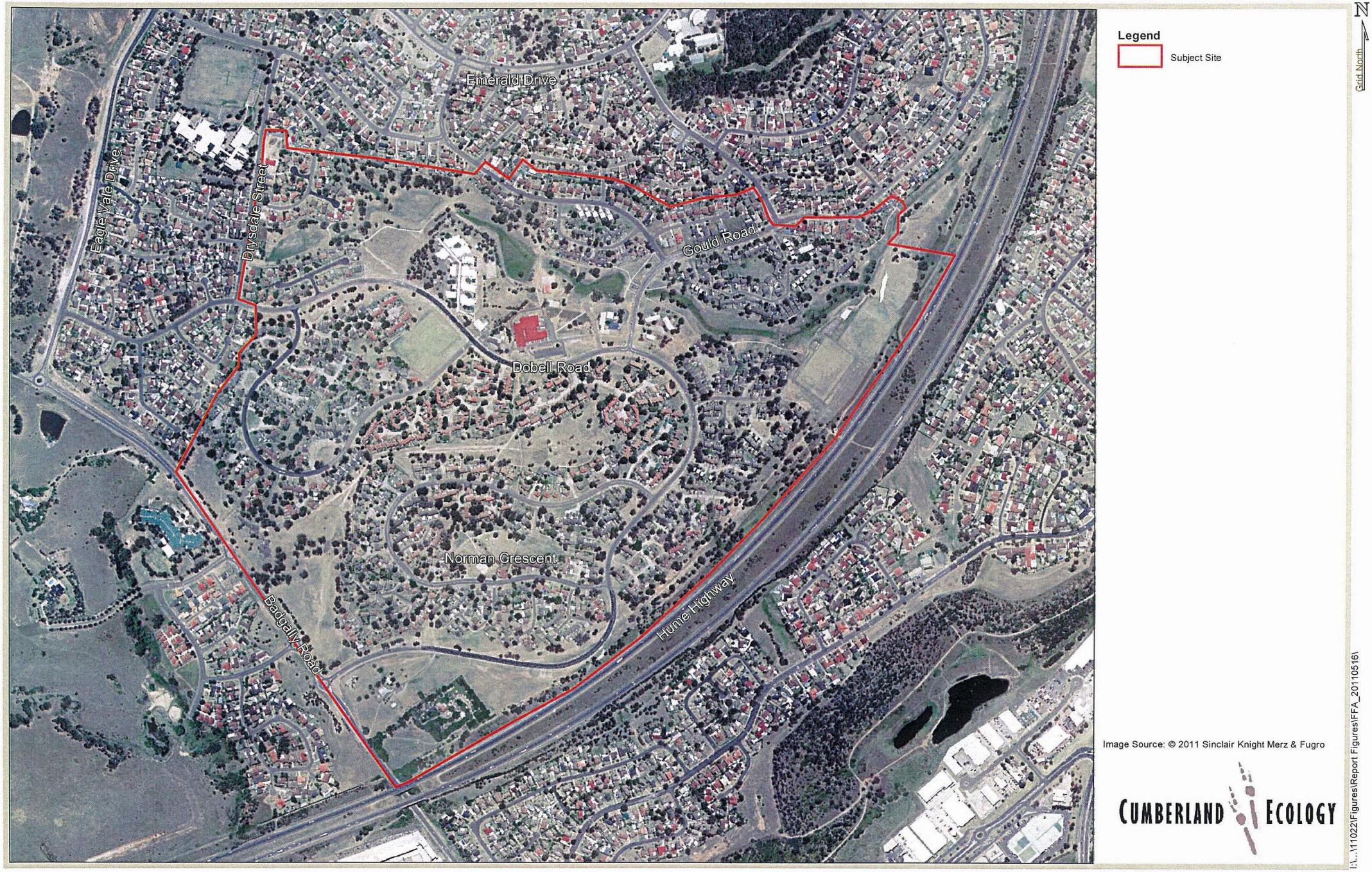

Figure 2.1. Subject Site

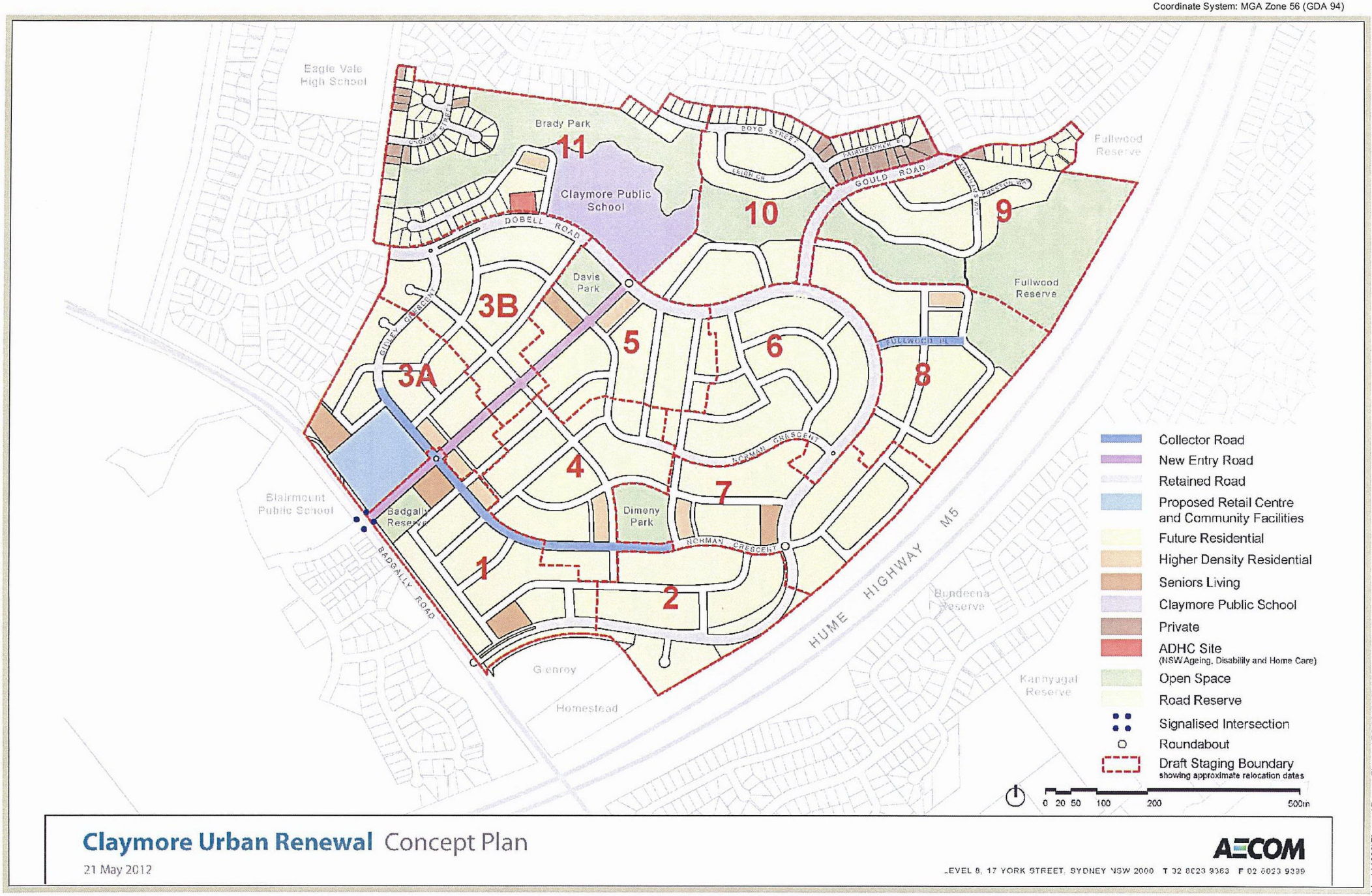

Figure 2.2. Preferred Plan for the Claymore Development

Chapter 3

Regulatory Context

This chapter outlines the regulatory context that influences the ecological aspects of the Claymore redevelopment. This legislation includes: relevant State and Commonwealth legislation as well as local council zoning.

3.1 Zoning

The site is zoned under the provisions of the Campbelltown (Urban Area) Local Environmental Plan. A number of land use zonings apply to the site with residential areas being zoned 2(b) Residential and open spaces within an open space zone. The zoning reflects the existing pattern of development and will need to be modified to reflect the new subdivision pattern and range of uses.

3.2 NSW *Environmental Planning and Assessment Act* 1979

The EP&A Act is the overarching planning document for NSW. This Act provides for the creation of planning instruments that guide land use. The Act also provides for the consideration of biodiversity values, which is addressed in Section 5A (Significant effect on species, populations or ecological communities or their habitats). The EP&A Act requires that an "Assessment of Significance" under Section 94A of the TSC Act, also known as the "Seven-Part Test", is undertaken in relation to species, communities, habitat and processes listed under either the TSC Act or the *Fisheries Management Act 1994* (FM Act).

Until recently, the Part 3A amendment to the EP&A Act consolidated the assessment and approval regime for all Major Projects previously addressed under Part 4 (Development Assessment) or Part 5 (Environmental Assessment) of the Act. There was no statutory requirement to undertake an "Assessment of Significance" for a development being assessed under Part 3A. An Environmental Assessment (EA) was required for Part 3A development proposals and was to be prepared in accordance with the Director-General's environmental assessment guidelines.

Under recent amendments to legislation the State Government is proceeding with the abolition of Part 3A as the process to assessing Major Projects. The Government is currently developing transitional provisions for dealing with projects such as this project that was commenced under Part 3A prior to the legislation changes. No further project applications will be accepted under Part 3A.

The Government is currently working on the preparation of policy and legislation for an assessment framework for projects of genuine state significance that will operate until the Department introduces a new planning system.

This report has been prepared under the requirements of the recently abolished Part 3A legislation as the project was commenced under this legislation. The draft Director-General's Environmental Assessment Requirements (DGR) for the Project, pursuant to Section 75 F(2) of the EP&A Act and as pertains to biodiversity issues, requests that the following are provided:

- A field survey of the site should be conducted and documented;
- Assessment, evaluation and report on the likely impacts on threatened species, populations, EECs and their habitats including but not limited to, Cumberland Plain Woodland, Cumberland Plain Land Snail, Sydney Plains Greenhood Orchid and Spiked Rice Flower;
- Identify any remnant EEC on the site, including a description of their condition, disturbance history and recovery capacity and the extent of any proposed EEC to be disturbed or removed;
- Identify the area of any hollow bearing, foraging, roosting, feed and nesting trees proposed to be removed or modified; and
- A description of the measures that will be taken to avoid or minimise impacts or compensate for any unavoidable impacts on the Project on threatened species populations or ecological communities.

3.3 NSW *Threatened Species Conservation Act* 1995

The TSC Act aims to protect and encourage the recovery of threatened species, populations and communities that are listed under the Act, through threat abatement and species recovery programs.

The TSC Act requires consideration of whether a development (Part 4) or an activity (Part 5) is likely to significantly impact threatened species, populations, communities or their habitat. The potential impacts of any developments, land use changes or activities would need to undergo an "Assessment of Significance" under Section 5A of the EP&A Act.

3.4 *Fisheries Management Act* 1994

The threatened species Schedules of the FM Act comprise lists of threatened marine, estuarine and freshwater fish or other aquatic animal life at any stage of their life history and ecological communities of fish. The Act provides for the conservation of key fish habitats and threatened species, populations and ecological communities of fish and marine vegetation. It does not include whales, terrestrial mammals, reptiles, birds or amphibians.

The FM Act does not apply to the proposed Project as there is no habitat available that would support a significant community of fish or aquatic mammals.

3.5 *Environment Protection and Biodiversity Conservation Act 1999*

The EPBC Act provides for the protection of nationally listed Matters of National Environmental Significance (MNES). The EPBC Act is administered by Department of Sustainability, Environment, Water, Population and Communities (DSEWPC).

A Project that may impact on MNES is referred to DSEWPC (via a "Referral") to determine whether the impact to MNES is likely to be significant. If the Project is determined to be likely to have a significant impact on MNES, the Project is declared a "controlled action" and additional assessments will be required to gain approval from the Commonwealth Minister for the Environment.

The Project has been referred to DSEWPC stating that it is not considered likely that the proposed development will cause a significant environmental impact as stated in the referral, despite no official decision being made as yet. It is considered that this will be the likely decision because there are no MNES within, or adjacent to, the subject site.

Chapter 4

Methodology

This chapter outlines the methodology utilised in this ecological study, including literature reviews, and flora and fauna survey techniques.

4.1 Literature Review

All relevant documentation provided by the client formed part of this literature review. The review also included database searches of the Atlas of NSW Wildlife (DECC (NSW), 2009) and the EPBC Act Protected Matters Search Tool (DEWHA, 2009) to obtain records of threatened flora and fauna species and endangered ecological communities listed under the TSC Act and EPBC Act respectively. The Atlas of NSW Wildlife search included all records within a 10 km radius of the subject site and the EPBC Act Protected Matters search included all protected matters that may occur in a 10 km radius. Vegetation mapping of the subject site and that in the surrounding locality by the NSW Department of Environment and Heritage (NSW DEH) was studied to gain an appreciation of broad vegetation types that occurred.

4.2 Site Inspection

4.2.1 Initial Site Inspection

An initial site inspection was conducted by Cumberland Ecology on the 29 April 2011. The intention of the inspection was to assess the nature and quality of the flora and fauna habitat within the subject site. The inspection was largely conducted from a vehicle with detailed inspections on foot conducted in areas containing open spaces.

4.2.2 Flora Surveys

Initial flora surveys were undertaken on 10 May 2011. These surveys were conducted in accordance with the (then) DEC Threatened Biodiversity Survey and Assessment Guidelines for Development and Activities (Working Draft) (DEC (NSW), 2004). These surveys involved the following:

- Random meander surveys to detect flora species across the subject site;
- Vegetation sampling within quadrats (20m x 20m) to obtain information on floristic composition and community structure;

- Targeted searches for threatened flora known or considered likely to occur within the subject site; and
- Targeted searches for endangered ecological communities (EECs) known or considered likely to occur within the subject site.

Vegetation within two quadrats was sampled according to DEC survey guidelines. The relative abundance and cover of each species within these quadrats was approximated using a modified Braun-Blanquet scoring system (Braun-Blanquet, 1927). The locations of the quadrats are shown in **Figure 4.1**. A further five 400m^2 sampling quadrats were undertaken on 14 March 2012. The information collected was used for the purposes of offset area assessment.

Within each quadrat, all vascular flora species present were identified to species level where possible, and recorded. All vascular plants recorded or collected were identified using keys and nomenclature provided in Harden (Harden, 1990-1993). Where known, taxonomic and nomenclatural changes have been incorporated into the results, as derived from PlantNET (Botanic Gardens Trust, 2010).

A number of random meander transects were also conducted across the subject site to collate a full list of species occurring across the site.

A list of species present on the subject land is provided in **Appendix A**.

4.2.3 Fauna Surveys

Fauna surveys were conducted by Cumberland Ecology on 10 May 2011 and consisted of the diurnal survey methods outlined below. Nocturnal survey methods were not used but likely nocturnal species were predicted based upon habitat assessment. An incidental list of fauna detected was prepared throughout the survey to indicate the most common species that utilise the site.

i. Fauna Habitat Assessment

The site was assessed for groundcover, shrub/understory cover, canopy cover as well as other habitat features such as bush rock, fallen trees and signs of fauna use such as scats, scratches and scrapings.

ii. Cumberland Plain Land Snail Searches

Targeted searches were conducted for Cumberland Plain Land Snails across the subject site. Searches were conducted at the base of each of the trees considered as possible habitat as well as under debris on the ground in an effort to locate any living snails and empty shells.

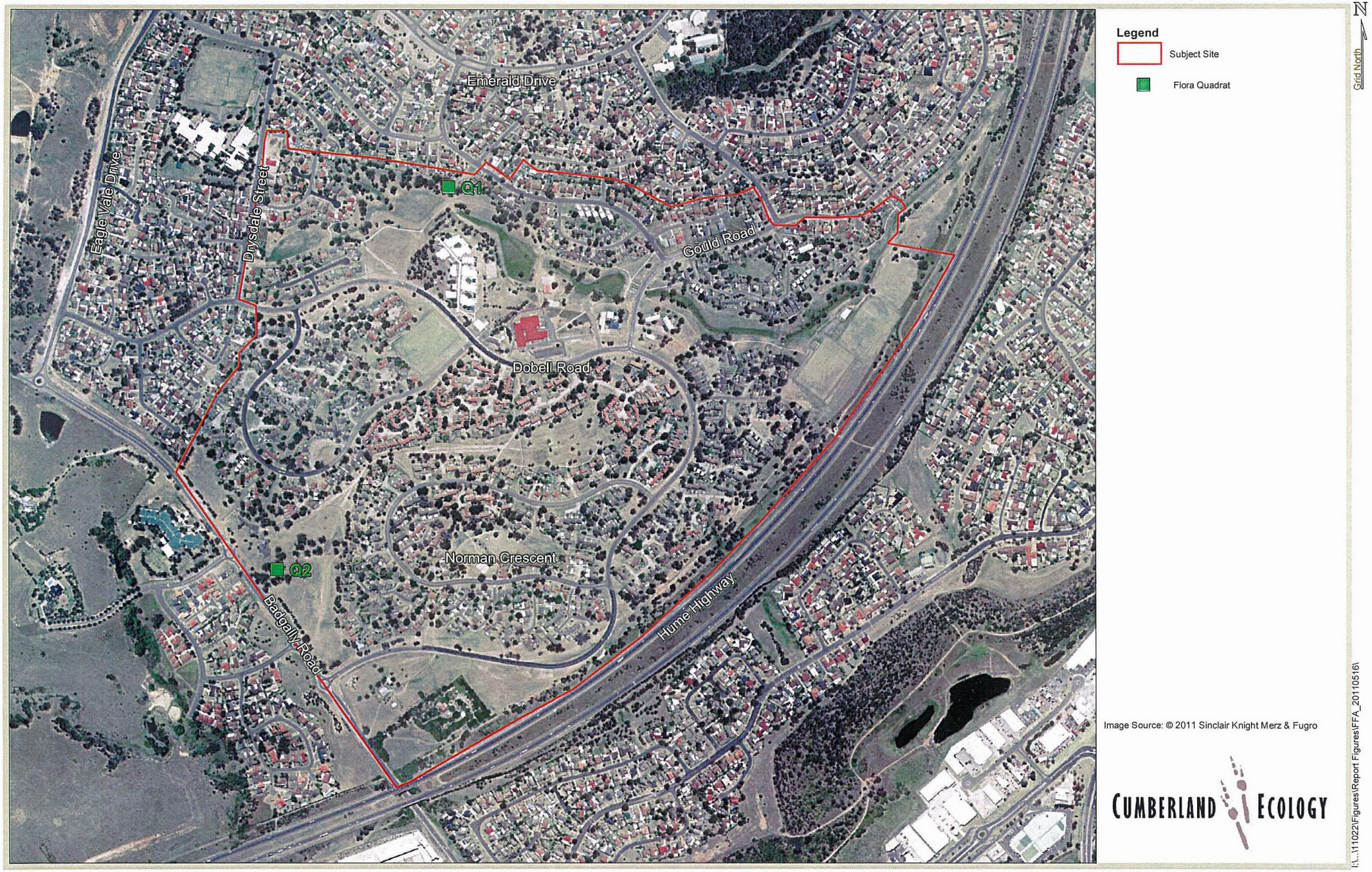

Figure 4.1. Flora Survey Locations

Chapter 5

Results

This chapter provides the results of the flora and fauna surveys across the subject site. The general features of the subject site are summarised directly below and detailed results of the surveys can be found in the sections below.

5.1 Site Description

The landscape of the subject site is highly disturbed with a large proportion currently existing as sealed roads and residential housing. As a result of this former land use and the lack of vegetation management on the subject site, the vegetation is largely dominated by exotic weeds within all plant strata excluding the canopy. The canopy is largely dominated by planted Australian native trees most of which are representative of the original vegetation community within the area, however regular occurrences of exotic native trees indicate that most of the trees in the area are planted. A number of native ground covers and shrubs are present but exotic species dominate in most locations. Canopy species are mostly native, while small trees and shrubs are largely absent.

Fauna habitat is generally poor across the subject site due to its highly degraded nature and exotic understorey. Few tree hollows are present for bats and roosting birds but dense leaf litter and residential housing provide ideal habitat for small terrestrial animals such as skinks and common urban birds. A complete list of flora and fauna can be found in **Appendix A** and **B** respectively.

5.2 Literature Review

The results of the database searches conducted as described in Section 4.1 are provided in **Tables C.1** and **C.2** in **Appendix C**.

5.3 Vegetation Communities

The majority of the subject site does not contain native vegetation, and consists of residential houses, roads and infrastructure. The natural or semi-natural vegetation that occurs on the subject site forms patches within reserves including Badgally Reserve, Dimeny Park, Fullwood Reserve and Davis Park. All of these areas are mown regularly and the vegetation consists of trees above a mown lawn, consisting of both native and exotic herbaceous

plants. Young mature native trees occur within the yards of houses and along roadsides within the subject site.

The highly disturbed nature of the vegetation within the subject site has resulted in the quality of the vegetation being considered of little conservation value, particularly within and around the residential buildings. Despite this level of disturbance, there are some areas of vegetation within the subject site that conform to State listed EECs. These areas are considered to be of conservation value.

The vegetation communities that are present within the subject site are listed here and discussed in detail below:

- River Flat Eucalypt Forest;
- Cumberland Plain Woodland; and
- Australian Native Plantations and Exotic Vegetation.
- A map of the vegetation present within the subject site is shown in Figure 5.1 and a table showing the areas of each vegetation community in the subject site is provided in Table 5.1.

Table 5.1 Vegetation Communities Occurring Within the Subject Site

Vegetation Community	Area currently on site (ha)
Cumberland Plain Woodland (CEEC)	2.75
River Flat Eucalyptus Forest (EEC)	0.33
Planted Native & Exotic Weeds	6.55
Total	**9.64**
Total EEC	3.08

5.3.1 River Flat Eucalypt Forest

This community is considered a modified form of River Flat Eucalypt Forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions, which is listed as an EEC under the TSC Act. This vegetation community is typically groundwater dependent due to its proximity to riparian corridors. The modification of the subject site's drainage patterns has led to a reduction in the distribution of this community on the subject site.

The River-flat Eucalypt Forest includes scattered, highly modified stands of paperbarks (*Melaleuca* spp) and various other tree species such as Swamp Oak (*Casuarina glauca*) and Cabbage Gum (*Eucalyptus amplifolia*). The area of River-flat Eucalypt Forest that is present

in the subject site is relatively small. Native shrubs and creepers are essentially missing from treed areas due to mowing and the ground layer is highly exotic.

Native shrubs are absent from this area, however, the ground stratum includes grasses such as *Austrostipa racemosa*, Red-legged Grass (*Bothriochloa macra*), Windmill Grass (*Chloris ventricosa*), Couch (*Cynodon dactylon*), and Weeping Meadow Grass (*Microlaena stipoides*). Native herbaceous plants include *Einadia polygonoides*, Kidney Weed (*Dichondra repens*), Twinning Glycine (*Glycine clandestina*) and *Oxalis perenans*. Exotic grasses are abundant and include such species as Paspalum (*Paspalum distichum*), African Love Grass (*Eragrostis curvula*) and Kikuyu (*Pennisetum clandestinum*). Exotic herbs include such species as Cats Ear (*Hypochaeris radicata*), Common Plantain (*Plantago lanceolata*), Fireweed (*Solanum madagascariensis*) and Spear Thistle (*Cirsium vulgare*). These ground cover species are similar to those that have been recorded within the Cumberland Plain Woodland (see Section 5.3.2).

5.3.2 Cumberland Plain Woodland

The Cumberland Plain Woodland within the subject site is listed as a Critically Endangered Ecological Community (CEEC) under the TSC Act. The occurrences of Cumberland Plain Woodland include various stands of Coastal Grey Box (*E. moluccana*), Forest Red Gum (*E. tereticornis*), Narrow-leaf Ironbark (*E. crebra*) and Spotted Gum (*Corymbia maculata*).

Native shrubs are essentially missing due to mowing and creepers are very few. The ground stratum includes grasses such as *Austrostipa racemosa*, Red-legged Grass (*Bothriochloa macra*), Windmill Grass (*Chloris ventricosa*), Couch (*Cynodon dactylon*), and Weeping Meadow Grass (*Microlaena stipoides*). Native herbaceous plants include *Einadia polygonoides*, Kidney Weed (*Dichondra repens*), Twinning Glycine (*Glycine clandestina*) and *Oxalis perenans*. Exotic grasses are abundant and include such species as Paspalum (*Paspalum distichum*), African Love Grass (*Eragrostis curvula*) and Kikuyu (*Pennisetum clandestinum*). Exotic herbs include such species as Cats Ear (*Hypochaeris radicata*), Common Plantain (*Plantago lanceolata*), Fireweed (*Solanum madagascariensis*) and Spear Thistle (*Cirsium vulgare*). A list of species encountered in the field surveys and/or predicted to occur based upon literature review and interpretation of database records is presented in this report in **Appendix A**.

Following the Commonwealth's flowchart of key diagnostic features and condition thresholds for this community, the patches of vegetation do not conform to the EPBC Act listed CEEC for the reasons set out below:

There are seven patches Cumberland Plain Woodland present on the subject site. The seven patches of Cumberland Plain Woodland have native tree species present with a minimum PFC of 10%. Of the seven patches present, five are greater than 0.5 ha in size. However, all five of those patches have less than 50% native perennial understorey species cover present. None of the five patches exceed 5 ha in size, or are contiguous with other patches which are 5 ha or greater in size. The patches exhibit exotic understorey with typically less than 30% native perennial species present.

Photograph 5.1 **Cumberland Plain Woodland within Badgally Reserve in the subject site**

5.3.3 Planted Natives and Exotic Weeds

The majority of vegetation in proximity to the buildings consists of planted native or exotic trees with species such as Mugga Ironbark (*Eucalyptus sideroxylon*), Spotted Gum (*Corymbia maculata*), Broad-leaved Paperbark (*Melaleuca quinquinervia*) and Tallowwood (*Eucalyptus microcorys*).

5.3.4 Flora

The vegetation of the subject site is highly degraded, and consists of remnant and planted trees over grassland. The trees are largely planted natives with the regular occurrence of exotics. Shrubs are generally absent with mostly exotic groundcovers. Some areas are dominated by native groundcovers and generally exist under native dominant canopy trees. The flora and habitat values of the subject site are highly degraded due to the persistent anthropogenic disturbance. Limited potential habitat for the threatened species *Pimelea spicata* occurs within the subject site. This species is discussed below.

5.3.5 Threatened Flora

i. Pimelea spicata

Pimelea spicata is listed as Endangered under the TSC Act and the EPBC Act. It is typically associated with Grey Box and Ironbark woodland such as Cumberland Plain Woodland and found on the well structured soils of the Wianamatta shale group. The species is highly resilient to ongoing disturbance and such a disturbance regime is considered important to the lifecycle of the species. As such the species is often found along disturbed edges of tracks and trails.

While no individuals of this species have been recorded within the subject site, potential habitat occurs on the site. However, it occurs in fragmented patches and is not considered to be important habitat for the conservation of the species. Given the high frequency and nature of the disturbance within the open space of the subject site as well as the scarcity of individuals within the locality it is considered to have a low chance of occurrence on the site and the development is unlikely to have a significant impact on this species.

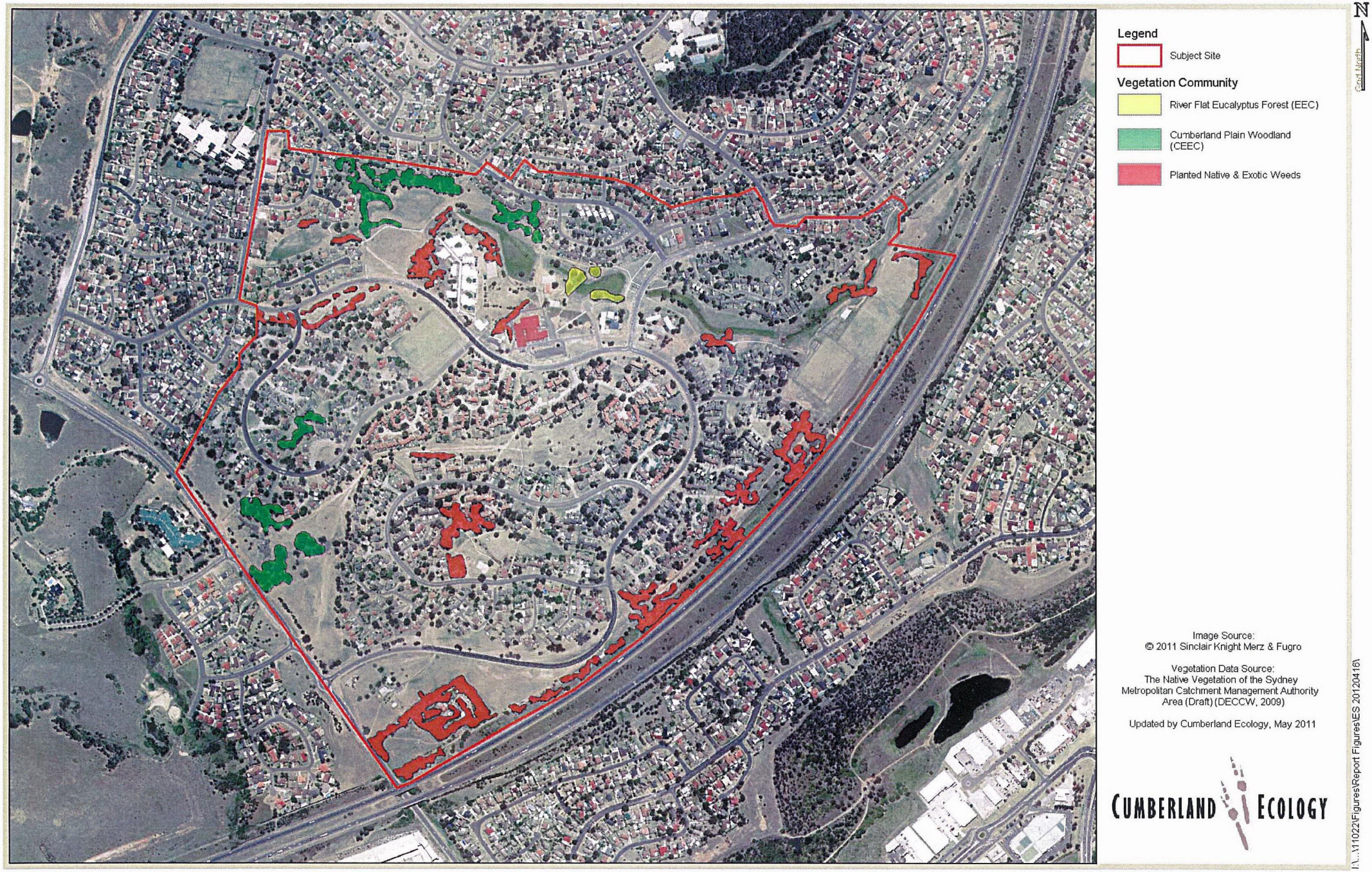

Figure 5.1. Vegetation of the Subject Site

5.4 Fauna

5.4.1 Habitat Assessment

The highly disturbed nature of the vegetation within the subject site has resulted in the fauna habitat being considered of little value to many species. There are however, numerous State and Commonwealth listed threatened species that have some potential to utilise the subject site. The subject site, also does contain habitat of value for some of the more common species that are typically found within the Western Sydney suburban area, particularly common birds and reptiles.

No obvious large tree hollows were detected during the tree hollow survey although a number of large mature trees were observed that showed good hollow recruitment potential (that is, they are considered likely to produce hollows in the short to medium term). It is likely that small hollows that were not sighted during the survey are present in a number of trees across the subject site. These hollows are likely to provide habitat for a number of small birds and microbats.

As a consequence of the modification of the subject site, the fauna within the subject site is typical of suburban areas. It is dominated by hardy native birds such as Australian Magpie (*Cracticus tibicen*), Magpie Lark (*Grallina cyanoleuca*), Australian Raven (*Corvus coronoides*), Eastern Rosella (*Platycercus eximius*), Rainbow Lorikeet (*Trichoglossus haematodus*) and Noisy Miner (*Manorina melanocephala*).

No mammals were recorded; however typical native mammal fauna species likely to occur include the Ringtail Possum (*Pseudocheirus peregrinus*) and Common Brush-tail Possum (*Trichosurus vulpecula*). It is expected that several exotic mammal species occur in the subject site including the European Red Fox (*Vulpes vulpes*), Feral Cat (*Felis catus*), Black Rat (*Rattus rattus*) and House Mouse (*Mus musculus*).

Reptiles are likely to be poorly represented due to lack of habitat and regular mowing but species likely to occur include grass and garden skinks (*Pseudomoia* spp, and *Lampropholis* spp.) as well as other common larger reptiles. Amphibians likely to occur include the Common Eastern Froglet (*Crinia signifera*) and Spotted Marsh Frog *(Limnodynastes tasmaniensis*). A list of species encountered in the field surveys and/or predicted to occur based upon literature review and interpretation of database records is presented in **Appendix B**.

5.4.2 Threatened Fauna

The subject site contains some habitat for a small range of threatened birds and bats. It is unlikely that the vegetation provides suitable habitat for any threatened amphibians, reptiles or terrestrial mammals and no threatened amphibians, mammals or reptiles are considered likely to occur in the subject site.

i. Birds

One threatened bird species listed as vulnerable under the TSC Act was recorded within the subject site, the Little Lorikeet (*Glossopsitta pusilla*). Several Little Lorikeets were recorded overflying the site during the survey. Nectar producing trees provide suitable feeding habitat for the Little Lorikeet and a small number of additional threatened nectarivorous birds such the Swift Parrot (*Lathamas discolor*), Black-chinned Honeyeater (*Melithreptus gularis*) and Regent Honeyeater (*Archeoptera phrygia*). While the latter species are relatively unlikely to occur within the subject site it is considered that it is possible that they would utilise the habitat during the flowering periods of dominant canopy trees. The Black-chinned Honeyeater is listed as Vulnerable under the TSC Act. The Swift Parrot is listed as Endangered under the TSC and EPBC Acts while the Regent Honeyeater is listed as Critically Endangered under the TSC Act and Endangered under the EPBC Act.

ii. Bats

While no tree hollows were recorded during surveys it is considered likely that numerous threatened bats forage throughout the subject site. There is potential for threatened microchiropteran bats to roost within small undetected tree-hollows and building cavities. Bat species predicted to have the potential to occur within the Subject site include the Southern Myotis (*Myotis macropus*), Yellow-bellied Sheath-tail Bat (*Saccolaimus flaviventris*) and Greater Broad-nosed Bat (*Scoteanax rueppellii*) as well as the Grey-headed Flying-fox (*Pteropus poliocephalus*) which could forage on the subject site. The microchiropteran bat species are listed as Vulnerable under the TSC Act while the Grey-headed Flying-fox is listed as Vulnerable under State and Commonwealth legislation.

Chapter 6

Impact Assessment

This chapter outlines the potential impacts of the proposed Project on State and Commonwealth listed flora and fauna. It describes in detail both direct and indirect impacts that could occur and short-term and long-term effects. General impacts are explained initially while the impacts as they relate specifically to the Project are described in further detail in the following sections.

6.1 Direct and Indirect Impacts

Direct impacts are impacts that occur from a Project as a result of the direct physical effect of the Project, such as the clearing of vegetation. These impacts are obvious in their visual effects and can potentially have a significant ecological impact on the subject site.

Indirect effects occur as a result of secondary processes that occur as a result of the Project. Typically, such effects occur over a longer time scale with less ecological impacts, or occur in areas adjacent to or downstream/downslope from the physical disturbance footprint. Examples of secondary impacts that occur as part of a development are weed invasion and associated edge effect, as well as sediment and erosion problems in riparian areas.

6.2 Vegetation Clearance

6.2.1 Endangered Ecological Communities

The site is zoned under the provisions of the Campbelltown (Urban Area) Local Environmental Plan. A number of land use zonings apply to the site with residential areas being zoned 2(b) Residential and open spaces within an open space zone allow a large-scale development of the subject site.

As a result of the Project, approximately 1.15 ha of Cumberland Plain Woodland will be removed from the subject site. The vegetation to be cleared occurs as isolated fragments of degraded woodland and forest. Although another EEC, River Flat Eucalypt Forest is present in the subject site, this vegetation community will not be cleared. The proposed areas of clearance for the subject site are shown in **Figure 6.1** whilst the size of each area of impact for each vegetation community occurring within the subject site can be viewed in **Table 6.1**.

Table 6.1 Summary of Vegetation Clearance

Vegetation Community	Area currently on site (ha)	Area to be cleared (ha)
Cumberland Plain Woodland (CEEC)	2.75	1.15
River Flat Eucalyptus Forest (EEC)	0.33	
Planted Native & Exotic Weeds	6.55	3.52
Total	**9.64**	**4.67**
Total EEC	3.08	1.15

Note: Rounded to 2 decimal places

In the context of the subject site itself the removal of this 1.15 ha of TSC Act listed Cumberland Plain Woodland is not expected to have a significant impact upon the community within the locality. The highly isolated, disturbed and fragmented nature of the vegetation indicates that the vegetation of the subject site is not viable in the longer term. This project will allow for the re-establishment of a significant area of C/EECs within the proposed offset areas, and can be seen as being beneficial to the longer term longevity of the C/EECs.

The 'Clearing of Native Vegetation' is listed as a Key Threatening Process and has been identified as a direct cause in the decrease in biodiversity (NSW Scientific Committee, 2004).

6.2.2 Groundwater Dependent Ecosystems

River Flat Eucalypt Forest is a typically a groundwater dependent ecosystem due to its close proximity to riparian areas. It is unlikely that the vegetation will be impacted as part of the proposed development due to the low level of excavation that will be used in close proximity to the vegetation. In addition to this, the drainage network of the subject site has not changed significantly. As a result, the water reaching the drainage line in the linear corridor will be of similar quality, and will recharge the groundwater system thoroughly. This should ensure that the vegetation of this community will remain unaffected as a result of the proposed development.

6.3 Threatened Flora

No threatened species of plants were detected within the subject site. Given the disturbance history, current condition and current management of the site, it is considered unlikely that any threatened plants occur within the subject site.

Potential habitat for *Pimelea spicata* occurs within the subject site. However, the species is considered to have a low chance of occurrence considering the high levels of disturbance of the site, the fragmented nature of the habitat and the lack of any records of the species nearby. The loss of up to 1.15 ha of marginal potential habitat for this species is not expected to cause a significant impact to this species.

As such, the development in its current form is not expected to have a significant impact on any listed threatened plant species.

6.4 Threatened Fauna

One threatened fauna species, the Little Lorikeet, has been recorded within the subject site, although only flying through the area. This species is likely to use the treed areas of the site for foraging on nectar. The subject site also provides some potential habitat for a number of State and Commonwealth listed threatened birds and bats as described in Chapter 5. The proposed Project will result in the removal of 1.15 ha of potential woodland habitat for a number of these threatened species and up to 3.52 ha of native and exotic plantings containing some potential marginal habitat. However, the impact of this removal is expected to be minimal, based on the following factors:

- The Project landscape and habitats are highly disturbed and fragmented and potential habitat value for most species would be expected to be low;
- The total extent of clearing of habitat is low;
- The occurrence of habitat features such as hollows is minimal;
- Species with some potential to occur are either relatively uncommon within the LGA and/or have large areas of foraging habitat available in the Sydney area and any dependence on the Project habitats is unlikely; and
- Habitat will be retained and enhanced within conservation areas within the subject site.

Further discussion on specific groups of threatened species is provided below.

6.4.1 Birds

The Project is not considered likely to have a significant impact on the threatened birds that are known to occur or have potential to occur on the subject site. The two EPBC listed threatened species that have potential to occur, the Swift Parrot and Regent Honeyeater, are migratory and present only in the area at certain times of the year. The Little Lorikeet is relatively common throughout Western Sydney and has a considerable amount of foraging habitat within this area. The Black-chinned Honeyeater is less common but still has the potential to forage within the subject site. On a regional scale, habitat for this species exists throughout NSW. With the clearance proposed, the loss of potential habitat for these

threatened species is considered unlikely to cause a significant impact on any of these species across their range.

6.4.2 Bats

The Project also provides some foraging habitat and potentially some breeding and roosting habitat, in the form of tree hollows, for TSC Act listed threatened bats. There is also potential foraging habitat for the Grey-headed Flying-fox, however no roosting habitat as the species roosts in established camps. For threatened microchiropteran bats, a considerable area of suitable habitat and a number of roost sites will remain present within the subject site. Additional habitat occurs within the conservation areas (see details in Section 7.2), as well as within areas adjacent to the proposed Claymore development. Due to this retention of habitat and the small area of habitat proposed to be cleared, it is considered unlikely that the vegetation proposed to be removed as part of the Project will cause a significant impact on any of the State listed microchiropteran bats or the Grey-headed Flying-Fox.

Consequently, the proposed extent of removal of trees from this urban landscape is not expected to have a significant effect on any threatened fauna species or populations within the LGA.

Coordinate System: MGA Zone 56 (GDA 94)

Legend

Subject Site

Vegetation Community

River Flat Eucalyptus Forest (EEC)

Cumberland Plain Woodland (CEEC)

Planted Native & Exotic Weeds

Vegetation to be Removed

N

Grid North

Image Source:
Claymore Urban Renewal Proposed Concept Plan, by AECOM, dated 02/11/2011

Vegetation Data Source:
The Native Vegetation of the Sydney Metropolitan Catchment Management Authority Area (Draft) (DECCW, 2009)

Updated by Cumberland Ecology, May 2011

CUMBERLAND ECOLOGY

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Figure 6.1. Proposed Project Impacts

Chapter 7

Mitigation Measures

This chapter provides an assessment of the avoidance measures and recommended mitigation measures for the proposed Project. These avoidance and mitigation measures will be utilised to minimise any potential impacts to the ecological values of the subject land as well as adjoining vegetation that may be indirectly impacted by the Project.

The process of avoidance and mitigation is as follows:

- Avoid: to the extent possible, developments should be designed to avoid or minimise ecological impacts;
- Mitigate: where certain impacts are unavoidable through design changes, mitigation measures should be introduced to ameliorate the ecological impacts of the future development;
- Offset: where mitigation and avoidance do not appropriately offset the impacts of the proposed development, offsetting measures will be introduced. In the case of this Project an area of the native vegetation communities present will be re-established in the Linear Park to the north of the subject site and in the area to the north of Fullwood Reserve. This is discussed in further detail in Section 7.3.

7.1 Avoidance Measures

The areas of vegetation currently occurring in the Subject site, those to be cleared and those to be retained are presented in **Table 7.1** below. This table indicates that 63% of the total C/EEC vegetation within the Subject site will be avoided and retained. It is noted that the Concept Plan for the Project has been amended in order to avoid all River-flat Eucalypt Forest clearance. Some of the areas retained are proposed to be re-vegetated to develop vegetation communities similar to those that originally occurred within the Subject site. Further details on re-vegetation are provided in **Section 7.3** below and within the Offset Assessment and VMP to be prepared for the Project. It is also recommended that any hollow bearing trees within the subject site are retained to ensure that habitat for birds and bats is retained.

Table 7.1 Summary of Vegetation Clearance and Retention

Vegetation Community	Area currently on site (ha)	Area to be cleared (ha)	Area to be retained (ha)
Cumberland Plain Woodland (CEEC)	2.75	1.15	1.6
River Flat Eucalyptus Forest (EEC)	0.33		0.33
Planted Native & Exotic Weeds	6.55	3.52	3.03
Total	**9.64**	**4.67**	**4.97**
Total EEC	3.08	1.15	1.93
		(37%)	(63%)

7.2 Recommended Mitigation Measures

A number of mitigation measures are recommended to be utilised for the proposed Project. These mitigation measures include those to be undertaken during the construction, operational and post-operational phases of the proposed Project. The major component of the post-operational phase is the implementation of the VMP. It is proposed that these mitigation measures be incorporated into the conditions of consent upon approval of the Project.

7.2.1 Construction and Operational Phases

During the construction and operational phases there is the potential for a number of direct and indirect ecological impacts. Potential impacts to flora and fauna occurring in these phases that can be managed include: unnecessary vegetation removal, runoff, sedimentation, erosion and pollution. As some of the subject site is located on sloped land, it is recommended that precautions be taken to minimise the impacts further down the slope. Recommended mitigation measures to be undertaken within the construction and operational phase are detailed below.

i. Access, signage and demarcation

Site inductions are to be given by the civil contractor to ensure all site workers and visitors are aware of any sensitive vegetation. Access to adjoining vegetation should only be granted if conducting or overseeing mitigation measures.

The development footprint should be clearly demarcated and signed, where appropriate, to ensure no vegetation beyond these boundaries is removed. Temporary fencing can be

erected to ensure construction and operational activities are contained within the development footprint.

ii. Erosion, Sediment and Pollution Control

During the construction and operational phases, precautions should be taken to ensure that no sediment or pollution enters adjoining vegetation. To reduce sedimentation on the construction site, erosion control measures need to be implemented. This may involve minimising the amount of exposed soils on the site at any given time. Silt traps should be established to prevent the impacts of sedimentation on the adjoining vegetation. During development, precautions should be taken to ensure that no pollution escapes the construction site. Pollution traps and efficient removal of pollution to an off site location will help to minimise pollution impacts. Such mitigation measures will assist in the control of weed invasion during construction.

iii. Water Management

To prevent excess runoff flowing off the building site, barriers should be established to divert the flow of water away from the adjoining vegetation and into appropriate drainage systems. Filters within the barriers will minimise the amount of sedimentation entering the waterways. These measures will also reduce the likelihood of weed invasion in adjacent areas.

iv. Habitat Retention

Where possible, the following habitat features should be retained:

- Mature native trees to provide feeding and potential nesting habitat;
- Hollow-bearing trees to provide nesting and roosting habitat for fauna species; and
- Riparian areas, to allow for the persistence of riparian habitats within the subject site.

v. Landscaping

To maintain the natural scenic values of the subject site, locally occurring species are recommended for use in landscape design. Landscaping and visual screening works on within the subject site should utilise species endemic to the Cumberland Plain to suit the existing landscape character. Utilisation of endemic species common in Cumberland Plain Woodland and River-flat Eucalypt Forest species within the landscaping will also provide potential habitat for native fauna species

7.3 Proposed Offsets

In order to compensate for the loss of Cumberland Plain Woodland vegetation, an offset strategy is to be developed. In this regard, the applicant acknowledges that prior to determination of any further development application under the Concept Plan, the Council must be satisfied that the biodiversity offset strategy as approved by the Director General is

not compromised by the development. The applicant further acknowledges that the offset strategy is to be implemented prior to the removal of any affected vegetation and/or ecological community.

The offset strategy is to be developed to include the maintain, improve and protect principles. An appropriate offset area location and size is to be determined. The offset area or areas determined will be subject to a Vegetation Management Plan (VMP). The VMP actions will include management and rehabilitation to reform community composition and structure of the original form of the community from which it was derived (or as near to as possible subject to asset protection zones). Weed removal should be the initial focus and the propagation and replanting of local native seed is recommended to hasten community recovery. The plan of the ongoing management under the VMP is to improve and maintain the quality of the vegetation within the offset area. The document will be prepared to contain specific management actions and performance criteria to ensure the quality of the vegetation is maintained.

Chapter 8

Conclusion

The subject site has had a long history of land use and development. Notwithstanding the high degree of modification of the landscape, areas of semi-natural vegetation remain and these have been derived from, or are low quality representations of two threatened ecological communities listed under the TSC Act:

- River-flat Eucalypt Forest; and
- Cumberland Plain Woodland.

The Cumberland Plain Woodland on site does not conform to the Commonwealth EPBC Act listing of the community.

The proposed redevelopment of the subject site will remove patches of species-poor Cumberland Plain Woodland within Badgally Reserve and the north western corner of the subject site. It will remove native trees from across the existing suburban areas. At this stage it is not possible to be precise about the numbers of trees to be removed in the redevelopment. Nevertheless, the development is likely/not likely to have a significant effect on CPW if the avoidance, mitigation and compensatory measures described in this report are implemented.

The impact avoidance and mitigation measures to be implemented will minimise the adverse effects of the Project on Cumberland Plain Woodland and threatened species habitat. Notwithstanding this, an offset strategy is proposed to address the net loss of Cumberland Plan Woodland on the subject site. The offset strategy is currently being developed to identify an appropriate offset area location and size and to include the principles of maintain, improve and protect. Ongoing management under a VMP is to improve and maintain the quality of the vegetation within the offset area.

No significant impacts are predicted for threatened species of plants or animals as a result of the redevelopment of the subject site.

References

Botanic Gardens Trust (2009) **PlantNET** http://www.rbgsyd.nsw.gov.au/search_plant_net

Braun-Blanquet, J. (1927) **Pflanzensoziologie Wien Springer**

Commonwealth Government (2004) ***Environment Protection and Biodiversity Conservation Act***

DECCW (2009). **The Native Vegetation of the Sydney Metropolitan Catchment Management Authority Area**. Department of Environment and Climate Change NSW, Hurstville.

OEH (2011) **Atlas of NSW Wildlife** http://wildlifeatlas.nationalparks.nsw.gov.au /wildlifeatlas/watlas.jsp.

DSEWPC (2011) **EPBC Protected Matters Search Tool** http://www.environment.gov.au/erin/ert/epbc/index.html

Harden, G.J. (1990) **Flora of New South Wales Volume 1** New South Wales University Press, Kensington.

Harden, G.J. (1991) **Flora of New South Wales Volume 2** New South Wales University Press, Kensington.

Harden, G.J. (1992) **Flora of New South Wales Volume 3** New South Wales University Press, Kensington.

Harden, G.J. (1993) **Flora of New South Wales Volume 4** New South Wales University Press, Kensington.

NSW Government (1979) ***Environmental Planning and Assessment Act***

NSW Government (1995) ***Threatened Species Conservation Act***

NSW Scientific Committee (2004) **Clearing of Native Vegetation – Key Threatening Process**, Sydney NSW.

Appendix A

Flora Species

Table A.1 Plant Species Recoded Within the Subject Site

Form	Scientific Name	Common Name	Q1	Q2	T1	T2
Trees					x	
Casuarinaceae	#*Casuarina glauca*	Swamp Oak				
Myrtaceae	*Eucalyptus amplifolia*	Cabbage Gum			x	
	E. crebra	Narrow-leaved Ironbark	5	5	x	x
	E. eugenioides	Thin-leaved Stringybark			x	
	**E. grandis*	Flooded Gum				x
	**E. microcorys*	Tallowwood			x	
	E. moloccana	Grey Box	5	1	x	x
	**E. nicholii*	Small-leaved Black Peppermint			x	
	E. tereticornis	Forest Red Gum		1	x	x
	#*Melaleuca styphelioides*	Prickly Paperbark			x	
Ulmaceae	**Ulmus parvifolia*	Small-leaved Elm			x	
Shrubs						
Oleaceae	**Olea europaea*					
	ssp cuspidata	African Olive			x	
Sapindaceae	*Dodonaea viscosa*					
	ssp cuneata	a Hopbush			x	
Rutaceae	**Murraya paniculata*	Murraya				x

CUMBERLAND ECOLOGY

Table A.1 Plant Species Recoded Within the Subject Site

Form	Scientific Name	Common Name	Q1	Q2	T1	T2
Solanaceae	**Lycium ferosissimum*	African Boxthorn	1	1	x	x
Herbs - Dicots						
Acanthaceae	*Brunoniella australis*	Purple Trumpet	1	1	x	x
Amaranthaceae	**Alternanthera pungens*	Khaki Weed	2		x	x
Asteraceae	**Arctotheca calendula*	Cape Weed	2		x	
	**Bidens pilosa*	Farmers Friends				
	Calotis cuneifolia	Blue Burr-daisy				
	**Cirsium vulgare*	Spear Thistle		1	x	
	**Conyza bonariensis*	Fleabane		2	x	x
	Cotula australis		2		x	
	Cymbonotus lawsonianus			2	x	
	Euchiton spaericum			1		x
	**Gnaphalium sp.*	a Cudweed			x	x
	**Hypochaeris microcephala*		2			
	**H. radicata*	Flatweed	2	2	x	
	**Senecio madagascariensis*	Fireweed			x	
	**Solvia sp.*	Bindii	4		x	x
	**Sonchus oleraceus*	Sow Thistle	2	1	x	x
	**Taraxacum officinalis*	Dandelion	2	3	x	x
Brassicaceae	**Lepidium africanum*			1	x	x

Table A.1 Plant Species Recoded Within the Subject Site

Form	Scientific Name	Common Name	Q1	Q2	T1	T2
Campanulaceae	*Wahlenbergia gracilis*	Small Bluebell				x
Caryophyllaceae	**Paronychia brasiliensis*		4	3	x	x
	**Petrorhagia nanteulii*	Pinks		1		
	**Spurgularia diandra*			1		
	**Stellaria media*	Chickweed			x	
Chenopodiaceae	*Einadia polygonoides*		2	2		x
	Einadia trigonos	Fishweed			x	
Convolvulaceae	*Dichondra repens*	Kidney Plant	4	4	x	x
Fabaceae	*Desmodium varians*	Tick Trefoil				x
	**Medicago polymorpha*				x	x
	**Trifolium repens*	White Clover			x	x
Lamiaceae	*Ajuga australis*		1			
	**Stachys arvensis*	Stagger Weed			x	
Malvaceae	**Malva parviflora*	Small-flowered Mallow	2		x	
	**Modiola caroliniana*		3	2	x	x
	Sida corrugata			2		x
	**S. rhombifolia*	Paddys Lucerne		1	x	x
Oxalidaceae	*Oxalis perennans*		2	3	x	
Pittosporaceae	*Bursaria spinosa*	seedlings	1			
Plantaginaceae	**Plantago lanceolata*	Lambs Tongue	4	4	x	x
Polygonaceae	*Rumex brownii*			1	x	

Table A.1 Plant Species Recoded Within the Subject Site

Form	Scientific Name	Common Name	Q1	Q2	T1	T2
Rubiaceae	**Richardia stellaria*			2	x	x
Scrophulariaceae	*Veronica plebeia*	Trailing Speedwell				x
Solanaceae	**Solanum nigrum*	Blackberry Nightshade		1		x
Verbenaceae	**Verbena bonariensis*	Small-flowered Purpletop				x
Herbs - Monocots						
Anthericaceae	*Arthropodium sp.*		2	2		
Commelinaceae	*Commelina cyanea*	Blue Wandering Jew				x
Cyperaceae	*Cyperus gracilis*		2	3	x	x
Iridaceae	**Romulea rosea*	Nutgrass			x	
Lomandraceae	*Lomandra filiformis ssp filiformis*	Wattle Mat-rush		1	x	x
Poaceae	*Austrostipa racemosa*			5	x	
	**Axonopus affinis*	Carpet Grass			x	
	Bothriochloa macra	Red Leg Grass		2	x	x
	**Chloris gayana*	Rhodes Grass	3	2	x	x
	C. truncata	Large Windmill Grass		1	x	x
	C. ventricosa	Windmill Grass	5	3	x	x
	**Cynodon dactylon*	Couch Grass	5		x	
	Danthonia sp.	a Wallaby Grass			x	x
	**Ehrharta erecta*	Veldt Grass			x	
	**Eleusine indica*	Crowsfoot Grass	2		x	

Table A.1 Plant Species Recoded Within the Subject Site

Form	Scientific Name	Common Name	Q1	Q2	T1	T2
	**Eragrostis curvula*	African Love-grass		2	x	x
	E. leptostachya	Paddock Love-grass	2	2	x	
	Eriochloa pseudoaccrotricha		2		x	x
	**Lolium sp.*	Rye Grass	2		x	
	Microlaena stipoides	Weeping Meadow-grass	2	4	x	x
	Paspalidium distans					x
	**Paspalum dilatatum*	Paspalum	2	2	x	x
	**Pennisetum clandestinum*	Kikuyu			x	
	**Setaria gracilis*	Slender Pigeon Grass		1		x
	Sporobolus creber	Slender Rats Tail Grass			x	x
	**S. indica var capensis*	Parramatta Grass				x
Vines						
Fabaceae	*Glycine tabacina*		2	4	x	x

Cover abundance in quadrats (modified Braun-Blanquet system)

- 1 = rare;
- 2 = occasional;
- c = common;
- v = very common but less than 5%;
- 5 = 5-25%;
- 6 = 26-50%;
- X = Present.

Appendix B

Fauna Species

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
Amphibia					
Bufonidae					
	*Rhinella marina**	Cane Toad		2	
Hylidae					
	Litoria caerulea	Green Tree Frog		1	
	Litoria dentata	Bleating Tree Frog		1	
	Litoria fallax	Eastern Dwarf Tree Frog		15	
	Litoria freycineti	Freycinet's Frog		1	
	Litoria latopalmata	Broad-palmed Frog		1	
	Litoria peronii	Peron's Tree Frog		10	
	Litoria tyleri	Tyler's Tree Frog		6	
	Litoria verreauxii	Verreaux's Frog		8	
	Litoria wilcoxii			1	
Myobatrachidae					
	Crinia signifera	Common Eastern Froglet		42	
	Heleioporus australiacus	Giant Burrowing Frog	V	3	
	Limnodynastes peronii	Brown-striped Frog		11	
	Limnodynastes tasmaniensis	Spotted Grass Frog		14	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Paracrinia haswelli	Haswell's Froglet		1	
	Pseudophryne australis	Red-crowned Toadlet	V	8	
	Pseudophryne bibronii	Bibron's Toadlet		2	
	Uperoleia laevigata	Smooth Toadlet		3	
Aves					
Acanthizidae					
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill		97	
	Acanthiza lineata	Striated Thornbill		17	
	Acanthiza nana	Yellow Thornbill		435	
	Acanthiza pusilla	Brown Thornbill		321	
	Acanthiza reguloides	Buff-rumped Thornbill		9	
	Gerygone albogularis	White-throated Gerygone		17	
	Gerygone mouki	Brown Gerygone		24	
	Hylacola pyrrhopygia	Chestnut-rumped Heathwren		1	
	Origma solitaria	Rockwarbler		9	
	Pyrrholaemus saggitatus	Speckled Warbler	V	5	
	Sericornis frontalis	White-browed Scrubwren		632	
	Smicrornis brevirostris	Weebill		109	
Accipitridae					

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Accipiter cirrocephalus	Collared Sparrowhawk		5	
	Accipiter fasciatus	Brown Goshawk		9	
	Accipiter novaehollandiae	Grey Goshawk		6	
	Aquila audax	Wedge-tailed Eagle		5	
	Aviceda subcristata	Pacific Baza		3	
	Elanus axillaris	Black-shouldered Kite		31	
	Haliastur sphenurus	Whistling Kite		1	
	Hieraaetus morphnoides	Little Eagle	V	7	
	Milvus migrans	Black Kite		2	
Acrocephalidae					
	Acrocephalus australis	Australian Reed-Warbler		30	
Aegothelidae					
	Aegotheles cristatus	Australian Owlet-nightjar		4	
Alaudidae					
	*Alauda arvensis**	Eurasian Skylark		1	
Alcedinidae					
	Ceyx azureus	Azure Kingfisher		7	
	Dacelo novaeguineae	Laughing Kookaburra		40	
	Todiramphus sanctus	Sacred Kingfisher		37	
Anatidae					

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Anas castanea	Chestnut Teal		4	
	Anas gracilis	Grey Teal		2	
	*Anas platyrhynchos**	Mallard		1	
	Anas superciliosa	Pacific Black Duck		20	
	Aythya australis	Hardhead		4	
	Chenonetta jubata	Australian Wood Duck		19	
	Cygnus atratus	Black Swan		3	
	Oxyura australis	Blue-billed Duck	V	1	
	Stictonetta naevosa	Freckled Duck	V	1	
Anhingidae					
	Anhinga novaehollandiae	Australasian Darter		3	
Ardeidae					
	Ardea ibis	Cattle Egret		7	
	Ardea modesta	Eastern Great Egret		2	
	Egretta garzetta	Little Egret		1	
	Egretta novaehollandiae	White-faced Heron		12	
	Ixobrychus dubius	Australian Little Bittern		1	
	Nycticorax caledonicus	Nankeen Night Heron		1	
Artamidae					
	Artamus cyanopterus	Dusky Woodswallow		68	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Artamus personatus	Masked Woodswallow		2	
	Artamus superciliosus	White-browed Woodswallow		1	
	Cracticus nigrogularis	Pied Butcherbird		5	
	Cracticus tibicen	Australian Magpie		62	x
	Cracticus torquatus	Grey Butcherbird		113	x
	Strepera graculina	Pied Currawong		24	x
Cacatuidae					
	Cacatua galerita	Sulphur-crested Cockatoo		47	
	Cacatua sanguinea	Little Corella		9	
	Cacatua tenuirostris	Long-billed Corella		8	
	Callocephalon fimbriatum	Gang-gang Cockatoo	V	2	
	Calyptorhynchus funereus	Yellow-tailed Black-Cockatoo		5	
	Eolophus roseicapillus	Galah		25	
Campephagidae					
	Coracina novaehollandiae	Black-faced Cuckoo-shrike		48	
	Coracina papuensis	White-bellied Cuckoo-shrike		1	
	Coracina tenuirostris	Cicadabird		3	
	Lalage sueurii	White-winged Triller		3	
Charadriidae					
	Elseyornis melanops	Black-fronted Dotterel		2	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Vanellus miles	Masked Lapwing		18	x
Cisticolidae					
	Cisticola exilis	Golden-headed Cisticola		7	
Climacteridae					
	Cormobates leucophaea	White-throated Treecreeper		31	
Columbidae					
	*Columba livia**	Rock Dove		1	
	Geopelia humeralis	Bar-shouldered Dove		2	
	Geopelia striata	Peaceful Dove		8	
	Leucosarcia picata	Wonga Pigeon		7	
	Lopholaimus antarcticus	Topknot Pigeon		1	
	Macropygia amboinensis	Brown Cuckoo-Dove		3	
	Ocyphaps lophotes	Crested Pigeon		47	x
	Phaps chalcoptera	Common Bronzewing		12	
	*Streptopelia chinensis**	Spotted Turtle-Dove		41	x
Coraciidae					
	Eurystomus orientalis	Dollarbird		2	
Corcoracidae					
	Corcorax melanorhamphos	White-winged Chough		11	
Corvidae					

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Corvus coronoides	Australian Raven		68	x
Cuculidae					
	Cacomantis flabelliformis	Fan-tailed Cuckoo		45	
	Cacomantis pallidus	Pallid Cuckoo		3	
	Cacomantis variolosus	Brush Cuckoo		4	
	Chalcites lucidus	Shining Bronze-Cuckoo		9	
	Eudynamys orientalis	Eastern Koel		8	
	Scythrops novaehollandiae	Channel-billed Cuckoo		4	
Estrildidae					
	Lonchura castaneothorax	Chestnut-breasted Mannikin		4	
	Neochmia temporalis	Red-browed Finch		2112	
	Taeniopygia bichenovii	Double-barred Finch		450	
	Taeniopygia guttata	Zebra Finch		3	
Falconidae					
	Falco berigora	Brown Falcon		5	
	Falco cenchroides	Nankeen Kestrel		28	
	Falco longipennis	Australian Hobby		1	
	Falco peregrinus	Peregrine Falcon		5	
Fringillidae					
	*Carduelis carduelis**	European Goldfinch		65	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
Hirundinidae					
	Hirundo neoxena	Welcome Swallow		28	x
	Petrochelidon ariel	Fairy Martin		411	
	Petrochelidon nigricans	Tree Martin		3	
Maluridae					
	Malurus cyaneus	Superb Fairy-wren		1026	
	Malurus lamberti	Variegated Fairy-wren		84	
Meliphagidae					
	Acanthorhynchus tenuirostris	Eastern Spinebill		95	
	Anthochaera carunculata	Red Wattlebird		16	
	Anthochaera chrysoptera	Little Wattlebird		36	
	Gliciphila melanops	Tawny-crowned Honeyeater		2	
	Lichenostomus chrysops	Yellow-faced Honeyeater		527	
	Lichenostomus fuscus	Fuscous Honeyeater		15	
	Lichenostomus leucotis	White-eared Honeyeater		29	
	Lichenostomus melanops	Yellow-tufted Honeyeater		31	
	Lichenostomus penicillatus	White-plumed Honeyeater		214	
	Manorina melanocephala	Noisy Miner		125	x
	Manorina melanophrys	Bell Miner		26	
	Meliphaga lewinii	Lewin's Honeyeater		70	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Melithreptus brevirostris	Brown-headed Honeyeater		10	
	Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V	3	
	Melithreptus lunatus	White-naped Honeyeater		53	
	Myzomela sanguinolenta	Scarlet Honeyeater		19	
	Philemon corniculatus	Noisy Friarbird		34	
	Phylidonyris niger	White-cheeked Honeyeater		1	
	Phylidonyris novaehollandiae	New Holland Honeyeater		8	
	Xanthomyza phrygia	Regent Honeyeater	CE	1	
Menuridae					
	Menura novaehollandiae	Superb Lyrebird		1	
Meropidae					
	Merops ornatus	Rainbow Bee-eater		2	
Monarchidae					
	Grallina cyanoleuca	Magpie-lark		53	
	Monarcha melanopsis	Black-faced Monarch		4	
	Myiagra cyanoleuca	Satin Flycatcher		2	
	Myiagra inquieta	Restless Flycatcher		14	
	Myiagra rubecula	Leaden Flycatcher		12	
Motacillidae					

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Anthus novaeseelandiae	Australian Pipit		5	
Nectariniidae					
	Dicaeum hirundinaceum	Mistletoebird		31	
Neosittidae					
	Daphoenositta chrysoptera	Varied Sittella	V	25	
Oriolidae					
	Oriolus sagittatus	Olive-backed Oriole		25	
Pachycephalidae					
	Colluricincla harmonica	Grey Shrike-thrush		60	
	Falcunculus frontatus frontatus	Eastern Shrike-tit		16	
	Pachycephala pectoralis	Golden Whistler		390	
	Pachycephala rufiventris	Rufous Whistler		138	
Pardalotidae					
	Pardalotus punctatus	Spotted Pardalote		254	
	Pardalotus striatus	Striated Pardalote		131	
Passeridae					
	*Passer domesticus**	House Sparrow		80	
Pelecanidae					
	Pelecanus conspicillatus	Australian Pelican		5	
Petroicidae					

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Eopsaltria australis	Eastern Yellow Robin		767	
	Melanodryas cucullata	Hooded Robin	V	2	
	Microeca fascinans	Jacky Winter		5	
	Petroica boodang	Scarlet Robin	V	6	
	Petroica goodenovii	Red-capped Robin		1	
	Petroica phoenicea	Flame Robin	V	1	
	Petroica rosea	Rose Robin		70	
Phalacrocoracidae					
	Microcarbo melanoleucos	Little Pied Cormorant		9	
	Phalacrocorax carbo	Great Cormorant		1	
	Phalacrocorax sulcirostris	Little Black Cormorant		6	
	Phalacrocorax varius	Pied Cormorant		4	
Phasianidae					
	Coturnix ypsilophora	Brown Quail		2	
Podargidae					
	Podargus strigoides	Tawny Frogmouth		9	
Podicipedidae					
	Tachybaptus novaehollandiae	Australasian Grebe		6	
Psittacidae					

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Alisterus scapularis	Australian King-Parrot		15	
	Glossopsitta concinna	Musk Lorikeet		6	
	Glossopsitta pusilla	Little Lorikeet	V	7	x
	Lathamus discolor	Swift Parrot	E	2	
	Platycercus elegans	Crimson Rosella		14	
	Platycercus eximius	Eastern Rosella		69	x
	Psephotus haematonotus	Red-rumped Parrot		59	x
	Trichoglossus chlorolepidotus	Scaly-breasted Lorikeet		2	
	Trichoglossus haematodus	Rainbow Lorikeet		47	x
Psophodidae					
	Cinclosoma punctatum	Spotted Quail-thrush		3	
	Psophodes olivaceus	Eastern Whipbird		33	
Ptilonorhynchidae					
	Ptilonorhynchus violaceus	Satin Bowerbird		15	
Pycnonotidae					
	*Pycnonotus jocosus**	Red-whiskered Bulbul		275	
Rallidae					
	Fulica atra	Eurasian Coot		4	
	Gallinula tenebrosa	Dusky Moorhen		11	
	Porphyrio porphyrio	Purple Swamphen		12	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
Recurvirostridae					
	Himantopus himantopus	Black-winged Stilt		1	
Rhipiduridae					
	Rhipidura albiscapa	Grey Fantail		340	
	Rhipidura leucophrys	Willie Wagtail		95	
	Rhipidura rufifrons	Rufous Fantail		62	
Scolopacidae					
	Gallinago hardwickii	Latham's Snipe		6	
Strigidae					
	Ninox novaeseelandiae	Southern Boobook		8	
	Ninox strenua	Powerful Owl	V	3	
Sturnidae					
	*Sturnus tristis**	Common Myna		68	
	*Sturnus vulgaris**	Common Starling		156	x
Threskiornithidae					
	Platalea flavipes	Yellow-billed Spoonbill		4	
	Platalea regia	Royal Spoonbill		5	
	Threskiornis molucca	Australian White Ibis		5	
	Threskiornis spinicollis	Straw-necked Ibis		3	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
Timaliidae					
	Zosterops lateralis	Silvereye		6152	
Turdidae					
	*Turdus merula**	Eurasian Blackbird		317	
	Zoothera lunulata	Bassian Thrush		1	
	Zoothera sp.	unidentified ground thrush		1	
Turnicidae					
	Turnix varius	Painted Button-quail		2	
Tytonidae					
	Tyto javanica	Eastern Barn Owl		2	
Gastropoda					
Bradybaenidae					
	*Bradybaena similaris**	Asian trampsnail		1	
Camaenidae					
	Meridolum corneovirens	Cumberland Plain Land Snail	E	25	
Helicidae					
	*Helix aspersa**	Brown gardensnail		4	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
Mammalia					
Acrobatidae					
	Acrobates pygmaeus	Feathertail Glider		1	
Bovidae					
	*Bos taurus**	European cattle		3	
	*Capra hircus**	Goat		3	
Canidae					
	*Canis lupus familiaris**	Dog		7	
	*Canis lupus**	Dingo, domestic dog		5	
	*Vulpes vulpes**	Fox		106	
Cervidae					
	*Cervus sp.**	Unidentified Deer		13	
Dasyuridae					
	Antechinus stuartii	Brown Antechinus		2	
	Dasyurus maculatus	Spotted-tailed Quoll	V	1	
Emballonuridae					
	Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V	1	
Equidae					
	*Equus caballus**	Horse		5	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
Felidae					
	*Felis catus**	Cat		4	
Leporidae					
	*Lepus capensis**	Brown Hare		2	
	*Oryctolagus cuniculus**	Rabbit		28	
Macropodidae					
	Macropod sp.	unidentified macropod		1	
	Macropus giganteus	Eastern Grey Kangaroo		4	
	Macropus robustus	Common Wallaroo		5	
	Wallabia bicolor	Swamp Wallaby		32	
Molossidae					
	Mormopterus "Species 2"	Undescribed Freetail Bat		2	
	Mormopterus norfolkensis	Eastern Freetail-bat	V	8	
	Tadarida australis	White-striped Freetail-bat		8	
Muridae					
	*Mus musculus**	House Mouse		6	
	Rattus fuscipes	Bush Rat		2	
	*Rattus rattus**	Black Rat		2	
Ornithorhynchida					

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
e					
	Ornithorhynchus anatinus	Platypus		5	
Petauridae					
	Petaurus breviceps	Sugar Glider		9	
	Petaurus sp.	glider		1	
Phalangeridae					
	Trichosurus sp.	brushtail possum		23	
	Trichosurus vulpecula	Common Brushtail Possum		9	
Phascolarctidae					
	Phascolarctos cinereus	Koala	V	463	
Pseudocheiridae					
	Pseudocheirus peregrinus	Common Ringtail Possum		11	
Pteropodidae					
	Pteropus poliocephalus	Grey-headed Flying-fox	V	16	
Suidae					
	*Sus scrofa**	Pig		1	
Tachyglossidae					
	Tachyglossus aculeatus	Short-beaked Echidna		35	
Vespertilionidae					
	Chalinolobus dwyeri	Large-eared Pied Bat	V	1	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Chalinolobus gouldii	Gould's Wattled Bat		17	
	Chalinolobus morio	Chocolate Wattled Bat		7	
	Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	2	
	Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V	3	
	Myotis macropus	Southern Myotis	V	4	
	Nyctophilus geoffroyi	Lesser Long-eared Bat		6	
	Nyctophilus gouldi	Gould's Long-eared Bat		3	
	Nyctophilus sp.	long-eared bat		4	
	Scoteanax rueppellii	Greater Broad-nosed Bat	V	5	
	Scotorepens orion	Eastern Broad-nosed Bat		5	
	Vespadelus darlingtoni	Large Forest Bat		1	
	Vespadelus pumilus	Eastern Forest Bat		2	
	Vespadelus regulus	Southern Forest Bat		1	
	Vespadelus sp.	Unidentified Eptesicus		2	
	Vespadelus vulturnus	Little Forest Bat		11	
Vombatidae					
	Vombatus ursinus	Common Wombat		19	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
Reptilia					
Agamidae					
	Amphibolurus muricatus	Jacky Lizard		4	
	Physignathus lesueurii	Eastern Water Dragon		6	
	Pogona barbata	Bearded Dragon		4	
Boidae					
	Morelia spilota	Carpet & Diamond Pythons		1	
Chelidae					
	Chelodina longicollis	Eastern Snake-necked Turtle		5	
Elapidae					
	Cryptophis nigrescens	Eastern Small-eyed Snake		1	
	Demansia psammophis	Yellow-faced Whip Snake		1	
	Hoplocephalus bungaroides	Broad-headed Snake	E	1	
	Pseudechis porphyriacus	Red-bellied Black Snake		8	
	Pseudonaja textilis	Eastern Brown Snake		5	
	Vermicella annulata	Bandy-bandy		2	
Gekkonidae					
	Diplodactylus vittatus	Wood Gecko		2	
	Oedura lesueurii	Lesueur's Velvet Gecko		5	

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
	Phyllurus platurus	Broad-tailed Gecko		5	
	Underwoodisaurus milii	Thick-tailed Gecko		1	
Pygopodidae					
	Pygopus lepidopodus	Common Scaly-foot		2	
Scincidae					
	Acritoscincus platynota	Red-throated Skink		3	
	Cryptoblepharus virgatus	Cream-striped Shinning-skink		7	
	Ctenotus robustus	Robust Ctenotus		7	
	Ctenotus taeniolatus	Copper-tailed Skink		8	
	Egernia whitii	White's Skink		1	
	Eulamprus heatwolei	Yellow-bellied Water-skink		3	
	Eulamprus quoyii	Eastern Water-skink		18	
	Eulamprus tenuis	Barred-sided Skink		9	
	Lampropholis delicata	Dark-flecked Garden Sunskink		19	
	Lampropholis guichenoti	Pale-flecked Garden Sunskink		20	
	Lygisaurus foliorum	Tree-base Litter-skink		2	
	Saiphos equalis	Three-toed Skink		1	
	Saproscincus mustelinus	Weasel Skink		2	
	Tiliqua scincoides	Eastern Blue-tongue		6	x

Table B.1 Fauna Species Present in The Subject Site and 10 km Radius

Common Name	Scientific Name	Common Name	Legal Status	Presence within locality	Presence on subject site
Typhlopidae					
	Ramphotyphlops nigrescens	Blackish Blind Snake		3	
Varanidae					
	Varanus varius	Lace Monitor		6	

Appendix C

Likelihood of Occurrence

Table C.1 Likelihood of Occurrence and Habitat Requirements of Threatened Flora

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence*
Acacia bynoeana	Bynoe's Wattle	E	V	Found in heath and woodland on sandy soils. Scattered from coast to mountains, uncommon. Associated overstorey species include Corymbia gummifera (Red Bloodwood), Scribbly Gum (Eucalyptus haemastoma), Parramatta Red Gum (Eucalyptus parramattensis), Banksia serrata and Angophora bakeri. Records occur north and east of the NWGC. No previous records occur within the Desktop Assessment Area	Unlikely. No suitable habitat.
Cynanchum elegans	White-flowered Wax Plant	E	E	Climber or twiner with a variable form. It occurs in dry rainforest gullies, scrub and scree slopes. It prefers the ecotone between dry subtropical rainforest and sclerophyll woodland/forest. However has been found in littoral rainforest; Eucalyptus tereticornis aligned open forest/ woodland; E. maculata aligned open forest/woodland; and Melaleuca armillaris scrub to open scrub. Flowers between August and May, peaking in November. Seeds are unlikely to persist in the seedbank. No previous records in the desktop assessment area.	Unlikely. No suitable habitat.

Table C.1 Likelihood of Occurrence and Habitat Requirements of Threatened Flora

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence*
Eucalyptus benthamii	Camden White Gum	V		Occurs in open forest. Requires a combination of deep alluvial sands and a flooding regime that permits seedling establishment	Unlikely. No suitable habitat.
Grevillea parviflora subsp. parviflora	Small Flower Grevillea	V	V	Occurs on sandy clay loam soils, often with lateritic ironstone gravels. Soils are mostly derived from Tertiary sands or alluvium and from the Mittagong Formation with alternating bands of shale and fine-grained sandstones. Soil landscapes include Lucas Heights and Berkshire Park. Often occurs in open, slightly disturbed sites such as along tracks. Flowering has been recorded between July to December as well as April-May. No existing records for the desktop assessment area. Although suitable habitat occurs for this species in the NWGC, it is outside of the species known range and therefore is considered unlikely to occur there.	Unlikely. No suitable habitat.
Leucopogon exolasius	Woronora Beard-heath	V	V	This plant occurs in woodland in areas of sandstone.	Unlikely. One record within a 10km of the subject site.
Leucopogon fletcheri subsp. fletcheri		E		Occurs in dry eucalypt woodland or in shrubland on clayey lateritic soils, generally on flat to gently sloping terrain along ridges and spurs.	Unlikely. No suitable habitat.

Table C.1 Likelihood of Occurrence and Habitat Requirements of Threatened Flora

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence*
Marsdenia viridiflora subsp. viridiflora		Endangered Population		Grows in vine thickets and open shale woodland	Potential. Small areas of degraded habitat exist within the subject site.
Melaleuca deanei	Deane's Melaleuca	V	V	Marshy heath on coastal sandstone plateaus.	Unlikely. No suitable habitat.
Persoonia hirsuta	Hairy Geebung	E	E	Found in sandy soils in dry sclerophyll open forest, woodland and heath on sandstone.	Unlikely. No suitable habitat.
Persoonia nutans	Nodding Geebung	E	E	Associated with dry woodland, Castlereagh Scribbly Gum Woodland, Agnes Banks Woodland and sandy soils associated with tertiary alluvium, occasionally poorly drained. Also occurs in Shale Gravel Transition Forest and Castlereagh Ironbark Forest. Endemic to the Western Sydney.	Unlikely. Small areas of degraded habitat exist within the subject site.
Pimelea spicata	Spiked Rice-flower	E	E	In western Sydney, it occurs on an undulating topography of well structured clay soils, derived from Wianamatta shale. It is associated with Cumberland Plain Woodland (CPW), in open woodland and grassland often in moist depressions or near creek lines. Has been located in disturbed areas that would have previously supported CPW	Potential. Small areas of degraded habitat exist within the subject site.
Pomaderris brunnea	Brown Pomaderris	V	V	Associated with open forests in association with Eucalyptus amplifolia, Angophora floribunda,	Unlikely. Small areas of degraded habitat exist within

Table C.1 Likelihood of Occurrence and Habitat Requirements of Threatened Flora

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence*
				Acacia parramattensis, Bursaria spinosa and Kunzea ambigua. It is found on the Colo River, the Nepean R. floodplain at Menangle, in creeklines at Wirrumbirra Sanctuary (Bargo) and on the Hawkesbury River. The distribution may extend into the southern section of Yengo NP along major creeklines and floodplains	the subject site.
Pterostylis saxicola	Syndey Plains Greenhood	E	E	Occurs in western Sydney from Freemans Reach in the north to Picton in the south. It grows in shallow soil in depression on sandstone rock escarpments. It lives in sclerophyll forest and woodland.	Unlikely. Small areas of degraded habitat exist within the subject site.

Table C.2 Likelihood of Occurrence and Habitat Requirements of Threatened Fauna

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence
Amphibians					
Heleioporus australiacus	Giant Burrowing Frog	V	V	The vegetation is typically woodland, open woodland and heath and may be associated with 'hanging swamp' seepage lines and where small pools form from the collected water. Within the Sydney region this species is confined to Sandstone environments, with breeding occurring in small streams.	Unlikely. No suitable habitat.
Litoria aurea	Green and Golden Bell Frog	E	V	Large permanent to semi-permanent freshwater wetlands, with dense stands of reeds.	Unlikely. No suitable habitat.
Litoria littlejohni	Littlejohn's Tree Frog, Heath Frog	V	V	Habitats include dams, creeks and lagoons in heathland or woodland. Favours higher woodland areas, particularly in areas of sandstone.	Unlikely. No suitable habitat.
Litoria rainformis	Southern Bell Frog	E	V	Inhabits swamps, dams and slow flowing streams with abundant emergent vegetation in open woodland and cleared areas.	Unlikely. No suitable habitat.
Pseudophryne australis	Red-crowned Toadlet	V		Hawkesbury sandstone and may be found beside temporary creeks, gutters and soaks, and under rocks and logs. Breeds in damp leaf litter that become inundated with heavy rain.	Unlikely. No suitable habitat.

Table C.2 Likelihood of Occurrence and Habitat Requirements of Threatened Fauna

Scientific Name	Common Name	Status TSC Act	Status EPBC Act	Habitat	Likelihood of occurrence
Invertebrates					
Meridolum corneovirens	Cumberland Plain Land Snail	E		Primarily inhabits Cumberland Plain Woodland. This community is a grassy, open woodland with occasional dense patches of shrubs.	Potential to occur. Suitable habitat within the study area within native woodland areas.
Reptiles					
Hoplocephalus bungaroides	Broad-headed Snake	E	V	Occur under large exfoliating slabs of sandstone and rock crevices in areas of undisturbed bushland, usually on tops of cliffs. Commonly found in rock on rock situations in this context also includes crevices in cliff faces	Unlikely. No suitable habitat.
Varanus rosenbergi	Rosenberg's Goanna	V		Found in coastal heaths, humid woodlands and wet and dry sclerophyll forests. Shelters in burrows, rock hollows or crevices. Known to lay eggs in burrow in termite mound.	Unlikely. No suitable habitat.
Aves					
Burhinus grallarius	Bush Stone-curlew	E		Well wooded floodplain forests, amongst fallen timber	Unlikely. No suitable habitat.

Table C.2 Likelihood of Occurrence and Habitat Requirements of Threatened Fauna

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence
Callocephalon fimbriatum	Gang-gang Cockatoo	V		Wetter forests, and woodlands, from sea level to 2000m on divide. From timbered foothills and valleys to suburban gardens.	Unlikely. No suitable habitat.
Calyptorhynchus lathami	Glossy Black-Cockatoo	V		Eucalypt forests and woodlands and forage in Allocasuarina. Nest in tree hollows	Unlikely. No suitable habitat.
Circus assimilis	Spotted Harrier	V		The Spotted Harrier occurs in grassy open woodland including acacia and mallee remnants, inland riparian woodland, grassland and shrub steppe (e.g. chenopods). It is found mostly commonly in native grassland, but also occurs in agricultural land, foraging over open habitats including edges of inland wetlands.	Unlikely. No suitable habitat.
Climacteris picumnus victoriae	Brown Treecreeper (eastern subspecies)	V		Drier forests, woodlands, scrub with fallen branches	Unlikely. No suitable habitat.
Daphoenositta chrysoptera	Varied Sitella	V		The Varied Sittella is sedentary and inhabits most of mainland Australia. Inhabits eucalypt forests and woodlands, especially those containing rough-barked species and mature smooth-barked gums with dead branches, mallee and Acacia woodland.	Unlikely. No suitable habitat.
Ephippiorhynchus asiaticus	Black-necked Stork	E		Associated with tropical and warm temperate terrestrial wetlands, estuarine and littoral	Unlikely. No suitable habitat.

Table C.2 Likelihood of Occurrence and Habitat Requirements of Threatened Fauna

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence
				habitats, and occasionally woodlands and grasslands, floodplains. Forages in fresh or saline waters up to 0.5m deep, mainly in open fresh waters, extensive sheets of shallow water over grasslands or sedgeland, mangroves, mudflats, shallow swamps with short emergent vegetation and permanent billabongs and pools on floodplains.	
Gallinago hardwickii	Latham's Snipe, Japanese Snipe		M	Soft wet ground or shallow water with tussocks and other green and dead growth. Wet drainage areas	Unlikely. No suitable habitat.
Glossopsitta pusilla	Little Lorikeet	V		Mostly occur in dry, open eucalypt forests and woodlands. They have been recorded from both old-growth and logged forests in the eastern part of their range, and in remnant woodland patches and roadside vegetation on the western slopes.	Small number recorded during surveys. Suitable foraging habitat within dominant canopy trees during flowering season.
Hieraaetus morphnoides	Little Eagle	V		The Little Eagle occupies habitats rich in prey within open eucalypt forest, woodland or open woodland. Sheoak or acacia woodlands and riparian woodlands of interior NSW are also used. For nest sites it requires a tall living tree within a remnant patch, where pairs build a	Unlikely. No suitable habitat.

Table C.2 Likelihood of Occurrence and Habitat Requirements of Threatened Fauna

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence
				large stick nest in winter and lay in early spring. Young fledge in early summer. It eats birds, reptiles and mammals, occasionally adding large insects and carrion	
Lathamus discolor	Swift Parrot	E	E	Forests, woodlands, plantations, banksias, street trees and gardens on the mainland	Potential. Suitable foraging habitat within dominant canopy trees during flowering season.
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V		Drier eucalypt forests, woodlands, timber on water courses, often no understorey, scrubs. Favours ironbark woodlands on western slopes.	Potential. Suitable foraging habitat within dominant canopy trees during flowering season
Ninox strenua	Powerful Owl	V		Pairs occupy large, probably permanent home ranges in forests to woodlands. Nest in large hollow	Unlikely. No suitable habitat.
Petroica boodang	Scarlet Robin	V		The Scarlet Robin breeds in drier eucalypt forests and temperate woodlands, often on ridges and slopes, within an open understorey of shrubs and grasses and sometimes in open areas. Abundant logs and coarse woody debris are important structural components of its habitat. In autumn and winter it migrates to more open habitats such as grassy open woodland or paddocks with scattered trees. It	Unlikely. No suitable habitat in such heavily urbanised areas.

Table C.2 Likelihood of Occurrence and Habitat Requirements of Threatened Fauna

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence
				forages from low perches, feeding on invertebrates taken from the ground, tree trunks, logs and other coarse woody debris.	
Rostratula australis	Australian Painted Snipe	E	E, M	Prefers fringes of swamps, dams and nearby marshy areas where there is a cover of grasses, lignum, low scrub or open timber. Nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds (ibid.). Breeding is often in response to local conditions; generally occurs from September to December. Roosts during the day in dense vegetation. Forages nocturnally on mud-flats and in shallow water. Feeds on worms, molluscs, insects and some plant-matter	Unlikely. No suitable habitat.
Xanthomyza phrygia	Regent Honeyeater	CE	E, M	Dry open forests, woodlands, especially red ironbark, yellow box, yellow gum	Potential. Suitable foraging habitat within dominant canopy trees during flowering season.
Mammals					
Cercartetus nanus	Eastern Pygmy-possum	V		Inhabits eastern forests and woodlands and feeds mostly on the pollen and nectar from banksias, eucalypts and understorey plants and will also eat insects, seeds and fruit	Unlikely. No suitable habitat.

Table C.2 Likelihood of Occurrence and Habitat Requirements of Threatened Fauna

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence
Chalinolobus dwyeri	Large-eared Pied Bat,	V	V	Roosts in caves, mines. Uncommon but observed in wet and dry eucalypt forests	Unlikely. No suitable habitat.
Dasyurus maculatus	Spotted-tailed Quoll	V	E	Occurs in wide variety of habitats in large remnants. Dens in tree hollows, hollow logs or rock crevices	Unlikely. No suitable habitat.
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V		Usually roosts in tree hollows in the higher rainfall forests within its range.	Possible. Suitable forage habitat throughout the study area.
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V		Forages above the canopy and eats mostly moths. Roosts in caves, old mines, road culverts	Possible. Suitable forage habitat throughout the study area.
Mormopterus norfolkensis	Eastern Freetail-bat	V		Inhabits dry and wet sclerophyll forests, coastal woodland. Roosts in tree hollows and buildings. Have been found roosting under the bark of trees.	Possible. Suitable forage habitat throughout the study area.
Myotis macropus	Southern Myotis	V		Known from a range of habitats close to water from lakes, small creeks to large lakes and mangrove lined estuaries	Possible. Suitable forage habitat throughout the study area.
Petaurus australis	Yellow-bellied Glider	V		Patchily distributed in wet sclerophyll forest.	Unlikely. No suitable habitat.
Petaurus norfolcensis	Squirrel Glider	V		Associated with dry hardwood forest and woodlands. Habitats typically include gum	Unlikely. No suitable habitat.

Table C.2 Likelihood of Occurrence and Habitat Requirements of Threatened Fauna

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence
				barked and high nectar producing species, including winter flower species. The presence of hollow bearing eucalypts is a critical habitat value	
Petrogale penicillata	Brush-tailed Rock-wallaby	E	V	Rocky areas of sclerophyll forest of inland and subcoastal southeastern Australia. Rocky areas in a variety of habitats, typically north facing sites with numerous ledges, caves and crevices	Unlikely. No suitable habitat.
Phascolarctos cinereus	Koala	V		Widespread in sclerophyll forest and woodlands. Requires relatively large home ranges.	Unlikely. No suitable habitat.
Potorous tridactylus tridactylus	Long-nosed Potoroo		V	Known from coastal heathy woodland but also occurs in rainforest, wet sclerophyll and coastal wallum. Dense cover for shelter adjacent to open areas for foraging	Unlikely. No suitable habitat.
Pseudomys novaehollandiae	New Holland Mouse		V	This species inhabits open heathlands, open woodland with a heathy understorey and vegetated sand dunes. It is commonly found in areas that are frequently burnt.	Unlikely. No suitable habitat.
Pteropus poliocephalus	Grey-headed Flying-fox	V	V	Roosts in large camps and disperses nightly up to 20km to feed in flowering eucalypts	Likely. Suitable foraging habitat within canopy trees across the subject site.

Table C.2 Likelihood of Occurrence and Habitat Requirements of Threatened Fauna

Scientific Name	Common Name	Status TSC Act	EPBC Act	Habitat	Likelihood of occurrence
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V		Occur in all habitats, from wet and dry sclerophyll forest, open woodland. Insectivorous and forage above the tree canopy. The species roosts in tree hollows and tend to be solitary for most of the year.	Possible. Suitable forage habitat throughout the study area.
Scoteanax rueppellii	Greater Broad-nosed Bat	V		Usually in tall wet forest, extending into drier forest along gullies. Forages along forest edges. Roosts in tree hollows	Possible. Suitable forage habitat throughout the study area.

APPENDIX 4

Mott MacDonald

Claymore Estate Renewal

Water Cycle Report

Contents

1. Introduction 3
1.1. Scope of Work 3

2. The Physical Environment 4
2.1. The Site 4
2.2. Data 7

3. Design Controls 9
3.1. Australian Rainfall and Runoff – Volume 1 (2001) 9
3.2. NSW Floodplain Development Manual (April 2005) 9
3.3. NSW Department of Environment and Climate Change 10
3.4. WSROC Salinity Code of Practice 12
3.5. BASIX 12
3.6. LANDCOM: Water Sensitive Urban Design Policy, DRAFT 13
3.7. Campbelltown (Sustainable City) DCP 2009 14
3.8. Campbelltown City Council Engineering Design Guide for Development (2009) 14

4. Water Management Options 15
4.1. Water Quantity Management 15
4.2. Water Quality Management 15

5. Water Quantity Modelling 17
5.1. Model Parameters 17
5.2. Management Strategies 25
5.3. Results 30

6. Hydraulics 38
6.1. The Model 38
6.2. Model Formulation 38
6.3. Results 43
6.4. Discussion 45
6.4. PMP/PMF Event Discussion 48

7. Water Quality Modelling 49
7.1. Model Parameters 49
7.2. MUSIC Methodology 49
7.3. Management Strategies 52
7.4. Results 56

Conclusions 59
7.5. Water Quantity 59
7.6. Water Quality 59

8. References 60

Appendix A: Drawings 61

Appendix B: *RAFTS* Model Data 62

Appendix C: Peak Flows from *RAFTS* 63

Appendix D: *HEC-RAS* Results 64

Appendix E: Salinity Maps 65

Appendix F: BASIX Output and Figure 66

Issue Revision and Record

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1. Introduction

1.1. Scope of Work

The Claymore Estate Renewal Project (CERP) proposes to rejuvenate the existing NSW Department of Housing (DOH) Claymore Housing Estate by creating a new integrated community. The project will provide approximately 1,490 dwellings to both new and existing residents, providing a safer and more aesthetically pleasing environment for the community. The redevelopment also creates an opportunity to assess and improve the water cycle management structures of the existing brownfield site.

This report details the procedures used and results obtained from analyses undertaken in developing the water cycle management to support the master planning Development Application (DA) for the CERP.

The purpose of the investigation is to:

- undertake a hydrologic, hydraulic and water quality assessment of the stormwater discharged from the site to demonstrate compliance with statutory requirements;
- identify appropriate measures to achieve the water quality and quantity statutory requirements and determine their location and land area required to implement the recommendations; and
- identify existing localised flood 'hot spots' and provide recommendations to rectify the situation.

The following analyses have taken into consideration the economical, engineering, environmental and social aspects of the works. Particular emphasis has been placed on protecting the environment and enhancing the biodiversity of the receiving water bodies and environment by implementing water sensitive urban design and best management practices.

2. The Physical Environment

2.1. The Site

The Claymore Estate area, which was built during the period 1979-1981, is a 125 hectare public housing estate located in the Campbelltown LGA, approximately 2km northwest of the Campbelltown CBD. The estate adjoins Eagle Vale to the north and west, the Hume Highway to the east, and Badgally Road to the south. The development area consists of approximately 1,100 cottages and townhouses that are part of a typical Radburn style subdivision layout.

The subject site is bisected by an overland flowpath which starts at a headwall from Drysdale Street and meanders west-east through the northern part of the development area. The flowpath then turns to the north-east before exiting the site and eventually connecting flows from Eaglevale and discharging beneath the Hume Highway via a large piped headwall (4 x 1800dia pipes). The flowpath grades at approximately 1% and includes a series of grassed detention basins which range in size from 6,000-16,000m^3. For the purpose of this report, we shall refer to this overland flowpath as the channel/ basin system. The following comments are also provided:

- A low flow piped system exists within the channel/ basin system. This piped system is typically 600dia but does increase to a 900dia at the north-east corner.
- Existing detention basins appear to have been previously designed and constructed to include staged storage. Here, piped outlets at embankment weirs typically increase to 1650dia to allow surcharge at downstream positions (refer section 5 and 6 for discussion).
- There are a series of existing stormwater piped outlets and flowpaths which convey surface flows from surrounding residential areas to the existing basins.

Throughout the estate there are also a number of parks and reserves; these areas together with the extensive watercourse provide approximately 29Ha of open space (Refer to Appendix A for the existing estate layout).

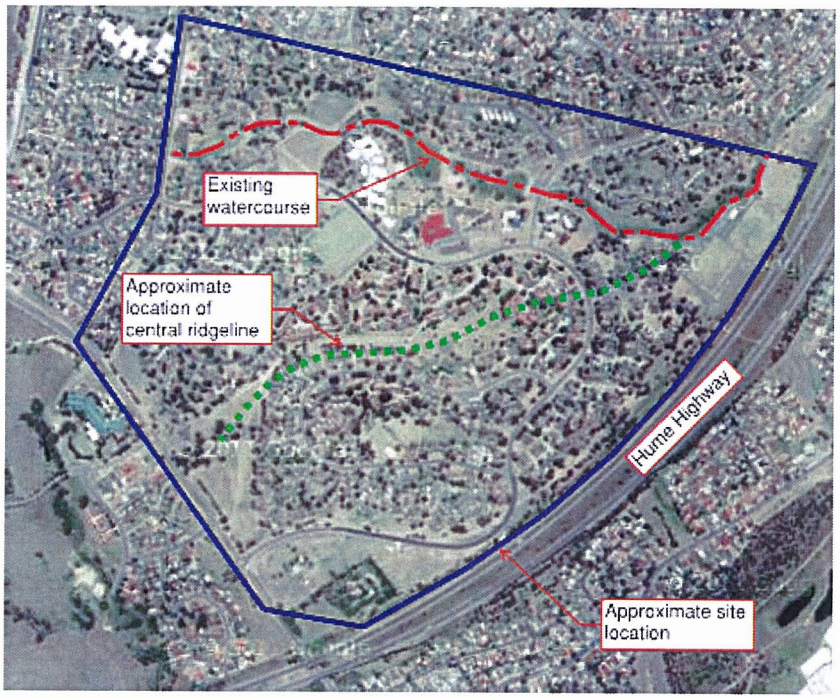

Figure 2.1 – Existing Site Layout

The overall development area can be split into 5 sub-catchments namely, (A) Western; (B) Central; (C) Eastern; (D) Northern and (E) Existing Woodbine. Each of these sub-catchments is defined by existing crests and the above mentioned flowpath. Natural crests will be maintained as much as possible during proposed development in order to utilise existing basins and avoid significant earthworks (refer figures W02 and W04).

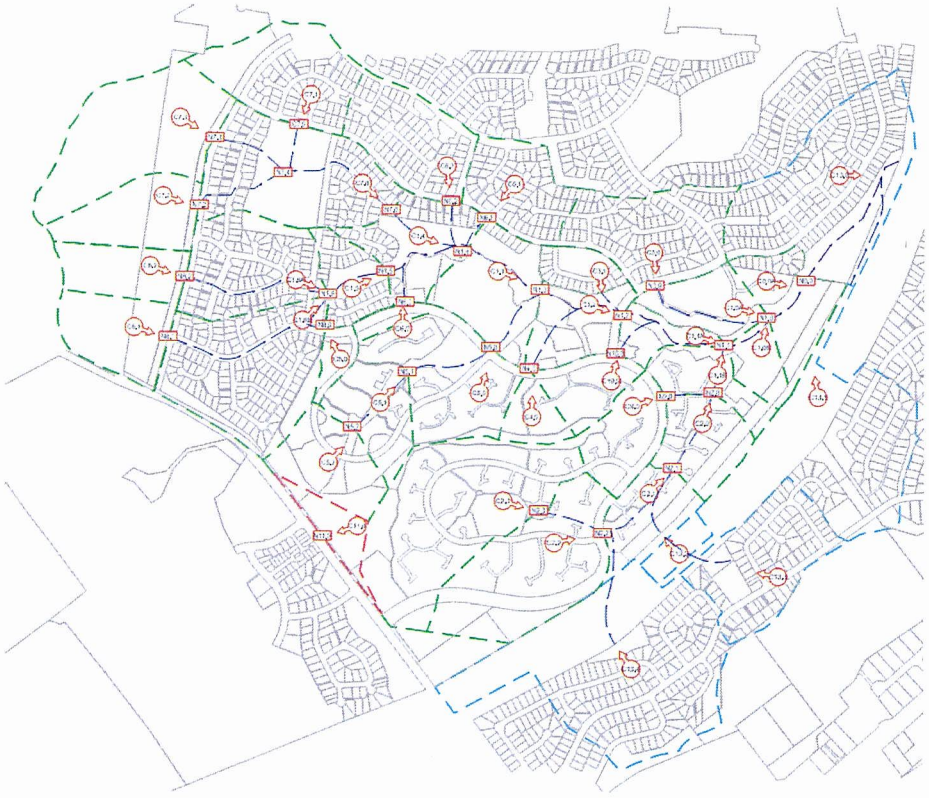

Figure 2.2 – Existing Catchment Plan

Northern Catchment – The natural crest to the north of the channel/ basin system runs generally along Emerald Drive, Alabaster Place and Tourmaline Street with catchment areas being residential. Most of these catchment areas remain unchanged from existing (external to development area) with piped discharges to basins being maintained.

Western Catchment – The western portion of the overall catchment area is a combination of existing open grassed areas, residential and schools (2). The majority of the catchment remains unchanged from the existing (external to development area).

Existing flowpaths and piped systems convey surface flows towards the channel/ basin system. The two primary connection points include:

(a) Through existing school and enter system at node N7.0 via an easement at corner of Crozier St; and
(b) At sag in Drysdale St via two existing 1800dia and 1350dia pipes (which appear to be the trunk stormwater lines for the upstream catchment), while an additional 600dia pipe allows flows to enter from the northern approach of Crozier Street.

Central Catchment – The existing central sub-catchment is brownfield and will be redeveloped as part of the proposed works. The sub-catchment is divided by 2 existing ridgelines and drains via numerous piped and overland flowpaths to the channel/ basin system (900dia, 1200dai etc.). The catchment is typically at 3-6%. The proposed development will include earthworks and regrading to redesign these flowpaths via new road network and connect to channel/ basin system through the water quality treatment train.

Eastern Catchment – The exiting eastern sub-catchment typically grades to the channel/ basin system via a trunk pipe and overland flowpath (N2.3-N2.1). This system includes 1450dia into 2 x 1650dia before discharging to channel/ basin system via 4 x 1800dia at a large outlet structure.

Woodbine Catchment – The existing sub-catchment of Woodbine drains from east to west towards the Hume Highway embankment were a series of 1050mm and 1200mm carry stormwater across the Hume Highway to the Claymore development. These piped systems discharge via headwalls onto the Claymore Development where defined swales and channels direct flow to the internal Claymore piped network. Future adjustments to the layout in these areas will need to consider accepting these offsite flows. Overland flows across the Hume Highway from Woodbine are not expected for storms up to the 100yr ARI due to the presence of large embankments and retaining walls restricting the likelihood of overland flows.

2.2. Data

2.2.1. Topography and Geology

Existing geological maps outline the CERP area to consist of Blacktown soils over weathered Ashfield shale of Triassic age, with isolated pockets of Hawkesbury Sandstone within the creek valleys. Typical characteristics of the soils include low fertility, tendency towards strongly acidic properties and prone to shrinkage and swelling.

Additional on-site geotechnical investigations are being undertaken by others to confirm the site-specific geology.

Topographic information for the catchments was obtained from detailed survey data provided by Vince Morgan Surveyors.

2.2.2. Proposed Layout

The proposed road (including cross sections), lot and open spaces layout have been taken from the current proposed master plan documentation.

2.2.3. Rainfall Data

2.2.2.1. Rainfall Records

The water quality analysis requires historical rainfall data recorded, by a pluviograph station. The Lucas Heights pluviograph recording station has been used and is situated approximately 15km from the development site. Historical rainfall records for the area were obtained from the Bureau of Meteorology from the following station:

Station No.	Location	Records	Data Interval
066078	Lucas Heights ANSTO	Aug 1984 – Aug 1993	Daily

2.2.2.2. Intensity-Frequency-Duration (IFD)

The design IFD data for the site was obtained from Bureau of Meteorology Coefficients for Campbelltown listed in Council's Engineering Design Guide for Development (2009). Probable Maximum Precipitation (PMP) was derived using the Bureau of Meteorology's Generalised Short Duration Method (2003).

A summary of the rainfall intensities derived is shown in

Table 2.1 - Claymore Rainfall Intensities (mm/hr)

Storm Duration (minutes)	Annual Recurrence Interval (years)			
	0.25 (3-month)	5	20	100
10	34.7	103	132	171
15	29.1	86.3	111	143
20	25.4	75.4	96.9	125
25	22.7	67.4	86.7	112
30	20.7	61.3	78.9	102
45	16.5	49.0	63.1	81.4
60	13.9	41.4	53.3	68.9
90	10.8	32.2	41.6	53.9
120	9.0	26.8	34.7	45.0
180	6.8	20.6	26.7	34.7
270	5.2	15.7	20.5	26.7
360	4.3	13.0	17.0	22.2
720	2.7	8.3	10.9	14.3

2.2.4. Existing Utility Services

Existing utility service locations were derived from service utility plans and site survey information for gas, electricity, sewer, stormwater, telecommunications and water.

3. Design Controls

3.1. Australian Rainfall and Runoff – Volume 1 (2001)

Prepared by the Institution of Engineers, Australia Australian Rainfall and Runoff – *A Guide to Flood Estimation* was written to "provide Australian designers with the best available information on design flood estimation". It contains procedures for estimating stormwater runoff for a range of catchments and rainfall events and design methods for urban stormwater drainage systems.

According to the document, good water management master planning should take into account:

- hydrological and hydraulic processes;
- land capabilities;
- present and future land uses;
- public attitudes and concerns;
- environmental matters;
- costs and finances; and
- legal obligations and other aspects.

3.2. NSW Floodplain Development Manual (April 2005)

The NSW Government's *Floodplain Development Manual – the Management of Flood Liable Land (2005)* is concerned with the management of the consequences of flooding as they relate to the human occupation of urban and rural developments. The manual outlines the floodplain risk management process and assigns roles and responsibilities for the various stakeholders.

The manual applies to the development, in particular in Appendix L – *Hydraulic and Hazard Categorisation* for ensuring safe overland flow paths are provided (see Figure L1 below).

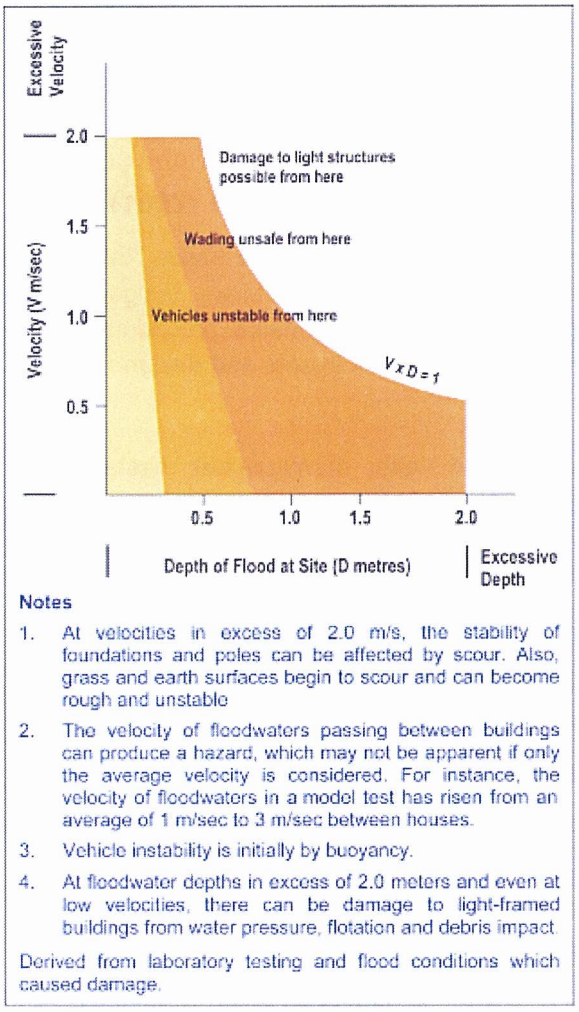

FIGURE L1 - Velocity & Depth Relationships

Figure 3.1 – Velocity Depth Relationships, FDM

Source: *NSW Floodplain Development Manual, 2004 (*Dept. of Infrastructure planning & Natural Resources*)*

3.3. NSW Department of Environment and Climate Change

The NSW Department of Environment and Climate Change (DECC), formerly the NSW Environment Protection Authority (EPA) has developed a set of guidelines known as the Managing Urban Stormwater (MUS) series. The set of guidelines includes:

- Managing Urban Stormwater: Council Handbook
- Environmental targets
- Managing Urban Stormwater: Source Control
- Managing Urban Stormwater: Soils & Construction
- Managing Urban Stormwater: Harvesting and Reuse

3.3.1. Managing urban stormwater: Environmental Targets

The NSW Department of Environment and Climate Change (DECC) encourages the principle of no net deterioration of water quality. Under its former name, the NSWEPA, the DECC published Managing Urban Stormwater: Environmental Targets, outlining recommended environmental targets for stormwater management in new urban developments. Among its recommendations are the following stormwater treatment objectives:

Table 3.1 – Stormwater Treatment Objectives for New Urban Areas from the Managing Urban Stormwater: Environmental Targets

Pollutant	Treatment Objective	Adopted Campbelltown City Council Treatment Objective
Gross Pollutant	90% retention of the annual average load for particles 0.5mm or less	95% retention of the annual average load for particles 0.5mm or less
Suspended Solids	85% retention of the annual average load	80% retention of the annual average load
Total Phosphorous	65% retention of the annual average load	45% retention of the annual average load
Total Nitrogen	45% retention of the annual average load	45% retention of the annual average load

The Campbelltown City Council Treatment objectives have been adopted for this report as they are specific for the Campbelltown City Council Area. These rates are also consistent with Australian Rainfall Quality (ARQ, 2006). Refer to section 7 for a detailed description of the analysis.

3.3.2. Managing urban stormwater: Source Control

The DECC guide, Managing Urban Stormwater: Source Control recommends the control of stormwater pollution at the source, rather than more traditional "end of line" systems that are unsightly and require high levels of ongoing maintenance. In this document, Water Sensitive Urban Design (WSUD) is described as "minimising the impacts of development on the total water cycle and maximising the multiple benefits of a stormwater system". It lists the main objectives of WSUD as:

- preservation of existing topographic and natural features;
- protection of surface water and groundwater sources;
- integration of public open space with stormwater drainage corridors, maximising public access; and
- passive recreational activities and visual amenity.

The broad principles of WSUD are listed as:

- minimising impervious area;
- minimising use of formal drainage systems (e.g. pipes);
- encouraging infiltration (where appropriate); and
- encouraging stormwater re-use.

3.3.3. Managing urban stormwater: Soils and Construction

Managing Urban Stormwater – Soils and Construction (4th edition, March 2004) are guidelines produced by the NSW Department of Housing to help mitigate the impacts of land disturbance activities on landforms and receiving waters by focusing on the removal of suspended solids in stormwater runoff from construction sites.

According to the guide, effective soil and water management during construction involves the following key principles:

- assess the soil and water implications of development at the subdivision or site planning stage (including salinity and acid sulphate soils);
- plan for erosion and sediment control concurrently with engineering design and before the land disturbance begins;
- minimise the area of soil disturbed;
- conserve topsoil for subsequent rehabilitation/revegetation;
- control surface runoff from upstream areas, as well as through the development site;
- rehabilitate disturbed lands as quickly as possible; and
- maintain soil and water management measures appropriately during, and after the construction phase until the disturbed land is fully stabilised.

3.4. WSROC Salinity Code of Practice

The Western Sydney Salinity Code of Practice was produced by the Western Sydney Regional Organisation of Councils (WSROC) to provide information on the current and best management practice for salinity management in the Western Sydney region. The document illustrates the methods used for assessing the salinity risk, recommended investigation methods and best management practices for managing salinity.

The guide lists the following key principles for salinity management:

- maintain natural water balance;
- maintain good drainage;
- avoid disturbance or exposure of sensitive soils;
- retain or increase vegetation in strategic areas; and
- implement building controls and/or engineering responses where appropriate.

3.5. BASIX

A water re-use assessment under the Building and Sustainability Index (BASIX) is outside of the scope of this report. However for water quality analysis a preliminary assessment has been undertaken to determine the approximate required rainwater tank volume per dwelling to achieve the minimum mandatory 40% efficiency rating for new dwellings (refer to section 7.3.1 for more details).

3.6. LANDCOM: Water Sensitive Urban Design Policy, DRAFT

Landcom's Water Sensitive Urban Design Policy has been prepared by Landcom to make sustainability objectives a key component of their many developments. The document provides targets and objectives for urban environments in regards to water conservation, pollution control and mitigation. The following table outlines Landcom's Target Objectives for new Greenfield developments:

Table 3.2 – LANDCOM WSUD Objectives

Objective		Baseline and Performance Target	Stretch Target
1	**WSUD Strategy**	(a) 100% of projects to have project-specific WSUD strategies.	
2	**Water Conservation**	Combination of water efficiency and reuse options – % reduction on base case.	
		(a) Single dwelling, no reticulated supply available: Baseline 40 % Performance 50+ % Stretch 65 %	
		(b) Single dwelling, reticulated supply available: Baseline 50 % Performance 65 % Stretch 75+ %	
		(c) Apartment, no reticulated supply available: Baseline 40 % Performance 50 % Stretch 60+ %	
3	**Pollution Control**	(a) 45% reduction in the mean annual load of Total Nitrogen (TN). (b) 65% reduction in the mean annual load of Total Phosphorus (TP). (c) 85% reduction in the mean annual load of Total Suspended Solids (TSS).	(a) 65% reduction in the mean annual load of Total Nitrogen (TN). (b) 85% reduction in the mean annual load of Total Phosphorus (TP). (c) 90% reduction in the mean annual load of Total Suspended Solids (TSS).
4	**Flow Management**	Maintain 1.5 year ARI peak discharge to pre-development magnitude Stream Erosion Index = 2.0	Maintain 1.5 year ARI peak discharge to pre-development magnitude Stream Erosion Index = 1.0

A combination of the above targets and mandatory guidelines from the relevant authorities has been used in this report and discussed in their relevant sections.

3.7. Campbelltown (Sustainable City) DCP 2009

An integral part of the master planning process for the CERP, the *Campbelltown (Sustainable City) DCP 2009* provides the necessary controls for the redevelopment of the site. Particular water management requirements include:

- compliance with Council's Engineering Design Guide for Development;
- compliance with the demands of the BASIX system; and
- adoption of the principles of WSUD (including a water cycle management plan).

3.8. Campbelltown City Council Engineering Design Guide for Development (2009)

Council's *Engineering Design Guide for Development*, which forms part of the larger *Campbelltown (Sustainable City) Development Control Plan (2009)*, sets out their requirements for the design of stormwater drainage for urban and rural areas. The Engineering Design Guide outlines the broad objectives of the policy of:

- retention of the natural stormwater system where possible;
- a high level of safety for all users;
- acceptable levels of amenity and protection from the impact of flooding;
- consideration given to the effect of floods greater than the design flood;
- a controlled rate of discharge to reduce downstream flooding impacts;
- protection of the environment from adverse impacts as a result of the development;
- maintenance of and enhancement of the regional water quality;
- sustainability of infrastructure; and
- economy of construction and maintenance.

The policy also provides detailed requirements for the hydrologic and hydraulic design and analyses of the proposed water management system including standard calculation factors and drawings.

4. Water Management Options

4.1. Water Quantity Management

4.1.1. Major/Minor Drainage System

The major/minor approach to street drainage is the recognised drainage concept for urban catchments within the Campbelltown City Council local government area.

"The minor system is the gutter and pipe network capable of carrying runoff from minor storms. The major system comprises the many planned and unplanned drainage routes which convey runoff from major storm to trunk drains, sometimes causing damage along the way." [1] *Australian Rainfall and Runoff, 2001*. The major system also exists to cater for minor system failures.

The overall aim of the major/minor approach is to ensure that hazardous situations do not arise on streets and footpaths, and that all buildings in urban areas are protected against floodwaters."[1]

4.1.2. Detention Basins

Detention basins temporarily detain stormwater runoff from urbanised catchments with the aim of reducing and attenuating the peak discharge at the outlet to reduce the risk of flooding to downstream lands as a result of a development. The storage volume may be above or below ground while discharges are accurately controlled via an orifice or throttled outlet pipe.

4.1.3. Rainwater Tanks

Rainwater tanks are sealed tanks designed to retain rainwater collected from roofs for subsequent re-use for toilet flushing, laundry or garden watering. Due to the uncertain nature of the rainwater supply, tanks are usually connected to mains water for "top-ups" in dry weather conditions.

4.2. Water Quality Management

4.2.1. Infiltration Devices

Consisting of a gravel bed and usually greater than 600mm depth, an infiltration device primarily removes sediments and attached pollutants (including nutrients, metals and other soluble pollutants) by filtration. They may be installed as conventional below ground trenches backfilled with filter media or beneath permeable paving and are designed to capture and treat the "first flush" volume of a rainfall event.

4.2.2. Gross Pollutant Traps

"Gross Pollutant Trap" is a term applied to either in-situ, or proprietary units that remove litter, vegetative matter and sediment. Although the numerous units fall under the under the one umbrella of gross pollutant traps, the actual mechanics of the different units vary, as do the achievable pollutant removal rates. GPTs come in a range of sizes, with the larger units able to effectively treat large catchment areas and high flow rates. They are usually sized based on

[1] Australian Rainfall and Runoff 2001

their maximum treatable flow being equal to, or greater than the 3-month Annual Recurrence Interval (ARI) storm event (typically 50% of the 1-year ARI storm event) of the upstream catchment.

Table 4.1 – Typical Pollution Removal Rates of Water Quality Treatment Devices

Device	Coarse Sediment	Fine Sediment	Free Oil & Grease	Nutrients	Metals
Infiltration Devices*	50-80%	30-50%	30-50%	30-50%	30-50%
Bio-Retention Systems*	80-100%	30-50%	30-50%	30-50%	30-50%
Vegetative Filter Strips	50-80%	10-50%	10-50%	10-50%	10-50%
Pit Inserts	80-100%	40-60%	40-60%	40-60%	40-60%
Gross Pollutant Traps	60-90%	10-50%	-	10-50%	10-50%

* Assumes pre-treatment of stormwater runoff to remove gross pollutants and to minimise ongoing maintenance.

Source: WSUD – Technical Guidelines for Western Sydney (2004)

5. Water Quantity Modelling

The assessment of water quantity was completed using both hydrological and hydraulic modelling. Here, computer based models of the existing and proposed catchments were constructed using XP-RAFTS. Design storms were applied to these models to give estimates of the 100-year ARI discharges, which are examined in the following sections. Assessment of these models then allowed the determination of basin sizes and requirements. Assessment was also undertaken on the existing basin sizes.

As an overall check, the existing 100-year ARI results from XP-RAFTS (at the outlet) were then compared with empirical estimation techniques (Rational Method) as recommended by the Australian Rainfall and Runoff (I.E Aust, 2001).

Computer based, one-dimensional, steady flow hydraulic models were then constructed to represent both the proposed and the existing networks using HEC-RAS. The 100-year ARI discharges from the hydraulic model were then input into the hydraulic model to determine the respective flood levels and extent.

The probable maximum precipitation (PMP) was estimated using the Bureau of Meteorology's Generalised Short Duration Method (2003). Using a similar process to the 100-year, probable maximum flows (PMF) were estimated in XP-RAFTS, with flood levels and extent determined in HEC-RAS.

5.1. Model Parameters

The user data inputs required by XP-RAFTS include catchment areas and slopes, pervious and impervious areas, IFD rainfall statistics and hydrological losses. Guidelines for determining these parameters are provided in the Australian Rainfall and Runoff (I.E Aust, 2001) and are broken up as follows:

5.1.1. Slopes

In accordance with AR&R (I.E Aust, 2001), the slopes of the sub-catchments were generated using "equal area" method. The slopes for each of the catchments are listed in Tables B.1 to B.6 in Appendix B.

Proposed sub-catchment slopes for links and catchments were derived from the proposed master plan layout and grading (as of April 2011), while the existing slopes were developed from aerial contours.

5.1.2. Impervious and Catchment areas

The extent of impervious area within the existing catchment was digitally measured from aerial imagery. Impervious and catchment areas for each of the sub-catchments are included in Tables B.1 to B.6 in Appendix B.

Similarly, the impervious areas within the proposed catchments were based upon the master plan density sketches supplied by Landcom.

Fraction impervious values for the proposed development were based on those values mentioned in Table 4.2 Campbelltown City Council Guidelines (CCC, 2009). Here footprint

areas were digitally measured from the master plan layout and assigned the below mentioned values. An average of 80% impervious has been assigned to residential due to the proposed variances in lot sizes across the site. (Typically range from 350m^2-700m^2).

Lot Area (Ha)	CCC DCP %IMP	IMP Area (Ha)
6.86	0.9	6.18
36.29	0.8	29.03
13.69	0.7	9.58
1.54	0.6	0.93
58.39		45.72
		78%
	Adopted Impervious	**80%**

Table 5.1 – Percentage Impervious Areas for Various Land Uses

Land Use	Adopted % Impervious
Roads and Industrial Areas	75%
Commercial/ Industrial	100%
Residential Housing	80%
Parks/Grass Land	10%

Source: Derived from UPRCT estimates and CCC, 2009

5.1.3. Intensity-Frequency-Duration (IFD)

Rainfall intensities were used as described in Section 2.2.3

5.1.4. Rainfall Losses

The loss model adopted to estimate rainfall excess in the development of design flow hydrographs was the Initial Loss-Continuing Loss model.

As specified in Council's Engineering Design Guide for Development (CCC, 2009), the following initial – continual loss parameters were utilised within the model:

- an Initial Loss of 15mm and a Continuing Loss of 2.5mm/hr for pervious areas; and
- an Initial Loss of 1.5mm and Continuing Loss of 0mm/hr for impervious areas.

5.1.5. Land Use

The land use within the existing catchments is considered to be predominantly urban. This type of land use does have some effect on the runoff by providing some "resistance" to the flow. The effect is simulated in XP-RAFTS by a storage delay coefficient called "PERN". The following typical values are in accordance with Council requirements:

Table 5.2 – Adopted PERN 'n' values

Catchment Type	PERN 'n'
Developed (Impervious Portion)	0.015
Developed (Pervious Portion)	0.025 – 0.03

Source: Engineering Design Guide for Development (2009)

5.1.6. Hydraulic Roughness Parameters

Hydraulic roughness parameters for the overland flow paths were estimated based upon site visits and were applied in accordance with those recommended in AR&R. A Manning's roughness parameter of 0.035 was applied for all grassed areas (including verges) while 0.013 was applied for all road pavements. These also satisfy parameters set out in the Council guidelines.

5.1.7. B-Multiplier

The b-multiplier (b) used in RAFTS is usually determined by calibration against recorded floods. As discussed in Section 5.1.8, the value for b is then used in the standard equation S=bQn. Council Guidelines (Engineering Design Guide for Development) specify a b-multiplier of 1.0. This value was subsequently used in this study.

5.1.8. *RAFTS* Catchments

Hydrologic modelling was carried out using the XP-RAFTS software package (XP Software, 2009). RAFTS is a non-linear runoff routing model that generates runoff hydrographs from rainfall.

A catchment is divided into a network of sub-catchments joined by links. The links represent natural watercourses, artificial channels, or pipes. The model divides each sub-catchment into 10 sub-areas. A sub-area is treated as a cascading non-linear storage governed by the relationship S=bQn. The coefficient 'b' is calculated from catchment parameters but can be calibrated to fit observed rainfall and streamflow data.

Rainfall is applied to each sub-area. Losses (representing infiltration, interception, etc) are subtracted from the rainfall and the excess is then converted into an instantaneous flow. This instantaneous flow is then routed through the sub-area storages to develop local sub-catchment hydrographs. Total flow hydrographs at various nodes in the drainage network are calculated by combining local hydrographs. Hydrographs are transported through the drainage network by time lagging or channel routing. Hydrographs may also be routed through the storage basins such as dams or detention basins.

5.1.9. Existing Catchment

As discussed in section 2.1, the existing overall catchment, was defined from aerial contours and is divided into four (5) sub-catchments namely (A) Western; (B) Central; (C) Eastern; (D) Northern and (E) Woodbine.

The proposed development site is 125 hectares, but also has contributing upstream areas, which give a total catchment size of approximately 301 hectares.

As described in Section 2.1, the pre-developed site has a constructed channel/ basin system which travels from west to east and conveys runoff from each of the 4 sub-catchments towards north-east before discharging under the Hume Highway. This watercourse consists of a series of detention basins which have been previously designed and constructed by others and will remain in the post-development scenario. Modelling in Section 5.1.10 & 5.3 will determine whether additional detention volumes and/ or control measures are required to ensure the overall discharge from the post development scenario does not exceed the overall site discharges in the existing scenario.

Each of the 5 catchments have further been divided into 39 sub catchments. These sub catchments ranged in size from 0.93 to 24.50 hectares (Refer to Tables B.1 to B.6 in Appendix B). Each of these sub-catchments naturally adjoin the system at various points and eventually discharge via a large headwall (4 x 1800dia) beneath the Hume Highway.

Figure W02 in Appendix A shows the existing catchment divisions, while Figure B.1 in Appendix B represents the existing networks within RAFTS. The division of catchments was based upon the overland flow paths and existing road and drainage networks. Overland flow paths generally match those specified by council. Some consideration of the proposed catchments was taken into account when developing the node network.

An existing detention basin exists within the Eaglevale High School sports fields, upstream of the Claymore site. This 6550m^3 basin has been included within the modelling. Details of the existing basin were provided by Campbelltown City Council.

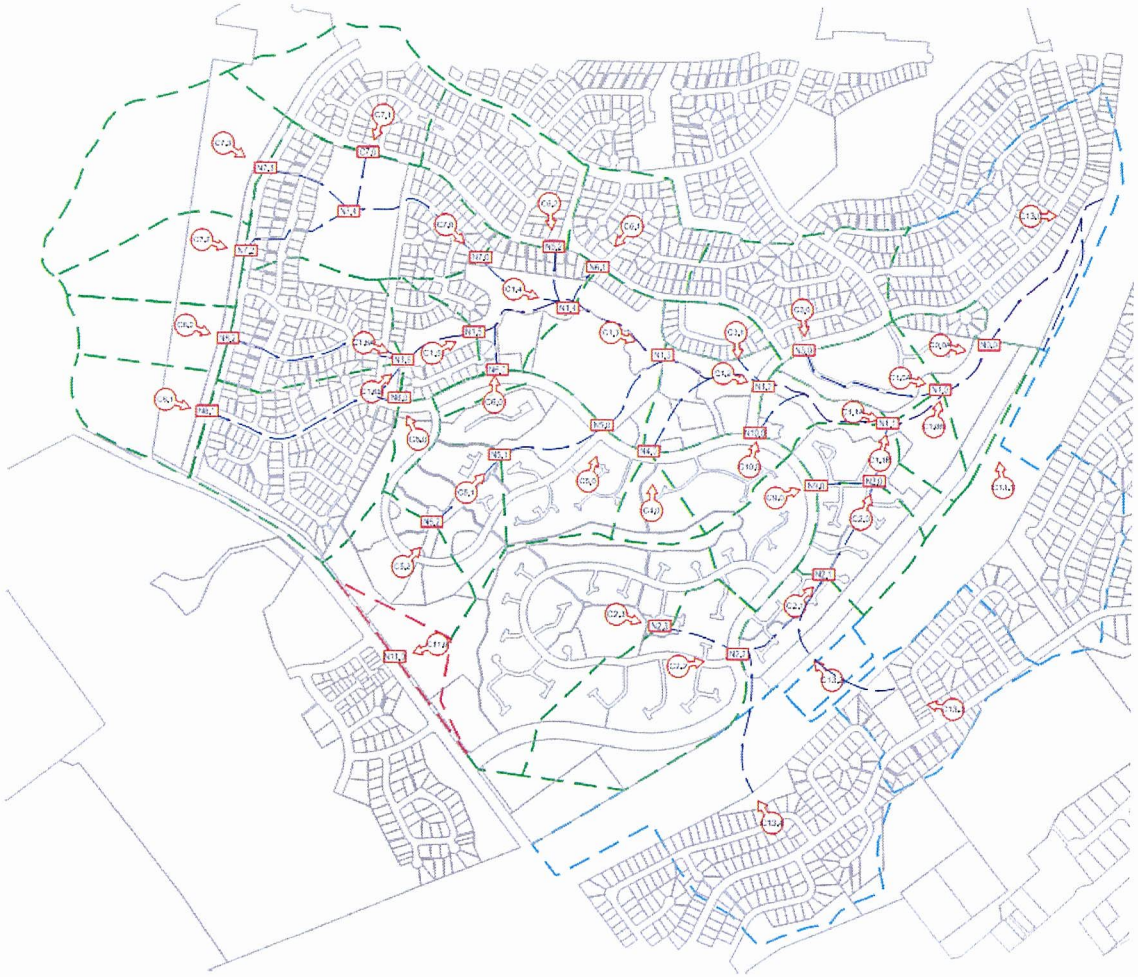

Figure 5.1 – Existing Catchment Plan

Site investigations have confirmed that the existing site has a combination of minor and major stormwater infrastructure in place to assist in conveyance of surface flows to their respective outlets.

The pre-developed RAFTS model was subsequently formulated by incorporating the following:

- "Catchment Nodes" were used to represent each of the 32 sub-catchments. Here, each node is representative of the catchment and is divided into both pervious and impervious values (refer Table in Appendix B);
- "Dummy Nodes" were used where two or more existing sub catchments joined, which allowed both inflow and outflow hydrographs to be assessed. Diversion links (with no lag time) were used to combine these inflow hydrographs; and
- Most of the links between nodes were modelled as channel routing links and are representative of the existing road profiles and low flow pipes. Sections were input from 12d as "HEC-2" and Manning's 'n' values were estimated from site visits.

The following comments are also provided:

- The performance of existing detention basins was assessed within RAFTS. This included modelling of (a) the low level piped outlets; (b) high level overflow weirs; and (c) storage volumes.
- There is an existing flowpath from N2.3 to N1.1 which conveys peak flows from the eastern catchment towards the primary channel / basin system. This flowpath travels along both existing roadways and via a formalised reserve amongst houses (central concrete path, trunk piped system, grassed overbanks to rear of properties). The trunk piped system includes a 1050dia pipe at the top of the catchment, which then becomes 2x 1650dia before discharging to the channel / basin system via a large concrete headwall structure and 4x 1800 dia.

  Piped flows from Woodbine enter the site along the Claymore/Hume Highway boundary these flows are picked up via the internal Claymore trunk drainage system from N2.3 to N1.1.

Figure 5.2 – Existing 4 x 1800dia Culverts

- It is noted that localised ponding occurs directly in front of this outlet structure in the existing scenario for up to 100m. Evidence was found on site that there is a large amount of sedimentation within the existing pipes. Section 6.0 will discuss further for proposed regrading of the area.
- There is an existing sag within Drysdale St (Node N1.6) which collects all upstream catchments prior to discharge to the channel / basin system. A series of trunk pipes (1800dia, 600dia and 1350dia) convey flows from this sag to the basin. It is noted that there are no less than 5 large kerb inlet pits at the sag point in the road. Those flows which are not conveyed via piped system then travel overland between the houses.

  For the purposes of modelling the overland flow through these houses, a 50% blockage factor has been assumed on the piped system. The subsequent flowrate which is used in Section 6.0 is 3.6m^3/s as shown in Table 5.6.
- There is a small catchment area adjacent to Badgally Rd which bypasses the channel / basin system and drains to the South. This has been included in the overall site discharge via a bypass node N11.0.
- Campbelltown City Council requested that the northern catchment be extended to include parts of Eaglevale, downstream of the site, to assess the impacts of the

proposed development at the Hume Highway inlet. This assessment has also considered any time to peak issues that may arise over this reach. Analysis of the time to peak has been undertaken and discussed in section 5.3.4

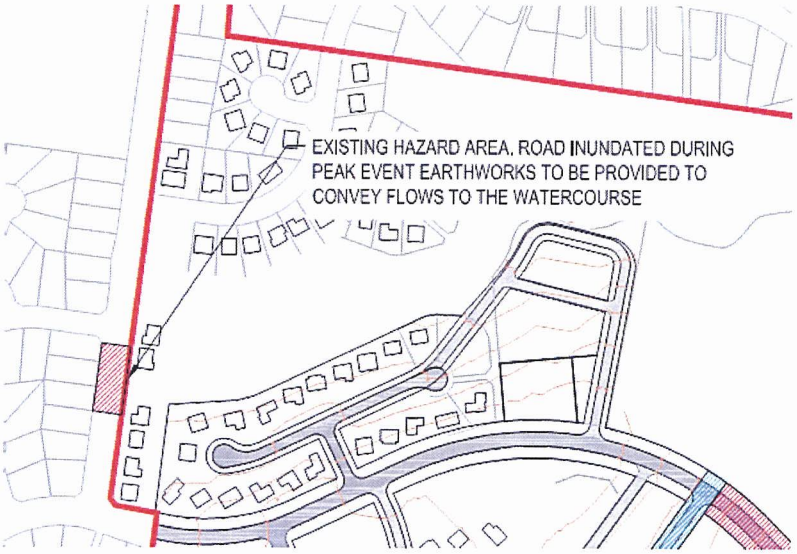

Figure 5.3 – Existing Drysdale Rd Hazard Area

5.1.10. Proposed Catchment

Catchment division in the proposed scenario is similar to existing with 5 primary sub-catchments.

In developing the post-developed RAFTS models, the overall catchment was also further divided into 42 sub-catchments. These sub-catchments ranged in size from 0.93 to 24.5 hectares. Each sub-catchment was determined from the proposed master plan road layout and site grading, while consideration was given to retaining existing significant infrastructure wherever possible.

Figure W04 in Appendix A shows the sub-catchment division while Figure B.2 in Appendix B illustrates the proposed RAFTS network.

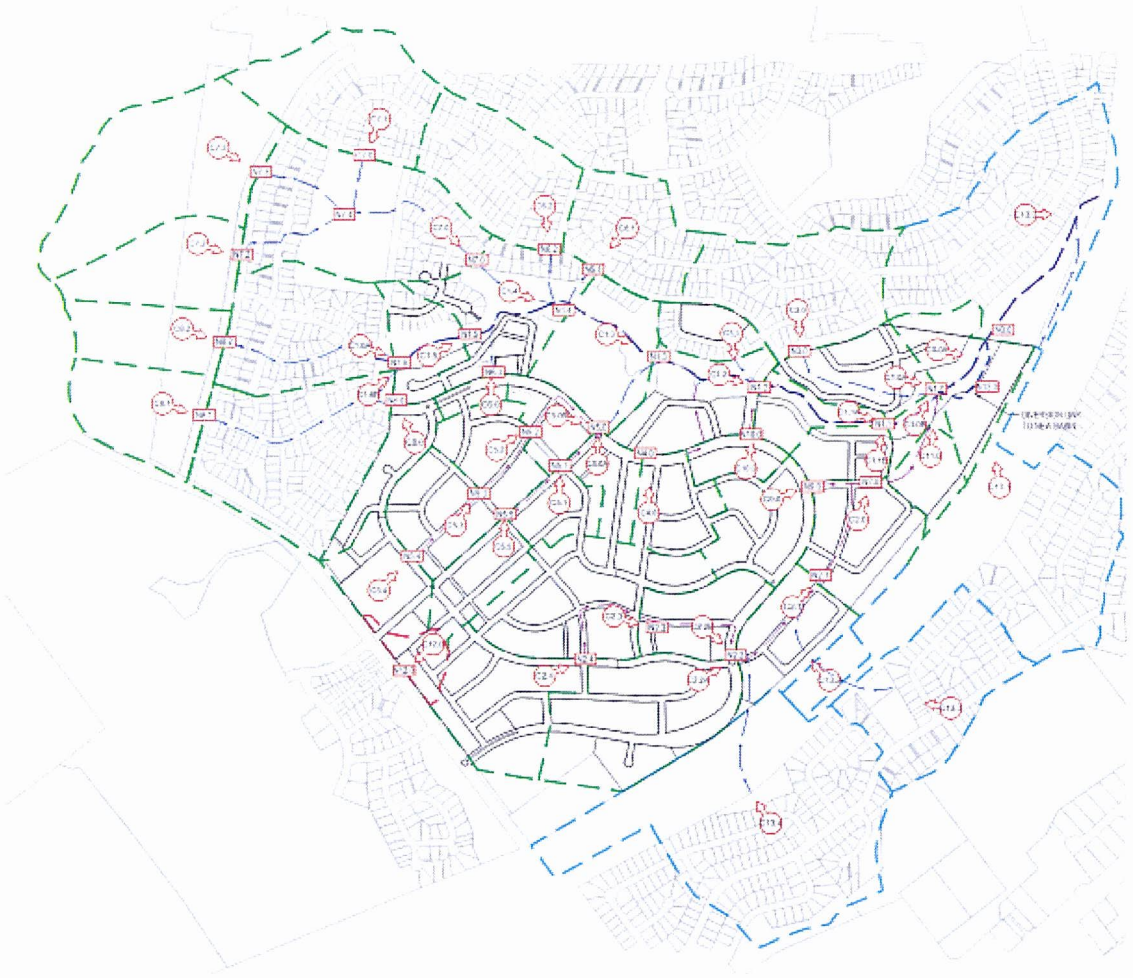

Figure 5.4 – Proposed Catchment Plan

As this project is primarily a brownfield development and includes upstream catchments which remain unchanged, some catchment areas have remained consistent with existing. This includes some road lines, impervious percentage, general catchment divisions, stormwater infrastructure and the like remaining. While redeveloped areas typically include modified flowpaths and increased housing density.

Most of the links were modelled as channel routing links and are representative of the road sections in the proposed master plan. Where considered practical, existing low flow pipes were maintained in the channel routing links while new pipes were also estimated / included along new roads where required.

Catchment areas, slopes and percentage impervious portions are tabulated in Appendix B.

The following comments are also provided:

- Catchment areas draining to existing Basins at Node N1.5 and N1.4 are typically unchanged from existing. Basin outlet configurations have consequently been maintained as per existing.
- Catchments directed towards the existing basins at N1.2 and N1.3 have typically been changed with increased impervious areas, piped systems and the like.

- An existing detention basin exists within the Eaglevale High School sports fields, upstream of the Claymore site. This 6550m^3 basin has been included within the modelling. Details of the existing basin were provided by Campbelltown City Council.
- The proposed basin configuration which has been included in the modelling includes an additional detention basin at the modified soccer field to the N-E (Node N13). This shall provide the additional storage volume which is required to satisfy statutory requirements. Refer Section 5.2 for discussion.
- The proposed basin has been modelled using a "diversion link" in order to allow a portion of flows into the basin. A staged storage outlet is then provided to allow flows to re-enter the channel system.

5.2. Management Strategies

5.2.1. Major/Minor System

The proposed drainage system will be major/minor system. The (minor) piped drainage system is to be designed to control nuisance flooding and enable effective stormwater management for the site. Council's standard requires that the minor system be designed for a minimum 5 year ARI.

The major drainage system incorporates overland flow routes through proposed roads and has been assessed against the 100 year ARI design storm event, with general safety and flooding issues being addressed for events in excess of the 100 year ARI storm. If the major system cannot meet the safety and flooding criteria, the capacity of the minor system will need to be increased.

Inlet and culvert blockages were considered in the modelling with a 50% blockage factor across all culverts being applied in order to assess overland flow paths.

In order to assess the adequacy and safety of the major drainage system, channel routing links were used in RAFTS to model flow paths along roads and pathways, while lagging links were used elsewhere. Although negligible attenuation is expected along the roadways, channel routing was used in order to assess flow depths and velocities in major storm events. The channel cross-sections were based on the proposed road cross-sections in the master plan. Low flow pipes in channel links were based off 5year ARI and were assumed to operate at 100% during assessment. The proposed pipe drainage system may be designed with greater capacity than this if required. The capacity of the existing drainage system needs to be assessed at the detailed design stage.

5.2.2. Detention Basins

Detention Basins were included in the hydrologic model to ensure that there is no increase to peak flows exiting the overall development, which could potentially have adverse impacts on downstream properties.

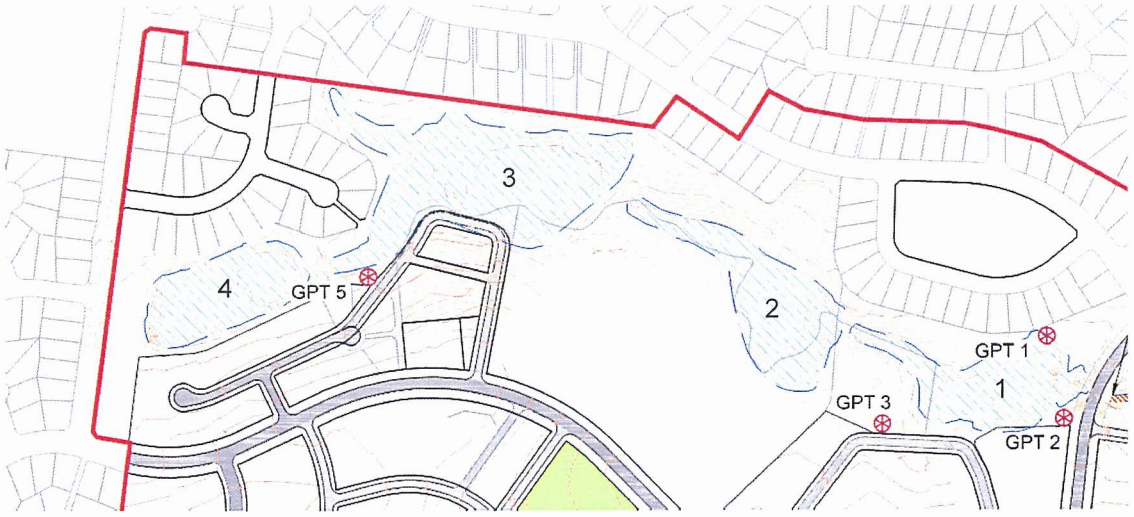

Figure 5.5 – Existing Detention Basins

Four (4) existing online detention basins were modelled along the length of channel using detailed survey information. Following an assessment of peak flowrates, an additional "offline" detention basin is proposed at Node N13.0 (at the existing modified soccer field) in order to decrease the peak flowrates generated from the proposed development. The basins were modelled with A standard Rafts piped discharge relationship is used (using the Std. RAFTS Culvert Method) in the analysis in conjunction with a staged discharge relationship for the overflow weir. The stage discharge relationship for the overflow weir has been calculated using a modified weir equation to best match the shape of the existing weir. The standard rafts calculation involves the use of a simple weir equation which will give inaccurate results as it does not allow for variations in the width or height of the weir.

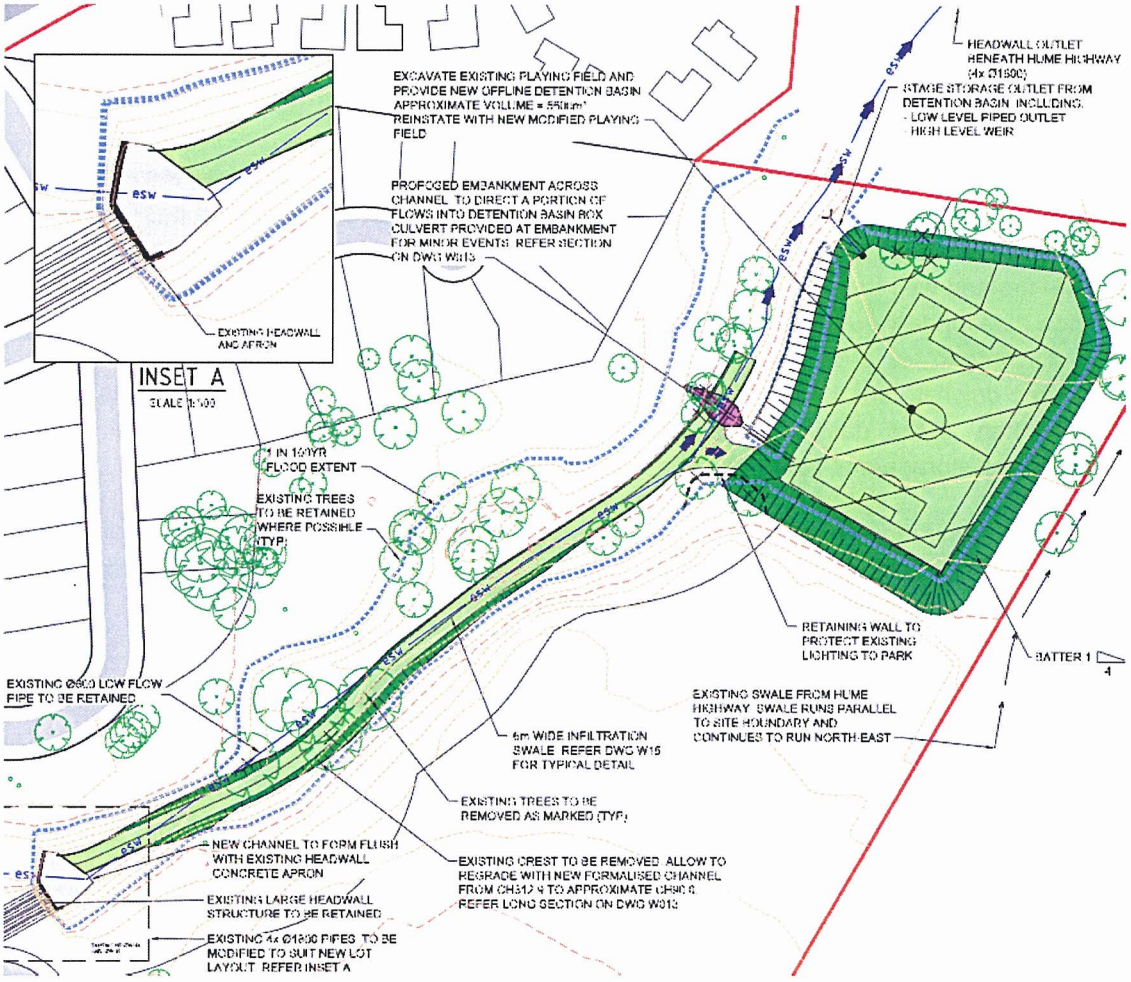

Figure 5.6 – Proposed Outlet Basin

The configuration of both the proposed control structure and basin storage is detailed on drawings W06 and W015 and includes the following:

- Basin storage;
  - Earthworks undertaken to lower the existing modified playing to approximate RL54.20 with minimum fall to outlet. Approximate volume of 5,300m^3 of storage has been provided to restrict post developed flow to existing.
  - Minor Flows Outlet: Low flow pipe outlet (Box Culvert) 2 x 2.1m x 0.6m
  - Major Flows Outlet: Combined low flow pipe and high level control weir (Normal RAFTS Weir)
  - Maximum 1.2m depth of flood storage in accordance with recommendations by AR&R (I.E Aust, 2001)

- Control weir / embankment installed within the existing channel, including:
  - Embankment formed to RL55.4 to ensure tailwater conditions are no longer imposed on the upstream 4x1800dia outlet structure at node N1.1;
  - Box culvert opening to be provided within the embankment in order to allow low flows to freely continue along channel system but restrict major flows.

- Side entry weir (0.3m below embankment – RL55.10) to allow a portion of those flows which are above the 5 year minor event to enter the basin for controlled discharge.

All basins were modelled with a stage-storage relationship extracted from aerial surveys and use the default discharge equations within RAFTS. The design of the proposed basin initially incorporated the sizing of the piped outlet to satisfy the 5 year permissible discharge rate. A high level crested weir was then introduced within the basin at the 20 year ARI top water level to provide a secondary outlet and mirror the existing regime. The peak design flow (100yr ARI) is then discharged via a combination of the piped and weir outlets and conveyed along the watercourse downstream. It should be noted that more detailed modelling of the basins shall be undertaken at the design stage when sufficient details are available to derive more accurate stage-storage and stage-discharge relationships.

The volumes required were refined by manual iteration until results showed that the total flows generated from the post-developed scenario did not exceed those in the pre-developed. The proposed basins and their volumes are shown in Table 5.3.

Table 5.3 – Modelled Detention Basins

Location (Catchment)	*RAFTS* Node	Volume (m^3)
Existing Basin 1	Node N1.2	6,000
Existing Basin 2	Node N1.3	12,420
Existing Basin 3	Node N1.4	13,850*
Proposed Basin 3*	Node N1.4	12,150
Existing Basin 4	Node N1.5	9,765
Proposed Basin 1	Node N13.0	5,600

*An extension of the existing Carter Place in the North West corner of the site is proposed. The extension works include creation of a new road segment extending over the existing 100 year ARI flood extent (refer drawing W011 for the existing flood extents). Refer section 4.3.2 for discussion.

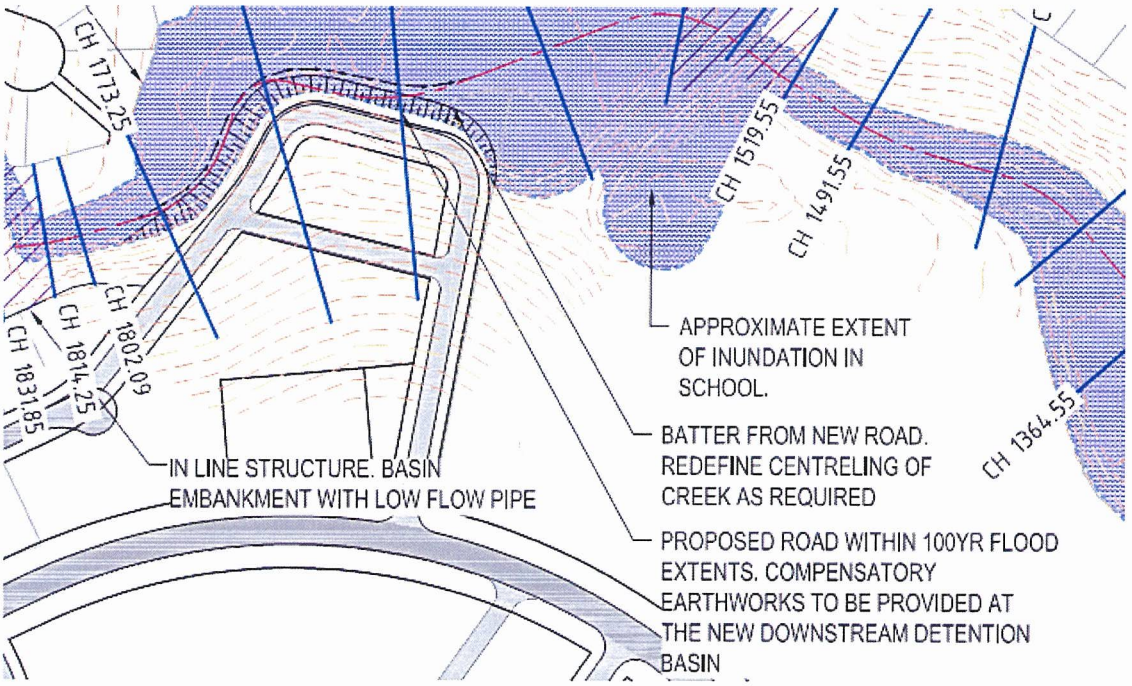

Figure 5.7 – Basin 3 Proposed Reduction

5.3. Results

5.3.1. Design Discharges

Design discharges were produced for a range of ARIs including the 5, 20, 50 and 100-year ARI events. Storm durations ranging from 10 minutes to 3 hours were modelled for each ARI, using AR&R temporal patterns, in order to identify the peak flow for each sub-catchment node. The design discharges for all of these events are shown in Appendix C.

Extended duration storms were simulated for the 6hr, 12hr and 24hr events to analyse any potential secondary peaks these storms were run for the 5 year and 100 year to asses any impacts.

5.3.2. Comparison of Post-developed and Existing Flows

The 100-year ARI flows for the post-development scenario are compared with existing conditions. From analysis, the critical storm duration for the 100 year ARI event at the outlet was 2 hours. However generally throughout the catchment the 1.5 hour duration storm is critical and has therefore been used for analysis in the HEC-RAS modelling. The shift to the critical 2 hour storm at the outlet is due to attenuation of flows caused by the proposed basin.

Comparative results are shown at various points in the site in Table 5.4 for the 100yr ARI event. Full results are included in Appendix C.

Table 5.4 - Comparison of Existing and Proposed 1 in 100 year ARI Flows

Existing		HEC-RAS Chainage (m)	Proposed	
Node	Flow (m^3/s)		Flow (m^3/s)	Node
N1.6	12.218	2043.15	12.286	N1.6
N1.5	13.01	1814.25	12.988	N1.5
N1.4	19.839	1519.55	20.650	N1.4
N1.3	16.958	1288.65	19.618	N1.3
N1.2	12.531	1055.85	14.707	N1.2
N1.1	31.622	727.15	33.838	N1.1
N1.0	37.577	514.25	39.886	N1.0
N0.0	38.528	423.88	35.927	N0.0
Hume Outlet	47.764	130.08	43.475	Hume Outlet

The basin sizes shown in Table 5.3 have been applied to the proposed models, subsequently allowing post-developed flows to be lower than existing at the outlets of the site.

The proposed peak discharge occurs during the 2 hour 100yr Storm event, the following is a comparison of the existing and proposed peak flow rates:

Table 5.5 - Comparison of Existing and Proposed 100 year ARI 120min Flows

Node	Existing	Proposed
N0.0	37.95m^3/s	37.69m^3/s
Hume Outlet (includes Bypass)	48.30m^3/s	44.88m^3/s

All 5yr to 100yr storm events satisfy pre to post scenarios with the exception of the 5yr 45minute duration storm. The site discharge for the existing site is 48.30m^3/s and 44.88m^3/s for the proposed. The 45min duration storm is not the critical duration storm for the 5yr ARI event and as such the differences in flows are, in our opinion acceptable.

Assessment of the downstream system has been undertaken up to the 4 x 1800mm dia. Hume Highway inlets as requested by Council. Results of the assessment demonstrate the that time to peak of the Claymore and Eagle Vale catchments do not now coincide due to the introduction of additional stormwater detention. Table 5.4 shows that the addition of the detention system in the Claymore site will reduce flows from the Claymore site and at the Hume Highway therefore no adverse effects are expected due to the development.

The basin 3 volume has been reduced in the proposed scenario due to the proposed extension of Carter Place in the North West corner of the site. The extension works include creation of a new road segment extending over the existing 100 year ARI flood extent (refer drawing W08 for the existing flood extents). In order to satisfy freeboard requirements the proposed road has been considered at a height greater than the 100yr flood level at this location (proposed flood level approximately RL69.07). The proposed road extends into the existing Basin 3 requiring minor earthworks to elevate the road, which will reduce the basin storage capacity by approximately 1,725m^3. It has been assumed that a batter at 1:4 will be provided from the edge of pavement to the basin floor. This will provide the worst case scenario for causing a reduction of storage in basin 3. This may be replaced with a retaining wall during the detailed design phase if required, which will improve storage within basin 3.

No additional compensatory earthworks within basin 3 have been proposed due to the preference to retain existing trees and open space in its current configuration. Minor regrading may be required to create a more defined basin invert.

As a result of the reduction in storage volume, a localised increase in flow rates throughout the main floodway in the order of 2m^3/s. HEC-RAS modelling of the proposed works has identified a proposed water level increase of approximately 40-80mm along the floodway in the vicinity of basin 3. The increase in flows has been offset with the proposed 5,600m^3 detention basin at the outlet of the site.

The results indicate that the proposed development will not have an adverse impact on downstream property as a result of increased flows. The flow rates shown in Table 5.4 are representative of stormwater runoff being carried in low flow pipes as well as those travelling along overland flow paths.

Hydraulic modelling is completed in Section 6 to assess the depth and extent of flood inundation in both the post developed and existing scenarios. For the purposes of this study, the low flows pipes are assumed to operate at full capacity (in both scenarios). Consequently the overland flow rates used in Section 6 are expressed in Table 5.6.

The following summary table includes all those flowrates which are generated from RAFTS. Figures are then used for HECRAS modelling within Section 6.0.

Table 5.6 - Existing and Proposed 100 year ARI Flows for HEC-RAS

HEC-RAS Chainage (m)	EXISTING (m^3/s)	*RAFTS* Node	HEC-RAS Chainage (m)	PROPOSED (m^3/s)	*RAFTS* Node
2043.15	3.6	N8.2	2043.15	3.6	N8.2
1990.15	12.218	N1.6	1990.15	12.286	N1.6
			1941.45	12.988	N1.5 (Inflow)
1814.25	4.69	N1.5 (Outflow)	1814.25	4.678	N1.5 (Outflow)
1666.75	19.839	N1.4 (Inflow)	1666.75	20.650	N1.4 (Inflow)
1519.55	12.267	N1.4 (Outflow)	1519.55	13.590	N1.4 (Outflow)
			1406.35	19.618	N1.3 (Inflow)
1288.65	12.087	N1.3 (Outflow)	1288.65	13.925	N1.3 (Outflow)
				14.707	N1.2 (Inflow)
1055.85	12.531	N1.2	1055.85	14.617	N1.2 (Outflow)
727.15	31.622	N1.1	727.15	33.838	N1.1
514.25	37.557	N1.0	514.25	39.886	N1.0
423.88	38.528	N0.0	423.88	35.927	N0.0
130.08	47.764	Hume Outlet	130.08	43.475	Hume Outlet

5.3.3. Comparison with other Results

The hydrologic model results were compared with a more approximate method described below to check that they were within the expected range.

2.2.2.3. Rational Method

The rational method is the most widely used empirical technique used for calculating design flow rates within Australia (as recommended in AR&R87). The rational method calculates the peak flow rate corresponding to the particular time of concentration for the catchment. These estimated flow rates are not related to any one specific storm event.

The position of the estimated peak flow rate was chosen as the outlet point of the eastern catchment (at the outflow of the watercourse adjacent to the Hume Highway). The result was then compared to the corresponding RAFTS node (Hume Outlet) – with all detention basins removed - as shown below in Table 5.7.

Table 5.7: Comparison of Results

Point / Node	Location	AR&R Rational Method	*RAFTS*
C1.1	Catchment Outlet (Hume Hwy)	56.88m^3/s	67.59m^3/s

Comparison has shown that the flowrates are within 19% and subsequently within a reasonable order of magnitude.

The difference in flowrates is explained by the following:

- the rational method is based on the theory of a basic triangular hydrograph,
- while RAFTS allows for generation of a varying rainfall hyetograph and therefore a more parabolic hydrograph.
- rational method does not consider any effect of minor and major (trunk) piped systems – which allow for flows to be conveyed much quicker towards the outlet, which in turn increases the peak flowrate.
- RAFTS allows for flowrates to be more accurately modelled through flowpaths, and
- the rational method assumes the catchment is uniformly defined, while RAFTS allows for more accurate delineation of sub catchments, which in turn allows for portions of the catchment to peak at different times or simultaneously.

5.3.4. Probable Maximum Flood

The 45 minute duration PMP storm produced the highest discharges. Estimated PMF discharges are up to 9 times the 100 year ARI flows with a flowrate of approximately 332m^3/s for the 45 minute duration storm. Detention Basin spillways will be designed at detailed construction certificated stage to convey half the PMF discharge in accordance with Campbelltown City Council's standards.

While it is recognised that an appreciation of the impacts of the PMF must be considered during the development assessment stage the critical parameters are the provision for evacuation and the structural integrity and safety of houses or other buildings subjected to high depth and velocities. It is accepted that the SES regional evacuation plans would address any need for evacuation. The structural integrity of any building impacted upon by the PMF event, needs to be addressed as part of the development application for the individual buildings.

The simple channel routing in the RAFTS model is inadequate to accurately assess flood behaviour with such high flows. However, in order to assess the structural integrity of dwellings during this event, RAFTS software is expected to provide results within an acceptable order of magnitude.

The expected PMF flow rate in both the existing and proposed scenarios is in excess of the capacity of the 4 x 1800mm dia. pipes traversing the Hume Highway to Jackson Park,

however flows are reduced in the proposed scenario. In this instance ponding is expected to occur along the embankment of the Hume Highway. This could result in flood waters rising to a depth enabling them to spill over into the Hume Highway corridor. Flooding over the Hume Highway and PMF flood extents have not been analysed in detail within this assessment.

5.3.1. Climate Change Assessment

An assessment of the impacts of Climate Change ass been undertaken to evaluate the impact climate variations may have on the proposed development.

Currently there are a number of future climate change scenarios that are based predictive modelling undertaken by both Government and private agencies. The various climate change scenarios differ in severity in relation to rainfall intensity and as indicated by in Campbelltown City Council's DCP an increase in rainfall intensity may occur for Campbelltown. As such Section 4.25 of the CCC DCP suggests an assessment be undertaken with an increase in rainfall intensity of 10% to assess the potential impacts.

Table 5.8 indicates the impact increased rainfall intensities will have on the development flows. Peak flows were examined against storm durations for the 100yr ARI event.

Table 5.8: Climate Change Assessment

		Peak Flow (m^3/s)	
Annual Recurance (Years)	**Storm Duration (Minutes)**	**Current**	**Projected**
100	25	40.074	43.491
100	30	38.785	42.128
100	45	37.19	41.894
100	60	41.883	47.13
100	90	43.475	47.519
100	120	44.876	50.016
100	180	36.798	40.085

Results indicate than an increase in flow rates of generally 10% were recorded. With a 10% increase in rainfall intensity, this corresponds to a 10% increase to flows in the existing and proposed scenarios. No apparent additional hazards were introduced as a result of the climate change scenario. It is recommended that the detention basin weirs should be designed to withstand rainfall events higher than the 100yr ARI event. As such no stability issues are expected under a 100yr Climate change scenario.

5.3.2. Overland Flow Depths and Velocities

The 100-year ARI flow depths and velocities are tabulated in Table 5.9. These depths and velocities are based on the assumption that the minor, piped drainage system conveys 100% of the 5-year ARI. Table 5.9 also compares the depths and velocities against the following criteria:

- A velocity-depth product of 0.4 m^2/s as recommended in AR&R
- Figure L1 of the NSW Floodplain Development Manual

In instances where RAFTS presented zero data was for overland flow, pipes were then excluded and the model re-run to be conservative. These are highlighted in yellow in Table 5.9.

Generally the upstream links (and the majority of proposed road corridors) in the central catchment satisfy the limits set above. Typically links at the upstream end of the catchments easily satisfy the velocity-depth product limits, but as flows increase down catchments the product is increased and in some instances the safety limits are exceeded.

Some potential hazard areas are identified as follows:

- Link 1.0-1.6 convey trunk overland flows through the central channel / watercourse, and as such the corresponding depth-velocity ratings for these channels exceed the standard maximum safe 0.4 depth to velocity rating. Due to the volume of flow, this was anticipated and has been excluded from the overland flow analysis. Flows through the watercourse have been assessed in the flood modelling (HEC-RAS) component of this report;
- Link 5.0 consists of a 1200dia pipe currently flowing through the existing Claymore School. This pipe has the capacity to convey the 1 in 5 year ARI peak event however; a 50% blockage on this pipe generates additional overland flow which does not satisfy the velocity depth criteria. Additional pits are recommended along Dobell Rd opposite the school to increase the inlet capacity to ensure the 1200dia pipe generally runs at capacity.
- Links 7.0, 6.1 and 6.2 are existing flow paths for external sections of the site to the North and North-West. Analysis of the existing minor system in these areas indicate that the pipes are undersized and may require upsizing to accommodate some additional flows above the 1 in 5 year ARI event to alleviate the potentially high overland flows. Generally these catchments to the North and North-West remain unchanged in the proposed scenario and therefore there is no additional increase in flows. Detailed DRAINS analysis of these areas is to be undertaken as part of future stages;
- Links 2.0-2.2 currently have oversized pipes (Link 2.0 has 2 x 1650dia pipes) which convey the 1 in 100 year ARI event;
- Links P16.4 through to P16.2 (these links convey flows from an upstream catchment and appear to present a problem);
- Links 3.0, 2.4 & 2.3 require upsizing to accommodate rainfall events greater than the 1 in 5 year ARI storm event. This is to be considered at the detailed design stage.

To enable the overland flows to be reduced in the areas mentioned above, the piped drainage system will need to be designed to a higher ARI than the 1 in 5 year ARI for the flow paths. The required ARI for the pipe drainage system at these locations will be confirmed at the detailed design stage. Refer to Figure W07 for positions.

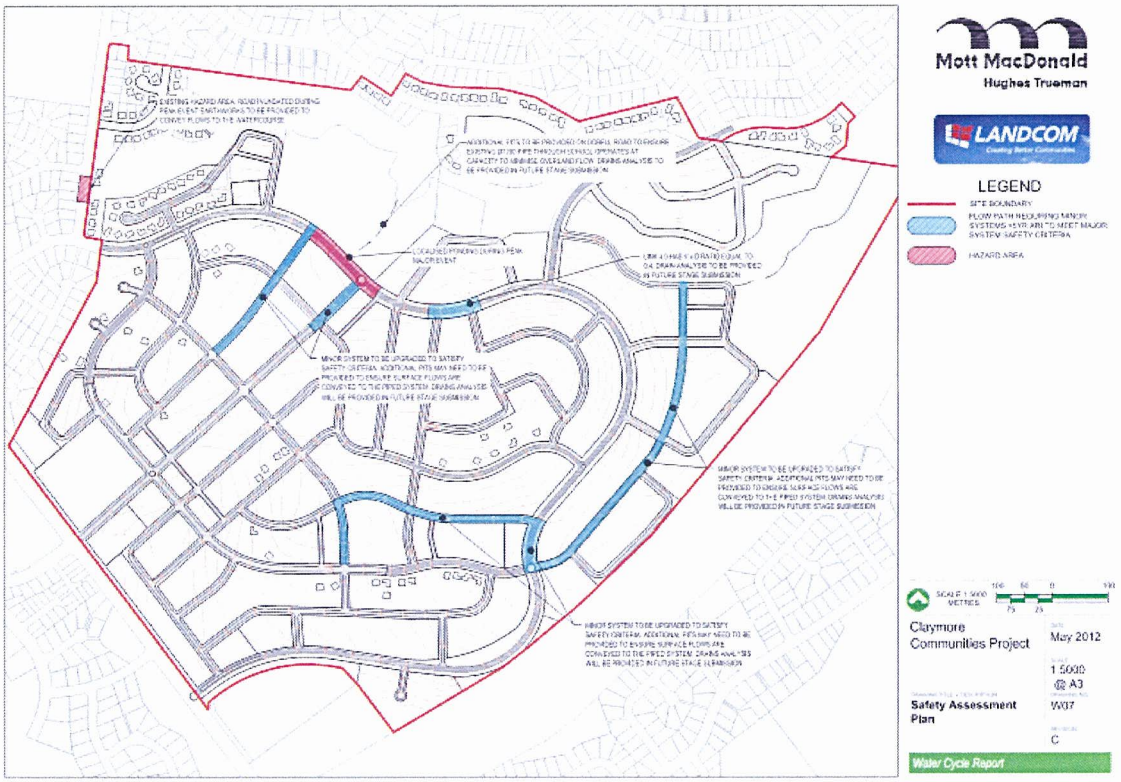

Figure 5.8 –Identified Potential Hazard Areas and Oversized Trunk Stormwater Lines

Table 5.9: Velocity – Depth Ratios

	Velocity (m/s)	Depth (m)	V*D	V*D<0.4
N2.0	2.71	0.30	0.82	NO
N2.1	1.53	0.51	0.77	NO
N2.2	2.00	0.48	0.96	NO
N2.3	1.87	0.31	0.59	NO
N2.4	2.85	0.18	0.52	NO
N3.0	2.34	0.30	0.71	NO
N3.1	1.19	0.24	0.29	YES
N4.0	3.28	0.12	0.40	NO
N4.1	1.57	0.18	0.29	YES
N5.0	2.49	0.43	1.06	NO
N5.1	2.61	0.18	0.47	NO
N5.2	2.22	0.26	0.59	NO
N5.3	1.24	0.33	0.41	NO
N5.4	2.43	0.14	0.34	YES
N5.5	2.36	0.10	0.23	YES
N6.0	1.33	0.09	0.12	YES
N6.1	2.45	0.23	0.56	NO
N6.2	3.35	0.23	0.75	NO
N7.0	1.72	0.64	1.10	NO
N8.0	1.91	0.14	0.27	YES
N9.0	2.70	0.12	0.33	YES
N10.0	1.49	0.09	0.14	YES
N11.0	1.23	0.15	0.19	YES

There are a number of existing pipes that are currently oversized for the 1 in 5 year ARI event. It is understood that these pipes were oversized to accommodate larger flows as they are at the tail end of the catchment. Here, a blockage factor of 50% has been applied, however it is likely that pipes of this size will not become blocked to this extent as pit blockages in the area only account for a small percentage of the catchment. In this instance during the detailed design phase appropriate pit blockage factors will be considered and additional pits added to alleviate any overland flow issues.

6. Hydraulics

6.1. The Model

The HEC-RAS hydraulic analysis program was used to analyse the effect of overland flows on both flood levels and the extent of inundation. The HEC-RAS Version 3.1.1 (May 2003) hydraulic model, the latest windows-based release from US Army Corps of Engineers, Hydrologic Engineering Centre, is widely used for analysis of hydraulic conditions where floodplain storage effects are small.

HEC-RAS is an integrated package of hydraulic analysis programs capable of performing one-dimensional, steady or unsteady flow, water surface profile calculations. The model can handle a full network of channels, a dendritic system or a single river reach. It is capable of modelling subcritical, supercritical and mixed flow water surface profiles.

The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's Equation). The effects of various obstructions such as bridges, culverts, weirs and obstructions in the floodplain are also considered in the computations.

6.2. Model Formulation

Formulating a HEC-RAS model involves defining river geometry, and boundary conditions.

HEC-RAS models were formulated to represent both the existing and proposed scenarios, subsequently allowing for assessment to be made on the extent of flood inundation, depths and the like. That is, the existing (pre-development) model is created to represent the extent of inundation and flood levels experienced by existing flows through the channel / basin system, while the proposed model encompasses any changes which may have been imposed on the flowpath by the new development footprint and extents for proposed basins, roads and the like.

6.2.1. River Geometry

The existing network contains one "reach" which extends from the sag at Drysdale Street, along the channel / piped system before discharging to the 4 x 1800dia pipes under the Hume Highway.

The proposed HECRAS model includes a storage basin using the lateral weir function in order to ensure that the flow rates are not exceeded at the downstream most section in the 1 in 100year ARI event.

2.2.2.4. Existing

Surveyed cross-sections from 12d were used to model the existing surface profile of the watercourse (and surrounding land) where overland flow will occur during peak events. Here cross Sections were positioned at critical points, while other sections placed between at 50 metre intervals. Drawings W08 to W010 show the cross-section locations for the existing scenario while diagrammatic layouts of the model are included in Appendix D.