Camellia Town Centre
Landfill Strategy

Draft Flooding and Contamination Study

59917128

Prepared for
Department of Planning and Environment

30 January 2018
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Cover Image: View of Parramatta River and the Camellia Town Centre site looking southeast from James Ruse Drive (Source: Google Maps, accessed 21 November 2017)

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Executive Summary

The Department of Planning & Environment (the Department/DPE) together with City of Parramatta Council (CoP) developed a Land Use and Infrastructure Strategy (the Strategy) for the Camellia Precinct that was exhibited in August 2015. The Strategy included a Structure Plan that identified the north western part of the precinct generally north of Grand Avenue as a town centre comprising mixed use residential development.

Since that time the Department and CoP have been working towards a rezoning proposal for the Camellia Precinct and have had a large number of technical studies undertaken to understand the constraints and opportunities of the precinct.

These technical studies have identified a number of issues including flooding and contamination that have the potential to require filling and may therefore impact ground levels across the Camellia Town Centre.

In February 2017, the preferred alignment for Stage 1 of the Parramatta Light Rail (PLR) was announced by Government. The Environmental Impact Statement (EIS) for Stage 1 of the PLR was exhibited in August 2017 and identified a light rail station within the Camellia Town Centre as well as a stabling facility to the south of the Town Centre. The EIS also identified that the PLR will cross James Ruse Drive. It is likely that PLR will be grade separated above James Ruse Drive, coming down to ground level in the Camellia Town Centre. James Ruse Drive also needs to be upgraded which is likely to include grade separation of its intersection with Hassall Street, which RMS is currently separately investigating.

The Camellia Town Centre

The Camellia Precinct covers the peninsula bounded to the north by the Parramatta River, to the south by Duck River and Western Motorway (M4), and to the west by James Ruse Drive. The precinct covers the majority of the suburbs of Camellia, and Rosehill, and the north-east portion of the suburb of Granville.

The proposed Camellia Town Centre is located in the northwest sector of the Camellia Precinct.

Existing Conditions

The Camellia precinct is subject to flooding from the Parramatta River, Clay Cliff Creek, Duck River, Duck Creek and A’Becketts Creek. Flooding assessments have been previously undertaken for all these watercourses.

The assessments of the potential impacts of landfill strategies within the Camellia Town Centre was undertaken using the 1D/2D floodplain model assembled in 2015 on behalf of DPE and Parramatta City Council.

It was previously determined that the 9 hour storm burst duration is critical for the lower Parramatta River. Consequently the local Camellia Precinct floodplain model was run to estimate design flood levels under the 9 hour storm burst in 2015.

It was also previously determined from results provided by the Sydney Metro CMA in 2012 that the 4 hour PMP storm is critical for the lower Parramatta River. This was in agreement with the conclusion of the SKM, 2001 that the 4 hour PMP storm is critical for the Parramatta CBD.

The 100 yr ARI flood extents and flood contours, depths, velocities, velocity x depth and hazards under Existing Conditions in the vicinity of the Camellia Town Centre are plotted in the 2015 Stage 2 Report for the Camellia Precinct – Drainage and Flooding Study (Cardno, 2015c).

Likewise the PMF extents and flood contours, depths, velocities, velocity x depth and hazards under Existing Conditions in the vicinity of the Camellia Town Centre are plotted also in the 2015 Stage 2 Report for the Camellia Precinct – Drainage and Flooding Study (Cardno, 2015c).
Concept Landfill Strategy

The concept landfill strategy evolved through the iterative testing of a total of 13 landfill scenarios to identify a landfill strategy which is viewed as having acceptable impacts. The aim was for the landfill strategy to have minimal impacts on 100 yr ARI flood levels and acceptable impacts in the PMF levels in any areas adjoining the Camellia Town Centre and in particular on residential and light industrial properties located west of James Ruse Drive.

The concept landfill strategy also needs to be integrated with the proposed vertical and horizontal alignments of the proposed Parramatta Light Rail and the Masterplan layout.

Figure 5 provides spot levels under Existing Conditions and the concept landfill strategy to indicate the concept landform. The intent of the landfill strategy and the proposed finished levels is detailed in Appendix A where various sections were plotted to compare existing ground levels and proposed future finished ground levels.

To assess the impact of Town Centre development on PMF levels buildings were represented as “hollow” footprint with a driveway opening to preserve floodplain storage in extreme floods. This was on the basis the contamination issues would limit the opportunity to construct basement car parking and that rather car parking would be at ground level internally with each building and would rise the required number of levels above ground level to provide the required number of car parking spaces. This internal car parking would most likely be enclosed by commercial premises and/or apartments on the perimeter of the building depending on the level of each floor.

The estimated 100yr ARI flood level differences under the concept landfill conditions in comparison with Existing Conditions are plotted in Figure 15 while the 100yr ARI flood level differences in the vicinity of the Town Centre under the concept landfill conditions are plotted in Figure 16.

It is concluded that the concept landfill strategy has a negligible adverse impact on 100 yr ARI flood levels outside the Town Centre and particularly negligible impact west of James Ruse Drive.

Figure 24 plots PMF profiles along the Parramatta River and compares the PMF levels adopted by Council and the PMF levels estimated under the landfill strategy.

As stated above the aim has been to also limit the fill through the Town Centre within reasonable limits in order to manage impacts on PMF levels west of James Ruse Drive. It was found that the PMF levels under the landfill strategy are lower than the PMF levels adopted by Council in 2005 and are therefore acceptable.

Possible Modified Landfill Strategy

During stakeholder consultation regarding the landfill strategy, the possibility of merging the landform proposed under the planning proposal for 181 James Ruse Drive with the proposed landfill strategy elsewhere in the Town Centre to create a modified landfill strategy was raised.

The assumed intent of the planning proposal for 181 James Ruse Drive is to fill the development to a level which is just above the 100 yr ARI flood level within the proposed development ie. to achieve the flood extents plotted in the 2012 Mott MacDonald study.

It was concluded from an assessment of 100 yr ARI flood levels under the modified landfill strategy that it would locally increase the 100 yr ARI flood levels west of James Ruse Drive by up to 0.08 m over a widespread area. It is expected that this would be unacceptable to the City of Parramatta and that the concept landform within 181 James Ruse Drive will need to be modified from the landform proposed in 2012.

Flood Risk Precincts

The Flood Risk Precincts which based on the results of the current modelling were mapped and differ in some areas with previously mapped zone extents.
Changes in the mapped extents of High, Medium and Low Flood Risk zones reflect the differences between the 100 yr ARI and PMF levels estimated by the Camellia Precinct model and the previous MIKE-11 model of the Parramatta River and the TUFLOW model of the Duck River and Duck Creek floodplain.

**Contamination**

The Precinct has been a centre for industrial and heavy industrial activities since at least the mid-1800s with many of the properties still zoned for industrial purposes. To facilitate the proposed redevelopment of the Precinct, many of the properties will require re-zoning to more sensitive land uses such as medium/high density residential and public recreation within the identified town centre area.

The aim was for the landfill strategy to have minimal impacts on 100 yr ARI flood levels and acceptable impacts in the PMF levels in any areas adjoining the Camellia Town Centre and in particular on residential and light industrial properties located west of James Ruse Drive. The proposed ground plane is generally either at existing levels or 200-500mm above the existing ground level or higher in some isolated locations. However, some areas of cut will be required, mostly between Grande Avenue and the Sandown Freight line.

Preliminary estimates indicate between approximately 27,300 m$^3$ and 104,100 m$^3$ cut will be required almost wholly located in the zone between Grande Avenue and the future light rail corridor depending on the thickness and uniformity of any capping layer. Additionally, preliminary estimates indicate that between approximately 102,500 m$^3$ and 179,300 m$^3$ of fill material may be required to achieve the future ground levels depending on the thickness and uniformity of any capping layer. The estimated cut and fill volumes are based on the following scenarios:

- The lower end bound for the cut volume is based only on the difference between the existing and future ground levels, not addressing any additional contamination and would result in capping layers ranging in depth from 0 mm to greater than 500 mm across the Town Centre depending on location;
- Mid-range estimates of cut and fill volume are based on excavating an additional volume through contaminated soil and capping with a minimum 300mm cap throughout the Town Centre;
- The upper end bound estimates of cut and fill volumes are based on excavating an additional volume through contaminated soil and capping with a minimum 500mm layer throughout the Town Centre.

The placement of the additional fill material would tend to mitigate the potential risks of direct exposure to shallow soil contamination. A 500mm cap of clean soil over contaminated soil is generally sufficient to provide adequate protection to potential human receptors. The soil cap would also provide additional soil column for potential contaminant vapour concentrations to attenuate as they migrate vertically upward. This would reduce the potential risks associated with inhalation of vapours or accumulation in confined spaces. However, this will not address the residual dissolved phase groundwater contamination. The groundwater contamination could potentially be addressed through installation of a slurry wall as identified in the Golder Report. Long term management of the contamination will likely be necessary to ensure the potential risks to human health and the environment are mitigated and the properties are suitable for the proposed redevelopment into medium/high density residential.

It should be noted that the landfill strategy and future building designs are one way to manage the potential risks associated with the subsurface contamination in the Town Centre. As noted above, there are a variety of considerations to determine an overall remediation strategy for the precinct. Some of these considerations may be competing at times, requiring a multi criteria analysis (MCA) to determine the most feasible management and/or remediation approach/approaches.

It is likely that a combination of management and remediation options will be required to reduce the potential risks to human health and the environment to allow the redevelopment of the Precinct.
Remediation and Validation Process

Properties within the Town Centre will be re-zoned to more sensitive land uses to allow for the future development of a multi-use urban centre. Since the properties will be re-zoned to a more sensitive land use, the requirements of State Environmental Planning Policy 55 – Remediation of Land (SEPP 55) will be triggered and developers must also follow the Council established policies and guidelines relating to development of contaminated land. Additionally, the environmental works must comply with the applicable state and federal legislation related to assessment and remediation of contaminated land.

A simplified cost benefit analysis (CBA) for the landfill strategy relative to the remediation cost estimates included in reports prepared by Golder in 2015.

In the Part 2 report (Golder 2015b), Golder completed a comprehensive evaluation of the remediation technologies that could be applicable to address the range of contaminants present in the precinct. The remediation alternatives evaluation was based on generalised conceptual site models (CSMs) that were developed for five categories of sites; two of which are actual sites in the Precinct with some available historical information and three hypothetical site scenarios. Based on the potentially applicable remediation alternatives for each category of site, the developed CSMs, and extensive assumptions and limitations, Golder developed costs estimates to remediate and validate each of the five types of site for the intended land use.

Some combination of a landfill strategy and other remediation alternatives will likely be required to render the sites within the Precinct as suitable for the proposed land uses. However, the costs would be balanced between the landfill strategy which considers flooding and additional remediation strategies required to render the sites as suitable for the proposed land uses. The cut and fill associated with the landfill remediation strategy would have higher capital costs than other remediation alternatives but it would reduce the volume of contaminated environmental media that would need to be managed and the overall potential risks. This would in turn lead to incremental cost reductions for implementation of other remediation strategies and long term management.

To evaluate the estimated costs for a landfill and remediation strategy, three scenarios were evaluated including:

- Scenario 1 - The low end bounds of cut and fill volume resulting effectively no uniform capping layer consequently 100% of the average estimated remediation costs would be required;
- Scenario 2 - The mid-range estimates of cut and fill volume resulting effectively in a uniform 300mm capping layer with an estimated 50% of the average estimated remediation costs would be required;
- Scenario 3 - The upper bound estimates of cut and fill volume resulting effectively in a uniform 500mm capping layer and 25% of the estimated remediation costs would be required

The cost estimates for these three scenarios are summarised below.

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The least expensive option would be Scenario 1 ie. to undertake the cut and fill for the proposed future ground levels with no uniform capping layer after completion and undertaking the necessary remediation and validation works to render the sites within the Precinct suitable for the proposed land uses. This scenario would also tend to provide the most confidence that the remediation and validation works are completed in accordance with the applicable legislation and would eventually and most likely enable the issuance of a Site Audit Statement/Site Audit Report for each site within the precinct.

Overall, there is approximately a 30% difference between the lower and upper estimates of implementing a landfill and flood mitigation strategy and the necessary remediation and validation works. Given the assumptions, limitations and available information on the contamination, this range provides a reasonable estimate of the relative costs of implementing the various scenarios. Slight changes to the assumptions on which the remediation and validation cost estimates were developed could have a large impact of the estimates. Therefore, cost will likely not be the only driver for determining the most effective strategy to address both the flooding and contamination issues within the Camellia Town Centre. However, this report establishes maximum ground levels that regardless of the remediation option elected, a development must satisfy. A copy of the maximum future ground levels is identified as Figure 28.
Table of Contents

Executive Summary

1 Background
   1.1 Context of the Study 1
   1.2 Study Area 1
   1.3 Purpose of this Report 1

2 Available Information
   2.1 Previous Studies 2
      2.1.1 2005 Lower Parramatta River Floodplain Study 2
      2.1.2 2012 Lower Parramatta River Flood Levels under Climate Change 3
      2.1.3 2007 Clay Cliff Creek Catchment Master Drainage Plan 3
      2.1.4 Clay Cliff Creek Flood Impact Assessments 3
      2.1.5 2015 Drainage and Flood Study 4
   2.2 Topography 6
   2.3 Aerial Photographs 6

3 Flooding Assessment
   3.1 Previous Modelling Approaches 7
      3.1.1 Lower Parramatta River Floodplain 7
      3.1.2 Duck River and Duck Creek Floodplain 7
   3.2 Modelling Approach 8
   3.3 Existing Conditions 9
   3.4 Concept Landfill Strategy 9
      3.4.1 Results 10
   3.5 Flood Impact Assessment 10

4 Planning Considerations
   4.1 Responding to Climate Change 11
      4.1.1 Lower Parramatta River 11
      4.1.2 Management Strategies 11
   4.2 Flood Risk Precincts 11

5 Contamination
   5.1 General Considerations 13
   5.2 Contamination and Flood Mitigation Strategy 14
   5.3 Remediation and Validation Process 15
      5.3.1 Legislative Requirements 15
      5.3.2 Process Overview 16
      5.3.3 Remediation Cost Benefit Analysis 17
      5.3.4 Other Considerations 20
6 Conclusions

6.1 The Camellia Town Centre
6.2 Existing Conditions
6.3 Concept Landfill Strategy
6.4 Possible Modified Landfill Strategy
6.5 Flood Risk Precincts
6.6 Contamination
6.7 Remediation and Validation Process

7 References

Appendix A Landfill Strategy Earthworks Volumes
Appendix B 181 James Ruse Drive
Tables

Table 1  Summary of Remediation Cost Estimates
Table 2  Comparison of Landfill and Remediation Cost Estimates

Figures

Figure 1  The Camellia Precinct
Figure 2  Camellia Precinct Waterways
Figure 3  Topography of Camellia Precinct

Landfill Strategy (Scenario 13b)

Figure 4  Camellia Town Centre Landfill Strategy
Figure 5  Comparison of Spot Levels in Camellia Town Centre
Figure 6  Ground Level Differences in the Camellia Town Centre without Concept Buildings
Figure 7  Ground Level Difference in the Camellia Town Centre with Concept Buildings

Figure 8  Adopted Roughness Zones for the Camellia Town Centre Landfill Strategy
Figure 9  100 yr ARI Flood Extent and Levels Overall – Landfill Strategy
Figure 10  100 yr ARI Flood Extent and Levels – Landfill Strategy
Figure 11  100 yr ARI Flood Depths – Landfill Strategy
Figure 12  100 yr ARI Flood Velocities – Landfill Strategy
Figure 13  100 yr ARI Flood Velocity x Depths – Landfill Strategy
Figure 14  100 yr ARI Flood Hazards – Landfill Strategy
Figure 15  100 yr ARI Level Differences Overall - (Landfill Strategy – Existing Conditions)
Figure 16  100 yr ARI Level Differences - (Landfill Strategy – Existing Conditions)

Figure 17  PMF Extent and Levels Overall – Landfill Strategy
Figure 18  PMF Extent and Levels – Landfill Strategy
Figure 19  PMF Depths – Landfill Strategy
Figure 20  PMF Velocities – Landfill Strategy
Figure 21  PMF Velocity x Depths – Landfill Strategy
Figure 22  PMF Flood Hazards – Landfill Strategy
Figure 23  Reference Locations
Figure 24  Comparison of Adopted PMF Levels and PMF Levels under Landfill Strategy along the Parramatta River

Figure 25  Camellia Flood Risk Precincts (Source: Parramatta City Council, 2015)
Figure 26  Camellia Flood Risk Precincts (Source: Figure 3-3, Volume 1, SKM, 2005)
Figure 27  Camellia Flood Risk Precincts (based on Landfill Strategy)
Figure 28  Proposed Design Levels for Urban Blocks in the Camellia Town Centre
Landfill Strategy Earthworks Volumes

Figure A.1 Cross Sections Locations and Extents
Figure A.2 Section AA
Figure A.3 Section BB
Figure A.4 Section CC
Figure A.5 Section GG
Figure A.6 Section FF
Figure A.7 Section DD
Figure A.8 Section EE
Figure A.9 Location of Areas for Cut and Fill Calculations

Composite Landfill Strategy (Scenario 14)

Figure B.1 Ground Level Difference under Composite Landfill Strategy
Figure B.2 100 yr ARI Flood Extent and Levels Overall – Composite Landfill Strategy
Figure B.3 100 yr ARI Flood Extent and Levels – Composite Landfill Strategy
Glossary

Average Recurrence Interval (ARI)  The long-term average period between occurrences equalling or exceeding a given value. For example a 20 year ARI flood would occur on average once every 20 years.

Annual Exceedance Probability (AEP)  The probability of an event occurring or being exceeded within a year. For example a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided.

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Australian Height Datum (AHD)  A common national surface level datum approximately corresponding to mean sea level.

Flood  The covering of normally dry land with water from a stream, river, estuary, lake, dam, major drainage and/or due to super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

Flood liable land  is synonymous with flood prone land (ie) land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).

Flood planning levels (FPL)  are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans.

Freeboard  A height added to flood levels to provide reasonable certainty that the risk exposure accepted by deciding on a particular flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, driveway crest levels, etc.

Local overland flooding  inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam

Mainstream flooding  inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

Probable maximum flood (PMF)  The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation (PMP), and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

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

1.1 Context of the Study

The Department of Planning & Environment (the Department/DPE) together with the City of Parramatta (CoP) developed a Land Use and Infrastructure Strategy (the Strategy) for the Camellia Precinct that was exhibited in August 2015. The Strategy included a Structure Plan that identified the north western part of the precinct generally north of Grand Avenue as a town centre comprising mixed use residential development.

Since that time the Department and CoP have been working towards a rezoning proposal for the Camellia Precinct and have had a large number of technical studies undertaken to understand the constraints and opportunities of the precinct.

These technical studies have identified a number of issues including flooding and contamination that have the potential to require filling and may therefore impact ground levels across the town centre.

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1.2 Study Area

The Camellia Precinct covers the peninsula bounded to the north by the Parramatta River, to the south by Duck River and Western Motorway (M4), and to the west by James Ruse Drive. The precinct covers the majority of the suburbs of Camellia, and Rosehill, and the north-east portion of the suburb of Granville.

The precinct includes a number of notable sites including the Rosehill Racecourse, Viva Energy site (Shell Clyde refinery), and the Sydney Speedway. The Camellia Precinct is shown in Figure 1. The extent of the Camellia Town Centre subject to the Masterplan is also identified in Figure 1.

The existing Camellia Precinct is predominantly industrial development, with the exception of the racecourse and speedway, and a small wetland to the east of the Viva Energy site. There is no existing residential development within the Precinct.

It is subject to flooding from the Parramatta River, Clay Cliff Creek, Duck River, Duck Creek and A’Becketts Creek (refer Figure 2).

1.3 Purpose of this Report

This study has been commissioned to inform the development of a masterplan for the future Camellia Town Centre that integrates the major infrastructure through an understanding of likely finished ground levels in the town centre, including how this will transition into adjoining land.
2 Available Information

The following information was utilised within this study:

2.1 Previous Studies

2.1.1 2005 Lower Parramatta River Floodplain Study

The Lower Parramatta River Floodplain Risk Management Study and Plan (LPRFS) was completed in 2005 in accordance with the provisions of the Floodplain Development Manual applicable at that time. This study included a Flood Study Review which re-assessed flood levels in a number of watercourses and in the tidal section of Parramatta River, between the Charles Street weir and Ryde (road) Bridge. The Flood Study Review provided the base data for the subsequent Floodplain Risk Management Study.

The study was commissioned by the Parramatta City Council (PCC) to update the previous data on flood levels and extents. PCC was aware that the results predicted in the 1986 study would be subject to change due to changes in the catchment such as urbanisation and the construction of flood mitigation projects in the upper catchment. It also recognised that the previous flood extent mapping was based on the best information available at the time, but it was of variable reliability and did not provide an assessment of flood hazard.

The LPRFS adopted the then best current practice to review the flood data which included (SKM, 2005):

- up-to-date catchment hydrology for the Upper Parramatta River Catchment;
- existing/updated hydrology for the tributaries within the Lower Parramatta River study area;
- Airborne Laser Survey;
- an additional 70 surveyed cross-sections;
- the widely used and accepted MIKE-11 hydraulic model;
- use of GIS to develop digital terrain models;
- multiple design storms to generate maximum flood levels; and
- appropriate methodology for estimating concurrent flows in tributaries.

Generally, results from the review compared well with previous studies. However, flood levels estimated in the 1986 Lower Parramatta Flood Study prepared by Willing and Partners in the Lower Parramatta River downstream of Subiaco Creek (including the Duck River confluence) were up to 1.2m lower than those derived in the 2005 review. The reasons for this difference as described in the 2005 Flood Study report include:

- revision of the critical duration to 9 hours for the Upper Parramatta River catchment in the 2005 study, due to the inclusion of channel routing and the effect of the Darling Mills Retarding Basin and other flood mitigation works. This leads to an increase in the volume of floodwaters;
- more detailed and complete survey data; and
- the adoption of an integrated modelling approach and consistent design storms for the main river and tributaries.

It is our understanding that PCC adopted the design flood levels from this study for planning purposes in 2005.
2.1.2 2012 Lower Parramatta River Flood Levels under Climate Change

In 2010, PCC commissioned a further study. The overall objective of this study was to review the 2005 Lower Parramatta River Floodplain Risk Management Study and Plan in the light of potential climate change impacts on flood behaviour.

It was expected that this would generally consist of the following:

- Assessing potential climate change impacts through modelling of the sensitivity analyses recommended by the “Practical Consideration of Climate Change: Floodplain Risk Management Guidelines” – Department of Environment and Climate Change, 2007 and incorporating the expected sea level rises outlined in the “NSW Sea Level Rise Policy Statement, 2009”.
- Determining whether the impact of climate change is a key issue at any locations within the Lower Parramatta river catchment.
- Examining current Management Plan options/recommendations to assess where appropriate modifications may be required and if so,
- Developing appropriate alternate recommendations incorporating climate change which can be integrated into the Lower Parramatta Floodplain Risk Management Plan.
- Outlining some potential climate change management strategies for existing and future development and associated practical issues.
- Assessing the significance of climate change impacts on flood planning levels for this catchment.

It is our understanding that the findings of this study have not yet been adopted or released by Council.

Based on discussions with Council in 2012 an indicative assessment of the impact of climate change on the 100 yr ARI flood levels in the year 2100 was undertaken to inform a Discussion Paper on Flooding of the DHA Site in Ermington (Cardno, 2012). This assessment was based on an assumed 15% increase in design rainfall (yielding a 12% increase in 100 yr ARI flood flows) and sea level rise of 0.9 m.

2.1.3 2007 Clay Cliff Creek Catchment Master Drainage Plan

A Catchment Master Drainage Plan for the Clay Cliff Creek catchment at Parramatta was prepared in 2007. The aim of the study as set out by Council was to identify overland flow problem areas, locations of surcharge due to insufficient pipe capacity and pit inlet capacity, and localised flooding with areas of improvement. The study aimed also to prepare cost effective options based on cost benefit analysis.

The 2007 study assembled a hydrological model of the Clay Cliff Creek catchment and input local flow hydrographs into an **xpswmm** 1D/2D floodplain model.

2.1.4 Clay Cliff Creek Flood Impact Assessments

Since 2013 a number of flood impact assessments for planned development within or adjacent to the Camellia Precinct on the Clay Cliff Creek floodplain have been undertaken in the Parramatta LGA including:

- 2-8 River Road West, Parramatta
- 32 Tramway Avenue, Rosehill
- 125-129 Arthur St, Rosehill
- 23 Oak St and 19-21 Hope St, Rosehill

On the basis that Cardno previously prepared a 1D/2D model of the Clay Cliff Creek floodplain which extends to its outfall into the Parramatta River the proposed approach was to extend this model to include a reach of the lower Parramatta River and its floodplain. In order to reduce the size of the overall model to assess the impacts of planned development the Clay Cliff Creek model was truncated at the railway line which is a local hydraulic control.
The Parramatta River was represented in the 1D/2D floodplain model as 2D terrain which was created from the cross sections extracted from the lower Parramatta River floodplain model between and including PARRAMATTA_R 3248 to PARRAMATTA_R 4452. The overbank areas not already represented in the Clay Cliff Creek model were included in the 2D domain using ALS data which was previously supplied by Council for the Clay Cliff Creek study.

The adopted downstream boundary condition was a stage hydrograph extracted from the lower Parramatta River floodplain model at PARRAMATTA_R 4452.

The upstream boundary conditions were a flow hydrograph in the Parramatta River extracted from the lower Parramatta River floodplain model at PARRAMATTA_R 3248 and the flow hydrograph generated by the Clay Cliff Creek model at the Railway Line. Local inflow hydrographs were also input within the study area based on the subcatchment discretisation adopted in the 2007 Clay Cliff Creek catchment study.

The roughness zones for the additional Parramatta River overbank areas were guided by the roughness values previously adopted in the 2007 Clay Cliff Creek catchment study.

It was previously determined that the 9 hour storm burst duration is critical for the lower Parramatta River while the 2 hour storm burst duration is critical for the Clay Cliff Creek catchment. Consequently the local xpswmm1D/2D floodplain model was run to estimate design flood levels under the 2 hour storm burst and the 9 hour storm burst.

The assessment of 20 yr ARI, 100 yr ARI and PMF flood levels, depths, velocities, velocity x depth and hazard was undertaken for the following scenarios

- Existing Conditions – 20 yr ARI and 100 yr ARI 2 hour and 9 hour design storm bursts and 4 hour PMP storm;
- Future Conditions – 20 yr ARI and 100 yr ARI 2 hour and 9 hour design storm bursts and 4 hour PMP storm
- Future Conditions – 100 yr ARI 2 hour and 9 hour design storm burst with 50% blockage and 100% blockage of the culvert under River Road West

2.1.5 2015 Drainage and Flood Study

In 2015 Cardno assessed flooding and drainage across the Camellia Precinct on behalf of the Department of Planning and Parramatta City Council. The study was commissioned in two stages; Stage 1 – Desktop Review, and Stage 2 – Detailed Modelling. The assessments were summarised as follows:

Based on the differences in the available flooding assessments completed to date and to better inform the consideration of flooding in the Camellia Precinct when preparing the Structure Plan the Stage 1 assessment recommended that a consistent flood modelling approach be adopted for the precinct. This was achieved by creating a local 1D/2D floodplain model based on the available 1D/2D floodplain models of the lower Clay Cliff Creek, Duck Creek and Duck River floodplains and the MIKE-11 Parramatta River sections, ALS data and site survey and boundary conditions obtained from Council’s MIKE-11 model as appropriate. The aim was to establish benchmark 100 yr ARI and indicative PMF levels and to inform the consideration of the potential impacts of concept development on flooding.

The 100 yr ARI flood levels estimated using Camellia Precinct TUFLOW floodplain model are compared with the design flood levels estimated using the MIKE-11 model of the Parramatta River and TUFLOW model of Duck River and Duck Creek in Table 4-1 and Table 4-2 respectively.
It was concluded that a reasonable level of agreement between the MIKE-11 100 yr ARI flood levels and the 100 yr ARI flood levels estimated by the local Camellia Precinct floodplain model. It is noted 100 yr ARI flood levels in the upper reach of the Parramatta River in the Camellia model are higher than the MIKE-11 flood levels. These flood level differences may be due to the bathymetry of the Parramatta River which was interpolated from the MIKE-11 sections. The refinement of this bathymetry may improve the level of agreement.

It was noted that the 100 yr ARI flood levels in Duck River and Duck Creek are lower than reported in the 2012 WMAwater study. This is attributed to the difference between the downstream boundary condition adopted in the 2012 study and the dynamic boundary condition incorporated in the Camellia Precinct model.

In relation to the PMF levels it is noted that in a reach of the Parramatta River downstream of James Ruse Drive that the PMF level estimated by the Camellia Precinct model is considerably higher than estimated by the MIKE-11 model. It is possible that the MIKE-11 model PMF levels in this reach are underestimated.

Likewise the PMF levels in Duck River and Duck Creek are lower than reported in the 2012 WMAwater study. This is attributed to the difference between the downstream boundary condition adopted in the 2012 study and the dynamic boundary condition incorporated in the Camellia Precinct model and the differences in the critical storm durations in the Parramatta River catchment and the Duck River and Duck Creek catchment.

**Flood Risk Precincts**

The Flood Risk Precincts which based on the results of the current modelling were mapped and differ in some areas with previously mapped zone extents.

Changes in the mapped extents of High, Medium and Low Flood Risk zones reflect the differences between the 100 yr ARI and PMF levels estimated by the Camellia Precinct model and the previous MIKE-11 model of the Parramatta River and the TUFLOW model of the Duck River and Duck Creek floodplain.

**Emergency Management**

Emergency management plans overviewed in the Stage 1 Report (Cardno, 2015b) included:

- The North-Western Metropolitan DISPLAN
- The Parramatta DISPLAN

Other emergency management issues which were also discussed in the Stage 1 Report (Cardno, 2015b) included:

- Flood warning
- Evacuation Routes
- Shelter in Place
- Sizing Temporary Flood Refuge

Emergency management issues discussed herein include:

- Typical time for floodwaters to fill basement car parking
- Indicative trigger levels for local warning systems for major development

The typical times to fill basement car parking located adjacent to the Parramatta River and indicative trigger levels for local warning systems for major development are overviewed based on assessments undertaken for the following two developments:

- 2-8 River Road West, Parramatta
- Royal Shores, Ermington
These two sites are located adjacent to the Camellia Precinct upstream of James Ruse Drive and downstream of Silverwater Road respectively.

While the flood level at any given time is a key factor when setting levels that trigger management responses of equal concern is the rate of rise of floodwaters at any given time. A review of the predicted rates of rise of floodwaters in a 100 year ARI event and the PMF disclosed that the rate of rise of floodwaters could vary from 0.6 m/hour (in a 9 hour 100 yr ARI event) to 1.8 m/hour (in a 2 hour 100 yr ARI event) to 2.5 m/hour (in a 3-4 hour PMF event). Concept trigger levels for both developments are outlined.

2.2 Topography

A surface Digital Elevation Model (DEM) was assembled previously using the following data:

- DEM data utilised in 2D TUFLOW hydraulic modelling of the 2012 Duck River and Duck Creek Flood Study Review (WMWater, 2012). The 2D DEM used in the TUFLOW model was based on a 2m x 2m rectangular computational grid;
- DEM data utilised in 2D xpswmm hydraulic modelling of the Clay Cliff Creek floodplain prepared by Cardno. The 2D DEM used in the xpswmm model was based on 2m x 2m rectangular computational grid;
- ALS data provided by Parramatta Council, where existing model DEM data (see above) is available this data has been adopted. However the previous DEM extents do not cover the entire Camellia Precinct study area, therefore Council’s ALS data has been used to extend DEM to cover the entire study area;
- ALS is unable to penetrate the surface of water bodies and therefore provides no data on the bed geometry of the Parramatta River. Hence the Parramatta River bed geometry was represented in the DEM based on the 1D cross sections extracted from the Lower Parramatta River MIKE11 model. The bed and bank geometry were interpolated between cross sections to create a 2D DEM of the river bed and banks.

Similar to the previous DEM’s a 2m x 2m rectangular computational grid has been adopted for the DEM for Camellia Precinct. The topography of the Camellia Precinct and surrounding areas is shown Figure 3.

2.3 Aerial Photographs

Aerial photographs were sourced from NearMap in April 2015.
3 Flooding Assessment

The Camellia precinct is subject to flooding from the Parramatta River, Clay Cliff Creek, Duck River, Duck Creek and A’Becketts Creek. Flooding assessments have been previously undertaken for all these watercourses.

The assessments of the potential impacts of landfill strategies within the Camellia Town Centre was undertaken using the 1D/2D floodplain model assembled in 2015 on behalf of DPE and Council. Previous modelling approaches and the approach adopted in 2015 are overviewed as follows.

3.1 Previous Modelling Approaches

3.1.1 Lower Parramatta River Floodplain

The Lower Parramatta River Floodplain Risk Management Study/Plan was completed in 2005 in accordance with the provisions of the Floodplain Development Manual applicable at that time. This study included a Flood Study Review which re-assessed flood levels in a number of watercourses and in the tidal section of Parramatta River, between the Charles Street weir and Ryde (road) Bridge. The Flood Study Review provided the base data for the subsequent Floodplain Risk Management Study.

The following should be noted with regards to the modelling methodology adopted within the Lower Parramatta River Floodplain Risk Management Study (SKM, 2005):

(i) Hydraulic modelling was undertaken using a MIKE-11 1D model based on over 600 cross sections and included a detailed representation of the Clay Cliff Creek system and roads. The locations of MIKE-11 model cross sections in the vicinity of the Camellia Town Centre are shown in Figure A.1;
(ii) The cross section extents only represent the main waterways and do not extend onto the adjoining floodplain consequently the temporary flood storage on the peninsula has not been accounted for within the model. While it is expected that this has minimal impact on estimated 100 year ARI flood levels and velocities in the lower Parramatta River it does have a potential impact on the estimated PMF levels;
(iii) The flood levels estimated by the MIKE-11 model have been extrapolated across the peninsula to map Flood Risk Precincts.

3.1.2 Duck River and Duck Creek Floodplain

In November 2012, WMAwater released the final report on the Duck River and Duck Creek Flood Study Review. This study reviewed and extended previous flood studies of the Duck Creek and Duck River floodplain. The aims of this study were to in part:

(i) undertake design flood analysis for the 20%, 5%, 2% and 1% average exceedance probability (AEP) events and the Probable Maximum Flood (PMF),
(ii) assess the possible effects of climate change (increase in design rainfalls) in accordance with the Department of Environment, Climate Change and Water’s current guidelines;
(iii) update the flood extent and hazard mapping to incorporate the most up to date and reliable ALS,
(iv) resolve anomalies with the historical flood height data adopted in the previous studies, undertake sensitivity analyses,
(v) assume consideration of blockage at each culvert,
(vi) identify properties inundated and assign design flood levels,
(vii) adopt downstream water levels consistent with those in the Lower Parramatta River Flood Study Review of May 2005.
The following should be noted with regards to the modelling methodology adopted within the Duck River and Duck Creek Flood Study Review (WMAwater, 2012):

- The hydraulic modelling approach was based on assembling and running an integrated one-dimensional/two-dimensional (1D/2D) hydrodynamic model. The floodplain and overbank areas were defined as part of the 2D model domain whilst in-bank features were represented in 1D elements;
- The 2D model extents encompassed the entire 100 year ARI flood extents. However, due to the extreme flooding in the PMF, the extent of flooding extends to the model boundary which indicates that PMF flood flows are attempting cross the northern portion of the Camellia Precinct toward the Parramatta River;
- A constant water level boundary condition was applied at the downstream limit of the TUFLOW model representing the peak water level in Parramatta River. These boundary levels were obtained from the 2005 Lower Parramatta River Floodplain Risk Management Study and Plan (SKM, 2005) MIKE-11 model. This assumption ignores any differences in the timing of flooding in the lower Parramatta River, and Duck River and Duck Creek and hence is a conservative approach;
- All buildings and storage tanks were assumed to act as flow obstructions with the outlines of these structures determined from aerial photography. These have therefore been removed from the hydraulic model as shown in Figure 4-3. This does not imply that the buildings are not flood affected, rather it is a conservative approach to assessing available flood storage on the floodplain.

### 3.2 Modelling Approach

The modelling approach which was adopted was to merge two models with a new reach of the Parramatta River and its floodplain as follows:

(i) The Duck River and Duck Creek TUFLOW model was adopted as supplied;

(ii) The 1D/2D xpswmm2D model of the Clay Cliff Creek floodplain and a reach of the Parramatta River assembled for the assessment of 2-8 River Road West and other nearby development sites on the Clay Cliff Creek floodplain was converted into a TUFLOW model;

(iii) A new section of the Parramatta River floodplain and the remaining areas of the Camellia precinct not previously included in the Duck River and Duck Creek floodplain model was represented in the extended local model in the 2D domain. The Parramatta River was represented in the 1D/2D floodplain model as 2D terrain which was created from the cross sections extracted from the lower Parramatta River floodplain model from between James Ruse Drive and downstream of Silverwater Road. The overbank areas not already represented in the Clay Cliff Creek model or the Duck River and Duck Creek model were included in the 2D domain using ALS data which was supplied by Council.

The adopted downstream boundary condition was a stage hydrograph extracted from the 2005 lower Parramatta River floodplain model for the 100 yr ARI 2 hour and 9 hour events and the PMF 4 hour event.

The upstream boundary conditions were a flow hydrograph in the Parramatta River extracted from the lower Parramatta River floodplain model at PARRAMATTA_R 3248 and the flow hydrograph generated by the Clay Cliff Creek model at the Railway Line and the upstream boundary conditions adopted for the Duck River and Duck Creek floodplain model runs. Local inflow hydrographs were also input within the study area based on the subcatchment discretisation adopted in the 2007 Clay Cliff Creek catchment study, the 2012 Duck River and Duck Creek flood study, the 2005 Lower Parramatta River Flood Study (for inflows from Vineyard and Subiaco Creeks) and the subcatchment discretisation adopted in the 2015 Flooding and Drainage Study.
The roughness zones for the additional Parramatta River overbank areas were guided by the roughness values previously adopted in the 2007 Clay Cliff Creek catchment study and the 2012 Duck River and Duck Creek flood study.

3.3 Existing Conditions

It was previously determined that the 9 hour storm burst duration is critical for the lower Parramatta River. Consequently the local Camellia Precinct floodplain model was run to estimate design flood levels under the 9 hour storm burst in 2015.

It was also previously determined from results provided by the Sydney Metro CMA in 2012 that the 4 hour PMP storm is critical for the lower Parramatta River. This was in agreement with the conclusion of the SKM, 2001 that the 4 hour PMP storm is critical for the Parramatta CBD.

The 100 yr ARI flood extents and flood contours, depths, velocities, velocity x depth and hazards under existing conditions in the vicinity of the Camellia Town Centre are plotted in the 2015 Stage 2 Report for the Camellia Precinct – Drainage and Flooding Study (Cardno, 2015c).

Likewise the PMF extents and flood contours, depths, velocities, velocity x depth and hazards under Existing Conditions in the vicinity of the Camellia Town Centre are plotted also in the 2015 Stage 2 Report for the Camellia Precinct – Drainage and Flooding Study (Cardno, 2015c).

3.4 Concept Landfill Strategy

The concept landfill strategy evolved through the iterative testing of a total of 13 landfill scenarios to identify a landfill strategy which is viewed as having acceptable impacts. The aim was for the landfill strategy to have minimal impacts on 100 yr ARI flood levels and acceptable impacts in the PMF levels in any areas adjoining the Camellia Town Centre and in particular on residential and light industrial properties located west of James Ruse Drive.

The concept landfill strategy also needs to be integrated with the proposed vertical and horizontal alignments of the proposed Parramatta Light Rail and the Masterplan layout.

To assess the impact of Town Centre development on PMF levels buildings were represented as “hollow” footprint with a driveway opening to preserve floodplain storage in extreme floods. This was on the basis the contamination issues are likely to limit the opportunity to construct basement car parking and that rather car parking would be at ground level internally with each building and would rise the required number of levels above ground level to provide the required number of car parking spaces. This internal car parking would most likely be enclosed by commercial premises and/or apartments on the perimeter of the building depending on the level of each floor.

Figure 4 is an annotated copy of the indicative Masterplan layout under the concept landfill strategy.

Figure 5 provides spot levels under Existing Conditions and the concept landfill strategy to indicate the concept landform. It should be noted that the red areas represent retention of existing ground levels. The intent of the landfill strategy and the proposed finished levels is detailed in Appendix A where various sections were plotted to compare existing ground levels and proposed future finished ground levels.

Figure 6 is a plot of ground level differences ie. ground levels under the concept landfill strategy – Existing Condition levels excluding buildings while Figure 7 includes buildings. It should be noted that:

- where buildings are present under existing conditions the “ground levels” within the building footprints have been interpolated from external levels consequently the ground level differences may not represent the actual change in surface level within the building footprints; and

- significant levels of ground level change in Figure 7 represent building footprints and/or walls around ground floor car parking which can be inundated in extreme floods like the PMF ie. these are not fill areas.
The adopted roughness zones for the concept landfill strategy are given in Figure 8.

### 3.4.1 Results

The estimated overall 100 yr ARI flood extents and flood contours under the concept landfill strategy are plotted in Figure 9.

The 100 yr ARI flood extents and flood contours, depths, velocities, velocity x depth and hazards under the concept landfill strategy in the vicinity of the Camellia Town Centre are plotted in Figures 10, 11, 12, 13 and 14 respectively.

The estimated overall PMF extents and flood contours under the concept landfill strategy are plotted in Figure 17.

The PMF extents and flood contours, depths, velocities, velocity x depth and hazards under the concept landfill strategy in the vicinity of the Camellia Town Centre are plotted in Figures 18, 19, 20, 21 and 22 respectively.

### 3.5 Flood Impact Assessment

The estimated 100yr ARI flood level differences under the concept landfill conditions in comparison with existing conditions are plotted in Figure 15 while the 100yr ARI flood level differences in the vicinity of the Town Centre under the concept landfill conditions are plotted in Figure 16.

It is concluded that the concept landfill strategy has a negligible adverse impact on 100 yr ARI flood levels outside the Town Centre and particularly negligible impact west of James Ruse Drive.

Figure 23 identifies reference locations for the PMF levels adopted by Council. Figure 24 plots PMF profiles along the Parramatta River and compares the PMF levels adopted by Council and the PMF levels estimated under the landfill strategy.

As stated above the aim has been to also limit the fill through the Town Centre within reasonable limits in order to manage impacts on PMF levels west of James Ruse Drive. It was found that the PMF levels under the landfill strategy are lower than the PMF levels adopted by Council in 2005 and are therefore acceptable.
4 Planning Considerations

4.1 Responding to Climate Change

In October 2007, the then NSW Department of Environment and Climate Change (DECC) released a guideline titled “Practical Consideration of Climate Change”. As discussed in the guideline, climate change is expected to have adverse impacts upon sea levels and rainfall intensities, both of which may have significant influence on flood behaviour at specific locations.

4.1.1 Lower Parramatta River

In 2010, Parramatta City Council commissioned a further study to review the 2005 Lower Parramatta River Floodplain Risk Management Study and Plan in the light of potential climate change impacts on flood behaviour. It is our understanding that the findings of this study have not yet been adopted or released by Council.

Based on discussions with Council in 2012, an indicative assessment of the impact of climate change on the 100 yr ARI flood levels in the year 2100 was undertaken to inform a Discussion Paper on Flooding of the DHA Site in Ermington (Cardno, 2012). This assessment was based on an assumed 15% increase in design rainfall (yielding a 12% increase in 100 yr ARI flood flows) and sea level rise of 0.9 m.

In the reach of the lower Parramatta River this climate change scenario would increase 100 yr ARI flood levels by 0.24 m at the Duck River confluence up to 0.31 m at James Ruse Drive. Upstream of James Ruse Drive the increase is around 0.45 m.

4.1.2 Management Strategies

Management Strategies for locations where the ramifications of Climate Change are considered Minor or Significant are discussed in Sections 4.1 and 4.2 of DECC, 2007 respectively and in the Stage 1 Report on Flooding and Drainage (Cardno, 2015).

4.2 Flood Risk Precincts

The approach adopted by Parramatta City Council to defining flood risk precincts has been as follows (refer Council’s 2006 Local Floodplain Risk Management Policy):

High Flood Risk

The high flood risk precinct is where high flood damages, potential risk to life, evacuation problems are anticipated or development would significantly and adversely affect flood behaviour. Within this precinct there exists a significant risk of flood damages without compliance with flood-related building and planning controls. This has been defined generally as the area of land below the 100 year flood that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties.

Medium Flood Risk

A significant risk of flood damage exists in the medium flood risk precinct, but these damages can be minimised by applying appropriate development controls. Generally, this has been defined as land below the 100 year flood that is not subject to a high hydraulic hazard and where there may be some evacuation difficulties.
Low Flood Risk

The Low Flood Risk Precinct is that area above the 100 year flood and most land uses would be permitted within this precinct. Although a risk of flood damages exists, appropriate planning and building controls can minimise the risk to an acceptable level.

This area has been defined as all other land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within either the High Flood Risk or the Medium Flood Risk Precinct.

The mapped Flood Risk Precincts for the Camellia Precinct based on flooding from the lower Parramatta River (both mapped extents) and the lower Duck River and lower Duck River floodplain all overlap. There is reasonably good agreement between the mapped extents except in relation to the Rosehill Racecourse.

Parramatta City Council has mapped the Flood Risk Precincts, data which was supplied to Cardno as GIS layers to inform the 2015 study, as shown in Figure 25;

The flood risk precincts were also mapped as part of the Lower Parramatta River Floodplain Risk Management Study (2005) (refer Figure 3-3 in Volume 1 of the FRMS&P Report (SKM, 2005)). This map is reproduced in Figure 26.

The Interim Flood Risk Precincts which are based on the results of the current modelling of the landfill strategy but without any drainage systems installed within the Town Centre are mapped in Figure 27.

It is noted that in Figure 27, the Medium Flood Risk precincts within the Town Centre located east of the railway line are associated with overland flows in the absence of local drainage systems within the Precinct. The adopted strategy for managing local drainage will greatly influence the extent of these Medium Flood Risk precincts.
5 Contamination

The following sections provide a high level summary of the primary known contamination issues in the Camellia Precinct (the Precinct) relative to the proposed flood mitigation strategies and anticipated future re-development of the Precinct. An overview of the remediation and validation process including a simple cost benefit analysis is also included. This summary has been based primarily on the information included in the following two documents:


5.1 General Considerations

The Precinct is undergoing a process to facilitate a large scale re-development of the area to compliment the longer term establishment of the Parramatta locale as Sydney’s second CBD. This process includes collaboration between the Parramatta City Council and the NSW Department of Planning and Environment. Two of the primary issues impacting the redevelopment of the Precinct are flooding and legacy subsurface contamination.

The Precinct has been a centre for industrial and heavy industrial activities since at least the mid-1800s with many of the properties still zoned for industrial purposes. To facilitate the proposed redevelopment of the Precinct, many of the properties will require re-zoning to more sensitive land uses such as high density residential and public recreation. Based on the Master Plan provided by DPE, the area north of Grand Avenue will form the town centre for the Precinct. Many of these properties have frontages on the Parramatta River.

The industrial activities, including oil refining, a tannery, a metal works, a lumber yard and asbestos products manufacturing, have resulted in subsurface contamination located throughout the Precinct. The exact locations and magnitude of the subsurface contamination is not known due mostly to the lack of publicly available information. The limited site-specific information reviewed by Golder indicated that the Precinct is impacted primarily by asbestos in shallow soils (up to 2 metres), hexavalent chromium in soil and groundwater, and petroleum and chlorinated hydrocarbons in soil and groundwater. There may be co-mingling of various contaminants in certain areas across property boundaries. There also may be remnant infrastructure such as underground storage tanks (USTs) and below ground piping across the Precinct. It should be noted that the groundwater in the Precinct is relatively shallow and is present at depths from 1.5 to 2.5 metres below ground level (m BGL).

Based on the information included in the Golder reports, extensive investigations have been conducted at various properties within the Precinct. Additionally, limited remediation has also been undertaken at some properties within the Precinct, most notably at the parcel located at 181 James Ruse Drive where a cap and contain remediation strategy has been implemented to address asbestos contaminated soil. However, very little specific information is publically available regarding the assessment and remediation works conducted within the Precinct. During preparation of their reports, Golder completed an exhaustive process to locate and procure specific information on assessment and remediation works conducted at various properties in the Precinct. However, these efforts did not produce significant amounts of specific information. Therefore, a large portion of the deliverables, particularly the Part 2 study (Golder, 2015b), focussed around general areas of contamination and hypothetical scenarios to provide an assessment of the environmental liabilities that could be present throughout the Precinct.
5.2 Contamination and Flood Mitigation Strategy

The following sections discuss the potential risks associated with the identified contamination during implementation of the recommended flood mitigation strategy.

The aim was for the landfill strategy to have minimal impacts on 100 yr ARI flood levels and acceptable impacts in the PMF levels in any areas adjoining the Camellia Town Centre and in particular on residential and light industrial properties located west of James Ruse Drive. The proposed ground plane is generally either at existing levels or 200-500mm above the existing ground level or higher in some isolated locations. However, some areas of cut will be required, mostly between Grande Avenue and the Sandown Freight Line.

Preliminary estimates indicate between approximately 27,300 m$^3$ and 104,100 m$^3$ cut will be required almost wholly located in the zone between Grande Avenue and the future light rail corridor depending on the thickness and uniformity of any capping layer. Additionally, preliminary estimates indicate that between approximately 102,500 m$^3$ and 179,300 m$^3$ of fill material may be required to achieve the future ground levels depending on the thickness and uniformity of any capping layer. The estimated cut and fill volumes are based on the following scenarios:

- The lower end bound for the cut volume is based only on the difference between the existing and future ground levels, not addressing any additional contamination and would result in capping layers ranging in depth from 0 mm to greater than 500 mm across the Town Centre depending on location;
- Mid-range estimates of cut and fill volume are based on excavating an additional volume through contaminated soil and capping with a minimum 300mm cap throughout the Town Centre;
- The upper end bound estimates of cut and fill volumes are based on excavating an additional volume through contaminated soil and capping with a minimum 500mm layer throughout the Town Centre.

Given the site is already effectively capped with hard stand in many locations, it is anticipated that this will be stripped and then reformed to design levels and “capped” with clean fill approximately 200 mm - 500mm above soil contamination, other than the areas of cut described above. During the stripping of the existing hardstand, presumably some surface soil, and the areas of cut, it is likely that site workers could be exposed to contaminated soil. Potential risks to site workers result from potential ingestion, dermal contact and/or inhalation of contaminants, vapours and/or dust particles. At this time, the specific concentrations and contaminants to which site workers may be exposed are not known. Therefore, the potential risks cannot be quantified. However, implementation of robust Occupational Health and Safety (OHS) measures should mitigate significant potential risks to future workers. Samples of the surface soil should also be collected to determine specific contaminant concentrations in exposed areas. The data could be used to:

(i) quantify the potential risks to site workers, and

(ii) determine the waste classification of the surface soil should it require off-site disposal or reuse in other areas of the Precinct.

When the hard stand is removed and the soil is exposed, rainfall and runoff will be able to infiltrate into the subsurface and potentially interact with shallow soil contamination. This interaction could have several effects and would be dependent primarily on the chemical and physical properties of the particular contaminants present in unsealed areas. The identified contaminants have differing properties (e.g. water solubility, volatility, etc.) which affect their fate and transport in the environment. Infiltration of significant amounts of stormwater could mobilise and/or expedite the migration of certain contaminants in soil and/or groundwater and ultimately to surface waters. Given the age of the contamination in the Precinct, equilibrium has likely been reached and removing the hard stand and infiltration of stormwater would disturb this equilibrium, potentially resulting in an increased mobility and/or partitioning of contaminants into different phases (i.e. adsorbed to vapour or adsorbed to dissolved phase).
Stormwater infiltrating through unsaturated, exposed soil could dissolve and/or mobilise contaminants downward vertically from soil to the relatively shallow groundwater table. This could result in an increased potential risk of contaminated groundwater discharging to the Parramatta River. Significant volumes of stormwater infiltrating into the subsurface could also temporarily raise the already shallow water table in localised areas. An increase in the water table elevation would increase potential risks associated with vapour production and inhalation (for volatile contaminants) by site workers. An increased water table elevation would also tend to increase the groundwater gradient and thus the groundwater flow velocity toward and potential discharge into the Parramatta River.

The placement of the additional fill material would tend to mitigate the potential risks of direct exposure to shallow soil contamination. A 500mm cap of clean soil over contaminated soil is generally sufficient to provide adequate protection to potential human receptors. The soil cap would also provide additional soil column for potential contaminant vapour concentrations to attenuate as they migrate vertically upward. This would reduce the potential risks associated with inhalation of vapours or accumulation in confined spaces. However, this will not address the residual dissolved phase groundwater contamination. Long term management of the contamination will likely be necessary to ensure the potential risks to human health and the environment are mitigated and the properties are suitable for the proposed redevelopment into medium/high density residential.

It should be noted that the landfill strategy and future building designs are one way to manage the potential risks associated with the subsurface contamination in the Town Centre. As noted above, there are a variety of considerations to determine an overall remediation strategy for the precinct. Some of these considerations may be competing at times, requiring a multi criteria analysis (MCA) to determine the most feasible management and/or remediation approach/approaches. It is likely that a combination of management and remediation options will be required to reduce the potential risks to human health and the environment to allow the redevelopment of the Precinct. This is further discussed in the following sections.

5.3 Remediation and Validation Process

5.3.1 Legislative Requirements

As discussed above, properties within the Town Centre will be re-zoned to more sensitive land uses to allow for the future development of a multi-use urban centre. Since the properties will be re-zoned to a more sensitive land use, the requirements of State Environmental Planning Policy 55 – Remediation of Land (SEPP 55) will be triggered and developers must also follow the Council established policies and guidelines relating to development of contaminated land. Additionally, the environmental works must comply with the applicable state and federal legislation related to assessment and remediation of contaminated land. The primary legislation applying to the future remediation and validation works include but are not limited to:

- Contaminated Land Management Act 1997
- NSW EPA (2017) Guidelines for the NSW Site Auditor Scheme (3rd Edition),
5.3.2 Process Overview

**SEPP 55**

The overall process outlined in SEPP 55 and the other legalisation to render each contaminated site within the Precinct suitable for the proposed land uses includes:

- **Stages 1 and 2: Completion of Preliminary and Detailed Site Investigations (PSI/DSI).** These investigations would result in delineation of the vertical and lateral extent of contaminants in environmental media. Based on the available information, extensive assessment activities have been undertaken at various sites within the Precinct.

- **Stage 3: Development and implementation of a Remediation Action Plan (RAP).** Most sites are likely in this stage, with various remediation options being considered and designed. Other than the former James Hardie site, Cardno is not aware of any other major remediation activities having been conducted in the Precinct.

- **Stage 4: Validation and Monitoring.** This Stage includes post remediation sample collection to validate the site is suitable for the proposed land use. On-going monitoring, including development of Environmental Management Plans (EMPs), may also be required to verify that the potential risks to human health and the environment are being appropriately managed in the long term by the implementation of the preferred remediation strategy.

It should be noted that multiple “sub-Stages” may be required to fully implement each stage of the investigation. The sub-Stages may include iterative remediation, assessment and validations works, waste classification, implementation of a combination of remediation technologies at a given site, preparation of quantitative Human Health and Ecological Risk Assessment/s (HHERA), and responding to Auditor comments, among others.

**Audit Process**

This environmental works will very likely be subject to review and endorsement by a NSW EPA accredited Auditor/s to ensure that the properties are suitable for the intended land uses. The Audit process includes an environmental consultant undertaking assessment and remediation works which the Auditor then reviews and provides comments/interim audit advice throughout the process. The ultimate goal of the Audit process is an issuance of a Section A Site Audit Statement/Site Audit Report (SAS/SAR) which states that the site is suitable for the intended land use. Long term management of the contamination issues may also be required to ensure the properties within the Precinct are suitable for the proposed change in land use. Legally, the polluter of the land is responsible for assessing and remediating the land in accordance with the applicable guidelines not necessarily the current owner (if different than the polluter), the developer, DPE and/or Council.

Typically, an individual property owner will engage a site auditor to provide a Site Audit Statement/Site Audit Report (SAS/SAR) for an individual property. In the Precinct, this could lead to complications in the planning and development process as the properties in this area are owned by multiple owners. One aspect an Auditor must evaluate is migration of contamination on-to and off-of a property. As stated above, it is likely that there are areas where there is comingled contamination from multiple adjacent or vicinity properties. Addressing the contamination on a single property (Lot and DP defined) would be problematic and could unduly complicate the planning and development process.
5.3.3 Remediation Cost Benefit Analysis

Cardno has undertaken a simplified cost benefit analysis (CBA) for the landfill strategy relative to the remediation cost estimates included in Golder’s reports. The CBA for the landfill strategy is based on the following assumptions:

- Between 27,300 m$^3$ and 104,100 m$^3$ of cut material will be produced, mostly north of Grand Avenue, namely:
  - The low end bound of the cut volume assumes a variable capping layer would be installed;
  - Approximately 73,400 m$^3$ of cut would be required for a uniform minimum 300mm capping layer throughout the Town Centre;
  - Approximately 104,100 m$^3$ of cut would be required for a uniform minimum 500mm capping layer throughout the Town Centre;

- Between 102,500 m$^3$ and 179,300 m$^3$ of fill material will be required, namely:
  - The low end bound of the cut volume assumes no uniform capping layer would be installed;
  - Approximately 148,000 m$^3$ of fill would be required for a uniform minimum 300mm capping layer throughout the Town Centre;
  - Approximately 179,300 m$^3$ of fill would be required for a uniform minimum 500mm capping layer throughout the Town Centre;

- The soil has an average density of 1.5 tonnes/m$^3$;

- All the cut material will be contaminated and be transported off-site for disposal at an appropriately licensed landfill;

- An average unit rate of $350$/tonne was used for excavation, transport and disposal fees;

- An average unit rate of $75$/tonne was used for transport, placement and nominal compaction of the imported fill material; and

- To account for labour, analytical data, report preparation and contingency, 10% was added to the excavation, transport and disposal costs for each scenario.

In the Part 2 report (Golder 2015b), Golder completed a comprehensive evaluation of the remediation technologies that could be applicable to address the range of contaminants present in the precinct. The remediation alternatives evaluation was based on generalised conceptual site models (CSMs) that were developed for five categories of sites; two of which are actual sites in the Precinct with some available historical information and three hypothetical site scenarios. A CSM was developed for each of the five sites which outlined the potential sources of contamination, fate and transport mechanisms, and evaluated the potential risks to human health and the environment. It should be noted that Golder concluded that it is highly unlikely that one remediation/management option could be applied to address the range of contaminants in the Precinct. A combination of remediation and management options would be required and all options would result in some contamination remaining in the Precinct. Cardno agrees with these conclusions.

Based on the potentially applicable remediation alternatives for each category of site, the developed CSMs, and extensive assumptions and limitations, Golder developed costs estimates to remediate and validate each of the five types of site for the intended land use. The assumptions and limitations for each site are too lengthy to reproduce in this report and the Golder report should be reviewed for this specific information. However, Cardno reviewed the reports in detail and agree that their assumptions and limitations were generally reasonable for the purposes of developing order of magnitude cost estimates. The five site categories for which order of magnitude cost estimates were developed include:
• 181 James Ruse Drive which is the former James Hardie facility. A RAP has been developed for the site. The site area is approximately 6.1 ha with 0.2 ha foreshore area;

• 1 Grand Avenue which is a former asbestos-cement products manufacturing plant with a low disturbance listed in the RAP. The site area is approximately 7.8 ha;

• Hypothetical Low Risk Site – A hypothetical site located along the western boundary of the Precinct or higher ground with no known history of industrial activity. The hypothetical site was assumed to be 3 ha. To scale this to a precinct wide estimate, Cardno assumed that one-third of the area within the study area would be low risk sites. This equates to approximately 6.9 ha of land;

• Hypothetical Low to Medium Risk Site – A hypothetical site located along the southern boundary of the Precinct with a history of industrial activity. The hypothetical site was assumed to be 3 ha. To scale this to a precinct wide estimate, Cardno assumed that two-thirds of the area within the study area would be low to medium risk sites. This equates to approximately 14.1 ha of land; and

• Hypothetical Chromium Contaminated Site – a hypothetical site located in the north eastern portion of the Precinct which has been subject to landfilling and hexavalent chromium contamination in soil and groundwater which is migrating off-site. It was also assumed that a 500m stretch of land on the river foreshore would be converted to public open space. The site was assumed to be 5 ha in size.

To account for inflation from the time the cost estimates were prepared by Golder, Cardno added a 5% to the total cost estimates for all of the scenarios.

Based on the scenarios, assumptions and limitations listed above, the order of magnitude cost estimates for the various remediation scenarios are summarised in Table 1, below.

### Table 1 Summary of Remediation Cost Estimates

<table>
<thead>
<tr>
<th>Remediation Method/Site</th>
<th>Cost Estimate – Low</th>
<th>Cost Estimate – High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut and Fill with no uniform or minimum cap</td>
<td>$28.4M</td>
<td>NA</td>
</tr>
<tr>
<td>Cut and Fill with uniform minimum 300 mm cap</td>
<td>$60.7M</td>
<td>NA</td>
</tr>
<tr>
<td>Cut and Fill with uniform minimum with 500 mm cap</td>
<td>$82.3M</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Golder Estimates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>181 James Ruse Drive</td>
<td>$24.5M</td>
<td>$30.5M</td>
</tr>
<tr>
<td>1 Grand Avenue</td>
<td>$2.9M</td>
<td>$3.4M</td>
</tr>
<tr>
<td>Hypothetical Low Risk Sites</td>
<td>$216,000</td>
<td>$622,000</td>
</tr>
<tr>
<td>Hypothetical Low to Medium Risk Sites</td>
<td>$714,000</td>
<td>$3.1M</td>
</tr>
<tr>
<td>Hypothetical Cr contaminated site</td>
<td>$6.6M</td>
<td>$7.9M</td>
</tr>
<tr>
<td>Total (+5% for inflation)</td>
<td>$36.7M</td>
<td>$47.8M</td>
</tr>
</tbody>
</table>
Some combination of a landfill strategy and other remediation alternatives will likely be required to render the sites within the Precinct as suitable for the proposed land use. However, the costs would be balanced between the landfill strategy which considers flooding and additional remediation strategies required to render the sites as suitable for the proposed land uses. The cut and fill associated with the landfill remediation strategy would have higher capital costs than other remediation alternatives but it would reduce the volume of contaminated environmental media that would need to be managed and the overall potential risks. This would in turn lead to incremental cost reductions for implementation of other remediation strategies and long term management.

To evaluate the estimated costs for a landfill and remediation strategy, three scenarios were evaluated including:

- **Scenario 1** - The low end bounds of cut and fill volume resulting effectively no uniform capping layer consequently 100% of the average estimated remediation costs in Table 1 would be required;
- **Scenario 2** - The mid-range estimates of cut and fill volume resulting effectively in a uniform 300mm capping layer with an estimated 50% of the average estimated remediation costs in Table 1 would be required;
- **Scenario 3** - The upper bound estimates of cut and fill volume resulting effectively in a uniform 500mm capping layer and 25% of the estimated remediation costs in Table 1 would be required.

The cost estimates for these three scenarios are summarised in Table 2, below.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Landfill Cost</th>
<th>Remediation Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$28.4M</td>
<td>$42.3M</td>
<td>$70.7M</td>
</tr>
<tr>
<td>2</td>
<td>$60.7M</td>
<td>$21.1M</td>
<td>$81.8M</td>
</tr>
<tr>
<td>3</td>
<td>$82.3M</td>
<td>$10.5M</td>
<td>$92.8M</td>
</tr>
</tbody>
</table>

As shown above, the least expensive option would be to undertake the cut and fill for the proposed future ground levels with no uniform capping layer after completion and undertaking the necessary remediation and validation works to render the sites within the Precinct suitable for the proposed land uses. This scenario would also tend to provide the most confidence that the remediation and validation works are completed in accordance with the applicable legislation in Section 5.3.1 and would eventually and most likely enable the issuance of a SAS/SAR for each site within the precinct.

The options that result in a uniform 300mm or 500mm capping layer are more expensive but the costs are driven by the large volumes of material that would require excavation and off-site disposal. Some additional remediation would be required under Scenario 2 to meet the statutory requirements whilst it is assumed that no additional remediation will be required with a uniform 500mm cap across the entire Precinct. However, there may be additional remediation required under Scenario 3 but the quantum of those costs are difficult to estimate.

Overall, there is approximately a 30% difference between the lower and upper estimates of implementing a landfill and flood mitigation strategy and the necessary remediation and validation works. Given the assumptions, limitations and available information on the contamination, this range provides a reasonable estimate of the relative costs of implementing the various scenarios. Slight changes to the assumptions on which the remediation and validation cost estimates were developed could have a large impact of the estimates. Therefore, cost will likely not be the only driver for determining the most effective strategy to address both the flooding and contamination issues within the Precinct.
5.3.4 Other Considerations

The final built form of the Town Centre will likely be largely capped with hardstand (roads, paths, car parking, etc) except recreational areas along the Parramatta River foreshore, the racecourse and other newly proposed park/recreational areas. The future hardstand cap will mitigate the potential risks with exposure to the shallow soil contamination as discussed above. The long term integrity of the capping layer will be critical to ensuring the potential risks to human health are appropriately managed. However, the hardstand and/or soil caps will not mitigate the potential risks of contaminated groundwater discharging to the Parramatta River. The potential risks to the environment (including the Parramatta River) must also be evaluated and addressed by the remediation strategy. As reported by Golder, the installation of a slurry wall along the Parramatta River would be one way to potentially manage the potential risks to the river. This would form part of the Audit process and would be independent of the land use changes.

Additionally, during redevelopment of the Town Centre, excavation will be necessary in some areas to facilitate building footings, below ground car parks or other below ground structures. During excavation, contaminated soil and/or groundwater will be encountered in some areas and would require appropriate management including off-site disposal at a licenced landfill, potential re-use in other areas of the Precinct or treatment and discharge of contaminated groundwater.

As stated above, under the current legislation, each individual Lot and DP would be required to undergo the process summarised in Section 5.3.2. This could lead to complications to render the sites within the Precinct as suitable for the proposed land uses. Each individual property owner/developer would be responsible for assessing and potentially remediating their individual sites with the ultimate goal of receiving a SAS/SAR. This will likely lead to multiple environmental consultants and Auditors being engaged to address the numerous individual properties within the precinct. This could lead to significant complications in the planning and development process.

Under an ideal scenario, DPE/Council would develop a strategy or planning mechanism that would require a holistic approach to the assessment and/or remediation of the contamination in the Precinct. This could include a Precinct-specific Development Control Plan (DCP) or guideline as outlined in Golder’s reports. This could also include a developer/property owner funded mechanism or structure that would manage the contamination issues Precinct-wide instead of an individual property basis. However, this would require buy-in from multiple property owners with potentially conflicting interests and/or tolerances for risk which complicates adopting a Precinct-wide strategy. It is anticipated that development throughout the Precinct will occur at different times including development at adjacent properties. This could create the risk of remediation at one site impacting the development of an adjacent property. There is no known mechanism within the NSW EPA or National contaminated land legislation that would restrain or control the potential risks with remediation of one property on the future development and/or remediation of an adjacent property. Therefore, the establishment of a Precinct-wide contaminated land management strategy or mechanism would be a novel, innovative approach in the industry.
6 Conclusions

The Department of Planning & Environment (the Department/DPE) together with City of Parramatta Council (CoP) developed a Land Use and Infrastructure Strategy (the Strategy) for the Camellia Precinct that was exhibited in August 2015. The Strategy included a Structure Plan that identified the north western part of the precinct generally north of Grand Avenue as a town centre comprising mixed use residential development.

Since that time the Department and CoP have been working towards a rezoning proposal for the Camellia Precinct and have had a large number of technical studies undertaken to understand the constraints and opportunities of the precinct.

These technical studies have identified a number of issues including flooding and contamination that have the potential to require filling and may therefore impact ground levels across the Camellia Town Centre.

In February 2017, the preferred alignment for Stage 1 of the Parramatta Light Rail (PLR) was announced by Government. The Environmental Impact Statement (EIS) for Stage 1 of the PLR was exhibited in August 2017 and identified a light rail station within the Camellia Town Centre as well as a stabling facility to the south of the Town Centre. The EIS also identified that the PLR will cross James Ruse Drive. It is likely that PLR will be grade separated above James Ruse Drive, coming down to ground level in the Camellia Town Centre. James Ruse Drive also needs to be upgraded which is likely to include grade separation of its intersection with Hassall Street, which RMS is currently separately investigating.

6.1 The Camellia Town Centre

The Camellia Precinct covers the peninsula bounded to the north by the Parramatta River, to the south by Duck River and Western Motorway (M4), and to the west by James Ruse Drive. The precinct covers the majority of the suburbs of Camellia, and Rosehill, and the north-east portion of the suburb of Granville.

The proposed Camellia Town Centre is located in the northwest sector of the Camellia Precinct.

6.2 Existing Conditions

The Camellia Precinct is subject to flooding from the Parramatta River, Clay Cliff Creek, Duck River, Duck Creek and A’Becketts Creek. Flooding assessments have been previously undertaken for all these watercourses.

The assessments of the potential impacts of landfill strategies within the Camellia Town Centre was undertaken using the 1D/2D floodplain model assembled in 2015 on behalf of DPE and Parramatta City Council.

It was previously determined that the 9 hour storm burst duration is critical for the lower Parramatta River. Consequently the local Camellia Precinct floodplain model was run to estimate design flood levels under the 9 hour storm burst in 2015.

It was also previously determined from results provided by the Sydney Metro CMA in 2012 that the 4 hour PMP storm is critical for the lower Parramatta River. This was in agreement with the conclusion of the SKM, 2001 that the 4 hour PMP storm is critical for the Parramatta CBD.

The 100 yr ARI flood extents and flood contours, depths, velocities, velocity x depth and hazards under Existing Conditions in the vicinity of the Camellia Town Centre are plotted in the 2015 Stage 2 Report for the Camellia Precinct – Drainage and Flooding Study (Cardno, 2015c).

Likewise the PMF extents and flood contours, depths, velocities, velocity x depth and hazards under Existing Conditions in the vicinity of the Camellia Town Centre are plotted also in the 2015 Stage 2 Report for the Camellia Precinct – Drainage and Flooding Study (Cardno, 2015c).
6.3 Concept Landfill Strategy

The concept landfill strategy evolved through the iterative testing of a total of 13 landfill scenarios to identify a landfill strategy which is viewed as having acceptable impacts. The aim was for the landfill strategy to have minimal impacts on 100 yr ARI flood levels and acceptable impacts in the PMF levels in any areas adjoining the Camellia Town Centre and in particular on residential and light industrial properties located west of James Ruse Drive.

The concept landfill strategy also needs to be integrated with the proposed vertical and horizontal alignments of the proposed Parramatta Light Rail and the Masterplan layout.

Figure 5 provides spot levels under existing conditions and the concept landfill strategy to indicate the concept landform. The intent of the landfill strategy and the proposed finished levels is detailed in Appendix A where various sections were plotted to compare existing ground levels and proposed future finished ground levels.

To assess the impact of Town Centre development on PMF levels buildings were represented as “hollow” footprint with a driveway opening to preserve floodplain storage in extreme floods. This was on the basis the contamination issues would limit the opportunity to construct basement car parking and that rather car parking would be at ground level internally within each building and would rise the required number of levels above ground level to provide the required number of car parking spaces. This internal car parking would most likely be enclosed by commercial premises and/or apartments on the perimeter of the building depending on the level of each floor as a sleeved approach.

The estimated 100yr ARI flood level differences under the concept landfill conditions in comparison with Existing Conditions are plotted in Figure 15 while the 100yr ARI flood level differences in the vicinity of the Town Centre under the concept landfill conditions are plotted in Figure 16.

It is concluded that the concept landfill strategy has a negligible adverse impact on 100 yr ARI flood levels outside the Town Centre and particularly negligible impact west of James Ruse Drive.

Figure 24 plots PMF profiles along the Parramatta River and compares the PMF levels adopted by Council and the PMF levels estimated under the landfill strategy. It is noted that the PMF levels under the landfill strategy are significantly lower than the PMF levels adopted by Council upstream of James Ruse Drive.

As stated above, the aim has been also to limit the fill through the Town Centre within reasonable limits in order to manage impacts on PMF levels west of James Ruse Drive notwithstanding the PMF levels under the landfill strategy are lower than adopted by Council in 2005. This approach was undertaken because Council is currently undertaking an update of its 2005 study using a 1D/2D modelling approach which is expected in due to course to lead to the adoption of PMF levels west of James Ruse Drive which are lower than the PMF levels adopted in 2005. When undertaking this update it is recommended that Council include the planning proposal for the Camellia Town Centre in its benchmark floodplain condition.

6.4 Possible Modified Landfill Strategy

During stakeholder consultation regarding the landfill strategy, the possibility of merging the landform proposed under the planning proposal for 181 James Ruse Drive with the proposed landfill strategy elsewhere in the Town Centre to create a modified landfill strategy was raised.

The assumed intent of the planning proposal for 181 James Ruse Drive is to fill the development to a level which is just above the 100 yr ARI flood level within the proposed development ie. to achieve the flood extents plotted in the 2012 Mott MacDonald study.
It was concluded from an assessment of 100 yr ARI flood levels under the modified landfill strategy that it would locally increase the 100 yr ARI flood levels west of James Ruse Drive by up to 0.08 m over a widespread area. It is expected that this would be unacceptable to the Council and that the concept landform within 181 James Ruse Drive will need to be modified from the landform proposed in 2012.

6.5 Flood Risk Precincts

The Flood Risk Precincts which based on the results of the current modelling were mapped and differ in some areas with previously mapped zone extents.

Changes in the mapped extents of High, Medium and Low Flood Risk zones reflect the differences between the 100 yr ARI and PMF levels estimated by the Camellia Precinct model and the previous MIKE-11 model of the Parramatta River and the TUFLOW model of the Duck River and Duck Creek floodplain.

6.6 Contamination

The Precinct has been a centre for industrial and heavy industrial activities since at least the mid-1800s with many of the properties still zoned for industrial purposes. To facilitate the proposed redevelopment of the Precinct, many of the properties will require re-zoning to more sensitive land uses such as high density residential and public recreation within the identified Town Centre area.

The aim was for the landfill strategy to have minimal impacts on 100 yr ARI flood levels and acceptable impacts in the PMF levels in any areas adjoining the Camellia Town Centre and in particular on residential and light industrial properties located west of James Ruse Drive. The proposed ground plane is generally either at existing levels or 200-500mm above the existing ground level or higher in some isolated locations. However, some areas of cut will be required, mostly between Grande Avenue and the Sandown Freight line.

Preliminary estimates indicate between approximately 27,300 m$^3$ and 104,100 m$^3$ cut will be required almost wholly located in the zone between Grande Avenue and the future light rail corridor depending on the thickness and uniformity of any capping layer. Additionally, preliminary estimates indicate that between approximately 102,500 m$^3$ and 179,300 m$^3$ of fill material may be required to achieve the future ground levels depending on the thickness and uniformity of any capping layer. The estimated cut and fill volumes are based on the following scenarios:

- The lower end bound for the cut volume is based only on the difference between the existing and future ground levels, not addressing any additional contamination and would result in capping layers ranging in depth from 0 mm to greater than 500 mm across the Town Centre depending on location;
- Mid-range estimates of cut and fill volume are based on excavating an additional volume through contaminated soil and capping with a minimum 300mm cap throughout the Town Centre;
- The upper end bound estimates of cut and fill volumes are based on excavating an additional volume through contaminated soil and capping with a minimum 500mm layer throughout the Town Centre.

The placement of the additional fill material would tend to mitigate the potential risks of direct exposure to shallow soil contamination. A 500mm cap of clean soil over contaminated soil is generally sufficient to provide adequate protection to potential human receptors. The soil cap would also provide additional soil column for potential contaminant vapour concentrations to attenuate as they migrate vertically upward. This would reduce the potential risks associated with inhalation of vapours or accumulation in confined spaces. However, this will not address the residual dissolved phase groundwater contamination. The groundwater contamination could potentially be addressed through installation of a slurry wall as identified in the Golder Report. Long term management of the contamination will likely be necessary to ensure the potential risks to human health and the environment are mitigated and the properties are suitable for the proposed redevelopment into medium/high density residential.
It should be noted that the landfill strategy and future building designs are one way to manage the potential risks associated with the subsurface contamination in the Town Centre. As noted above, there are a variety of considerations to determine an overall remediation strategy for the precinct. Some of these considerations may be competing at times, requiring a multi criteria analysis (MCA) to determine the most feasible management and/or remediation approach/approaches. It is likely that a combination of management and remediation options will be required to reduce the potential risks to human health and the environment to allow the redevelopment of the Precinct.

6.7 Remediation and Validation Process

Properties within the Town Centre will be re-zoned to more sensitive land uses to allow for the future development of a multi-use urban centre. Since the properties will be re-zoned to a more sensitive land use, the requirements of State Environmental Planning Policy 55 – Remediation of Land (SEPP 55) will be triggered and developers must also follow the Council established policies and guidelines relating to development of contaminated land. Additionally, the environmental works must comply with the applicable state and federal legislation related to assessment and remediation of contaminated land.

A simplified cost benefit analysis (CBA) for the landfill strategy relative to the remediation cost estimates included in reports prepared by Golder in 2015.

In the Part 2 report (Golder 2015b), Golder completed a comprehensive evaluation of the remediation technologies that could be applicable to address the range of contaminants present in the precinct. The remediation alternatives evaluation was based on generalised conceptual site models (CSMs) that were developed for five categories of sites; two of which are actual sites in the Precinct with some available historical information and three hypothetical site scenarios. Based on the potentially applicable remediation alternatives for each category of site, the developed CSMs, and extensive assumptions and limitations, Golder developed costs estimates to remediate and validate each of the five types of site for the intended land use.

Some combination of a landfill strategy and other remediation alternatives will likely be required to render the sites within the Precinct as suitable for the proposed land uses. However, the costs would be balanced between the landfill strategy which considers flooding and additional remediation strategies required to render the sites as suitable for the proposed land uses. The cut and fill associated with the landfill remediation strategy would have higher capital costs than other remediation alternatives but it would reduce the volume of contaminated environmental media that would need to be managed and the overall potential risks. This would in turn lead to incremental cost reductions for implementation of other remediation strategies and long term management.

To evaluate the estimated costs for a landfill and remediation strategy, three scenarios were evaluated including:

- **Scenario 1** - The low end bounds of cut and fill volume resulting effectively no uniform capping layer consequently 100% of the average estimated remediation costs would be required;
- **Scenario 2** - The mid-range estimates of cut and fill volume resulting effectively in a uniform 300mm capping layer with an estimated 50% of the average estimated remediation costs would be required;
- **Scenario 3** - The upper bound estimates of cut and fill volume resulting effectively in a uniform 500mm capping layer and 25% of the estimated remediation costs would be required.

The cost estimates for these three scenarios are summarised below.
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Landfill Cost</th>
<th>Remediation Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$28.4M</td>
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The least expensive option would be Scenario 1 ie. to undertake the cut and fill for the proposed future ground levels with no uniform capping layer after completion and undertaking the necessary remediation and validation works to render the sites within the Precinct suitable for the proposed land uses. This scenario would also tend to provide the most confidence that the remediation and validation works are completed in accordance with the applicable legislation and would eventually and most likely enable the issuance of a SAS/SAR for each site within the precinct.

Overall, there is approximately a 30% difference between the lower and upper estimates of implementing a landfill and flood mitigation strategy and the necessary remediation and validation works. Given the assumptions, limitations and available information on the contamination, this range provides a reasonable estimate of the relative costs of implementing the various scenarios. Slight changes to the assumptions on which the remediation and validation cost estimates were developed could have a large impact of the estimates. Therefore, cost will likely not be the only driver for determining the most effective strategy to address both the flooding and contamination issues within the Camellia Town Centre. However, this report establishes maximum ground levels that regardless of the remediation option elected, a development must satisfy. A copy of the maximum future ground levels is identified as Figure 28.
7 References


Figure 1  The Camellia Precinct
Figure 2  Camellia Precinct Waterways
Figure 3  Topography of Camellia Precinct
Figure 5  Comparison of Spot Levels in Camellia Town Centre
Figure 6  Ground Level Differences in the Camellia Town Centre without Concept Buildings
Figure 8  Adopted Roughness Zones for the Camellia Town Centre Landfill Strategy
Figure 9  100 yr ARI Flood Extent and Levels Overall – Landfill Strategy
Figure 10  100 yr ARI Flood Extent and Levels – Landfill Strategy
Figure 14  100 yr ARI Flood Hazards – Landfill Strategy
Figure 15  100 yr ARI Level Differences Overall - (Landfill Strategy – Existing Conditions)