficulties are felt more acutely by the elderly and disabled. The majority of houses considered under this option would be raised by 1.2 to 1.5 metres in order to provide a freeboard of 0.5 metres above the 1% AEP flood level. It is likely that some property owners will opt for raising the house by more than 2 metres in order to provide non-habitable floor space under the house. Some residents in similar schemes in other local government areas have regarded the final result of house raising as unsatisfactory.

The general streetscape could be significantly altered where houses are raised significantly.

The long-term impacts of house raising are considered to be small. However, there will be disruption to the residents' way of life during the carrying out of the house raising. It may also take a short time to re-establish gardens and landscaping after the house raising.

The channel improvements to Mardi Creek are expected to cause minimal social impact, as would the construction of the detention basin on the old abattoir site.

15.5 Comparison of Floodplain Risk Management Options

The merit approach outlined in the NSW Government Flood Policy requires several factors to be considered in the selection of a preferred floodplain management strategy, including:

- flood mitigation effectiveness;
- environmental impacts;
- social impacts; and
- economic performance.

One suitable technique to compare options is to prepare a matrix that would enable all options to be compared with reference to relevant criteria.

Clearly, one option is to maintain the current planning and development system without major works. This is identified as the "Status Quo" option.

The comparison matrix presented in Table 15.3 compares the existing situation (Status Quo) and 14 management options against 19 criteria used to evaluate or identify flood mitigation effectiveness, economic performance, environmental impacts and social impacts. The evaluation criteria are defined below.

1. *Buildings protected in the 1% AEP design flood* - number of existing flood-liable buildings that would be protected in the 1% design flood as a result of option.

2. *Reduced flood risk* - assumed to be equivalent to the percentage reduction in mean annual damages as a result of option.

3. *Localised Adverse Hydraulic Impacts* - defined as increases in depth velocity or rate of rise of floodwaters in or adjacent to protected area.

4. *Capital cost* - estimated cost of investigation, design and construction of works option.

5. *Operating Cost* - annual operating and maintenance costs.

6. *Damages Reduction* - reduction in mean annual damages (direct and indirect) due to option.

7. *Benefit-cost ratio* - ratio of reduction in mean annual damages (direct and indirect) to full annual cost (operation, maintenance and amortization) of option.

8. *Economic sensitivity* - change in benefit-cost ratio for 1% variation in discount rate.

9. *Recurrent-Capital ratio* - ratio of capitalised operating and maintenance costs to capital cost of project.

10. *Nett Present Value* - sum of capital cost plus capitalised operating and maintenance costs of option.

11. *Relative cost-effectiveness* - ratio of benefit-cost ratio of option to the highest benefit-cost ratio of

all options examined.

12. *Affordability* - ratio of the cost of the option having the highest benefit-cost ratio to cost of option.

13. *Access* - ratio measure of serviceability of road network during flood periods, assessed on the basis of reduction in inundated area in 1% AEP event.

14. *Safety* - ratio measure of reduced risk to life within flood-liable area, assessed as the reduction in premises flooded in the 1% AEP flood.

15. *Community Acceptance* - perceived relative acceptance of option by the community in general and those directly affected by option.

16. *Flora* - impact on existing flora due to option.

17. *Fauna* - impact on existing fauna due to option.

18. *Visual impact* - impact of option on local landscape.

19. *Recreation* - impact of option on recreation use of open space areas.

The economic analysis in Table 15.3 is based on 2007 values, when the analysis was undertaken. The changes to flood damages from 2007 to 2010 have been assumed to be simply CPI adjustments and thus, the comparative values in Table 15.3 are unchanged by the base date used.

Table 15.3

Comparison Matrix For Floodplain Management Options

Criteria	Options					
	Status Quo	**Panonia Road Levee**	**Flood Channel**	**New Highway Bridge**	**Widen Tuggerah Lakes Entrance**	**House Raising**
1. EFFECTIVENESS						
- Houses protected 1% AEP flood	-	155	1	1	10	219
- Reduced flood risk	-	0.9%	0.35%	2.67%	0.17%	2.12%
- Localised adverse hydraulic effects	No	Yes	No	Negligible	No	No
2. ECONOMICS						
- Capital cost	-	2,856,000	2,142,000	4,800,000	714,000	7,825,400
- Annual operation and maintenance	-	57,100	42,800	96,000	142,800	-
- Annual damage reduction	-	97,700	26,800	237,300	13,100	162,400
- Benefit - cost	-	0.37	0.14	0.53	0.067	0.29
- Sensitivity	-	0.04	0.015	0.10	0.002	0.04
- Recurrent / capital	-	0.276	0.276	0.276	2.76	-
- Nett Present Value	-	3,643,800	2,733,900	6,568,200	2,684,600	7,825,400
- Relative cost effectiveness	N/A	0.02	0.01	0.053	0.003	0.013
- Affordability	N/A	0.20	0.27	0.22	0.27	0.093
3. SOCIAL						
- Access	-	4%	-	-	-	-
- Safety	-	3.7%	-	-	2%	41.6%
- Acceptance	Moderate	Low - Moderate	Low	Moderate	Moderate	Low - Moderate
4. ENVIRONMENT						
- Flora	No	Possible	Yes	No	No	No
- Fauna	No	Possible	Yes	No	No	No
- Visual	No	Yes	Yes	Improve	Minor	Possible
- Recreation	No	Yes	Minor	No	Minor	Minor

Table 15.3 (CONT.)

Comparison Matrix For Floodplain Management Options

Criteria	Options			
	Culvert Duplication	**Cobbs Road Basin**	**Channel Works Downstream of Railway**	**Scheme 2**
1. EFFECTIVENESS				
- Houses protected 1% AEP flood	6	6	6	62
- Reduced flood risk	10.6%	4.11%	4.23%	49.43%
- Localised adverse hydraulic effects	Moderate	Minor	Minor	Moderate
2. ECONOMICS				
- Capital cost	1,142,400	714,000	714,000	2,599,000
- Annual operation and maintenance	5,700	14,300	14,300	52,000
- Annual damage reduction	943,200	365,400	377,000	4,399,700
- Benefit - cost	10.65	5.53	5.70	18.3
Sensitivity	1.37	0.58	0.6	3.0
- Recurrent / capital	0.069	0.277	0.277	0.16
- Nett Present Value	1,221,200	911,900	911,900	3,313,000
- Relative cost effectiveness	0.577	0.30	0.31	0.99
- Affordability	0.60	0.80	0.80	0.22
3. SOCIAL				
- Access	-	-	-	-
- Safety	1%	1%	1%	12%
- Acceptance	Moderate - High	Low	Low - Moderate	Moderate
4. ENVIRONMENT				
- Flora	No	Minimal	Minimal	Minimal
- Fauna	No	Minimal	Minimal	Minimal
- Visual	Minor	Yes	Yes	Yes
- Recreation	No	No	No	No

Analysis of the data presented in the comparison matrix is summarised in Table 15.4 which shows the relative performance of each of the options against the evaluation criteria category. The relative performance is ranked from 1 for the highest. Equal weightings have been attached to each of the four criteria in order to assess the ranked order of the options.

Table 15.4

Summary Comparison of Floodplain Management Options

Options	Criteria				Overall	Rank
	Effectiveness	Economics	Social	Environment		
Status Quo	15	3	9	1	30	3
Panonia Road Levee	7	12	12	14	45	9
Flood Channel	14	14	15	15	58	10
Replace Highway Bridge	13	11	7	3	34	4
Widen Tuggerah Lakes Entrance	12	15	8	4	39	6
House Raising	6	13	11	8	38	5
Culvert Duplication	8	7	2	6	23	2
Cobbs Road Detention Basin	10	9	14	10	43	8
Channel Works Downstream Railway	11	8	13	9	41	7
Mardi Scheme 2	1	3	4	11	19	1

The results presented in Table 15.4 indicate that the channel improvements to Mardi Creek between Gavenlock Road and the Pacific Highway is the superior works option. These works have been undertaken during the study period

The Mardi Scheme 2 works option was the first ranked option. This option includes duplication of the culverts under the Pacific Highway and railway, which was ranked second as an independent works option. This scheme has been adopted as the drainage strategy for Mardi Creek

The `Status Quo' option was ranked third, following the channel improvements to Mardi Creek and duplication of the culverts under the Pacific Highway and railway.

Raising of the Pacific Highway bridge over the Wyong River was found to be the best performed option for Wyong River flood mitigation, followed by house raising.

Both of these options are ranked below the `Status Quo' option and are thus considered to be marginally desirable. The house raising option may be more desirable from the landowners' point of view, depending on the funding arrangements for such work.

The top five priority ranking of flood mitigation options, based on the assessment of the feasible flood mitigation options is:

(i) channel improvements to Mardi Creek between Gavenlock Road and the Pacific Highway (these works were constructed circa 1996);

(ii) augmentation of the Mardi Creek culverts under the Pacific Highway and Main Northern Railway (requiring further review due to recent RTA road works on the Pacific Highway and maintenance operations along the Main Northern Railway);

(iii) Status Quo (continuing with existing practices);

(iv) raising of the Pacific Highway bridge over the Wyong River; and

(v) implementation of a house raising programme.

16. FLOODPLAIN RISK MANAGEMENT OPTIONS - FUTURE AND CONTINUING FLOOD RISK

16.1 General

The current Local Environmental Plan land zonings for the Wyong River floodplain are shown on Figure 15. This map shows that the flood-liable land is comprised of lands zoned for the following purposes:

- residential;
- business;
- light industrial;
- rural;
- open space;
- major special use areas; and
- environmental protection.

The future residential development on the floodplain is effectively restricted to infill development in the Panonia Road-Boyce Avenue area immediately downstream of the Pacific Highway and in the Tacoma and Tacoma South residential areas. These areas generally can be classified as `High Hazard-Flood Fringe'.

There is potential for some future house construction to be undertaken on rural properties. These rural properties are generally located in `High Hazard - Flood Storage' areas on the lower floodplain.

There are some 20 remaining vacant sites or undeveloped lots within the Tuggerah Straight Industrial Area that could be the subject of development applications.

The bulk of future development on the floodplain will be within or adjacent to existing developed areas and will potentially derive some flood mitigation benefits from any proposed works undertaken for flood mitigation of existing development.

Wyong Shire Council has relied on its Flood Prone Land Development Policy over the past 20 years to control development on the floodplains.

In Section 5.2.1 of this report, it was noted that some 85 additional domestic buildings have been constructed on the floodplain (comprising 64 completely new buildings and 11 replacement buildings) between 1995 and 2007. In the Tuggerah Straight Industrial Area, 53 new developments (between 1995 and 2007) were identified from the 1995 potential of 80 to 100 buildings.

In the consultant's view, Council's existing policy has a number of inconsistencies, as follows:

- freeboard allowance;
- use of floodways; and
- use of flood fringe (new developments).

The current flood policy specifies a minimum freeboard of 0.3 m above the designated flood level, whereas the Floodplain Development Manual recommends a minimum freeboard of 0.5 m.

Freeboard is a factor of safety which is intended to compensate for localised hydraulic affects, wave action and other factors, such as uncertainty in the predicted flood level. Freeboard is not intended to provide protection against floods greater than the design flood event.

In the consultant's opinion, the freeboard required under the existing Flood Prone Land Development policy provides the minimum acceptable factor of safety for the study area. Whilst the freeboard may be the minimum acceptable based on the river hydraulics, it provides only limited protection against the bow wave created by vehicles moving along inundated roads or speeding boats. It is suggested that Council give consideration to increasing the freeboard requirement for residential buildings to conform to the Manual recommendations.

Consideration must also be given to climate change, particularly sea level rise impacts, with regard to DECCW's "Sea Level Rise Policy Statement" 2010.

The higher freeboard requirement would add approximately $4,000 to the cost of a new house. The additional cost of building at the higher level is significantly less than the replacement cost of floor coverings which would be destroyed with minimum depth of flooding.

The estimated reduction in mean annual flood damages for the higher freeboard requirement has a tangible benefit-cost ratio of 0.4. It is not possible to attach a monetary value to intangible benefits, including reduced trauma associated with flooding. However, it would seem reasonable to assume that the combined tangible and intangible benefits would exceed the marginal costs incurred in adopting the higher freeboard for residential properties.

Thus, it is considered that increasing the freeboard for residential properties to 0.5 m as recommended in the Manual, can be justified on the basis of the reduced direct and indirect damages and intangible benefits, including greater sense of safety.

Development within existing urban areas is "usually permitted" in High Hazard areas under the existing policy. Thus, the policy allows infill development, including subdivision, filling and erection of buildings, subject to specific conditions of approval, but does not appear to require that flooding conditions at other locations are not significantly affected.

Floodways are areas where the depth and velocity of floodwaters may cause structural damage to buildings and may pose a risk to the safety of persons attempting to wade through the floodwaters. Floodways, by their definition, are areas which, if blocked, cause an increase in flood levels and a re-distribution of flood flows to other parts of the floodplain.

The northern end of the Tuggerah Straight Industrial Area is located within "High Hazard - Floodway" as shown on Figure 12.

The flood-liable section of the east Wyong residential area is located in a "High Hazard - Floodway" area, where the depth of floodwaters exceeds 0.75 m and the velocity of floodwaters is typically 0.6 m/s. Thus, floodwaters may pose a risk to the safety of persons attempting to wade.

New development is not considered to be appropriate in High Hazard areas.

Thus, the consultant considers that future development within “High Hazard" areas should either be prohibited or considered on its merits rather than "usually permitted" under the policy. Similarly new development in “Low Hazard – Flood Fringe” should be considered “On merits”. Conversion to “On merits” designation would create greater consistency with the intent of the Floodplain Development Manual. A recommended revision of the development guidelines appears as Table 16.1 below with accompanying text in italic text.

Table 16.1

Proposed Assessment of Development for Flood-prone Lands

Type of Development [7]	Flood Hazard Categories					
	Flood Fringe		Flood Storage		Floodway	
	Low Hazard	High Hazard	Low Hazard	High Hazard	Low Hazard	High Hazard
LAND ZONED RESIDENTIAL [1] [2] [3] [4] [5] [6]						
Concessional (see definition below)	On Merits	On Merits	On Merits	On Merits	Unsuitable for Development	Unsuitable for Development
Infill development				On Merits		
New Development				Unsuitable for Development		
LAND ZONED COMMERCIAL / LIGHT INDUSTRIAL / INDUSTRIAL OR SIMILAR [3] [4] [5] [6]						
Concessional (see definition below)	On Merits	On Merits	On Merits	On Merits	Unsuitable for Development	Unsuitable for Development
Infill development				On Merits		
New Development				Unsuitable for Development		
LAND ZONED RECREATION, OPEN SPACE, CONSERVATION ZONE, NON URBAN CONSTRAINED LANDS, SPECIAL USES [1] [2] [3] [4] [5] [6]						
Structures, including buildings and filling	On Merits	On Merits	On Merits	Unsuitable for Development	Unsuitable for Development	Unsuitable for Development
Other developments permissible in zone, i.e. wetlands, playing fields, parks, walkways, etc…	On Merits	On Merits	On Merits	On Merits	On Merits	On Merits
REZONING TO MORE INTENSE LAND USE	On Merits	On Merits	On Merits	Unsuitable for Development	Unsuitable for Development	Unsuitable for Development
ALL ZONE TYPES SUBDIVISION	On Merits	On Merits	On Merits	Unsuitable for Development	Unsuitable for Development	Unsuitable for Development

Notes:

[1] The maximum size of residential (enclosed) garages in high hazard flood storage areas is proposed at 50 m^2. This is based on the size of a double car garage and small storage area. The cumulative

impact of garages larger than these in the floodplain is considered high. Open styled carports are considered more appropriate in this area.

(2) Freeboard for all development is to be increased to 500mm in line with the Floodplain Development Manual and current best practice.

(3) Fencing must not result in any significant obstruction of the flow of floodwaters. Continuous solid fencing will not be permitted in high hazard areas.

(4) Environmental Improvement works sympathetic to the surrounding environment and Essential Infrastructure are to be considered on merits in all flood hazard categories.

(5) The construction of new or upgrade of existing roads will be considered on merits.

(6) Mine subsidence areas will have an additional allowance added to it. Please refer to the Mine Subsidence Board for further information.

(7) Development Categories

Concessional Development is considered as the following:

- *Dwelling additions up to 40m^2 at no less than the same level as the existing approved building. The allowance for additions shall be made no more than once for any given property.*

- *Additions to Commercial and Industrial Uses of up to an additional 100 m^2 or 20% (whichever the less) of the Gross Floor Area of the existing building at no less than the same level as the existing building. The allowance for additions shall be made no more than once for any given property*

Infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land.

New development: refers to development of a completely different nature to that associated with the former land use.

Redevelopment: refers to rebuilding in an area as urban areas age.

NOTE - Anything that is to be "considered on merits" must be referred to a DA Engineer.

The Policy would have greater significance and impact if it were incorporated into a Development Control Plan (DCP).

It is further noted that the Flood Prone Land Development Policy prevents re-zoning of High Hazard land to more intense land uses.

16.2 Tuggerah Straight Industrial Area

The 1992 study (Ref 7) found that filling to 1% AEP flood level for future development in the Tuggerah Straight Industrial Area would significantly affect flood levels between the Freeway and the Pacific Highway. These results were reviewed for the current study and additional hydraulic modelling indicated that the resultant increase in 1% AEP flood levels for filling to 2% AEP flood level would be less than 0.1 metres upstream (west) of Gavenlock Road and less than 0.05 metres between Gavenlock Road and the Pacific Highway.

The 2% AEP flood has been adopted as the Designated Flood event for the Tuggerah Straight Industrial Area.

Thus, it is concluded that future filling and development within the Tuggerah Straight Industrial Area will produce a minor increase in flood levels and damages for existing development. A preliminary assessment of the resultant flood damages indicates that mean annual flood damages may be increased by approximately $125,000. This represents an increase in mean annual flood damages for the Tuggerah Straight Industrial Area equal to 1.5% of existing damages.

In 1996, it was noted that the damages to be incurred by further development would increase the total flood damages for the area by a further 15% to 20% due to the greater number of premises flooded. The development envisaged in 1995 has occurred.

The damages incurred by future development could be reduced by introducing a freeboard requirement for commercial and industrial developments. For example, if a freeboard of 0.3 m was introduced, future floor levels would be 0.1 to 0.2 m above the 1% AEP flood level. The marginal cost for the higher floor level would be significantly less than the resultant reduction in flood damages. It is estimated the benefit-cost ratio is approximately 1.5. Such an option would have to be investigated in further detail if it is to be introduced, to ensure raising floor levels does not introduce other constraints, such as vehicular access to buildings / loading docks.

16.3 Rural Residential Development in the Deep Creek Area

The impact of the construction of flood mounds for rural-residential development along Mardi Road was investigated in Ref. 10. This investigation found that flood levels along Deep Creek, between the Sydney-Newcastle Freeway and the Wyong River, would be increased by a maximum of 30 millimetres with no change in flood level produced elsewhere on the floodplain. Thus, it can be concluded that the construction of flood mounds in the rural-residential area is unlikely to have a significant impact on flood behaviour.

Whilst the flood models suggest it is possible to provide individual protection to dwellings in the Deep Creek area, emergency access to and from isolated buildings during flood time will be difficult. Thus, it would not be prudent to allow unrestricted development in this area.

A prudent response to development pressure is then:

- prohibit re-zoning in the area unless such re-zoning is to a lower population density zoning;
- prohibit further sub-division that would create additional lots and potential building entitlements.

16.4 Railway Embankment

SRA had proposed to raise the Main Northern Railway by 0.15 to 0.2 m between Mardi Creek and the Wyong River. This proposed raising of the railway has been partially carried out in recent years as a result of re-ballasting and/or part of the electrification project in the 1980's. The impact of this proposed raising of the railway line was investigated in Reference 11, which found that flood levels in the Tuggerah Straight Industrial Area would be increased by a maximum of 0.16 metres unless additional culverts were provided under the railway embankment.

The size of the additional culverts was not determined but was viewed as likely to be large.

The increase in flood levels would increase the estimated mean annual flood damages for the Tuggerah Straight Industrial Area by approximately $105,000 (some 2 percent) for existing development.

Clearly, Wyong Shire Council will need to maintain a dialogue with the railway infrastructure operators (in this case, Rail Corporation NSW) to ensure any future raising of the embankments or rail levels are compensated for by additional culverts beneath the railway embankment.

16.5 Wyong Nursing Home

The Wyong Nursing Home, located on the southern bank of the Wyong River channel, upstream of the Pacific Highway, is a major source of concern regarding flood liability and flood evacuation. The Nursing Home has developed over a number of years and currently has approximately a 90 bed capacity for high care patients.

The existing floor levels of the buildings range from RL 4.35 m AHD to RL 4.95 m AHD.

The buildings are located on a relatively high knoll with vehicular access from McPherson Road.

Ground levels along the access route are of the order of RL 2.8 m AHD to RL 3.0 m AHD. The design 1% AEP flood levels at the site is RL 5.25 m AHD, while the design 10% AEP flood level is RL 4.2 m AHD. Thus, while the floor levels are above the highest recorded flood, there is a significant issue relating to flood evacuation.

The flood evacuation routes from the Nursing Home will be cut in a once in 5 year (20% AEP) flood. The residents will be forced to either remain or be evacuated by boat. The Nursing Home has prepared a flood warning and evacuation plan, which relies on its own staff to organise the flood warning and facilitate the evacuation.

In the June 2007 flood, the Nursing Home relied on the SES for flood warning and flood evacuation. Given the Nursing Home will have staff skilled in the care of the home's residents and the operation of the Nursing Home, it seems unrealistic to expect the same staff to operate a flood warning system.

A more reliable system of evacuation would be:

- SES to provide warnings to evacuate the Nursing Home;
- the SES to assist in the actual evacuation;
- the Nursing Home to be responsible for the alternative accommodation and care of residents until the evacuated buildings can be re-occupied.

17. CONCLUSIONS

A number of conclusions can be drawn from the Floodplain Risk Management Study which lead to inclusions in the Floodplain Risk Management Plan. These conclusions are as follows:

- The study area (Wyong River and Mardi Creek from Woodbury's Bridge to a point 1.4 kilometres upstream from Tuggerah Lakes) covers some 18.34 sq kilometres. Thirteen (13) percent of the study area is zoned "Wetland Management Zone" while ten (10) percent is zoned as "Open Space". The remainder is generally cleared and used for residential, commercial/industrial uses and agriculture (grazing).

- There are 404 houses on the floodplain with floor levels below the 1% AEP flood level.

- There are 148 commercial and light industrial premises on the floodplain.

- The total average annual flood damage is some $9.22 million. The ranking of the contributions to flood damage are:

    - Commercial/Industrial: 82 percent
    - Public Utilities: 11 percent
    - Residential: 7 percent

- The commercial/industrial damage is virtually all sustained in the Tuggerah Straight Industrial Area.

- Wyong Shire Council's development control has been based on their Flood Prone Land Development Policy (circa 1986). The increase in buildings on the floodplain in the past 15 years suggests that the Policy is not achieving its objectives of minimising the financial and emotional cost of flooding.

  The Flood Policy should be updated and incorporated into a Development Control Plan. The creation of the DCP and its public exhibition will provide greater public awareness of floodplain management and will have greater standing in the Land and Environment Court. It is understood that the development of such a DCP is currently underway.

- The Lower Wyong River has an operational flood warning system, though it has not been tested in a large flood. Similarly, the general lack of floods has the potential to create a situation where on-going maintenance of the flood warning system and infrastructure is overlooked.

- The 2005 Floodplain Development Manual introduces concepts of:

    - flood risk;

    - flood modification, property modification and responses modification measures to mitigate flood risk;

- flood planning levels (FPLs) based on a design (or historical flood) plus an appropriate freeboard; and

- the PMF event as the measure to classify "flood liable land".

A variety of flood modification and property modifications have been examined as ways to address existing flood risks. Other than works in Mardi Creek (which have been virtually completed), none of the measures examined are attractive in terms of capital required, reductions in flood damages, or by benefit/cost analysis.

- Continuing flood risk occurs through the continued existence of development in the flood liable land areas, while, essentially, future risk relates to future development.

- The principal mechanism for managing continuing and future flood risk is via development controls.

- Council's current development controls for flooding derive from the Flood Prone Land Development Policy, dated circa 1986. The Policy should be incorporated into a Development Control Plan and modified with regard to the freeboard requirements, the development types covered and criteria adopted.

- Additional measures appear warranted for rural residential development in the area.

- Changes to the Main Northern Railway Line and the Pacific Highway have the potential to significantly increase flood levels. The impacts on flooding of the recent significant road works along Tuggerah Straight by the RTA are unknown. Whilst this infrastructure is owned and operated by other government instrumentalities, Wyong Shire Council should continue to monitor works on the infrastructure links.

- The vulnerability to flooding of the Wyong Nursing Home has been a source of on-going concern to Wyong Shire Council, however, the flood warnings for evacuation are now issued by the SES and the evacuation of residents (should the need arise) appears more likely . In this situation, the appropriate action for Wyong Shire Council is a continuing dialogue with SES and the Nursing Home to ensure adequate warning and evacuation measures remain in place.

- The lack of floods in the past 20 years has diminished the general public's awareness of flood risk. This should be addressed by a public education program. A revision of the Flood Liable Lands DCP would assist in this regard.

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FIGURES