Christmas Creek System
Flood Levee Audit Report
Audit of Levee Banks of the Lower Macleay Floodplain

Report №: 113010-05

Christmas Creek

December 2015

Revision № 01
Executive Summary

This report presents an audit of the Christmas Creek levee system as of December, 2015. The Christmas Creek levee system forms an integral part of the overall flood mitigation system on Christmas Creek. The levee system is comprised of two earthen levee banks, each approximately 1200m in length, located on both the left and right banks of Christmas Creek (looking downstream). A gated headworks structure spanning Christmas Creek defines the upstream extent of the levee system. The levees help prevent nuisance flooding of the Glenrock floodplain that is predominantly used for agricultural purposes with a small number of dwellings.

The scope of this audit included but was not limited to:

1. Compilation of all the known reports and information available on the levees and a summary of their findings and recommendations.
2. Comparison of the levee design crest levels, existing crest levels and flood levels
3. A defects inspection (visual) of the levees to identify areas of anomalies, such as missing levees, low sections, localised depressions, and signs of erosion/scour or instability.

It is noted that a geotechnical investigation was not undertaken as part of this audit. Furthermore, the following items were not included in the scope of this audit although it is recommended they be carried out at later date:

1. Preparation of cost estimate for the remediation of all identified defects and a total cost to repair the levees.
2. Preparation of a condition rating for each levee based on the risk of failure and the likely consequence of a failure.
3. Preparation of an Operation & Maintenance Manual. It is proposed that one document for the entire Lower Macleay flood levee system be developed.

As a result of this audit it was found that the Christmas Creek right bank levee appears to be in relatively good condition with minimal defects identified. The levee crest was shown to be approximately 250mm above the initial design height, with only one potential low point identified on the approach to the southern headworks abutment.

The left bank levee was found to be in relatively poor condition. Approximately 20% of the levee was found to be covered in thick vegetation, making a visual inspection difficult. The lack of maintenance appears to be the result of difficult access to the levee, given that it spans over a number of private properties. The crest levels of the left bank levee were again found to be on average 250mm higher than the initial design levels however, areas of levee crest and shoulder erosion were identified.

The existing crest levels of both left and right bank Levees were found to be approximately 250mm below the 1 in 2 year ARI flood levels outlined in a 2013 flood study undertaken by WMA water on behalf of the Kempsey Bypass Alliance. This is consistent with the estimated level of flood immunity of the adjacent Macleay River levees (Kempsey to Frederickton) (1).

Recommendations resulting from the audit include:
• Remediation of all defects listed in this report.
• A geotechnical consultant be engaged to carry out a stability and seepage assessment on the Christmas Creek levee system to gain an understanding of the structural reliability during a flood event.
• The design level of flood immunity provided by the levees to be re-assessed based on the updated flood data shown in this report.
• An Operation & Maintenance Manual to be developed in line with the information presented in this report.
# Table of Contents

1.0 INTRODUCTION ................................................................................................................................. 6

2.0 SCOPE OF AUDIT ................................................................................................................................. 6

3.0 DESCRIPTION OF THE LEVEE SYSTEM ............................................................................................ 7

4.0 LEVEE CONDITION .............................................................................................................................. 8

  4.1 RIGHT BANK LEVEE GENERAL OBSERVATIONS ........................................................................... 8

  4.2 LEFT BANK LEVEE GENERAL OBSERVATIONS ............................................................................. 9

5.0 LEVEE DESIGN LEVELS, FLOOD LEVELS AND EXISTING LEVELS ......................................................... 9

  5.1 EXISTING SURFACE LEVELS ........................................................................................................... 9

  5.2 LEVEE DESIGN LEVELS ..................................................................................................................10

  5.3 FLOOD LEVELS ............................................................................................................................10

  5.4 DISCUSSION ................................................................................................................................11

    5.4.1 Low Points ............................................................................................................................11

    5.4.2 Estimated Level of Flood Immunity .......................................................................................11

6.0 PREVIOUS REPORTS AND INFORMATION ..........................................................................................11

  6.1 SUMMARY OF FINDINGS AND RECOMMENDATIONS ................................................................11

7.0 GEOTECHNICAL INVESTIGATION OF LEVEES ..................................................................................12

8.0 PREPARATION OF AN OPERATION & MAINTENANCE MANUAL .......................................................12

9.0 DEFECTS INSPECTION REPORT .......................................................................................................13

10.0 CONCLUSION ....................................................................................................................................13

11.0 RECOMMENDATIONS .....................................................................................................................14

12.0 REFERENCES ....................................................................................................................................14

APPENDIX A - PHOTOGRAPHS OF LEVEES
APPENDIX B - ORIGINAL LEVEE DESIGN PLANS
APPENDIX C - SUMMARY OF SCANNED REPORTS KEMPSEY MACLEAY FLOODPLAIN
APPENDIX D - EXISTING LEVEE SURVEY PLANS
APPENDIX E - DEFECTS INSPECTION REPORT
APPENDIX F - GENERAL ADVICE ON REMEDIATION MEASURES
APPENDIX G - INSPECTION AND MAINTENANCE INFORMATION
List of Figures and Tables

Figure A1: Christmas Creek right bank levee looking upstream (approx. chainage 1000)
Figure A2: Christmas Creek right bank levee looking downstream (approx. chainage 170)
Figure A3: Christmas Creek right bank levee headworks structure
Figure A4: Christmas Creek right bank levee looking downstream (approx. chainage 40)
Figure A5: Christmas Creek left bank levee looking downstream (typical) (approx. chainage 540)
Figure A6: Christmas Creek left bank levee vegetation issue looking upstream (approx. chainage 520)
Table 1: Summary of Christmas Creek Levees
Table E1: Christmas Creek left bank levee Defects Inspection Report
Table E2: Christmas Creek right bank levee Defects Inspection Report
Table E3: Priority Level Description
Table G1: Inspection and maintenance information
1.0 INTRODUCTION

The audit of the Christmas Creek levee system forms part of a widespread audit of the entire Lower Macleay flood levee system. The Christmas Creek levee system commences at the junction of Christmas Creek and the Macleay River approximately 35km upstream of the Macleay River outlet at South West Rocks.

The flood system on Christmas Creek forms a critical part of the overall Lower Macleay flood mitigation system, designed to protect important urban and rural land within the Kempsey Shire from the effects minor flood events. Specifically, the Christmas Creek levee system is designed to contain flood waters entering from the Macleay River within Christmas Creek during low ARI flood events to help prevent nuisance flooding of the adjacent agricultural land between Frederickton and Kempsey.

The Christmas Creek flood levees were designed and constructed in the 1960’s. Since this time, the condition of the levees has deteriorated due to a lack of maintenance. The purpose of this audit is to assess the current condition of the Christmas Creek levee system and provide recommendations to remediate any issues found.

The location and site plan of the Christmas Creek Levee system is shown on the drawings located in Appendix D of this report. Photographs of the levees can also be seen in Appendix A of this report.

2.0 SCOPE OF AUDIT

The breadth of the audit was restricted to the Christmas Creek levee system. This system is made up of the right and left bank Christmas Creek levees.

The scope of the audit included but was not limited to:

1. Compilation of all the known reports and information available on the levee system and a summary of their findings and recommendations.
2. Comparison of the levee design crest levels, existing crest levels and flood levels.

This was undertaken by:

a. Obtaining the levee design crest levels and flood levels from either:

   i. The original design plans, or
   ii. Previous flood studies.

b. Completing a survey of the Christmas Creek levee system to confirm existing levels.

c. A defects inspection (visual) of the levee system to identify areas of anomalies, such as missing levees, low sections, localised depressions, and signs of erosion/scour or instability.
The following items were not included in the scope of the audit although it is recommended they be carried out at a later date:

1. Preparation of a cost estimate for the remediation of all identified defects and a total cost to repair the levee system.

2. Preparation of a condition rating for the levee system based on the risk of failure and the likely consequence of failure.

3. Preparation of an Operation & Maintenance Manual. It is proposed that one document for the entire Lower Macleay flood levee system be developed.

Due to budget constraints, a geotechnical investigation could not be undertaken on all levees within the Lower Macleay Flood Mitigation System. The Christmas Creek levee system was considered lower risk as compared to the urban levees for the following reasons:

1. The levee system protects mostly agricultural land and only a small number of dwellings.

2. The levee system is typically relatively low in height compared to the surrounding natural surface.

The urban levees were therefore given priority over the rural levees (including Christmas Creek) and as a result this audit did not include any geotechnical investigation.

### 3.0 DESCRIPTION OF THE LEVEE SYSTEM

The Christmas Creek levee system form part of the overall Macleay River left bank levee system from Kempsey to Frederickton, by means of connecting the Macleay River left bank levee with higher ground in East Frederickton. The levee system is comprised of two 1200m long earthen levee banks, situated on both the left and right Creek banks, commencing at the mouth of Christmas Creek. A gated box culvert headworks structure spanning across Christmas Creek defines the upstream extent of the levee system (refer Appendix A of this report for photographs).

The right bank Christmas Creek levee ties the Macleay River left bank levee to the headworks structure located approximately 1200m upstream. The Right bank Levee maintains a relatively constant crest height before increasing in height substantially in the approach to the headworks abutment.

The left bank Christmas Creek levee ties the higher ground at the Northern headworks abutment to higher ground in Eastern Frederickton approximately 1200m downstream. The levee maintains a relatively constant crest height over its entire length.

Table 1 outlines the typical profile of each of the Christmas Creek levees.
4.0 LEVEE CONDITION

In accordance with the scope of this audit as outlined in Section 2.0, a defects inspection (visual) was carried out on both the left and right bank Christmas Creek levees in order to assess their condition. Individual defects were visually identified during the walk-over inspection and have been discussed in Section 9.0 of this report.

Along with the individual defects, general observations from the walk-over inspection were also recorded. These observations are discussed in Section 4.1 and Section 4.2 of this report.

For the purpose of assisting in the identification of defects, guidance was taken from the information provided in the JK Geotechnics 2014 reports on the urban levees (2). Useful sections of this information has been summarised in Appendix F and Appendix G of this report.

4.1 RIGHT BANK LEVEE GENERAL OBSERVATIONS

The Christmas Creek right bank levee appears to have been regularly mown and kept free of large vegetation. The levee generally has a thick covering of grass and a small amount of woody weeds (refer Figure 1 in Appendix A of this report). The levee has a rounded crest that appears to maintain a relatively consistent longitudinal grade. A minor visual low point was identified at the southern approach to the head works abutment.

No sections of major instability were identified (to be confirmed by a suitably qualified geotechnical engineer), although minor cattle and vehicle tracks are evident on the crest. There is no noticeable erosion of the water side and protected side batter slopes aside from scour identified at the outlet of a piped culvert that passes through the levee.

A number of cattle fences were identified running perpendicular over the levee (refer Figures A2 and A3 in Appendix A of this report). This could potentially create an issue if moving debris was to strike the fence during a flood event. Recommendations regarding the treatment of this issue are outlined in Appendix F of this report.
A summary of the individual defects identified during the walkover inspection can be seen in the Defects Inspection Report located in Appendix E of this report. A more thorough assessment of the levee crest levels has also been made in Section 5.0 of this report.

4.2 LEFT BANK LEVEE GENERAL OBSERVATIONS

On inspection it appears that the Christmas Creek left bank levee has had considerably less maintenance than the right bank Levee. This is likely due to the difficult access to the levee, given that it spans through a number of private residential properties.

Approximately 20% of the levee (Ch: 100-520) is covered in thick vegetation consisting of long grass, shrubs and small to large trees (refer Figure A6 in Appendix A of this report). This vegetation makes a visual inspection difficult and issues such as animal burrows and localised erosion are difficult to identify.

Three pipe culverts were identified during the inspection and minor scouring was identified at each of the outlets. It should also be noted that two of the three culverts identified are designed to drain excess water from the retention basins located within the Macleay Valley House lot (Lot ID 22615) into Christmas Creek. Based on aerial photography it appears that these culverts have been placed under the levee, meaning that sections of the levee were most likely excavated to lay the PVC pipes. If not correctly reinstated this may cause areas of local instability within the levee, an increased risk of piping failure may also be present. A suitably qualified geotechnical engineer should therefore be engaged to assess the stability of the levee in these areas.

Overall the levee appears to be in average condition. Although no major instability issues were identified (to be confirmed by a suitably qualified geotechnical engineer), a number of undulations and areas of erosion were identified on the levee crest and batters (refer Figure A5 of Appendix A of this report).

A summary of the individual defects identified during the walkover inspection can be seen in the Defects Inspection Report in Appendix E of this report. A more thorough assessment of the levee crest levels has also been made in section 5.0 of this report.

5.0 LEVEE DESIGN LEVELS, FLOOD LEVELS AND EXISTING LEVELS

5.1 EXISTING SURFACE LEVELS

A topographic survey was carried out on the levees to confirm the existing levels and identify any potential low points. The survey was carried out using Global Navigation Satellite System (GNSS) Surveying Equipment which is typically accurate to approximately ±30mm.

The survey is presented in the longitudinal and cross sections prepared for both left and right bank Christmas Creek levees, which can be seen in Appendix D of this report.
5.2 LEVEE DESIGN LEVELS

The original levee design levels were taken from the Macleay River County Council Flood Mitigation Plan:


The levels as shown on the original design plans reference Standard Datum. In order to compare the design levels with the surveyed and flood levels, a conversion from Standard Datum to Australian Height Datum (AHD) is required.

Ideally this conversion would be made utilising bench marks as shown on the original design plans. Using survey instrumentation to identify the levels of these bench marks in AHD would allow a precise conversion to be made. Unfortunately no bench marks could found on the Christmas Creek levee system.

In the absence this information, an average conversion value between Standard Datum and AHD has been used. This value has been identified by Council through comparison of a number of Standard Datum bench marks around the Shire and their corresponding levels in AHD. However, it should be noted that the conversion between Standard Datum and AHD over these bench marks was not consistent, ranging from approximately 50mm to 200mm.

The following formula was used to make the conversion from Standard Datum to AHD:

\[(x - 100) \times 0.3048 - 0.083\]

Where:

- X is the design level 100 ft below standard datum
- 0.3048 is the conversion from ft to meters
- 0.083 is an approximation of the difference between Standard Datum and AHD in the Kempsey Shire

The original design plans for both left and right bank Christmas Creek levees are presented in Appendix B of this report. The original design levels converted to (m) AHD are also presented on the drawings in Appendix D of this report.

5.3 FLOOD LEVELS

The design flood immunity level of the Christmas Creek levee system is unknown. Since the construction of the system however, Council has commissioned a number of flood studies that may be useful in determining an approximate flood immunity level of the levees.

The most up to date study encapsulating the Christmas Creek system was carried out by WMA water on behalf of the Kempsey Bypass Alliance in 2013. This study yielded the 50%, 20%, 10%, 2% and 1% annual exceedance probability (AEP) flood levels across an area spanning from Kempsey to South of Smithtown including the river and floodplain areas. For ease of interpretation the AEP terms have been converted to their corresponding Average Recurrence Interval (ARI) i.e. 1 in 100 year ARI flood.
The flood levels estimated in the 2013 study have been compared against the surveyed levee crest levels and design levee crest levels in Appendix D of this report.

5.4 DISCUSSION

5.4.1 Low Points

A low point or section of levee bank may lower the flood immunity level provided by the levee, increasing the frequency of flooding of the protected area. As the low points/sections will likely be overtopped more frequently than the rest of the levee crest, localised erosion and further deterioration of the levee may also occur in these areas.

For the purpose of the investigation a low point or section on the levee is defined as:

- A point or section at which the existing crest level is a minimum of 100mm lower than the original design level or;
- In the case where the levee crest has been constructed above the original design level for the majority of its length, a point at which the existing level is a minimum of 250mm lower than the surrounding levee will be considered a low point/section.

From the drawings presented in Appendix D of this report it can be seen that the crest level of the left bank levee is consistently approximately 250mm above the original crest design level. Two low points were identified on the left bank levee, these are summarised in Table E1 of Appendix E of this report. The gradient of the batter slopes of the levee were also found to be generally consistent with the original design plans, although some areas of erosion were identified during the visual inspection (refer Section 4.2 of this report).

The right bank levee was also found to be approximately 250 mm above the original design level with a relatively consistent longitudinal grade over its entire length (refer Appendix D of this report). The only low point identified was on the approach to the head works abutment. This low point is identified in table E2 in Appendix E of this report. The gradient of the batter slopes of the levee were also found to be generally consistent with the original design plans.

5.4.2 Estimated Level of Flood Immunity

Both left and right levee banks can be seen to be consistently approximately 250mm below the 1 in 2 year ARI flood level (refer Appendix D). This is consistent with the estimated level of flood immunity of the adjacent Macleay River levees (Kempsey to Frederickton) (1).

6.0 PREVIOUS REPORTS AND INFORMATION

6.1 SUMMARY OF FINDINGS AND RECOMMENDATIONS

Since the construction of the Macleay Valley flood mitigation system in the 1960’s a number of reports and assessments have been completed that present information regarding the maintenance and operation of the Lower Macleay flood levee system.
Council currently does not have an information register identifying all the available information on the levee banks or the flood mitigation system as a whole. In order to increase the accessibility of this information in future, the following activities were completed as part of this audit:

- All of the available reports concerning the Lower Macleay levees were compiled. To achieve this a thorough search of Council archives was undertaken.
- All reports were then electronically scanned, filed and summarised.

A summary of this information can be seen in Table C1 in Appendix C of this report.

It should be noted that no documentation has been located that relates specifically to the Christmas Creek system, aside from the original design plans. However, information presented in many of the broader scoped documents may apply to the Christmas Creek levees.

7.0 GEOTECHNICAL INVESTIGATION OF LEVEES

As stated in Section 2.0, due to budget constraints, a geotechnical investigation could not be undertaken on all levees within the Lower Macleay Flood Mitigation System. The Christmas Creek levee system was considered lower risk as compared to the urban levees for the following reasons:

1. The levee system protects mostly agricultural land and only a small number of dwellings.
2. The levee system is typically relatively low in height compared to the surrounding natural surface (less than 0.5m).

The urban levees were therefore given priority over the rural levees (including Christmas Creek) and as a result this audit does not include geotechnical investigation.

8.0 PREPARATION OF AN OPERATION & MAINTENANCE MANUAL

In order for Council to prioritise any remediation measures recommended in this study it is recommended that an Operation & Maintenance plan be developed as one document for the entire Lower Macleay flood levee system.

The preparation of this manual is not part of the Scope of this Audit. It has not yet commenced and has been listed as a recommendation in Section 11.0 of this report.

Appendix F and Appendix G of this report summarise typical levee defects and their corresponding management measures as outlined during the inspection of the Lower Macleay urban flood levees carried out by JK Geotechnics in July 2014 (2). This information may be used for guidance when creating the operation and maintenance plan. However, it should be noted that the remediation measures outlined are site specific and remediation works should not be undertaken prior to seeking advice from a suitably qualified geotechnical engineer.
9.0 DEFECTS INSPECTION REPORT

In order to summarise the defects noted in this audit a Defects Inspection Report was created. This report is presented in Appendix E of this report.

The Defects Inspection Report incorporates the defects identified as part of this audit including:

- The observations of the walkover inspection (section 4.0).
- Low points identified as part of the topographic survey (section 5.0).

The information provided in the defects inspection report, along with the information in Appendix F and Appendix G of this report should form the basis for the prioritisation of each of the proposed remediation measures and the associated cost estimation.

10.0 CONCLUSION

An audit in accordance with the scope outlined in Section 2.0 of this report was carried out on the Christmas Creek levee system. All available reports on the levees were compiled, a topographic survey was completed and a walkover (visual) defects inspection was carried out.

It was found that the Christmas Creek right bank levee is in reasonable to good condition and appears to have been regularly mown and maintained. No major slumping or erosion was identified with only minor scouring occurring at the culvert outlet. The crest was found to have a consistent longitudinal grade with only minor undulations. A topographic survey showed that the crest level is consistently 250mm above the original design height. One low point was identified on the approach to the head works abutment.

The Christmas Creek left bank levee was found to be in slightly worse condition than the right bank levee and there is an apparent lack of maintenance over a number of sections. A number of properties along the levee have allowed vegetation to grow on the levee crest and batters creating issues with inspection and potentially creating areas of instability (to be confirmed by a suitably qualified geotechnical engineer).

Three pipe culverts passing through the left bank levee were identified. These pipes appear to have been placed after the construction of the levees and the quality of the reinstatement work is unknown. If not correctly reinstated this may cause areas of local instability within the levee, an increased risk of piping failure may also be present.

No major instability issues were identified on the left bank levee (to be confirmed by a suitably qualified geotechnical engineer). However, a number of undulations and areas of erosion were identified on the levee crest and batters. Overall the levee crest was typically found to be approximately 250mm above the original design level.

The WMA water 2013 flood study was used to estimate the level of flood immunity of the levee system. It was found that both left and right bank levee crests were approximately 250mm below the 1 in 2 year ARI flood level. This was also found to be consistent with the level of flood
11.0 **RECOMMENDATIONS**

It is recommended that all defects listed in the Defects Inspection Report in Appendix E of this report be remediated. The priority level and description of each of the defects listed in Appendix E should be taken into account when prioritising the remediation works. Given the amount of vegetation on the left bank levee it is recommended that a secondary visual inspection be carried out once the vegetation has been cleared.

An Operation & Maintenance Manual should also be developed in line with the information presented in this report (specifically Appendix D, E and F) to ensure that the appropriate level of maintenance of the levee system is upheld to avoid further degradation of the levees in future.

Given the amount of vegetation within the Christmas Creek left bank levee corridor, removing all vegetation could be very expensive. As a cost saving measure a suitably qualified geotechnical engineer should be engaged for advice on what specific trees (if any) may remain within the levee corridor.

It is recommended that the suitability of the design levee crest levels be re-assessed taking into account the estimated level of flood immunity presented in this report. It is suggested that this be undertaken as part of a holistic assessment of the suitability of the crest levels for all of the levees within the Lower Macleay Floodplain.

In order to gain a better understanding of the reliability of the levee during a prolonged flood event, it is recommended that a stability and seepage analysis be undertaken on the levee system by a suitably qualified geotechnical engineer. Where appropriate, the information provided by such an assessment should then form part of the levees Operations and Maintenance plan.

12.0 **REFERENCES**

1. Kempsey Shire Council  
   **Kempsey to Frederickton Flood levee Audit**  
   May 2015
2. JK Geotechnics  
   **Report to Kempsey Shire Council on Geotechnical Investigation for Lower Macleay Floodplain Levee Assessment**  
   July 2014
3. CIRIA  
   **International Levee Handbook**  
   2013
APPENDIX A -

PHOTOGRAPHS OF LEVEES
Figure A1: Christmas Creek right bank levee looking upstream (approx. chainage 1000)

Figure A2: Christmas Creek right bank levee looking downstream (approx. chainage 170)
Figure A3: Christmas Creek right bank levee headworks structure

Figure A4: Christmas Creek right bank levee looking downstream (approx. chainage 40)
Figure A5: Christmas Creek left bank levee looking downstream (typical) (approx. chainage 540)

Figure A6: Christmas Creek left bank levee vegetation issue looking upstream (approx. chainage 520)
APPENDIX B -

ORIGINAL LEVEE DESIGN PLANS
APPENDIX C -

SUMMARY OF SCANNED REPORTS

KEMPSEY MACLEAY FLOODPLAIN

(Reports specifically related to Hat Head not included)
<table>
<thead>
<tr>
<th>Report By Macleay River County Council’s Civil Engineer</th>
<th>Report Date</th>
<th>Summary of Aims</th>
<th>Findings / Recommendations</th>
</tr>
</thead>
</table>
| • Reviewing the 1953 Proposal of the Macleay Valley Flood Mitigation Committee.  
• Submitting an overall Plan of Flood Mitigation for the Lower Macleay Valley.  
Macleay River County Council. | October 1962 | Review the 1953 Proposal of the Macleay Valley Flood Mitigation Committee and prepare an overall Plan of Flood Mitigation Works for the Lower Macleay Valley.  
A description of the various works proposed and estimated costs of their construction. | The 1953 Proposal of the Macleay Valley Flood Mitigation Committee substantially endorsed a comprehensive and detailed plan of works (including estimate of cost). This was based on additional and more accurate data and detailed investigation.  
The works envisaged compromise in the main, levees, floodgated headworks, floodways, drains and river bank stabilisation and protection. |
| Macleay River Flood Mitigation Model Investigation.  
Manly Hydraulics and Soils Laboratory.  
Department of Public Works. | August 1963 | Construction of a physical model in order to investigate the effect of various flood mitigation works. | Found that the following works would reduce the flood menace  
• Raising Eden St embankment  
• Removing the Pola Creek Island  
• Incorporating the addition of a training wall trough in central Kempse |
| Flood Mitigation Report on Investigation of Alternative Methods for the further drainage of floodwater from the Swanpool, Kinchela and Ball’s Creek Areas. | August 1965 | Explore the possibility of and consider alternative schemes to provide for the further requirements of flood drainage of the Swanpool, Kinchela and Ball’s Creek areas. | Recommend submission to the Department of Public Works for approval to the Korogora 1964 Scheme combined with a Ball’s Creek to Saltwater Inlet Scheme. |
| Report on the Hydrological Implications of Flood Mitigation works on the floodplain of the Macleay River below Kempsey.  
University of New England. | August 1967 | Measure and analyse the manner in which inundation has been reduced by flood mitigation measures | Demonstrated reduction in area, depth and time of inundation of floods due to mitigation measures. |
<table>
<thead>
<tr>
<th>Report</th>
<th>Report Date</th>
<th>Summary of Aims</th>
<th>Findings / Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Resources of the Macleay Valley.</td>
<td>May 1968</td>
<td>Study of the physiography, climate, groundwater potential and surface water resources. Review the current water requirements Assessments made of possible future water development.</td>
<td>Achieved study aims. Provides good historical records of rainfall and runoff.</td>
</tr>
<tr>
<td>Macleay River County Council Additional Works Programme 1970 -1976.</td>
<td>Sept 1970</td>
<td>Feasibility, benefits and costs of constructing and operating Ryan’s Cut investigated.</td>
<td>Recommended construction of Ryan’s Cut Construction determined to be feasible. Benefit to cost ratios ranged from 1 to 2.5 at discount rates of 7% and 5 % respectively.</td>
</tr>
<tr>
<td>Macleay River County Council Additional Works Programme 1970 -1976.</td>
<td>October 1970</td>
<td>Summarise results of and prepare BCRs on the studies of the following projects: Bellimbopinni Drainage, Big Hill Cut, Ryan’s Cut, Gladstone Bank Protection, Kempsey Training Levee. Macleay River Floodways. Additional Drainage.</td>
<td>All Project s except for Bellimbopinni Drainage and Macleay River Floodways showed a benefit from the provision of flood mitigation exceeding the cost of the works required.</td>
</tr>
<tr>
<td>Report</td>
<td>Report Date</td>
<td>Summary of Aims</td>
<td>Findings / Recommendations</td>
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</tbody>
</table>
| Site Investigation of Fabridam, Belmore Floodway. Sinclair Knight Consulting Engineers. | August 1971 | Site Investigations to study:  
• The extent, quality and compaction of fill areas.  
• The adequacy of the foundations.  
• The overall stability of the Fabridam and structure under operating conditions. | Results indicated:  
• Poor compaction and high moisture contents indicating significant fill settlements likely to occur.  
• Existing floor foundations founded in cut can safely take a bearing pressure of 1,500 pds. per sq. ft.  
• Structure has a factor of safety of 3 with respect to stability. |
| Flood Mitigation on the Macleay River. | 6 Dec 1976 | Provide a scope and purpose of efforts to mitigate the effects of flooding in the Macleay River Valley. | Provides a factual account of flood mitigation works undertaken over the previous 21 years.  
Provides a historical record of levee bank construction. |
| Environmental Impact Statement Additional Drainage Seven Oaks Area Department of Public Works. | Nov 1978 | EIS on the effects of the proposed additional drainage works in the Seven Oaks Area. | EIS prepared |
Policies adopted for the conditions of approval of developments in these Flood Prone Areas.  
<table>
<thead>
<tr>
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<th>Summary of Aims</th>
<th>Findings / Recommendations</th>
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</thead>
<tbody>
<tr>
<td>NSW Coastal Rivers. Flood Plain Management Studies. Summary Report Macleay Valley. LM &amp; P Consultants.</td>
<td>Dec 1980</td>
<td>Report on flood management measures currently in operation and constraints on their effectiveness. Identify areas of potential for flood losses, assess their significance and evaluate practical mitigation measures. Recommend proposals which conform to an overall flood plain management strategy. Report on economic constraints to the implementation of these proposals.</td>
<td>Provided a prioritised list of recommended works and measures. (no list was ever provided)</td>
</tr>
<tr>
<td>Flooding Effects From The Raising of The Pacific Highway North Of Frederickton. Public Works Department.</td>
<td>May 1981</td>
<td>Investigation of the flooding effects of the raising of the Pacific Highway North of Frederickton on surrounding properties. The proposed work on the Pacific Highway is from 8 km to 13.25km North of Kempsey.</td>
<td>The report recommended modifications to the design proposed by the Department of Main Roads in order to reduce the impact to an acceptable level.</td>
</tr>
<tr>
<td>Macleay River Flood Study Webb, Mckeown &amp; Associates Pty Ltd. NSW Public Works, Report No. 88050.</td>
<td>April 1989</td>
<td>Flood Study of the Lower Macleay River to determine the design conditions for the 1 in 20, I in 50 and 1 in 100 year floods and an extreme event.</td>
<td>Flood behaviour throughout the study area for the 1 in 20, I in 50 and 1 in 100 year floods and the extreme flood calculated and results provided on plan views.</td>
</tr>
<tr>
<td>Report</td>
<td>Report Date</td>
<td>Summary of Aims</td>
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</tbody>
</table>
| Lower Macleay Valley Flood Mitigation.      | July 1994   | The Kinchela Creek and Belmore River Floodways were originally designed based on the use of Fabridams. These were constructed but failed soon after. Subsequently replaced with lift gates. The aim of this report is to assess the actual capacity of these lift gates compared to the original floodway design capacity of the Fabridams. | Kinchela Creek Findings/Recommendations  
Original Fabridam Floodway Design Capacity of 71 cum/sec as against actual lift gate capacity of 41 cum/sec.  
- Greater discharge could be achieved by enlarging lift gates  
Belmore River Findings/Recommendations  
- Original Fabridam floodway Design Capacity 560 cum/sec as against actual lift gate capacity of 400 cum/sec.  
- To achieve a greater floodway discharge the Belmore River would have to be widened at the same time.                                                                 |
| Review Of Kinchela Creek and Belmore River Floodway Capacities. |             |                                                                                                                                                                                                                 |                                                                                                                                                                                                                           |
| NSW Public Works.                           |             |                                                                                                                                                                                                                 |                                                                                                                                                                                                                           |
| Kinchela EIS.                               | July 1994   | Investigate implications of constructing a channel to be linking the eastern floodway to the headwaters of Korogoro Ck. The purpose would be to pass the smaller floods direct to the ocean after the eastern floodway was opened thereby preventing major inundation of the swamps and reducing the depth and duration of flooding on farmlands. This Stage 1 Report is an assessment of the general hydraulic feasibility of the proposal. | Flood models with various options run which demonstrated that the proposal was hydraulically feasible.  
The construction of the Flood Channel would necessarily lead to more frequent moderate to high flows in the creek but would not increase the peak flows from major floods.                                    |
| Kinchela Creek Flood Channel Stage 1 Report. |             |                                                                                                                                                                                                                 |                                                                                                                                                                                                                           |
| Webb, Mckeown & Associates Pty Ltd.         |             |                                                                                                                                                                                                                 |                                                                                                                                                                                                                           |
| Kinchela EIS.                               | October 1994| This second stage of the investigation is concerned with the economic appraisal of the proposal. This involves the calculation of the Benefit Cost Ratio. Two alternative proposals examined:  
1. Alter the operation of the Kinchela and Belmore Floodways so that the gates are opened at a higher flood level (on the Kempsey Traffic Bridge). Would require raising the levee system on Kinchela Creek and possibly the minor raising on the Macleay | Original proposal (channel to be constructed linking the eastern floodway to the headwaters of Korogoro Creek) had a Benefit Cost Ratio of 0.5.  
Alternative Proposals:  
1. Benefit Cost Ratio of 2.4. Almost equivalent benefits to the channel could be achieved by modifying the operation of the floodway gates and carrying out minor levee amplification. Costs would                                                                 |
<p>| Kinchela Creek Flood Channel Stage 2 Report. |             |                                                                                                                                                                                                                 |                                                                                                                                                                                                                           |
| Webb, Mckeown &amp; Associates Pty Ltd.         |             |                                                                                                                                                                                                                 |                                                                                                                                                                                                                           |</p>
<table>
<thead>
<tr>
<th>Report</th>
<th>Report Date</th>
<th>Summary of Aims</th>
<th>Findings / Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinchela EIS. Kinchela Creek Flood Channel Stage 3 Report.</td>
<td>Nov 1995</td>
<td>Provide a summary of the benefits and costs associated with a range of mitigation strategies including those options outlined in the Stage 1 &amp; 2 Reports. No EIS to be prepared.</td>
<td>Summary of Benefit Cost Ratios for 8 different mitigation strategies ranging from a do nothing option to major works – including the options considered in the earlier reports. Opening the headworks gates on the Belmore River and Kinchela Creek during a flood not a viable option – disbenefits of allowing a lot more water onto properties in the headwaters would outweigh any measurable benefits elsewhere. No EIS ever completed.</td>
</tr>
<tr>
<td>Lower Macleay Floodplain Management Study.</td>
<td>Feb 1997</td>
<td>Review previous flood study using currently available data and up-to-date technology to determine the nature and extent of the flood problem. Using this updated study, examine options to be incorporated into a floodplain management study.</td>
<td>Recommendations of various options regarding • Village Mitigation • Structural • Changes to Operations • Drainage Modifications • Water quality/Data Collection</td>
</tr>
<tr>
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</tr>
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</tr>
<tr>
<td>Review of Environmental Factors for the raising of Kinchela Creek Levees and Associated Works.</td>
<td>Dec 1997</td>
<td>Prepare a REF for the raising of the levees along Kinchela Creek, Belmore River and Rainbow Reach together with the modification to the management of Council’s Flood Mitigation System and the proposed modifications to drainage systems.</td>
<td>REF Determined 2 December 1997 by Council’s Director Operational Services.</td>
</tr>
<tr>
<td>Lower Macleay Floodplain Management Plan. Draft for Public Exhibition. Webb, McKeown &amp; Associates Pty Ltd</td>
<td>March 1999</td>
<td>In February 1997, Council published the Lower Macleay Floodplain Management Study. It provided recommendations covering works, practices and changes to planning instruments which would provide the framework for more effective management of the floodplain. This Plan now draws the Study recommendations together into a formal plan of management for the floodplain within which specific works and measures can be implemented.</td>
<td>Floodplain Management Plan produced tabulated Elements of the plan prioritised.</td>
</tr>
<tr>
<td>Report</td>
<td>Report Date</td>
<td>Summary of Aims</td>
<td>Findings / Recommendations</td>
</tr>
<tr>
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<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Upper Belmore Flood Management Strategy.</td>
<td>July 2000</td>
<td>Undertake a Floodplain Management Strategy Study to identify actions and works need to enhance the environment and improve water quality and sustain the land productivity of the Upper Belmore area.</td>
<td>Five Strategies developed which provided a framework for the future direction of water quality and land management in the Upper Belmore Study Area. Actions, Management Options, Considerations, Responsibility and Costs prepared for each of these Strategies</td>
</tr>
<tr>
<td>Webb, Mckeown &amp; Associates Pty Ltd.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macleay River Flood March 2001 Flood Damages Data Collection.</td>
<td>March 2004</td>
<td>Gather Information in relation to the March 2001 flood including:</td>
<td>Damage costs were quantified. The Actual Flood Damage Costs compared to the Potential Flood Damage Costs were low due to the length of flood warning time and the flood awareness of the affected population. Difference between the modelled and reported flood behaviour in reasonable agreement. Cochrane St and RSL levees reportedly overtopped in good agreement with the model. Eden St Levee overtopped 0.4 m earlier than anticipated – further investigation beyond the scope of the study.</td>
</tr>
<tr>
<td>Webb, Mckeown &amp; Associates Pty Ltd.</td>
<td></td>
<td>• Damage and costs incurred</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Brief verification of results produced by previously established hydrologic and hydraulic models</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Compared observed flood behaviour with previous predictions and studies.</td>
<td></td>
</tr>
<tr>
<td>Macleay River at Kempsey. Draft Geomorphologic Assessment.</td>
<td>August 2007</td>
<td>Identify any morphological trends in the Macleay River channel between the Kempsey Railway Bridge and Frederickton. Morphological trends determined through the collation and analysis of available hydrosurvey. Hydraulic Modelling also undertaken to quantify the potential impacts of observed bed changes in terms of flood levels.</td>
<td>The waterway areas along the study reach have not varied significantly over the last 50 years (ie between 2007 and 1957.) Virtually no change in the flood level in the in 100 flood resulting in changes in the underlying bathymetry adopted in the model.</td>
</tr>
<tr>
<td>Webb, Mckeown &amp; Associates Pty Ltd.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report</td>
<td>Report Date</td>
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<tr>
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</tr>
</tbody>
</table>
| Kempsey Flood Study.                        | Jan 2008    | Provide:  
1. A summary of available data.  
3. Details of the calibration and verification of the hydraulic models.  
4. An analysis and interpretation of model results to quantify the design flood behaviour for the CBD under existing conditions. |
| Hydraulic Modelling Draft Report.           |             | Numerical models to quantify the hydrology and hydraulics of the Macleay River Catchment established and calibrated making best use of data currently available.  
Detailed 2D hydraulic model of the study area around Kempsey established (Model Details spatial distribution of flood levels, depths and flow velocity)  
Current Models significantly more detailed and refined compared to previous studies. Enables a sound technical basis upon which the future development of the CBD can be assessed.  
Models developed suitable for use in the assessment of strategic development and redevelopment options for the CBD. |                                                                                                                                                                                                                                                                                                                                                                                          |
| Webb, Mckeown & Associates Pty Ltd.         |             |                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                          |
| Kempsey Levee Gradient Sensitivity Assessment. | March 2008  | Identify how different shaped hydrographs (ie those of similar peak magnitude but of different volumes and/or rates of rise) affect the flood gradient and whether this in turn affects the location and/or sequence in which the Kempsey CBD levees are overtopped. | Eden and Cochrane St Levees would be overtopped in a 1 in 5 year, Short St Levee in a 1 in 100 year and the RSL Levee in a 1 in 10 year event.  
Eden St Levee would overtop first in most circumstances.  
Recommend low points in the Eden St and Cochrane St Levees be filled to achieve protection at 7.4m and 5.9m AHD respectively. |                                                                                                                                                                                                                                                                                                                                                                                          |
<p>| Department of Environment and Change.       |             |                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                          |
| Webb, Mckeown &amp; Associates Pty Ltd.         |             |                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                          |
| NSW Levee Study for Emergency Management SES | Sept 2008   | Provide current information of a number of Levees throughout NSW including those of the Lower Macleay.                                                                                                         | Unable to locate Appendices relating to Lower Macleay Floodplain.                                                                                                                                                                                                                                                                                                                                                                                     |</p>
<table>
<thead>
<tr>
<th>Report</th>
<th>Report Date</th>
<th>Summary of Aims</th>
<th>Findings / Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floodgate and Drain Management Guidelines.</td>
<td>March 2002</td>
<td>Guidelines developed by Council to assist Council staff, private contractors and landholders to undertake “Best Practice” in flood mitigation drain and flood gate management.</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Design Report. Fredericton Levee North (constructed as part of the Kempsey Bypass)</td>
<td>Nov 2011</td>
<td>Design Report provides information on the alignment of the Fredericton Levee, the proposed wall and embankment sections, design details and associated issues. Prepared by Kempsey Bypass Alliance.</td>
<td>Construction Plans prepared. Levee designed to retain the 1 in 100 year flood with a freeboard of 500mm. Cantilever sheet piles provided along the river bank where an earth levee is not feasible. Reinforced concrete flood wall on secant piles used where vibrations caused by construction of sheet piles may endanger properties.</td>
</tr>
<tr>
<td>Development and Operation of the Macleay River Flood Mitigation System.</td>
<td>Not Known</td>
<td>Details the Scheme’s history of construction, basic aims and its Operation in times of flood.</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Maintenance and operating manual flood control structure at Kinchela Creek.</td>
<td>Not Known</td>
<td>Sets out a Maintenance and Operating Manual for the flood control structure at Kinchela Creek.</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>List of all Flood Mitigation Engineering Design / Construction Plans going back to 1955.</td>
<td>Not Known</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
</tbody>
</table>
APPENDIX D -

EXISTING LEVEE SURVEY PLANS
APPENDIX E -

DEFECTS INSPECTION REPORT
## Table E1: Christmas Creek left bank levee Defects Inspection Report

### Defects Inspection Report

**Christmas Creek Left Bank Levee (CCLB)**

<table>
<thead>
<tr>
<th>Action / Defect No.</th>
<th>Chainage</th>
<th>Description</th>
<th>Priority Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCLB 1</td>
<td>-</td>
<td>Vegetation on levee. A number small and large trees are present on and around the levee bank over its entire length as well as thick vegetation on the levee between Ch: 100-520</td>
<td>1</td>
</tr>
<tr>
<td>CCLB 2</td>
<td>140</td>
<td>Pipe culvert under levee, monitor scouring. Pipe culvert appears to have been installed after levee construction. Excavations while laying the pipe may have caused local area of instability</td>
<td>1</td>
</tr>
<tr>
<td>CCLB 3</td>
<td>460</td>
<td>Pipe culvert under levee, monitor scouring. Pipe culvert appears to have been installed after levee construction. Excavations while laying the pipe may have caused local area of instability</td>
<td>1</td>
</tr>
<tr>
<td>CCLB 4</td>
<td>640</td>
<td>Pipe culvert under levee, mild scouring, monitor.</td>
<td>2</td>
</tr>
<tr>
<td>CCLB 5</td>
<td>740-760</td>
<td>Minor erosion of levee crest</td>
<td>2</td>
</tr>
<tr>
<td>CCLB 6</td>
<td>-</td>
<td>Fence on Levee. A number of fences cross the levee bank that can be seen on the aerial photography in Appendix A of this report. Generally running perpendicular across levees posing low threat</td>
<td>3</td>
</tr>
<tr>
<td>CCLB 7</td>
<td>145</td>
<td>Low Point. Localised low point approximately 250mm lower than surrounding areas, still above design height</td>
<td>1</td>
</tr>
<tr>
<td>CCLB 8</td>
<td>-</td>
<td>A number of sections of the levee have uneven shoulders and crests due to minor erosion over time. The centre of the crest however, still generally remains at a consistent level.</td>
<td>2</td>
</tr>
</tbody>
</table>
### Table E2: Christmas Creek right bank levee Defects Inspection Report

#### Defects Inspection Report
Christmas Creek Right Bank Levee (CCRB)

<table>
<thead>
<tr>
<th>Action / Defect No.</th>
<th>Chainage</th>
<th>Description</th>
<th>Priority Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCRB 1</td>
<td>10-70</td>
<td>Low Area up to 500 mm below original design level. Given a lower priority level as this area of the levee is significantly higher than the rest of the surrounding levees. The main purpose of the height increase is most likely to provide access to the head works, rather than offering increased flood protection.</td>
<td>2</td>
</tr>
<tr>
<td>CCRB 2</td>
<td>-</td>
<td>Fence on Levee. A number of fences cross the levee bank that can be seen on the aerial photography in Appendix D of this report.</td>
<td>2</td>
</tr>
<tr>
<td>CCRB 3</td>
<td>300</td>
<td>Pipe culvert under levee, mild scouring, monitor.</td>
<td>2</td>
</tr>
<tr>
<td>CCRB 4</td>
<td>-</td>
<td>Woody weeds present on the levee, to be removed as per Appendix F</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table E3: Priority Level Description

The recommended priority levels are based on the following criteria:

<table>
<thead>
<tr>
<th>Priority Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very Poor Condition - Needs to be urgently actioned</td>
</tr>
<tr>
<td>2</td>
<td>Poor Condition – Needs to be actioned as soon as possible</td>
</tr>
<tr>
<td>3</td>
<td>Average Condition – Needs to be actioned when practical</td>
</tr>
</tbody>
</table>
APPENDIX F -

GENERAL ADVICE ON REMEDIATION MEASURES
INTRODUCTION

As part of the Audit of the Levee banks of the Lower Macleay Floodplain, JK Geotechnics were commissioned to carry out geotechnical investigations on the following urban levees:

- Eden Street Levee (refer Report N\^o113010 - 01)
- Cochrane Street levee (refer Report N\^o113010 - 01)
- Hat Head Village levee (refer Report N\^o113010 - 02)
- Hat Head Control levee (refer Report N\^o113010 - 02)
- Smithtown levee (refer Report N\^o113010 - 03)

As part of this work JK Geotechnics provided guidance and general comments regarding a number of remedial measures to be carried out on the levee banks. Due to budget constraints and the lower risk nature of the rural levees, geotechnical works were not carried out on rural levees as part of this audit. In the interim the advice provided in the urban levee reports has been summarised for guidance on all levees. It should be noted that the following advice is site specific and should be used for planning and cost estimation purposes only. Advice from suitably qualified geotechnical engineers must be sought prior to carrying out works which may affect the structural or operational integrity of the levees.

TREE AND ROOT REMOVAL

**Beyond upstream (protected side) toe**

Where dense tree coverage occurs beyond the upstream levee toe, it is recommended that all trees be removed for a 2.5m zone width along the toe. This should only be completed once after completing the relevant consultation process (if required) and obtained all appropriate approvals. Some large mature trees may be left if an experienced geotechnical engineer deems it appropriate.

The trees should be cut down at their bases. Following cutting, the bases should be ground down to surface level. All felled trees and existing fallen branches should then be removed from the strip and appropriately disposed, off site.

**Levee and downstream (water side) toe**

Trees and roots identified on/in the levee and along the downstream toe must be completely removed, including their root balls and as much of their root system as possible. This will inherently require removal of sections of the levee and reconstruction to an engineering design. It is recommend that a suitable geotechnical engineer be on site whilst the levee sections are being boxed out to confirm the extent of removal, and more so to prevent unnecessary over-excavation.

**Removal of woody vegetation**

All small woody vegetation located on the levees should be completely removed, together with their root balls and as much of their root system as possible. This work may comprise of a localised excavation to remove the root ball. This small excavation should then be backfilled with roadbase in maximum 150mm layers and rigorously compacted with a vertical rammer compactor, then top dressed and grassed.
ANIMAL BURROWS AND NESTS

Any animal burrows or nests should be filled as soon as possible. Where possible a grout tube should be inserted to the end of the hole. CIRIA C7321 (2013) suggests that the holes be filled with a low pressure, flowable grout at an appropriate viscosity to adequately fill the horizontal holes. The grout should comprise a 3:1, cement:bentonite mix (3). Under no circumstances should the grout be placed at sufficient pressure to cause hydraulic fracture of the levee. Care must be taken so that slumping of the grout does not cause loss of contact with the crown of the holes. Once the grout emanates onto the upstream shoulder, the grout tube should be retracted whilst still pumping. Immediately on completion of pumping, the holes should be plugged/dry-packed with a non-shrink grout which should prevent grout loss.

As an alternative to grouting, the affected sections of the levee could be boxed out down to a level where the holes and nests are revealed. The ends of the boxed out sections should be graded at no steeper than 1V on 1H to reduce side wall collapse in the earthfill and to facilitate compaction up against the cut faces. The base of the larger boxed out section be compacted with at least eight passes of a 4-5 tonne self-propelled smooth drum roller. If the subgrade is sand it should be moistened during rolling to facilitate compaction. Consideration must be made as to the type of compaction noting that a vibratory roller may cause vibration induced damage to nearby residence.

The backfill material and methodology will be site specific, depending upon the existing levee conditions. However, most of the rural levees are likely to be constructed of silty floodplain type soils. As such the Earth fill procedures outlined in the Cochrane Street, Eden Street and Smithtown levee geotechnical reports produced by JK Geotechnics will likely provide a general idea of the required works.

STORMWATER OUTLET STRUCTURES

The existing stormwater outlets that are present underneath a number of the levees need routine inspection, vegetation clearing, clean out and maintenance. Some common problems identified during this audit include:

- Inlets have no measures preventing inflow of litter, eroded debris and leaf litter.
- Headwalls adjacent to the flood gates require repair or reconstruction.
- Flood flaps/gates can become forced closed and partially buried by accumulated debris.

Common maintenance measures may be used to rectify these issues. Where levee bank sections must be reinstated an appropriate engineering methodology is to be used.

FENCES ON LEVEE

Issues regarding fences on the levee may occur if the fences were ever knocked out by flood debris, vandals, etc., they could gouge out the levee and possibly cause a breach during an overtopping event. JK Geotechnics have stated that they would prefer the removal of the majority of fences off the levees. This however, may not be possible in every case. If a fence is thought to create a potential issue but may not be removed, a geotechnical engineer should be consulted.
REINSTATING THE LEVEE CREST

A methodology for the reinstatement of minor low points in the levee crests has been outlined by JK Geotechnics in the Cochrane Street and Hat head levee reports. A number of the details are site specific and hence for other locations a suitably qualified geotechnical engineer will need to be consulted prior to carrying out these works. A summary of the methodology is outlined in the following:

- Strip topsoil and grass, dispose of spoil
- Drain the site during construction using appropriate measures throughout excavations
- Proof roll the subgrade using a static roller ensuring no soft or unstable areas
- Choose materials similar in nature and grading as the existing levee for earth fill
- Compact imported earth fill using large pad foot roller to a density ratio of 98% SMDD
- Top dress and grass earth fill area with a hardy perennial grass

For a more detailed description of potential required works see the Cochrane Street and Hat head levee 2014 geotechnical reports.

RE-CONSTRUCTING A SECTION OF LEVEE

If a defect has caused significant damage to a levee bank, an entire section of levee may need to be re-constructed. If unsure whether the entire section of levee will need to be rebuilt a geotechnical engineer should be consulted. An example of reconstructing a section of levee can be seen in the Hat Head 2014 geotechnical report by JK Geotechnics. It must be noted that this is a site specific design and hence will not directly apply to any other levee bank. However, the construction process outlined may be useful for cost estimation and planning purposes. Geotechnical advice should be sought prior to any levee reconstruction works.
APPENDIX G -

INSPECTION AND MAINTENANCE INFORMATION
<table>
<thead>
<tr>
<th>Item to Inspect</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass Cover on Crest and Shoulders</td>
<td>The grass cover on the levee must be regularly mowed. The inspecting officer must check grass cover and health to ensure that there is sufficient surface protection against erosion. Top dress and re-grass as appropriate.</td>
</tr>
<tr>
<td>Vegetation (trees, bushes &amp; weeds)</td>
<td>No such vegetation is permitted to grow on the levee. Should new vegetation be encountered, then it should be removed together with its root ball. The localised excavation required to remove the root ball should be backfilled with road base in maximum 150mm layers and rigorously compacted with a vertical rammer compactor, then top dressed and grassed. For all large plants seek advice from a suitably qualified geotechnical engineer.</td>
</tr>
<tr>
<td>Animal Burrows</td>
<td>Burrows should be filled as soon as possible following identification. If burrows are found, then a suitably qualified geotechnical engineer should be contacted for further advice. General guidance on remediation is also provided in Appendix F of this report.</td>
</tr>
<tr>
<td>Slope Instability and Erosion</td>
<td>The crest and shoulders should be inspected for evidence of slope instability and erosion; for example, tension cracks, scarps, slumps, subsidence and erosion rills. Should these be found, a suitably qualified geotechnical engineer should be contacted for further advice.</td>
</tr>
<tr>
<td>Seepage</td>
<td>If seepage at the downstream (protected side) toe is observed during flood periods, a suitably qualified geotechnical engineer should be contacted immediately.</td>
</tr>
<tr>
<td>Crest Settlement</td>
<td>If longitudinal and/or transverse cracking and/or depressions are observed along the crest, a suitably qualified geotechnical engineer should be contacted for further advice. General guidance on remediation measures is also provided in Appendix F of this report.</td>
</tr>
<tr>
<td>Tampering with Levee Condition</td>
<td>If any excavation appears to have been completed on or adjacent to the levee, a suitably qualified geotechnical engineer should be contacted for further advice. Notwithstanding, small excavations would need to be boxed out (if already backfilled) and replaced with compacted road base, as per ‘Vegetation’ above. Service providers should not install additional buried services within or in close proximity to the levee. If additional buried services need to be installed, a suitably qualified geotechnical engineer should be contacted for further advice. If wheel ruts have removed the grass cover, then the surface protection should be repaired.</td>
</tr>
<tr>
<td>Subsidence of Backfill at Test Pit Locations</td>
<td>In completing geotechnical investigations on the urban levees test pits may be carried out on the downstream batter of the levees. Should subsidence of the test pit backfill be observed, then the grass cover should be stripped, and backfill topped up with roadbase in maximum 150mm layers and rigorously compacted with a vertical rammer compactor. Following this, the roadbase should be top dressed and grassed.</td>
</tr>
<tr>
<td>Fences over Levee</td>
<td>Inspect the condition of the fences. If the fences have been impacted and have caused disturbance to the levee, then a suitably qualified geotechnical engineer should be contacted for further advice.</td>
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</tr>
<tr>
<td>Stormwater Outlet Pipes</td>
<td>All inlet and flood gate structures must be inspected and appropriately maintained. Any obstructions to the inlets (eg. Long grass, eroded debris, leaf litter, general litter, etc.) must be removed. The flood gates must not be obstructed and their operation must be checked. A CCTV inspection of each outlet pipe should be completed on a yearly basis to assess the condition of the pipe and whether it requires cleaning. If any damage of the pipes is observed, causing potential damage to the levee, then a geotechnical engineer should be contacted for further advice.</td>
</tr>
<tr>
<td>River/Creek Bank Erosion/Regression</td>
<td>River and Creek bank erosion should be monitored where it is close to the upstream toe of the levee. Should regression occur such that it removes support from the upstream toe, then a geotechnical engineer should be contacted for further advice.</td>
</tr>
<tr>
<td>Transition points of levee and flood gate abutment/roadway etc.</td>
<td>Inspect either side of the transition point for evidence of seepage and movement (eg. differential settlement and cracking). Should these be found, then a geotechnical engineer should be contacted for further advice.</td>
</tr>
</tbody>
</table>