NSW GOVERNMENT | Public Works

WAGGA WAGGA LEVEE UPGRADE

Concept Design Report

Report Number: DC 11177

December 2011

Wagga Wagga City Council

A division of the Department of Finance and Services

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1. Introduction

The city of Wagga Wagga is located on the Murrumbidgee River and the catchment area, at the city, is 26,400 km2. It has a population of approximately 60,000 and, on numerous occasions since official records began in 1886, has been threatened by major floods.

The city is protected from flooding by three levee systems with a total length of approximately 15 km. The main levee protecting Wagga Wagga, south of the Murrumbidgee River, was originally constructed in the 1960's, and subsequently upgraded between 1978 and 1983 to a level 1 metre above the record 1974 flood. This flood is now considered to be a 60 year ARI event.

Temporary levees had been constructed around North Wagga Wagga since 1936. In 1990, a levee was constructed to provide flood security for a 1 in 20 year flood.

These flood levees are generally well maintained and their condition has been audited on at least two occasions (1993, 2007). Findings from these audits included :-

- The levee may need to be raised in some areas to provide the required level of flood security.
- Some areas of river banks, which support the town levees, may need to be stabilised
- Trees and shrubs, which are growing on the levee, should be removed
- There are areas of the levee where minor erosion is evident.

Wagga Wagga City Council has also initiated the development of a Floodplain Risk Management Plan to address the management of the flood problem around Wagga Wagga. The plan has included :-

- Flood Study to define design flood levels, flows and velocities (2004, 2006)
- Floodplain Risk Management Study (2009)
- Floodplain Risk Management Plan (2009).

One of the high priority recommendations of the Floodplain Risk Management Plan is to investigate the feasibility of raising the flood levees at Wagga Wagga. This priority recommendation will be achieved by the development of a costed and feasible concept/preliminary design for the levee upgrade, such that further planning and project development can proceed.

This report presents the recommended Concept Design for raising the flood levees to the required design levels.

2. Design Criteria and Assumptions

In order to develop and progress the designs to the concept stage, a number of design criteria and assumptions have been adopted. As designs progress beyond the concept phase, these assumptions may need to be re-considered and appropriate design modifications included. Nevertheless, at this concept phase, design criteria and assumptions that have been adopted include those as listed below.

Levee Concept Designs

- The scope of the concept design is to be sufficient to provide a cost estimate and basis for proceeding to detailed design and/or modifications to accommodate the proposed precinct works.
- The existing levee is in a reasonable condition, and has been proven by successful operation during past floods.
- The concept design is based on the current geotechnical information and assessed condition of the levee.
- The concept design of the levee upgrade works will be compatible with proposed levee precinct works, but will not include any of the specific precinct works concept or designs.

Design Flood Levels.

- Design Flood Levels (DFL) for the Main Levee are taken from the WMA report (Ref 1 : Figure 25) for the 1% AEP flood.
- Design Flood Levels (DFL) for the North Wagga Wagga Levee and Bank Two Levee are taken from the WMA report (Ref 1 : Figure 29) for the 5% AEP flood.

Flood Freeboard.

- Freeboard allowance is provided from the NSW Public Works report (Ref 13).

Spillways

- Spillways act to minimise the development of hazardous flows within the levee and as such are located at or near the lower parts of the protected areas.

River Bank Stability.

- River banks are stable and/or the concept design will not reduce bank stability.

City Services.

- The city drainage system is satisfactory, and it is only required to extend the length of existing pipes where necessary.
- Power, communication, sewer etc are assumed to be unaffected by the upgrade works.

Road Crossings.

- Where road crossings are above DFL, temporary flood closure systems will be used.

- Where major road crossings are below DFL, permanent flood gates will be installed
- Where minor road crossings are below DFL, the road crossings will be raised.

Flood Warning Time.

- There will be sufficient flood warning time to allow for installation of flood gates.

Levee Alignment.

- The alignment of the augmented levee will follow the alignment of the existing levee, wherever feasible.

Geotechnical Information.

- The existing geotechnical information is representative of the condition of the entire levee.
- The area at the golf course (rubbish tip) is sufficiently impermeable and will not fail due to uncontrolled or excessive seepage.

3. Geotechnical Investigation

3.1 Geotechnical Information

Information regarding the condition and geotechnical properties of the levee, foundations and potential borrow areas is available from several reports. These reports are :-

- Murrumbidgee River Levee Bank Assessment. Aitken and Rowe. 17 August 2007. (Ref 1)
- Borrow Pit Investigation for Levee Bank Construction. Aitken and Rowe. 17 January 2008. (Ref 2).
- Geotechnical Investigation at Levee Bank. Aitken and Rowe. 15 December 2009. (Ref 3)
- Borrow Pits Investigation for Levee Bank Construction – Tasman Road Pit and Kooringal Road Pit. Aitken and Rowe. 15 December 2009. (Ref 4).
- Geotechnical Investigation for Proposed Riverbank and Levee Protection Works. Jeffery and Katauskas P/L; 5 August 2005 (Ref 5), 31 August 2005 (Ref 6), 24 November 2005 (Ref 7), 14 March 2006 (Ref 8).

A summary of the findings of each of the investigations is provided as follows :-

Reference 1.

This investigation was undertaken along the length of the Main Levee. It included drilling of twenty five (25) bore holes to 5 metres depth, Dynamic Cone Penetrometer (DCP) testing and in-situ density testing at fifteen (15) locations on the crest of the levee. The purpose of the investigation was to determine the nature and type of the existing levee bank and to assess its condition.

The borehole investigation revealed that the levee bank is comprised of low to medium plasticity silty clay, sandy clay and medium to high plasticity silty clays. The levee is commonly underlain by natural alluvium comprising low plasticity clayey silt, silty clay, sandy clay and medium to high plasticity silty clay.

The embankment material appeared to be placed “uncontrolled” and there were inconsistencies in the degree of compaction. Laboratory testing indicated permeabilities of up to 9×10^{-9} m/sec on low plasticity sandy clays. Insitu densities were of the order of 90% (relative density) and Emerson Class values were generally in the range of 1 - 2 (ie potentially dispersive).

Remedial measures recommended in the report included :-

- Placement of a clay liner for stability and seepage control, requiring some cut and fill (to the existing levee embankment).
- Strip vegetation and topsoil from levee areas to be upgraded.
- Proof roll exposed surface
- Place imported clay fill, in 150mm layers (compacted) at 98% MDD and -2% to 0% of OMC.
- Inner and outer batters of the upgraded levee to be provided with a protective layer of topsoil.

Reference 2.

This investigation was undertaken to provide geotechnical information for materials from the proposed borrow pit located approximately 1.2 km from the junction of Rowan and Marah Streets in North Wagga Wagga. Twenty (20) boreholes were drilled at the site, to a depth of 5 metres, and representative samples were recovered for laboratory testing.

The investigation revealed that the borrow pit site is generally covered with 0.1 – 0.2 m of topsoil which overlies natural alluvium deposits comprising low to medium plasticity clayey silt, silty clay and medium to high plasticity silty clays. Some areas exhibited low to medium plasticity sandy clay, fine to medium grained clayey sand and clayey sandy gravel at depth.

Permeabilities of the materials ranged from 1×10^{-9} to 2×10^{-10} m/sec. Emerson Class values were generally in the range of 1 – 2 (ie potentially dispersive).

Recommendations from the report were :-

- The silty clay and sandy clay encountered in the borrow area is considered to be suitable for levee construction.
- The clayey sand and clayey sandy gravel materials are not recommended for use in levee bank construction.
- Strict compaction control is required during placement of the materials.

Reference 3.

This investigation was undertaken along the length of the North Wagga Wagga and Bank Two Levees and at selected locations on the Main Levee. It included drilling of fourteen (14) bore holes to depths ranging from 2.7 to 6.5 metres, Dynamic Cone Penetrometer (DCP) testing and insitu density testing. Unconsolidated tri-axial tests were also carried out on three (3) undisturbed samples. The purpose of the investigation was to determine the nature, type and condition of the existing levee bank and to assess its condition.

The borehole investigation revealed that the levee bank is comprised of low to medium plasticity silty clay, sandy silty clay and medium to high plasticity silty clays. The levee is commonly underlain by natural alluvium comprising medium to high plasticity silty clay and fine to medium grained silty sand and clayey sand.

The levee embankment material appeared to be placed “uncontrolled” and there were inconsistencies in the degree of compaction. Laboratory testing indicated permeabilities of up to 1×10^{-8} m/sec on low plasticity sandy clays. Insitu densities were generally above 90% (relative density) and Emerson Class values were generally in the range of 3 - 5 (ie low dispersion characteristics).

Remedial measures recommended in the report included :-

- Placement of a clay liner for stability and seepage control, requiring some cut and fill (to the existing levee embankment).
- Strip vegetation and topsoil from levee areas to be upgraded.
- Scarify, moisture condition and proof roll excavated foundations.
- Place imported clay fill, in 150mm layers (compacted) at 98% MDD at +/-2% of OMC.

- Avoid lamination in compacted clay layers.
- Inner and outer batters of the upgraded levee to be provided with a protective layer of topsoil.

Reference 4.

This investigation was undertaken to provide geotechnical information for materials from the proposed borrow pits located at :-

- Tasman Road – at the western side of Tasman Road, near the Wagga Wagga gun club.
- Kooringal Road – to the south west corner of Kooringal Road and Copland Street.

Tasman Road. Seven (7) boreholes were drilled at the site, to a depth of 5 metres, and representative samples were recovered for laboratory testing.

The investigation revealed that the borrow pit site is generally covered with 0.1 – 0.2 m of topsoil which overlies natural alluvium deposits comprising medium to high plasticity silty clays.

The silty clay material encountered in all boreholes is considered to be "suitable" for levee construction provided that strict compaction control is maintained as the clay material is considered to have a tendency to be moderately to highly dispersive.

Koorigal Road. Fourteen (14) boreholes were drilled at the site, to a depth of 5 metres, and representative samples were recovered for laboratory testing.

The investigation revealed that the borrow pit site is generally covered with 0.1 – 0.2 m of topsoil which overlies natural alluvium deposits comprising low plasticity sandy clayey silt/clayey silt, low to medium plasticity silty clay, medium to high plasticity silty clays and medium plasticity silty sandy clay.

The silty clay and silty sandy clay material encountered in all boreholes is considered to be "suitable" for levee construction provided that strict compaction control is maintained as the clay material is considered to have a tendency to be moderately to highly dispersive. Care should be exercised to ensure exclusion of low plasticity sandy/clayey silt and silty clay.

References 5-8.

These reports, by Jeffery and Katauskas P/L, address stability concerns and development of remedial works for river bank stabilisation works between Small Street and Tompson Street.

These investigations were primarily focussed on river bank stability analyses, however investigations did provide data that supplements data from the levee bank investigations by Aitken and Rowe (Ref 1-4).

A summary of the investigation results, as they relate to the condition of the levee are as follows :-

- Fine grained soils within the levee have the potential for shrink-swell reactivity.
- The clayey soils have Emerson Class 2 values, which indicate moderate potential for dispersive behaviour

- There is foreign matter (eg topsoil, building rubble etc) included in the levee (Ref 5) and it is interpreted that there was limited earthworks control in construction of the levee.

3.2 Geotechnical Design

The geotechnical investigation findings and associated data have been used in the development of the concept design for the upgrade of the levee. The concept design includes the following geotechnical design guidelines :-

- Topsoil (100mm minimum) to be stripped from the works area surface of the levee and stockpiled for re-use.
- The exposed 0.5 metres (perpendicular to face) of embankment clay to be excavated from the levee. Satisfactory quality materials can be re-used in the upgraded levee.
- Scarify and moisture condition the excavated surface of the levee works area.
- Proof roll the excavated surface, using a heavy "padfoot" type roller.
- Place, spread and moisture condition clay fill on the levee works area.
- "Mix-in" adjacent existing levee materials to create total working width of 2.5 metres (minimum).
- Use a heavy "padfoot" type roller to compact levee fill to a minimum of 93% Maximum (Modified) Dry Density at moisture content within range of +/- 2% of Optimum Moisture Content to achieve a 150mm compacted layer.
- Final outer levee batter slope to be 3.5(h):1(v) (maximum slope). A batter slope of 4(h):1(v) is preferred.
- Provide minimum topsoil cover to embankment of 100mm.
- Provide gravel layer to the crest of the levee.
- Provide dense and durable vegetation to batters of levee.

3.3 Information Shortfall

The available geotechnical information is suitable for concept design of the levee upgrade works, however additional information is considered to be necessary for final design. This additional geotechnical information would include :-

- Investigation of golf course area (Main Levee) to verify condition and adequacy of foundations.
- Targeted boreholes at specific areas of interest or concern (eg sites where Council has experienced problems).
- Compaction and moisture content curves for levee embankment fill and borrow areas.
- Test pits to investigate foundations at new levee alignments and levee extensions (eg at cemetery).

A detailed scope of work for the final design stage geotechnical investigation should be developed for the Wagga Wagga Levees.

4. Design Levels

4.1 Design Flood Levels

Design flood levels for the Wagga Wagga levee have been taken from the flood study report by WMA Water (Ref 9). This flood study has advanced work done in previous flood studies for Wagga Wagga.

The design hydraulic modelling has used a hydrodynamic two-dimensional (2D) TUFLOW model. The majority of data for the construction of the model was derived from airborne laser survey (ALS) data, which is accurate to +/- 0.15 metres. A key inclusion into the model was the alignment and elevation of the Main and North Wagga Wagga leves, based on survey data used from earlier studies.

The hydraulic model was calibrated using recorded flood data and then used to develop design flood information for the 10, 5, 2 and 1% AEP events as the PMF.

Wagga Wagga City Council have determined that the design levels for the levee will be based on the following design flood events :-

- Main Levee – 100 year ARI flood event; and
- North Wagga Wagga Levee – 20 year ARI flood event.

The Design Flood Levels (DFL), with appropriate freeboard allowance, have been assigned in accordance with the appropriate flood levels determined from the range of ARI events, as provided in the flood study (Ref 1). These design flood levels are shown in **Figures 4.1** and **4.2**.

The design flood levels are then superimposed onto the length of the existing/extended levee alignment of the Main Levee and North Wagga Wagga Levee to determine the degree of levee rising required at each particular location.

4.2 Flood Freeboard

The freeboard allowance, which is the incremental difference in height between the level of the design flood and the Design Crest Level (DCL) of the Wagga Wagga Levees, was determined (Ref 13) as :-

▪ Main Levee	0.90 metres
▪ North Wagga Wagga Levee	0.75 metres
▪ Bank Two Levee	0.75 metres

The purpose of freeboard is to provide a reasonable certainty that the risk exposure associated with a particular design flood is actually provided. Generally, freeboards are added to levee crest levels to allow for:-

- Uncertainties in the estimates of flood levels, such as inadequacies in the historical data;
- Increases in flood level as a result of wind and wave action;
- Differences in flood levels due to 'local factors' such as local water surge;

- Post construction settlement, which effectively reduces the long term level of the levee;
- Reduction in crest level due to defects in the levee and surface erosion, plus effects of vehicle, animal or pedestrian crossings and lack of levee maintenance;
- Potential changes in rainfall patterns as a result of climate change; and
- Computational uncertainties, inadequacies in survey data and other sources of error.

5. Levee Options

5.1 Alignment

Upgrade of the levees at Wagga Wagga is to follow the alignment of the existing levee, apart from at the following locations :-

- Main Levee (Ch 5600-5800), adjacent to Tarcutta Street, between Cross Street and Morrow Street. The levee alignment is relocated, by up to 10 metres, towards Tarcutta Street to permit future City Precinct Works to be incorporated into the levee and river bank area.
- Main Levee (Ch 7260-7330) adjacent to Lonergan Place. The existing concrete wall was located to pass around a building which has since been demolished. It is proposed to straighten the levee alignment so as to continue the adjacent embankment levee alignment.
- Main Levee (Ch 8900-9080) at cemetery. The levee is extended, as an embankment levee, to the cemetery entrance. A low return embankment is located beside the entrance road to provide closure to the levee.
- Bank Two Levee (Ch 755-860). The raised levee is extended to cover high ground not covered by the existing levee.

Within the remainder of the levee, the alignment has been adjusted as much as possible (and also considering other constraints) to produce upgrade works that fit onto the existing levee. The upgrade works are generally only located on one side of the embankment levee. This will minimise disturbance to the existing levee, minimise the extent of excavation and foundation preparation and generally produce lower upgrade costs.

These alignment options are generally referred to in this report as :-

- Upstream alignment – involving raising of the embankment levee, by raising of the crest and upstream (water) face of the levee.
- Downstream alignment – involving raising of the embankment levee, by raising of the crest and downstream (urban development) face of the levee.
- Centreline alignment – involving raising of the embankment levee, by raising of the crest and both faces of the levee.

The alignment concepts are shown in **Figure 5.1**.

5.2 Options

The type of levee adopted for Concept Design should be the one that is most suitable to satisfy design, cost and operational needs. The objectives of the Concept Design should therefore be :-

- Provide a levee type that is compatible with the existing levee, location and degree of augmentation required.
- Provide a levee type that is most suitable to the design flood exposure.
- Provide a levee type that is compatible with required operation, maintenance and community use for the area.

These criteria indicate that the following types of levees could be considered for upgrade works at Wagga Wagga :-

- Embankment levee
- Crib-wall embankment levee
- Sheetpile wall
- Cantilever retaining wall
- Hybrid levee consisting of a base levee type plus inclusions where necessary satisfy particular requirements (eg limited space).

A brief description of each of these levee types, noting advantages/disadvantages, will be of assistance in providing a rationale for selection of suitable option(s) for the levee upgrade works. These levee types are described below.

Embankment Levee. Most of the Wagga Wagga Levees are of this type. The levee type consists of compacted earthfill, won from local excavations. The fill is usually compacted to near Optimum Moisture Content (OMC) at a density of 95-98% of maximum (standard) density or 93-95% of maximum (modified) density. Compaction specifications should be designed with consideration of the expected exposure conditions during the life of the levee. Additives (usually lime or gypsum) are often added to the fill to stabilise materials that are highly dispersive.

Foundations for the levee type are stripped to remove topsoil and organic matter, and excavation extended to form a central key trench to provide a deeper barrier to intercept potentially damaging seepage under the levee.

Levee batter slopes are designed to provide acceptable stability under design loading conditions. External batter slopes are commonly flattened by addition of topsoil and/or random fill to provide erosion protection and to allow for maintenance access.

The crest of the levee is sheeted with gravel and provided with a uniform crossfall to allow rainfall runoff to be evenly directed to the levee batter best equipped to accept this runoff – usually the flatter, well vegetated outer batter.

This type of levee is most adaptable for raising existing embankment levees and where there is sufficient space to achieve acceptable batter slopes. The levee can be landscaped to be sympathetic to surrounds.

A typical embankment levee is shown in **Appendix C**.

Crib-wall Embankment Levee. This type of levee is basically an embankment type levee, where one (or both) faces are supported by a steep crib-wall (or block work type wall). Reasons for such arrangement include reduction in "footprint" of the levee to satisfy some space constraints or to permit landscaping to the (usually) inner batter.

Crib-walls (or similar) are usually commercially available and can be tailored to suit particular needs.

The remainder of the embankment levee is constructed in a similar manner and specification to the embankment type levee. The crib-wall does not perform any function in providing flood protection to the town or city.

A typical crib-wall embankment levee is shown in **Appendix C**.

Sheetpile Levee. This type of levee consists of a single line wall constructed from driven sheet piles. The size of the sheet piles depends upon the height of the levee, expected life of the piles (ie required corrosion allowance) and the required depth of embedment.

Sheet pile walls are particularly advantageous to address the following levee design issues :-

- Where space constraints limit other types of levees.
- Where deep foundation problems need to be addressed (eg deep layers of highly permeable foundations).
- Where stability problems need to be addressed (eg over-steep river banks).

The top of the sheet pile walls can be capped by use of timber planks, steel channels or concrete capping etc to improve the appearance of the levee and eliminate safety issues.

A typical sheet-pile levee is shown in **Appendix C**.

Cantilever Retaining Wall Levee. Cantilever retaining walls are usually constructed in reinforced concrete. These walls are used, in a similar manner to the sheet-pile walls, where space limitations exist. The cantilever wall is suitable for higher retaining wall type levees and where foundation conditions are adequate to support these very heavy structures.

Cantilever walls (concrete) are in-flexible structures and therefore require particular attention to provide continuous water barriers by way of water-stops between sections of wall. Differential settlement issues need to be addressed.

A typical cantilever retaining wall levee is shown in **Appendix C**.

Hybrid Levee. The hybrid levee option can be considered as a combination of the above levee options. Commonly, the hybrid levee would be based on the embankment levee concept, with included components designed to solve particular issues, for example :-

- Embankment levee with upper level sheet pile walls to reduce footprint or extent of the outer batter.
- Crib wall levee.
- Embankment levee with retaining wall on inner batter to permit extension of urban development.
- Embankment levee with sheet pile cut-off wall in foundations to intercept deep foundation problem.

5.3 Comparative Costs

Recent construction of levees of different types throughout NSW has provided a good record of relative costs for these types of levees. The data has clearly demonstrated that for similar conditions and for no significant constraints, embankment type levees are more cost effective by a significant margin.

Cost data for various levee types is summarised in **Table 5.1** below. The table presents the relative costing in terms of a cost ratio.

Table 5.1 Comparative Levee Costs

Levee Type	Cost Ratio
Earthfill Embankment	1
Sheet Pile	3.5
Concrete Cantilever Wall	5
Concrete Wall and Removable Panels	5.5

Based on the data, the concept design work for Wagga Wagga has developed from an embankment type levee as the base (or starting) option. Hybrid modifications are used where required by specific constraints. More expensive options (eg sheet pile) are only considered where an embankment type levee (or hybrid) cannot be constructed or where it is obvious that a simple augmentation of an existing non-embankment arrangement is appropriate.

5.4 Option Selection

The concept design for upgrade of the Wagga Wagga Levee is based on consideration of the following :-

- Extent of levee raising, as determined by the Design Flood Level and freeboard.
- Local constraints such as topography, urban development and infrastructure.
- Levee alignment.
- Suitability of levee option(s).
- Cost relativities.

The levees have been segmented into short lengths which are similar in nature and then, with consideration of the above criteria, an upgrade option for each segment is determined. The assessment process is shown in **Appendix A** and the final concept is presented in the Concept Design Drawings which are included in this report.

6. Design Details

6.1 Levee Types

The options review and assessment process, as described in Section 5 of this report, has resulted in determination of a levee Concept Design that addresses the design requirements. The proposed arrangement, typical section details and elevation details for this concept design are shown on the concept drawings which are included in this report.

Specific levee types that have been adopted are described in the following sections of this report. Effort has been made to minimise the number of levee types and expected construction techniques, such that overall construction costs can be minimised.

Embankment Levee

Should there be no constraints for embankment levee works, the recommended design for a new embankment levee at Wagga Wagga (considering potentially available materials) would be :-

- Central clay core, compacted to a minimum of 93% maximum (Modified) dry density at moisture content within +/- 2% of optimum moisture content.
- Strip existing topsoil to a depth of 100mm (minimum) and remove all organic matter over the full "footprint" of the levee upgrade works.
- Excavate a foundation key trench, to a minimum additional depth of 0.5 metres, under the new levee to provide additional seepage cut-off.
- Construct embankment clay core with 2(h):1(v) downstream batters and 3(h):1(v) upstream batters.
- Add topsoil protection to downstream batter (100mm thick)
- Add topsoil protection to the upstream batter to form a 4(h):1(v) batter.
- Provide 3 metre wide crest, surfaced with a layer of gravel. The crest should have a uniform crossfall (3%) to direct rainfall runoff to the outer batter.
- Provide good dense vegetative cover on the levee batters.

The flat upstream batter is provided to allow for inspection and maintenance access and for provision of erosion protection for flood and wave action.

A 3 metre wide gravelled crest is provided to allow for close-up all weather access, particularly during times of major flood.

The above design is considered to be an ideal solution for a new levee, however most of the embankment levee work at Wagga Wagga is comprised of augmentation work to existing embankment levees. This augmentation work has been designed in line with the above principles but also according to the following additional design considerations :-

- Levee augmentation works are aligned to minimise the extent of disturbance to the existing levee, by aligning the works to occupy the levee crest and only one batter, where possible.

- Upstream levee topsoil batters are steepened to 3.5(h):1(v) where necessary, to avoid these batters extending into the river or a considerable distance over the edge of steep slopes.
- Where levee sections are located adjacent to steep slopes (either river banks or oversteep existing levee batters), the augmented levee is aligned to permit trimming of the overstep bank to produce a more stable combined batter.
- Where levees are adjacent to existing roads, and hence access along the levee crest is not essential, crest width can be reduced to 1.5 metres.
- The existing levee, following excavation of surface topsoil and dessicated materials, will be compacted with a heavy roller prior to surface preparation and placement of new earthfill.
- Downstream levee batters are flattened to 3-4(h):1(v) to suit local park areas. These batters are to be topsoiled and grassed.

These design considerations are shown on the drawings, with typical levee sections shown on **Drawing – 002** and typical concept design works details shown on **Drawings 041-044** and **131-133.**

<u>Sheet Pile Levee</u>

Sheet pile levees are proposed at locations where other levee options will not be practical due to space constraints. The sheet pile type levee is proposed along the Main Levee as follows :-

- Ch 4400-4460. This section of levee upgrade requires the inner batter "footprint" to be reduced to allow for possible extension of the adjacent car-park. The walking track on the crest of the adjacent concrete wall levee (Cadell Place) needs to continue on the outer side of this sheet pile augmentation to maintain continuity.
- Ch 6060-6120. The existing levee is confined between significant development on the city side and steep levee/river banks. Any expansion of the levee will either impact on the development or extend into the Murrumbidgee River.
- Ch 6900-6905. The existing embankment levee deviates from the general alignment of the adjacent levee and runs under the railway bridge. It is proposed to straighten the levee by extending the upper level sheetpile wall from the adjacent "hybrid" levee. The sheet pile wall will be capped with a concrete sill.

At these locations the sheet pile walls extend above existing levels by approximately 0.5 – 1 metre. Sheet pile AZ 12-770 (Z profile, 94 kg/m) section is proposed. This sheet piling will be compatible with that proposed for the hybrid embankment/sheet pile levees (see below).

The top of the sheet pile walls is to be trimmed with a small inverted (steel) channel.

<u>Concrete Wall Levee</u>

The existing levee along Cadell Place (Ch 4460-4860) consists of an embankment, supported at the inner edge of the crest, by a reinforced concrete cantilever retaining wall. The wall supports this section of levee to reduce the levee "footprint" and thus accommodate the Cadell Place roadway. The top of the retaining wall is just above the new DFL.

It is proposed to not add any permanent loading to this retaining wall and so not reduce the current margin of safety. The crest of the existing embankment will not be raised.

The retaining wall will be raised to the new DCL by adding a new reinforced concrete section to the top of the wall to provide compatibility with the existing façade. The new concrete will be secured to the existing wall by dowelled bars drilled and grouted into the top of the existing wall.

Hybrid Levees

The term "hybrid levee" has been introduced to describe a series of levee configurations that are based on the earthfill embankment levee, but have included components of other levee types, to address one (or more) design constraints that cannot be satisfied by a pure embankment levee. Hybrid design levees developed for the Wagga Wagga concept design include :-

Embankment/Sheet Pile. This is the most commonly used hybrid levee configuration developed for the concept design. The arrangement consists of a steeper 3.5(h):1(v) outer batter embankment levee and 900mm high sheet pile wall at the outer edge of the levee crest. The intent is to reduce the outer "footprint" of the levee.

The configuration has been mostly used along the Main Levee to allow trimming of the overstep levee/river bank and to prevent new batters from extending considerable distances towards (or into) the Murrumbidgee River.

Design loadings adopted for the sheet pile component are :-

- Light truck (8 tonne total) loading on the levee crest, 0.6 metres minimum distance from the sheet pile wall.
- Embankment fill (saturated) density ; 2t/m^3
- Embankment strength properties ; Cohesion = 0 kPa, Friction angle = 30^o
- Maximum fill height ; 0.9 metres

The resulting design specification for the sheet pile component is :-

- Pile section ; AZ 12-770 (94.3 kg/m, Z profile)
- Maximum fill height supported by cantilever height ; 0.9 metres.
- Minimum embedment length ; 2.8 metres.

A typical hybrid "embankment/sheet pile" levee is shown on **Drawing – 002.**

Embankment/Gabion Wall. This is used occasionally to reduce the footprint of a low embankment levee, often in conjunction with aesthetic considerations. The supporting gabion wall is designed as a simple gravity retaining wall.

This arrangement is used in two locations :-

- Main Levee (Ch 5920-5960), where a small carpark extension requires that the internal batter "footprint" be locally reduced within a long length of embankment levee. The facing of this levee batter is required to present an aesthetic appearance.
- Bank Two Levee (either end of Mill Street). The levee, constrained between Mill Street and the boundary of a private property, requires that either end of the outer batter be prevented from spilling into the private property. Rather than re-designing the entire length of this levee, the two short lengths at either end are supported by a single height (1 metre) gabion wall.

A typical hybrid "embankment/gabion wall" configuration is shown on **Drawing – 002.**

Embankment/Box Culvert. This hybrid levee type has been employed at one location (Main Levee ; Ch 4930-4990) where space constraints exist on both sides of the embankment levee. These constraints are a block of flats very close to the inner batter and a steep slope adjacent to the outer batter.

The hybrid levee is formed by lowering the height of the crest of the existing levee and placing inverted box culverts on this lowered crest. The base of the upturned culverts is filled with compacted clay (to above DFL) so that access along the levee crest is maintained through the box culverts. By lowering and widening the existing levee, there is scope to (marginally) trim the existing levee batters and thus improve bank stability.

The hybrid "embankment/box culvert" levee is shown on **Drawing – 002.**

6.2 Spillways

The Wagga Wagga levees are designed to cater for a specific design flood, the corresponding design flood levels for which are based on analysis of historical data and hydraulic modelling to determine flood levels along the length of river adjacent to the levee. A freeboard allowance is added to these design flood levels to cover issues including the following :-

- Uncertainty in flood level estimation
- Wind/wave action
- Erosion and settlement of levee crest
- Defects in the levee, such as cracking in the crest, low points etc.

The freeboard allowance provided to a flood levee however, is not specifically provided to assure protection against floods larger than the design flood. The freeboard in fact caters for, among other things, likely defects in the upper portions of the levee and it is therefore not recommended to rely on this flood freeboard for additional flood protection.

In order to prevent a catastrophic levee failure from floods significantly greater than the design flood, it is common practice to provide a spillway in the levee, at levels marginally above the design flood level. This spillway enables large floods (in excess of the design flood) to enter the protected area in a controlled manner rather than risk a sudden failure of the levee via the potentially insecure freeboard portion of the levee.

Should there be a sudden and/or premature failure of the levee, the consequences would be severe. These would include :-

- Loss of Life. People would expect that their levee is secure and unless extreme flood levels are being experienced, the level of preparedness may not be optimal. A levee failure with little warning time in conjunction with low levels of preparedness will heighten the number of people at risk and may cause loss of life that would not otherwise occur.
- Damage. Sudden levee failure and rapid entry of flood water will cause significantly more damage than entry of flood water in a slow and controlled manner.

Spillway Design

The option to construct spillways into the levee design has been provided in accordance with the Floodplain Risk Management Guideline No 14 – Spillways for Urban Levees. The guideline predicates that the spillway is located at or towards the downstream end of the city, or the lowest part of the city, to minimise the development of hazardous flows. In the case of the Wagga Wagga levees, the spillway locations were determined as follows :-

- Main Levee – located at the downstream end of the levee, across the Olympic Highway from Alan Staunton Park. This is also the lowest area within the levee protected area.
- North Wagga Wagga Levee – located at the downstream end of the levee, beside Hopkirk Street. This is also the lowest area within the levee protected area.
- Bank Two Levee – located at the raised Mill Street (east) intersection.

The spillway levels (and locations) were selected such that they :-

- Provide reasonable protection against wave action during the design event.
- Provide for reasonable tailwater build-up prior to the levee overtopping.
- Do not operate until above the Design Flood Level.

It should be noted that these spillways act to minimise the development of hazardous flows within the levee and as such have been designed to practical limits to suit the levee arrangement and topography. Due to the magnitude of the area protected by the levee, and the range and variability of floods that exceed the design flood, it is not possible that all protected areas will be inundated prior to levee overtopping from all floods that exceed the design flood.

The likely development of inundation within the Main Levee and the North Wagga Wagga Levee is shown in **Figures 6.1** to **6.6.**

Spillway Details

Spillways are designed to allow flood water to enter into levee protected areas via a lowered levee embankment. The lowered embankment is protected by a lining of 300mm thick rockfill mattresses which accommodate the expected spillway flow velocities. The mattresses are laid over a layer of geotextile to prevent internal erosion of the levee fill.

Mattress protection is extended over the crest of the levee, down the inside batter of the levee and for 2 metres beyond the base of the levee to provide for energy dissipation at the toe of the levee.

Typical details for the spillways on the Main Levee and North Wagga Wagga Levee are shown on **Drawing – 002.**

The area protected by the “Bank Two” Levee is small and it is considered that a suitable spillway can be achieved by the raised Mill Street (east) intersection.

The proposed spillway details are as listed in **Table 6.1** below.

ble 6.1 Spillway Details

Location	**Details**
Main Levee	200 metres wide Ch 420 – 620 Spillway crest 0.4m above DFL
North Levee	100 metres wide Ch 2850 – 2950 Spillway crest 0.25m above DFL
Bank Two Levee	33 metres wide Ch 248 – 285 (Mill Street – east) Spillway crest 0.25m above DFL

6.3 Levee Crossings

The levees at Wagga Wagga cross the main railway line, several major roads/highways and a number of minor roads and access roads into properties which lie on the outside of the levee.

In order to accommodate these crossings, the following design guidelines have been adopted :-

Crossing above DFL. At these locations along the levee, flood protection is required for the freeboard component only. Continuous ingress of flood water is not considered in this situation and protection measures can include :-

- Temporary sandbagging
- Wave action suppression (eg from roadway itself)
- Earthfill barrier
- Temporary flood barriers (eg Bauer K-System Mobile Flood Protection System), information for which is included in **Appendix C**.

Crossing below DFL. At these locations along the levee, full flood protection is required, including for the freeboard component. The flood protection system at these locations will be exposed to flood water and wave action and therefore must be of a secure nature. Protection measures could include :-

- Construction of full height levee.
- Raise road to at least DFL.
- Structural flood gates (eg Bauer "Demflood" system), information for which is included in **Appendix C**.

In the case of major road/highway crossings and the railway crossing, it will be too expensive to raise (relative to any levee works) and so levee work will need to consist of structural flood gates.

These design guidelines have been employed to provide concept design closure systems for each of the levee openings at Wagga Wagga. Details of these closure systems are given below.

Main Levee.

Flowerdale Road (Ch 1320 – 1340)

The Flowerdale Road crossing currently consists of a gravelled road, ramped over the crest of the existing levee. The crest of this road ramp is at RL 180.255 m AHD.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 180.21 m AHD and therefore the existing road crossing does not need to be raised. The upgraded levee will be terminated into the batters of the existing road embankment.

Local Crossing (Ch 1720 – 1740)

This local crossing provides access over the levee to a business enterprise. Access consists of a gravelled ramp over the crest of the existing levee. The crest of this road ramp is at RL 180.25 m AHD.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 180.39 m AHD indicating that only minor (0.14 m) "topping" of the levee is required.

It is proposed to augment the existing access ramp, with compacted earthfill and gravel sheeting, to provide access to the upgraded levee DCL. Ramp grades will be 10(h): 1(v).

Olympic Highway, Travers Street (Ch 2050 – 2160)

This major intersection on the Olympic Highway consists of a dual carriage highway and round-about at the intersection with Travers Street.

The level of this major intersection is above the DCL of the proposed levee upgrade. There are no levee works proposed at this location.

Local Crossing (Ch 2400 – 2420)

This local crossing provides access to several dwellings and businesses located outside of the levee adjacent to Travers Street. Access consists of a gravelled ramp over a slightly lowered crest of the existing levee. The crest of this road ramp is at RL 180.62 m AHD.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 181.02 m AHD, indicating that a small raising of the ramp (0.4 metres) is required.

It is proposed to augment the existing access ramp, with compacted earthfill and gravel sheeting, to maintain access at the new DCL. Ramp grades will be 8(h):1(v) (inside levee) and 10(h):1(v) (outside levee).

Billagha Street (Ch 3130 – 3150)

The Billagha Street crossing currently consists of a gravelled road, ramped over the crest of the existing levee. This road is a "dead-end" road.

Wagga Wagga City Council have determined that this road can be closed and therefore, a full height levee is proposed to cross this road.

Narrung Street (Ch 4000 – 4030)

The Narrung Street crossing currently consists of a sealed road, ramped over the crest of the existing levee. The crest of this road ramp is at RL 181.38 m AHD.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 182.28 m AHD (0.90 m above DFL) and therefore the existing road crossing does not need to be raised using a permanent structure. Temporary flood closure (for freeboard) can be achieved by one of the methods listed at “Crossing above DFL”.

The upgraded levee will be terminated by ramping down the levee into the batters of the existing Narrung Street embankment.

Hampden Avenue (Ch 4220 – 4260)

This major intersection and approach to the Hampden Avenue bridge consists of a dual carriage highway and “Tee” intersection with Fitzmaurice Street.

The level of this major intersection is above the DCL of the proposed levee upgrade. There are no levee works proposed at this location and the levees, either side of this intersection, will be constructed into the batters of the intersection road embankments.

Timber Bridge (Ch 4380- 4400)

The Hampden Avenue timber bridge, which is now not used for traffic, abuts into the earth embankment which forms part of the levee.

The level of this abutment embankment is above the DCL of the proposed levee upgrade. There are no levee works proposed at this location and the upgraded levee foundations, either side of this bridge abutment, will be excavated into the batters of the abutment.

Johnston Street (Ch 5242 – 5267)

The Johnston Street crossing, which leads into a park area, currently consists of a sealed road with kerb and gutter. The roadway is not raised above the local topography and the crest of this street, at the levee alignment, is at approximately RL 180.95 m AHD. The intersection with Church Street is immediately adjacent to the alignment of the levee.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 182.67 m AHD, which is 1.7 m above the existing street level. Raising the streets in this area, including provision of adequate approach grades and associated raised services and access to amenities will be expensive and therefore a flood gate closure structure is proposed.

It is proposed to install a “Demflood” type barrier system to provide closure at this location. The concept is shown on **Drawing - 002** and technical details are included at **Appendix C** to this report. A typical flood barrier is also shown in **Appendix C.**

Support for the flood gate will be provided as follows :-

- Ch 5242 – the embankment levee will be terminated and supported by a concrete cantilever retaining wall. The end panels of the flood gate will be supported by a steel channel encased into the concrete wall.
- Ch 5267 – the proposed retaining wall adjacent to the "restaurant" will include a right angle leg towards Johnston Street. This leg will be a full height cantilever wall terminating with a "wing wall" to provide support for the end of flood gate, in a similar fashion to the opposite face.
- Intermediate supports for the flood gate are provided by steel columns fitted into foundations, constructed just below roadway level. The roadway will be reinstated over the gate foundations, and will need to be locally excavated to permit gate assembly.

The overall dimensions of the flood gate will be 25 m wide and 1.87 m high.

Local Crossing (Ch 6340 – 6360)

This new local crossing will provide access over the levee to river bank protection works. Access consists of a gravelled ramp over the crest of the upgraded levee, originating at the corner of Small Street and Bentley Place.

The proposed access ramp will consist of compacted earthfill and gravel sheeting, to provide access. Ramp grade on the inside of the levee will need to be relatively steep (5(h):1(v)) to avoid encroaching onto the street formation, however a 10(h):1(v) grade can be provided on the outer side of the levee.

Rail Bridge (Ch 6900 – 6905)

The main railway line crosses over the existing embankment levee via a raised via-duct bridge. The railway line is marginally above the existing levee, the crest of which is at the DFL for levee upgrade (ie RL 182.0 m AHD). It is proposed to not raise the railway line.

It is proposed to curtail the adjacent embankment levees and provide a sheet pile extension from the embankment levees on either side of the rail bridge. The sheetpile levee will pass under the rail bridge and be topped with a concrete sill to achieve the required DFL (ie no freeboard). The sheetpile wall will be raised, either side of the railway line, to meet the embankment levees adjacent to the rail crossing. It is considered that the rail bridge will suppress any wave action and the sheetpile wall will not experience any settlement or require a defects freeboard allowance. Potential erosion from small amounts of overtopping at this location can be accommodated with rockfill mattresses located at the toe of the lower section of sheetpile wall.

Hammond Avenue (Ch 7668-7688)

The Hammond Avenue crossing, which is next to a small bridge over Marshalls Creek, currently consists of a major sealed road with kerb and gutter. The roadway is not raised above the local topography and the crest of this roadway, at the levee alignment, is at approximately RL 180.75 m AHD.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 183.00 m AHD, which is 2.25 m above the existing street level. Raising of Hammond Avenue (including the Marshalls Creek bridge), associated raised services and access to amenities, will be expensive and therefore a flood gate closure structure is proposed. It is proposed to install a "Demflood" type barrier system to provide closure at this location.

The upgraded embankment levee on either side of Hammond Avenue will be terminated and supported by a concrete cantilever retaining wall. The end panels for the flood gate will be supported by a steel channel encased in the concrete wall. Intermediate supports for the flood gate are provided by steel columns fitted into concrete foundations, constructed just below roadway level. The roadway will be reinstated over the gate foundations, and will need to be locally excavated to permit gate assembly.

The overall dimensions of the flood gate will be 20 m wide and 2.4 m high.

<u>Copland Street (Ch 8381-8411)</u>

The levee alignment crosses Copland Street adjacent to a major round-about intersection at Kooringal Road.

Copland Street is not raised above the local topography and the crest of this street, at the levee alignment, is at approximately RL 181.18. The intersection with Kooringal Road is immediately adjacent to the alignment of the levee.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 183.21 m AHD, which is 2.0 m above the existing street level. Raising of both streets and the Round-about, including provision of adequate grades and associated raised services and access to amenities, will be expensive and therefore a flood gate closure structure is proposed. It is proposed to install a “Demflood” type barrier system to provide closure at this location.

The upgraded embankment levee on either side of Copland Street will be terminated and supported by a concrete cantilever retaining wall. The end panels for the flood gate will be supported by a steel channel encased in the concrete wall. Intermediate supports for the flood gate are provided by steel columns fitted into concrete foundations, constructed just below roadway level. The roadway will be reinstated over the gate foundations, and will need to be locally excavated to permit gate assembly.

The overall dimensions of the flood gate will be 30 m wide and 2.18 m high.

<u>Cemetery Entrance (Ch 9080)</u>

Topographic information requires that the levee (to DCL) extends beyond the entrance roadway to the cemetery, into an area which is part of the cemetery. This option is considered to be inappropriate. The cemetery access road is at RL 180.65 m AHD which is 2.6 m below the DCL (RL 183.25 m AHD) and so a permanent flood closure arrangement is necessary.

It is proposed to provide the following :-

- Construct a small earthfill levee, with a flat (4(h):1(v)) grassed batter on both sides. The levee is located beside the access road into the cemetery and finishes at high ground beside this access road.
- Minimise the crest width of the levee (1.5m) to reduce impact.
- Construct the crest of this levee to DFL (RL 182.35 m AHD) only, with protection to the inside face to cater for any minor overtopping that may occur due to wave action.

North Wagga Wagga Levee.

Hampden Avenue (Ch 4276 - 8)

The Hampden Avenue crossing, which is between the Parken Pregan Bridge and the intersection with Gardiner Street, currently consists of a major sealed road with kerb and gutter. This road (and bridge) is the main access from North Wagga Wagga to the city centre. The roadway is not significantly raised above the local topography and the crest of this roadway, at the levee alignment, is at RL 179.25 m AHD.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 180.90 m AHD, which is 1.65 m above the existing road level. Raising of Hampden Avenue (including the bridge), the Gardiner Street intersection, associated raised services and access to amenities, will be expensive and therefore a flood gate closure structure is proposed. It is proposed to install a “Demflood” type barrier system to provide closure at this location.

The upgraded embankment levee on either side of Hampden Avenue, will be terminated and supported by a concrete cantilever retaining wall, into which the closure panels for the flood gate will be supported by an encased steel channel. Intermediate supports for the flood gate are provided by steel channels fitted into foundations, constructed at roadway level.

The overall dimensions of the flood gate will be 15 m wide and 1.80 m high.

Marah Street (Ch 979 – 994)

The Marah Street crossing consists of a secondary two lane sealed road. The crest of the roadway is at RL 180.12 m AHD, which is 0.9 m below the DCL of the new levee. The road therefore needs to be raised by a small amount (150 mm) to be above the DFL and thus qualify for use of a temporary closure mechanism during the design flood event.

It is proposed that the Marah Street crossing be upgraded, by raising the roadway to 0.5 metres below the proposed DCL and re-sealing. Suitable vertical curves and approach grades will be required. Such raising is considered appropriate, as wave action, surge etc (ie some freeboard components) will not be experienced at this location due to protection provided by the roadway.

Mill Street (Ch 1210 – 1230)

The levee alignment crosses Mill Street, which provides the main access between North Wagga Wagga and the small community which is protected by the “Bank Two” levee. During the design flood event, the section of Mill Street between the two levees, acts as a floodway.

The Mill Street (North Wagga Wagga) crossing is raised to align with the crest of the existing levee, at approximately RL 179.93 m AHD. This is approximately 1 metre below the proposed DCL of the new levee. It is proposed to install a “Demflood” type barrier system to provide closure at this location.

The upgraded embankment levee on either side of Mill Street will be terminated and supported by a concrete cantilever retaining wall. The end panels for the flood gate will be supported by a steel channel encased in the concrete wall. Intermediate supports for the flood gate are provided by steel columns fitted into concrete foundations, constructed just below roadway level. The roadway will be reinstated over the gate foundations, and will need to be locally excavated to permit gate assembly.

The overall dimensions of the flood gate will be 15 m wide and 1.17m high.

<u>Hampden Avenue (Ch 1670 – 1690)</u>

The Hampden Avenue crossing currently consists of a sealed road, ramped over the crest of the existing levee. This road was recently raised to a new crest level of RL 179.95 m AHD.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 180.67 m AHD (ie 0.29 m above the road level) and therefore the existing road crossing does not need to be raised using a permanent structure. Temporary flood closure (for freeboard) can be achieved by one of the methods listed at “Crossing above DFL”.

The upgraded levee will be terminated by ramping down the levee into the batters of the existing Hampden Avenue embankment.

<u>Local Access (Ch 2290 – 2300)</u>

This new local access ramp will provide access over the levee to a property that is located outside of the levee. Access will consist of a gravelled ramp over the crest of the upgraded levee.

The proposed access ramp will consist of compacted earthfill and gravel sheeting, to provide access. Ramp grades will be 6(h):1(v).

<u>Brotherwood Street (Ch 2800 – 2820)</u>

The Brotherwood Street crossing currently consists of a sealed road, ramped over the crest of the existing levee. The crest of this road ramp is at RL 179.88 m AHD

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 180.55 (ie 0.73 m above the road level) and therefore the existing road crossing does not need to be raised using a permanent structure. Temporary flood closure (for freeboard) can be achieved by one of the methods listed at “Crossing above DFL”.

The upgraded levee will be terminated by ramping down the levee into the batters of the existing Brotherwood Street embankment.

<u>Gardiner Street (Ch 3050 – 3070)</u>

The Gardiner Street crossing currently consists of a two lane sealed road. The adjacent levee terminates into the road embankment, at the road level. The crest of this road is at RL 179.80 m AHD.

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 180.55 m AHD (ie 0.75 m above the road level) and therefore the existing road crossing does not need to be raised using a permanent structure. Temporary flood closure (for freeboard) can be achieved by one of the methods listed at “Crossing above DFL”.

The upgraded levee will be terminated by ramping down the levee into the batters of the existing Gardiner Street embankment.

<u>Bank Two Levee.</u>

<u>Mill Street (west) (Ch 1370 - 5)</u>

The Mill Street crossing currently consists of a sealed road, ramped over the crest of the existing levee. The crest of this road ramp is at RL 180.18 m AHD

The Design Crest Level (DCL) of the upgraded levee, at this location, is RL 180.85 m AHD (ie 0.67 m above the road level) and therefore the existing road crossing does not need to be raised using a permanent structure. Temporary flood closure (for freeboard) can be achieved by one of the methods listed at “Crossing above DFL”.

The upgraded levee will be terminated by ramping down the levee into the batters of the existing Mill Street embankment.

<u>Mill Street (east) (Ch 250 - 280)</u>

The Mill Street (east) crossing consists of a four way intersection – two lane sealed Mill Street, bitumen sealed East Street and a gravel surfaced laneway. The intersection includes a slip-lane beside Mill Street and turning lane from East Street. The levee opening, on alignment, is approximately 30 metres wide. The crest of the roadway includes a cross-fall which varies from RL 180.31 m AHD to RL 179.67 m AHD. This is 1.28 m to 0.67 m below the DCL (RL 180.95 m AHD) of the new levee. The road therefore needs to be raised by up to 0.53 m to be above the DFL and thus qualify for use of a temporary closure mechanism during the design flood event.

Because of the potential width, complexity and cost of a floodgate at this location, it is proposed that the Mill Street (east) intersection be upgraded, by raising the roadway to 0.5 metres below the proposed DCL and re-sealing. Suitable vertical curves and approach grades will be required. Such raising is considered appropriate, as wave action, surge etc (ie some freeboard components) will not be experienced at this location due to protection provided by the roadway.

<u>East Street (Ch 735 – 750)</u>

The levee alignment crosses East Street, which is the main “through street” for the community surrounded by the “Bank Two” Levee. Immediately outside of this levee crossing, is an access lane into private property. East Street is a narrow, bitumen sealed road with kerb and gutter on one side of the road.

The East Street crossing is approximately 0.6 metres below DFL and approximately 1.35 metres below the proposed DCL of the new levee (ie RL 181.05 m AHD). Because of the very close local access road intersection, kerb and gutter beside the road and the significant height required for infill of the levee opening, it is proposed to install a “Demflood” type barrier system to provide closure at this location.

The upgraded embankment levee on either side of East Street will be terminated and supported by a concrete cantilever retaining wall. The end panels for the flood gate will be supported by a steel channel encased in the concrete wall. Intermediate supports for the flood gate are provided by steel columns fitted into concrete foundations, constructed just below roadway level. The roadway will be reinstated over the gate foundations, and will need to be locally excavated to permit gate assembly.

The overall dimensions of the flood gate will be 15 m wide and 1.5 m high.

Summary

A summary of the proposed levee crossing treatment, and implications for flood event action, is given in **Table 6.3.**

Table 6.3 Levee Crossings

Location	Description	Upgrade Works	Flood Action
Main Levee			
1320-1360	Flowerdale Road.	Nil	Nil.
1720-1740	Local crossing	Raise 0.14 metres by gravel topping to levee crest and ramps, to DCL.	Nil.
2050-2160	Olympic Highway	Nil	Nil.
2400-2420	Local crossing	Raise levee 0.4 metres by gravel topping to levee crest and ramps, to DCL.	Nil.
3130-3150	Billagha Street	Road closed and construct full height levee.	Nil.
4000-4030	Narrung Street	Retain existing sealed road crossing at 0.9m below DCL	Temporary barrier.
4220-4260	Hampden Avenue	Nil	Nil.
4380-4400	Timber Bridge	Nil	Nil.
5242-5267	Johnston Street	Flood gate, 25m wide x 1.87m high, to DCL.	**Major floodgate.**
6340-6360	Local crossing	New ramp over levee, to DCL	Nil.
6900-6905	Rail bridge	Sheet pile wall under rail bridge, concrete cap to DFL	Temporary barrier.
7668-7688	Hammond Avenue	Flood gate, 20m wide x 2.4m high, to DCL.	**Major floodgate.**
8381-8411	Copland Street	Flood gate, 30m wide x 2.18m high, to DCL.	**Major floodgate.**
9000-9010	Cemetery entrance	Low return embankment beside entry roadway.	Temporary barrier.
North Levee			
4276-8	Hampden Avenue	Flood gate, 15m wide x 1.80m high, to DCL.	**Major floodgate.**
979-994	Marah Street	Raise existing sealed road crossing by 0.4m to then be 0.5m below DCL	Temporary barrier.
1210-1230	Mill Street	Flood gate, 15m wide x 1.17m high, to DCL.	**Major floodgate.**
1670-1690	Hampden Avenue	Retain existing sealed road crossing at 0.29m below DCL	Temporary barrier.
2290-2300	Local crossing	New ramp over levee, to DCL	Nil.
2800-2820	Brotherwood Street	Retain existing sealed road crossing at 0.73m below DCL	Temporary barrier.
3050-3070	Gardiner Street	Retain existing sealed road crossing at 0.75m below DCL	Temporary barrier.
Bank Two			
1370-5	Mill Street (west)	Retain existing sealed road crossing at 0.67m below DCL	Temporary barrier.
250-280	Mill Street (east)	Raise existing sealed road intersection by between 0.17m to 0.78m to then be 0.5m below DCL.	Temporary barrier/spillway.
735-750	East Street	Flood gate, 15m wide x 1.5m high, to DCL.	**Major floodgate.**

7. Construction Methodology

Construction of the upgrade works for the Wagga Wagga levees will mostly involve earthworks to raise and extend the three existing embankment levees. Other particular construction processes required for the levee upgrade works include :-

- Sheet pile installation
- Erection of gabion walls
- Construction of rockfill mattress lined spillways
- Raising road crossings
- Construction of flood gate support walls, footings, flood gate assemblies (commissioning stage) and storage shed
- Placement of box culverts on levee
- Raising and extending concrete retaining walls.

Each of these activities will incorporate specific construction methodologies, however it is anticipated that a construction contractor will make every effort to select equipment and processes that will be compatible with many of the construction processes. For example, hydraulic excavators could be used for earthworks (excavation, filling etc) together with pile driving by use of a pile driving hammer fitted to the excavator.

A description of an anticipated construction methodology for each of the major components of work is provided below.

Embankment Levee. Upgrade of the Wagga Wagga Levees is primarily an earthworks operation, with two basic operations involved :-

- The major component is upgrade of the existing embankment levees, where the majority of the embankment is retained. Topsoil is stripped from the surface of the levee, followed by excavation of a layer of lower quality embankment fill. The levee is then augmented to the final design levels.
- At ends of the levee where extensions are required and in several proposed re-alignment sections, a new embankment levee is proposed.

The construction process is similar for both operations and for the major augmentation process, the following construction process is envisaged :-

- Surveyor to peg out the location and levels for the embankment works and monitor the works during construction.
- Prepare various construction stage access tracks to and from the levee works.
- Implement approved traffic control measures.
- Excavator to strip and stockpile 100 mm thickness (minimum) of topsoil from “footprint” of works area. The stockpile sites will be at selected locations, adjacent to the levee.
- Excavate a layer of embankment fill from the levee and foundations and trim to design lines. Excavated materials (of suitable quality) will be conditioned and re-used in adjacent upgraded embankment works.
- Compact the surface of excavated levee, using a heavy self-propelled compactor to achieve maximum densification of the existing levee.
- Progressive truck delivery of clay fill to the levee works platform, sourced from suitable materials excavated from the levee and materials from nominated borrow areas.

- Prepare foundations of new works by tyning and moisture conditioning prior to placement of new fill.
- Spread levee fill into 300mm thick (loose) layers. Moisture condition material as required and grade to level.
- Compact new fill with heavy self-propelled padfoot roller. During the process, draw existing embankment material into the new fill to achieve a sound bond between new and existing levee fill.
- As clay fill level rises, add topsoil (and if necessary, random fill) to the outer batter of the levee.
- Continue the process along the length of the levee, using materials locally excavated from the levee, supplemented by fill imported from borrow areas.
- Undertake quality testing of compacted fill.
- During the construction process, suppress dust from access tracks using water cart.
- At the crest of upgraded levee, import new gravel, place in uniform layer and compact to level and grade.
- Trim outer batter topsoil to level and grade, fertilise and grass. Maintain the batter by regular watering and repair of local erosion
- Restore area and topsoil all disturbed areas.

Equipment required is anticipated to include :-

- Trucks - delivery of embankment fill and topsoil from borrow areas and local stockpiles
- Excavators – win and load materials from borrow area and stockpiles, excavate levee and foundations to design lines.
- Grader – grade, level and trim levee fill, maintain access tracks
- Water Cart – dust suppression, maintain condition of fill, maintenance of topsoil and vegetation
- Compactor – spreading of fill, compaction of clay fill to levee embankment and foundation preparation
- Miscellaneous vehicles – delivery of materials and equipment, soil testing, personnel transport.

Sheet Pile Walls. Sheet piling operations include the following :-

- Sheet pile retaining wall (0.9 metres high) along the outer edge of the raised levee crest.
- Sheet pile retaining wall along the outer edge of the existing levee crest.
- Sheet pile retaining wall under the railway line bridge, in a new alignment.

Generally, the sheet pile walls can be installed using a pile driving head fitted to an excavator. The operation would be carried out when the levee embankment reaches the level of the completed base of the wall. At this construction stage, the embankment working platform will be of sufficient width to allow for delivery and storage of the sheet piles on the levee and for the excavator to manoeuvre. As piles will be 4.5 metres long (and weigh 300kg each) a small crane would be required to lift the piles into position.

At the railway crossing, it will be necessary to embed the piles into a trench beneath the railway line. The trench in this location would be backfilled with concrete to secure the piles. Either side of the railway line, the piles can be driven by conventional equipment.

Equipment required is anticipated to include :-

- Excavator, with pile driving hammer
- Small crane.
- Trenching machine or small excavator.
- Ready-mix concrete truck.
- Miscellaneous delivery vehicles, including trucks to deliver sheet piles.
- Personnel vehicles.

Spillways. The two spillways (Main Levee and North Wagga Wagga Levee) include major work components as follows :-

- Excavation of levee and foundations to form spillway channel – 2100 m^3
- Rockfill mattresses (300mm thick) – 3850 m^2

The Main Levee spillway is 200 metres wide and the North Wagga Wagga Levee spillway is 100 metres wide.

The construction methodology for each spillway is envisaged to be as follows :-

- Surveyor to peg out the location and levels for the spillway.
- Prepare adjacent work area for delivery and stockpile of materials (geotextile, rockfill, mattresses etc).
- Excavator to strip and stockpile 100 mm thickness (approximately) of topsoil from "footprint" of works area.
- Excavator to remove embankment fill from the levee and trim to design lines for the spillway. Excavated materials, surplus to site requirements, to be trucked to the levee for re-use in upgraded embankment works.
- Lay geotextile fabric on prepared foundations.
- Deliver and assemble mattresses, in position, on the prepared spillway profile.
- Truck delivery of 1200 m^3 of graded rockfill (800 m^3 Main Levee, 400 m^3 North Wagga Wagga Levee) to a stockpile site, adjacent to works.
- Fill mattresses, with rockfill from the stockpile, using an excavator.
- Close mattresses and lace closed.
- Restore area and topsoil all disturbed areas.

Equipment required is anticipated to be trucks (delivery of rockfill, transport of excess fill and topsoil), excavator (placement of rockfill, excavation of levee and loading of excess materials, final spreading of topsoil), grader (prepare work area and access track, final rehabilitation) plus miscellaneous delivery and personnel vehicles.

Gabion Walls. Minor gabion walls are required at two locations, with a total volume of 120 m^3 (75 m^3 at Mill Street, 45 m^3 at Tarcutta Street). It is expected that this minor work would be undertaken by the same team that undertakes construction of the spillway work.

The foundation for these walls would be cleared and levelled as part of the embankment levee work, so the gabion construction process would include :-

- Surveyor to peg out the position and levels for the walls.
- Lay geotextile fabric on prepared foundations, with additional fabric for fixing to the embankment fill side of each wall.
- Deliver and assemble gabion baskets in position.
- Truck delivery of 120 m^3 of graded rockfill to a stockpile site, adjacent to works.
- Fill gabion baskets, with rockfill from adjacent stockpile, using a backhoe.
- Close gabion baskets and lace closed.

Equipment required is anticipated to be truck (delivery of rockfill), backhoe (placement of rockfill) plus miscellaneous delivery and personnel vehicles.

<u>Floodgates</u>. Six (6) large flood gates are required at locations where major roads cross the levee at levels below the proposed DFL. The flood gates consist of a removable post and beam system, concrete base beam and a cantilever retaining wall at either end of the opening. The roadways will not be raised or re-aligned.

Construction of these flood gates is anticipated to involve the following procedure :-

- Implement traffic control measures.
- Close one half of road and excavate trench for base beam.
- Place pre-fabricated reinforcement cage into trench, fix post support fittings and pour concrete base beam.
- Backfill excavation and provide temporary re-seal to road.
- Repeat procedure for other half of road.
- Excavate foundations for end retaining walls.
- Fix reinforcement and formwork, fix flood gate fittings and pour concrete to walls and foundations.
- Undertake trial (commissioning) assembly of flood gate.
- Store suitably identified removable gate components in purpose built shed.
- Reinstate road crossing.

Equipment required could include :-

- Excavator – for trench excavation, foundation trimming
- Small crane – for placing reinforcing cage
- Ready mix truck – concrete delivery and placement
- Truck – delivery of materials, removal of waste/excess materials
- Small equipment such as power tools, generator, plate compactor, concrete vibrator.
- Personnel vehicles.

<u>Road Crossings</u>. At some minor road/levee crossings, it is more economic to raise the road to at least the DFL. The crossings range from minor local access ramps to two lane sealed roads (eg Marah Street, Mill Street (East)).

Construction of these works will be in accordance with conventional road building operations and equipment.

<u>Box Culverts</u>. A 60 metre section of the Main Levee consists of a lowered embankment levee, topped with 3000 x 900 mm concrete box culverts. The upturned box culverts are partially filled with compacted clay to form a trafficable levee crest and to provide a water tight levee. The culverts will be placed on a bed of sand/clay mix.

The construction process is envisaged to involve :-

- Excavate levee crest to design level and trim batter slopes as required.
- Mix and spread bedding layer of sand/clay mix prior to culvert placement.
- Construct access ramp onto levee for delivery of box culverts.
- Unload box culverts from back of delivery truck and place into position with small mobile crane, working from inside the previously placed culvert section.
- Place and compact fill into box culvert.

Equipment required could include :-

- Delivery truck
- Small mobile crane
- Grader to mix and spread sand/clay bedding mix.

Concrete Retaining Walls. The concrete retaining walls beside Cadell Place and to the north-east of Church Street are 300-400 mm thick, depending on height and location. The walls are reinforced (both faces) with S12-16 bars (ref Drawing C-749). These walls will be raised by up to 900mm (Cadell Place) and 700mm (Church Street) to provide additional freeboard only. No additional permanent loading is proposed for these walls.

It is proposed to upgrade these walls by raising in reinforced concrete, at the same thickness as the existing walls. The construction process is therefore envisaged as follows :-

- Clear works area and remove all attachments (eg handrails) to expose the top of the concrete walls.
- Scrabble the top surface of the concrete wall.
- Drill holes at 300mm centres (approximately) into the top of the wall.
- Epoxy grout 16mm starter bars into the concrete and place extension reinforcement to design level.
- Secure formwork onto either face of the existing concrete wall to design level.
- Place concrete into forms and vibrate. Concrete delivery would be by ready-mix trucks and delivered by concrete pump.
- Strip formwork (after appropriate time) and re-instate original attachments.
- Restore site and topsoil areas as required.

Equipment required is anticipated to be ready-mix trucks (delivery of concrete), concrete pump and pipework (concrete transfer), miscellaneous delivery trucks (reinforcement, formwork), generator and power tools (starter bar holes, formwork cutting and drilling etc), and miscellaneous personnel vehicles.

8. Cost Estimate

The cost estimate for the upgrade of the Wagga Wagga Levees is based on estimated quantities as determined from 3D computer models of the levee works (eg all earthworks volumes), itemised individual items of other work components and appropriate unit rates for these quantities and other items of work.

Unit cost rates have been obtained from tender analysis of recent similar works (where available) or from current published estimating data. Allowances are also included to cover miscellaneous works that will be required as part of the levee upgrade. These miscellaneous items will include :-

- Minor raising/relocating of power and communication services.
- Miscellaneous landscaping and restoration works
- Local drainage works
- Re-vegetation to levee batters and maintenance of batters

Allowances for indirect project items are also included. These allowances are expressed as a percentage of the direct capital cost, as follows :-

▪ Design and Investigation	10%
▪ Construction Management	12%
▪ Project Management	9%
▪ Contingencies	30%

The resulting estimated cost, based on the concept design, is **$17.5 M**. A detailed sub-division of this cost estimate is provided in **Appendix B** to this report.

The cost estimate does not include some additional works that are expected to be required to fully complete the levee upgrade project. These items of work could include the following :-

- River bank stabilisation works.
- Upgrade to services including drainage, sewer, communications etc.
- River Precinct works.
- Miscellaneous alterations to Wagga Wagga facilities eg local kerb and gutter, general roadworks, local community improvements etc.

It should also be noted that the cost estimate is based on the works being undertaken in a single contract, without any inflation adjustments. Should it be necessary to complete the works over a number of years, it would be necessary to increase the estimated cost. For example, sequencing the work over a 10 year period and allowing for an annual 3% cost index increase, the estimated cost of the upgrade works would rise to approximately **$20 M**.

9. Conclusions

Conclusions arising from the concept design of the upgrade works for the Wagga Wagga Levee are :-

- The concept design is based on a number of design criteria and assumptions. Should these criteria and assumptions need to be varied, the concept design may need to be re-considered as the design progresses.
- The concept design is based on results from the geotechnical investigations that were undertaken between 2005 and 2009. These investigations have recommended a number of design criteria which have been incorporated into the concept design.
- Additional geotechnical investigations are required for the detailed design stage of the project.
- The Design Flood Levels (DFL) for the levee upgrade are based on :-
    - Main Levee – 100 yr ARI flood event.
    - North Wagga Wagga Levee – 20 yr ARI flood event.
    - Bank Two Levee - 20 yr ARI flood event.

  These DFL's are sourced from the WMA Water flood study (Ref 9)
- The flood freeboard allowance for the levee upgrade is :-
    - Main Levee – 0.9 metres.
    - North Wagga Wagga Levee – 0.75 metres.
    - Bank Two Levee – 0.75 metres.

  The freeboard allowances have been sourced from the NSW Public Works freeboard study (Ref 13).
- The upgrade works will generally follow the alignment of the existing levee and generally be located on only one face of the levee to minimise impact and cost of the works.
- Levee types that are considered for the upgrade works are ones that are deemed to best satisfy the design objectives. These levee types are :-
    - Embankment Levee
    - Crib-wall embankment levee
    - Sheet pile wall
    - Cantilever retaining wall
    - Hybrid Levee (based on an embankment levee)
- Embankment type levees are the most economic and are used in the concept design wherever feasible.
- Spillways are provided in the three levees to allow large floods, which exceed the design flood, to enter the protected area in a controlled manner. The spillways are located near the lower areas within the levee to minimise the development of hazardous flows.
- Spillways are provided in the levees as follows :-
    - Main Levee – 200 metres wide (Ch 420-620)
    - North Wagga Wagga Levee – 100 metres wide (Ch 2850-2950)
    - Bank Two Levee – 33 metres wide (Mill Street (east)).
- Road crossings at the levees are provided with flood protection as follows :-
    - Major roads below DFL – flood gate
    - Minor roads below DFL – raise road to at least DFL plus temporary flood barrier.
    - Roads above DFL – temporary flood barrier.

- Construction methodologies and equipment requirements for the upgrade works are based on the assumption that a contractor will minimise the types of equipment and construction processes that are employed.
- The estimated cost for the upgrade works is **$17.5 M**. This cost estimate does not include works which are not directly related to the upgrade of the levee, nor does it include any allowance for inflation as a result of staging of the works.

10. References

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