

Source: Sydney Catchment Authority

Department of Planning and Environment

Greater Macarthur

Water Management

August 2015

Executive summary

The New South Wales government has developed a strategy to guide the future growth of the Sydney metropolitan Area for the next 20 years to ensure the future productivity and liveability of the city. The strategy is titled *A Plan for Growing Sydney*.

Within *A Plan for Growing Sydney* there a number of actions identified. Action 2.4.2 of *A Plan for Growing Sydney* requires the development a framework for the identification of new growth centres.

In response to this Action, the Department of Planning and Environment is undertaking the Greater Macarthur Investigation Area project. The overarching aim of this project is the determination of whether the Greater Macarthur Investigation Area is suitable for urban development and population growth.

The brief for this project responded to the Action by focussing on:

- Flood modelling - Review and collation of existing flood studies for the Investigation Area and the undertaking of flood modelling to define the flooding conditions (flood levels, velocities, hazard and flood category) for conditions up to the Probable Maximum Flood event and also considering projected climate change impacts
- Site planning - Identification of an appropriate flood planning level and the preparation of a flood evacuation strategy within the requirements of the Floodplain Development Manual
- Planning advancement – Examination of future refinement of the analysis that should be completed as potential site planning proceeds
- Water Cycle Management - Development of a strategic level stormwater cycle management strategy addressing policy, infrastructure and service requirements along with WSUD principles and provision of advice on the feasibility of the adopted strategy
- Riparian Corridor assessment - Completion of a review of available data and undertake a Riparian Corridor Assessment and provision of a description of how the WSUD measures could impact the riparian corridor

The study area adopted for this investigation includes both the Greater Macarthur Investigation Area as shown in *A Plan for Growing Sydney t*ogether with additional surrounding lands giving a study area of approximately 15,970 ha.

This report is subject to, and must be read in conjunction with, the limitations set out throughout the document (Greater Macarthur Water Management) and the assumptions and qualifications contained throughout the Report.

A significant amount of literature has been identified and is applicable to the Study Area. The majority of the literature has been focussed upon the projected and historical impacts of past and proposed mining operations within the area. As such it has related primarily, as related to this study, water quality, watercourse form and stability subsidence.

Minimal information was identified that considered flooding conditions. The material that was sourced focussed on flooding in the reaches of the Nepean River near Menangle and Douglas Park together with some information on conditions in the area near Wilton and tributary watercourses near Menangle. Only one report provided a comprehensive assessment of conditions within the Study Area. That report specifically considered the Nepean River

catchment area upstream of the Study Area and also the impacts of the upstream major water storages (Cataract Dam, Cordeaux Dam, Avon Dam and Nepean Dam) together with the water supply transfer system.

Later flooding studies that considered the Nepean River conditions built upon results from that investigation.

The hydrological analysis completed for this study included the consideration of the design flood hydrographs from the upstream catchment area together with design flows from within the Study Area. As a result of the significant difference in the size of the upstream catchment and the Study Area it was found that the peaks of the hydrographs were not coincident. Therefore, the flows and flow conditions within significant lengths of the tributary watercourses, to the Nepean River, within the Study Area were primarily impacted by the locally generated stormwater runoff values. Flow conditions along the Nepean River and lower portion of larger tributaries were impacted by the hydrographs originating from the upstream catchment together with some impact from the local catchment.

Design flows form the hydrological analysis were then input to an extensive HEC-RAS hydraulic model covering the Nepean River and many of the larger tributaries to the Nepean River to determine design flood levels, average flow velocities, flood hazard values and the watercourse classification.

Figures depicting the flood extent and flood levels have been provided for the 2, 20, 100 year ARI design events together with a Probable Maximum Flood representation. Tabulated flood levels are also provided to provide a more comprehensive representation of the flooding conditions. The flood levels have shown that in areas outside the influence of backwater effects from the Nepean River there is a minimal difference in the flood levels for the 2 year to 100 year ARI flood levels. This is a direct result of the steep terrain and watercourses giving quite high predicted design flow velocities. Figure ES-1 provides a diagrammatic representation of the 100 year ARI flood levels throughout the Study Area.

Figures are also presented to show the flow velocity predicted by the HEC-RAS hydraulic model. The velocity distribution across each section has been inferred from the distribution of the conveyance capacity distribution across each cross section. These are presented for the 20 and 100 year ARI events together with the Probable Maximum Flood event.

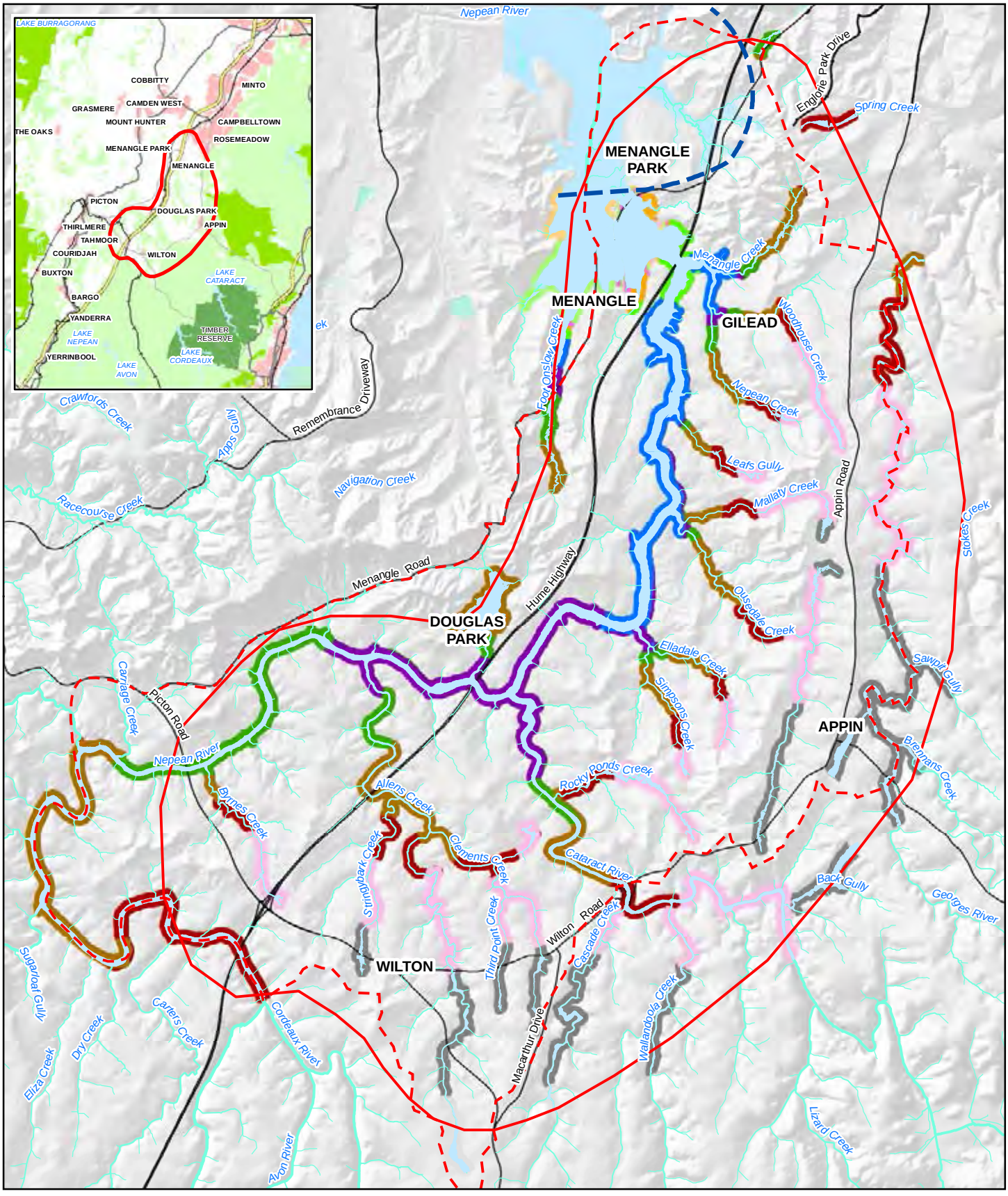
The flow hazard and watercourse classification have also been provided for the modelled watercourses. The results are also provided in Figures and they show, using the adopted six level classification system, the majority of the watercourse would be classified as being high hazard for the 100 year ARI event. This is shown in Figure ES-2.

Similarly, the majority of the watercourses would be classified as floodway areas for the design 100 year ARI event.

Proposed development areas are generally located along the higher ridge area and this has posed complexities in the selection of a cost effective WSUD strategy that provides protection to the riparian corridors. The assessment has indicated that protection of riparian corridors would be best be achieved by having WSUD measures located within or adjacent to APZs.

Three WSUD strategies have been evaluated. All three could be made to achieve a nil or beneficial effect resulting from the proposed development. The preferred strategy comprises:

- Dwellings fitted with water efficient appliances and rainwater tanks as required to satisfy BASIX requirements
- A conventional minor pipe drainage network and major drainage network to convey flows to the regional water quality treatment measures



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flood Levels and Extents

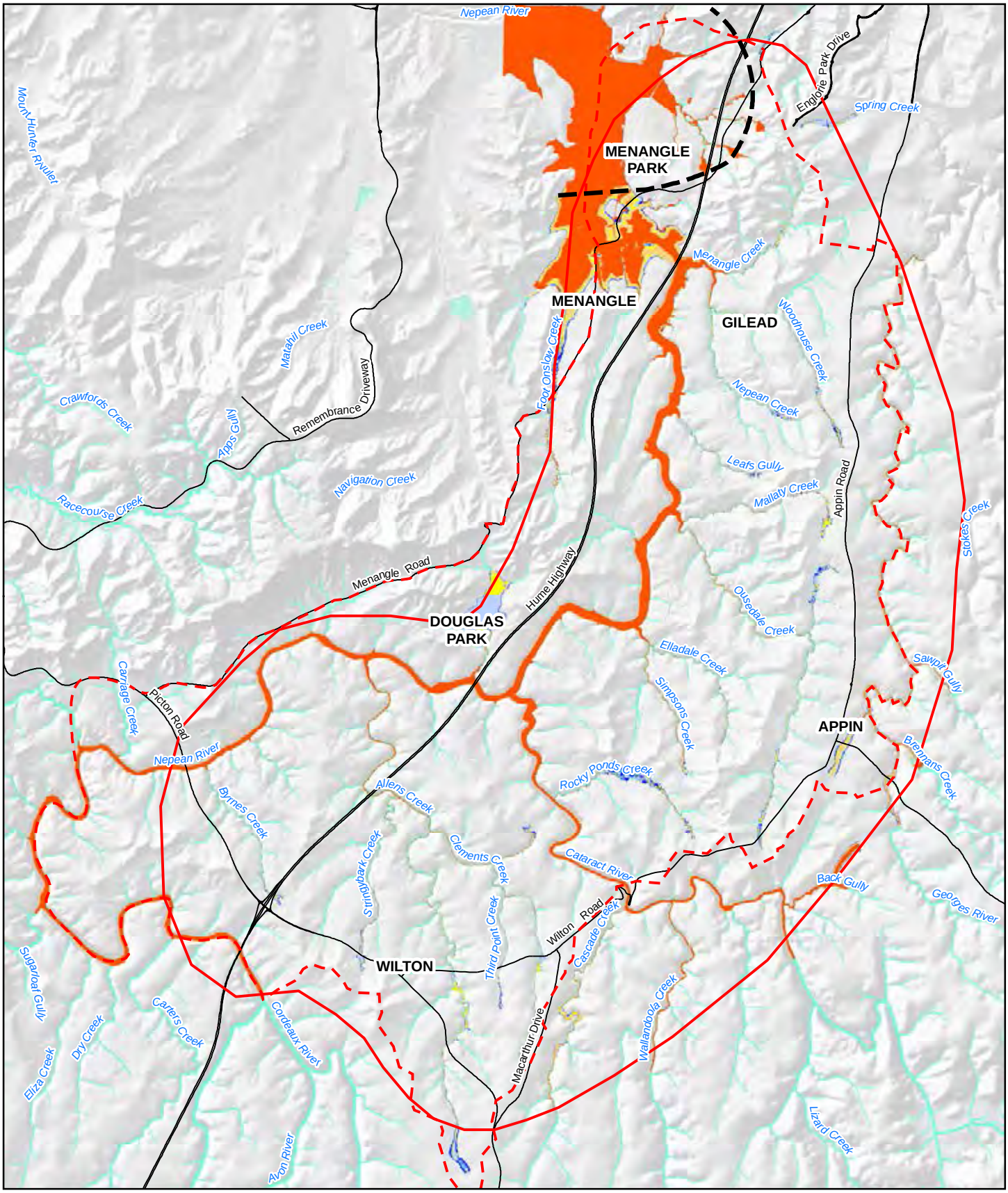
Figure ES-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\ExecSumm\2217728_ES001_Existing_100YR_FloodExt_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent

Hazard

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flood Hazard

Figure ES-2

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\ExecSumm\2217728_ES002_100YR_Hazard_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

- Construction of the perimeter road located within, or adjacent to the APZ, in such a form as to convey the major stormwater flows to the water quality measures. This functionality could be achieved through using an enlarged capacity pipe network system for this road or construction, use of a single cross fall road to enhance the flow conveyance capacity or, where the landform suits, of a swale system parallel to the road
- Construction of a combined bioretention with and detention area at each discharge point from the major/minor drainage discharge location into the creekline vegetation areas. This will include a 0.5m of extended detention which will drain through the bioretention element. The biorention area will be designed to maximise nutrient removal.
- Opportunistic incorporation of pocket parks or landscape water bodies into the development footprint will be adopted to effectively contribute a further 1.5% of catchment area as bioretention.
- Litter and gross pollutant traps at the discharge of the piped drainage system into the regional water quality control facilities

The selected strategy, Figure ES-3, has staging costs estimated as shown in Table ES-1-1. The values shown in this table do not explicitly include any contingency allowances.

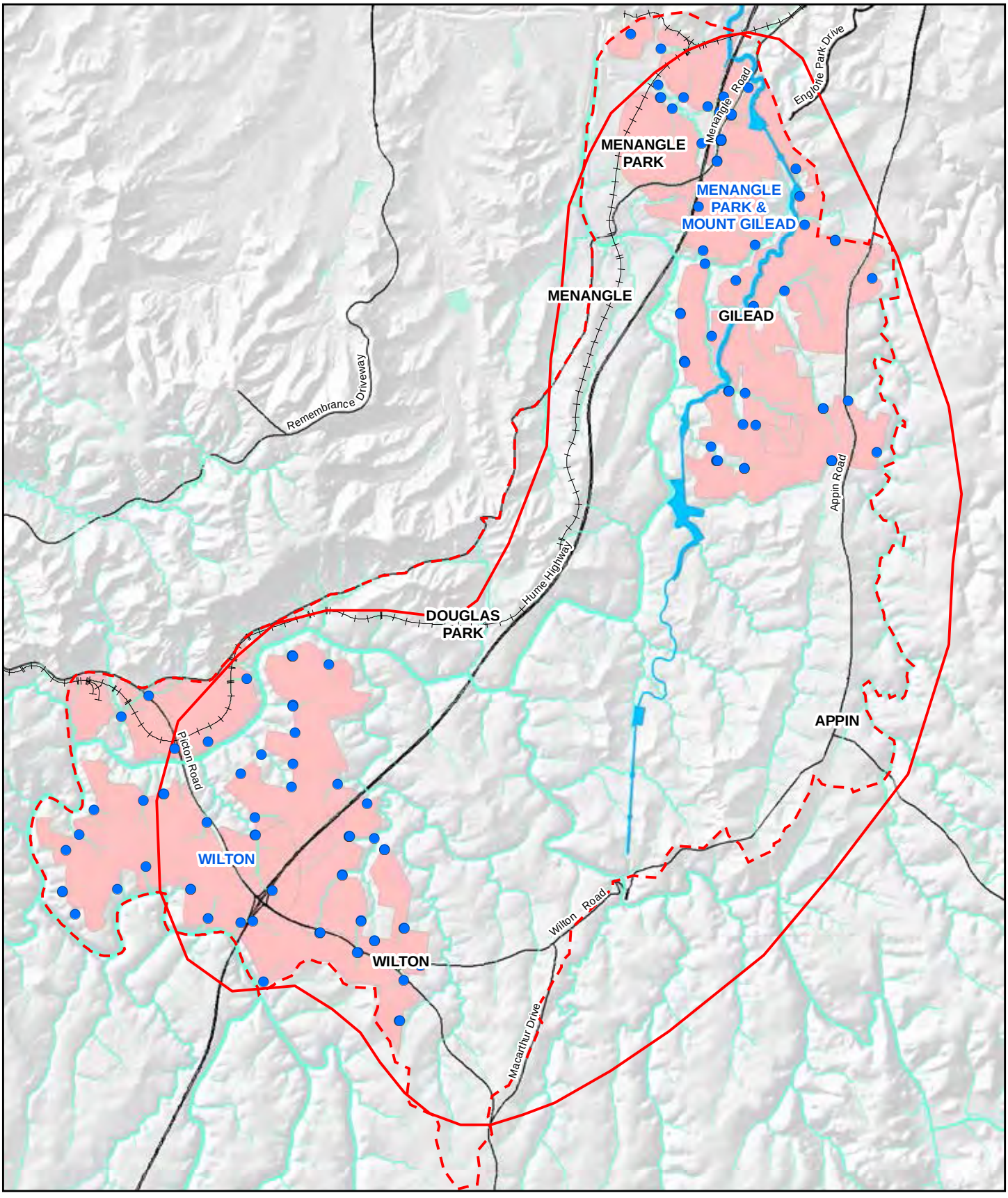
Table ES-1-1 Estimated costs

Parameters	Menangle Park & Mount Gilead	Wilton
Capital cost for upgrade of perimeter road ($m)	2.57	2.00
Capital cost of combined bioretention and detention structures at APZ ($m)	67.60	73.10
Total capital cost ($m)	**$70.10**	**$75.10**
O&M costs for additional works on perimeter road ($m/a)	0.04	0.05
O&M costs for combined bioretention and detention structures at APZ ($m/a)	0.58	0.51
Total O&M costs ($m/a)	**0.62**	**0.56**

The investigation has evaluated the selection of an appropriate design flood level and flood planning level within the Study Area. The two affected Councils currently adopt the design 100 year ARI event to establish the design flood level. Retention of that same standard is considered to be appropriate within the Study Area as no unusually high flood or safety risk to potential residents or emergency staff, should evacuation be required.

Suggested evacuation routes are generally along ridge lines to create evacuation routes following upward sloping alignments from all locations to a major (or likely major), future traffic route.

Since there has been limited information available to verify the hydraulic modelling, it is recommended that, should further investigations be undertaken for the Study Area and there be a significant flood event, then flood levels should be collected to provide verification data for a future model review It is also recommended that periodic updating of the hydrologic and hydraulic assessment be completed as any future planning proceeds for potential urban development.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Developable Areas
- Road
- Railway
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Preferred WSUD Strategy and Staging

Job Number 22-17728
Revision 1
Date 27 Aug 2015

Figure ES-3

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\ExecSumm\2217728_ES003_Strategy1_WQ_locations_1.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

Glossary

Terms	Definition
1 dimensional	A flow area where the flow, in plan view, is aligned effectively along a single path.
2 dimensional	A flow area where the flow, in plan view, is permitted in two directions. An example would be an estuary or a watercourse having a main channel and a floodplain that has a significant flow along or across the floodplain.
50%ile	See median.
Annual exceedance probability	The risk of a flood of a given size being exceeded in any single year. A flood of a 1% AEP flood has a low risk of being exceeded in any single year.
Annual rainfall	The yearly rainfall recorded at a single rainfall station.
Asset protection zone	The set back distance for development from bush fire prone land. Generally APZs are maintained in such a manner as to have a minimal fire fuel load.
Australian height datum	A reference plane for the measurement of elevation. Approximately equal to mean sea level.
Average recurrence interval	The average period (in years) between the recurrence of a flood of a given magnitude when considered within an long period of records. The average recurrence interval, for larger floods, is approximately the reciprocal of the annual exceedance probability.
Catchment	Land surface area draining to a particular location in space.
Channel	Comprises the bed and banks of a watercourse(to the top of the highest bank)
Climate change	The rainfall and sea level changes that are projected to occur as a result of temperature changes. Secondary effects of projected climate change will include a change in the magnitude, extent and frequency of flooding along watercourses.
Core riparian zone	That area of the riparian zone that is not classified as
Crime prevention through environmental design	A design strategy that is intended to reduce crime through the implementation of appropriate design (location, layout, lighting, landscaping etc) form.
Dam	A structure built across a watercourse with the intent of storing a significant volume of water.
Digital evaluation model	An electronic representation of the terrain form or level
Ecological community	A naturally occurring group of native plants, animals and organisms that interact in a unique habitat.
Ecology	The study of the interaction among plants, animals and other organisms and their broader environment.

Terms	Definition
Endangered ecologically community	An ecologic community whose existence is endangered through a variety of processes. Usually the processes creating the threat are anthropogenic (created by humans).
Evaporation	Vaporisation of water. In hydrology considerations the evaporation is generally determined by the temperature, solar radiation and wind speed.
Evapotranspiration	The sum of the evaporation and plant transpiration into the atmosphere.
Flood	A relatively high streamflow in a watercourse when the water is likely to overtop the banks of the watercourse.
Flood affected land	Land that becomes affected (generally by inundation) during a flood.
Flood depth	The depth of flow occurring during a flood.
Flood fringe	The portion of the flow cross section remaining after excluding the floodway and flood storage areas.
Flood hazard	The potential for persons, vehicles or structures to be dislodged, injured or damaged during a flood.
Flood level	The level, in mAHD, of a flood at a particular location.
Flood profile	A plot or diagrammatic representation of the change in flood level along a watercourse.
Flood standard	The flood of a specified magnitude that is adopted for planning purposes as an input element into the establishment of building controls.
Flood storage	An area of flow where there is not a significant water flow during a flood. They are normally not aligned with defined channels and only provide a area where water temporarily ponds during the passage of a flood.
Floodway	Areas of flow where a significant water flow will occur during a flood. They are often aligned with defined channels. These areas, if partially blocked, can cause a significant increase in the upstream flood level and redistribution of the flow.
Fluvial	Found in, or associated with, rivers.
Groundwater	Water located below the ground surface in soil pore spaces. The pore spaces may be either saturated with water or unsaturated.
GSAM	A technique used to assess the probable maximum precipitation in areas where tropical storms are unlikely to be the cause of the lar rainfall events. It is applicable for design durations in excess of 12 hours.
GSDM	A technique used to assess the probable maximum precipitation in areas where tropical storms are unlikely to be the cause of the lar rainfall events and the design event is no longer that 6 hours duration.
GTSMR	A technique used to assess the probable maximum precipitation in areas where tropical storms are likely to be the cause of the larger rainfall events.
Gully	A landform created by flowing water eroding into soil. Synonymous with a small watercourse.

Terms	Definition
Gully erosion	Soil erosion that occurs within unstable open channels or concentrated flows (gullys).
Hazard	A situation that poses a threat to life, health, property or the environment.
HEC-RAS	A 1 dimensional steady state hydraulic modelling software package developed by the US Army Corps of Engineers Hydrologic Engineering Centre.
Hydraulic	The study of water flow to define the flow characteristics (velocity, velocity distribution and depth or pressure head).
Hydraulic conveyance	A term used to describe the flow capacity of a watercourse.
Hydraulic profile	See also flood profile.
Hydraulic roughness	A parameter that is used within the mathematical modelling of flood behaviour to represent the resistance to flow caused by vegetation.
Hydrology	The study of rainfall and stormwater runoff processes.
Infiltration	The process by which water that falls onto the soil surface enters the soil.
Intensity frequency duration	A relationship between the design rainfall intensity, the frequency (or ARI) of the rainfall event and the duration of the rainfall event.
Lag	The period (measured in hours) between a rainfall event (or intensity) and the occurrence of the resulting flow at a specific location.
Landscape mapping	The presentation of soil landscape information on a map or figure.
LIDAR	Airborne Light Detection and Ranging (LIDAR) is a remote sensing technology used to determine the ground level by measuring the distance from a plane flying at a known elevation.
Load	Annual amount of pollutant observed or predicted at a location.
mAHD	Elevation measured vertically from a datum called the Australian Height Datum.
Mean	Average value calculated from a series of data.
Median	Middle value within a series of data.
MIKEII	A hydraulic model for determination of unsteady (time dependent) flow conditions within a 1 dimensional (or looped 1 dimensional) flow regime.
Onsite detention	The provision of a relatively small detention structure on each lot to restrict the peak post development flow rate to a nominated value. The nominated value is often, but not necessarily, the pre developed peak flow rate.
pH	The negative logarithm of the activity of the hydrogen ion in an aqueous solution. Solutions having a value less than 7 are termed acidic while those having a value in excess of 7 are termed alkaline.
Potential evaporation	The amount of evaporation that would occur in the presence of an unrestricted water source.

Terms	Definition
Potable water	Water that has a water quality suitable is safe for human consumption.
Precipitation	Synonymous with rainfall.
Probabilistic rational method	A flow estimation method developed from the Rational Method which directly relates the design flow to a critical storm duration related to the catchment area, the rainfall intensity and catchment area. Factors are applied to the runoff coefficient to include an effect of the rainfall intensity.
Probable maximum flood	The maximum flood value that can reasonably be expected at a location. Normally it is the result of an extreme rainfall (probable maximum precipitation) event over the catchment area.
Probable maximum precipitation	The maximum rainfall that can reasonably be expected over a catchment. Normally it is related to the air temperature and moisture holding capacity.
Regional detention	The provision of regional detention structures that each serve several lots to restrict the peak post development flow rate to a nominated value.
Riparian	Of, or relating to, the banks of a watercourse.
Riparian corridor	The transition area between land (or terrestrial environment) and a watercourse (or aquatic environment).
Riparian corridor	Comprises the channel and vegetated riparian zone
Riparian protection zone	The interface area between land and a river or stream that is to be protected by the implementation of the endemic vegetation.
RORB	A hydrologic model used for quantifying surface runoff from the rainfall falling on a catchment.
Sewage	The water carried waste to be removed from a community.
Sewer overflow	A structure or location where a discharge occurs from a sewer.
Sodic soils	Those soils which contain an unusually high amount of Sodium. These soils are typically unstable, exhibit poor physical and chemical properties, impede soil infiltration, have low water availability and impede vegetation growth.
Soil landscape	An area of land having a common suite of soil types and visible features (landscape) attributes.
Stormwater	The surface runoff that occurs during and immediately following a rainfall event.
Strahler stream ordering	A classification system that attributes an order (or label) to watercourses according to the number of contributing upstream tributaries. The order starts at unit at the upstream end and increases each time two tributaries of al least the same order combine.
Stream erosion index	A measure of the increases erosion hazard within a watercourse. Normally quantified based upon the change in the annual flow regime.
Stream order	The classification given to a watercourse under the Strahler classification

Terms	Definition
	system
Subsidence	The motion of the earth's surface as it shifts downward relative to some datum.
Terrain	A physical geography term used to describe the vertical and horizontal dimension of the landform.
TUFLOW	A two dimensional mathematical model used to predict flow patterns (depths and velocities) as water flows over the landform.
Upsidence	The motion of the earth's surface as it shifts upward relative to some datum.
Urban capability	The potential of land to effectively support urban development without unacceptable degredation of land and water resources.
Vegetated riparian zone	The combined inner 50 percent of land adjacent to a channel and the outer 50 percent
Vegetation mapping	The preparation of a plan of the landform showing the distribution and quality of vegetation communities.
VRZ	That portion of the riparian corridor excluding the main channel.
Wastewater	Water that has been adversely impacted in quality by anthropogenic influences.
Water quality	Is a representation of the physical, chemical and biological characteristics of water.
Water sensitive urban design	A land planning and engineering design approach that integrates the elements of the urban water cycle (stormwater, groundwater, wastewater and potable water) to minimise environmental degradation.
Watercourse	A depression, river or creek (whether modified or not) in which water flows (either intermittently or permanently).
Watercourse blockage	The placement or occurrence of a structure across a watercourse that provides partial or complete blockage of the watercourse cross section.
Weir	A structure located across a watercourse. A weir is generally designed to regularly overtop during times of flow. The water storage capacity of a weir is generally smaller than that for a dam.
XP-RAFTS	A hydrologic model used for quantifying surface runoff from the rainfall falling on a catchment.

Abbreviations

Abbreviations	Definition
%ile	Percentile
AEP	Annual exceedance probability
AHD	Australian height datum
ANZECC	Australian New Zealand Environment and Conservation Council
APZ	Asset protection zone
ARI	Average recurrence interval
BOM	Bureau of Meteorology
C_{10}	Runoff coefficient for 10 year ARI event
CPTED	Crime prevention through environmental design
CRZ	Core riparian zone
DCP	Development Control Plan
DEC	Department of Environment and Conservation
DIPNR	Department of Infrastructure, Planning and Natural Resources
DPE	Department of Planning and Environment
EEC	Ecologically Endangered Community
GCC	Growth Centres Commission
GDSM	Generalised short duration method
GSAM	Generalised South Australian method
ha	Hectares
IEAust	Institute of Engineers Australia
IFD	Intensity-frequency-duration
L/p/d	Litres per person per day
LEP	Local Environmental Plan
LES	Local Environmental Study
LGA	Local government area
LIDAR	Light detection and ranging
m^3/s	Cubic metres per second
mAHD	Metres Australian Height Datum
Mg/L	Milligrams per litre
ML	Mega litres
ML/d	Megalitres per day
mm	Millimetres
NARCliM	NSW / ACT Regional Climate Modelling
NorBE	Nil or beneficial effect
NOW	NSW Office of Water
OEH	Office of Environment and Heritage
PMF	Probable maximum flood
PMP	Probable maximum precipitation
PRM	Probabilistic rational method
RPZ	Riparian protection zone
SCA	Sydney Catchment Authority
SEI	Stream erosion index
SEPP	State Environmental Protection Plan
SILO	Scientific information for land owners
SS	Suspended solids
STP	Sewage treatment plant
SWJRPP	Sydney West Joint Regional Planning Panel
TN	Total nitrogen
TOB	Top of bank

Abbreviations	Definition
TP	Total phosphorus
VRZ	Vegetated riparian zone
WMA	Water Management Act
WSUD	Water sensitive urban design

DISCLAIMER

This report: has been prepared by GHD for the Department of Planning and Environment and *may only be used and relied on by the Department of Planning and Environment for the purpose agreed between GHD and the Department of Planning and Environment as set out in section 1.2 of this report.*

GHD otherwise disclaims responsibility to any person other than the Department of Planning and Environment arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD and described throughout this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by the Department of Planning and Environment and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared the preliminary cost estimate set out in Appendix K of this report ("Cost Estimate") using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD and detailed in that Appendix. The Cost Estimate has been prepared for the purpose of evaluating the options and must not be used for any other purpose.

The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the project can or will be undertaken at a cost which is the same or less than the Cost Estimate.

GHD does not guarantee that this document (Greater Macarthur Water Management) and associated electronic files are free of computer viruses or other conditions that may damage or interfere with data, hardware or software with which it might be used.

Table of contents

1. Introduction 1
   - 1.1 Background 1
   - 1.2 Brief 1
   - 1.3 Study area 2
   - 1.4 Terminology 4
   - 1.5 Report structure 4
2. Study area and features 5
   - 2.1 Study area 5
   - 2.2 Local Government areas 5
   - 2.3 Topography 5
   - 2.4 Catchments and watercourses 5
   - 2.5 Water storages for drinking water supply 8
   - 2.6 Water supply weirs 8
   - 2.7 Other major infrastructure 9
   - 2.8 Existing surface land uses 11
   - 2.9 Mining 11
   - 2.10 Restricted land uses 11
   - 2.11 Climate data 15
   - 2.12 Historical flooding information and data 15
   - 2.13 Soils 16
   - 2.14 Watercourse conditions 16
   - 2.15 Vegetation 16
3. Previous studies and development proposals 19
   - 3.1 Planning proposals and rezoning 19
   - 3.2 Regional flooding studies 25
   - 3.3 Local drainage studies 25
   - 3.4 Mining impact studies 25
   - 3.5 Water quality studies 25
4. Streams and riparian corridors 28
   - 4.1 Stream classification 28
   - 4.2 Watercourse form and condition 28
   - 4.3 Riparian vegetation overview 30
   - 4.4 Terminology 30
   - 4.5 Riparian corridors 30
5. Hydrologic, hydraulic and WSUD analysis methods 35
   - 5.1 Overview 35

5.2 Scenarios considered 35
5.3 Hydrologic analysis 36
5.4 Hydraulics 38
5.5 WSUD analysis and form 43
6. Assumptions 45
6.1 General 45
6.2 Specific 45
7. Developed water management strategy 49
7.1 Extent of development 49
7.2 Preferred WSUD strategy 49
7.3 Asset protection zones 52
7.4 Earthworks 52
7.5 Flood levels 52
7.6 Flood extents 53
7.7 Flow velocities 53
7.8 Flood hazard 57
7.9 Flow classification 57
7.10 Catchment areas for potential watercourse piping 57
7.11 Stream erosion potential 60
8. Implementation of WSUD strategy 61
8.1 Preferred WSUD strategy 61
8.2 Design requirements and standards 61
8.3 Recommended flood planning level 61
8.4 Likely ownership and maintenance responsibility 61
8.5 Indicative capital costs 62
9. Evacuation planning 65
9.1 The site form 65
9.2 Guidance materials 65
9.3 Potential evacuation routes 65
9.4 Potential emergency accommodation 67
10. Strategy refinement with planning advancement 68
11. Summary 69
12. References 72

Table index

Table ES-1-1 Estimated costs v
Table 3-1 Performance targets 21
Table 3-2 Existing and developed predicted flow rates and predicted flood levels 22
Table 4-1 Recommended riparian corridor widths 30
Table 4-2 Recommended riparian corridor strategy 32
Table 5-1 Existing scenarios considered 35
Table 5-2 Adopted loss rates 37
Table 5-3 Adopted catchment roughness values 37
Table 5-4 Existing hydraulics scenario 40
Table 5-5 Downstream boundary flood heights (GHD; 2008) 40
Table 5-6 Definition of flood hazard (Australian Emergency Management Institute; 2014) 42
Table 5-7 Flood categorisation 43
Table 6-1 Water quality targets 46
Table 8-1 Cost estimates for preferred WSUD strategy 62
Table 8-2 Staging estimated costs 63
Table 11-1 Staging estimated costs 71

Figure index

Figure ES-1-1 100 year ARI flood levels and extents iii
Figure ES-1-2 100 year ARI flood hazard iv
Figure ES-1-3 Preferred WSUD strategy and staging vi
Figure 1-1 Study area 3
Figure 2-1 Topography and watercourses 6
Figure 2-2 Study area slopes 7
Figure 2-3 Major infrastructure 10
Figure 2-4 Existing land use 12
Figure 2-5 Mining leases 13
Figure 2-6 Bulli seam longwalls 14
Figure 2-7 Soil landscapes 17
Figure 3-1 Planning proposals 20
Figure 3-2 Previously determined flood levels 24
Figure 3-3 Bulli seam longwalls and water quality sampling locations 27

Figure 4-1 Strahler stream order 29
Figure 4-2 Watercourse cross section 34
Figure 6-1 Engineering functional requirements 47
Figure 7-1 Development extent 50
Figure 7-2 Adopted water management strategy 51
Figure 7-3 100 year ARI flood levels 54
Figure 7-4 PMF flood levels 55
Figure 7-5 100 Year ARI average velocity and extents 56
Figure 7-6 100 Year ARI flood hazard 58
Figure 7-7 100 year ARI flow classification 59
Figure 8-1 Potential WSUD strategy within Development Areas 64
Figure 9-1 Evacuation planning 66

Appendices

Appendix A – Data details
Appendix B – Previous relevant investigations
Appendix C – Legislation, Policies and Guidelines Considered
Appendix D – Water cycle options and assessment
Appendix E – Hydrologic and hydraulic analysis
Appendix F – Flood level mapping
Appendix G – Velocity mapping
Appendix H – Flood hazard mapping
Appendix I – Flood classification mapping
Appendix J – Flood level profiles
Appendix K – Cost estimates

1. Introduction

1.1 Background

Sydney is a global city housing over 4 million people. The projected growth for the Sydney Metropolitan Area over the next 20 years has been estimated at 1.6 million people with a growth of over 900,000 predicted to occur in Western Sydney.

The New South Wales government vision for Sydney is that it should be a strong global city and a great place to live.

The New South Wales government has developed a strategy to guide the future growth of the Sydney metropolitan Area for the next 20 years to ensure the future productivity and liveability of the city. The strategy is titled *A Plan for Growing Sydney*.

To achieve the vision, the Government has identified a number of goals for Sydney. The goals are:

- Sydney remain as a competitive economy
- It is a city of housing choice to meet individual lifestyles and needs
- It is a great place to live with strong, health and well connected communities
- It should be a sustainable and resilient city that protects the natural environment

1.2 Brief

Within *A Plan for Growing Sydney* there a number of actions identified. Action 2.4.2 of *A Plan for Growing* Sydney requires the development a framework for the identification of new growth centres.

In response to Action 2.4.2 the Department of Planning and Environment (DPE) is undertaking the Greater Macarthur Investigation Area project. The overarching aim of this project is the determination of whether the Greater Macarthur Investigation Area (Investigation Area) is suitable for urban development and population growth.

A number of threshold issues are concurrently being investigated to guide the determination of the suitability of the area for growth. This Water Management, Flood and Riparian Corridor study represents one of those threshold investigations.

The brief for this project responds to requirements identified by DPE to assist with the site assessment. The brief has specifically identified the need for:

- Flood modelling
  - Review and collation of existing flood studies for the Investigation Area
  - Having regard to the Floodplain Development Manual and Council guidelines undertake a strategic level assessment to:
    - Develop flood modelling for the Investigation Area and prepare flood level contour, flood extent and hazard mapping for a range of events up to and including the Probable Maximum Flood (PMF) event
    - Identification of an appropriate flood planning level
    - Preparation of an appropriate flood evacuation strategy to meet effective flood access requirements within the Floodplain Development Manual (DIPNR 2005)

        - Examine how flood levels will change as a result of climate change using the practice described in the *Floodplain Risk Management Guideline: Practical Consideration of Climate Change*
        - Examine the future refinement of the analysis that should be completed as potential site planning proceeds

- Water Management
  - Development of a strategic level water cycle management strategy addressing policy, infrastructure and service requirements along with WSUD principles
  - Recommend planning controls and land management strategies having regard to stormwater objectives of OEH
  - Provide advice on the feasibility of the adopted strategy
- Riparian Corridor
  - Completion of a review of available data and, if necessary, undertake a Riparian Corridor Assessment
  - Determination of the stream ordering within the Investigation Area
  - Establishment of the framework for future Riparian Assessments along with the determination of consultation and the level of information required to obtain strategic level approvals within the Water Management Act (WMA)
  - Provision of a discussion of the opportunities for the location of regional or local on-line stormwater measures within the Riparian Corridor
  - Provision of a discussion of the opportunities for lower order watercourses then may potentially be modified to facilitate efficient land development
- Earthworks
  - Identification of potential areas for cut and fill operations to facilitate efficient land development

1.3 Study area

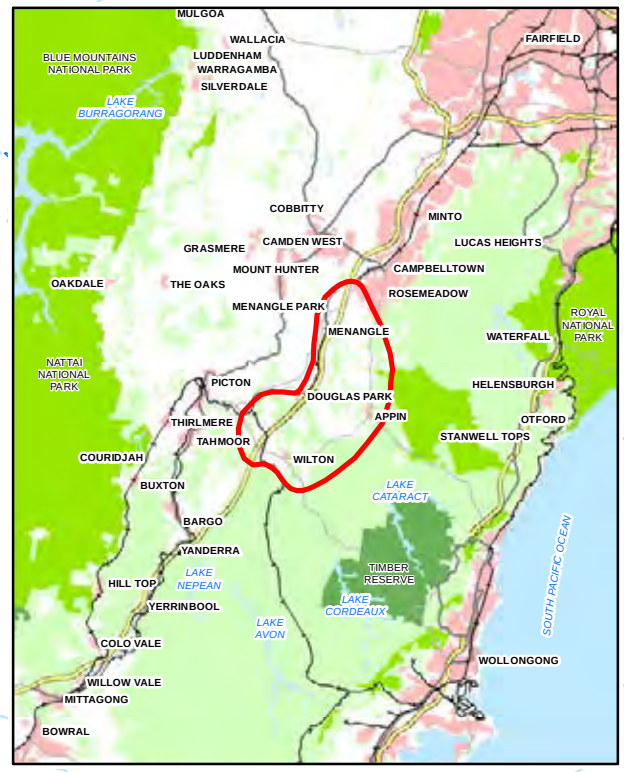
The study area adopted for this investigation includes the extent of an Investigation Area and an Urban Capable Area.

1.3.1 Investigation boundary

The initial project was identified as being the Greater Macarthur Investigation Area as shown in *A Plan for Growing Sydney.* This boundary is shown as the red boundary line on Figure 1-1 and extends from, approximately Menangle in the north, to near Wilton in the south, and from near Maldon in the west to near Appin in the east. The total area enclosed within this boundary is approximately 17,620 ha.

1.3.2 Urban capable boundary

A second boundary described as the Urban Capable boundary is also shown on Figure 1-1 as a dashed line. The alternate boundary has been developed during this assessment to potentially provide a more logical boundary that that shown in *A Plan for Growing Sydney* when considering initial outputs from the concurrent studies. The total area within this boundary is approximately 15,970 ha.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Distributor Road
- Railway
- Watercourse
- Waterbody
- State Conservation Area
- Weir

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Study Area

Figure 1-1

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM014_InvestigationArea_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

1.3.3 Boundary refinement

This report will consider the potential flooding related impacts within both boundaries to provide input to the selection of a final development boundary, should a decision be made to undertake urban development and/or further more detailed assessments.

1.4 Terminology

Location and watercourse names used within this report are those obtained from the Geographic Names Board. During the study there has been reports identified, and used, which contain additional place and road names.

1.5 Report structure

The report initially provides a description of the characteristics and features of the Study Area and surrounds. It then summarises relevant findings from previous applicable studies. Following that it contains a description the methodology and assumptions made for the assessment along with the developed WSUD strategy. Issues associated with the implementation of, and further advancement of the WSUD strategy is then provided. Finally, the implementation of the water management strategy is discussed.

2. Study area and features

2.1 Study area

The project Study Area includes both the Greater Macarthur Investigation Area as shown within *A Plan for Growing Sydney* and also the Urban Capably Boundary discussed in Section 1.3.

Menangle is located north of the Study Area which extends southward to near Wilton, west to near Maldon and east to near Appin. Figure 1-1 provides a detailed map of the Study Area and the two potential Investigation Area boundaries.

2.2 Local Government areas

The study area includes portions of the Local Government Areas (LGAs) of both Campbelltown City Council and Wollondilly Council.

2.3 Topography

The terrain shows a significant variation in level over the Study Area. In the area around Menangle the terrain level is approximately 80 mAHD while it reaches levels of approximately 270 mAHD near Appin and also approximately 270 mAHD near Wilton.

Along the length of the Nepean River, downstream of the constructed weirs, the terrain is relatively flat while there is a significant increase in elevation toward Appin Road in the east and Wilton Road near the southern boundary of the Study Area as shown in Figure 2-1.

Several of the watercourses have an incised form as reflect by the colour shading in Figure 2-1. This is particularly pronounced along the upper reaches of the Nepean, Cataract, Cordeaux and Avon Rivers.

Ground surface slopes have been derived from the available LiDAR data and are shown in Figure 2-2. On this figure the red shading represent the steepest slopes while the areas shaded as green have slopes of less than 1 vertical in 6 horizontally (1:6). On this figure the areas shown as green and yellow would be readily developable, ignoring all other ecological and bushfire constraints, using slab on ground construction with the orange areas having development constraints dur to the slope.

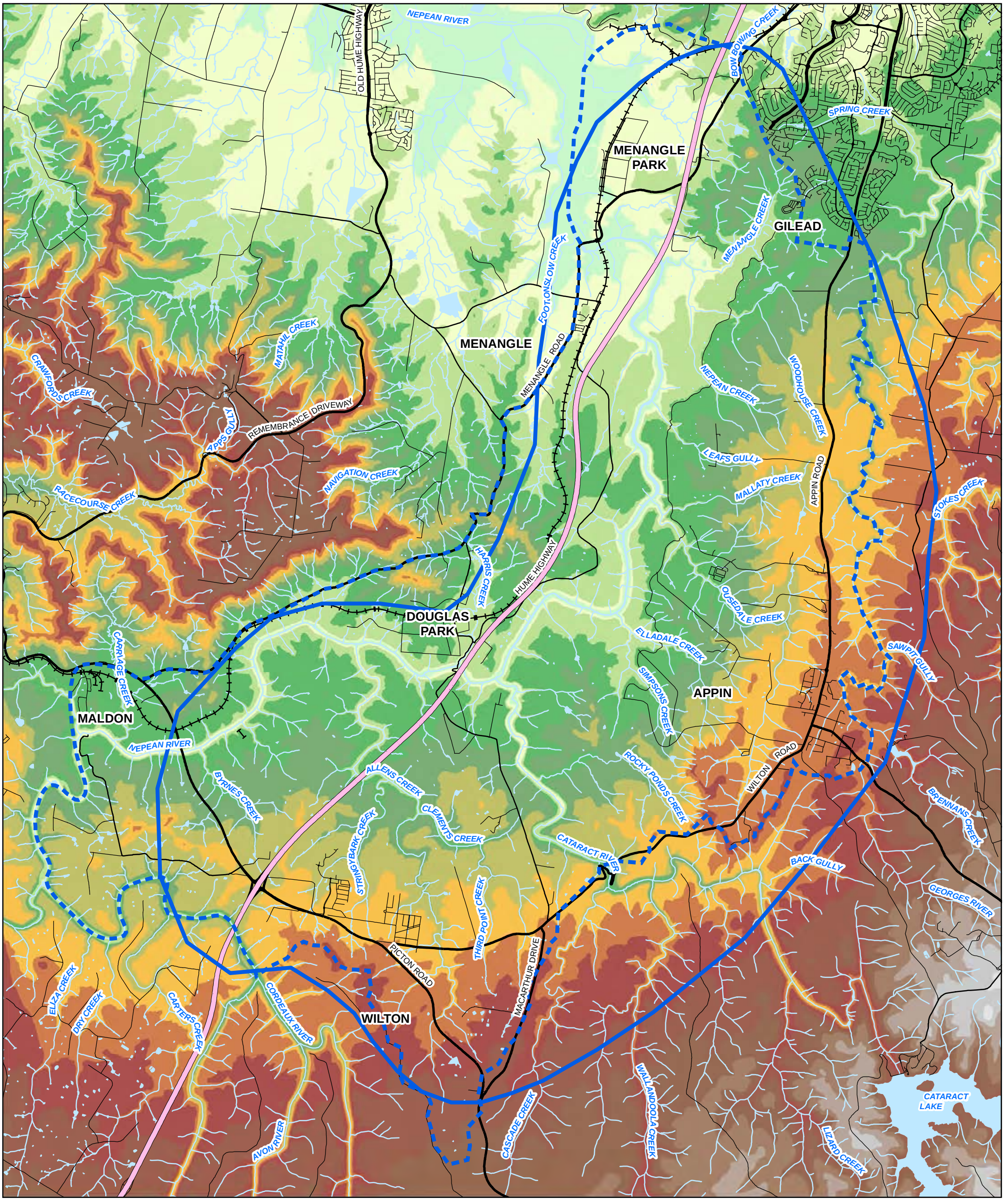
2.4 Catchments and watercourses

Two main catchments exist within and adjacent to the Study Area. They are:

- Nepean River
- Georges River

The Nepean River discharges into the Hawkesbury River and thence Broken Bay while the Georges River drains to Port Hacking.

The Upper Nepean catchment area includes the area encompassing the parts of the Cataract, Cordeaux, Avon and Nepean Rivers and is represented by lands classified as a Special Area, as described in Section 8.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Railway
- Motorway
- Primary Road
- Distributor Road
- Local Road
- Watercourse
- Waterbody

Elevation

- <= 50m
- 50m - 75m
- 75m - 100m
- 100m - 125m
- 125m - 150m
- 150m - 175m
- 175m - 200m
- 200m - 225m
- 225m - 250m
- 250m - 275m
- 275m - 300m
- 300m - 325m
- 325m - 350m
- 350m - 375m
- 375m - 400m
- 400m - 425m
- > 425m

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Topography and Watercourses

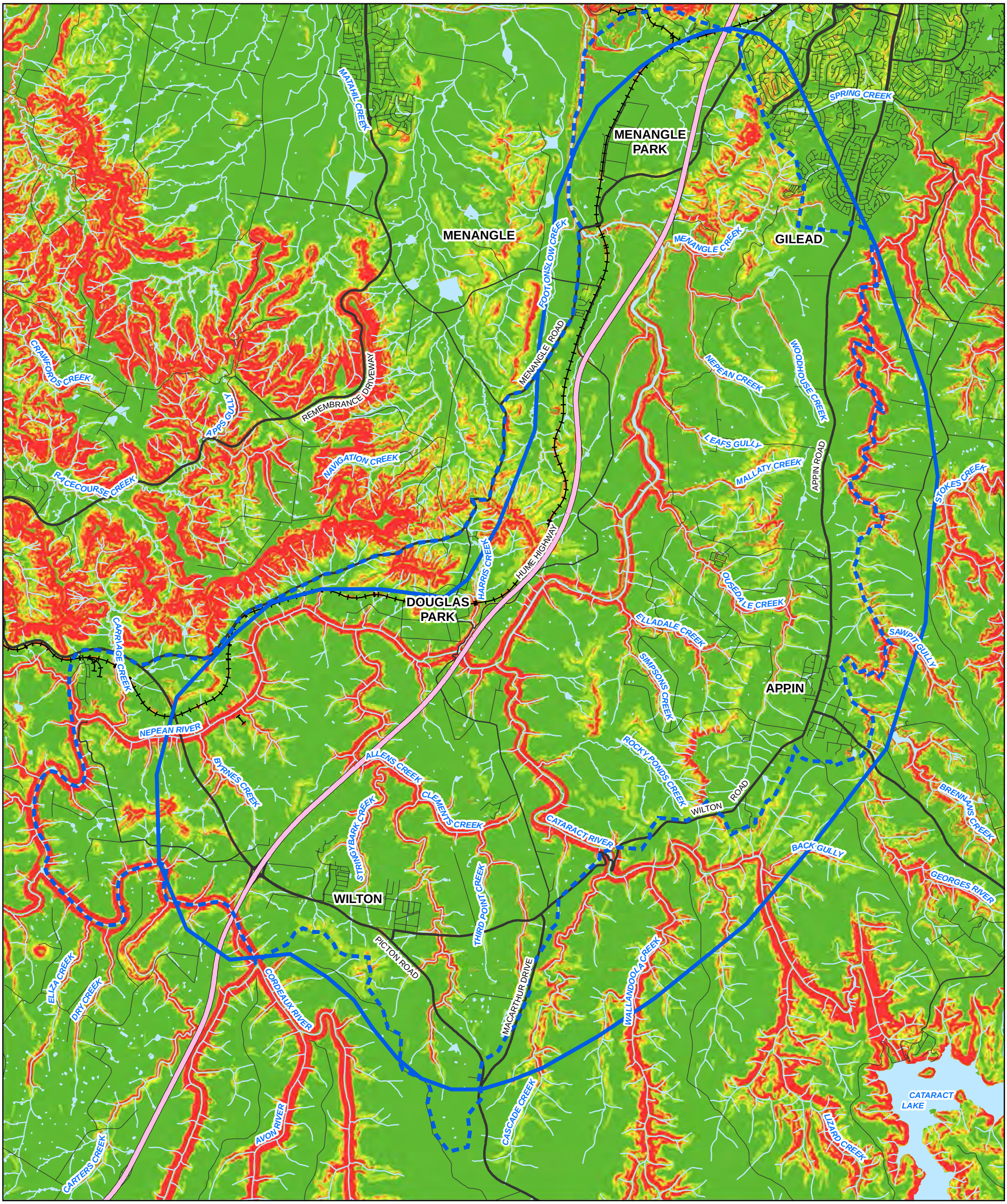
Figure 2-1

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM013_Topography_Watercourse_InvestigationArea_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Railway
- Motorway
- Primary Road
- Distributor Road
- Local Road
- Watercourse
- Waterbody

Slope

- <= 1:10
- 1:10 - 1:6
- 1:6 - 1:5
- 1:5 - 1:4
- > 1:4

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Study Area Slopes

Figure 2-2

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM012_Slopes_InvestigationArea_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

Major watercourses within and adjacent to the Study Area include:

- Nepean River - Major tributaries to the Nepean River are the Cordeaux, Avon, Cataract and Bargo Rivers
- Cataract River - A tributary of the Nepean River
- Cordeaux River – A tributary of the Nepean River
- Avon River – A tributary of the Cordeaux River
- Bargo River – A tributary of the Nepean River with a catchment area of 132 km^2
- Allens Creek – A tributary of the Nepean River
- Ousedale Creek – A tributary of the Nepean River
- Georges River

The Avon River is a tributary of the Cordeax River with their confluence being located upstream of the Study Area. The confluence of the Nepean River and Cordeax River is also located upstream of the Study Area. Similarly, the Bargo River confluence with the Nepean River is located upstream of the Study Area boundary.

Numerous smaller creeks are direct tributaries to both the Nepean River and Georges River as shown in Figure 2-1 .

2.5 Water storages for drinking water supply

Upstream of the Study Area there are four water storages that supply water into the potable water supply system for Sydney. They are:

- Nepean Dam (also known as Lake Nepean), located on the Nepean River upstream of the southern extent of the Study Area, has a catchment area of 320 km^2
- Cordeaux Dam (also known as Lake Cordeaux) has a catchment area of 91 km^2 and construction of the dam was completed in 1926
- Avon Dam (also known as Lake Avon) is located on the Avon River upstream of its confluence with the Cordeaux River. The dam has a catchment area of 142 km^2
- Cataract Dam (also known as Lake Cataract) is located south east of the Study Area on the Cataract River. The dam has a catchment area 130 km^2

2.6 Water supply weirs

Several weirs exist within the Study Area for the purpose of supplying water for general extraction by licensed users. These are the following structures:

- Pheasants Nest Weir – Water from the Nepean Dam and Cordeux Dam is extracted from this weir to be diverted, by tunnel, to Broughtons Pass Weir
- Broughtons Pass Weir – This weir is located on the Cataract River downstream of the Cataract Dam and is used to divert water into the Upper Canal as part of the Sydney water supply
- Menangle Weir – This weir is approximately 3 m high and 78 m wide. This weir supplies water to licenced water users
- Douglas Park Weir – This weir forms part of the Douglas Park Drive causeway. The weir is approximately 0.8 m high and 40 m wide and supplies water for licenced users
- Maldon Weir – This weir is a concrete structure that is approximately 15 m high and 40 m wide and the weir pool is a water supply for licenced water users

2.7 Other major infrastructure

Major infrastructure elements within the Study Area include elements for water supply, wastewater, roads and rail as shown in Figure 2-3.

Water supply

The Upper Canal which is also part of the potable water supply system for Sydney is located within the Study Area.

Water released form the Nepean Dam and Cordeax Dam flows downstream to Pheasants Nest Weir. At that location water is diverted to Broughtons Pass Weir through a tunnel. Water released from the Cataract Dam flows downstream along the Cataract River to Broughtons Pass Weir.

From Broughtons Pass Weir water is transferred into the Upper Canal to traverse the Study Area on its way to the Prospect water filtration plant.

Water is also extracted at Broughtons Pass Weir for piping to the Macarthur water filtration plant near Appin. This plant provides water to the Campbelltown, Camden Appin, Ingleburn and Wilton areas.

The Upper Canal forms a constraint within the Study Area.

Wastewater and recycled water

The West Camden STP capacity has been expanded to, in part, allow for the future servicing of future population growth within the STP catchment and to also allow for potential transfers of wastewater from the area around Menangle and Menangle Park. The West Camden STP discharges into Matahil Creek and thence the Upper Nepean River.

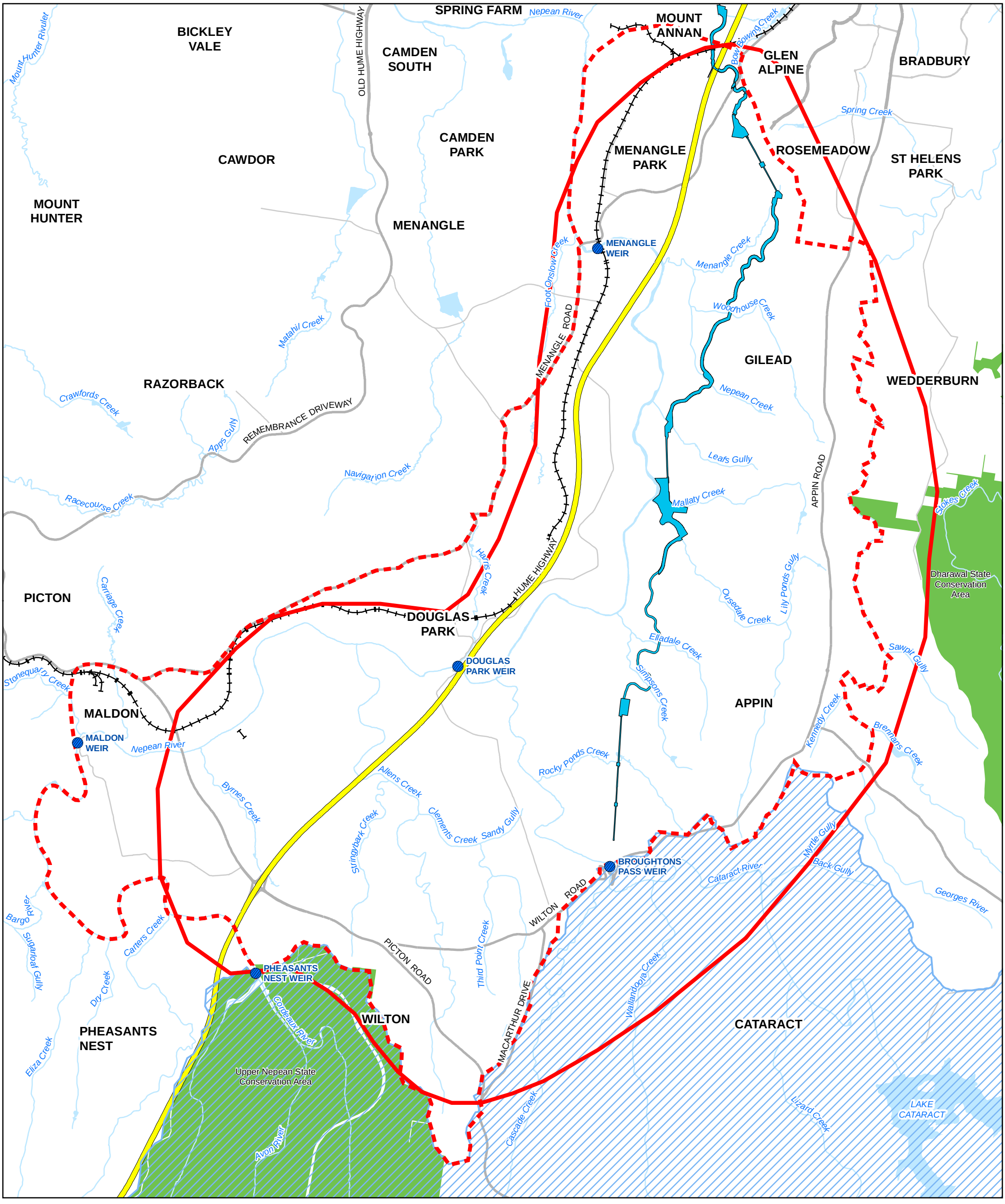
The Picton Water Recycling Plant is predicted to have an increase in flow rates as a result of urban growth and the connection of processing plants. The treatment plant and associated farm are located south of Picton and south of the Study Area. Any discharge from either the RWP or the far would find its way into one of Teatree Gully or Back Creek and thence Stonequarry Creek and eventually the Nepean River (Sydney Water 2014).

Appin has a wastewater collection system to prevent the uncontrolled discharge of wastewater to the environment.

Roads

Major roads within and near the Study Area include:

- Hume Highway (Hume Freeway, Hume Motorway, M31)
- Appin Road
- Menangle Road
- Picton Road
- Wilton Road
- Macarthur Drive



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Distributor Road
- Railway
- Watercourse
- Waterbody
- State Conservation Area
- Weir
- Upper Canal
- Special Area

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Major Infrastructure

Figure 2-3

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM016_MajorInfrastructure_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

Rail

The Main Southern Rail line passes through the Study Area. Figure 2-3 shows the location of the rail line as passing from into the Study Area from Campbelltown and passing through Menangle Park and Douglas Park before continuing through to Maldon and Camden.

The only rail crossing of the Nepean River is located south of Menangle Park.

2.8 Existing surface land uses

Land use within the Study Area, Figure 2-4, has been focused largely on agricultural pursuits with small pockets of urban development. The agricultural uses have included relatively small acreage grazing parcels, pockets of intense uses such as chicken sheds and food production (market garden style agriculture). Extractive industries (sand mining) have also been pursued north of Menangle.

Figure 2-4 identifies the existing land use within the Study Area.

Urban areas within the Study Area include Appin, Menangle Park, Douglas Park and Wilton.

2.9 Mining

Underground mining has been undertaken over a large portion of the Study Area with further mining planned to be undertaken until approximately 2030.

Three mine subsidence districts cover the Study Area. The extent of mining leases is shown in Figure 2-5.

Documentation prepared for Illawarra Coal, a subsidiary of BHP Billiton, shows the existing and planned extent of mining within the Study Area as indicated in Figure 2-6.

2.10 Restricted land uses

Restricted land use areas exist within the study area for the purposes of protecting the water supply area around Lake Cataract reservoir and protecting the water supply channel to Prospect Reservoir.

Relevant restricted land use areas are:

- Upper Canal – This is a “Controlled Area -no entry”
- Catchment areas up to and including water offtake locations on Cordeaux and Cataract rivers – These are designated as being “Special Areas – no entry”

In general the public is not permitted to enter either of these classifications of restricted land use. Consent to enter these areas can be sought from WaterNSW. Consent to enter these areas may be granted under specific circumstances and for a specific activity when an application meets all of the mandatory conditions of:

- The activity cannot be completed elsewhere
- The activity will benefit WaterNSW’s management of the relevant area or provide a broader public benefit
- The activity will not compromise the operation or management of the asset
- The activity will not:
  - Lower the water quality within the storages or catchments
  - Lower the water quality of surface and ground waters discharging into the structures
  - Have a negative impact on the ecological integrity

The restricted land use areas are shown in Figure 2-3.

BICKLEY VALE
CAMDEN
OLD HUME HIGHWAY
CAMDEN SOUTH
SPRING FARM
NEPEAN RIVER
MOUNT ANNAN
BOW BOWING CREEK
GLEN ALPINE
BRADBURY
AMBARVALE
SPRING CREEK
CAMDEN PARK
CAWDOR
MENANGLE PARK
ROSEMEADOW
ST HELENS PARK
CAMPBELLTOWN
MOUNT HUNTER
MENANGLE
GILEAD
MENANGLE WEIR
MENANGLE CREEK
FOOTONSLOW CREEK
MATAHIL CREEK
MENANGLE ROAD
WOODHOUSE CREEK
CRAWFORDS CREEK
RAZORBACK
APPS GULLY
REMEMBRANCE DRIVEWAY
NEPEAN CREEK
WEDDERBURN
NAVIGATION CREEK
LEAFS GULLY
MALLATY CREEK
APPIN ROAD
RACECOURSE CREEK
STOKES CREEK
PICTON
HARRIS CREEK
HUME HIGHWAY
DOUGLAS PARK
OUSEDALE CREEK
ELLADALE CREEK
SAWPIT GULLY
CARRIAGE CREEK
DOUGLAS PARK WEIR
SIMPSONS CREEK
MALDON
APPIN
MALDON WEIR
NEPEAN RIVER
WOLLONDILLY
ROCKY PONDS CREEK
BYRNES CREEK
BRENNANS CREEK
STRINGYBARK CREEK
CLEMENTS CREEK
BROUGHTONS PASS WEIR
CATARACT RIVER
BACK GULLY
WILTON ROAD
GEORGES RIVER
THIRD PONT CREEK
PICTON ROAD
PHEASANTS NEST WEIR
DRY CREEK
ALLENS CREEK
MACARTHUR DRIVE
WILTON
CATARACT
ELIZA CREEK
PHEASANTS NEST
CORDEAUX RIVER
WALLANDOOLA CREEK
CATARACT LAKE
CARTERS CREEK
AVON RIVER
CASCADE CREEK
LIZARD CREEK

© Land and Property Information (a division of the Department of Finance and Services) 2012

LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- LGA
- Railway
- Motorway
- Primary Road
- Distributor Road
- Watercourse
- Waterbody
- Upper Canal
- Special Area
- Weir

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Existing Land Use

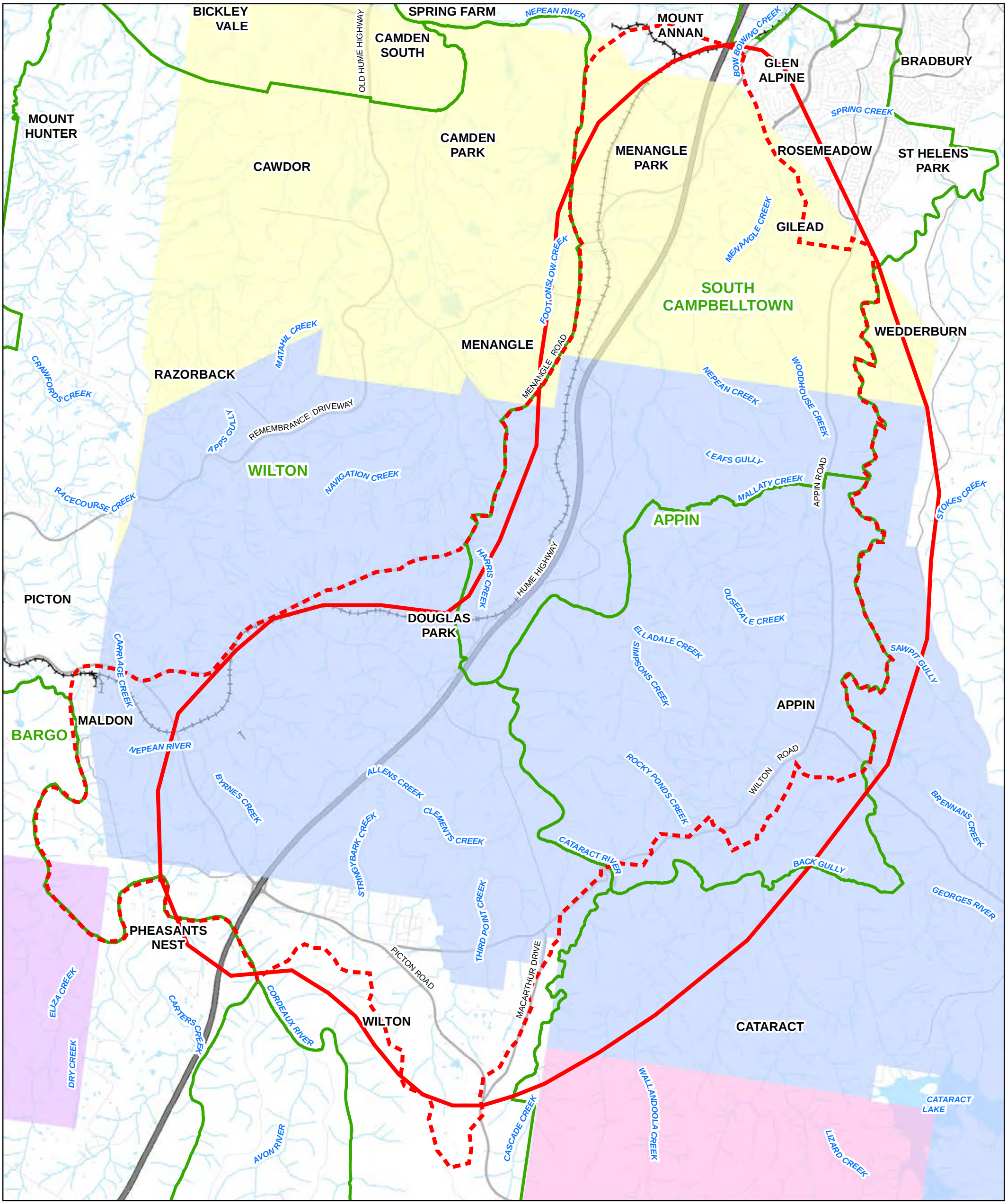
Figure 2-4

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM002_ExistingLandUse_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Mines Subsidence District
- Railway
- Motorway
- Primary Road
- Distributor Road
- Local Road
- Watercourse
- Waterbody

Mining lease

- Endeavour Coal Pty Limited
- Illawarra Coal Holdings Pty Ltd
- Tahmoor Coal Pty Ltd
- Wollongong Coal Limited

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Mining Leases

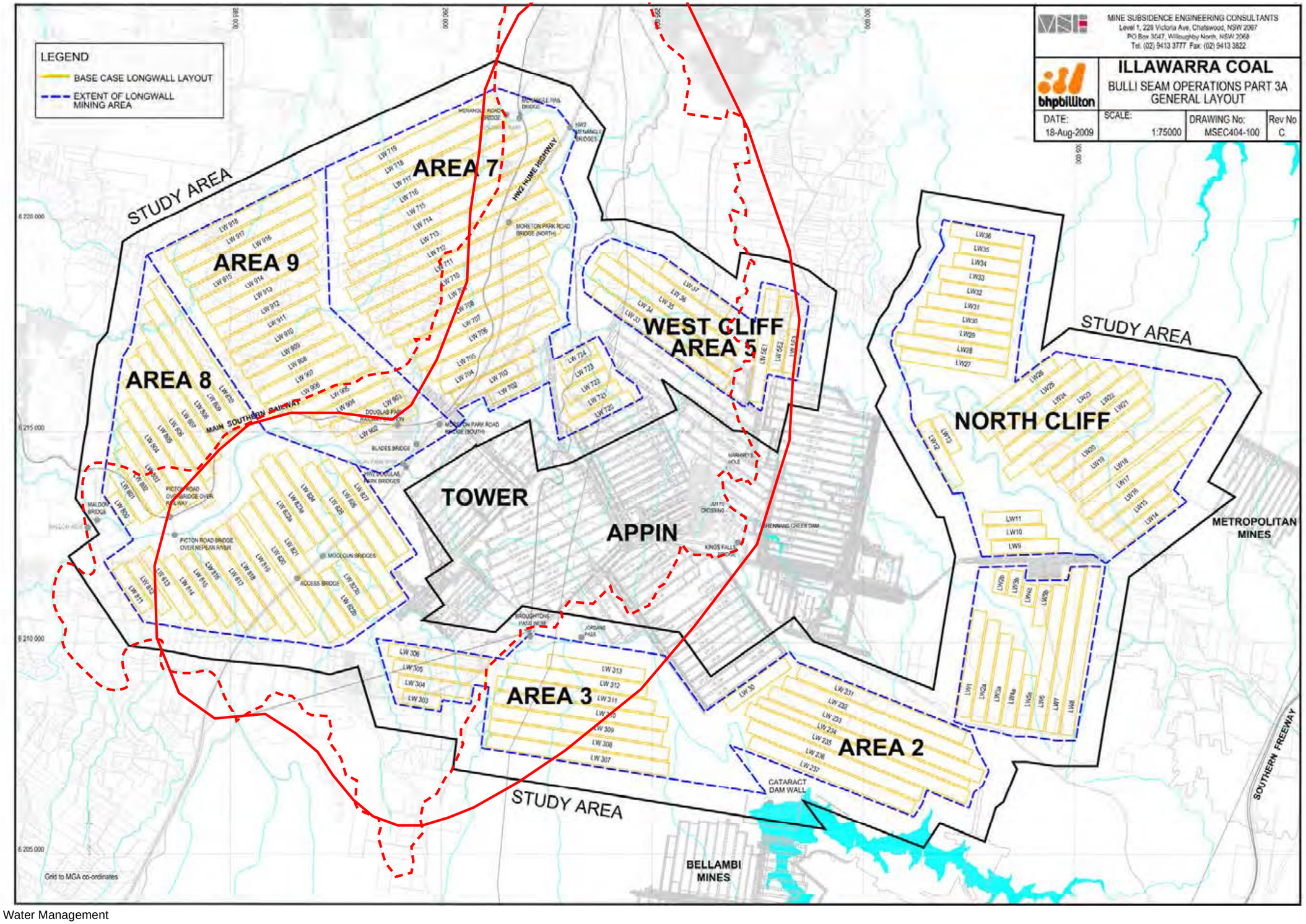
Figure 2-5

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM009_MiningLease_InvestigationArea_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton



Greater Macarthur Water Management

Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Urban Capable Boundary

Investigation Area Boundary

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Bulli Seam Longwalls

Figure 2-6

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM017_BulliLongWalls_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD, Illawarra Coal and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012). Illawarra Coal, Background data, 2015. Created by: gmcdiarmid, tmorton

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Restrictions on the development form and extent resulting from these restrictions would include:

- Residential development would be precluded in both types of restricted access area
- Stormwater runoff would not be permitted to discharge into the Upper Canal corridor. This would require that all stormwater from catchment areas upstream of the corridor would have to discharge to a watercourse upstream of the corridor
- It is anticipated that access for construction of roads across the Upper Canal corridor could be anticipated and this vehicular crossing over the corridor would be possible

2.11 Climate data

A discussion of the climate data at the Study Area is given in Appendix A. This text provides a brief summary of the material in Appendix A.

2.11.1 Rainfall

The average annual historical rainfall over the Study Area was found to be approximately 810 mm with a historical variation form approximately 460 mm to a high of approximately 1,240 mm.

Design rainfall data for this study has been adopted from the SILO data set for the Picton Council Depot (Station No: 68052). This station had a slightly lower average annual 50%ile value of 780 mm. This difference was not considered to be significant as the majority of the study elements involved the use of design rainfall values rather than the historical rainfall values.

There has been a progressive reduction in the decadal rainfalls at the Picton site between the 1970s and the 2000 to 2009 decade.

Typical years of rainfall show a slight seasonal rainfall trend with the lower average rainfall records being shown in the period of May to September inclusive with the higher rainfalls being recorded during late summer and early autumn.

The mean rainfall in each month was below 100 mm.

2.11.2 Temperature

Temperate records indicated that maximum mean temperatures could reach near 40^{o}C in January while the maxim daily temperate could drop to near 22^{o}C during June and July.

2.12 Historical flooding information and data

Historical data had been used for the undertaking of the *Upper Nepean River Flood Study* (DLWC 1995). No additional historical flood data was identified from a literature review undertaken for this assessment.

Three previous studies had been completed for current planning proposals. They were for the planning proposals for Menangle Park, Morton Road Menangle and Wilton Junction.

The first two studies identified used the HEC-HAS hydraulic model to assess flow conditions while the various studies relating to the Menangle planning proposal (GHD 2008) used the HEC-RAS software and a later study also adopted the TUFLOW model for assessing existing flooding conditions in the same area.

Data from these three studies was used for a verification check on the developed hydraulic models.

2.13 Soils

A review of the available soil landscape mapping showed six soil landscapes to be present at the Study Area, as discussed in detail in Appendix A. The present soil landscapes were:

- Blacktown – flat to gently undulating rises developed on shales of the Wianamatta Group.
- Hawkesbury – located along the major streamlines within the study area. Characterised by steep, rocky valley slopes of major watercourses incised into Hawkesbury sandstones
- Luddenham – occupies elevated areas through the central section of the study area. Characterised by rolling to steep hills developed on shales of the Wianamatta Group
- Lucas Heights – occupies gently undulating plateau areas along the eastern and south-eastern margins of the study area
- Picton – isolated occurrences on the margins of the southern half of the study area. Characterised by steep slopes prone to mass movement consisting of colluvial materials developed on shales of the Wianamatta Group
- Theresa Park – occupies alluvial floodplains and terraces along the Nepean River, Menangle Creek and Foot Onslow Creek in the northern extent of the study area

None of the identified soil landscapes posed major limitations on the potential for urban development within the Study Area. The location of the various soil landscapes is shown in Figure 2-7.

2.14 Watercourse conditions

The Strahler stream ordering system, refer Appendix A, has been used previously to classify stream within the Study Area. The previous classifications were reviewed and updated within this study.

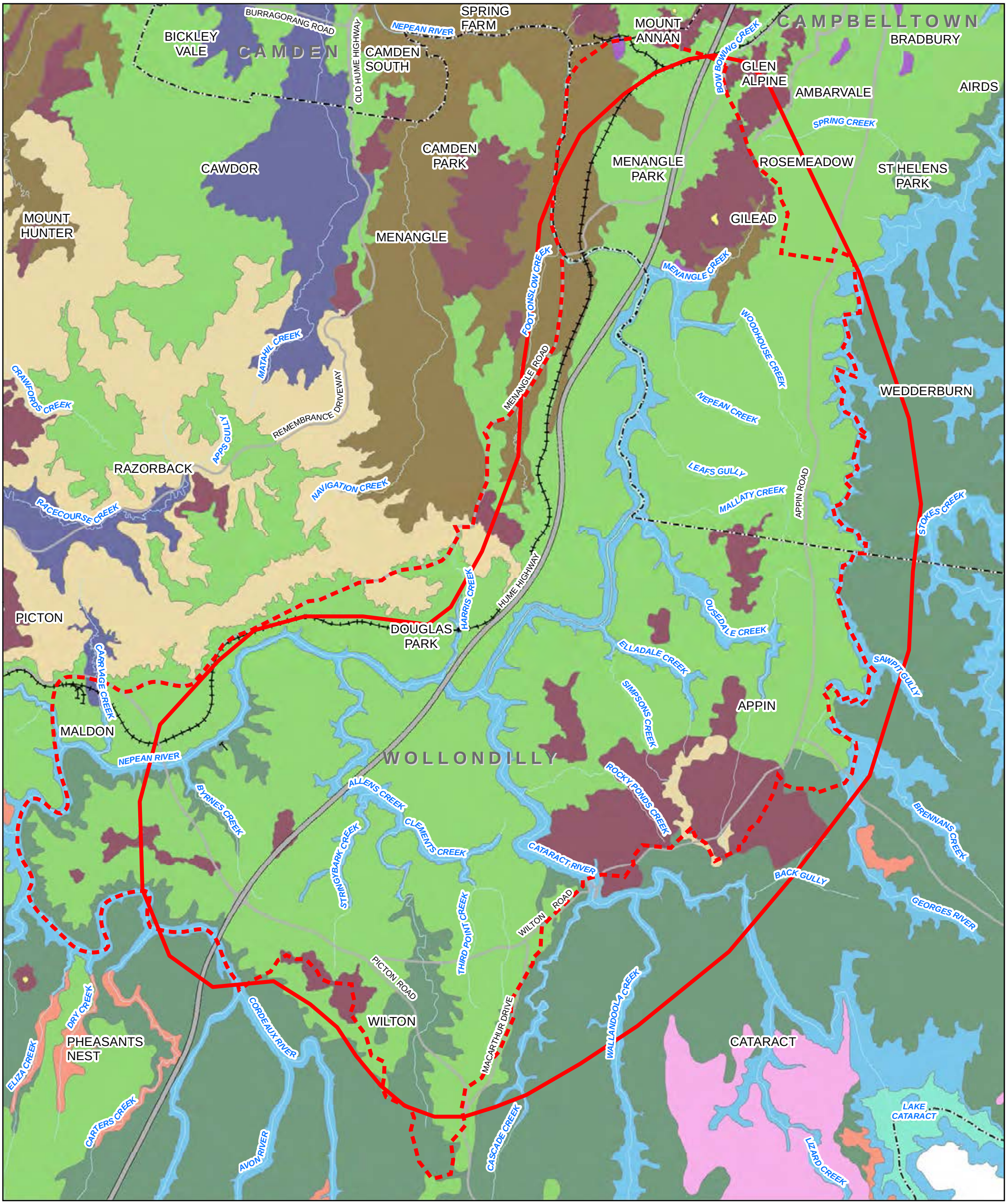
Many of the watercourses within the study area have previously been mapped and their condition assessed for studies undertaken for mining activities. Since no detailed site inspections were completed for this study it was assumed that mapping remained appropriate.

As indicated by the Study Area topography, many of the watercourses were relatively deeply incised.

2.15 Vegetation

Riparian vegetation within the Greater Macarthur area is likely to comprise the following vegetation communities, several of which are listed as Endangered Ecological Communities (EEC's) under both the *NSW Threatened Species Conservation Act (1995)* and the Federal Governments *Environmental Protection and Biodiversity Conservation Act (1999*). Mapping of communities has been undertaken in a concurrent study (ecological 2015). The communities included:

- Moist Shale Woodland
- Alluvial Woodland
- Riparian Forest
- Shale Plains Woodland
- Shale Hills Woodland
- Cumberland Shale –Sandstone Ironbark Forest
- Shale Sandstone Transition Forest (High Sandstone Influence)



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- LGA
- Railway
- Motorway
- Primary Road
- Watercourse
- BLACKTOWN
- DISTURBED TERRAIN
- GYMEA
- HAWKESBURY
- LUCAS HEIGHTS
- LUDDENHAM
- MADDENS PLAINS
- MONKEY CREEK
- PICTON
- THERESA PARK
- VOLCANIC
- WATER

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Soil Landscapes

Figure 2-7

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM010_SoilLandscapes_InvestigationArea_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

- Shale Sandstone Transition Forest (Low Sandstone Influence)
- Sydney hinterland Exposed Sandstone Woodland
- Sydney Hinterland Grey Gum Ridgetop Forest
- Upper Georges River Sandstone Woodland
- Nepean Sandstone Gully Forest
- Sydney Hinterland Apple-Blackbutt Gulley Forest
- Western Sandstone Gully Forest
- Coastal Sandstone Riparian Scrub
- Cumberland Riparian Scrub
- Riparian Scrub

3. Previous studies and development proposals

3.1 Planning proposals and rezoning

Planning proposals have been prepared for significant land rezonings for the following sites:

- Menangle Park
- Wilton Junction
- Moreton Park Road, Menangle
- Mt Gilead
- Macquarie Road, Appin
- West Appin

The location of the planning proposals are shown in Figure 3-1. Each of these planning proposals has been considered during this study. A detailed summary of key relevant features from these planning proposals is provided within Appendix B of this report. A number of planning proposals have also previously been prepared for smaller developments within the Study Area – these were not considered in as much detail as the ones specifically identified above.

Detailed discussions of the relevant components of the planning proposals are provided in Appendix B with brief overviews are provided below.

3.1.1 Menangle Park

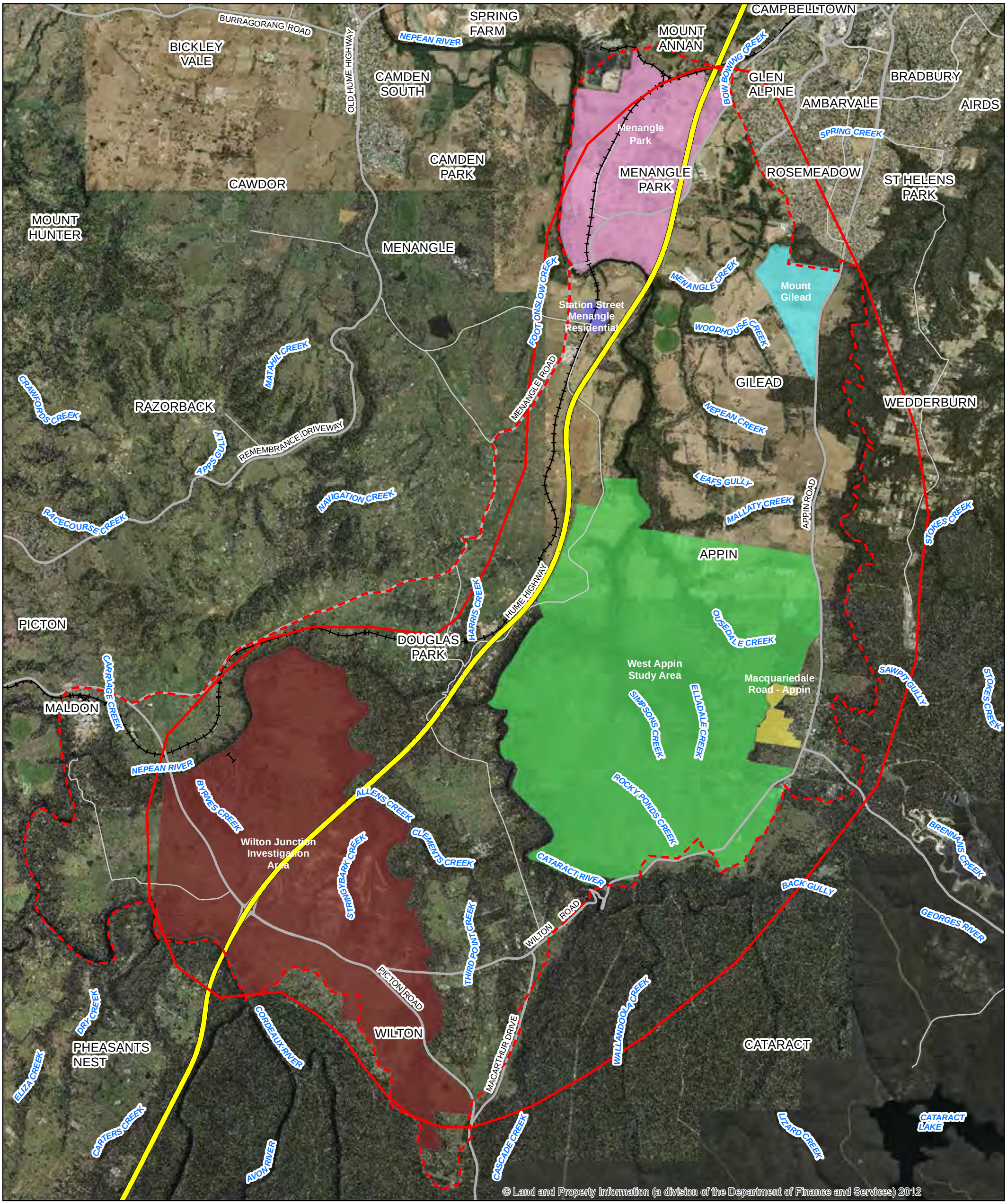
This planning proposal is for the development of land located around the eastern side of the Menangle village. The site covers approximately 890 ha of land bounded by the Nepean River to the west and south, the Hume Highway and Menangle Road to the east and Mount Annan Botanic Garden to the north.

As part of the technical studies completed for the proposal there was an assessment of the impacts of flooding from the Nepean River and tributaries. That study (GHD 2008) showed a significant portion of the subject site to be impacted by the 100 year ARI flood event.

Areas of high quality vegetation were identified throughout the development area and these posed further constraints on the development form. The ecological constraints have been addressed through a combination of retention and enhancement of riparian corridors and implementation of an offsetting strategy.

Following a detailed review of the development potential a yield of approximately 3,400 dwellings has been adopted for the site.

AECOM (2010) have documented a proposed WSUD strategy for the Menagle Park area. WSUD objectives adopted for the site are detailed in Table 3-1.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Distributor Road
- Railway
- Macquariedale Road - Appin
- Menangle Park
- Mount Gilead
- Station Street Menangle Residential
- West Appin Study Area
- Wilton Junction Investigation Area

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Planning Proposals

Figure 3-1

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM011_PlanningProposalAreas_InvestigationArea_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

Table 3-1 Performance targets

Objective	Performance Measure and Target
Water conservation	Combination of water efficiency and reuse for a 45% reduction on the benchmark water use(247 L/p/d) *Stretch target* - 60% reduction on the benchmark water use Where a reticulated non potable recycled water supply is available the target reduction is increased to 60% with the stretch target increased to 70% reduction on benchmark water use
Stormwater pollution control	55% reduction in mean annual load of Total Nitrogen 70% reduction in mean annual load of Total Phosphorus 85% reduction in mean annual load of Total Suspended Solids
Flow management	Maintain 1.5 year ARI peak discharge to pre-development values Stream Erosion Index of 2 *Stretch target* – Stream Erosion Index of 1
Flood protection	Maintain the 5 to 100 year ARI peak flow rates to pre-development values
Riparian corridor management	Corridors to meet NSW Office of Water requirements
Wastewater pollution control	No dry weather sewer overflows Restrict wet weather sewer overflows to a maximum of 10 overflows each 10 years

The adopted WSUD scheme contained a mix of regional wetlands and bioretention areas fur urban catchments along with a range of swales along roads in flatter areas.

An evaluation of the element sizing indicated an average wetland area of 450 m^2/ha of catchment area (4.5% of total catchment area) when ignoring a Transgid site and the bioretention areas averaged 75m^2/ha of catchment (0.75% of catchment area).

3.1.2 Wilton Junction

Wilton Junction water cycle management strategy

The Study area for the study was identified (J Wyndham Prince 2014) as being approximately 2,480 ha located around the Hume Highway-Picton Road intersection near Wilton. The Nepean River forms the northern and western boundaries of the site while Allens Creek forms the eastern of the Study area. Of that total area, approximately 455 ha (Bingara Gorge) has already been rezoned for residential development.

The study reports that a land capability assessment for the site has not identified any soils related impediment that would preclude development. The report does acknowledge the soils to be erosive and aggressive to concrete but there was reportedly no evidence of salinity or sodicity concentrations that would be an impediment to development.

The proposed water cycle management strategy was documented to include:

- On lot measures:
  - Water efficient fittings and appliances in dwellings
  - Rainwater tanks on each dwelling – to satisfy BASIX requirements
  - Minimisation of impervious surface areas
- Water quality measures:
  - Street level treatments – vortex style gross pollutant traps
  - Subdivision treatment – raingardens
- Water quantity control measures:

  - An online detention basin on Allens Creek upstream of Picton Road
- Water holding structures
  - Six are proposed – two of these only receive treated wastewater effluent.

The report indicated that an estimate of the 100 year ARI flow at Maldon Weir was obtained from an XP-RAFTS model using different values for the Bx parameter. The predicted design flow rates of between 5,800 m^3/s and 6,700 m^3/s agreed well with the earlier value of 6,500 m^3/s determined using the DLWC RORB model.

Figure 3-2 and Table 3-2 provide results from that investigation report. The predicted flood levels were determined based upon the use of Manning n values of 0.07 for watercourse inverts and 0.20 for overbank areas.

Table 3-2 Existing and developed predicted flow rates and predicted flood levels

Location	Flow rates Existing 100 year ARI	Design flood flow rate	Flood levels Existing 100 year ARI
104.15	140	133	-
104.17	-	-	183.9
104.20	-	-	174.4
104.25	-	-	138.3
104.27	256	247	122.1
104.32	315	303	117.3
104.40	-	-	98.0
104.44	343	332	85.7
1.23	-	-	181.4
1.25	5077	5076	-
1.26	-	-	149.5
1.32	5087	5087	-
1.51	5791	5791	117.7
1.55	5800	5799	112.7
1.60	-	-	101.1
1.62	5815	5814	105.8
1.63	5938	5939	-
1.64	5965	5966	-
1.65	7166	7168	-

The adopted water quality targets adopted were reported as being total phosphorus (TP) of 0.035 mg/L and total nitrogen (TN) concentrations of 0.7 mg/L.

The adopted raingarden sizes were an average of 1% of the catchment area. The total estimated stormwater infrastructure cast was identified as being approximately $104 million.

3.1.3 Moreton Park Road, Menangle

The proposed initial land use for this site of approximately 297 ha has focussed on warehousing, logistics and manufacturing.

Elton (2011) has prepared a Planning Proposal submission for the Moreton Park Road site. Key issues from that submission include:

- The proposal was for potential creation of employment lands along Moreton Park Road and residential development and open spaces adjacent to Menangle Village. The total site area being approximately 600 ha
- The preferred wastewater servicing option was identified as being an onsite wastewater recycling plant
- The housing component of the proposal was identified as being above the estimated 100 year ARI level of between 77 mAHD and 78 mAHD

3.1.4 Mt Gilead

The Planning Proposal covers an area of approximately 210 ha, located adjacent to Appin Road, is largely cleared of vegetation. The topography generally has a slope of less that 5^{o} sloping toward the north-west. The northern portion of the site drains into Menangle Creek while the southern portion drains into the Woodhouse Creek catchment

Pockets of Cumberland Plains Woodland, Shale Sandstone Transition Forest and River-flat Eucalypt Forest are present on the site.

The proposed land use is generally residential.

Stormwater quality treatment will be through the application of “end of line” treatments such as gross pollutant traps and biofilters located within public open space areas.

3.1.5 Macquarie Road, Appin

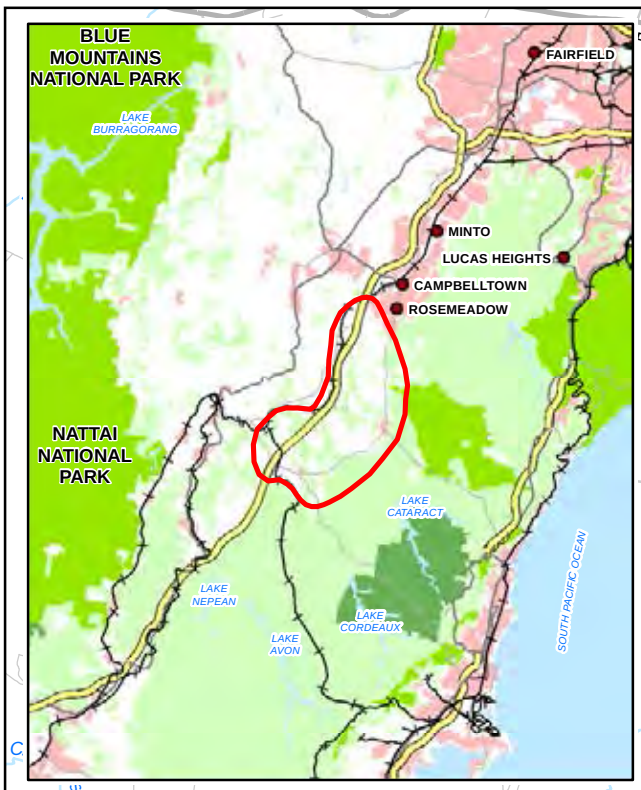
Patterson Britton & Partners (2006) prepared a preliminary riparian corridor assessment for this Planning Proposal.

Key matters from the report include:

- Ousedale Creek, a Category 2 watercourse, is located along the western side of the study area and three tributaries to Ousedale Creek drain the site
- The proposed land use is residential lots

3.1.6 West Appin

This is an area extending approximately from the west of the existing Appin village, south along Wilton Road, along the Cataract River, along the Nepean River, across the Nepean River to the Hume Highway and north to near Mallaty Creek, across to Appin Road and then south to Appin.



SPRING FARM
MOUNT ANNAN
CAMPBELLTOWN
CAMDEN SOUTH
GLEN ALPINE
BRADBURY
CAMDEN PARK
MENANGLE PARK
ROSEMEADOW
ST HELENS PARK
MENANGLE
GILEAD
WEDDERBURN
RAZORBACK
PICTON
DOUGLAS PARK
MALDON
APPIN
PHEASANTS NEST
WILTON
CATARACT

Nepean River
Matahil Creek
Bow Bowing Creek
Spring Creek
Menangle Creek
Woodhouse Creek
Nepean Creek
Leafs Gully
Mallaty Creek
Stokes Creek
Dharawal State Conservation Area
Ousedale Creek
Elladale Creek
Simpsons Creek
Sawpit Gully
Kennedy Creek
Rocky Ponds Creek
Brennans Creek
Myrtle Gully
Back Gully
Georges River
Cataract River
Sandy Gully
Clements Creek
Stringybark Creek
Byrnes Creek
Third Point Creek
Allens Creek
Wallandoola Creek
Cascade Creek
Lizard Creek
LAKE CATARACT
Upper Nepean State Conservation Area
Cordeaux River
Avon River
Carters Creek
Eliza Creek
Dry Creek
Sugarloaf Gully
Bargo River
Racecourse Creek
Navigation Creek
Apps Gully
Harris Creek
Carriage Creek
Stonequarry Creek
Foot Onslow Creek

OLD HUME HIGHWAY
HUME HIGHWAY
MENANGLE ROAD
APPIN ROAD
PICTON ROAD
WILTON ROAD
MACARTHUR DRIVE
REMEMBRANCE DRIVEWAY

77.7
77.8
77.9
78
78.1
78.2
78.3
78.4
78.5
78.6
78.7
78.8
78.9
79
79.1
79.2
79.3
79.4
79.5
101.1
105.8
110.3
85.7
112.7
98.0
117.7
117.3
122.1
138.3
174.4
183.9
149.5
181.4

LEGEND

- Wyndham Prince Prediction Top Water Level (m AHD)
- ERM 1% AEP Flood
- Investigation Area Boundary
- Urban Capable Boundary
- Railway
- Motorway
- Primary Road
- Distributor Road
- Local Road
- Watercourse
- Waterbody

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Previously Determined Flood Levels

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Figure 3-2

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM029_FloodLevels_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

3.2 Regional flooding studies

As indicated in Section 2.12 there has only been one regional flood study that partially covers the Study Area completed – that is the Upper Nepean Flood Study (DLWC 1995).

That study and the associated hydrological model have provided key inputs to this study. That study included the development of a RORB hydrological model which has been used to develop inflow hydrographs into the Study Area for several major upstream watercourses.

3.3 Local drainage studies

As summarised in Appendix B, there has been three main studies that have considered mainstream flooding within the Study Area. They were the studies associated with planning proposals for Wilton Junction and Moreton Road, Menangle.

A separate study has been prepared to support a planning proposal for Menangle Park. In that work there was an assessment of flood levels in the region downstream of Menangle Bridge and the tributary watercourses draining through the planning proposal area. Results from that study have been incorporated into the modelling results from this study.

3.4 Mining impact studies

Numerous investigations and report have been prepared for the assessment of potential and actual impacts from historical mining operations within, and adjacent to, the Study Area. These reports are discussed in detail in Appendix B of this report.

The studies have considered and reported on, as applicable to this study, the:

- Predicted subsidence impacts for and from historical mining operations
- Observed subsidence impacts from historical mining operations
- Predicted water quality impacts for and from historical mining operations
- Observed water quality impacts from historical mining operations
- Predicted and observed watercourse form impacts for and from historical mining operations
- Observed watercourse impacts from historical mining operations

In summary, for the Study Area these reports have indicated:

- Mining operations have had an impact on watercourses through the occurrence of subsidence, upsidence and closure but these landform changes have not had significant impacts on the flooding (high flow condition) in watercourses and in most instances the impacts have not been significant in low flow conditions
- Generally the observed subsidence, upsidence and closure values have been less than those predicted to occur
- Mining operations have had an impact on water quality in watercourses but these generally have not been large enough to have significant impacts on the aquatic habitat values and aquatic ecologic values in watercourses. Water quality monitoring locations are depicted in Figure 3-3

3.5 Water quality studies

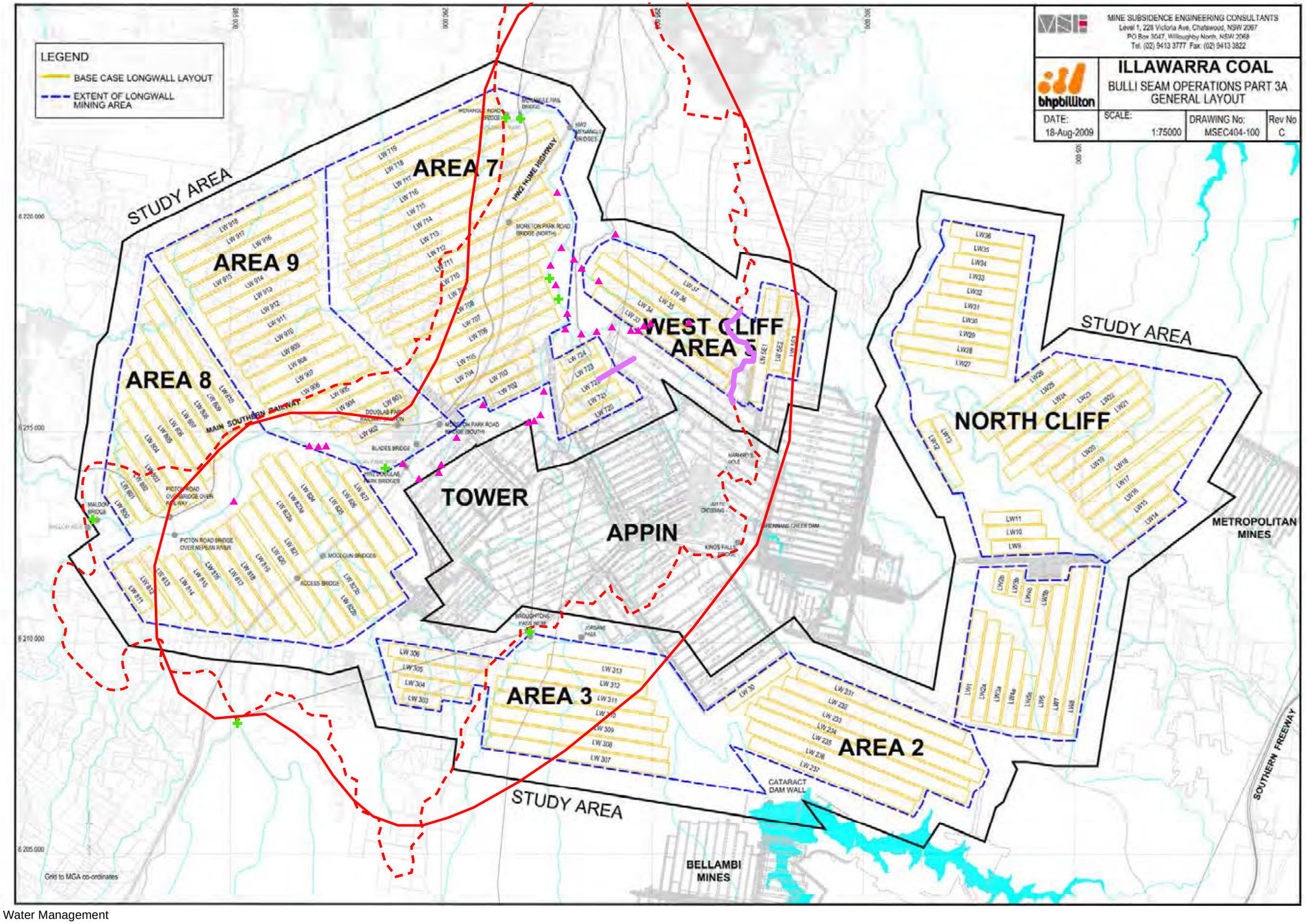
Minimal data, except for that completed as described in Section 3.4, has been sourced discussing water quality data within the Study Area. Some historical data has been available from the:

- Water NSW (formerly Sydney Catchment Authority)
- Sydney Water

- Environmental Protection Authority

The majority of this data has been specifically related to parameters associated with the monitoring of water quality in relation to the potable water supply as compared to that relating to the broader nutrient loadings and suspended solids loading as generally considered within stormwater management assessments.

The soured data, as described in Appendix B, has shown a long term improvement in the water quality.



Greater Macarthur Water Management

Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Urban Capable Boundary
- Investigation Area Boundary
- Illawarra Coal
- Others
- Numerous locations

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Bulli Seam Longwalls and Water Quality Sampling Locations

Figure 3-3

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM027_WQ_Monitoring_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD, Illawarra Coal and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012). Illawarra Coal, Background data, 2015. Created by: gmcdiarmid, tmorton

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

4. Streams and riparian corridors

4.1 Stream classification

As described in Appendix A, the watercourses within the Study Area have been classified and mapped using the Strahler classification system, with the classification shown in Figure 4-1.

Prior to the undertaking of the mapping a comparison of the best available mapping of watercourses (1:25,000 map scale) covering the Study Area with LiDAR data indicated that the mapped watercourses are often poorly aligned spatially with watercourse positions.

To improve the spatial accuracy of riparian corridor mapping, a LiDAR derived watercourse network was developed based on a minimum catchment area of 10 hectares. The Strahler (1952) stream order system methodology was subsequently applied to the LiDAR derived stream network in the study area.

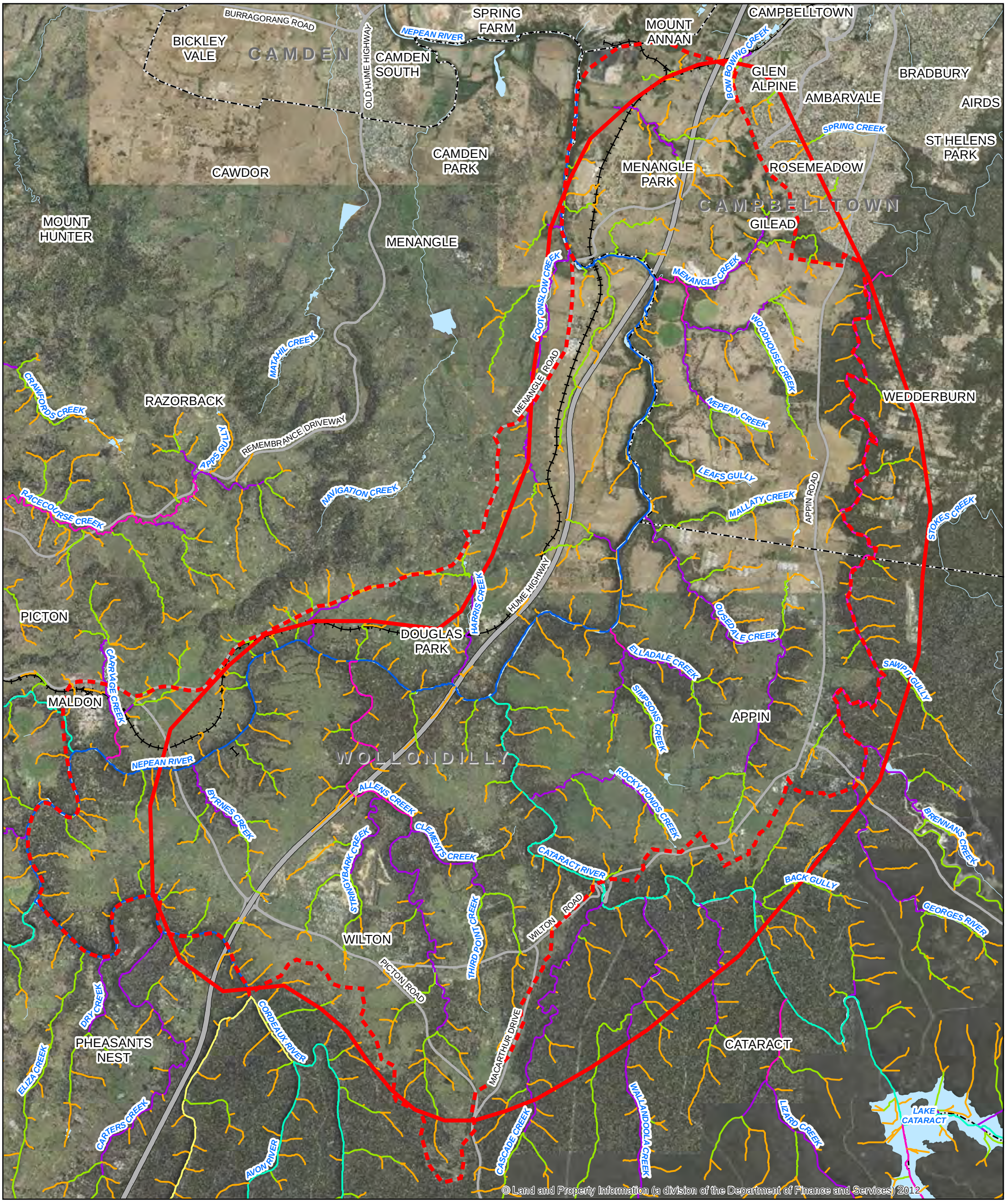
Details of the Strahler ordering are given in Appendix A. Figure A-14 indicates the Strahler stream ordering process for a generic catchment. Numbering begins at the top of a catchment with headwater ('new') flow paths being assigned the number one. Where two flow paths of order one join, the section downstream of the junction is referred to as a second order stream. Where two second order streams join, the watercourse downstream of the junction is referred to as a third order stream, and so on. Where a lower order stream (e.g. first order) joins a higher order stream (e.g. third order), the area downstream of the junction will retain the higher stream order.

4.2 Watercourse form and condition

The majority of watercourses within the study area greater than 3rd order are confined valley systems incised into the surrounding landscape. The rugged nature of these systems means that they are relatively undisturbed and largely in good geomorphic condition. These systems are also robust and are not prone to changes in channel form in response to alterations in hydrologic regimes.

The main exception is the lower reach of the Nepean River in the northern extent of the study area. Here the river becomes primarily alluvial with floodplains and terraces typically flanking both sides of the channel. A review of channel changes along a section of the Nepean River downstream of Menangle Park through a review of historical aerial photographs dating from 1958 indicated the channel remained relatively stable with only localised occurrences of bank retreat of up to 10 metres over the time period. As a result, the Nepean River channel through this reach is considered relatively laterally stable, although it has the capacity adjust in response to alterations in hydrologic regimes.

The bulk of first and second order watercourses are primarily located in the cleared, lower sloped sections of the study area and exhibit both channelised and unchannelised watercourse forms. These watercourses have been subject to a variety of agricultural pressures including clearing of riparian vegetation, unrestricted stock access and the construction of online farm dams. As a result, many of these watercourses are considered to be in moderate to poor geomorphic condition and in places exhibit evidence of channel incision and ongoing bank erosion issues.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- LGA
- Railway
- Motorway
- Primary Road
- Watercourse
- Waterbody

Stream Order

- 1
- 2
- 3
- 4
- 5
- 6
- 7

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Strahler Stream Order

Figure 4-1

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM007_StrahlerStreamOrder_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

4.3 Riparian vegetation overview

The riparian vegetation within the Greater Macarthur area is being mapped in detail by EcoLogical (2015).

4.4 Terminology

Terminology for the discussion of the riparian vegetation includes:

- Watercourse means "river" within the meaning of the Water Management Act 2000
- *Channel* comprises the bed and banks of the watercourse (to the highest bank)
- *Vegetated riparian zone* means the combined inner 50 per cent of land adjacent to a channel and the outer 50 per cent
- *Riparian corridor* (RC) incorporates the channel plus the vegetated riparian zone (VRZ) on each side of the channel
- *Stream order* means the watercourse order as classified under the Strahler stream ordering system of for watercourses according to the number of tributaries associated with it

4.5 Riparian corridors

4.5.1 Legislative and planning framework

In preparing this riparian corridor strategy, GHD reviewed the following documents and incorporated relevant requirements:

- NSW Office of Water (NOW) (2012), *Guidelines for riparian corridors on waterfront land*
- *NSW Water Management Act 2000*
- NSW Office of Environment and Heritage (2014) *Framework for Biodiversity Assessment (FBA), NSW Biodiversity Offsets Policy for Major Projects*
- NSW Government Department of Primary Industries *Policy and guidelines for fish habitat conservation and management. (2013 update)*

4.5.2 Watercourse categories

For the purposes of this strategy, GHD classified waterfront land in the Greater Macarthur area into four watercourse categories based on the Strahler stream order. Current 1:25 000 topographic maps were used to determine the appropriate stream order. A desktop GIS mapping task was undertaken to identify the stream categorisation and 'top of bank' (TOB) mapping. Recommended minimum riparian corridor widths are described in Table 4-1, below, and proposed built forms adjacent to watercourses are shown in Figure 4-2.

Table 4-1 Recommended riparian corridor widths

Stream Order	Riparian Category	Minimum Riparian Width (either side of the channel)	Total Riparian Corridor Width
1st Order	Category 1	10m Vegetated Riparian Zone (VRZ)	20m plus channel width
2nd Order	Category 2	20m VRZ	40m plus channel width
3rd Order	Category 3	30m VRZ	60m plus channel width
4th Order and greater	Category 4	40m VRZ	80m plus channel width

4.5.3 Riparian corridor management strategy

Development should comply with the watercourse category controls in a way that achieves the objectives for the relevant category.

The riparian corridor matrix (NOW, 2012) identifies certain non-riparian works that are allowed within the outer 50 per cent of the VRZ (such as asset protection zones, pathways, detention ponds etc), the riparian category these types of works can occur in and the offsetting requirements (the 'averaging rule') for such works.

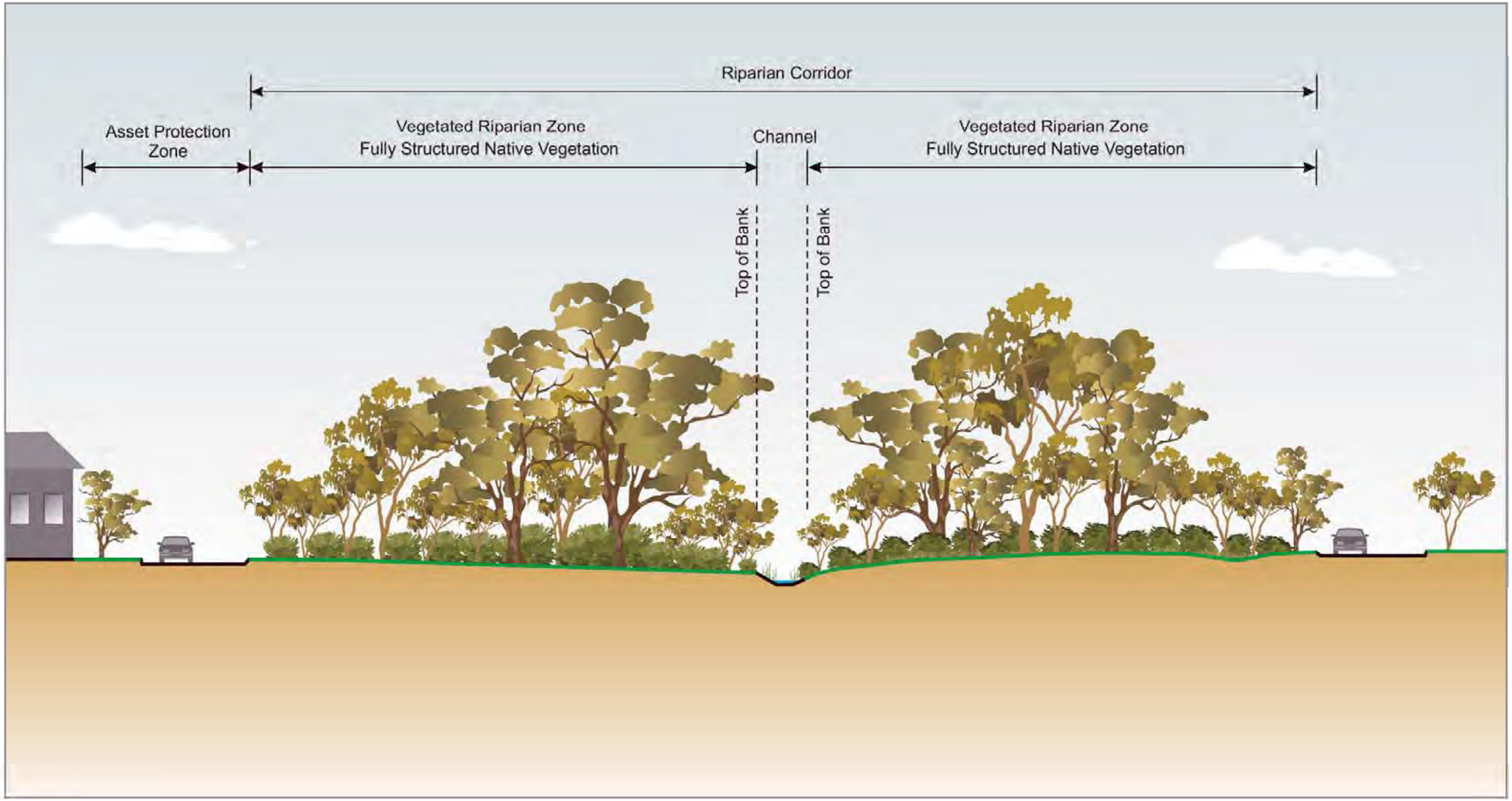
Specific objectives and controls for each watercourse category (based on NOW controlled activity guidelines for riparian corridors 2012) are described in Table 4-2.

Table 4-2 Recommended riparian corridor strategy

Riparian Category	Objectives	Controls
Category 1	• To retain, maintain and improve where possible the natural functions of the watercourse including bed and bank stability to protect local water quality. • Where it is not possible to retain the natural functions of a stream, an engineered solution to the watercourse will be considered subject to the proposed development satisfactorily demonstrating minimal impacts on downstream riparian protection areas. • Any realigned watercourse must meet all of the above outcomes.	• Provide a total riparian corridor of 20m (10m VRZ each side of channel plus the width of the channel). • Restore and rehabilitate the VRZ with local provenance vegetation. • Filling is to be avoided in order to retain the natural stream bed and bank profile.
Category 2	• To retain, maintain and improve where possible the natural functions of the watercourse including bed and bank stability to protect local water quality. • Where the natural functions of a stream are proposed to be retained and restored, a continuous, viable VRZ which emulates the native vegetation communities in the area is to be provided to facilitate a stable watercourse. • Provide a continuous, vegetated riparian corridor for the movement of flora and fauna species. • Any realigned watercourse must meet all of the above outcomes.	• Provide a riparian corridor of 40m (20 m VRZ each side of watercourse) plus the width of the channel. • Restore and rehabilitate the VRZ with fully structured, local provenance vegetation. • Minimise the number of road crossings and ensure riparian connectivity is maintained. • Provide lateral connectivity for in-stream function • Engineered drainage solutions are to be used as a last resort within the riparian corridor with appropriate Water Sensitive Urban Design (WSUD) approaches to be used within sensitive areas.
Category 3	• To maintain and improve the natural functions of the watercourse and its aquatic and terrestrial qualities and provide a continuous, vegetated riparian corridor for the movement of flora and fauna species. • To maintain and improve the viability of native riparian vegetation. • To provide a continuous, viable VRZ which	• Provide a riparian corridor of 60m (30 m each side of watercourse) plus the width of the channel. • Restore and rehabilitate the VRZ with fully structured, local provenance vegetation. • Ensure vegetation in the VRZ is at a density that would occur naturally. • Minimise the number of road crossings and ensure riparian connectivity is maintained.

Riparian Category	Objectives	Controls
	emulates the native vegetation communities in the area to facilitate a stable watercourse, while allowing limited opportunities for vegetated dry basins in a manner that does not reduce the function of the riparian corridor. • To recognise that the riparian protection areas are located within urban contexts and provide, in addition to their environmental benefits, valuable amenity, character, landscape and open space benefits to the people who live, work and play in the local area.	• Provide lateral connectivity for in-stream function.
Category 4	• To maintain and improve the natural functions of the watercourse and its aquatic and terrestrial qualities and provide a continuous, vegetated riparian corridor for the movement of flora and fauna species. • To maintain and improve the viability of remnant native riparian vegetation. • To provide a continuous, viable VRZ which emulates the native vegetation communities in the area to facilitate a stable watercourse, while allowing limited opportunities for vegetated dry basins in a manner that does not reduce the function of the riparian corridor.	• Provide a riparian corridor of 80m (40 m each side of watercourse) plus the width of the channel. • Restore and rehabilitate the VRZ with fully structured, local provenance vegetation. • Ensure vegetation in the VRZ is at a density that would occur naturally. • Minimise the number of road crossings and ensure riparian connectivity is maintained. • Maintain riparian connectivity by using piered supports. • Ensure lateral connectivity for in-stream function. • Provide linkages to stands of remnant native vegetation where applicable

Figure 4-2 shows a typical cross section under the proposed riparian corridor management regime.



Paper Size A3

0 0.045 0.09 0.18 0.27 0.36

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Watercourse Cross Section

Figure 4-2

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM030_Watercourse_CrossSection_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD, Illawarra Coal and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012). Illawarra Coal, Background data, 2015. Created by: gmcdiarmid, tmorton

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

5. Hydrologic, hydraulic and WSUD analysis methods

5.1 Overview

This section of the report provides an overview of the hydrological, hydraulic and WSUD analysis methodology that has been sued to develop the preferred water management strategy.

Appendix E provided a detailed description of the methods used for the hydrologic, hydraulic and WSUD analysis with only an overview summary provided in this section.

5.2 Scenarios considered

Rainfall and flooding conditions were assessed for the following flood event envelopes:

- 2 Year ARI – to inform the low flow events and the Stream Erosion Index (SEI).
- 20 Year ARI – to inform flooding and the extent of relatively frequent flood events smaller than the flood planning event.
- 100 Year ARI – to inform the flood planning level and extent of flooding for that event
- PMF – to identify the maximum likely (excluding any failure of an upstream water storage dam) flood event.

For each scenario, a local catchment rainfall was considered concurrent with a relatively low flow rate/level within the Nepean River and then a flow rate in the Nepean River matching the design ARI concurrent with a relatively flow rate within the local catchments draining to the main rivers.

The specific scenarios considered as part of the hydrological assessment are provided in Table 5-1.

Table 5-1 Existing scenarios considered

Defined Events	Locally Modelled Event	Regional Hydrographs
2 Year ARI	2 Year ARI	No hydrograph
20 Year ARI	20 Year ARI	Peak 20 Year ARI
100 Year ARI, 20 Year ARI Nepean River	100 Year ARI	Peak 20 Year ARI
100 Year ARI, 20 Year ARI Nepean River – Climate Change 10%	100 Year ARI + 10% IFD Data	Peak 20 Year ARI
100 Year ARI, 20 Year ARI Nepean River – Climate Change 20%	100 Year ARI + 20% IFD Data	Peak 20 Year ARI
100 Year ARI, 20 Year ARI Nepean River – Climate Change 30%	100 Year ARI + 30% IFD Data	Peak 20 Year ARI
100 Year ARI, 100 Year ARI Nepean River	100 Year ARI	Peak 100 Year ARI
PMP	PMP	Peak 100 Year ARI
PMP, PMP Nepean River	PMP	PMP Nepean River

5.2.1 Climate change impacts

Event trends

McLukie (DEC 2007) has indicated possible changes in rainfall volumes for consideration in flooding assessments. These include. This includes:

- Increase of 10% in peak rainfall volume.
- Increase of 20% in peak rainfall volume.
- Increase of 30% in peak rainfall volume.

These variations to the 100 year ARI rainfall intensity/volume data has been adopted for this study.

These increases suggested by DEC (2007) are generally consistent with changed rainfall intensities indicated by Ministry for the Environment (2010) which suggests an increase in rainfall intensity of about 8% per 1^{o}C temperature increase.

To assess for these outcomes, the IFD data obtained for the assessment was scaled to provide the appropriate change in the rainfall intensity. Tailwater conditions for the model remained unchanged as a result of climate change sensitivities.

5.3 Hydrologic analysis

5.3.1 Approach

Runoff rates and volumes within the Study Area were assessed using the XP-RAFTS non-linear runoff routing model. This is an industry standard model for undertaking event rainfall and runoff predictions.

Runoff hydrographs generated using the XP-RAFTS were incorporated into the HEC-RAS hydraulic modelling for the study.

As described in Section 5.3.4 the flows generated from the upstream external catchments using the RORB hydrological model were summed, in consistent temporal units, to the flows generated using the XP-RAFTS software to give the maximum flow rate throughout the subject site.

The maximum flow rates within each reach of the hydraulic model were then determined as being the maximum flow rates within that reach.

5.3.2 Catchment representation

Sub-catchments

The Study Area catchment was sub-divided for the undertaking of the hydrological analysis to provide an appropriate level of flow definition for this strategic planning study. The sub-catchment distribution and characteristics are described in detail in Appendix E.

Land use

The current land use is a combination of vegetated, rural, small urban areas and some extractive industries. Should urban development occur within the catchment it is likely that all lands except the vegetated areas could become developed.

Impervious fractions

For the existing rural and vegetated lands an impervious fraction of 0.1 was adopted in the modelling.

Loss rates

Loss rates represent the amount of rainfall that is initially, initial loss, or continuously (continuous loss) assumed to infiltrate into the soil or be lost from that rainfall and runoff process. Loss rates shown in Australian Rainfall and Runoff (Institution of Engineers Australia 1987) for eastern New South Wales catchments have been adopted. These loss rates are consistent with indicative values nominated by the two Councils. The loss rates provided in Table 5-2 have been adopted.

Table 5-2 Adopted loss rates

	Initial Loss	Continuing Loss
Pervious	10 mm	2.5 mm/hour
Impervious	1 mm	0 mm/hour
Probable Maximum Precipitation	0.1 mm	1.0 mm

Catchment roughness

Watercourses within the catchment frequently exhibit rock outcropping occurs with much of the Nepean River indicating a rock form.

Table 5-3 summarises the range of Manning's n values adopted in the assessment.

Table 5-3 Adopted catchment roughness values

	Manning's n values Adopted
Pervious	0.05 – 0.1
Impervious	0.013 - 0.015

Chow (1959) supports the values considered in the assessment with pervious values representing natural streams of varying vegetation density and the impervious values representing a concrete or asphalt surface.

Terrain slopes

A digital elevation model of the Study Area was created using LIDAR and contour information from the NSW Land and Property Information.

5.3.3 Design rainfalls

Up to 100 year ARI

Design rainfall intensities for the 2, 20 and 100 year ARI events were obtained from the Bureau of Meteorology and the design rainfall was applied to the model using standard temporal patterns from Australian Rainfall and Runoff (IEAust; 1997).

Probable maximum precipitation

The PMP was determined using both the Generalised Short Duration Method (GSDM) (for storm durations up to 6 hours) and the Generalised South Australian Method (GSAM) (for storm durations greater than 12 hours).

Predicted peak flow rates for tributary watercourses within the Study Area occur in events less than the 6 hour event for local catchment runoff, only use of the GSDM was required for these locations.

The Nepean River however, considered a PMP flow derived from input hydrographs from modelling undertaken as part of the Upper Nepean Flood Study. PMP induced flows (PMF flows) were input to the Study Area at Pheasants Nest Weir and the Cataract River. The *Upper Nepean Flood Study* (DLWC 1995) indicated that, typically, from a regional perspective, the 12 hour storm event was critical with PMP flow peaks four to six times that of the 100 year ARI.

5.3.4 Upstream flows

External catchments upstream of the Study Area boundary were derived from the earlier RORB modelling completed for the *Upper Nepean Flood Study*. Use of that modelling allowed for the incorporation of an impact from the Nepean, Cataract, Avon and Cordeaux dams.

It must be noted that the modelling undertaken in 1995 did not consider the operational influence of other major water supply infrastructure of Water NSW associated with Pheasants Nest Weir and Broughtons Pass Weir which extract and transfer water to the Sydney drinking water system. Similarly the earlier study did not consider, in detail, any operational matters associated with possible releases of water during flood times.

5.3.5 Design flow rates

Design flow rates were determined for watercourses within the Study Area by applying the nominated sub-catchment configuration, loss rates, catchment characteristics to the XP-RAFTS model and then operating the model for the design ARI events having a broad range of durations. From the results the maximum flow rates was extracted from the results and applied within the hydraulic modelling.

Comparison to previous studies

Design flows along the Nepean River predicted from the adopted modelling approach were consistent with flow rates previously reported for the Nepean River.

5.4 Hydraulics

The HEC-RAS model was selected to provide the hydraulic analysis for this study.

5.4.1 Scenarios considered

The scenarios described in Section 5.2 were analysed using the HEC-RAS model.

5.4.2 Model adopted

HEC-RAS (US Army Corps of Engineers 2010) was the model selected for the analysis. This model was selected because:

- There was only a relatively minor part of the study area, which had not already been considered using 2 dimensional modelling, where 2 dimensional modelling would significantly enhance the analysis.
- Significant lengths of the watercourses were relatively steep and these would challenge the stability of many 2 dimensional (or 1 dimensional/2 dimensional flow) models without providing any significant improved value from the results
- For a planning assessment a 2 dimensional flow definition would be of minimal incremental value.

Hydraulic predictions were made using the development 1 dimensional HEC-RAS model which is a steady state model that allows for hydraulic calculations to be made on a full network of natural and constructed channels and is capable of modelling subcritical, supercritical and mixed flow regimes.

5.4.3 Watercourse representation

Watercourses analysed

Hydraulic analysis was generally restricted to the 2nd order and higher watercourses when the catchment area exceed 15 ha.

This limit was placed on the analysis as it was assumed that many of the 1st order watercourses, located within potential development areas, would be removed with any urban development. Further, the 1st order streams had relatively low design flow rates and depths.

To determine flood regimes within the Study Area a hydraulic model was established for existing conditions of selected watercourses. Watercourses were selected on the basis of significance (being named), order and catchment area contributing to its watershed. A list of watercourses that were assessed for hydraulic condition is provided in Appendix E.

Watercourse naming

Development of the hydraulic model required the development and linking of several models together to provide an easy to follow set of results. The naming shown on Figure J-1 is used where tabulations of predicted flood levels are provided.

The flow long sections provided in Appendix J have been presented as a consolidated long section for each watercourse (ie with a running chainage along the watercourse and ignoring segment names) for ease of understanding.

5.4.4 Downstream boundary conditions

Localised boundary conditions

All assessed watercourses considered an up and downstream boundary condition. A normal depth boundary condition was considered equal to the average bed gradient of each corresponding creek. The bed gradient for each watercourse is provided in Appendix E.

Regional boundary conditions

Historically flood assessments have indicated that the Nepean River is likely to be in flood concurrent with increased flows from local catchments. As part of this assessment the consideration of these concurrent flood conditions have been considered but also instances where flooding does not happen concurrently. The GHD flood study for the Menangle development considered a 5 year, 20 year and 100 year Nepean River flood coinciding with a local 2 year, 100 year and PMP events. To consider regional influences, the hydrologic and hydraulic model considers various inflow hydrographs and downstream flooding conditions for the Nepean River within the hydraulic modelling undertaken. A summary of the scenarios considered for the hydraulic modelling scenarios undertaken are provided in Table 5-4.

Table 5-4 Existing hydraulics scenario

Scenario	Locally Modelled Event	Regional Hydrographs	Downstream Boundary Condition
2 Year ARI	2 Year ARI	No hydrographs	5 Year ARI Nepean River (consistent with GHD (2008))
20 Year ARI	20 Year ARI	Peak 20 Year ARI	20 Year ARI Nepean River
100 Year ARI, 20 Year ARI Nepean River	100 Year ARI	Peak 20 Year ARI	20 Year ARI Nepean River (consistent with GHD (2008))
100 Year ARI, 100 Year ARI Nepean River	100 Year ARI	Peak 100 Year ARI	100 Year ARI Nepean River
PMP Event	PMP Event	Peak 100 Year ARI	100 Year ARI Nepean River
PMP, PMP Nepean River	PMP Event	PMP Event Nepean River	PMP Event

The downstream boundary flood heights corresponding to each of the scenarios is outlined in Table 5-5 and discussed in the following section.

Downstream boundary

Nepean at Menangle Park is a low gradient flood plain environment that was assessed by GHD in 2008 for development. The Nepean River and associated tributaries in this location were modelled in Tuflow for the 5, 20, 100 and PMF events. For this assessment, given the adoption of a one dimensional model, the incorporation of two dimensional flooding results (taken from the existing scenario) will be considered for sections downstream of the Foots Onslow Creek and Nepean River confluence.

The following Table 5-5 presents the adopted downstream boundary conditions. The downstream boundary conditions are the result from the incorporation of the two dimensional flooding outcomes in Menangle (GHD; 2008).

Table 5-5 Downstream boundary flood heights (GHD; 2008)

Scenarios	Event Considered	Flood Height (mAHD)
2 Year	5 YR at Nepean River and Foot Onslow Creek, Menangle	73.5
20 Year and 100 Year	20 YR at Nepean River and Foot Onslow Creek, Menangle	75.8
100 Year and PMP	100 YR at Nepean River and Foot Onslow Creek, Menangle	77.3
PMP	PMP at Nepean River and Foot Onslow Creek, Menangle	81.5

5.4.5 Structures

The major structures located along the watercourse were the water supply weirs discussed in Section 2.6. These structures were each represented in the hydraulic analysis with the upstream flood level being set at the crest level for the structure when its influence was not drowned through backwater flood effects from further downstream.

5.4.6 Watercourse roughness values

There are three predominant land uses that watercourses traverse. These were:

- Pastoral/cleared land
- Heavy vegetation
- Urban areas

Typically the main watercourses within the Study Area (Nepean, Cataract and Georges Rivers) are bed rock defined incised channels. On this basis many of the watercourses have a well-defined channel typical of a roughness of 0.05. Outside of the channel, watercourses are extensively lined with dense riparian vegetation. It has been considered that this dense riparian vegetation would represent a Manning's n value of typically 0.1. Manning's n has been based on typical values defined by Chow (1959).

5.4.7 Design flood levels

Design flood levels were determined using the HEC-RAS hydraulic model for the 2, 20 and 100 year ARI events together with the PMF event throughout the Study Area.

The actual methodology adopted for the analysis is described in detail in Appendix E.

Flood level predictions from the predictive modelling are discussed in Section 7 of the report and are provided in detail in Appendix J, in the form of flood profiles and tabulated flood profiles

Results of the flood predictions are discussed in Section 7 of this report.

5.4.8 Flow velocities

Design flow velocities were also determined from the HEC-RAS hydraulic model for the 2, 20 and 100 year ARI events together with the PMF event throughout the Study Area.

The actual methodology adopted for the analysis is described in detail in Appendix E with the results of the analysis discussed in Section 7 of this report.

5.4.9 Hazard

The *NSW Floodplain Development Manual* (DIPNR 2005) does indicate that there is a limiting maximum depth of water of 0.3 m for vehicles and a limiting maximum velocity of 2 m/s for vehicle stability and it also places upper limits on depth (0.8 m) and velocity (2.0 m/s) for people to safety wade in water.

Recent reports prepared for the revision of Australian Rainfall and Runoff (Cox etal 2010) and Shand etal (2011) have provided diagrams of hazard categories for pedestrians and vehicles. Cox etal (2010) provided information relating to pedestrians and reported the hazard (velocity depth product) separately for infants having a height mass product less than 25 and frail persons, children (height mass product between 25 and 50) and adults with a height mass product in excess of 50 as well as more generally children and adults. The second study for vehicle stability (Shand etal 2011) has also shown a draft interim classification.

A flood hazard classification system that has been adopted for the definition of the flow areas has been adopted from Attorney-General's Department (2014). Information reported by the

Attorney-General's Department (2014) does differ from that reported in a Stage 1 report for the revision of Australian Rainfall and Runoff (Cox etal 2010). In that document the hazard (velocity depth product) is reported separately for infants having a height mass product less than 25 and frail persons , children (height mass product between 25 and 50) and adults with a height mass product in excess of 50.

This classification system adopts a six level classification system, H1 to H6, based upon a combination the velocity depth product with limiting values superimposed for flood depth and flood velocity.

Flood hazard was determined for the existing and proposed conditions in accordance with the NSW Floodplain Development Manual. Since the majority of floodwaters are deeper than 1 metre, the majority of the assessed watercourses are categorised as high hazard.

The definition of hazard levels are summarised in Table 5-6.

Table 5-6 Definition of flood hazard (Australian Emergency Management Institute; 2014)

Hazard	Depth Velocity Product	Depth (m)	Velocity (m/s)
H1	Less than or equal to 0.3	0.3	2.0
H2	Less than or equal to 0.6	0.5	2.0
H3	Less than or equal to 0.6	1.2	2.0
H4	Less than or equal to 1.0	2.0	2.0
H5	Less than or equal to 4.0	4.0	4.0
H6	Greater than 4.0	Greater than 4.0	Greater than 4.0

5.4.10 Flow classification

Floodway, flood fringe and flood storage

The *NSW Floodplain Development Manual* (DIPNR 2005) proposes the use of three hydraulic categories. Namely:

- Floodway – These are identified as areas where there is a significant flow during flood times and, even if only partially obstructed, there would be a significant increase in flood levels or flow distributions across the floodplain.
- Flood fringe – The area between the floodways and the flood storage areas.
- Flood storage – Defined as areas of the floodplain that are important for temporary storage of floodwaters. Filling of flood storage areas would increase downstream flood levels but by a relatively small amount as compared to the effect of filling of a floodway.

No single definition of these classifications exists. Examples of definitions include:

- Floodway – as a first pass estimate, velocity depth product greater than 2 m^2/s (Worley Parsons 2014); velocity depth product in excess of 0.3 m^2/s for 1% AEP event and velocity depth product in excess of 1 m^2/s for the PMF (BMT WBM 2012)
- Flood fringe - as a first estimate, areas of velocity depth product lower than 2 m^2/s and depth lower than 0.3 m (Worley Parsons 2014)velocity depth product less than 0.3 m^2/s and depth less than 0.5 m for 1% AEP event and velocity depth product less than unity and depth less than 1 m for PMF (BMT WBM 2012)

- Flood storage areas – if filled would not increase flood levels by more than 0.1 m and/or increase downstream flows by more than 10% - NSW Floodplain Development Manual (2005); velocity depth product lower than 0.2 m^2/s and depth in excess of 0.3 m (Worley Parsons 2014); velocity depth product less than 0.3 m^2/s and depth greater than 0.5 m for 1% AEP event and velocity depth product less than unity and depth in excess of 1 m for PMF (BMT WBM 2012)

An iterative and more complex process for delineating the floodplain has been described by Thomas and Golaszewski (2012).

The definition adopted for this study has been as shown in Table 5-7.

Table 5-7 Flood categorisation

Category	100 year ARI Conditions	PMP Conditions
Floodway	velocity x depth >0.3 or velocity > 4 m/s	velocity x depth >1.0 or velocity > 4 m/s
Flood Storage	velocity x depth <0.3 and depth >0.5 m	velocity x depth <1.0 and depth >1.0 m
Flood Fringe	velocity x depth <0.3 and depth <0.5 m	velocity x depth <1.0 and depth <1.0 m

Flood Category, that is, the categorisation of floodway, flood storage and flood fringe lands has been assessed on the basis of the outcomes provided in Appendix I.

5.5 WSUD analysis and form

5.5.1 BASIX

It has been assumed that each dwelling and other building will be fitted with rainwater tanks and water efficient fittings to comply with the BASIX requirements. No specific analysis of the dwelling water balance has been completed.

5.5.2 Analysis

Hydrologic and detention basin sizing

An XP-RAFTS model was established for a generic catchment for both the undeveloped and developed land uses. Through evaluating the change in runoff rates and volumes as a result of the land use it was possible to determine a required 100 year ARI detention volume that would be required to achieve a nil increase in the peak rates of runoff. The required detention volume was 230 m^3/ha of catchment.

The above volume can achieve a nil increase in the peak rate of runoff for the 100 year ARI design rainfall and runoff events.

Should development proceed it would be necessary to also match the peak rates of runoff for smaller design events, at the detailed design stage, to minimise any change to the stream erosion index to reduce the potential for erosion downstream of the detention storages.

The detention volumes were located at each catchment outlet for the regional detention options while it was apportioned uniformly across the dwellings for the evaluation of the onsite detention option.

Water quality

A water quality target has not been adopted for the Study Area. Pollutant load values adopted for this assessment were, at the outlet of the regional combined detention basins/bioretention areas were:

- Hydrocarbons – non visible on discharge
- Litter – total removal
- Coarse solids –total removal
- Suspended solids – 85% removal
- Total phosphorus – 70% removal
- Total nitrogen – 45% removal

No stretch target was included for the evaluation of the regional system. Some additional benefit would be expected from the incorporation of pocket parks (allowed as 1% of the catchment area) and similar features within landscaped areas of the proposed development.

These values were generally consistent with recently adopted values shown in Table 6-1 and gave a prediction of a nil average annual increase in pollutant loads from the Study Area.

The analysis was undertaken using the MUSIC model applied to a generic catchment area to assess the required bioretention area that would be required to mitigate the impacts of the development. Results of the analysis indicated that a bioretention area of 1.5% of the catchment area would be adequate when incorporating ae extended detention depth of 0.5 m over the bioretention area was provided to maximise the amount of stormwater filtered through the bioretention area during a period not exceeding 1.5 days.

5.5.3 Adopted design form

The adopted design form for the WSUD measures would include:

- Construction of a perimeter road to direct all stormwater, up to the 100 year ARI design event, to the regional detention basin for that catchment
- Water would and pass through a forebay/GPT after discharging from the perimeter road but priot to entering the main portion of the regional detention basin/bioretention area. The forebay/GPT function would be to provide a settling area for coarse material and litter to restrict maintenance requirements for the bioretention area
- A bioretention area would be constructed on the base of the detention basin to provide a filtration of the low flow stormwater
- Above the bioretention area there would be an extended detention storage so that smaller flows could be detailed and then drain through the bioretention media to provide a filtering to remove pollutants prior to discharging to the downstream, watercourse
- High flows would discharge from the detention basin through a discharge structure into the downstream watercourse without a significant retention period

6. Assumptions

6.1 General

As a result of this being a strategic level study without detailed site planning being available, a number of general assumptions have been made. The assumptions have included:

- An overall impervious fraction for the potential developed form would be 65%
- An average lot density of 15 lots/ha would be applicable across the Study Area
- The estimated total number of lots would be around 97,000

6.2 Specific

Tables 6-1 and 6-2 provide guidance and selected specific requirements that have been considered in developing this strategy.

More detailed design information is provided by:

- Campbelltown (Sustainable City) Development Control Plan
- Development Control Plan 2015 of Wollondilly Shire Council
- Growth Centres Development Code prepared by the Growth Centres Commission (2006)
- Water Sensitive Urban Design prepared by Landcom (2009)
- Managing Urban Stormwater: Council Handbook (Draft) prepared by the Environmental Protection Authority (1997)

A summary of parameters adopted from these studies and specifically applied within this assessment are contained in Table 6.1. It should be noted that Table 6.1 is not a comprehensive list of potential future design requirements for any potential urban development for the Subject Site.

More detailed requirements and guidance that need consideration, should development planning proceed are also provided in the above documents.

Table 6-1 Water quality targets

Parameter	Campbelltown City Council	Wollondilly Council	EPA	Growth Centres	Landcom (Landcom 2009)	Menangle Park
Litter			Retention of litter larger than 50 mm for flows up to 25% of 1 year ARI			
Gross pollutant (> 5 mm)		70% load				
Coarse sediment		90% load (for sediments 0.1 to 5 mm)	Retention for sediments > 0.125 mm for flows up to 25% 1 year ARI			
Fine sediment (< 0.1 mm)		50% load				
SS Removal	80%		80%(1) of annual load	Mandatory - 85% of load Stretch – 90% of load	Baseline – 85% Stretch – 90%	85%
TP Removal	45%	Objectives set by Healthy Rivers Commission	45%(1) of annual load	Mandatory - 65% of load Stretch – 85% of load	Baseline – 65% Stretch – 85%	70%
TN removal	45%	Objectives set by Healthy Rivers Commission	45%(1) of annual load	Mandatory - 45% of load Stretch – 65% of load	Baseline – 45% Stretch – 65%	55%
Hydrocarbons	-	Greater of 90% of load or Total site discharge to have TPH < 10 mg/L	No visible oils or grease for flows up to 25% 1 year ARI			
Stream Erosion Index				2		2
Flow				Maintain 1.5 year ARI at pre-developed value		

Notes: 1. Design storm of 25% of 1 year ARI flow to be adopted

Figure 6-1 Engineering functional requirements

Parameter	Campbelltown Council	Wollondilly Council	Adopted
Onsite detention	Post development flow not to exceed pre-developed value for events up to 100 year ARI magnitude	Discharge to mimic that for the pre-developed condition for all events up to 100 year ARI	Not adopted
Onsite detention	Acceptable when existing system under capacity Currently no formal policy	Acceptable when existing system under capacity	Not adopted
Floor levels	Minimum of 150 mm above surrounding ground level Minimum floor levels at controlling 100 year ARI flood level plus freeboard	Generally 100 year ARI plus 500 mm freeboard	For main stream flooding – minimum habitable floor level at 100 year ARI level plus freeboard. Not specified in this report for overland flows
Major / minor drainage concept	Adopted	Adopted	Adopted
Impervious fractions for landuses	Provided in Section 4.9.4		Not adopted
Probable maximum flood	Safe passage of the PMF must be demonstrated		Not adopted as a flood planning level
Floodways and channels -	Hazard – velocity depth product is not restricted but should be minimised	When hazard (velocity depth product) exceeds 0.4 there must be provision for personal safety Channels are to be designed to have Froude numbers less than 0.8 Maximum velocity in grass lined channels not to exceed 2.5 m/s	Not specified in this strategy
Detention basins	Basin to perform in full range of events up to 100 year ARI magnitude to mitigate peak flow increases		Basin to perform in full range of events up to 100 year ARI magnitude to mitigate peak flow increases
	High flow outlet to be sized for the 100 year ARI event	High flow outlet to be sized for the 100 year ARI event	High flow outlet to be sized for the 100 year ARI event
	Spillway to be sized for at least the ½ PMF event without failure		Spillway to be sized for at least the ½ PMF event without failure

Parameter	Campbelltown Council	Wollondilly Council	Adopted
WSUD	Principles adopted	Principles adopted	Principles adopted. Allowed for treatment in detention basins but pocket parks may be included into final design
	Distribute water quality treatment preferred rather than relying upon end of pipe solutions		End of pipe solution for each catchment. Landform requires many treatment locations
	Need to consider site characteristics, social issues, operational, maintenance costs in selecting measures/strategy		Site characteristics to be considered in detail at detailed design
Public Safety	All measures will be considered using NSW Police "Safer by Design or Crime Prevention Through Environmental Design" principles		At detailed design measures will need to be considered using Safer by Design or Crime Prevention Through Environmental Design
Rainwater tanks	Required to satisfy BASIX		Assumed adopted for satisfy BASIX
Climate Change	The effects of a 10% increase in rainfall intensity is to be examined		At detailed design will need consideration
Buildings on flood affected land		Buildings, fillings and structures are allowed in floodplain areas other than floodway limits for 100 year ARI event, buildings and structures in these area are to be designed to withstand flood damage (buoyancy, scour and debris impacts)	Buildings permitted on floodplain areas outside floodways. Building controls will be applicable.

7. Developed water management strategy

7.1 Extent of development

The extent of development adopted for the initial elements of the investigation is that shown in Figure 7.1. The total development footprint represents an area of approximately 9,280 ha within the Study Area boundary and approximately 9,230 ha within the Urban Capable boundary.

As will be discussed later, in Sections 8 and 9 the final Developable Area was smaller than that shown in Figure 7-1.

The development extent shown in figures within this and subsequent sections of the report do not show a restricted buffer along the edges of the Upper Canal. At the scale of figures provided within this report such a buffer would not be visible.

Examination of the available terrain data suggests that stormwater from upslope of the Upper Canal could potentially be directed around the corridor without the incorporation of a significant buffer area upslope of the corridor. It will be necessary to construct detention facilities immediately upslope of the corridor.

Accessed information has not identified the need for a buffer area. As part of design advancement it would be prudent to liaise with WaterNSW to confirm any specific requirements relating to the appropriate protection of this corridor.

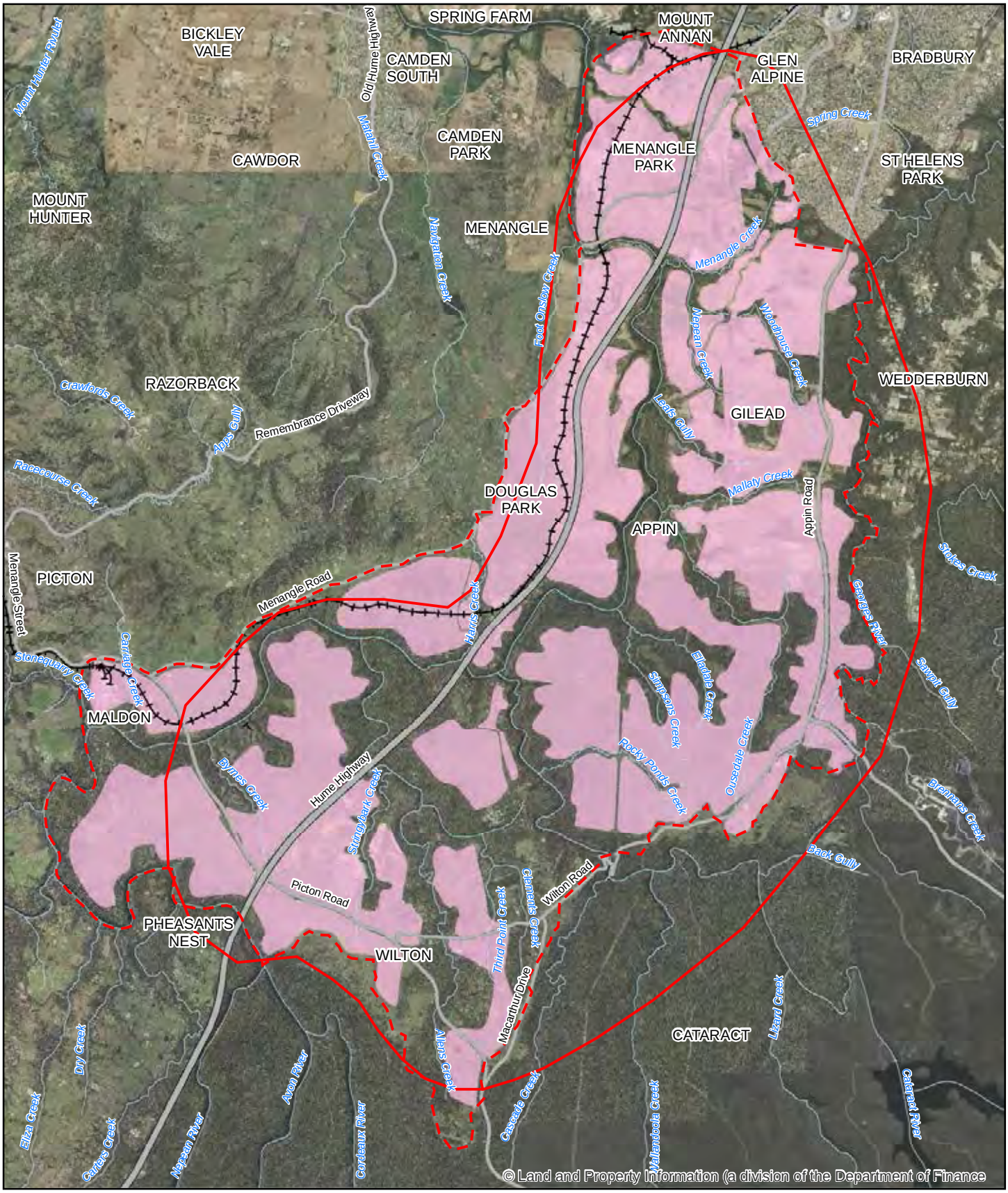
The development footprint is general focussed along ridge lines, which happen to be largely cleared of vegetation, on the eastern side of the Nepean River. Along the Nepean River floodplain the development footprint includes more low lying lands with some of the footprint being flood affected in a PMF or other large flood event.

The Upper Canal which traverses the potential development footprint, east of the Nepean River, forms a barrier to development as no stormwater flow can be permitted to impact the function of the Upper Canal or the water quality within the Upper Canal. As a result, all stormwater upslope of the Upper Canal must be discharged to an existing natural watercourse to traverse the Upper Canal corridor without impact. This requirement also means that there needs to be a minimal increase in the design flow where watercourses cross the Upper Canal corridor to minimise any future erosion risk near the canal.

7.2 Preferred WSUD strategy

The final WSUD strategy, Figure 7-2, is allowed as including:

- Dwellings fitted with water efficient appliances and rainwater tanks as required to satisfy BASIX requirements
- A conventional minor pipe drainage network and major drainage network to convey flows to the regional water quality treatment measures
- Construction of the perimeter road located within, or adjacent to, the APZ in such a form as to convey the major stormwater flows to the water quality measures. This functionality could be achieved through using an enlarged capacity pipe network system for this road or construction, use of a single cross fall road to enhance the flow conveyance capacity or, where the landform suits, of a swale system parallel to the road
- Construction of a combined bioretention and detention area at each discharge point from the major/minor drainage discharge location into the creekline vegetation areas



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Developable Areas
- Motorway
- Primary Road
- Railway
- Watercourse

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Development Extent

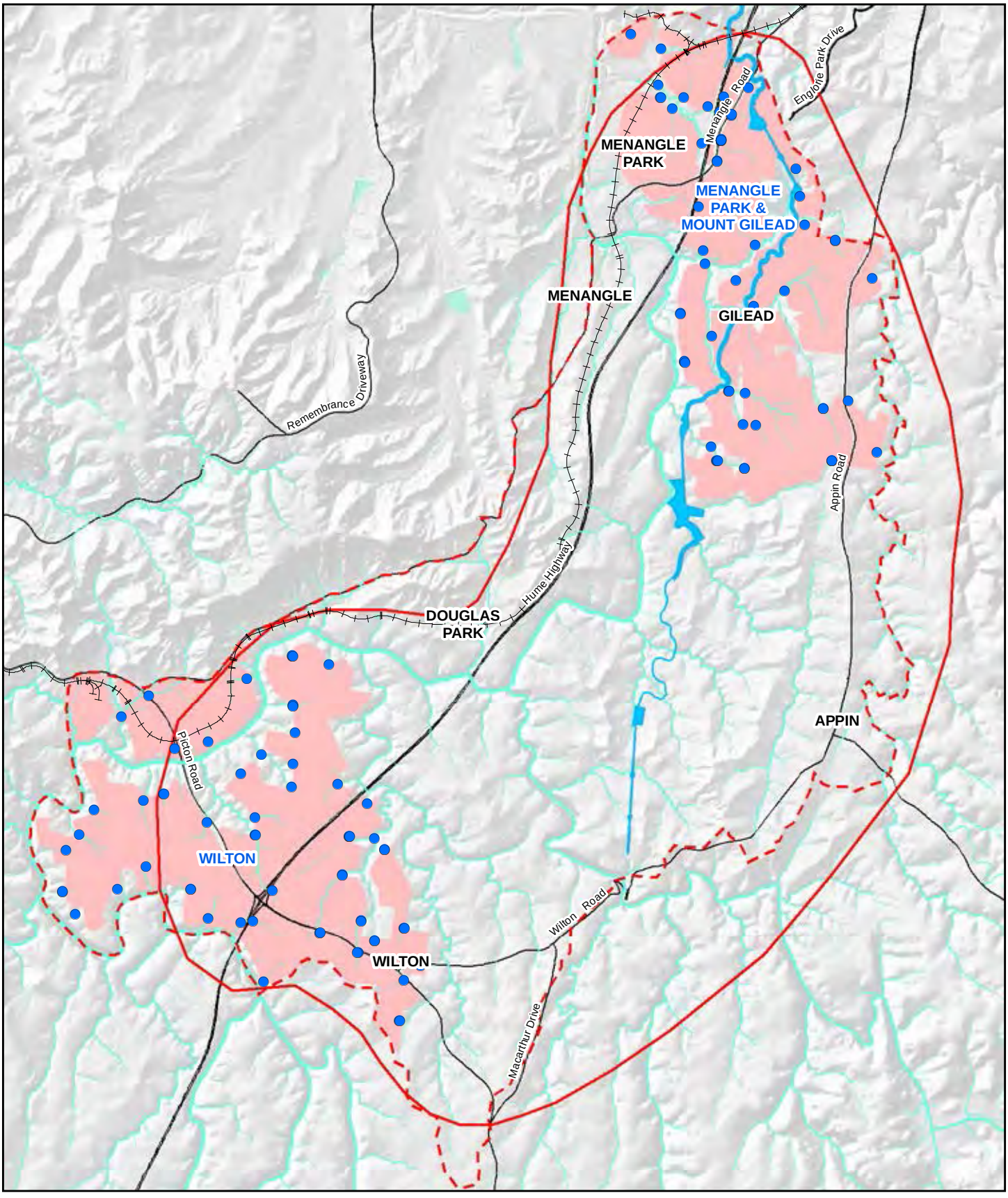
Figure 7-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM020_ProposedDevelopmentExtents_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Developable Areas
- Road
- Railway
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	1
Date	27 Aug 2015

Preferred WSUD Strategy

Figure 7-2

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM032_Strategy1_WQ_locations_1.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

- Opportunistic incorporation of pocket parks of landscape water bodies into the development footprint will be adopted but their benefit has not been considered in this analysis
- Litter and gross pollutant traps at the discharge of the piped drainage system into the regional water quality control facilities

7.3 Asset protection zones

An asset protection zone has been assumed between the proposed development footprint and retained areas of vegetation.

A separate concurrent study has assessed the minimum size of those APZs.

Within the development of the WSUD strategies it has been assumed that stormwater infrastructure can be constructed within, or partially within, the APZs where required. This is required to (a) provide emergency access around the perimeter of the proposed residential area an (b) restrict the number of locations where stormwater would be discharges into the downslope riparian vegetation. The approach of directing all stormwater, up to the 100 year ARI magnitude, through regional stormwater quality facilities has required the perimeter road, or adjacent lands, to be used to convey stormwater to the nearest water quality control measure.

Use of the APZ, or partial use of the APZ, in this manner has established a minimum width for the corridor adjacent to the riparian vegetation. In areas where the APZ is less than 40 m wide it is suggested that a minimum width of 40 m should be adopted for the APZ/infrastructure area to make appropriate provision for construction of the perimeter road, the water quality control measures and a possible sale if it becomes impractical to convey the entire 100 year ARI flow within a pipe or other structure incorporated into the perimeter road design.

At a future detailed design stage it would be possible to refine the width of the combined APZ / infrastructure area.

7.4 Earthworks

A preliminary review has been completed to assess the potential opportunities to rationalise and maximise the potential development footprint through the undertaking of earthworks to restrict the 100 year ARI flood extent.

Since the potential development footprint east of the Nepean River is largely focussed long ridge lines it is not practical to significantly impact the development footprint in this area through the undertaking of bulk earthworks. In the area along the Nepean River there is a very limited opportunity to optimise the potential development footprint without increasing the design flood levels.

Similarly, only modest optimisation of the potential development area can be achieved west of the Nepean River.

7.5 Flood levels

Design flood levels have been predicted for the 2, 20 and 100 year ARI events together with the PMF event throughout major watercourses within the Study Area. The detailed predictions of the flood levels are given in Appendix F, in plan view, and Appendix J in the form of flood profiles together with tabulations of the flood levels for each considered watercourse.

Design flood levels have been calculated for the 2, 20, and 100 year ARI existing conditions design events together with a PMF event as described in Appendix E.

Figure 7-3 depicts the overall predicted flood levels and flood extent within the Study Area. The width of the flood is shown by the width of the central light blue area along watercourses and identified as “Flood extent” within the legend. The flood level is represented by a colour shading each side of the flood extent. To facilitate the definition of the flood levels it was found appropriate to adopt a “flood level colour ramp” that varies the in the magnitude of the depth change as the colour gradation changes. This was necessary to provide adequate flood level definition along the Nepean River while in the steeper tributary areas the band level change width was made larger.

Figure 7-3, when considered in conjunction with the Study Area topography, Figure 2-1, demonstrates how along the Nepean River downstream of approximately Douglas Park the flood gradient is relatively flat in the area of relatively flat terrain along the Nepean floodplain. Upstream of that location the flood profile along the Nepean River becomes steeper as the river bed gradient steepens.

In the tributaries, where the terrain is steeper, there is a corresponding increase in the hydraulic profile.

In the downstream area, near Menangle Park, it was not practical to provide the colour banding due to the different source, TUFLOW, of the predicted flood levels.

Figure 7-4 provides a similar representation for the PMF event. The increased flood levels can readily be observed along watercourse through the positioning of the start and end of the different colour bands. It is noticed that in many of the Tributary watercourses to the Nepean River there is not except at the downstream end of some watercourses a significant change in the flood level (as the location of the colour bands has not changed greatly). The most significant change in the PMF flood level is observed along the Nepean River downstream of, approximately, Wilton.

7.6 Flood extents

Design flood extents have been derived from the predicted flood levels for the 2, 20 and 100 year ARI events together with the PMF event and the developed site terrain model. The flood extent has been determined as being the lateral extent of the predicted flooding at each cross section throughout hydraulically modelled major watercourse reaches within the Study Area.

Figure 7-3 provides the predicted flood extents throughout the Study Area for the 100 year ARI event. The flood extent is indicated by the width of the light blue line along the assessed watercourses. As shown by this figure the flood extent is generally confined within the incised watercourses and within the relatively steep vegetated lands along the watercourses where development would be unlikely to proceed irrespective of flooding conditions.

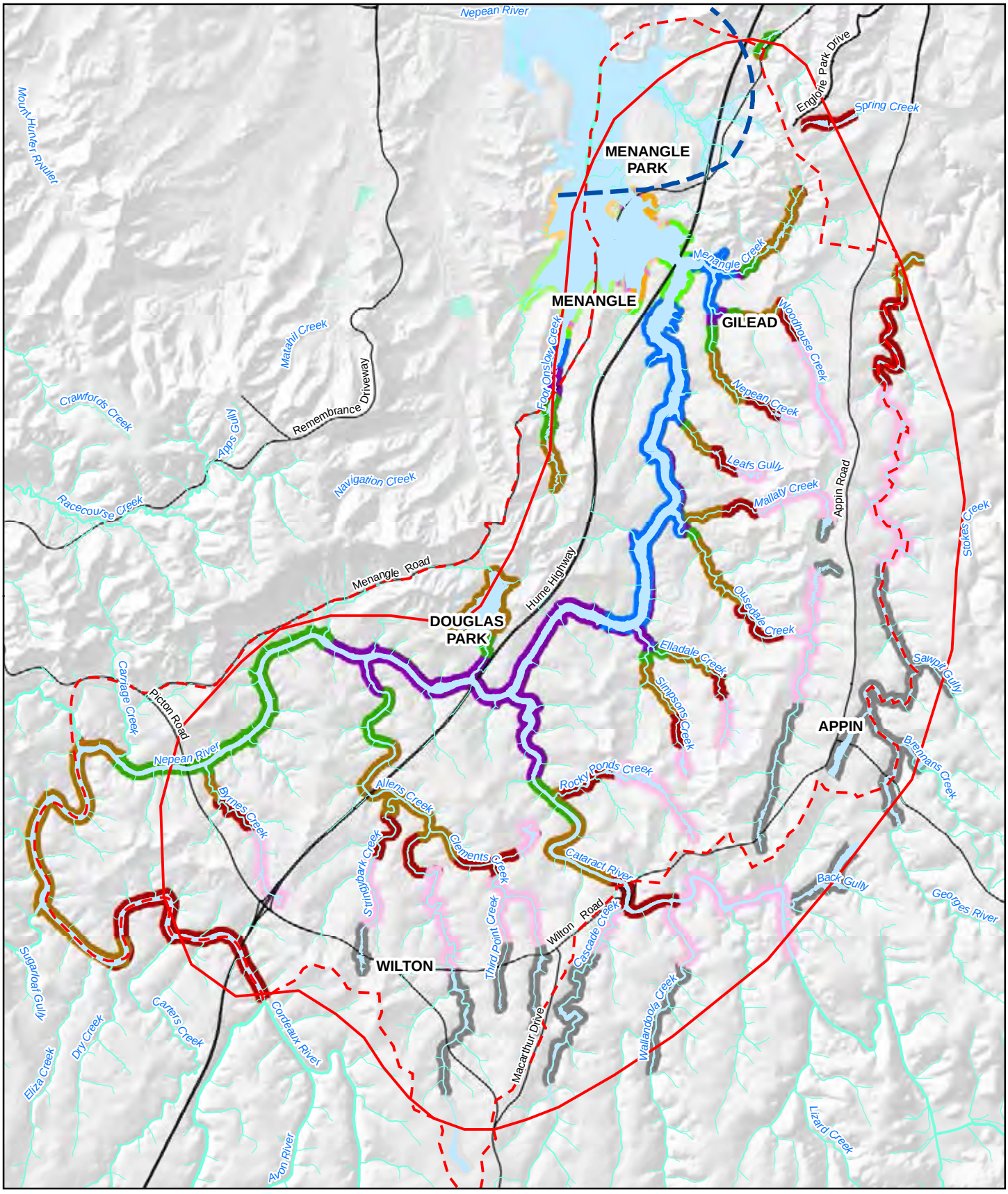
Figure 7-4 provides a similar representation of the flood extent for the PMF event. The increased flood width can be observed along watercourses through the widening of the light blue shading.

More detailed flood extent maps are provided in Appendix F.

7.7 Flow velocities

Design flow velocities have been derived from the predicted flood levels for the 2, 20 and 100 year ARI events together with the PMF event.

Figure 7-5 provides the predicted average cross sectional flow velocities throughout the Study Area for the 100 year ARI event where results have been predicted using the HEC-RAS modelling. Results presented in Figure 7-5 are average values at a location along the watercourse. These do differ from results provided in Appendix G. The Appendix G figures do show a more detailed flow distribution allowing the water velocity to vary across the waterway at each location.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI
Flood Levels and Extents

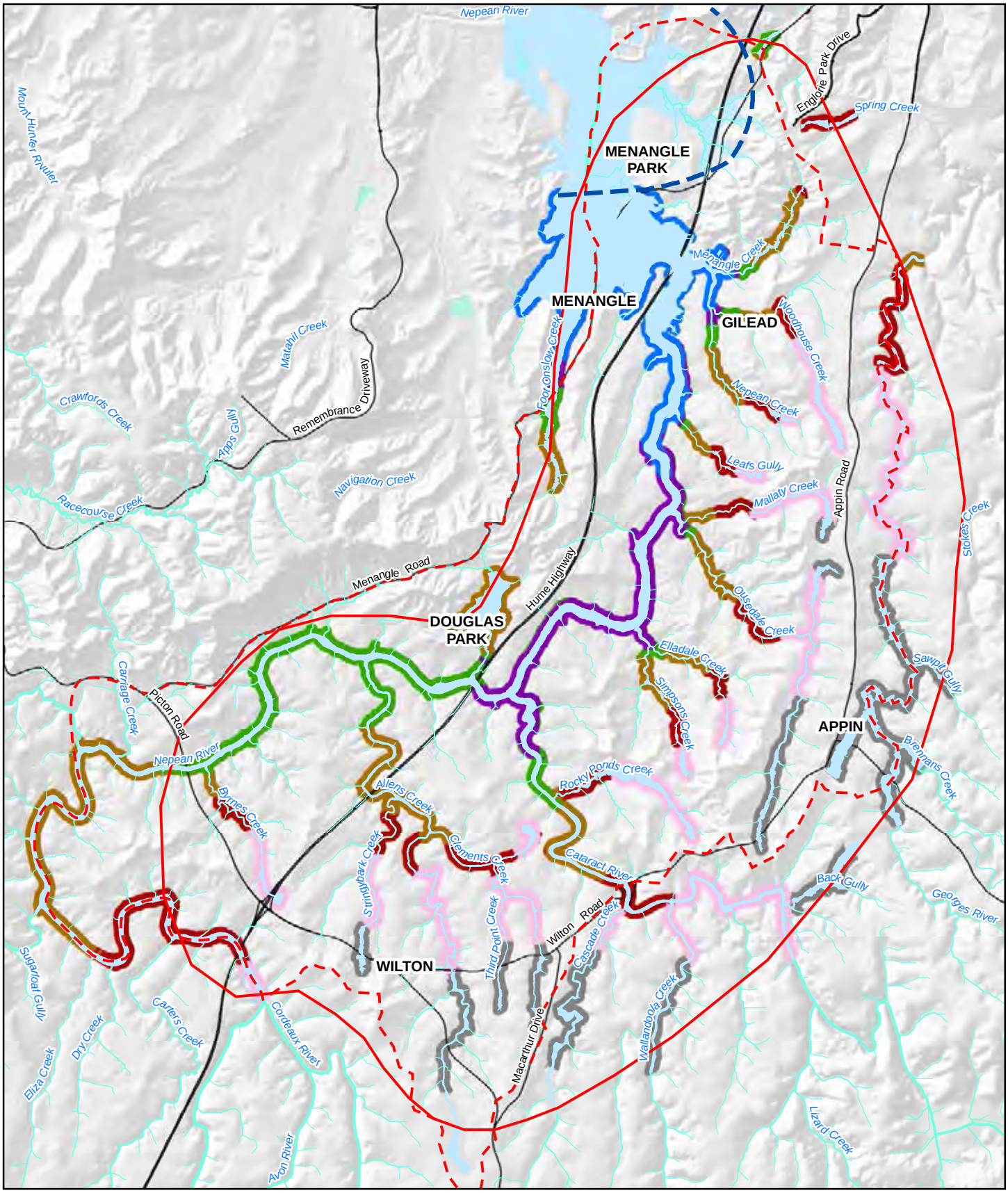
Figure 7-3

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM021_Existing_100YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	>250

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

PMF
Flood Levels and Flood Extents

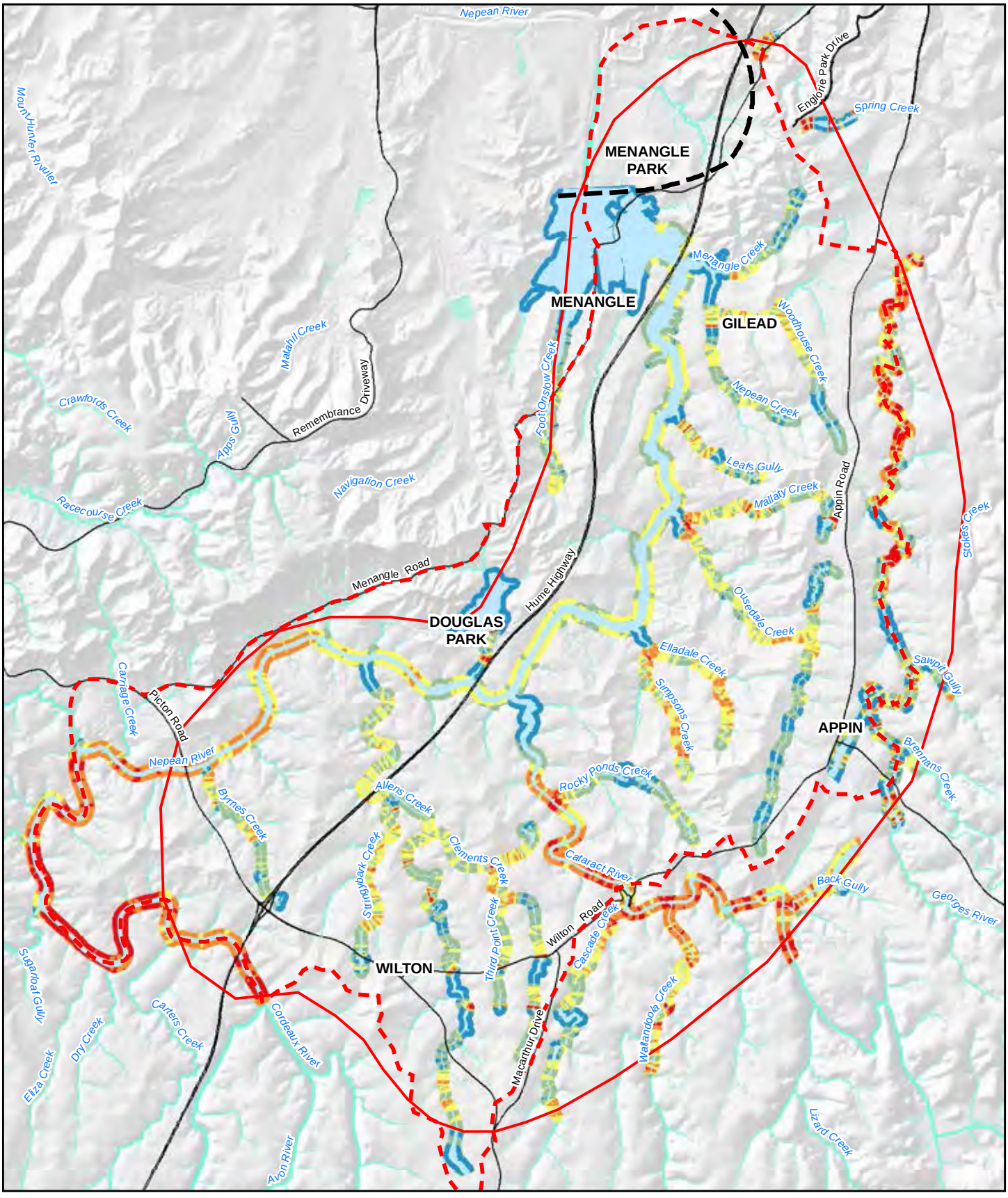
Figure 7-4

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM022_Existing_PMF_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Velocity

<1	1 - 2	2 - 3	3 - 4	>4

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	21 Aug 2015

100 year ARI Average Velocity and Extents

Figure 7-5

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM026_100YR_Velocity_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

Figure 7-5 indicates many reaches of the waterways to have an average velocity predicted to be lower than 2 m/s for the 100 year ARI event. These are the areas shown with either blue of light green along the watercourses, higher velocities were predicted reaching to between 3m/s and approximately 4 m/s in localised areas which are mapped as orange and red bands. The flow velocities are predicted to change in magnitude across the cross sections in direct relation to the depth of flow and hence the watercourse relative roughness.

The larger watercourses, for example the Nepean River, did indicated a predicted change in velocity as one traversed across a cross section as reflected in Appendix G figures. The water was predicted to have a smaller velocity adjacent to the edge of the flooding as compared to the central area of the watercourse. This difference in velocity at any cross section on the watercourse would be reflected in nature.

More detailed flood velocity maps along with maps for the 20 year ARI and PMF event are provided in Appendix G along with the more detailed mapping of the 100 year ARI values.

7.8 Flood hazard

The flood hazard (velocity –depth product) has been derived from the predicted flood levels and flow velocities for the 100 year ARI event and is shown in Figure 7-6. A more detailed presentation of the predicted conditions are provided in Appendix H.

The relative magnitude of the flood hazard has been presented into six hazard categories as discussed in Section 5.4.9 of this report. As can be observed from Figure 7-6 the majority of the flooded area is classified as being high hazard and generally unsafe for entry.

7.9 Flow classification

Flow classification has been presented for the 100 year ARI event in Figure 7-7. Three flow categories are shown – floodway, flood fringe and flood storage. The adopted classification definition is provided in Section 5.4.10 of this report.

A significant proportion of the flooded area is classified as being floodway for the 100 year ARI event.

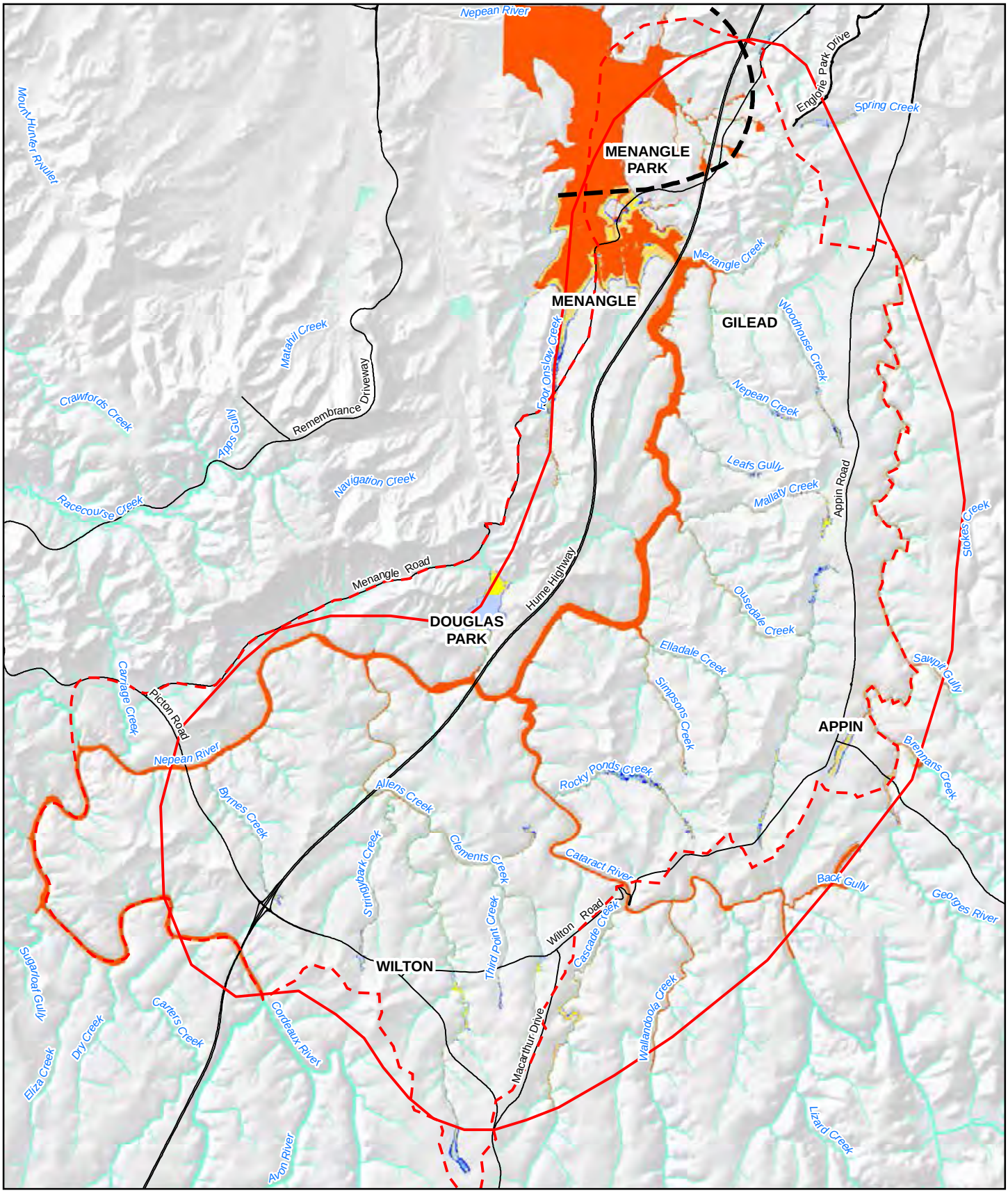
7.10 Catchment areas for potential watercourse piping

The Rational Method was used to estimate the catchment area that can be adequately serviced by a minor drainage system using 1800 mm internal diameter pipe. The following assumptions were made:

- Pipe installed at a slope of 1 in 50
- Catchment area idealised as a square to allow for estimation of time of concentration
- Travel velocity of water over ground is 1 m/s
- IFD data obtained from the Bureau of Meteorology website for Camden
- Lot size of 450 m^2 with an impervious percentage of 70% as a gross area estimation, allowing for parks and open land combined with residential areas

With a design ARI of 20 years for a town centre (as per Campbelltown Council guidelines for a Minor System), the area serviceable is 35 hectares. Using a design ARI for urban residential (5 years), the area serviceable by the minor system increases to 47 hectares.

Based upon this calculation it should be possible to formalise first order watercourses when the catchment area is less than approximately 40 ha.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent

Hazard

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

100 Year ARI Flood Hazard

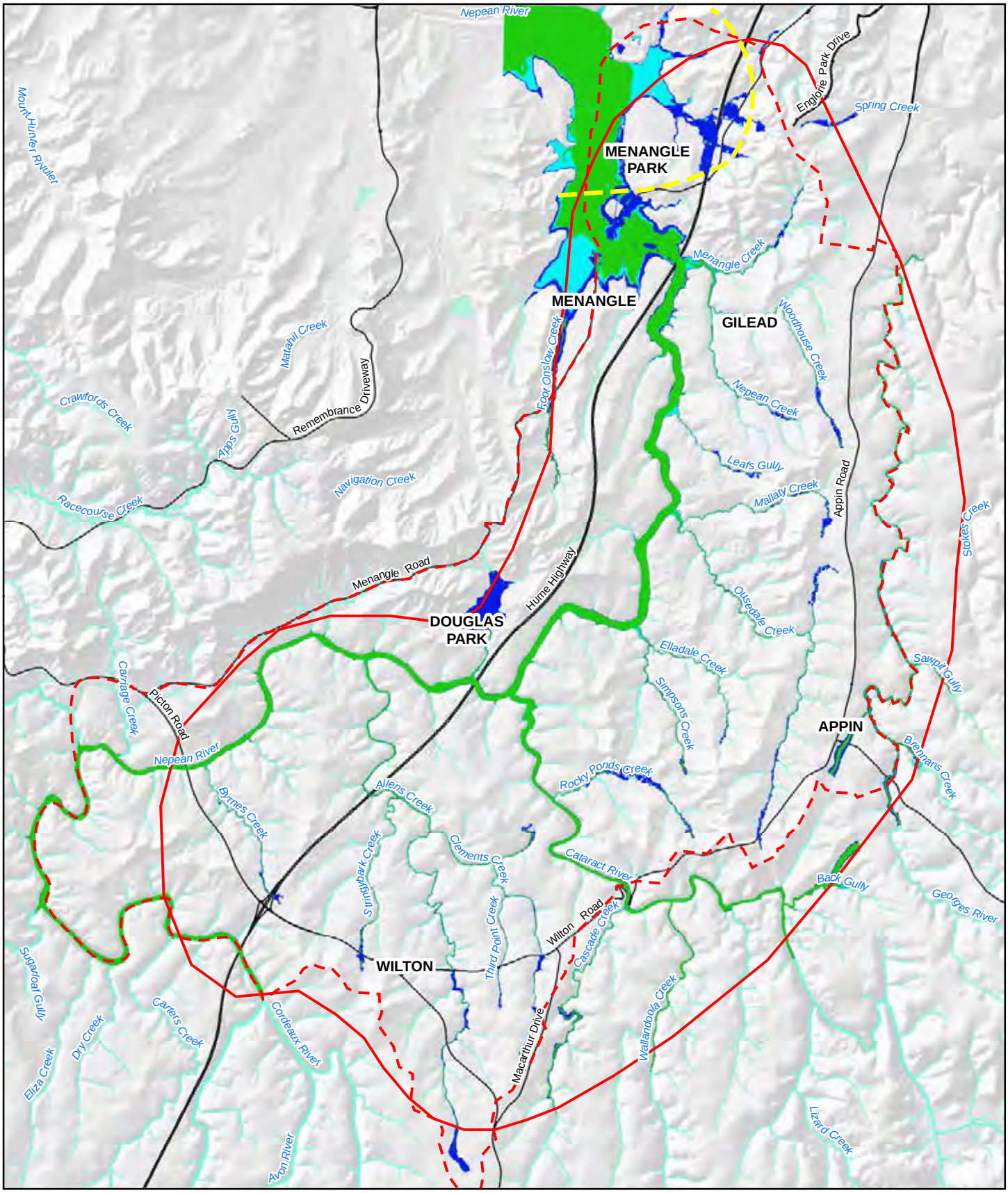
Figure 7-6

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM024_100YR_Hazard_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent
- Floodway
- Flood storage
- Flood fringe

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flow Classification Figure 7-7

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM025_100YR_Classification_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

7.11 Stream erosion potential

The Stream Erosion Index (SEI) provides a means for assessing the long term stability and stream health of streams by evaluating the period of time that discharges exceed a critical value which reflects the upper limit of flow rate for the stream remaining stable. This parameter reflects the long term of flows in excess of a threshold value that relying upon the evaluation of short period peak flow velocities during runoff events not exceeding a threshold value. Several values have been proposed as indicating the limiting criteria for the maintenance of stream stability and stream health (Duncan etal 2014).

Because of the preferred WSUD strategy, described in Section 7.2, being to mitigate increases in peak flow rates discharging off the proposed residential areas it should be possible, at detailed design stage, to keep the SEI to a modest value. This would restrict the long term potential for significant stream erosion.

8. Implementation of WSUD strategy

8.1 Preferred WSUD strategy

The preferred WSUD stormwater management strategy was described in Section 7.2 with more extensive details provided in Appendix D.

8.2 Design requirements and standards

Implementation of a selected WSUD strategy will require consideration of both human and structural safety.

Human safety, in terms of place making, can be addressed through the development of the design to be consistent with *Crime Prevention through Environmental Design* (CPTED) and *Safer by Design* Principles.

Human safety, or egress from unsafe places, can also be encouraged through the design provision of relatively flat grades on built earthworks and the provision of possible egression paths from possible watercourses.

The safety of structures against failure, needs to consider the development of structure forms that will not fail. The preferred WSUD structure has minimised this safety concern through not positioning major water detention structures in positions where they are less likely to fail as a result of partial or complete debris blockage of outlets of detention and water quality functions.

8.3 Recommended flood planning level

The investigation has evaluated the selection of an appropriate design flood level and flood planning level within the Study Area.

The two affected Councils currently adopt the design 100 year ARI event to establish the design flood level. Retention of that same standard is considered to be appropriate within the Study Area as they has not been any locations identified where the adoption of that standard would create areas of unusually high flood or safety risk to potential residents or emergency staff, should evacuation be required.

Based upon adoption of the above design flood level, the flood planning level would become the 100 year ARI flood level plus a freeboard allowance. No evidence has been found during this investigation to suggest that the currently adopted freeboard allowances should be amended within the Study Area.

8.4 Likely ownership and maintenance responsibility

8.4.1 Stormwater elements

The WSUD strategy has been developed on the assumption that the infrastructure located in open space (not on individual lots) will be owned and maintained by one of the Councils.

Any measures constructed on individual lots are assumed to be owned and maintained by the lot owner.

Should a separate utility be created for managing the stormwater system then the only change would be that the works would need to be owned and maintained by the created utility.

8.4.2 Riparian corridor ownership and maintenance

The riparian corridors have been assumed to be owned and maintained by Campbelltown City Council and Wollondilly Shire Council. It is considered unlikely that the Council's would have sufficient financial resources to purchase the riparian corridors.

Maintenance of the extensive riparian corridors would also pose significant financial burden onto the Councils. Further consideration will need to be given to the financing of the maintenance by Council – the most attractive option would appear to be the incorporation of a special rate component, possibly as a Section 94 style contribution, to create a fund to finance the relatively high costs of the maintenance within a high ecologic value and community environment.

An alternate proposal, but not favoured due to current practicalities, would be for a private entity to undertake the maintenance from a similar form of financing through a Section 94 style special rate created fund.

8.5 Indicative capital costs

Indicative capital and operating costs have been prepared for two of the WSUD strategies. Costing was not prepared for the strategy of using the detention basins/water quality control facilities within the riparian corridors. The development of those cost estimates and the underlying assumptions are detailed in Appendix K.

The estimated capital and O&M costs for the preferred WSUD strategy, Figure 8-1 are given in Table 8-1. To consider the monetary values listed in Table 8-1 it is important to examine the assumptions reported in Appendix K.

Table 8-1 Cost estimates for preferred WSUD strategy

Parameters	Menangle Park & Mount Gilead	Wilton
Capital cost for upgrade of perimeter road ($m)	2.57	2.00
Capital cost of combined bioretention and detention structures at APZ ($m)	67.60	73.10
Total capital cost ($m)	**$70.10**	**$75.10**
O&M costs for additional works on perimeter road ($m/a)	0.04	0.05
O&M costs for combined bioretention and detention structures at APZ ($m/a)	0.58	0.51
Total O&M costs ($m/a)	**0.62**	**0.56**

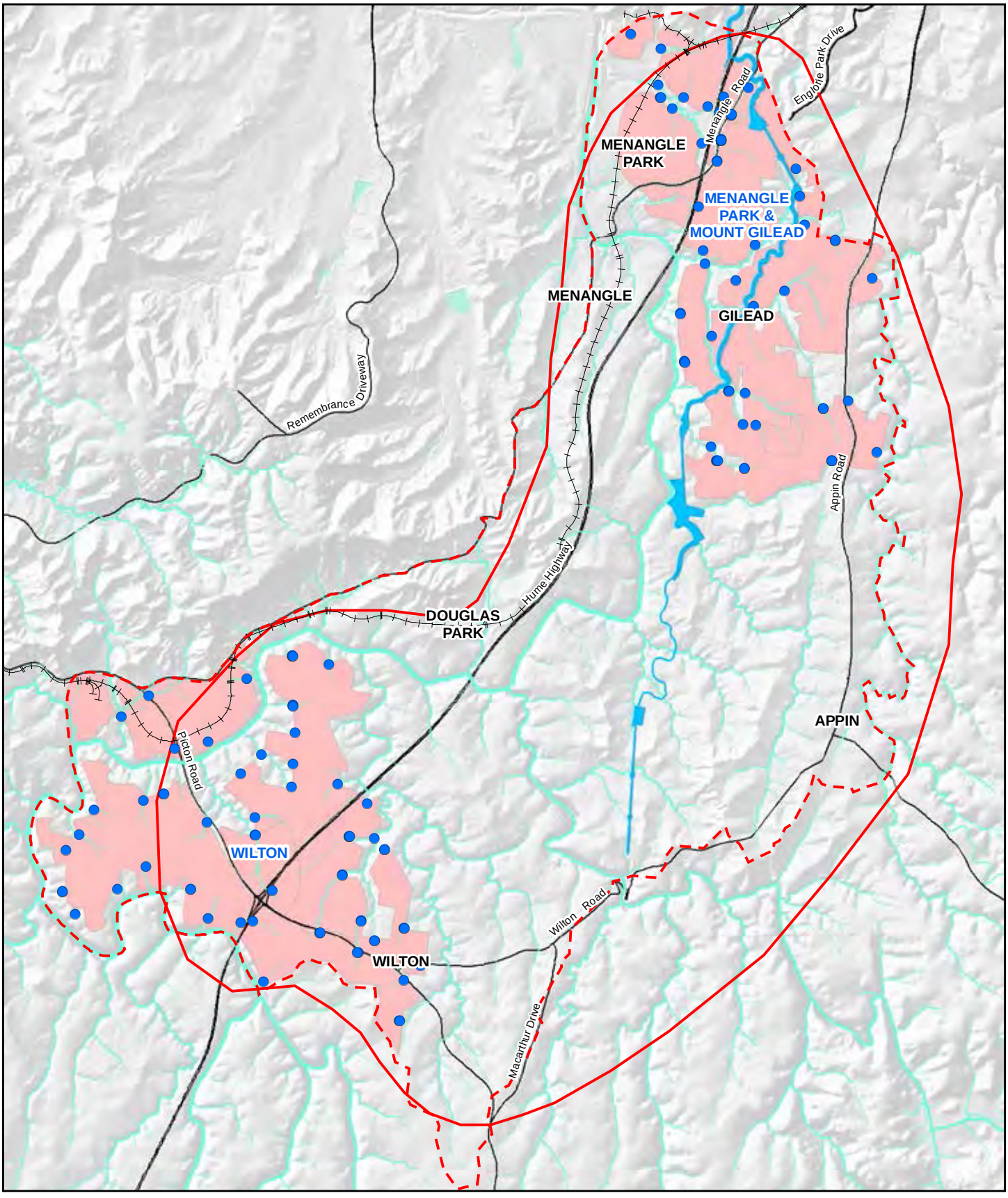
When including a contingency of 30% the capital costs increases to approximately $189 million and the annual operation and maintenance cost increases to approximately $1.5 million/annum.

Table 8-2 provides the number and size of the allowed structures.

Table 8-2 Staging estimated costs

Area	No Structures	Bioretention Area (m^2)	Detention Volume (m^3)	Capital Cost ($m)	O&M Cost ($m/a)
Menangle Park & Mount Gilead	39	200,692	453,773	70.10	0.62
Wilton	44	266,840	511,443	75.10	0.56
Total	83	467,532	965,216	145.2	1.18

The costs listed in that table exclude any contingency values and the details of the derivation are provided in Appendix K.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Developable Areas
- Road
- Railway
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Potential WSUD Strategy within Developable Areas

Job Number 22-17728
Revision 1
Date 27 Aug 2015

Figure 8-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM034_Potential_WSUD_WQ_locations_1.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

9. Evacuation planning

9.1 The site form

The site topography for the potential development footprint has largely been guided by the presence of riparian vegetation and vegetation along steeper areas adjacent to watercourse.

This feature has identified many distinct pockets of urban development located along ridge lines. Additional development areas are also located along lower floodplain areas.

9.2 Guidance materials

Guidance document relating to flood response planning and evacuation planning include classifications - Evacuation Planning (Attorney-General's Department 2005) and Attorney-General's Department 2014, Technical Flood Risk Management Guideline: Flood emergency response classification of floodplain (Attorney-General's Department 2014) in addition to the NSW Floodplain Development Manual.

Further, there are general planning guidance documents relating to the planning for evacuation in emergency conditions.

9.3 Potential evacuation routes

Suggested evacuation or egress routes are shown by the arrows in Figure 9-1 for the entire Study Area. In general the routes have been shown as following upward sloping routes from any location to a major (or likely major), future traffic route. This approach provides the maximum opportunity for safe egress and also could position roads in locations where they would be relatively safe from closure in a potential time of bushfire.

For the two Development Areas only restricted elements of those routes will be required.

9.3.1 Existing major roads

A review of the flood security of the existing roads – Appin Road, Menangle Road, Picton Road and Wilton Road should be completed to confirm that either, they are flood free to act as emergency evacuation routes or that they can be cost effectively upgraded, if required, to achieve an adequate level of flood protection.

They have not been shown as flooded in this assessment as localised flash flooding has not been addressed throughout the entire Study Area.

Historical flooding of some of these roads and roads connecting to them has been reported.

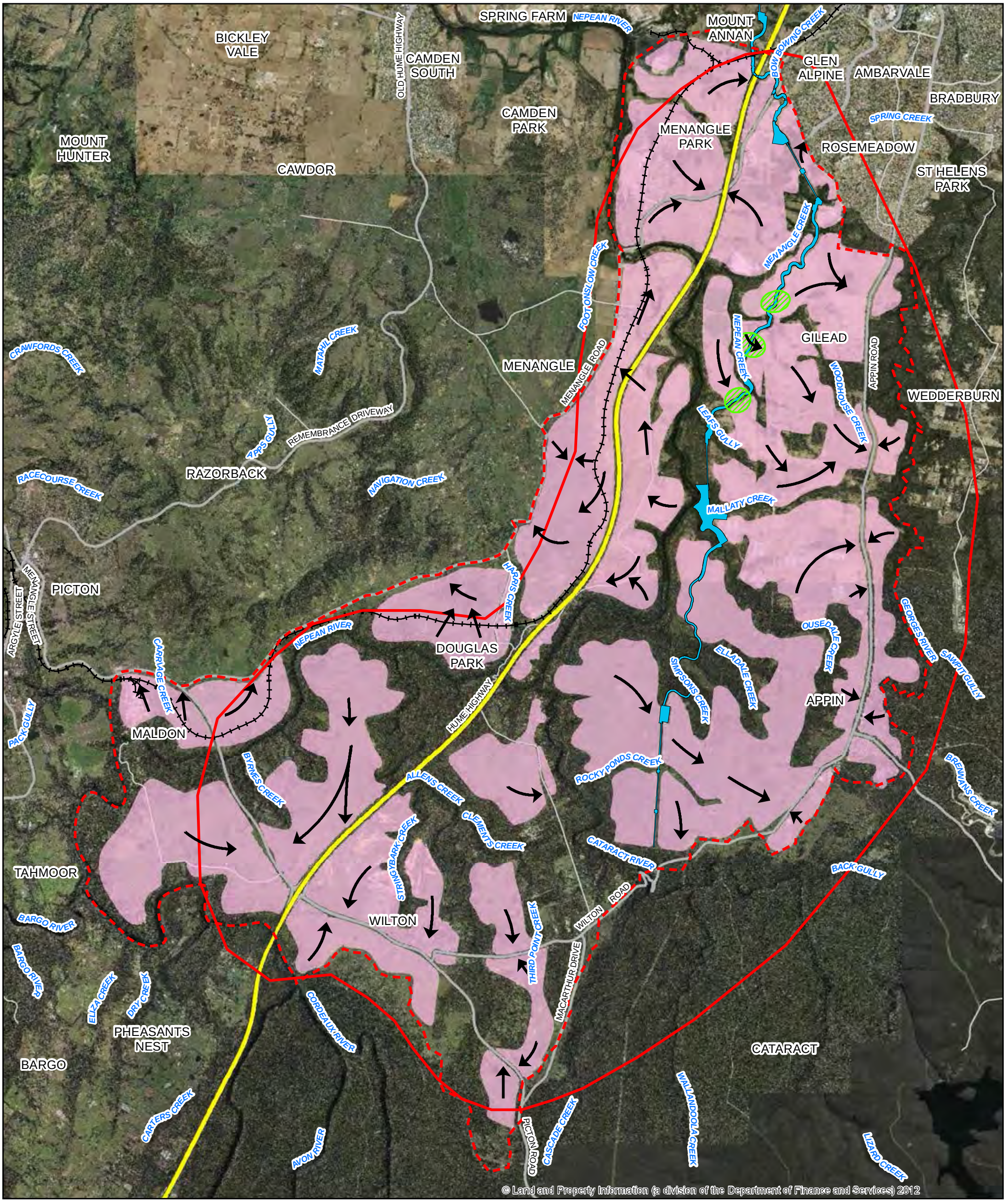
It has been assume that these roads would form the key routes within an evacuation route plan.

9.3.2 East of Upper Canal

In this area the terrain is relatively high and the development footprint will not be subject to flooding. In this portion of the Subject site the egress rout should approximately follow the ridge crest as this provides both a relatively consistent upslope for the road while also not significantly altering the local drainage catchment areas.

East of Appin Road access would most probably be created onto Appin Road through the new local street network.

Two crossings of the tunnel within the Upper Canal corridor would be required south of Simpsons Creek to facilitate evacuation for small areas located to the west of the Upper Canal corridor. The number of crossings could be reduced with the construction of adequate culvert or bridge structures over across Rocky Ponds Creek.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Distributor Road
- Railway
- Developable Areas
- Evacuation Direction
- Upper Canal
- Possible New Bridge over Upper Canal

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 1
Date 27 Aug 2015

Evacuation Planning

Figure 9-1

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\2217728_WM028_EvactuationPlanning_1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

North of Ousedale Creek three crossings of the Upper Canal corridor would be required to provide egress from lands located to the west of the Upper Canal corridor. These structures would need to be designed to retain the functionality of the water supply while also providing appropriate water quality protection to the canal.

9.3.3 Between Upper Canal Corridor and Nepean River

North of Menangle Creek it is anticipated that egress would be provided onto either Menangle Road or connecting to the existing road network unless a new connection was made to the Hume Highway.

In areas south of Douglas Park and south of the Nepean River the egress would generally be along ridges to Wilton Road or to Picton Road.

One area along Douglas Park Drive would egress to Douglas Park Drive and thence to Picton Road. An upgrade of a section of Douglas Park Road would probably be required to achieve an appropriate service level when considering flash flooding conditions in local small catchment areas.

9.3.4 Between Nepean River and Hume Highway

In the Douglas Park area egress would be most probably be provided to Menangle Road unless suitable accesses were created to the Hume Highway.

9.3.5 West of Hume Highway and west of Nepean River

Resident located in this area would be expected to have an egress route to Menangle Road and thence along Menangle Road. As indicated earlier, a review of Menagle Road should be completed to confirm that it would have, or could be provided with an appropriate level of service.

9.4 Potential emergency accommodation

While this section of the report is focussed upon the provision of appropriate egress routs, it would also be appropriate to give consideration to having public facilities such as school halls and similar public halls and community centres established in areas that could be accessed to provide emergency accommodation for residents if they require evacuation for any reason.

10. Strategy refinement with planning advancement

Should a decision be made to progress with urban development within the Study Area then it is recommended that consideration be given to the following:

- Making contact with Illawarra Coal to attempt to gain access to the detailed water quality sampling, stream assessments, and ecosystem monitoring and assessment data to better understand the background conditions for the Subject Site. This data would prove useful in defining required performance conditions for the proposed development.
- Completing an in depth assessment of the practicality of, and implications on, site planning of using the perimeter road as a device for conveying stormwater runoff to the nearest bioretention area. This would identify any strategic issues in respect the development staging and permit the refinement of the width of the APZs / infrastructure corridors adjacent to areas of riparian vegetation.
- Periodically updating the hydrologic and hydraulic modelling for changes in the anticipated or achieved impervious fraction throughout the Study Area. These updates would then provide an update for the establishment or refinement (when appropriate) of the flood planning level.
- Minimal historical information exists in respect to flood levels throughout the Study Area. This is not perceived to be critical in reaches of watercourses having deep incised watercourses but it could become important in areas where the watercourses are less incised. Should there be a significant flood event during further site planning, it would be prudent to obtain flood levels throughout the Study Area to verify, or refine, the flood level predictions.
- When the development density distribution is advanced, it would be prudent to update the site hydrology to determine whether the sizing of elements within the WSUD strategy require refinement.

11. Summary

The New South Wales government has developed a strategy to guide the future growth of the Sydney metropolitan Area for the next 20 years to ensure the future productivity and liveability of the city. The strategy is titled *A Plan for Growing Sydney*.

Within *A Plan for Growing Sydney* there a number of actions identified. Action 2.4.2 of A Plan for Growing Sydney requires the development a framework for the identification of new growth centres.

In response to this Action, the Department of Planning and Environment is undertaking the Greater Macarthur Investigation Area project. The overarching aim of this project is the determination of whether the Greater Macarthur Investigation Area is suitable for urban development and population growth.

The brief for this project responded to the Action by focussing on:

- Flood modelling - Review and collation of existing flood studies for the Investigation Area and the undertaking of flood modelling to define the flooding conditions (flood levels, velocities, hazard and flood category) for conditions up to the PMF event and also considering projected climate change impacts
- Site planning - Identification of an appropriate flood planning level and the preparation of a flood evacuation strategy within the requirements of the Floodplain Development Manual
- Planning advancement – Examination of future refinement of the analysis that should be completed as potential site planning proceeds
- Water Cycle Management - Development of a strategic level stormwater cycle management strategy addressing policy, infrastructure and service requirements along with WSUD principles and provision of advice on the feasibility of the adopted strategy
- Riparian Corridor assessment - Completion of a review of available data and undertake a Riparian Corridor Assessment and provision of a description of how the WSUD measures could impact the riparian corridor

The study area initially adopted for this investigation includes both the Greater Macarthur Investigation Area as shown in *A Plan for Growing Sydney t*ogether with additional surrounding lands giving a study area of approximately 15,970 ha. Subsequently the Developable Area was reduced to two smaller precincts.

A significant amount of literature has been identified and is applicable to the Study Area. The majority of the literature has been focussed upon the projected and historical impacts of past and proposed mining operations within the area. As such it has related primarily, as related to this study, water quality, stream form and stability subsidence.

A minimal amount information was identified that considered flooding conditions. The material that was sourced focussed on flooding in the reaches of the Nepean River near Menangle and Douglas Park together with some information on conditions in the area near Wilton and tributary watercourses near Menangle. Only the report titled Upper Nepean River Flood Study reported on a comprehensive assessment of conditions within the Study Area. That report specifically considered the Nepean River catchment area upstream of the Study Area and also the impacts of the upstream major water storages (Cataract Dam, Cordeaux Dam, Avon Dam and Nepean Dam) together with the water supply transfer system.

Later studies that considered the Nepean River flooding built upon results from that investigation.

The hydrological analysis completed for this study included the consideration of the design flood hydrographs from the upstream catchment area together with design flows from within the Study Area. As a result of the significant difference in the size of the upstream catchment and the Study Area it was found that the peaks of the hydrographs were not coincident. Therefore, the flows and flow conditions within significant lengths of the tributary watercourses, to the Nepean River, within the Study Area were primarily impacted by the locally generated stormwater runoff values. Flow conditions along the Nepean River and lower portion of larger tributaries were impacted by the hydrographs originating from the upstream catchment together with some impact from the local catchment.

Design flows form the hydrological analysis were then input to an extensive HEC-RAS hydraulic model covering the Nepean River and many of the larger tributaries to the Nepean River to determine design flood levels, average flow velocities, flood hazard values and the watercourse classification.

Figures depicting the flood extent and flood levels have been provided for the 2, 20, 100 year ARI design events together with a PMF representation. Tabulated flood levels are also provided to provide a more comprehensive representation of the flooding conditions. The flood levels have shown that in areas outside the influence of backwater effects from the Nepean River there is a minimal difference in the flood levels for the 2 year to 100 year ARI flood levels. This is a direct result of the steep terrain and watercourses giving quite high predicted design flow velocities.

Figures are also presented to show the flow velocity predicted by the HEC-RAS hydraulic model. The velocity distribution across each section has been inferred from the distribution of the conveyance capacity distribution across each cross section. These are presented for the 20 and 100 year ARI events together with the PMF event.

The flow hazard and watercourse classification have also been provided for the modelled watercourses. The results are also provided in Figures and they show, using the adopted six level classification system, the majority of the watercourse would be classified as being high hazard for the 100 year ARI event. Similarly, the majority of the watercourses would be classified as floodway areas for the design 100 year ARI event.

Proposed development areas are generally located along the higher ridge area and this has posed complexities in the selection of a cost effective WSUD strategy that provides protection to the riparian corridors. The assessment has indicated that protection of riparian corridors would be best be achieved by having WSUD measures located within or adjacent to APZs.

Three WSUD strategies have been evaluated over the entire study area. The preferred strategy comprises:

- Dwellings fitted with water efficient appliances and rainwater tanks as required to satisfy BASIX requirements
- A conventional minor pipe drainage network and major drainage network to convey flows to the regional water quality treatment measures
- Construction of the perimeter road located within, or adjacent to the APZ, in such a form as to convey the major stormwater flows to the water quality measures. This functionality could be achieved through using an enlarged capacity pipe network system for this road or construction, use of a single cross fall road to enhance the flow conveyance capacity or, where the landform suits, of a swale system parallel to the road
- Construction of a combined bioretention and detention area at each discharge point from the major/minor drainage discharge location into the creekline vegetation areas. The biorention would have a slow drainage (1.5 days) of extended detention storage to

maximise water filtration and the biorention would be designed to maximise nutrient removal.

- Opportunistic incorporation of pocket parks of landscape water bodies into the development footprint (allowed as 1.5% of catchment area) will be adopted
- Litter and gross pollutant traps at the discharge of the piped drainage system into the regional water quality control facilities

The selected strategy staging cost has been determined for the precincts at Menangle Park and Mount Gilead as well as at Wilton as shown in Table 11-1.

Table 11-1 Staging estimated costs

Stage	No Structures	Bioretention Area (m^2)	Detention Volume (m^3)	Capital Cost ($m)	O&M Cost ($m/a)
Menangle Park and Mount Gilead	39	200,692	453,773	70.1	0.62
Wilton	44	266,840	511,443	75.10	0.56

The investigation has evaluated the selection of an appropriate design flood level and flood planning level within the Study Area. The two affected Councils currently adopt the design 100 year ARI event to establish the design flood level. Retention of that same standard is considered to be appropriate within the Study Area as no unusually high flood or safety risk to potential residents or emergency staff, should evacuation be required.

Suggested evacuation routes are generally along ridge lines to create evacuation routes following upward sloping alignments from all locations to a major (or likely major), future traffic route.

Since there has been limited information available to verify the hydraulic modelling, it is recommended that, should further investigations be undertaken for the Study Area and there be a significant flood event, then flood levels should be collected to provide verification data for a future model review It is also recommended that periodic updating of the hydrologic and hydraulic assessment be completed as any future planning proceeds for potential urban development.

12. References

AECOM 2010, Menangle Park WSUD Strategy

Attorney-General's Department 2014, Technical flood risk management guideline: flood hazard

Bartley R and Speirs W 2010, A review of sediment and nutrient concentration data from Australia for use in catchment water quality models, eWater Cooperative Research Centre Technical Report

Bio-Analysis Ltd 2009, Illawarra Coal – Bulli Seam Operations – Aquatic Ecology Assessment

BMT WBM 2010, Draft NSW MUSIC Modelling Guidelines

BMT WBM 2012, Newcastle City-wide Floodplain Risk Management Study and Plan

Bureau of Meteorology, 1988, Climatic Atlas of Australia

Campbelltown City Council 2009, Campbelltown (Sustainable City) Development Control Plan 2009, Volume 2 Engineering Design and Development

Campbelltown City Council 2014, Campbelltown (Sustainable City) Development Control Plan 2014

Campbelltown City Council 2015, Mt Gilead Planning Proposal, Report to Council Meeting of 17 February 2015

Cardno 2013, West Cliff Longwalls 33-38 Aquatic Ecology Monitoring May 2002 – December 2012

Cardno 2014a, West Cliff Longwalls 33-38 Aquatic Ecology Monitoring 2002 – 2013

Cardno 2014b, Appin Area 9 Longwalls 901 to 904 Extraction Plan Appendix C – Water Management Plan

Cardno 2014c, Appin Area 9 Longwalls 901 to 904 Extraction Plan Appendix D – Biodiversity Management Plan

Chow VT 1959, Open Channel Hydraulics

Comur Consulting 2012, End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwall 704

Cox RJ, Shand TD and Blacka MJ 2010, Australian Rainfall & Runoff Revision Projects, Project 10 Appropriate Safety Criteria for People, Stage 1 Report

Department of Environment and Climate Change 2007, Practical Consideration of Climate Change, Floodplain Risk Management Guideline

Department of Infrastructure, Planning and Natural Resources 2005, Floodplain Development Manual: the management of flood liable land

Duncan HP, Fletcher TD, Vietz G and Urrutiaguer M 2014, The Feasibility of Maintaining Ecologically and Geomorphically Important Elements of the Natural Flow Regime in the Context of a Superabundance of Flow: Stage 1 – Kororoit Creek Study, Technical Report 14.5 Melbourne Watercourse Research-Practice Partnership

Ecoengineers 2007, Assessment of Water Quality Effects West Cliff Colliery Longwalls 34 to 36

Ecoengineers 2008, Assessment of Surface Water Flow and Quality Effects Appin Colliery Longwalls 705 to 710

Ecoengineers 2012, End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwall 705

Ecoengineers 2013, End of Panel Assessment of Water Flow and Quality Effects West Cliff Colliery Longwall 35

Ecoengineers 2014a, End of Panel Assessment of Water Flow and Quality Effects West Cliff Colliery Longwall 36

Ecoengineers 2014b, End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwalls 705 to 710

ecoLogical 2015, Greater Macarthur Investigation Area Biodiversity Assessment Report

Elton Consulting 2011, Moreton Park Road, Menangle Planning Proposal Submission

Environmental Protection Authority 1997, Managing Urban Stormwater: Council Handbook (Draft)

ERM 2008, Constraints and Opportunities Mapping for the Wollondilly Development Site, NSW (Draft)

GHD 2007, Report for Menangle Park Development Riparian Corridor Assessment

GHD 2004, Menangle Park Master Planning Project Local Flood and Drainage Analysis: Q03/33 Existing Drainage Environment Report

GHD 2008, Report for Menangle Park Flood Study, Rev 4

GHD 2010, Menangle Park Local Flooding and Stormwater Quantity Management (Detention)

Gilbert & Associates 2009, Report Bulli Seam Operations Surface Water Assessment

Growth Centres Commission 2006, Growth Centres Development Code

Hazelton P.A. and Tille P.J. 1990, Soil Landscapes of the Wollongong-Port Hacking 1:100,000 Sheet.

Illawarra Coal 2009a, Bulli Seam Operations Stream Risk Assessment

Illawarra Coal 2009b, Bulli Seam Operations Upland Swamp Risk Assessment

Illawarra Coal 2013, West Cliff Area 5 Longwall 35 End of Panel Report

Illawarra Coal 2014, West Cliff Area 5 Longwall 36 End of Panel Report

Institution of Engineers Australia 2000, Australian Rainfall and Runoff – A Guide to Flood Estimation

J Wyndham Prince 2014, Wilton Junction Water Cycle Management Strategy

Land and Water Conservation 1995, Upper Nepean River Flood Study

Landcom 2009, Water Sensitive Urban Design Book 1 | Policy (Draft)

Landcom 2010, Menangle Park LES Local Flooding and Stormwater Quality Management (Detention)

MSEC 2008, Report on the Prediction of Subsidence Parameters and the Assessment of Mine Subsidence on Natural Features and Surface Infrastructure Resulting from the Extraction of Proposed Longwalls 705 to 710 at Appin Colliery in Support of the SMP Application

MSEC 2009, Report on the Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Bulli Seam Operations in Support of the Part 3 Application

MSEC 2012a, Appin Colliery – Longwall 704 End of Panel Assessment Subsidence Monitoring Report for Appin Longwall 704

MSEC 2012b, Appin Colliery Longwalls 901 to 904 Subsidence Predictions and Impact Assessments for Natural Features and Surface Infrastructure in Support of the Extraction Plan

MSEC 2013, West Cliff Colliery –Longwalls 37 and 38 Subsidence Predictions and Impact Assessments for Natural features and Surface Infrastructure in Support of the Extraction Plan

MSEC 2014a, BHP Billiton Illawarra Coal: West Cliff Colliery – Longwall 36 End of Panel Subsidence Report for West Cliff Longwall 36

MSEC 2014b, Appin Colliery – Longwall 705 End of Panel Subsidence Monitoring Report for Appin Longwall 705

New South Wales Government 2005, Floodplain Development Manual – the management of flood liable land

NPWS 2002, Interpretation Guidelines for the Native vegetation Maps of the Cumberland Plain, Western Sydney, Final Edition

NSW Department Primary Industries 2006, Reducing the Impact of Weirs on Aquatic Habitat, NSW Detailed Weir Review

NSW Environment Protection Authority 1997, Managing Urban Stormwater: Treatment Techniques (Draft)

Office of Water 2012, Guidelines for riparian corridors on waterfront land

Office of Water 2014, Hawkesbury-Nepean Valley Flood Management Review Report Stage 1 Review Report

Patterson Britton & Partners 2006, Proposed Residential development at Macquariedale Road, Appin, Preliminary Riparian Corridor Investigation

Planning & Infrastructure undated, Report to Sydney West Joint Regional Planning Panel Pre-Gateway Planning Proposal – Moreton Park Road, Menangle

Shand TD, Cox RJ, Blacka MJ and Smith GP 2011, Australian Rainfall & Runoff Revision Projects, Project 10 Appropriate Safety Criteria for Vehicles, Stage 2 Report

Strahler AN 1952, Hypsometric (area-altitude) analysis of erosional topology, Geological Society of America, Bulletin Volume 63, No 11, pp.1117-1142

Sydney Catchment Authority, undated a, Dams of Greater Sydney and Surrounds Upper Nepean

Sydney Catchment Authority 2008, Annual water quality monitoring report 0607

Sydney Water 2012, Sewage Treatment System Impact Monitoring Program Case Study: Long Term Water Quality Trends in the Hawkesbury-Nepean River (1994-2011)

Sydney Water 2014, Modification to the Picton Water Recycling Plant Section 75W Modification Application, Environmental Assessment

The Ecology Lab 2008, Appin Longwalls 705-710 Effects of Mine Subsidence on Aquatic Habitat and Biota

Thomas and Golaszewski 2012, Refinement of Procedures for Floodway Delineation, Proceedings 52nd Annual NSW Floodplain Management Authorities Conference

US Army Corps of Engineers 2010, HEC-RAS River Analysis System, User's Manual, version 4.1, Hydrologic Engineering Section

Wollondilly Shire Council 2014, Planning Proposal to Amend Wollondilly Local Environmental Plan 2011

Worley Parsons 2014, Hunter River Flood Study (Muswellbrook to Denman)

Appendices

Appendix A – Data details

A.1 Boundaries

A.1.1 Study area

The Study Area adopted for this investigation includes the extent of an Investigation Area and an Urban Capable Area.

A.1.2 Study boundary

The initial project was identified as being the Greater Macarthur Study Area as shown in *A Plan for Growing Sydney.* This boundary is shown as the red boundary line on Figure A-1.

A.1.3 Urban capable boundary

A second boundary described as the Urban Capable boundary is also shown on Figure A-2. The alternate boundary has been developed during this assessment to potentially provide a more logical boundary for the study area.

A.2 Local Government areas

The Study Area straddles the common boundary of Campbelltown City Council and Wollondilly Shire Council as shown in Figure A-5.

A.3 Sydney Catchment Authority area

A relatively small portion of the Study Area is located within the *State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011* boundary. The portion of the Study Area within the SEPP area is shown in Figure A-2 and is located generally south of Wilton Road between Wilton and Appin.

The area in question is located downstream of Lake Cataract and Lake Cordeaux and is classified as “Special Area - no entry” on Sydney Catchment Authority mapping. The SCA web site indicates that the restrictions are not applicable to privately owned lands and public roads within the nominated Special Area.

A.4 Air imagery

Air imagery for the study was sourced from Land Property Information and SIX Maps.

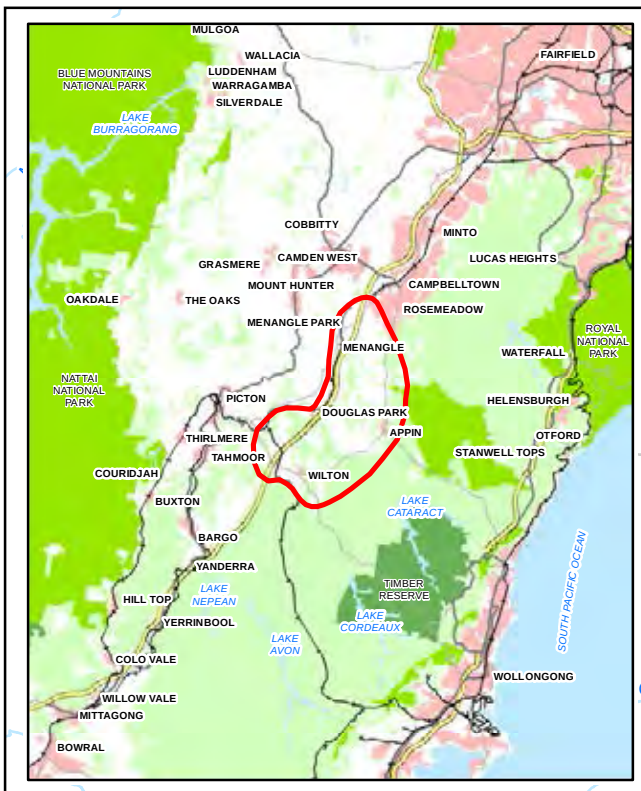
A.5 Land uses

A.5.1 Existing

Land use within the Study Area has historically been focused largely on agricultural pursuits with small pockets of urban development. The agricultural uses have included relatively small acreage grazing parcels, pockets of intense uses such as chicken sheds and food production (market garden style agriculture). Extractive industries (sand mining) have also been and are continuing to be pursued along the Nepean River downstream of Menangle Bridge.

Urban areas within the Study Area include Appin, Menangle, Douglas Park, Wilton and parts of Glen Alpine and Rosemeadow.

Underground mining has been undertaken over a large portion of the Study Area with further mining planned. Figure A-2 shows the existing and planned extent of underground mining within the Study Area.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Distributor Road
- Railway
- Watercourse
- Waterbody
- State Conservation Area
- Weir

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Study Area

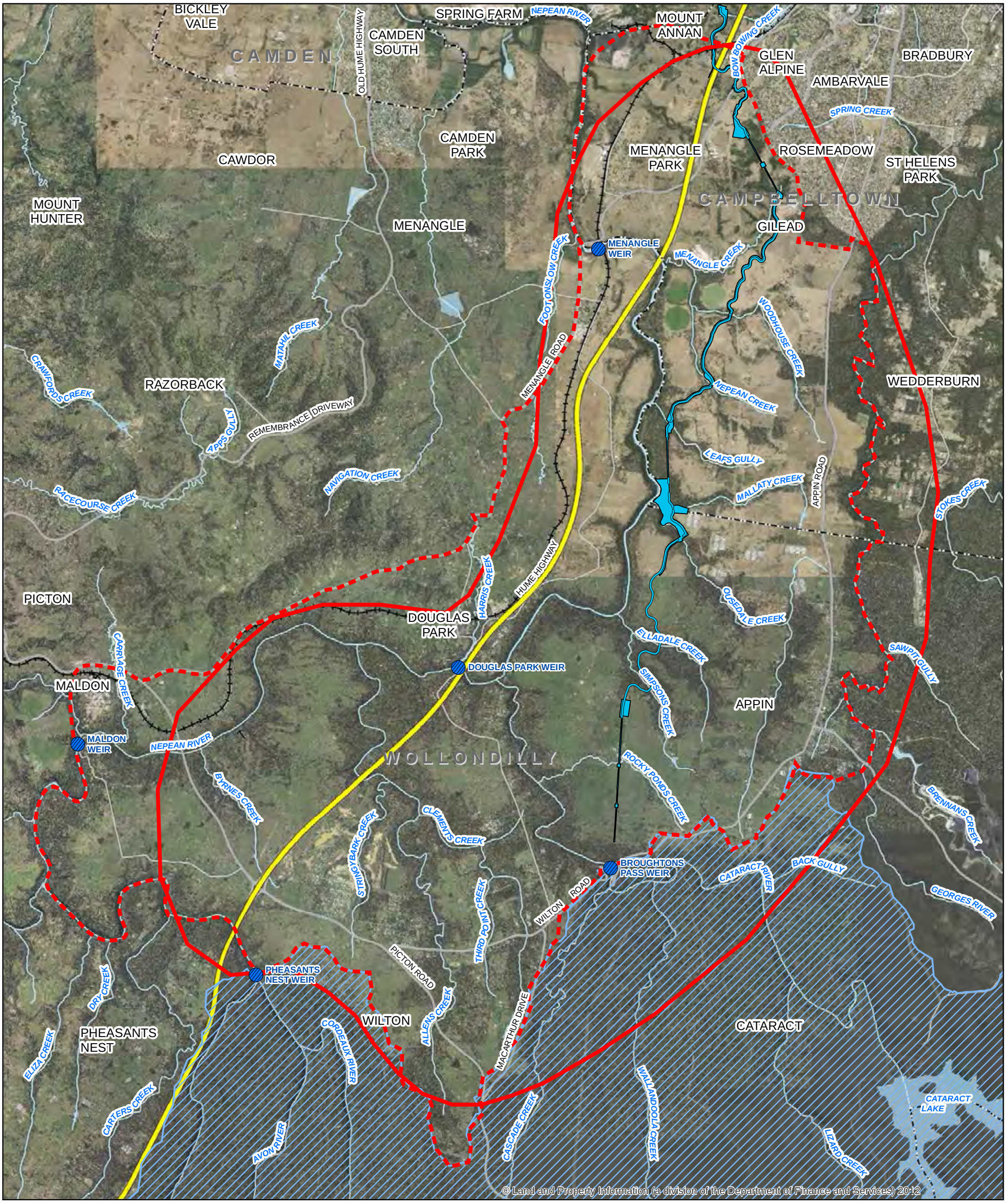
Figure A-1

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_A\2217728_A007_StudyArea_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- LGA
- Railway
- Motorway
- Primary Road
- Distributor Road
- Watercourse
- Waterbody
- Upper Canal
- Special Area
- Weir

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Existing Land Use

Figure A-2

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_A\2217728_A006_ExistingLandUse_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

A.5.2 Proposed

This study, together with the concurrent studies, for the Study Area are being undertaken to assess the potential extent of land capable and suitable for potential urban development. At present the form of the urban development (distribution and amount of each of dwelling areas, industrial, employment and retail) has not been defined.

Assessment of the suitability of the land for urban development is being evaluated using a comprehensive suite of parameters and considerations.

Should the Study Area be found capable and suitable for urban development then further planning studies would be completed to assess the refined development detail.

A.6 Water catchment areas

The Study Area is located primarily within the Upper Nepean Catchment. A small area to the east and north east of the Study Area is located within the Georges River catchment.

A.7 Topographic information

A.7.1 LIDAR

LIDAR topographic information was available from Land and Property Information. A terrain model was formed from the LIDAR information and that used to then develop contours for the Study Area.

The terrain model created from the LIDAR showed watercourses in slightly different locations to those shown on 1:25,000 topographic maps covering the Study Area. This watercourse locations derived from LIDAR have been adopted for this study.

The LIDAR data was used to create both a topographic map, Figure A-3, and then a slope map, Figure A-4, from the topographical data.

The topographic map clearly identifies the incised nature of many of the watercourses within the Study Area. The incised nature of the watercourses is reinforced by the slope map.

A.7.2 Major infrastructure in study area

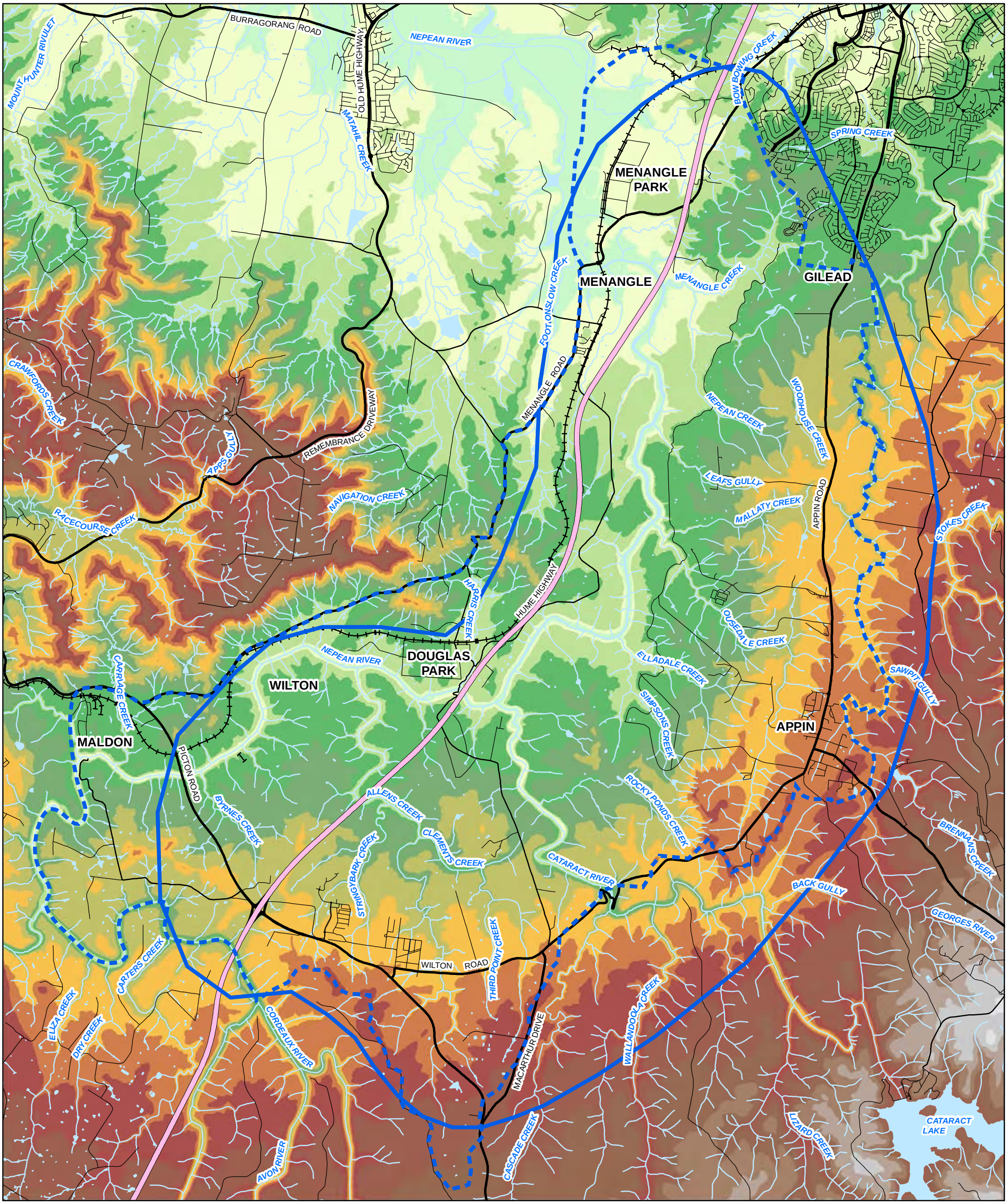
Water supply

Nepean Dam, located on the Nepean River, Avon Dam, Cataract Dam and Cordeaux Dam are located upstream of the study area and impact the catchment hydrology.

The Avon, Cordeaux and Nepean Dams discharge into the Cordeaux River prior to it entering the Nepean River. Water is extracted an Pheasants Nest weir and is transferred to Broughtons Pass Weir, located on the Cataract River. Water is then extracted from the Broughtons Pass Weir and is conveyed to Prospect Reservoir by way of the Upper Canal which passes through the Study Area.

Relevant characteristics of the dams are described by Water NSW (formerly Sydney Catchment Authority) as being:

- Avon Dam – located on Avon River; catchment area 142 square kilometres, capacity 214,360 ML
- Cataract Dam – located on Cataract River below the junction with the Loddon River; catchment area 130 square kilometres, capacity 94,300 ML
- Cordeaux Dam – located on Cordeaux River; catchment area 91 square kilometres, capacity 93,640 ML
- Nepean Dam – catchment area 320 square kilometres, capacity 70,170 ML



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Railway
- Motorway
- Primary Road
- Distributor Road
- Local Road
- Watercourse
- Waterbody

Elevation

- <= 50m
- 50m - 75m
- 75m - 100m
- 100m - 125m
- 125m - 150m
- 150m - 175m
- 175m - 200m
- 200m - 225m
- 225m - 250m
- 250m - 275m
- 275m - 300m
- 300m - 325m
- 325m - 350m
- 350m - 375m
- 375m - 400m
- 400m - 425m
- > 425m

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Study Area Topography

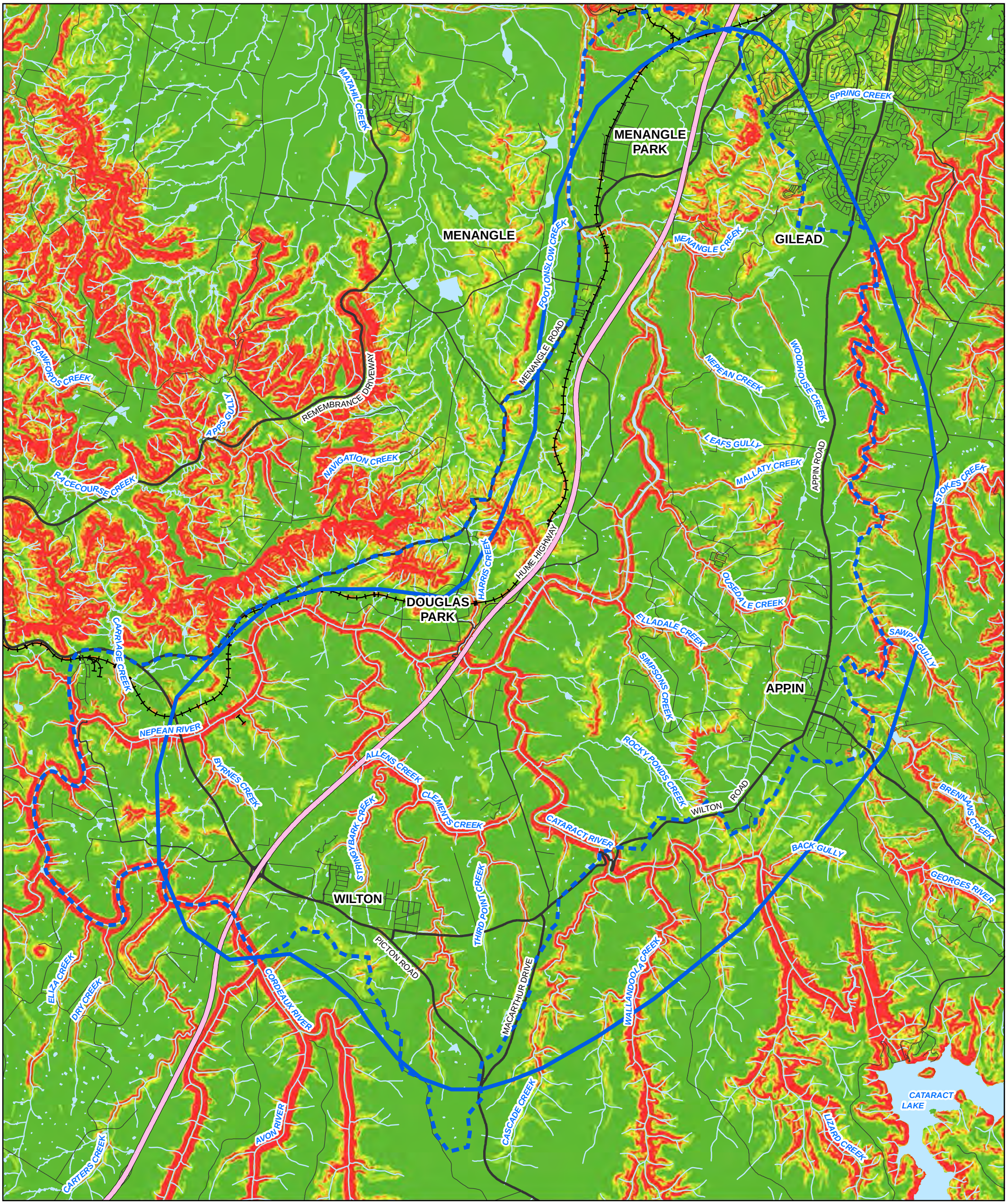
Figure A-3

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_A\2217728_A001_StudyArea_Topography_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Railway
- Motorway
- Primary Road
- Distributor Road
- Local Road
- Watercourse
- Waterbody

Slope

- <= 1:10
- 1:10 - 1:6
- 1:6 - 1:5
- 1:5 - 1:4
- > 1:4

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Study Area Slopes

Figure A-4

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_A\2217728_A002_StudyArea_Slopes_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

Other significant water infrastructure includes:

- Pheasants Nest Weir – water from the Nepean Dam and Cordeux Dam from to this weir on the Nepean River. From this location water is diverted, by tunnel, to Broughtons Pass Weir
- Broughtons Pass Weir – located on the Cataract River downstream of the Cataract Dam
- Upper Canal – this canal transports drinking water from Broughtons Pass Weir to Prospect Reservoir located north of the Study Area
- Menangle Weir – this weir is constructed of sandstone blocks and is approximately 3 m high and 78 m wide. This weir, which supplies approximately 20 water users, was constructed as compensation for the construction of the Nepean Weir.
- Douglas Park Weir – this weir forms part of the Douglas Park Drive causeway and is reportedly owned by Wollondilly Council. The weir is approximately 0.8 m high and 40 m wide and supplies water for licenced users.
- Maldon Weir – this weir is reportedly privately owned. It is a concrete structure that is approximately 15 m high and 40 m wide and did provide a freshwater supply for industrial purposes however the water extraction is now downstream of the weir. Other private water users extract water from the weir pool.

Wastewater

The West Camden STP capacity has been expanded to, in part, allow for the future servicing of future population growth within the STP catchment and to also allow for potential transfers of wastewater from the area around Menangle and Menangle Park. The West Camden STP discharges into Matahil Creek and thence the Upper Nepean River and does not impact the Study Area.

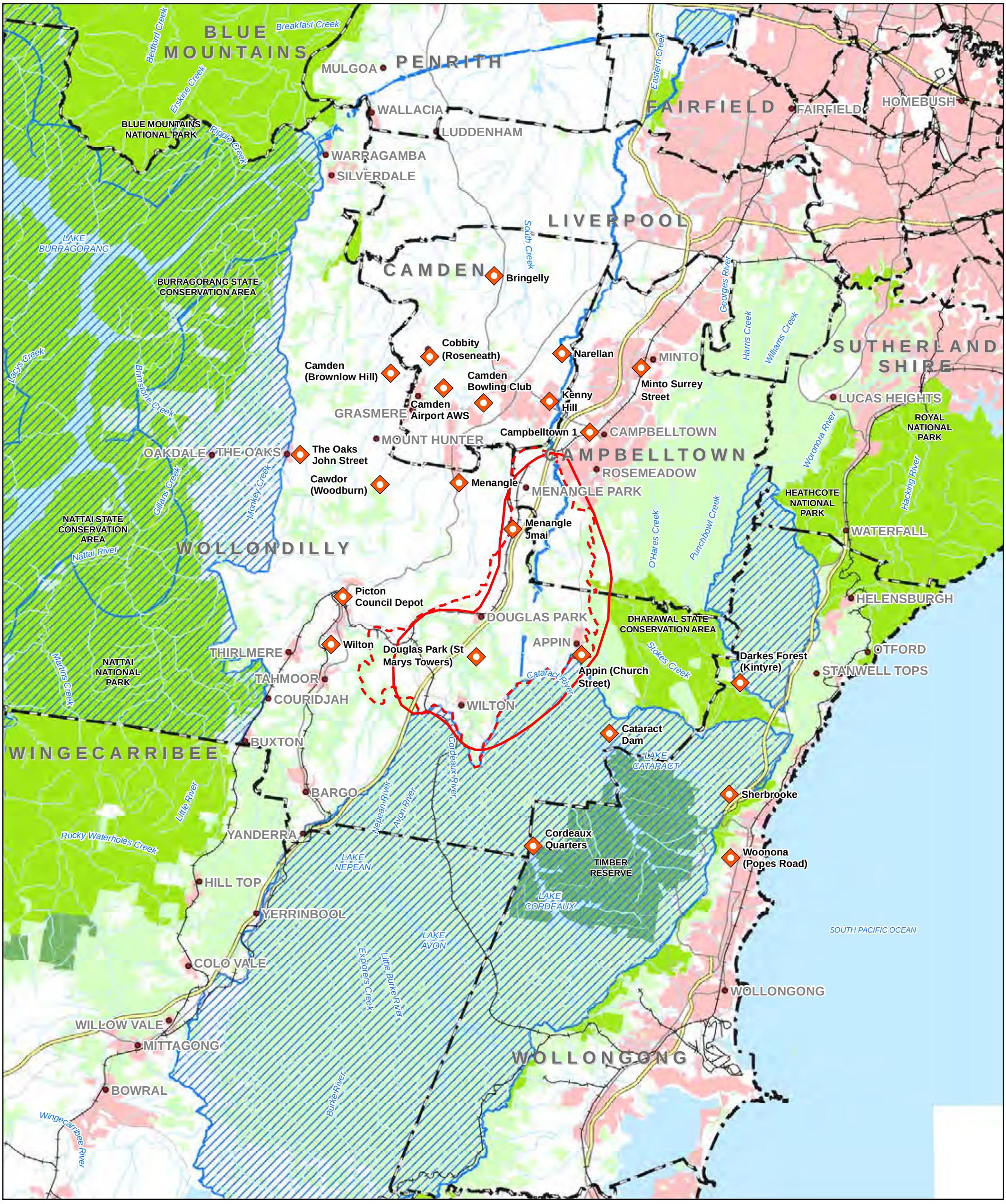
The Picton Water Recycling Plant is predicted to have an increase in flow rates as a result of urban growth and the connection of processing plants. The treatment plant and associated farm are located south of Picton and south of the Study Area. Any discharge from either the RWP or the far would find its way into one of Teatree Gully or Back Creek and thence Stonequarry Creek and eventually the Nepean River (Sydney Water 2014).

Roads

Major roads within and near the Study Area include:

- Hume Highway (also known as Hume Freeway, Hume Motorway, M31)
- Appin Road
- Menangle Road
- Picton Road
- Wilton Road
- Macarthur Drive

Douglas Park Drive, which connects Douglas Park and Wilton Road has a relatively low level causeway crossing of the Nepean River. This causeway, also known as the Douglas Park Weir, has not been explicitly included in the hydraulic analysis as it reportedly regularly overtops.



LEGEND

- Town
- Investigation Area Boundary
- Urban Capable Boundary
- Built up area
- Railway
- Dual Carriageway
- Principal Road
- Secondary Road
- Minor Road
- Track
- Watercourse
- Waterbody
- ForestryReserve
- NatureConservationReserve
- ForestOrShrub
- LGA
- SCA boundary
- Rainfall Station

Paper Size A3

0 1.5 3 6 9 12

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Nearby Daily Rainfall Stations

Figure A-5

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_A\2217728_A003_Rainfall_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

Rail

The Main Southern Rail line passes through the Study Area. Figure A-1 shows the rail line as passing from Campbelltown, north of the Study area, and then passes through Menangle Park, Douglas Park and continues through Maldon and Camden.

The main rail crossing within the Study Area is that where it crosses the Nepean River south of Menangle Park. South of that crossing the rail line is located west of the Nepean River.

Rail crossings of watercourses of have not been specifically incorporated into the hydraulic modelling completed within this investigation.

A.8 Historical climate data

A.8.1 Rainfall

Catchment wide rainfall

An initial verification of the average annual rainfall falling across the Study Area was undertaken. This was completed by obtaining data records for nearby Bureau of Meteorology sites (operational and closed) that had in excess of 30 years of data. In some cases the data series was incomplete with some missing years of data.

The sites selected are identified in Table A-1 while their location is shown in Figure A-5.

Statistics were reviewed for each station for years having complete rainfall records and the results are shown in Figure A-6.

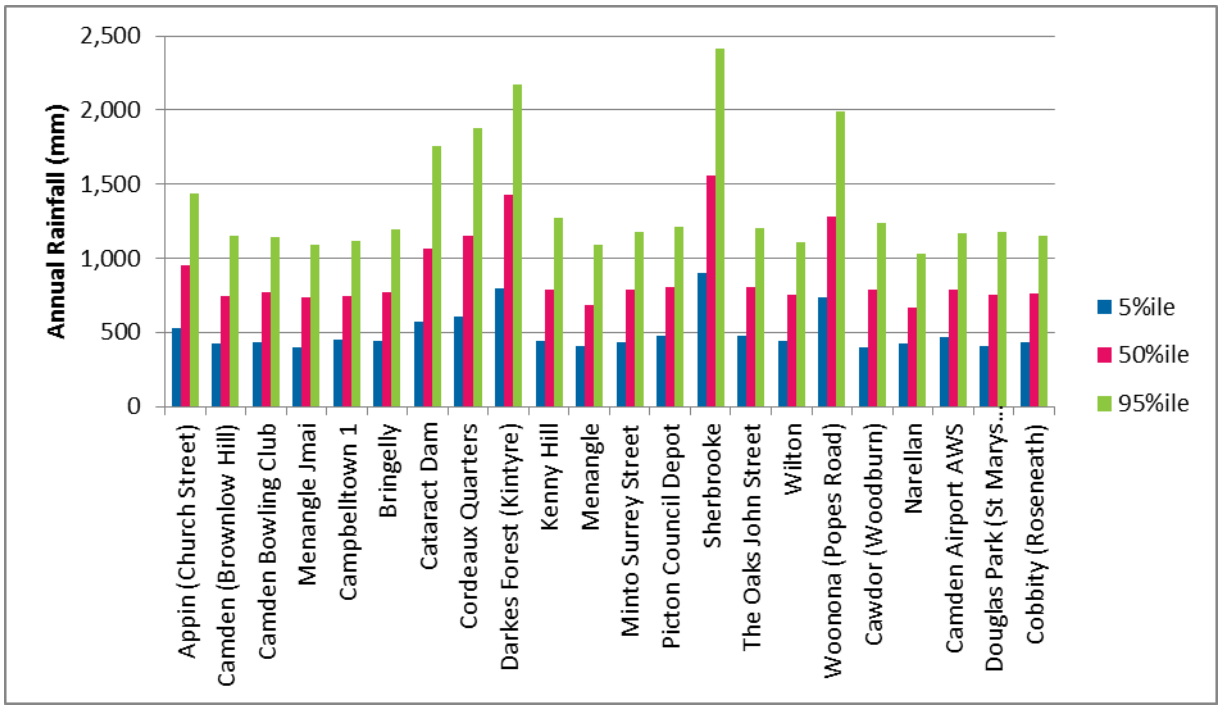


Figure A-6 Average annual rainfalls at nearby stations

Table A-1 Nearby annual rainfall totals

Station Number	Station Name	First year with complete record	Last year with complete record
67015	Bringelly	1867	2014
68001	Appin (Church Street)	1907	1996
68007	Camden (Brownlow Hill)	1884	1883
68011	Camden Bowling Club	1884	1974
68013	Menangle Jmai	1878	1990
68014	Campbelltown 1	1846	1960
68016	Cataract Dam	1904	2003
68020	Cordeau Quarters	1933	1967
68024	Darkes Forest (Kintyre)	1895	2013
68037	Kenny Hill	1926	1969
68041	Menangle	1896	1967
68043	Minto Surry Street	1890	1989
68052	Picton Council Depot	1880	2014
68059	The Oaks John Street	1913	1974
68056	Sherbrooke	1893	1970
68066	Wilton	1872	1965
68108	Woonona (Popes Road)	1930	2008
68122	Cawdor (Woodburn)	1963	2014
68150	Narellan	1896	1932
68192	Camden Airport AWS	1943	2012
68200	Douglas Park (St Marys Towers)	1974	2014
68207	Cobbity (Roseneath)	1889	1973

Based upon the site locations shown in Figure A-5 and the rainfall statistics shown in Figure A-6 it was concluded that a reasonable representation of the rainfall over the Study area could be determined by deleting the records for Darkes Forest (Kintyre), Sherbrooke and Woonona (Popes Road). These three sites were deleted on the basis that their annual rainfalls were significantly greater than that for the rest of the stations, the surrounding topography and the distance from the Study Area. For the reduced data set the average rainfalls were:

- 5%ile annual rainfall – approximately 460 mm
- 50%ile annual rainfall – approximately 810 mm
- 95%ile annual rainfall – approximately 1,240 mm.

The above analysis is only indicative as it does not consider the inconsistency in the number of years of data at the stations and the period over which the data was available.

Adopted rainfall series

For this assessment, daily rainfall data was obtained as SILO Patched Point Data from the Queensland Climate Change Centre of Excellence. SILO Patched Point Data is based on historical data from a particular Bureau of Meteorology (BOM) station with missing data 'patched in' by interpolating with data from nearby stations. For this assessment, SILO data was obtained for BOM Picton Council Depot (Station No: 68052) located approximately 13 km west of the study area. Whilst not being spatially located within the Study area, Picton had an annual rainfall pattern closely representing the probability distribution of the annual data series.

A.8.2 Annual rainfall variability

The annual rainfall data for the Greater Macarthur Study Area Study area reflects known patterns for the region, with recent notable years of high rainfall associated with documented storms and high rainfall events. The period of rainfall data used for this assessment extended from January 1899 to December 2014 and is summarised as annual totals in Figure A-7. Also noted is the decadal changes in rainfall from 1950 to present with there being a decreasing rainfall average.

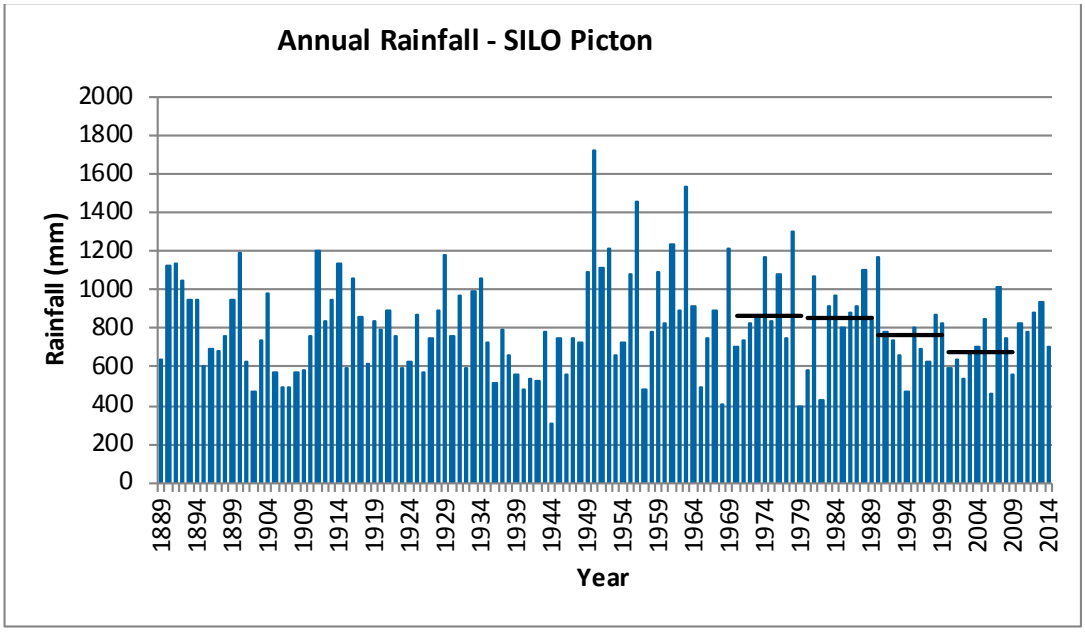


Figure A-7 Annual rainfall data for the Macarthur study area

The annual rainfall records for the complete data set showed:

- 5%ile annual rainfall - 476 mm
- Median annual rainfall - 780 mm
- 95%ile annual rainfall – 1210 mm.
- Mean annual rainfall – 812 mm
- Minimum annual rainfall – 303 mm in 1944
- Maximum annual rainfall – 1723 mm in 1950

Consistent with observations from surrounding regions, lower annual averages were found prior to 1950, followed by a period of higher average annual rainfalls until the 1970's. Figure A-7 shows the annual averages from the past four decades declining distinctly before a increase over the past four years.

A.8.3 Monthly rainfall variability

The variability of the aggregated monthly rainfall records are shown in Figure A-8. The aggregated data shows a typical representation of rainfall for the region – higher average mean monthly rainfalls in the summer and autumns months while the months of lowest rainfall were in late winter and early spring.

The 5%ile monthly rainfall was relatively low varying between approximately 3 and 13 mm. The corresponding 95%ile monthly rainfalls varied between approximately 150 and 265 mm. September (early spring) had the lowest 95%ile rainfall value.

Generally there was a relatively large difference between the mean and 95%ile rainfall values in summer and autumn, indicating large storms are common during these times. An exception was December which had a 95%ile monthly rainfall that was relatively small compared to the average monthly December rainfall. June had the lowest 95%ile rainfall value.

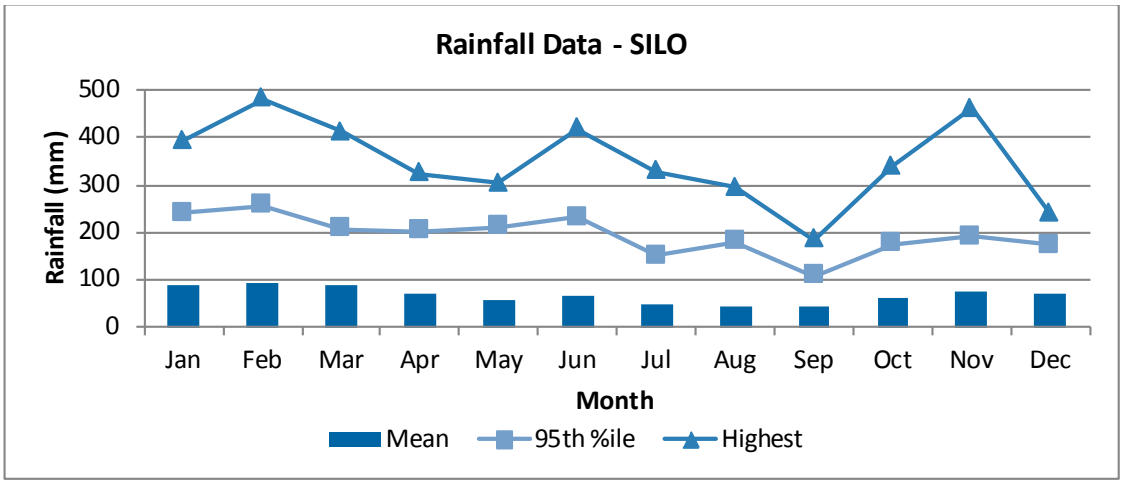


Figure A-8 Monthly rainfall data for the Macarthur study area

A.8.4 Temperature

Temperature data was obtained from the Bureau of Meteorology website for Camden Airport AWS (Station No: 068192) climatic station.

Whilst the station is located outside the study area, it is in close proximity to the study area and provides an appropriate understanding of the temperature patterns in the study region. The Camden Airport AWS site also provided the most complete data set of those stations nearby to the Study area.

Figure A-9 shows the 50%ile daily maximum temperature recoded each month together with the 5%ile and 95%ile values for each month. There was a significant variation in the observed temperatures between the summer and winter values.

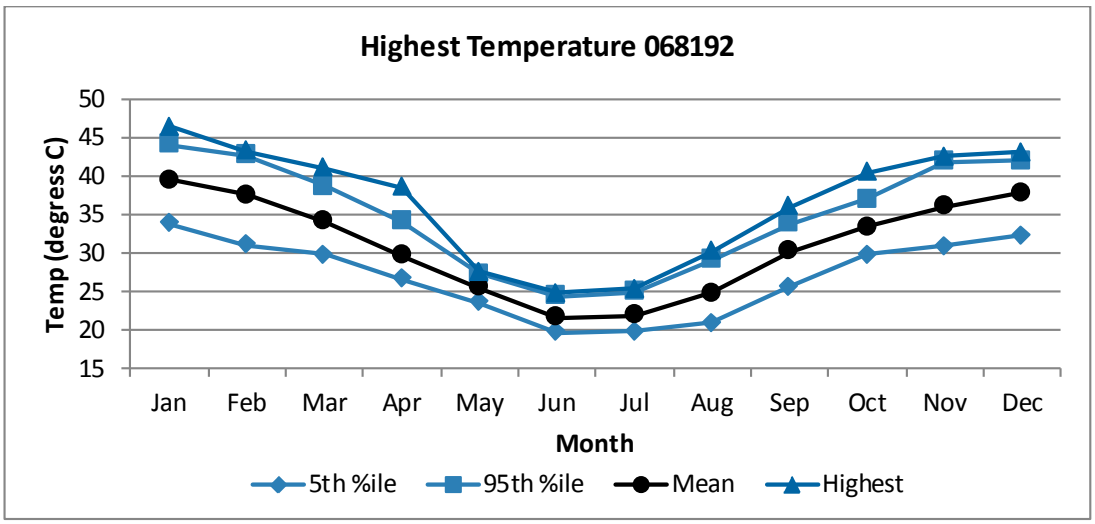


Figure A-9 Highest recorded temperatures for the Macarthur study area

A.8.5 Evaporation

Monthly and annual Pan evaporation values have been interpolated from dat on the Bureau of Meteorology website (accessed 13 March 2015) and then verified, for the Study area, from the Climatic Atlas of Australia.

Adopted average pan evaporation rates are given in Table A-2.

Table A-2 Evaporation and transpiration rates

Month	Average Pan Evaporation (mm)	Average Potential Transpiration (mm)	Average Actual Transpiration (mm)
January	220	150	85
February	165	125	80
March	135	115	65
April	100	80	40
May	70	55	25
June	55	40	30
July	70	40	30
August	85	60	30
September	110	85	40
October	150	125	70
November	150	150	80
December	240	160	80
Annual	1600	1170	670

Note: Monthly values and annual values were determined from charts. Thus monthly values may not sum exactly to the provided annual values.

A.8.6 Evapotranspiration

Potential and actual evapotranspiration data was obtained from the Bureau of Meteorology web site (accessed 13 March 2015). The obtained actual evapotranspiration data is shown in Table A-2.

Actual evaporation is described on the web site as that evapotranspiration which would occur from a large area under an unlimited rainfall condition over an area sufficiently large that there would not be any localised upwind conditions created. Potential evaporation is described on the web site as that evapotranspiration which would occur from a large area under the existing rainfall conditions for a large area without local upwind conditions.

The data suggest that the average annual actual evapotranspiration is approximately 42% of the average annual pan evaporation and approximately 57% of the annual potential evapotranspiration value.

A.9 Design rainfalls

Design rainfalls for events up to the 100 year ARI magnitude were determined from the Bureau of Meteorology web site.

A.10 Historical flooding

An indication of the magnitude of recent flooding in the Nepean River can be determined from Figure A-10. This figure was adapted from data in the *Hawkesbury-Nepean Valley Flood Study Review Stage One* (Office of Water, 2014)

This figure indicates that the historical floods since 1908 have all been smaller than the 5% AEP magnitude (1 in 20 year ARI).

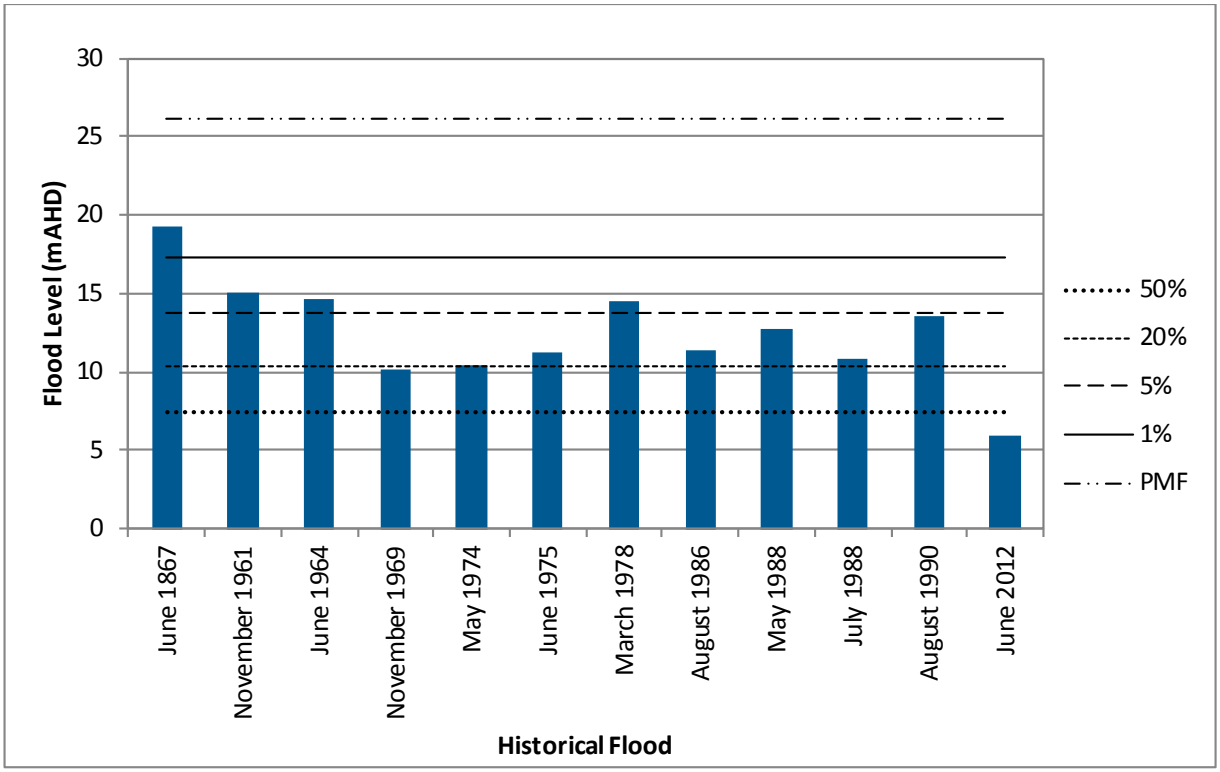


Figure A-10 Significant floods at Penrith

An analysis of the provided flow data for the Broughtons Pass Weir and the Pheasants Nest Weir was completed and the derived graphs of the annual maximum daily flow values are given in Figures A-11 and A-12. These two figures show that the largest flood during their monitoring period was that in 1988. The 1988 only ranked as being under a 20% AEP event at Penrith.

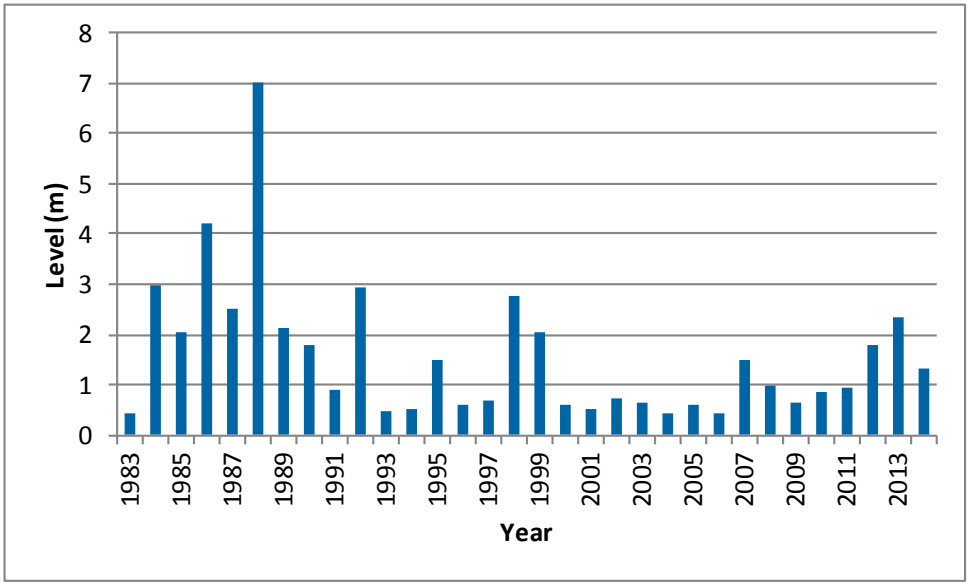


Figure A-11 Recent maximum flood levels at Broughtons Pass Weir

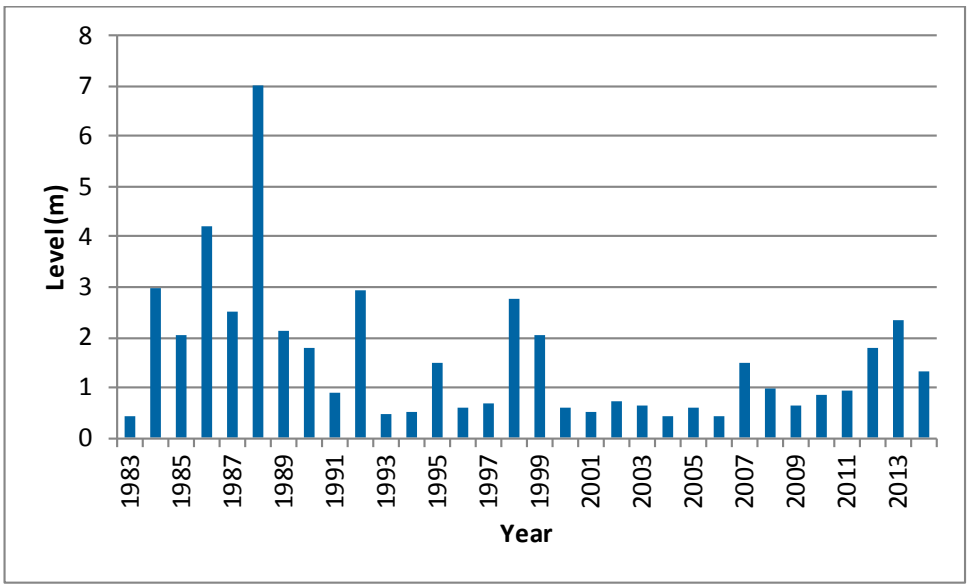


Figure A-12 Recent maximum flood levels at Pheasants Nest Weir

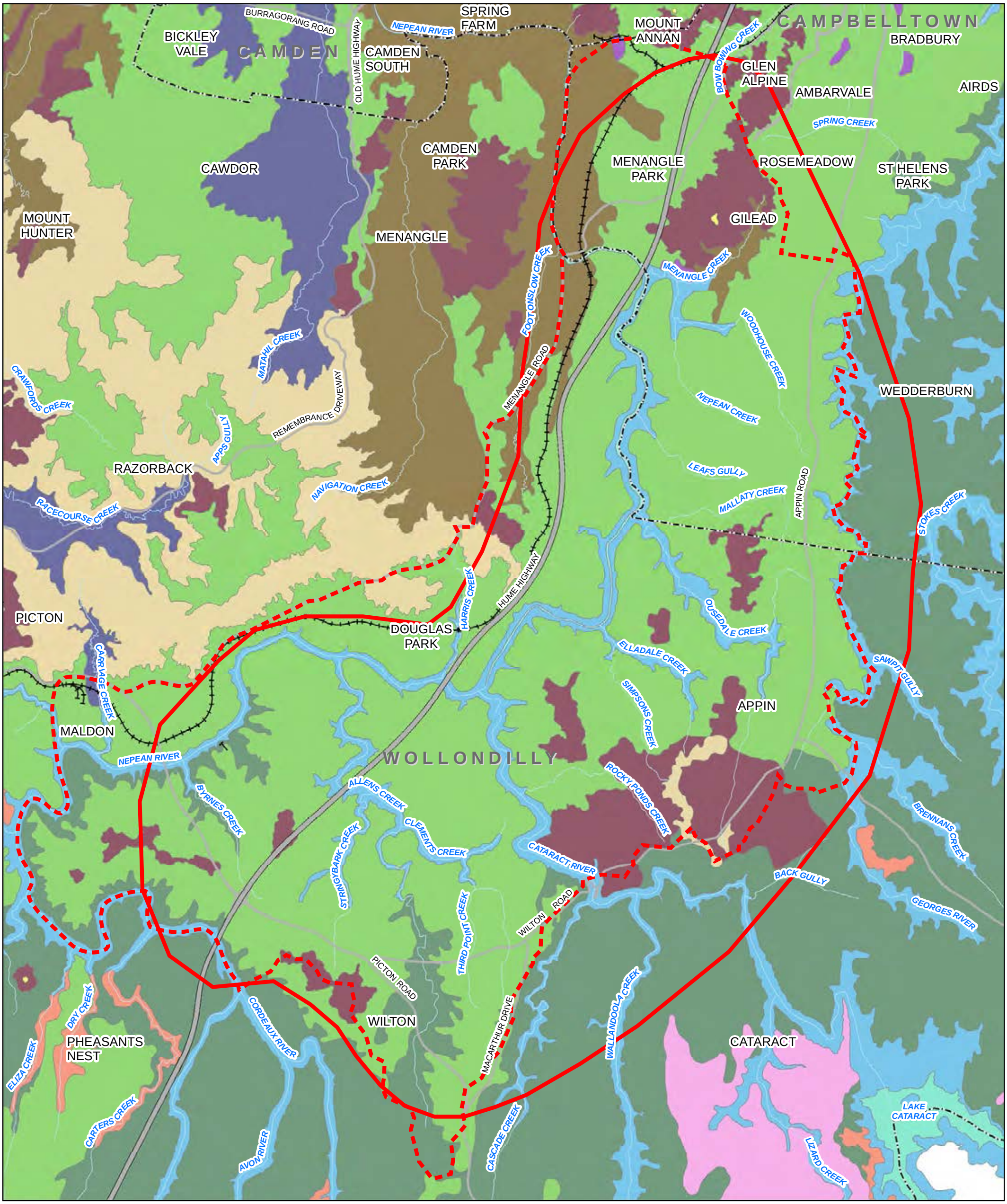
A.11 Soils

A.11.1 Landscape mapping

The study area is covered by the Soil Landscapes of the Wollongong-Port Hacking 1:100,000 Sheet (Hazelton and Tille, 1990). This indicates that six different soils landscapes occupy the study area, Figure A-13 with the Blacktown soil landscape dominant, covering approximately 60 % of the Study Area and approximately 70 % of the Urban Capable Area. The six soil landscapes are briefly described below:

- Blacktown – flat to gently undulating rises developed on shales of the Wianamatta Group.
- Hawkesbury – located along the major streamlines within the study area. Characterised by steep, rocky valley slopes of major watercourses incised into Hawkesbury sandstones.
- Luddenham – occupies elevated areas through the central section of the study area. Characterised by rolling to steep hills developed on shales of the Wianamatta Group.
- Lucas Heights – occupies gently undulating plateau areas along the eastern and south-eastern margins of the study area.
- Picton - isolated occurrences on the margins of the southern half of the study area. Characterised by steep slopes prone to mass movement consisting of colluvial materials developed on shales of the Wianamatta Group.
- Theresa Park – occupies alluvial floodplains and terraces along the Nepean River, Menangle Creek and Foot Onslow Creek in the northern extent of the study area.

Table A-3 provides the percentage cover of each of the six soil landscapes in the study area and outlines the urban capability and key limitations as defined by Hazelton and Tille (1990). In addition, there are some minor areas mapped in the soils landscape mapping as disturbed terrain and water (dams).



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- LGA
- Railway
- Motorway
- Primary Road
- Watercourse
- BLACKTOWN
- DISTURBED TERRAIN
- GYMEA
- HAWKESBURY
- LUCAS HEIGHTS
- LUDDENHAM
- MADDENS PLAINS
- MONKEY CREEK
- PICTON
- THERESA PARK
- VOLCANIC
- WATER

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Soil Landscapes

Figure A-13

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_A\2217728_A004_SoilLandscapes_InvestigationArea_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

Table A-3 Percentage cover, urban capability and key limitations of soil landscapes in the study area.

Soil Landscape	Study Area (GHD) Coverage	Study Area (URBIS) Coverage	Urban Land Capability	Key Limitations
Blacktown	60.4 %	69.9 %	High	Moderately reactive. Seasonal waterlogging. Localised sodic and/or saline subsoils.
Hawkesbury	9.7 %	8.6 %	Not capable	Extreme erosion hazard. Mass movement hazard (rockfall). Steep slopes. Rock outcrops. Thin, stony soils of low fertility
Luddenham	9.9 %	9.3 %	Low to Moderate	High erosion hazard on steeper slopes. Potential mass movement hazard on steeper slopes. Localised impermeable, highly plastic, moderately reactive subsoils.
Lucas Heights	14.9 %	5.5 %	High	Stony, hard-setting soils of low fertility
Picton	0.7 %	1.5 %	Not capable	Extreme erosion hazard. Mass movement hazard (slumping). Steep slopes. Impermeable and reactive plastic subsoils.
Theresa Park	3.9 %	4.6 %	High in flood free areas.	Localised flooding. Seasonal waterlogging. High erosion hazard for concentrated flows.
Disturbed Terrain and Water	0.5 %	0.6 %	Not Capable	NA

More detailed assessments of soil properties undertaken for past rezoning and development proposals support the general soil landscape limitations of Hazleton and Tille (1990).

For the Wilton Junction rezoning proposal, which is dominated by the Blacktown soil landscape, J Wyndham Prince (2014) summarise key soil constraints as mild agressivity to concrete and widespread sodic soils, both of which can be managed during earthworks and site preparation stages of development.

A.11.2 Significant erosional areas

A review of aerial imagery indicates that gully and sheet erosion is prevalent on steeper slopes in the north western extent of the study area within the Foot Onslow and Harris Creek catchments. Bank erosion and channel incision issues are particularly prevalent along the channel of Foot Onslow Creek. Gully erosion is also common along drainage lines located within the Picton soil landscape.

Elsewhere, existing areas of erosion are limited to isolated occurrences, primarily manifested as gully erosion along drainage lines in cleared sections of the study area.

A.12 Watercourses

A detailed investigation of all watercourses within the Study Area has not been completed as part of this investigation but some data is available as described in the previous studies undertaken for mining operations.

A.12.1 Watercourse definition and Strahler stream ordering

The *NSW Water Management Act 2000* (WMA) controls the extraction, use, construction of works, and the carrying out of activities in or near waterfront land in NSW. Waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river, lake or estuary. 'River' is defined as any watercourse, whether perennial or intermittent and whether comprising a natural channel or a natural channel artificially improved and any tributary, branch or other watercourse into or from which a watercourse flows.

The NSW Office of Water (NoW) Guidelines for riparian corridors on waterfront land (NoW 2012) state that 'where a watercourse does not exhibit the features of a defined channel with bed and banks, the Office of Water may determine that the watercourse is not waterfront land for the purposes of the WMA'. These guidelines provide for the protection of waterfront land identified as riparian corridors based on stream order under the Strahler (1952) system as applied to the watercourse mapping found on current topographic maps (1:25000 and coarser).

Comparison of the best available mapping of watercourses (1:25,000 map scale) covering the study area with LIDAR data indicates that the mapped watercourses are often poorly aligned spatially with watercourse positions as more accurately defined by LIDAR. As such, defining riparian corridors based on the existing watercourse mapping would present spatial inaccuracies in areas protected under the WMA and associated potential constraints to development.

Hence, to improve the spatial accuracy of riparian corridor mapping, a LIDAR derived watercourse network was developed based on a minimum catchment area of 10 hectares. The Strahler (1952) stream order system methodology was subsequently applied to the LIDAR derived stream network in the study area.

Figure A-14 indicates the Strahler stream ordering process for a generic catchment. Numbering begins at the top of a catchment with headwater ('new') flow paths being assigned the number one. Where two flow paths of order one join, the section downstream of the junction is referred to as a second order stream. Where two second order streams join, the watercourse downstream of the junction is referred to as a third order stream, and so on. Where a lower order stream (e.g. first order) joins a higher order stream (e.g. third order), the area downstream of the junction will retain the higher stream order.

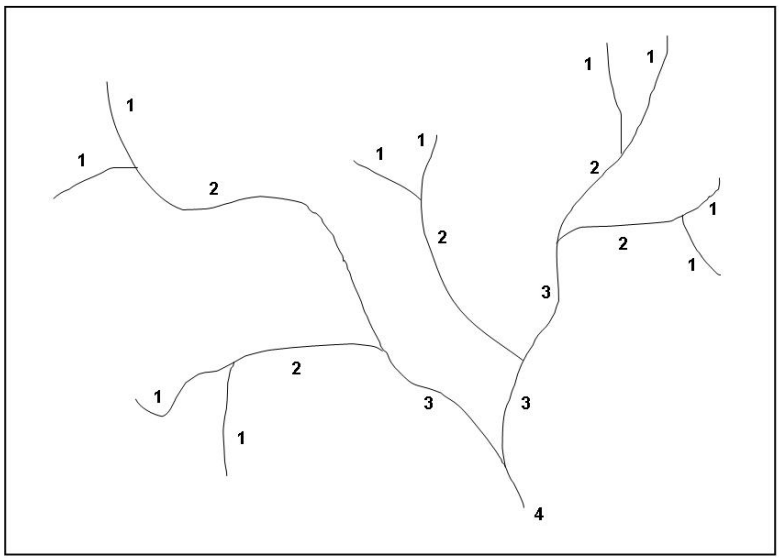


Figure A-14 Stream order for a generic catchment using Strahler (1952) Method

The results of the stream ordering exercise are displayed in Figure A-15. The Nepean River through the study was provided a stream order of 7 based on Bio-Analysis (2009).

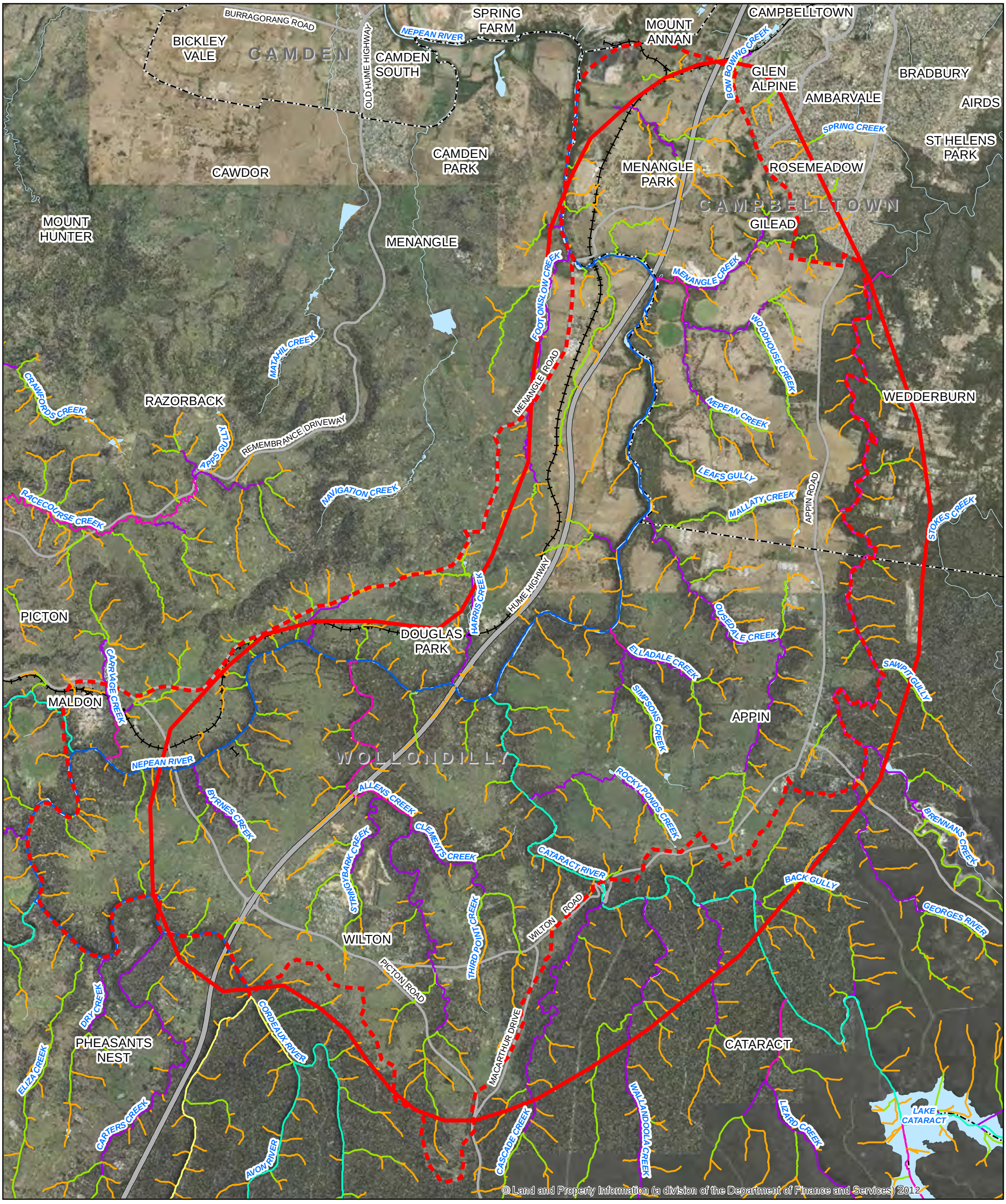
A.12.2 Watercourse form and condition

The majority of watercourses within the study area greater than 3rd order are confined valley systems incised into the surrounding landscape. The rugged nature of these systems means that they are relatively undisturbed and largely in good geomorphic condition. These systems are also robust and are not prone to changes in channel form in response to alterations in hydrologic regimes.

The main exception is the lower reach of the Nepean River in the northern extent of the study area. Here the river becomes primarily alluvial with floodplains and terraces typically flanking both sides of the channel. GHD (2009) examined channel changes along a section of the Nepean River downstream of Menangle Park through a review of historical aerial photographs dating from 1958. This indicated the channel remained relatively stable with only localised occurrences of bank retreat of up to 10 metres over the time period. As a result, the Nepean River channel through this reach is considered relatively laterally stable, although it has the capacity adjust in response to alterations in hydrologic regimes.

The bulk of first and second order watercourses are primarily located in the cleared, lower sloped sections of the study area and exhibit both channelised and unchannelised watercourse forms. These watercourses have been subject to a variety of agricultural pressures including clearing of riparian vegetation, unrestricted stock access and the construction of online farm dams. As a result, many of these watercourses are considered to be in moderate to poor geomorphic condition and in places exhibit evidence of channel incision and ongoing bank erosion issues.

This is supported by J. Wyndham Prince (2014) who found that many of the largely ephemeral watercourses in the Wilton Junction study area did not exhibit defined channels and where channels exist, they are typically eroded as result of livestock access. Similarly, Ecological (2015) in respect to the Mt Gilead planning proposal, found that many of the first and second order watercourses in the respective study areas are moderately to highly degraded with none or limited aquatic and riparian value.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- LGA
- Railway
- Motorway
- Primary Road
- Watercourse
- Waterbody

Stream Order

- 1
- 2
- 3
- 4
- 5
- 6
- 7

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Strahler Stream Order

Figure A-15

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_A\2217728_A005_StrahlerStreamOrder_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

A.13 Vegetation

A detailed study of the vegetation within the Study Area is being undertaken by a concurrent study. The following provides a brief assessment of the vegetation as relating to proposed riparian corridor requirements.

A.13.1 Vegetation types

The riparian vegetation within the Greater Macarthur area has been mapped and described in the Cumberland Plain Mapping Project (NPWS, 2002). Riparian vegetation within the Greater Macarthur area was mapped as containing the following vegetation communities:

- Shale Sandstone Transition Forest (EEC)
- Shale Plains Woodland *(Cumberland plain woodland)* (EEC)
- Shale Hills Woodland *(Cumberland plain woodland)* (EEC)
- Alluvial Woodland *(River flat eucalypt forest)* (EEC)
- Moist Shale Woodland (EEC)
- Sandstone Ridgetop Woodland
- Upper Georges River Sandstone Woodland
- Western Sandstone Gully Forest

Mapping of communities has been undertaken in a concurrent study (ecological 2015). The communities included:

- Moist Shale Woodland
- Alluvial Woodland
- Riparian Forest
- Shale Plains Woodland
- Shale Hills Woodland
- Cumberland Shale –Sandstone Ironbark Forest
- Shale Sandstone Transition Forest (High Sandstone Influence)
- Shale Sandstone Transition Forest (Low Sandstone Influence)
- Sydney hinterland Exposed Sandstone Woodland
- Sydney Hinterland Grey Gum Ridgetop Forest
- Upper Georges River Sandstone Woodland
- Nepean Sandstone Gully Forest
- Sydney Hinterland Apple-Blackbutt Gulley Forest
- Western Sandstone Gully Forest
- Coastal Sandstone Riparian Scrub
- Cumberland Riparian Scrub
- Riparian Scrub

A.14 Council design standards and requirements

Design standards for Campbelltown City Council and Wollondilly Shire Council have been identified in relevant Council documentation. In general, the nominated requirements of Council have been adopted for this study.

Appendix B – Previous relevant investigations

B.1 Regional flooding studies

Upper Nepean flood study

Land & Water Conservation (1995) completed the *Upper Nepean River Flood Study*. The primary objective of the study were documented as being the definition of flood behaviour in the Upper Nepean River if terms of flow rates, flood levels and flood behaviour for design events between 5 and 200 year ARI together with that for the PMF.

Appendix B of the Upper Nepean Flood Study provided annual and partial series flood data for Menangle Road Bridge and Menangle Weir. These two locations are shown in Figure A-1 while Figure B-1 provides a plot of the maximum annual flood levels for the monitoring period at Menangle Weir.

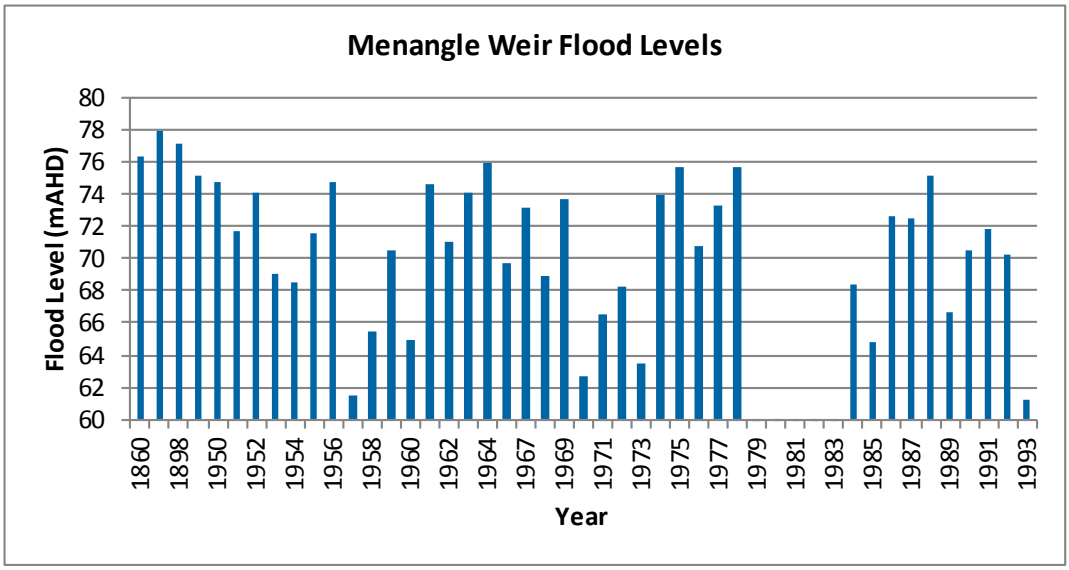


Figure B-1 Historical flood levels at Menangle Weir

Figure B-2 provides a comparison of the maximum annual flood levels at Menangle Weir and Menangle Bridge. As expected the flood levels are in close agreement. This was expected due to the close proximity of the sites.

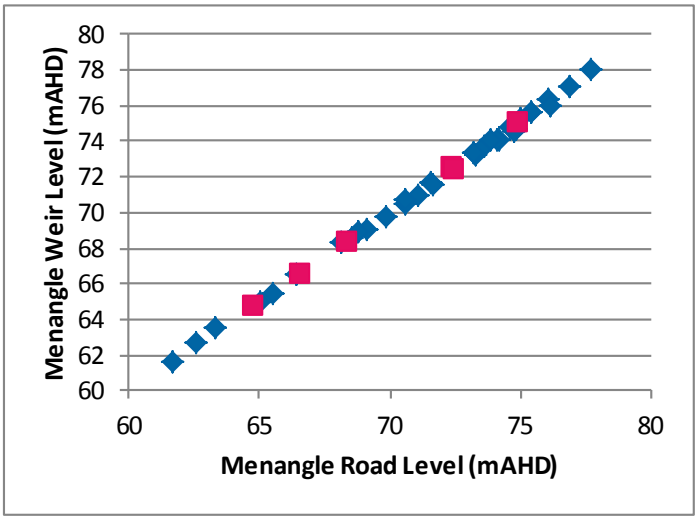


Figure B-2 Correlation of Menangle Road and Menangle Weir levels

A frequency analysis of the flood level of the Menangle Weir data was completed and the results are shown in Figure B-3. From the frequency analysis it is estimated that:

- 2 year ARI level – 71.3 mAHD
- 10 year ARI – 76.3 mAHD
- 20 year ARI level – 55.5 mAHD
- 100 year ARI – 79.4 mAHD
- 200 year ARI – 80.0 mAHD
- 500 year ARI level – 80.7 mAHD.

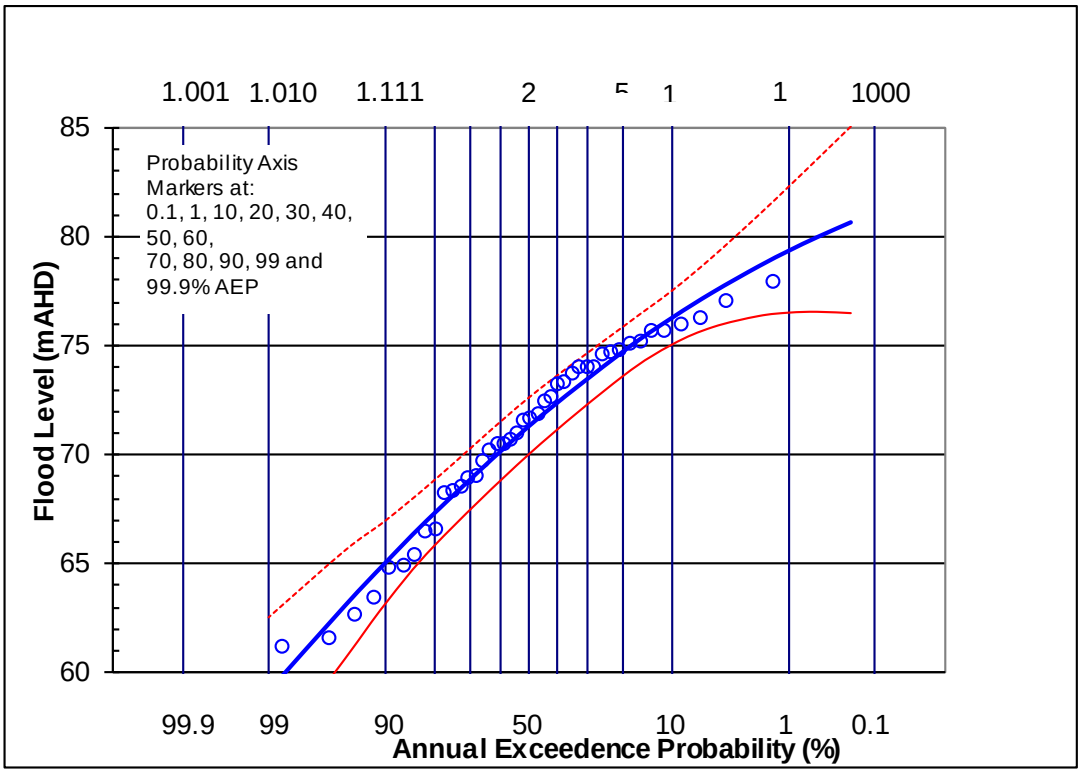


Figure B-3 Frequency analysis for Menangle Weir

Hydrologic components of the study include the determination of historical and design flood levels using a flood frequency analysis, establishment of a RORB hydrological model and verification of the predicted flows for historical events against gauging data together with verification against and earlier XP-RAFTS model.

The hydrological model used in the study extended downstream of the Investigation to near the Wallacia Weir.

Calibration and verification of the model was undertaken for the flood events of 1964, 1975, 1978, 1988 and August 1990. The model calibration was reported as being reasonable – some of the difficulty in achieving a good model calibration was the rainfall distribution and the large floodplain storage. Design flows from the RORB model were input into the MIKE11 model which provided additional flow attenuation in the downstream portion of the study area.

Design flow rates were determined from the MIKE11 model with selected results being provided in Table B-1.

Table B-1 Design flows (40 Hour)

ARI (years)	Maldon Weir RORB (m3/s)	Maldon Weir FFS (m3/s)	Menangle Weir Flow (m3/s)
5	2,500	2,200	2,450
20	4,700	4,300	5,200
100	6,500	6,800	7,950
200	7,250	-	9,110
PMF	9,650		

Peak flow rates extracted from the MIKE11 model for the 48 hour storm at Menangle Road were:

- 5 year ARI – 2,400 m^3/s
- 20 year ARI – 5,200 m^3/s
- 100 year ARI – 7,900 m^3/s
- 200 year ARI – 9,000 m^3/s
- PMF – 16,300 m^3/s

Design flood levels were determined for critical duration flood events. At Menangle the flood levels were very close to those from the earlier study (Willing & Partners 1992).

Selected flood levels are provided in Table B-2.

Table B-2 Deck and flood levels at Menangle Road

Structure	Deck Level (mAHD)	Flood Frequency (ARI – 5 year)	Flood Frequency (ARI – 100 year)
Menangle Rail Bridge	79.44	74.5	77.8
Menangle Road bridge	63.85	74.4	77.7

B.2 Planning proposals

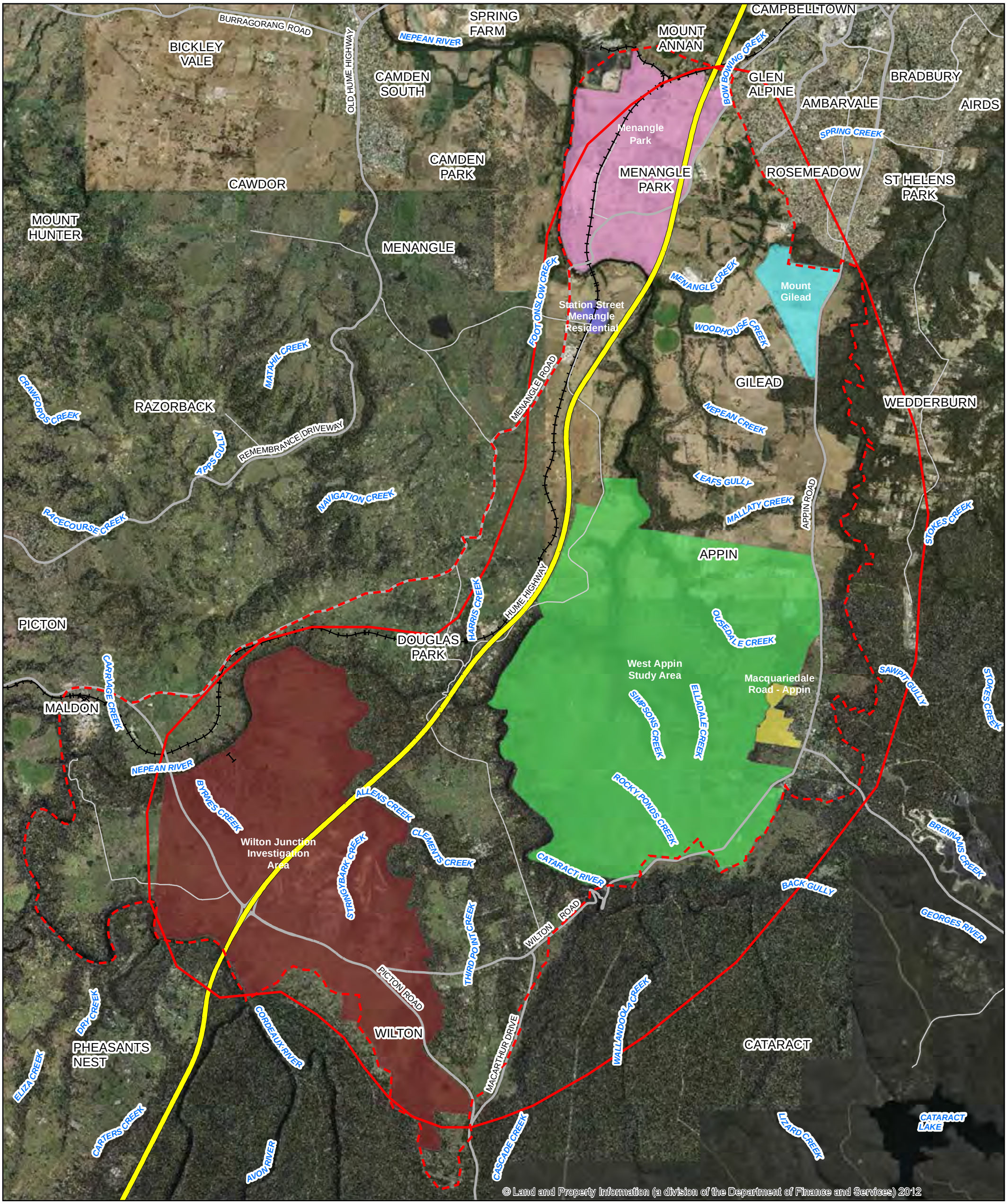
B.2.1 Menangle Park

Menangle Park Master Planning Project Local Flood and Drainage Analysis: Q03/33

This project involved the examination of the existing flooding regime at the site and identified constraints on future development urban development; proposed planning controls to make future urban development compatible with flood hazards, addressed flood flow conditions to ensure they would be compatible with WSUD principles, optimised the development potential through consideration of urban design whilst also considering site salinity, mine subsidence and extractive industry constraints.

Two reports were produced for the project. They were to describe:

- Flood constraint mapping (GHD 2003 Draft)
- The existing drainage environment and opportunities (GHD 2004a)



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Distributor Road
- Railway
- Macquariedale Road - Appin
- Menangle Park
- Mount Gilead
- Station Street Menangle Residential
- West Appin Study Area
- Wilton Junction Investigation Area

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Planning Proposals

Figure B-4

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_B\2217728_B001_PlanningProposalAreas_InvestigationArea_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

The first study reported on the establishment of a RAFTS model for the study area. Loss rates in the model were adopted consistent with the requirements of Campbelltown City Council and consistent with AR&R (Institution of Engineers Australia, 2000) and the model operated for a range of design ARIs up to the PMF and storm durations exceeding the critical duration for the watercourses. Predicted design flows were verified against values determined for other flood studies in the Western Sydney area.

The 9 hour design storm was the one found to be the critical duration.

The studies reported on flow rates and flood levels for the Nepean River and tributaries.

The second report (GHD 2004a) provided an identification of site constraints and opportunities based upon flooding, drainage and riparian vegetation issues.

Report for Menangle Park Development Riparian Corridor Assessment

The objectives of this report (GHD 2007) were identified as including:

- The identification of appropriate stream categories and management objectives
- Formation of a basis for an agreement on a "preferred riparian corridor network"

The adopted stream categorisation identified three categories:

- Category 1 – Environmental corridor – having a minimum CRZ of 40 m from the top of each bank with a further 10 m to counter edge effects. The corridor was identified as including local providence native vegetation with utility services, APZs, recreational activities and stormwater treatment facilities located outside the CRZ.
- Category -2 – Terrestrial and aquatic habitat - having a minimum CRZ of 20 m from the top of each bank with a further 10 m to counter edge effects. The corridor was identified as including local providence native vegetation with stormwater treatment facilities located outside the CRZ.
- Category 3 – Bank stability and water quality - having a minimum CRZ of 10 m from the top of each bank with a further 10 m to counter edge effects. The corridor was identified as including local native vegetation for restoration works.

Report for Menangle Park Flood Study

Objectives of this study (GHD 2008) were to define the existing flood behaviour for the Menangle Park Release Area for Nepean River flooding and tributaries, investigate options for maximising development opportunities and the preparation of flood maps.

A TUFLOW model was established for the area and flood conditions assessed for the 1%, 5% and 20% AEP events together with the PMF event.

The report provided a comparison of the predicted TUFLOW results for the 100 year ARI event and those from the earlier DLWC MIKE11 analysis. Within the Study Area the level difference for the existing conditions varied from a maximum of -0.96 m at Menangle Rail Bridge to +0.29 m near the downstream extent of the Study Area.

The report also provided flood impact results for the assessment of various geometries for the extraction of construction sands on the southern floodplain. Flood extent maps were also created for the Nepean River and the tributaries. The tributary flood maps, while having greater detail than those from the earlier study (GHD 2004), were not significantly different in flood extent and level.

Figures showing the velocity distribution for the study area and the flood hazard were also provided for the 100 year RAI event.

Supplementary reports have also been prepared.

Menangle Park LES Local Flooding and Stormwater Quality Management (Detention)

THE LES prepared for Campbelltown City Council and Landcom (GHD 2010) provided a detailed description of a site WSUD strategy and flooding information for the study area. The report then went on to discuss development opportunities and constraints and provide preliminary costing information for key elements within the strategy.

Some of the information in this report represented a repeat presentation of information in earlier GHD reports.

In this study the earlier TUFLOW model was extended to include the main tributaries to the Nepean River. Through discussions with Campbelltown Council it was determine appropriate to consider the the 20 year ARI backwater level in the Nepean River for the 100 year ARI discharges off the subject site, For the smaller design events of the 2 and 5 year ARI the level in the Nepean River was adopted.

Section 5 of the report provides information on the proposed sizes of proposed detention basins along with the flow attenuation achieved for the 2 and 100 year ARI events by each basin and the approximately locations, geometries and footprints. Indicative outlet structures were also identified. The range of detention volumes varied from 80 m^3/ha to 243 m^3/ha. The latter value achieved significant over attenuation of the peak flow rates.

Concept costing was provided for the proposed detention basins and the works proposed upstream of one of the detention basins. For the detention basins the preliminary cost estimates averaged approximately $1.1 million with a range from approximately $740,000 to a maximum of nearly $1.6 million. The detention basin cost estimates equated to an average of approximately $34,300/ha of catchment with a range from approximately $14,700/ha of catchment to approximately $67,400/ha of catchment.

Menangle Park WSUD Strategy

AECOM (2010) have documented a proposed WSUD strategy for the Menagle Park area. WSUD objectives adopted for the site are detailed in Table B-3.

Table B-3 Performance targets

Objective	Performance Measure and Target
Water conservation	Combination of water efficiency and reuse for a 45% reduction on the benchmark water use(247 L/p/d) *Stretch target* - 60% reduction on the benchmark water use Where a reticulated non potable recycled water supply is available the target reduction is increased to 60% with the stretch target increased to 70% reduction on benchmark water use
Stormwater pollution control	55% reduction in mean annual load of Total Nitrogen 70% reduction in mean annual load of Total Phosphorus 85% reduction in mean annual load of Total Suspended Solids
Flow management	Maintain 1.5 year ARI peak discharge to pre-development values Stream Erosion Index of 2 *Stretch target* – Stream Erosion Index of 1
Flood protection	Maintain the 5 to 100 year ARI peak flow rates to pre-development values
Riparian corridor management	Corridors to meet NSW Office of Water requirements
Wastewater pollution control	No dry weather sewer overflows Restrict wet weather sewer overflows to a maximum of 10 overflows each 10 years

AECOM provided a detailed discussion of the site water (rainfall and runoff) water balance for the study area, water conservation targets and how they could be achieved, stormwater treatment and flow management strategies, riparian corridor management and wastewater pollution control strategies to achieve a WSUD outcome. The above was followed by a discussion of maintenance issues and some preliminary costing for the bioretention and wetland areas.

The adopted WSUD scheme contained a mix of regional wetlands and bioretention areas fur urban catchments along with a range of swales along roads in flatter areas.

An evaluation of the element sizing indicated an average wetland area of 450 m^2/ha of catchment area (4.5% of total catchment area) when ignoring a Transgid site and the bioretention areas averaged 75m^2/ha of catchment (0.75% of catchment area).

The report summarised the results as being that the wetlands areas corresponded to 6% of the impervious catchment area) while the bioretention area corresponded to 1% of the impervious catchment area and indicated these provided sufficient water quality treatment to achieve the nominated target results.

B.2.2 Wilton Junction

Wilton Junction Water Cycle Management Strategy

The Study area for the study was identified (J Wyndham Prince 2014) as being approximately 2,480 ha located around the Hume Highway-Picton Road intersection near Wilton. The Nepean River forms the northern and western boundaries of the site while Allens Creek forms the eastern of the Study area. Of that total area, approximately 455 ha (Bingara Gorge) has already been rezoned for residential development.

The study reported that a land capability assessment for the site has not identified any soils related impediment that would preclude development. The report does acknowledge the soils to be erosive and aggressive to concrete but there was reportedly no evidence of salinity or sodicity that would be an impediments to development.

The proposed water cycle management strategy was documented to include:

- On lot measures:
  - Water efficient fittings and appliances in dwellings
  - Rainwater tanks on each dwelling – to satisfy BASIX requirements
  - Minimisation of impervious surface areas
- Water quality measures:
  - Street level treatments – vortex style gross pollutant traps
  - Subdivision treatment – raingardens
- Water quantity control measures:
  - An online detention basin on Allens Creek upstream of Picton Road
- Water holding structures
  - Six are proposed – two of these only receive treated wastewater effluent.

The report indicated that an estimate of the 100 year ARI flow at Maldon Weir was obtained from an XP-RAFTS model using different values for the Bx parameter. The predicted design flow rates of between 5,800 m^3/s and 6,700 m^3/s agreed well with the earlier value of 6,500 m^3/s determined using the DLWC RORB model.

Predicted design flow rates and flood levels around the perimeter of the Study area were provided in the report and are shown in Table B-4.

Table B-4 Existing and developed predicted flow rates and predicted flood levels

Location	Flow rates Existing 100 year ARI	Design flood flow rate	Flood levels Existing 100 year ARI	Design
104.15	140	133	-	
104.17	-	-	183.9	
104.20	-	-	174.4	
104.25	-	-	138.3	
104.27	256	247	122.1	
104.32	315	303	117.3	
104.40	-	-	98.0	
104.44	343	332	85.7	
1.23	-	-	181.4	
1.25	5077	5076	-	
1.26	-	-	149.5	
1.32	5087	5087	-	
1.51	5791	5791	117.7	
1.55	5800	5799	112.7	
1.60	-	-	101.1	
1.62	5815	5814	105.8	
1.63	5938	5939	-	
1.64	5965	5966	-	
1.65	7166	7168	-	

The adopted water quality targets adopted were reported as being TP 0.035 mg/l and TN 0.7 mg/L.

The adopted raingarden sizes were an average of 1% of the catchment area and each had an average of 1m depth.

The total estimated stormwater infrastructure cast was identified as being approximately $104 million.

B.2.3 Moreton Park Road, Menangle

A report on Sydney West Joint Regional Planning Panel (SWJRPP) prepared by Planning & Infrastructure (undated) identifies the proposed land use for this site of approximately 297 ha has focussed on warehousing, logistics and manufacturing. No information of direct relevance to flooding, stormwater or water quality was contained in the document.

ERM (2008) completed a study identifying constraints and opportunities for the site. Specific information from that study of direct relevance included:

- Vegetation mapping – the mapping identified three communities across the site – Shale Sandstone Transition Forest, Cumberland Plain Woodland and River-flat Eucalypt Forest on Coastal Floodplains.
- Flood level assessment – flood levels downstream of the subject site were available from the earlier *Upper Nepean River Flood Study*. These levels were extrapolated to provide indicative 100 year ARI levels upstream past the site.

Elton (2011) has prepared a Planning Proposal submission for the Moreton Park Road site. Key issues from that submission include:

- The proposal was for potential creation of employment lands along Moreton Park Road and residential development and open spaces adjacent to Menangle Village. The total site area being approximately 600 ha.
- The preferred wastewater servicing option was identified as being an onsite wastewater recycling plant
- The housing component of the proposal was identified as being above the estimated 100 year ARI level of between 77 mAHD and 78 mAHD.

B.2.4 Mt Gilead

A report to Campbelltown City Council (Campbelltown City Council 2015, Minutes of 17 February 2015) provided some information on the Planning Proposal.

Material of specific relevance extracted from that report indicates:

- The land area is 210 ha, located adjacent to Appin Road, is largely cleared of vegetation
- The topography generally has a slope of less that 5^{o} sloping toward the north-west. The northern portion of the site drains into Menangle Creek while the southern portion drains into the Woodhouse Creek catchment
- The site is considered to be of a very low risk of PASS and the soils are expected to present a low risk of salinity
- The site contains pockets of Cumberland Plains Woodland, Shale Sandstone Transition Forest and River-flat Eucalypt Forest.
- Watercourses on the site were mapped as being predominately 2^{nd} order with a limited extent of 3^{rd} order in the north-west corner of the site and 1^{st} order stream upstream of the 2^{nd} order reaches.
- As part of the project development MSEC, based upon likely mining processes of the Bulli Seam, has reportedly estimated potential maximum subsidence values of the order of 1120 to 1440 mm. The report then indicated that the likely subsidence on the Mt Gilead site was likely to be less that the above prediction as it would be outside the perimeter of the subsidence trough.

- Should mining advances permit the mining of the Balgownie Seam then the maximum predicted subsidence values could increase by an additional 750 to 850 mm.
- The proposal does discuss the retention of an “artificial lake” being retained. The lake is shown as being outside the planning proposal.
- The report indicates that stormwater quality treatment will be through the application of “end of line” treatments such as gross pollutant traps and biofilters located within public open space areas.
- Flooding and peak flow controls received minimal discussion in the Planning Proposal main document.

B.2.5 Macquariedale Road, Appin

Patterson Britton & Partners (2006) prepared a preliminary riparian corridor assessment for this Planning Proposal.

Key matters from the report include:

- Ousedale Creek, a Category 2 watercourse, is located along the western side of the study area. The proposed riparian corridor is shown as 50m from the creek centreline
- Three ephemeral tributaries are located approximately perpendicular to Ousedale Creek and these are also considered as Category 2 watercourses. The total width of the riparian corridor was shown as being 50 m.

The Planning Proposal report (Wollondilly Council 2014) provided comments from agencies and comments relevant to this study included:

- Office of Water, in February 2014, supported the application of an E2 zoning to the Ousedale Creek riparian zoning and recommended consideration be given to the application of an E2 zoning to the riparian corridors along the northern and middle tributaries to Ousedale Creek.
- Sydney Water noted that the proposed site could be potentially serviced by the existing wastewater system but that augmentation of the system may be required.

B.3 Mining operations and impacts

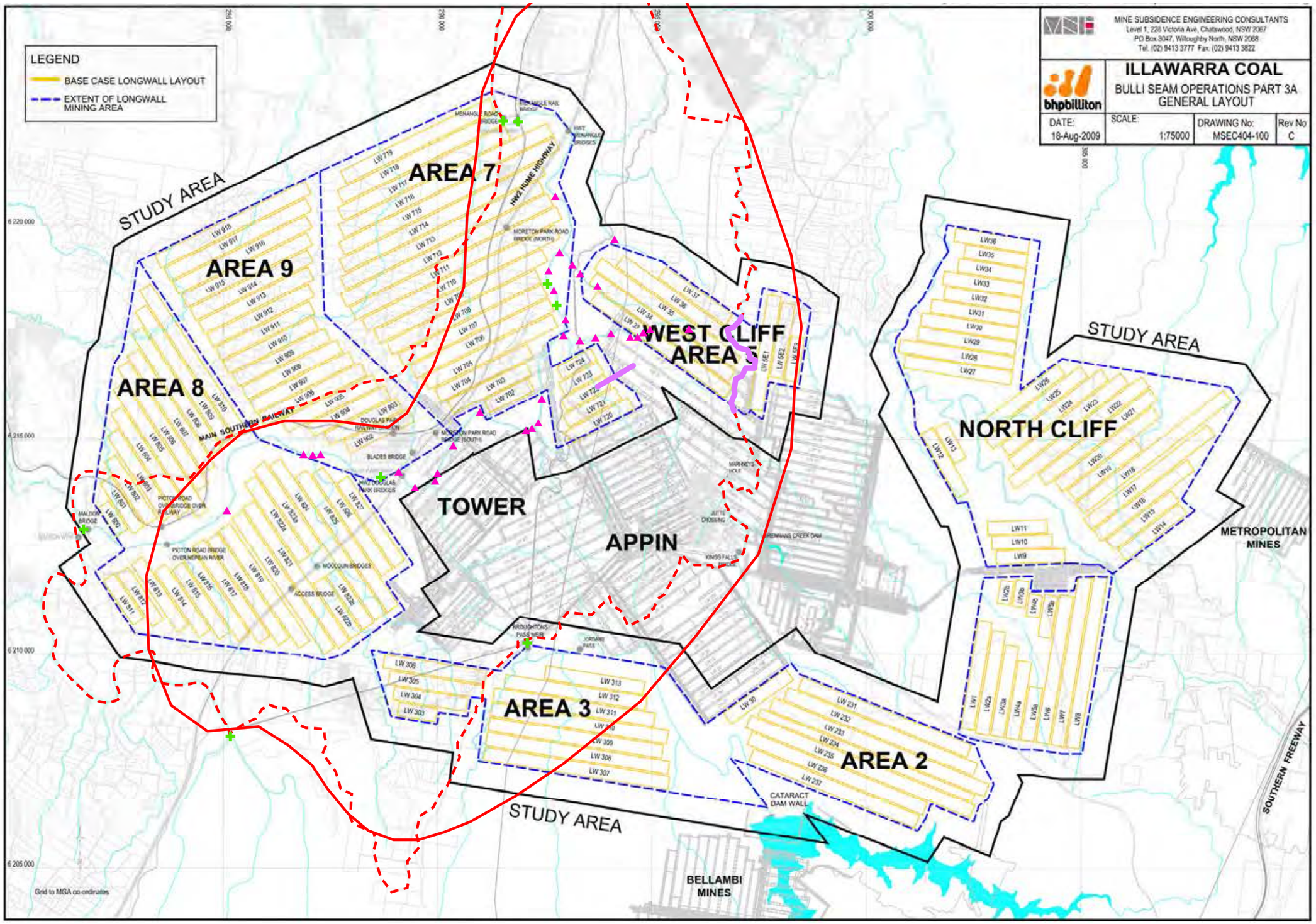
Numerous reports have been prepared to support and report on impacts of mining operations in and adjacent to the Study Area. Water quality impacts have been reported for the mining operations across a significant proportion of the Study Area. The monitoring locations referenced in the report within this Section of text are shown in Figure B-5

B.3.1 Bulli Seam Operations

This project is also called “Bulli Seam Operations”. A comprehensive environmental assessment has been documented covering much of the Study Area for the seeking of approval for the continued operation and expansion of the current mining operations at Appin Mine and West Cliff Colliery. Appin Mine and West Cliff Colliery are owned an operated by Illawarra Coal Holdings Pty Ltd which is a subsidiary of BHP Billiton Pty Limited.

Reports of specific relevance to this investigation include:

- Bulli Seam Operations Executive Summary
- Bulli Seam Operations Surface Water Assessment Appendix A - (Mine Subsidence Engineering Consultants 2009)
- Bulli Seam Operations Surface Water Assessment Appendix C - (Gilbert & Associates 2009)



Greater Macarthur Water Management

Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Urban Capable Boundary
- Investigation Area Boundary
- Illawarra Coal
- Others
- Numerous locations

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Bulli Seam Longwalls and Water Quality Sampling Locations

Figure B-5

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_B\2217728_B002_BulliLongWalls_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD, Illawarra Coal and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012). Illawarra Coal, Background data, 2015. Created by: gmcdiarmid, tmorton

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

- Bulli Seam Operations Surface Water Assessment Appendix D - (Bio-Analysis 2009)
- Bulli Seam Operations Surface Water Assessment Appendix O – (Illawarra Coal 2009)
- Bulli Seam Operations Surface Water Assessment Appendix P (Illawarra Coal 2009)

A summary of information from selected reports is contained below.

MSEC 2009, Report on The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting From the Bulli Seam Operations in Support of the Part 3 Application

The MSEC (2009) report provided information focussed on the site geology, features within the study area for the operations and provides extensive material on projected mine subsidence impacts on the natural and built environment.

The proposal that was assessed included the continuation of existing mining operations in the Bulli Seam at Appin Mine and West Cliff Colliery by undertaking further extraction in areas known as Area 3, Area 3, Area 5, Area 7, Area 8 and Area and North Cliff.

Details on the Bulli Seam are provided in the report and the maximum predicted subsidence for "base case" mining for each area is shown in Table B-5.

Table B-5 Bulli Seam Data and predicted Maximum Subsidence

Area	Minimum Depth (m)	Maximum Depth (m)	Average Seam Thickness (m)	Maximum Predicted Total Subsidence (mm)
Area 2	300	450	2.0	1,350
Area 3	380	480	2.2	1,250
Area 5	450	530	2.4	1,300
Area 7	470	650	3.0	1,600
Area 8	430	720	2.2	1,200
Area 9	480	850	2.9	1,600
North Cliff	340	540	2.5	1,400

The "base case" mining is described in detail Section 2.1 of the report and is summarised as including:

- Length of longwalls – varying in length from 525 m to 4,375 m
- Void widths - typically being 310 m but with a few varying to a minimum value of 190 m and a maximum width of 340 m
- Solid chain pillar widths - typically between 35 and 45 m but a few are shown as being wider

Gilbert & Associates 2009, Report Bulli Seam Operations Surface Water Assessment

The Gilberts & Associates (2009) report provided information that focused on the catchment area, the existing hydrologic regime, the existing water quality regime, predicted hydrologic impacts of potential mine subsidence and predicted impacts on water quality.

Water quality monitoring results for Nepean River, Allens Creek, Harris Creek, Simpsons Creek Ousedale Creek, Menangle Creek and Leafs Creek were reported for the period from April 2002 to August 2008.

Results for pH are provided in Table B-6.

Table B-6 pH observations

Location	ANZECC Default Lower Trigger (mg/L)	Proportion of Exceedances of default value (%)	ANZECC Default Upper Trigger (mg/L)	Proportion of Exceedances of default value (%)
Nepean River[1]	6.5	1	8	46
Allens Creek	6.5	1	8	71
Harris Creek	6.5	0	8	12
Simpsons Creek	6.5	7	8	40
Ousedale Creek	6.5	5	8	14
Leafs Gully	6.5	45	8	0
Menangle Creek	6.5	0	8	9
Georges River – Upper Zone[1]	Range from approximately 4.5 to approximately 9.8. Most observations between 6 and 9.			
Georges River Middle Zone[1]	Range from approximately 7 to approximately 10. Most observations between 7.3 and 9.			
Georges River – Downstream Zone[1]	Range from approximately 6.3 to near 9.5. Most observations between 6.8 and 9.			

Note: [1] Numerical percentages not provided

Dissolved oxygen readings were reported as showing:

- Allens Creek - 35% of observations were lower than the recommended lower ANZECC trigger level while 25% of the observations exceeded the upper trigger concentration
- Harris Creek - 60% of observations were lower than the recommended lower ANZECC trigger level while 18% of the observations exceeded the upper trigger concentration
- Simpsons Creek - 72% of observations were lower than the recommended lower ANZECC trigger level while 15% of the observations exceeded the upper trigger concentration
- Ousedale Creek - 71% of observations were lower than the recommended lower ANZECC trigger level while 7% of the observations exceeded the upper trigger concentration
- Leafs Gully – all 11 samples were within the recommended ANZECC limits
- Menangle Creek - 73% of observations were lower than the recommended lower ANZECC trigger level while 3% of the observations exceeded the upper trigger concentration

- Georges River – Upper Zone – Range of observations between approximately 10% to 180% of saturation. The Middle Zone had a range of observations of between approximately 40% to near 200% of saturation while the Upper Zone range was between approximately 10% to near 180% of saturation.

Results for the nutrient parameters are summarised in Table B-7.

Table B-7 Nutrient results

Parameter	Location	ANZECC Default Trigger (mg/L)	Percentage of Exceedances of default value	Median concentration (mg/L)
Total Phosphorus	Nepean River	> 0.02	39.6	0.02
	Mallaty Creek	> 0.02	73.2	0.05
	Harris Creek	> 0.02	41.7	0.02
	Simpsons Creek	> 0.02	68.4	0.07
	Ousedale Creek	> 0.02	84.1	0.065
	Menangle Creek	> 0.02	39.6	0.02
	Georges River – Upper Zone	> 0.02	28.8	.01
	Georges River – Middle Zone	> 0.02	39.3	0.02
	Georges River - Lower Zone	> 0.02	38.6	0.02
	Cataract River	> 0.02	28.1	0.01
	Rocky Ponds Creek	> 0.02	100	0.45
Total Kjeldahl Nitrogen	Nepean River	>0.25	85.3	0.4
	Mallaty Creek	>0.25	94.6	1.1
	Harris Creek	>0.25	63.9	0.45
	Simpsons Creek	>0.25	89.5	1.1
	Ousedale Creek	>0.25	81.8	0.6
	Menangle Creek	>0.25	85.3	0.4
	Georges River – Upper Zone	>0.25	65.5	0.4
	Georges River – Middle Zone	>0.25	77.1	0.6

Parameter	Location	ANZECC Default Trigger (mg/L)	Percentage of Exceedances of default value	Median concentration (mg/L)
	Georges River - Lower Zone	>0.25	71.9	0.4
	Cataract River	>0.25	27.2	0.2
	Rocky Ponds Creek	>0.25	99.0	2.2

Notes: [1] Also below the lower limit of 6.5 mg/L for 1% of observations

TNK was not observed to be flow related but the concentration was reported as being highly variable

Fluvial characteristics were reported for watercourses within the study area for the project. The characteristics are summarised in Table B-8 which is sourced from Gilbert & Associates (2009).

Table B-8 Fluvial Watercourse Features

Stream	Approximate Distribution of Pools, Rockbars and Boulder Fields (%)		
	Pools	Rockbars	Boulder Fields
Nepean River	95	1	4
Allens Creek	50	20	30
Harris Creek	10	15	25
Simpsons Creek	15	5	35
Elladale Creek	20	5	40
Ousedale Creek	40	30	10
Mallaty creek	20	25	15
Carriage Creek	50	10	15
Byrnes Creek	25	10	50
Georges River	50	20	10

The risk assessment was developed from specialist technical studies undertaken to assess matters including, but not restricted to hydrologic, mine subsidence, hydrologic, flood and ecologic conditions for the area of the investigation.

Comprehensive stream mapping was provided in that report. That mapping provides useful background for this study by showing mapping for each watercourse identifying areas having boulder fields, islands, lakes, pools, riffles, rock bars, rock shelfs, sandbars, sediment , waterfalls and vegetated drainage lines.

A swamp risk assessment provided information on swamps through the study area, potential impacts that could occur to the swamps and identified monitoring programs for each swamp.

Illawarra Coal 2009a, Bulli Seam Operations Stream Risk Assessment

The risk assessment contained a detailed mapping of watercourse forms (specifically rock bar locations) throughout a significant portion of the study area of this project and also provided information predicted further impacts of mining along with proposed ongoing monitoring programs to assess future impacts.

Contingency plans were also identified to respond to any future impacts observed from the ongoing monitoring programs.

Illawarra Coal 2009b, Bulli Seam Operations Upland Swamp Risk Assessment

The risk assessment contained a detailed mapping of the locations of upland swamps together with the existing terrain contours and the predicted terrain contours following mining operations. The study also provided proposed ongoing monitoring programs to assess future impacts and a discussion of some temporary works that had been installed at some of eth swamp locations.

Contingency plans were also identified to respond to any future impacts observed from the ongoing monitoring programs.

Bio-Analysis 2009, Aquatic Ecology Assessment

The aquatic ecology assessment (Bio-Analysis 2009) reported on aquatic ecology sampling and concurrent water quality sampling results for locations within major watercourses throughout the throughout the study area for autumn 2009.

B.3.2 Appin Colliery – Longwalls 34 to 36

Illawarra Coal 2014, West Cliff Area 5 Longwall 36 End of Panel Report

The bhpbilliton report (2014) indicated that:

- Far field horizontal and vertical movements had occurred at the Upper Canal but differential horizontal movements were within survey tolerance.
- There were no reports of damage to major water infrastructure (tunnels and pipelines).
- No significant water quality impacts were reported as being observed.
- It was noted that increased release of water for Brennans Creek Dam, as discussed for Longwall 35, had provided an improved aquatic condition.
- Reported aquatic impacts were within predicted ranges.

MSEC 2014a, BHP Billiton Illawarra Coal: West Cliff Colliery – Longwall 36 End of Panel Subsidence Report for West Cliff Longwall 36

The report (msce 2014) indicated that:

- There were no reported impacts, as a result of subsidence / upsidence on ponding of water, flooding, scouring of watercourses, surface water flow diversions or mining induced springs.
- There was no reported impacts on The Upper Canal or major watermains

Illawarra Coal 2013, West Cliff Area 5 Longwall 35 End of Panel Report

This report (bhpbilliton 2013) provided a summary of measured and observed impacts of the extraction of Longwall 35.

The report showed, as relevant to this study:

- The reported upsidence at the Georges River was variable relative to initial predictions, at some locations it was less that predicted while at other locations it was similar to that predicted or larger than predicted.
- No impacts were reported on Sydney Water/Sydney Catchment Authority assets.
- No significant impacts on the water quality or flow regime were observed in the Georges River.
- An increase in the release of water from Brennans Creek Dam was implemented to return pool levels to pre mining values.

Ecoengineers 2007, Assessment of Water Quality Effects West Cliff Colliery Longwalls 34 to 36

Ecoengineers (2007) provided an assessment of the potential surface water impacts of the proposed extraction of these three longwalls.

Water quality monitoring was reported for both the Georges River and Mallaty Creek. The data is summarised in Table B-10 for selected parameters

Table B-10 Mean quality parameters August 2004 to October 2007 – Mallaty after Dec 2005

Site	Location (Relative to Longwalls)	pH	EC (ms/cm)	DO (% saturation)
GRQ17	Upstream	8.53	1,586	113
GRQ17A	Adjacent	8.51	1,568	102
GRQ18	Downstream	8.15	1,247	89
MC130		7.54	285.5	60
MC05		7.04	4,836	54

The parameters for the Georges River sites showed a minimal variation in mean values.

The predicted impacts included river bed diversions from fracturing of rock bands in the Georges or Nepean Rivers were considered to be likely to significantly impact the river flows.

Ecoengineers 2013, End of Panel Assessment of Water Flow and Quality Effects West Cliff Colliery Longwall 35

Water quality data reported in the assessment showed:

- EC at sites Pool 40, Pool 43 and Pool 60 on the Georges River during mining of Longwalls 33, 34 and 35 were within the range that had been observed at the same sites prior to the undertaking of mining of LW33, LW 34 and LW35
- pH at sites Pool 40, Pool 43 and Pool 60 on the Georges River during mining of Longwalls 33, 34 and 35 were within, with one exception, the range that had been observed at the same sites prior to the undertaking of mining for these longwalls. The majority of the observations were within +/- 2 standard deviations of the respective mean site value. It was noted that the observation outside 3 standard deviations of the mean, recorded in Pool 60, was indicated as a fault measurement as it was not reflected at any other site on that day.
- DO at sites Pool 40, Pool 43 and Pool 60 on the Georges River during mining of Longwalls 33, 34 and 35 were generally above the mean value minus 2 standard

deviations. There was a slightly greater proportion of the number of observation days following the commencement of mining below the minus 3 standard deviations. During mining of LW35 there were 3 days of an observation being below -2 standard deviations.

- Leafs Gully, Site LG10 - During mining of LW34 and LW35 the EC was always within +/- 3 standard deviations of the mean with the greatest concentrations being observed soon after the commencement of mining of LW35. The pH concentrations were generally above -2 standard deviations from the mean except for two samples prior to the undertaking of mining of LW35. DO concentrations were highly variable but all except one were in excess of -2 standard deviations below the mean. The variance in observations was attributed to the ephemeral nature of the watercourse.
- Mallaty Creek, Sites MC100, MC106 and MC109 – Only sites MC100 and MC109 were operational during the mining period for LW34 while all were operable during mining of LW35. Two peak observations were observed (3,470 and 3,830µs/cm) during mining of LW35 at site MC109 but the report indicated it to be unlikely that these were caused by fracturing as the site is upstream of MC106 where no variation was observed. The pH concentrations were generally above -2 standard deviations from the mean except for two samples prior to the undertaking of mining of LW35. DO concentrations were highly variable but all were in excess of -2 standard deviations below the mean. The variance in observations was attributed to the ephemeral nature of the watercourse.
- Nepean Creek, Sites NC10 – For the period of monitoring the EC reading remained below the pre mining value. One observation prior to the commencement of mining of LW35 was below the -3 standard deviation limit. As for Mallety Creek, the DO concentration was highly variable due to the ephemeral nature of the watercourse.
- No statistically significant difference was reported between observations taken at rockbars RB43 and RB64 on the Georges River.

Ecoengineers 2014a, End of Panel Assessment of Surface Water Effects West Cliff Colliery Longwall 36

The Ecoengineers (2014) report was Attachment D to the bhpbilliton (2014) West Cliff Area 5 Longwall 36 End of Panel Report.

Mining of LW36 occurred between late 2013 and early in the second half of 2014. Water quality data reported in the assessment showed:

- EC at sites Pool 40, Pool 43 and Pool 60 on the Georges River during mining of Longwalls 33, 34 and 35 were within the range that had been observed prior to the undertaking of mining of LW36
- pH at sites Pool 40, Pool 43 and Pool 60 on the Georges River showed that Pool 60 dropped below the -3 standard deviation value for significant periods while Pool 43 dropped to below the minus 2 standard deviations of the respective means.
- DO at sites Pool 43 and Pool 60 fell below the minus 3 standard deviations for part of the mining period but were above minus 2 standard deviations at the end of the mining period.
- Mallaty Creek, Sites MC100 and MC110 – Interstingly Site MC110 appears to match that of MC109 reported on previously. Site MC100 upstream of LW36 showed no change while MC110 increased to be relatively constant at approximately 6,000 µs/cm to 7,500 µs/cm. The pH concentrations were generally above the long term mean value and no systematic reduction in pH was observable at either site. As for earlier monitoring for LW35 the DO concentrations were highly variable but all except two observations were in

excess of -2 standard deviations below The variance in observations was attributed to the ephemeral nature of the watercourse.

- Nepean Creek, Sites NC10 – For the period of monitoring the EC reading remained elevated above the long term mean value. All pH observations were between the long term mean and minus 2 standard deviation values. The DO concentrations were generally below the mean value and below 40% saturation.

B.3.3 Appin Colliery – Longwalls 37 to 38

West Cliff Colliery – Longwalls 37 and 38 Subsidence Predictions and Impact Assessments for Natural Features and Surface Infrastructure in Support of the Extraction Plan

MSEC (2013) provided am comprehensive set of predictions for eth proposed mining. Subsidence that could impact this study wes given as being:

- The maximum predicted upsidence in the Georges River was identified as being 190 mm and subsidence as being 120 mm. These were identified as potentially changing ponding areas at times of low flow but were identified as being unlikely to significantly impact flood levels.
- Potential release of seam gas into the Georges River was identified as a potential impact.
- The maximum predicted subsidence for Mallatey Creek was shown as being 1125 mm with a maximum upsidence predicted as being 650 mm and a maximum closure of 650 mm. These were identified as potentially causing localised changes on flood levels.

B.3.4 Appin Colliery – Longwalls 33 to 38 Aquatic Ecology

West Cliff Longwalls 33-38 Aquatic Ecology Monitoring May 2002 – December 2012

The Cardno (2013a) report described results of post extraction monitoring result of December 2012 for Longwalls 33 and 34 together with current extraction results for Longwall 35 and pre-extraction conditions for Longwalls 36 to 38.

The results showed:

- No significant change with time in the aquatic and riparian habitat in the Georges River
- The aquatic macroinvertebrates did indicate the Georges River to be under stress
- During the monitoring period there had been some limited recovery in fauna at the majority of the monitoring sites when compared to earlier results but there was a decline, reported to be unlikely to be related to mining operations, downstream of Longwall 33

West Cliff Longwalls 33 – 38 Aquatic Ecology Monitoring 2002 – 2013

Cardno (2014b) reported on aquatic ecology monitoring results for Longwalls 33 to 38. This report reported on the continuation of monitoring undertaken during 2002, 2005, 2007, 2008, 2010 and 2012.

The report indicated:

- There had been no significant changes in the Georges River riparian habitat since monitoring commenced.
- The aquatic macroinvertebrate fauna had been impacted by previous environmental stress prior to mining commencing and is reportedly still stressed.
- Results for November 2013 sampling had shown macroinvertebrate habitat quality in 2013 at one monitoring site and this was most likely attributed to mining operations.

- Increased releases from Brennans Creek Dam had offset some of the impact of loss of habitat in the Georges River and it was recommended that the increased release be maintained for as long at practical in times of low flow.
- No impact of mining Longwall 36 was reported.

B.3.5 Appin Colliery – Longwalls 701 to 704

Comur Consulting 2012, End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwall 704

The End of Panel report for Longwall 704 (Ecoengineers 2012) reported no periods when significant flow impacts were predicted to occur by the differencing of flow rates at Menangle Weir and Maldon Weir. No obvious sudden changes in flow were observed in the area of the mining.

Gas emissions were reported into the Nepean River but there was no reported significant impact of the emissions during the –period of mining.

Ecoengineers 2012, End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwall 704

The End of Panel report for Longwall 705 (Illawarra Coal 2014) summarised results from Ecoengineers 2014) and reported no significant flow impacts were measured or observed within the Nepean River as a result of the mining operations for extraction of the longwall. Three gas releases were reported into the Nepean River but these were reported as not creating a significant impact on the water quality. Similarly, there was no reported significant impact was reported on first or second order streams as a result of the operation.

MSEC 2012a, Appin Colliery – Longwall 704 End of Panel Subsidence Monitoring Report for Appin Longwall 704

The report indicated that observed closure of the Nepean River was less than the predicted closure that was expected for the mining of Longwall 704. For fourteen sections across the river the maximum closure from this operation was reported as being 102 mm with the minimum being 6 mm with the observed value at only two sections exceeding 50 mm.

B.3.6 Appin Colliery – Longwalls 705 to 710

The Ecology Lab 2008, Appin Longwalls 705-710 Effects of Mine Subsidence on Aquatic Habitat and Biota

The report indicated that watercourses were not expected to experience significant aquatic impacts as a result of the proposed mining operations.

MSEC 2008, Report on The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence on Natural Features and Surface Infrastructure Resulting From the Extraction of Proposed Longwalls 705 to 710 at Appin Colliery in Support of the SMP Application

Predictions provided for the effects on the Nepean River channel were a maximum predicted subsidence of 60 mm, a maximum predicted cumulative upsidence of 380 mm and a maximum predicted cumulative closure of 545 mm. The report noted that earlier subsidence and upsidence for West Cliff Longwalls 34 to 36 had been observed to have greater effects on the Nepean River than those predicted for this mining.

Ecoengineers 2008, Assessment of Surface Water Flow and Quality Effects Appin Colliery Longwalls 705 to 710

Ecoengineers (2008) as part of the documentation for the *Appin Colliery Area 7 Longwalls 705 to 710 Subsidence Management Plan Application* provided predictions of surface water impacts for the proposed extraction of Longwalls 705 to 710.

The following predictions were provided in the report:

- There was the potential for some slight changes in the frequency and extent of water inundation should upsidence occur as predicted. The impact was not reported as being significant for flood levels and were lively to be within the natural variability of the river level
- Gas emissions into the Nepean River as a result of rock fracture was identified as a potential impact of the lining
- The occurrence of low pH conditions were likely to occur in the Nepean River as a result of the mining.

The report showed:

- On 10th and 13th December 2007 the Total Phosphorus concentrations along the assessed length of the Nepean River varied between approximately, 0.005 mg/L and 0.53 mg/L
- On 14th and 16th January 2008 the Total Phosphorus concentrations along the assessed length of the Nepean River varied between approximately, 0.12 mg/L and 0.25 mg/L
- On 18th and 21th February 2008 the Total Phosphorus concentrations along the assessed length of the Nepean River varied between approximately, 0.005 mg/L and 0.18 mg/L
- On 17th and 20th March 2008 the Total Phosphorus concentrations along the assessed length of the Nepean River varied between approximately, 0.02 mg/L and 0.10 mg/L
- On 15th and 16th April 2008 the Total Nitrogen concentrations along the assessed length of the Nepean River varied between approximately, 0.3 mg/L and 0.8 mg/L while Total Phosphorus concentrations along the assessed length of the Nepean River varied between approximately, 0.005 mg/L and 0.12 mg/L
- For the same monitoring dates most of the tributary Dissolved Oxygen readings exceeded 80% of saturation but there were some observations as low as approximately 20% of saturation with low values being consistently reported at sites NR5 and NR40 and some low values at NR3. The location of gauging sites is shown in the report.
- The likelihood of sib-bed diversions as a result of mining Longwalls 705 – 710 was rare
- The likelihood of gas emissions into the Nepean River was high but the consequences of emissions would be negligible under high flow (>34 ML/d) conditions and significant under low flow (<13 ML/d)conditions
- Ecoengineers 2008, Assessment of Surface Water Flow and Quality Effects Appin Colliery Longwalls 705 to 710

MSEC 2014b, Appin Colliery – Longwall 705 End of Panel Subsidence Monitoring Report for Appin Longwall 705

The report indicated that no visible effects were observed to have occurred on the Nepean River, tributary creeks or water courses as a result of extraction of Longwall 705.

Ecoengineers 2014b, End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwalls 705 to 710

Average Baseline water quality data was provided for several nearby sites for the period July 2002 to October 2007 as detailed below in Table B-9.

Table B-9 Reported water quality average values

Site	Electrical Conductivity (mS/cm)	pH	DO (% Saturation)
Nepean River			
NR2	646	8.16	90.2
NR4	582	8.08	93.8
NR6	578	7.99	94.1
NR7	506	8.05	88.3
NR9	515	8.05	93.9
NR11	496	7.69	87.1
NR20	480	7.76	88.0
NR30	470	7.74	83.9
Tributaries to Nepean River			
Harris Creek – NR3	2,100	7.80	104.5
Catacract River – NR5	334	7.36	69.4
Elladale Creek – NR8	3,028	7.11	62.0
Ousedale Creek – NR10	1,492	7.79	100.9

The significant difference in the baseline electrical conductivity values was reported to be a result primarily of the soil landscapes from which the water was derived.

Water related effects of the mining were summarised as being:

- There was no statistically significant loss of surface flows as a result of the mining in times of dry weather
- There was two observations during mining when the pH at site NR11 having pH reading was lower than two standard deviations below the baseline mean value
- EC values recorded at NR11 were below the long term baseline value at the site during the mining period and was similar to that during mining during the previous two years
- Dissolved oxygen observations ate NR11 were generally within one standard deviation of the long term baseline mean value with only one exception
- The Nepean River was well oxygenated with the DO along the river averaging approximately 70% saturation for sampling on 9 January 2013
- TP was generally low in both the Nepean River and at the tributary sites being lower than 0.1 mg/L at all sampling sites on 9 January 2013

- TN was generally low in the Nepean River with a maximum of approximately 0.3 mg/L for sampling on 9 January 2013

The maximum predicted subsidence was identified as being up to 1495 mm after completion of Longwalls 8, 9 and 10. Minimal prediction was predicted under the Nepean River.

B.3.7 Appin Colliery – Longwalls 901 to 904

MSEC 2012b, Appin Colliery Longwalls 901 to 904 Subsidence Predictions and Impact Assessments for Natural Features and Surface Infrastructure in Support of the Extraction Plan

Key results from the assessment, in the context of this report, were:

- The longwalls had been set back from the Nepean River by a minimum distance of 125 m from the closest bank.
- The maximum predicted subsidence along the river was assessed as being 30 mm, the maximum predicted upsidence was predicted as being 110 mm while the maximum closure was assed as being 200 mm
- Fracturing of the river bed was identified as being possible but loss of river was not identified as being likely
- Predicted changes in grade of the tributaries to the Nepean River were shown as being minimal in the context of the natural grade and were reported as not being likely to significantly impact the tributary watercourses

Cardno 2014b, Appin Area 9 Longwalls 901 to 904 Extraction Plan Annex C – Water Management Plan

This plan provides a summary of the detail studies undertaken to support the proposed extraction. The report summarised predicted results as showing:

- Nepean River - maximum predicted total subsidence – 30 mm, maximum predicted upsidence 110 mm and maximum predicted closure 200 mm
- Nepean River tributary (passing over longwalls) - maximum predicted total subsidence – 1175 mm, maximum predicted upsidence 575 mm and maximum predicted closure 625 mm
- Harris Creek (east of end of longwals) - maximum predicted total subsidence – < 20 mm, maximum predicted upsidence < 20 mm and maximum predicted closure < 20 mm
- Negligible environmental consequences were predicted to be likely for Harris Creek
- A loss of groundwater yield was predicted at some private bores with drawdowns predicted to be within the 5 to 10 m range at some locations
- The potential for surface water inflow into the min was identified as being low.

Cardno 2014c, Appin Area 9 Longwalls 901 to 904 Extraction Plan Annex D – Biodiversity Management Plan

Minimum significant residual impacts were reported as being predicted within watercourses impacted by either subsidence or upsidence

B.4 Water Quality Assessments

Long term water quality data (1994 to 2011) has been reported by Sydney Water (2012). The analysis of data for over 200 observations during the period using flow adjusted parameters, were reported for Maldon Weir as showing for median values:

- A significant increase in pH. The median value reported for 2010-2011 was reported as being 8.0
- A significant increase in Total phosphorus. The median value for 2010-2011 was reported as being 0.014 mg/L while the filterable total phosphorus was shown as being 0.007 mg/L
- A significant increase in DO saturation at the site. The median value reported for 2010-2011 was reported as being 10.26% saturation
- No significant trend was reported over the same period for either Total nitrogen or electrical conductivity. Total nitrogen was reported as having a median value of 0.39 mg/L for the same monitoring period.
- Dissolved inorganic nitrogen was reported as having a median value of 0.16 mg/L for the same monitoring period.
- Electrical conductivity median value was reported as being 179.5 μS/cm for the same period

Appendix C – Legislation, Policies and Guidelines Considered

Many pieces of legislation, government policies and planning/design guidelines are applicable when investigating or planning a potential new residential area. The pieces of legislation and policies that have been considered during the development of this study are identified below.

C.1 Legislation

- Water Management Act 2012

C.2 Policies

- State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011
- Sydney Regional Environmental Plan No 20 – Hawkesbury Nepean River (No 2 – 1977)
- Campbelltown Local Environmental Plan 2014 (Draft)
- Campbelltown (Sustainable City) Development Control Plan 2009
- Wollondilly Local Environmental Plan 2011
- Wollondilly Development Control Plan 2011
- Wollondilly Development Control Plan 2015 (Draft)
- Growth Centres Development Code

C.3 Guidelines

- ANZECC Guidelines for Fresh and Marine Water Quality
- Policy and guidelines for fish habitat conservation and management updated 2013 *(DPI 2013)*
- Using MUSIC in the Sydney Drinking Water Catchment 2012
- Water Sensitive Design Guide for Rural Residential Subdivisions (2011)
- Office of Water guidelines (numerous)

Appendix D – Water cycle options and assessment

D.1 Definition of Water Sensitive Urban Design

Water Sensitive urban design, in a very broad, consideration represents an integrated planning and engineering design of the complete urban water cycle taking into consideration stormwater, water supply, wastewater and groundwater.

With appropriate management of all of these elements the issues of flow rates, flow volumes, changes in groundwater regimes and water quality will be appropriately addressed.

Inn most circumstances it is impractical to achieve an ideal balance of potential impact on these facets of the urban water cycle.

D.2 Elements within the urban water cycle

D.2.1 Water demand

The demand for water can be divided into that water which is required to meet potable water standards and that which does not need to meet potable water standards. Generally potable water standard is required where water is likely to be ingested or used for washing of cooking and eating utensils.

Non potable water can potentially be used for purposes such as garden watering, car washing, toilet flushing and cloths washing.

D.2.2 Potable water

Wastewater is generally considered to be that water created through human (domestic, commercial or industrial) use.

Frequently this water is classified as being either:

- Grey water – that created by operations such as cloths washing, showers, bathing etc and water which can be potentially used to satisfy non potable water demands
- Black water – is generally taken as being that water created by toilet usage, some commercial uses and selected industrial purposes. This water is treated prior to being reused within an urban area.

Sewer mining would be a technique that would be able to partially satisfy the potable water demand on an ongoing basis.

D.2.3 Stormwater

Stormwater is that surface runoff water which is created as a direct result of rainfall onto the catchment area. There is normally a rapid response of surface water flows from rainfall falling onto impervious catchment areas together with a slower response to rainfall falling onto pervious areas.

Stormwater can be harvested, stored and reused, with minimal or nil treatment, as a substitution for the non potable component of the required water supply. Harvesting and reuse of stormwater is in part achieved through the tanks required to achieve the required BASIX rating for residential developments. Rainwater harvesting tanks are also used on some commercial and industrial buildings.

Use of extensive stormwater harvesting would require the construction of significant water storages to balance the storage and retention of runoff during times of high rainfall to have it available for use during times of low rainfall.

D.2.4 Groundwater

A result of urban development is the reduction, as a direct result of the increased impervious areas, unless intervention prevents, in the volume of water that infiltrates into the soil.

D.3 Water utility

Sydney Water is anticipated to be the water utility should development within the Study Area proceed.

D.4 WSUD evaluation for this report

A separate concurrent study is considering the potential servicing requirements of the Study Area. This report will focus consideration on the stormwater management (flow rates, flow volumes and water quality) elements within the WSUD principles.

D.5 Potential stormwater impacts of development

Potential stormwater impacts of urban development, without the implementation of appropriate WSUD measures can include, without the implementation of mitigation measures:

- Increased rates of peak runoff
- Increased runoff frequency and runoff volumes
- Adverse impact on runoff water quality and in the receiving waters
- Reduced infiltration resulting from the increased impervious area resulting from the development

Secondary impacts that can occur from development included increased summer (particularly) are elevated temperatures resulting from heat island effects caused by the introduced impervious areas.

D.5.1 Increased peak rate of runoff

As indicated above, the introduction of urban areas as a result of development will increase the peak rate of runoff from a catchment area. The increased rate of peak runoff, without implementation of mitigation measures, can lead to increased erosion of the downstream watercourses as a direct result of the increased shear stress placed on the watercourse or as a result or the increased frequency of runoff and hence increased soil moisture level along the watercourses.

The Stream Erosion Index and permissible shear stresses are common measures used to assess the potential impacts of the increased peak rates of runoff.

The most common and effective impact mitigation measure is the provision of detention storages throughout the development. Stormwater detention can also be achieved through purpose constructed measures (detention basins) or a relatively small amount of detention can be achieved as an indirect result of the implementation of other management measures such as swales and bioretention facilities.

D.5.2 Increased runoff frequency and runoff volume

The runoff will increase in frequency and volume as a direct result of the additional impervious areas resulting from roads, roof areas and other impervious surfaces. Prior to a site becoming developed it is possible that a modest rainfall would not have created a surface runoff event but through the undertaking of the development and the introduction of road and paved areas there will become surface runoff whenever the rainfall amount exceeds a value of around 1 mm in any rainfall event.

This will have the effect of increasing the number of runoff events each year and also increasing the runoff volumes for individual events and also annually.

Some reduction in the impact of introducing roof areas for dwellings will be achieved through a rainwater tank on each property, as required by BASIX. The inclusion of stormwater detention measures will not mitigate these impacts.

Additional impact mitigation measures can include:

- Minimising the impervious area introduced into the development footprint
- Maximising the potential for site infiltration of water while being cognisant of potential adverse effects.

D.5.3 Water quality

Water quality of urban runoff frequently contains pollutants with the main ones being oils, nutrients sediments and heavy metals.

The concentration of the various pollutants will be dependent upon the development form and the development stage. For example, the potential sediment load off an urban area is potentially the greatest when the earthworks are being undertaken to establish the area and then become reduced as the urban area stabilises following dwelling construction.

For this assessment it is assumed that appropriate erosion control measures will be in place to control the export of sediments during the construction phase and this will not be specifically considered in the report. Only the ongoing sediment export will be considered in detail.

Similarly the nutrient load can vary throughout the life of an urban development with the greatest export of nutrients occurring at the time when there is significant amounts of garden establishment being undertaken and hence significant applications of lawn fertiliser being applied.

Various techniques are commonly used for treating urban runoff to improve the water quality. These techniques include, but are not restricted to, intervention measures such as biofiltration, wetlands, sedimentation and planning controls such as minimising the potential for pollutant export through the application of source controls.

D.5.4 Reduced infiltration

Reducing the amount of water that can infiltrate into the groundwater is not typically controlled within urban developments. Reduced infiltration is the direct result of the introduction of a greater amount of impervious surfaces as a result of the urban development.

Intervention measures including the use of porous pavements or infiltration areas within the development can be used to restrict this impact. However, care does need to be applied at the design stage to ensure that the underlying soil is suitable for regular water infiltration without the formation of relatively wet areas that become unusable.

D.6 Evaluation of potential WSUD measures

Comprehensive discussions of potential WSUD measures has been provided by Joint Committee on Water Sensitive Cities (2009) and EPA (1997).

This document will only provide a discussion of the techniques that have been considered in detail during this assessment. Alternate techniques could however be used, should development be approved, to achieve suitable outcomes.

D.7 Water conservation

D.7.1 BASIX

It has been assumed that each dwelling will be designed to include water conservation measures to comply with BASIX requirements. These measures are likely to include:

- Installation of water efficient appliances including water efficient toilets, taps, washing machines and dishwashers
- Installation of rainwater tanks on each dwelling with plumbing to water consuming fittings that do not require a potable water supply. Atypical dwelling tank sixe of around 3,500 L has been assumed based upon analyses undertaken for the Sydney region to provide a reasonable measure of water conservation while being reasonably cost efficient

The application of these measures, together with general household water conservation measures, will provide some measure of water conservation. Studies have shown the potential for reductions in potable water demand of 30 to 40% through the use of rainwater tanks on dwellings.

Rainwater tanks will not provide a significant flow reduction in 100 year ARI events unless they are oversized but they do provide a noticeable benefit in reducing the frequency of roof runoff it times of small rainfall events.

D.7.2 Regional stormwater harvesting

Regional stormwater harvesting requires the collection and holding of stormwater during times of runoff. The water is stored until times of water demand.

This form of water conservation does one of:

- Construction of large water storages that permanently contain stormwater held for reuse
- Use of aquifer storage and recharge (ASR) techniques

Further, depending upon the water quality of the stored stormwater and the proposed end use it may be necessary to provide treatment of the stored water prior to its reticulation to end users.

Examination of the topography of the proposed development area has shown the development areas will largely be along ridges and there are not many locations suitable for relatively large scale permanent stormwater storage except within some of the more incised creeks in heavily vegetated areas. Given the required balance of a broad range of values being applied to the proposed development, it is not anticipated that the construction of permanent water storage in heavily vegetated areas will be acceptable. However, construction of these storages is potentially technically possible.

No further consideration will be provided to regional stormwater harvesting within this investigation.

At this time there has not been a detailed evaluation of the potential for use of ASR as a water conservation measure. Initial evaluation suggests ASR is unlikely to provide significant benefits in the region.

D.8 Stormwater quantity control

Control of peak rates of runoff from developed areas can be achieved on a regional basis or at individual lots. Both forms of flow control are potentially suited to application within the Subject Site.

D.8.1 Regional detention

Regional detention (or detention) is the term applied to the construction of a series of centralised detention basins when each provides a flow control function for multiple lots. In this

process the regional detention basin is designed to restrict the peak rate of discharge to the predevelopment values at the basin site while upstream of the basin there will be an increased peak a maximum discharge as compared to that for the predevelopment condition.

A volume of approximately 230 m^3/ha of development lot could be suitable for the basins.

Detention will restrict the peak rates of flow off the development area but do not contribute significantly to either the reduction in the volume of site runoff or the removal of pollutants from the stormwater.

The main disadvantage of regional detention would be that there can be adverse upstream impacts in regions where the peak rate of runoff is increased from the natural value. In these locations there would be a potential increase in the stream erosion index.

A benefit to Government of the application of this form of detention strategy would be that the maintenance of the detention structures would be more reliable than that for onsite detention structures.

D.8.2 Onsite detention

Onsite detention is the term applied to the application of a requirement for flow control on each individual development site. In this technique a maximum permissible discharge rate is determined for each lot and a detention structure is required to be included on each lot to restrict the maximum discharge rate, for the 100 year ARI rainfall event, to the required maximum value for that lot.

The volume of required detention on each lot will be dependent upon the lot size, development form and hence relative impervious area on the lot.

An initial evaluation of r the Study Area has indicated that a volume of approximately 220 m^3/ha of development lot could be suitable.

Onsite detention will restrict the peak rates of flow off the development area but do not contribute significantly to either the reduction in the volume of site runoff or the removal of pollutants from the stormwater.

Two main forms of onsite detention are applied. Typical techniques include:

- Installation of dedicated structures to collect and detain the stormwater.
- Installation of oversized rainwater tanks with a slow draining upper section to match the required detention volume.

The first technique is the most common. It requires the construction of a structure where it can collect runoff from the entire lot (or at the least the entire impervious area) so that the runoff rate can be controlled appropriately.

A disadvantage of the application of a broad scale onsite detention strategy would be that the ultimate efficiency of the strategy is dependent upon all lot owners to maintain the individual systems. Failure to maintain the systems can make them inoperable.

A benefit to Government of the application of an onsite detention strategy would be that the capital cost of the detention structures would be directly borne by lot purchasers without the need for funding and construction of regional structures.

D.8.3 Combination of above options

A detention strategy for a site as large as the Study Area would be to apply a different form of flow control across the total area. This option is not canvassed in detail.

D.8.4 Infiltration

Infiltration of stormwater can be achieved through the introduction into the design of distinct infiltration areas.

Examples of how infiltration of water could be achieved could include:

- Use of porous paving, where practical, as part of the development footprint to restrict the extent of impermeable concrete and bitumen surfaces. Infiltration that occurred through the porous pavers and between pavers would reduce the volume of stormwater runoff and also recharge the groundwater
- Connecting outflows from installed rainwater tanks (or flow bypasses for dirty runoff) to a relatively small porous structure prior to the discharge to the regional stormwater collection system. When there is overflow from the tanks there would some amount of infiltration of stormwater into the ground and this would recharge the groundwater
- Collecting runoff from the road kerb or paved surfaces and directing flows into street tree surrounds would assist in the watering of the trees and also reduce the runoff volume. This option would probably be most practical in public spaces containing large paved areas.
- Bioretention or wetland areas could be designed to include a small leakage area that provides some groundwater recharge.

All of the above techniques could be implemented to assist in the recharge of the groundwater and reduce the increase in the increase in the volumetric stormwater runoff. However, the impact of infiltration on reducing the peak rate of stormwater runoff for large design rainfall events would be minimal.

Significant care would also need to be applied during the design process, should the soils be conducive to infiltration, to avoid the potential for creating unintended saturated areas within the urban footprint. This suggests that application of infiltration techniques may need to be only applied to selected areas within the development footprint.

D.9 Water quality treatment

Four of the more common forms of water quality treatment have been considered within this study as they could be applicable on a regional basis. The application of pocket parks has not ben addressed in detail but they could be incorporated as part of the overall catchment required stormwater treatment areas.

D.9.1 Wetlands

Wetlands are permanent waterbodies that have naturally, or been designed to, contain significant areas of aquatic vegetation.

Constructed wetlands normally will contain permanent water and have areas of relatively shallow permanent water so that both open water areas and areas containing aquatic vegetation are created to maximise the ecological function within the waterbody.

Wetlands are relatively efficient in their pollutant removal capability.

D.9.2 Floating wetlands

Floating wetlands are relatively new forms of wetlands that are constructed by establishing vegetative plantings in floating beds of material and then are placed and fixed in position on waterbodies. These structures have an advantage in that they can be applied on waterbodies or ponds that are relatively deep to improve the removal of nutrients.

The performance of floating wetlands is relatively high when considered on the basis of the unit load (kg/ha of wetland) of pollutants removed.

D.9.3 Bioretention

Bioretention areas are specially design areas planted with aquatic species and are normally dry or only damp except during times of stormwater runoff. They are frequently relatively shallow areas that frequently only have a maximum inundation depth of around 0.5 to 1 m for rainfall events.

Bioretention areas do not perform a significant flow control (detention) function for large runoff events. The pollutant removal capacity of bioretention areas is relatively high when compared to the other techniques.

Bioretention areas can be incorporated into detention basins which are normally dry and do not contain permanent water to improve the pollutant removal capacity of the detention basin.

D.9.4 Ponds

Ponds are normally considered as being waterbodies that do not have significant areas af aquatic vegetation – either fringing or floating. The nutrient removal is achieved primarily through sediment settlement and the retention of absorbed nutrients.

Ponds are relatively low in their pollutant removal capacity as there is a minimal amount of biological activity to remove dissolved nutrients.

D.10 Evaluation of WSUD stormwater management strategies

Three WSUD strategies were evaluated for the study area and are discussed in Sections D.10.2 through D.10.4.

Following a reduction in the Developable Area the extent of work in the preferred strategy was refined.

D.10.1 General discussion

The potential development footprints are generally located along ridge lines on the eastern side of the Nepean River. This has hindered the development of an efficient stormwater drainage strategy as there are numerous natural discharge locations where stormwater will drain into the downslope vegetated areas.

Due to the location of the potential development areas along ridges it will be necessary, to minimise impacts on downstream waterways, to construct an unusually large number of determine facilities, should regional detention facilities be adopted, to mitigate downstream impacts. Detention and water quality facilities would be required to prevent there being adverse impacts on the Upper Canal as it passes through the study area.

The location of any stormwater management facilities would be readily compatible with the adopted staging strategy.

An initial evaluation of undertaking extensive site regrading works was completed to determine the economic viability of reducing the number of discharge locations. At this strategy stage it was not considered practical to substantially reduce the number of discharge locations from the potential development footprint.

An evaluation of three WSUD strategies has been considered to demonstrate that different strategies can, at this concept level evaluation, be made to perform for the Study Area and to provide an initial evaluation of the relative features of the systems to aid in the selection of a preferred WSUD strategy for managing the site stormwater.

Features of the three strategies are described below.

Common assumptions made across the three options include:

- No capital cost included for acquiring the riparian vegetated corridors and no maintenance cost included for these elements
- Capital and O&M costs for the BASIX requirements are not included in the cost estimates
- Assumed that 15 dwellings (or equivalents) will be achieved
- The watercourses draining the potential development areas have only been mapped where the catchment area exceeds a value of 10 ha. A significant amount of smaller watercourses exist and drain the potential development areas but it has been assumed that site regrading would be undertake as part of the lend development to restrict the discharge locations.
- A permitter road would be constructed around the periphery of development areas adjacent to bushland and this road would be used to direct flows in excess of the minor street drainage system capacity to the respective discharge location. This would require the roads to be suitably graded and planned.
- Use of the perimeter road in the manner described in the last point would require the development to be undertaken in a planned and co-ordinated manner to ensure the long term functioning of the perimeter road.
- It may also, when the strategy is considered in a greater level of detail, require the APZ to be locally increased to facilitate the achievement of a suitable road grading.

D.10.2 Strategy 1 – Onsite detention and regional bioretention areas

Description

This WSUD strategy is allowed as including:

- Dwellings fitted with water efficient appliances and rainwater tanks as required to satisfy BASIX requirements
- Application of an onsite detention requirement on each lot to restrict the peak rate of runoff off lots to a value not exceeding the predeveloped value off the lot for all design events up to the 100 year ARI critical duration (post development) value
- A conventional minor pipe drainage network and major drainage network to convey flows to the regional water quality treatment measures
- Construction of the perimeter road located within, or adjacent to the APZ, in such a form as to convey the major stormwater flows to the water quality measures. This functionality could be achieved through using an enlarged capacity pipe network system for this road or construction, use of a single cross fall road to enhance the flow conveyance capacity or, where the landform suits, of a swale system parallel to the road.
- Construction of a bioretention area at each discharge point from the major/minor drainage discharge location into the creekline vegetation areas
- Opportunistic incorporation of pocket parks of landscape water bodies into the development footprint will be adopted but their benefit has not been considered in this analysis
- Litter and gross pollutant traps at the discharge of the piped drainage system into the regional water quality control facilities
- Regional bioretention areas of 2.7% of the catchment area at each discharge from the stormwater system

Discussion

The application of an onsite development strategy is relatively common within urban areas, especially when considering infill development where the capacity of existing infrastructure is limited.

The application of this strategy to a greenfield site is less common. However, to provide maximum protection for vegetation and watercourses outside the development area such a strategy could be appropriate unless protection and/or stabilisation against erosion of the downstream watercourses is provided.

Broad scale hydrologic analysis of this option has indicated that the separation of peak rates of runoff from road areas and lot areas, through the incorporation of detention on each lot, has significantly minimised the need for any detention for flows off the roads.

The incorporation of pocket parks and landscape features that double as stormwater storages will include the system performance.

Water quality treatment would be achieved through the provision of a relatively small bioretention area at each discharge point from the development footprint. A total of approximately 158 bioretention areas would be required unless alternate compensating works are undertaken. Where practical there has been a rationalisation of measure locations to minimise the number of facilities. Figure D-1 provides the identified discharge locations while Figure D-2 provides a more detailed representation of the locations works.

In general the water quality facilities are located where stormwater will:

- Discharge from the development footprint in watercourses having a catchment larger than 10 ha
- Discharge onto existing major roadways
- Discharges past the Upper Canal.

Analysis of the topography has shown that the number of bioretention areas could be reduced by the construction of longer perimeter roads or flow conveyance paths along the APZs but this would in many locations require the acquisition of a wider APZ that that currently identified in a concurrent study.

Land Take

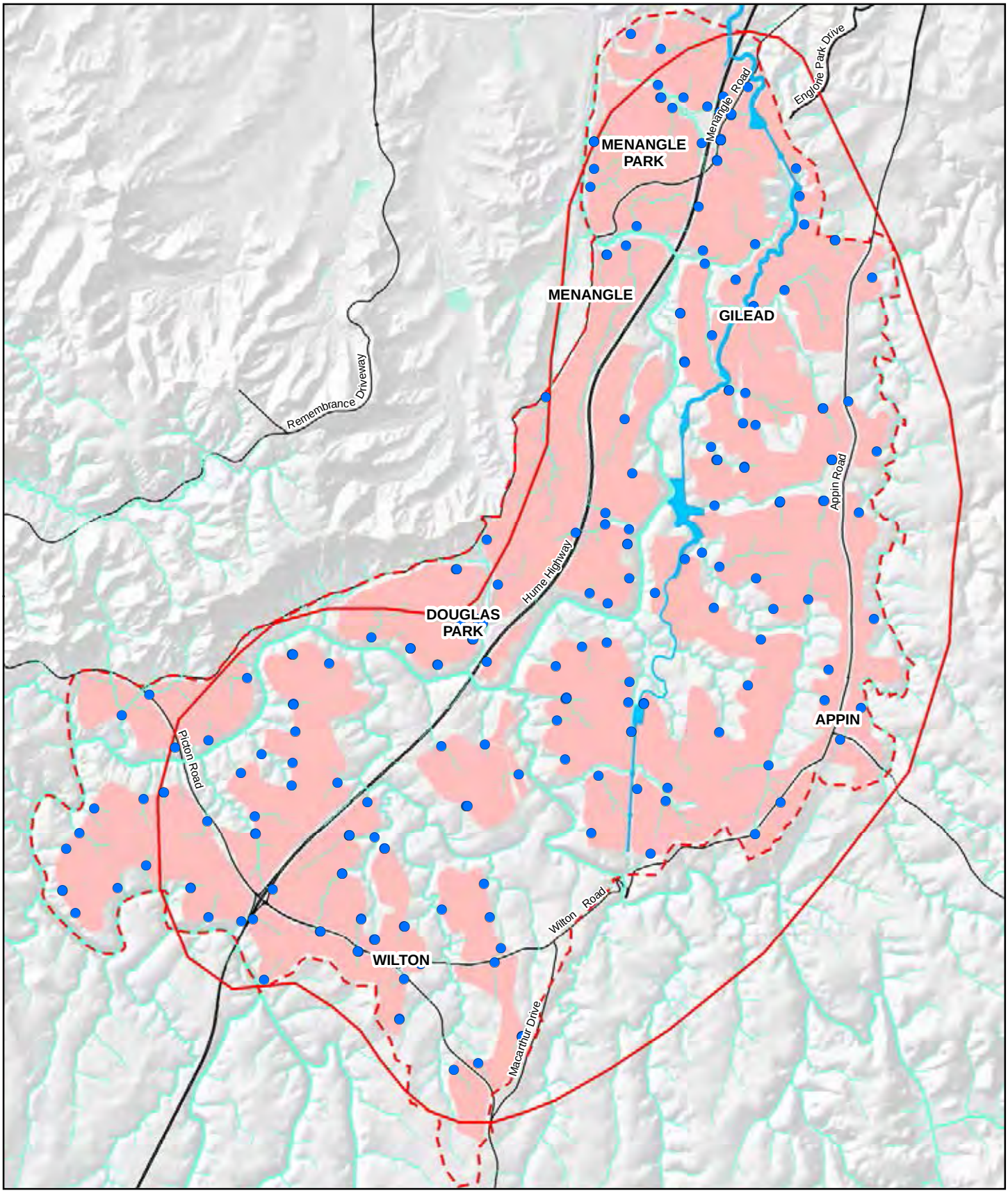
This strategy would not have any land take requirement for the provision of the detention function as this would be incorporated onto each lot.

The indicative land take for the identified infiltration areas would total approximately 110 ha. When including the associated works (embankments, access tracks and similar measures) the total require land take is likely to increase to approximately 130 ha.

Costs Estimate

The estimated costs are:

- Capital cost for detention - $1,110m
- Capital cost contribution for upgrade of perimeter road for enhanced drainage system - $10m
- Capital cost for water quality measures - $220m
- O&M costs for detention - $7.0m/a
- O&M contribution for perimeter road - $0.2m/a
- O&M costs for water quality measures - $1.6m/a



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Strategy 1 - Potential Water Quality Facility Locations

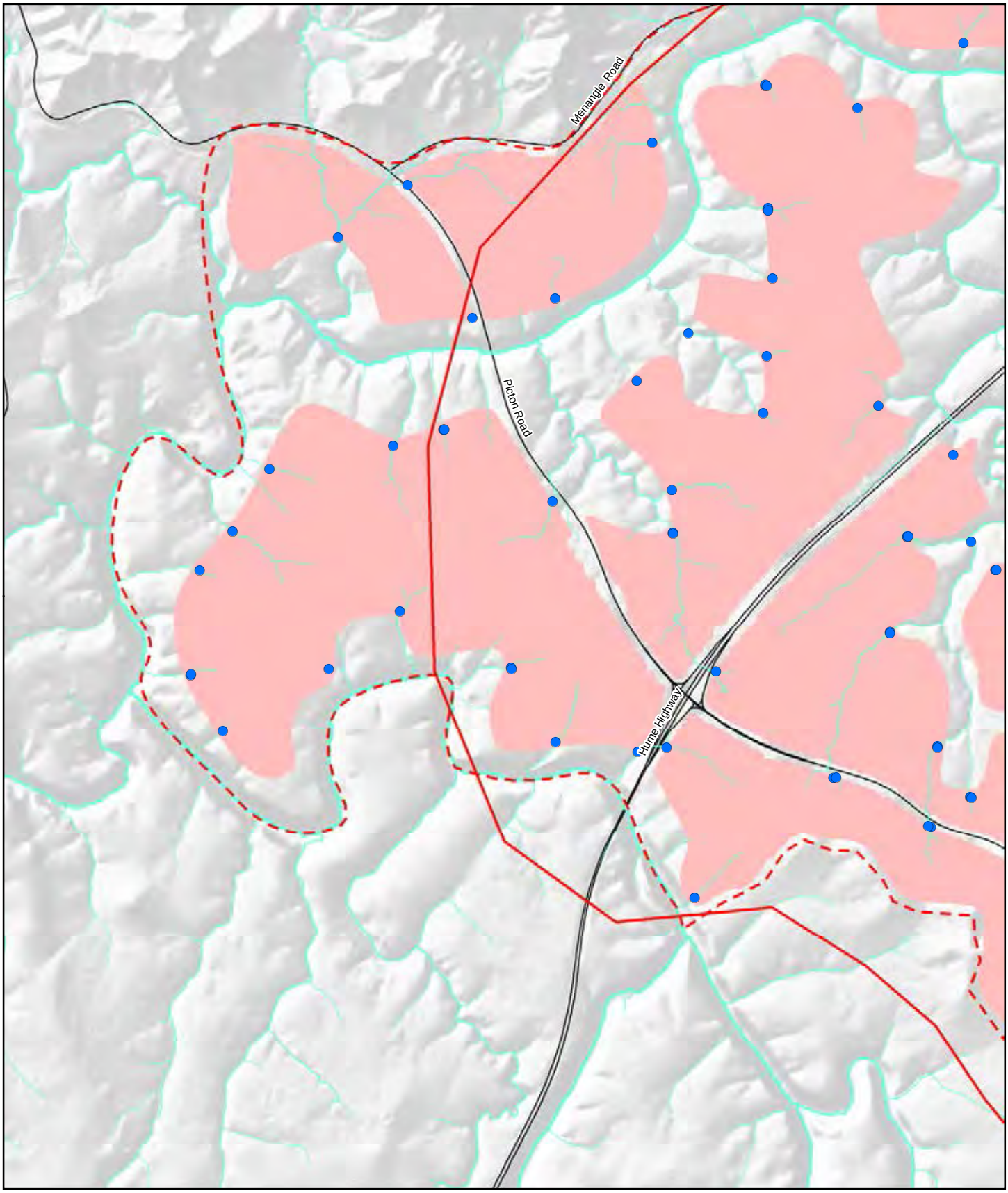
Figure D-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D001_Strategy1_WQ_locations_0.mxd

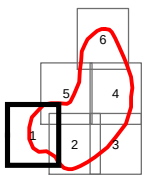
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential water quality treatment facilty



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

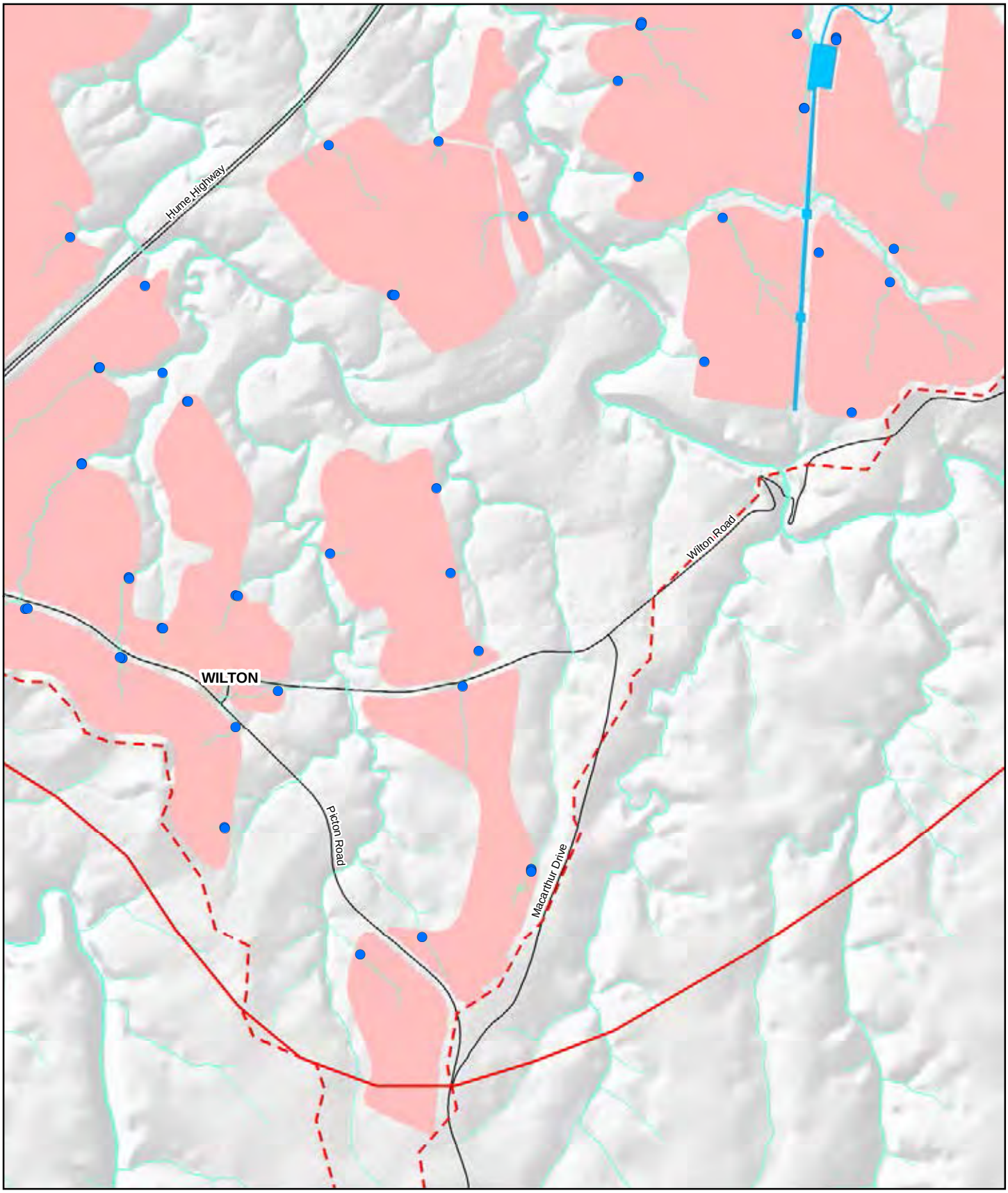
Strategy 1 - Potential Water Quality Facility Locations Detail - Sheet 1 Figure D-2a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D002_DDP_Strategy1_WQ_Locations_0.mxd

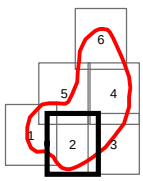
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

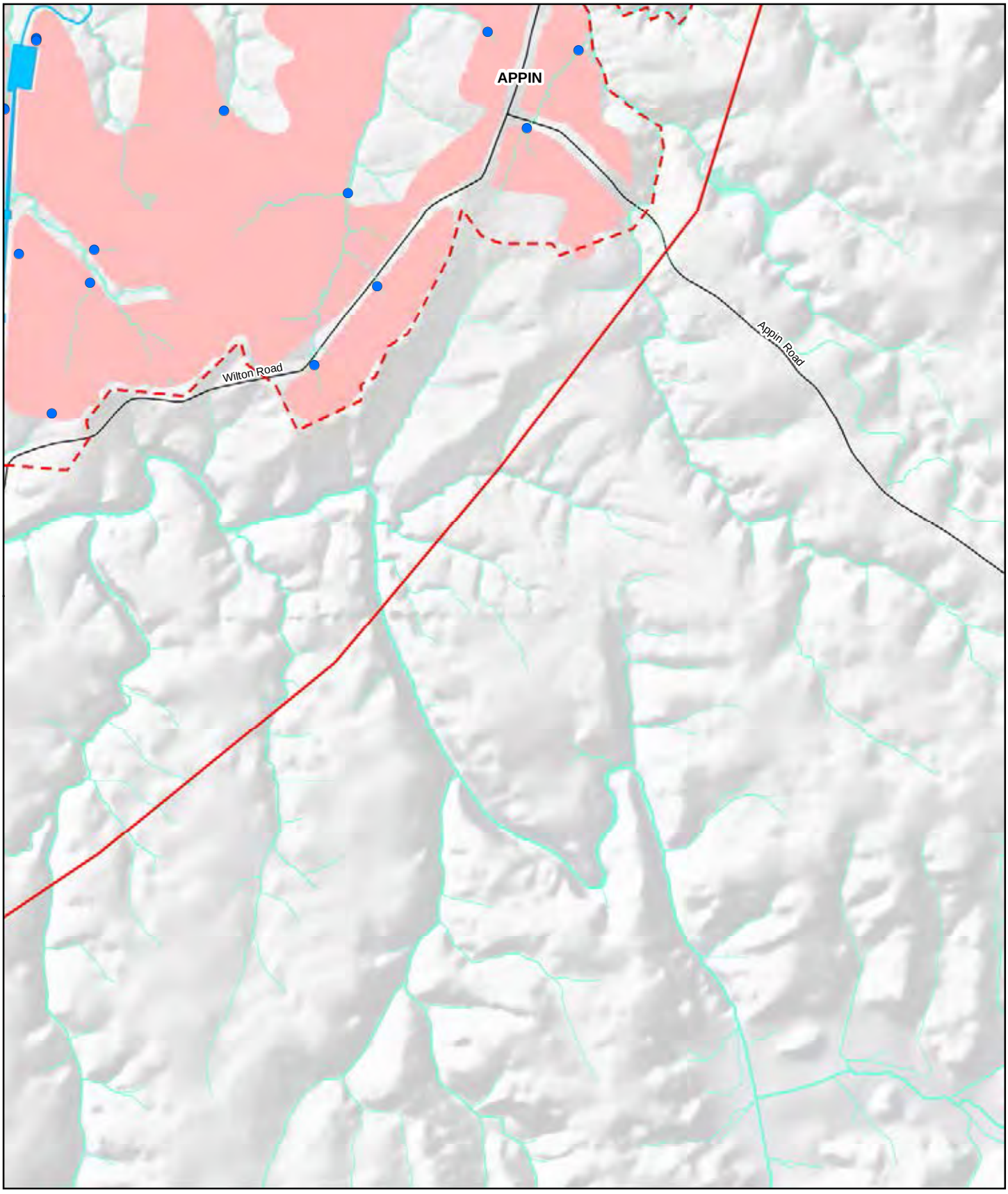
Strategy 1 - Potential Water Quality Facility Locations Detail - Sheet 2 Figure D-2b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D002_DDP_Strategy1_WQ_Locations_0.mxd

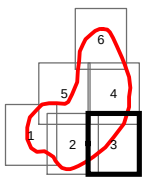
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

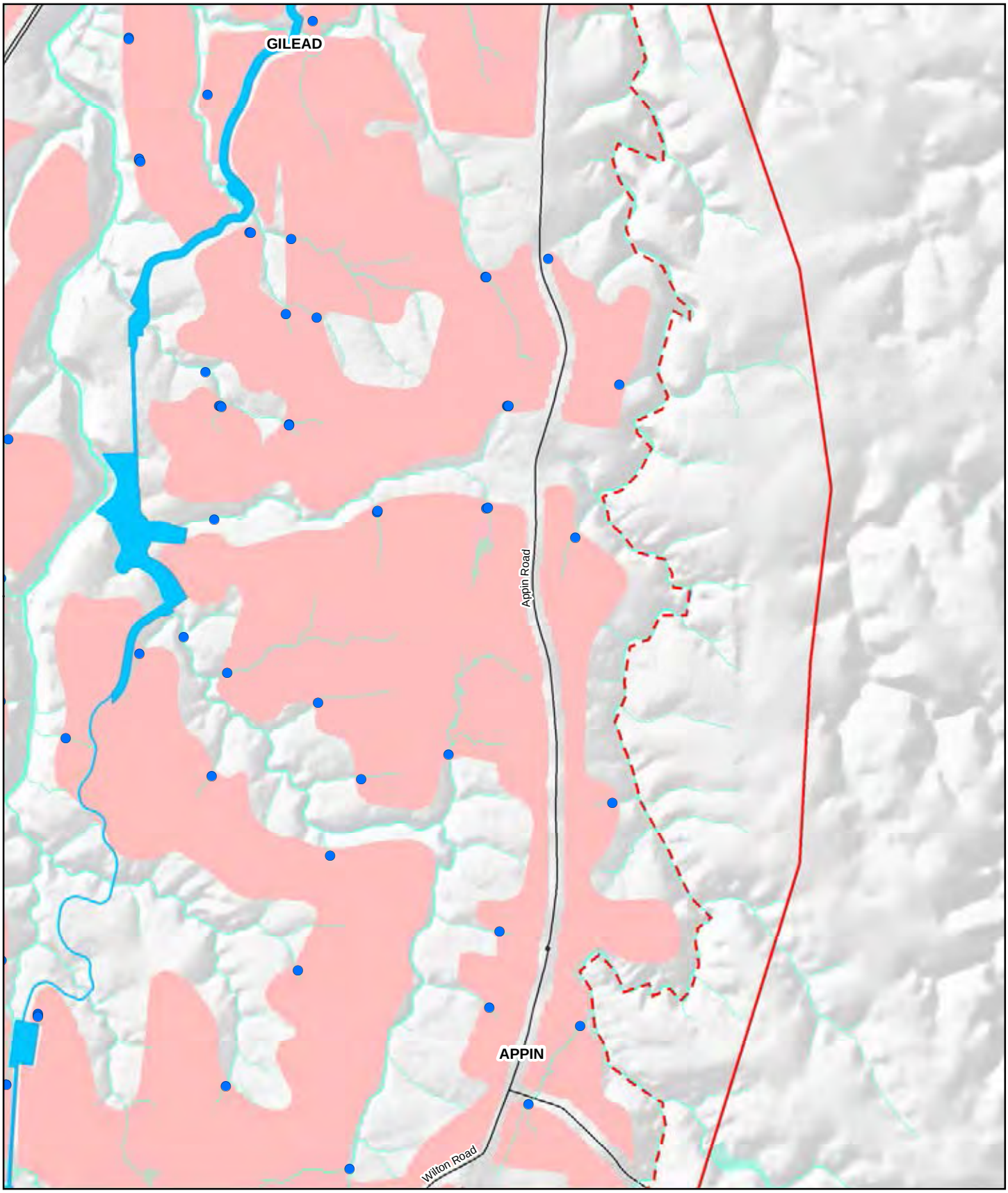
Strategy 1 - Potential Water Quality Facility Locations Detail - Sheet 3 Figure D-2c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D002_DDP_Strategy1_WQ_Locations_0.mxd

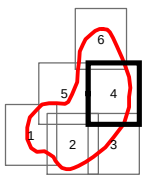
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

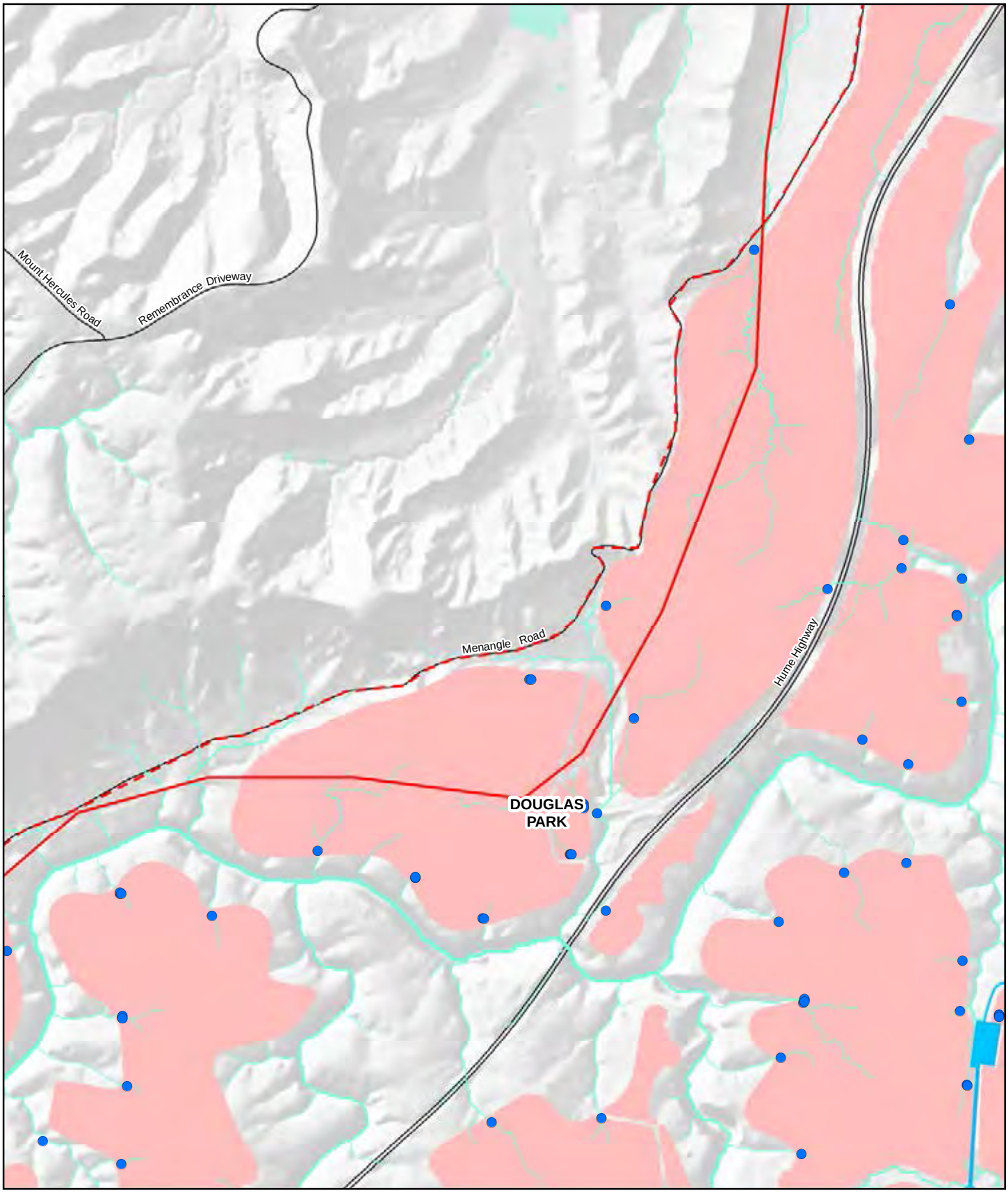
Strategy 1 - Potential Water Quality Facility Locations Detail - Sheet 4 Figure D-2d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D002_DDP_Strategy1_WQ_Locations_0.mxd

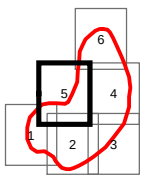
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

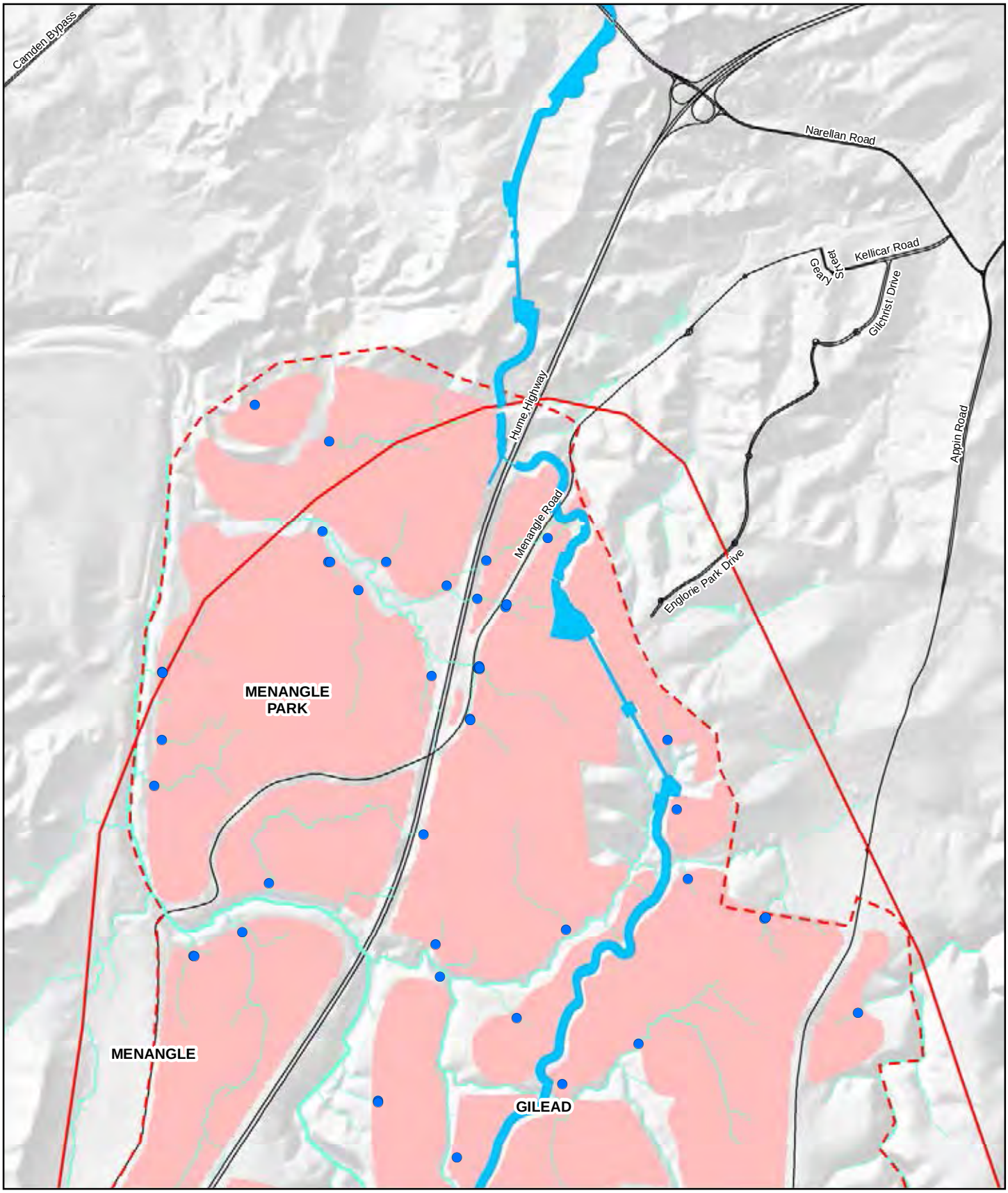
Strategy 1 - Potential Water Quality Facility Locations Detail - Sheet 5 Figure D-2e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D002_DDP_Strategy1_WQ_Locations_0.mxd

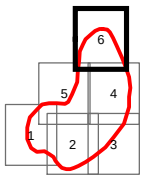
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Strategy 1 - Potential Water Quality Facility Locations Detail - Sheet 6

Figure D-2f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D002_DDP_Strategy1_WQ_Locations_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

Implementation

Implementation of the WSUD strategy would not be significantly impacted by the direction of servicing being either north to south or south to north.

Similarly the location of the water quality works would not be significantly impacted by the direction of the servicing.

The main implementation issue would be the need to plan the entire area draining to each water quality facility to ensure an appropriate perimeter road grading to convey flows in excess of the minor stormwater system to the required water quality facility. A difficulty with this approach is that a form of land banking may be necessary to achieve appropriate land ownership to be able to achieve this outcome.

Table D-1 gives a summary of key features of three WSUD strategies.

D.10.3 Strategy 2 – Regional detention in APZ with regional bioretention with discharge from each catchment

Description

This WSUD strategy is allowed as including:

- Dwellings fitted with water efficient appliances and rainwater tanks as required to satisfy BASIX requirements
- A conventional minor pipe drainage network and major drainage network to convey flows to the regional water quality treatment measures
- Construction of the perimeter road located within, or adjacent to the APZ, in such a form as to convey the major stormwater flows to the water quality measures. This functionality could be achieved through using an enlarged capacity pipe network system for this road or construction, use of a single cross fall road to enhance the flow conveyance capacity or, where the landform suits, of a swale system parallel to the road.
- Construction of a combined bioretention and detention area at each discharge point from the major/minor drainage discharge location into the creekline vegetation areas. The detention volumes were set at 230m^3/ha and regional bioretention at 1.5% of catchment area
- Opportunistic incorporation of pocket parks of landscape water bodies into the development footprint will be adopted as 1.5% of the catchment areas
- Litter and gross pollutant traps at the discharge of the piped drainage system into the regional water quality control facilities

Discussion

- This WSUD strategy is relatively conventional in that it maximised the protection afforded to the downstream environment while maintaining regional detention and water quality functions.
- Broad scale hydrologic analysis of this option has indicated that the separation of pear rates of runoff from road areas and lot areas, through the incorporation of detention on each lot, has significantly minimised the need for any detention for flows off the roads.
- The incorporation of pocket parks and landscape features that double as stormwater storages will include the system performance.

Table D.1 Evaluation of Scheme

Parameter	Strategy 1		Strategy 2		Strategy 3	
	Strengths	Weaknesses	Strengths	Weaknesses	Strengths	Weaknesses
Hydrological performance	• Provides impact restriction off developed area for all design events	-	• Provides impact restriction off developed area for all design events	-	-	• Does not provides impact restriction off developed area for all design events at all locations
Hydraulic performance	• Nominal impact on flood levels and velocities as compared to those today at all locations	-	• Nominal impact on flood levels and velocities as compared to those today at all locations	-	-	• In watercourse where detention has not been provided in APZ there will be impacts down to the detention basin
Watercourse stability	• Strategy will provide good flow control and stability through the bushland areas assuming maintenance undertaken by lot owners	-	• Strategy will provide good flow control and stability through all bushland areas	-	-	• Strategy will provide limited flow control and stability control through the bushland areas
Land take	• Land take at approximately 110 ha including land in APZ	-	• Land take approximately 212 ha including land in APZ	-	• Least land take at approximately 75 ha including land in APZ	-
Capital cost estimate	-	• Capital cost approximately $1,340 million	• Lowest at approximately $310	-	• Not estimated	-
Operating and maintenance cost estimate	-	• O&M cost of approximately $8.8 million per annum	• Lowest at approximately $2.7 million per annum	-	• Not estimated	-

Water quality treatment would be achieved through the provision of a bioretention area at each discharge point from the development footprint. A total of approximately 158 bioretention areas would be required unless alternate compensating works are undertaken. Where practical there has been a rationalisation of measure locations to minimise the number of facilities. Figure D-3 provides the identified discharge locations.

In general the water quality facilities are located where stormwater will:

- Discharge from the development footprint in watercourses having a catchment larger than 10 ha
- Discharge onto existing major roadways
- Discharges past the Upper Canal.

Analysis of the topography has shown that the number of bioretention areas could be reduced by the construction of longer perimeter roads or flow conveyance paths along the APZs but this would in many locations require the acquisition of a wider APZ that that currently identified in a concurrent study.

The detention or flow control function would be provided in a regional facility collocated with each bioretention area in the APZ.

Land Take

This strategy would not have any land take requirement for the provision of the detention function as this would be incorporated onto each lot.

The indicative land take for the identified infiltration areas would total approximately 120 ha. When including the associated works (embankments, access tracks and similar measures) the total require land take is likely to increase to approximately 140 ha.

Costs Estimate

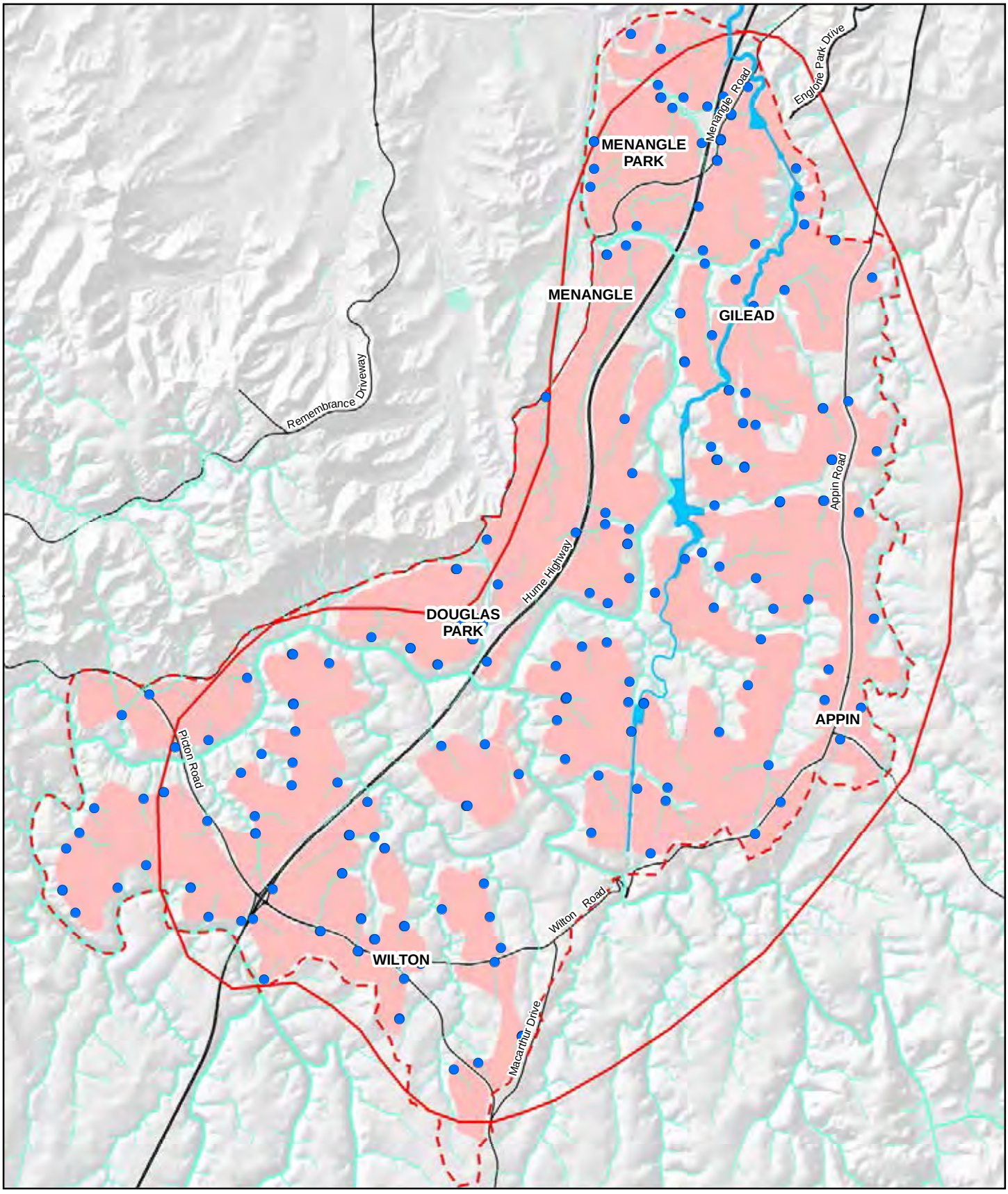
The estimated costs are:

- Capital cost for combined detention and water quality measures - $310m
- Capital cost contribution for upgrade of perimeter road for enhanced drainage system - $10m
- O&M costs contribution for perimeter road – $0.2m/a
- O&M costs for combined detention and water quality measures - $2.5m/a

Implementation

Implementation of the WSUD strategy would not be significantly impacted by the direction of servicing being either north to south or south to north.

The main implementation issue would be the need to plan the entire area draining to each water quality facility to ensure an appropriate perimeter road grading to convey flows in excess of the minor stormwater system to the required water quality facility. A difficulty with this approach is that a form of land banking may be necessary to achieve appropriate land ownership to be able to achieve this outcome.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty
- Upper Canal

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Strategy 2 - Potential Dentention and Water Quality Facility Locations

Figure D-3

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D003_Strategy2_WQ_locationsA.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

D.10.4 Strategy 3 – Consolidated regional detention in APZ with bioretention

Description

This WSUD strategy, Figure D-4, is allowed as including:

- Dwellings fitted with water efficient appliances and rainwater tanks as required to satisfy BASIX requirements
- A conventional minor pipe drainage network and major drainage network to convey flows to the regional water quality treatment measures
- Construction of the perimeter road located within, or adjacent to the APZ, in such a form as to convey the major stormwater flows to the water quality measures. This functionality could be achieved through using an enlarged capacity pipe network system for this road or construction, use of a single cross fall road to enhance the flow conveyance capacity or, where the landform suits, of a swale system parallel to the road
- Construction of a combined bioretention and detention area at some discharge points from the major/minor drainage discharge location into the creekline vegetation areas. In opportunistic locations where the terrain and footprint is more suited there would be regional detention and water quality facilities constructed online to creeks to reduce the number of structures within the APZ. Regional detention was allowed at 230m^3/ha and bioretention allowed at 1.5% of catchment area
- Opportunistic incorporation of pocket parks of landscape water bodies into the development footprint will be adopted at 1.5% of catchment area
- Litter and gross pollutant traps at the discharge of the piped drainage system into the regional water quality control facilities

Discussion

This WSUD strategy is relatively conventional in that it maximised the protection afforded to the downstream environment while maintaining regional detention and water quality functions.

Broad scale hydrologic analysis of this option has indicated that the separation of pear rates of runoff from road areas and lot areas, through the incorporation of detention on each lot, has significantly minimised the need for any detention for flows off the roads.

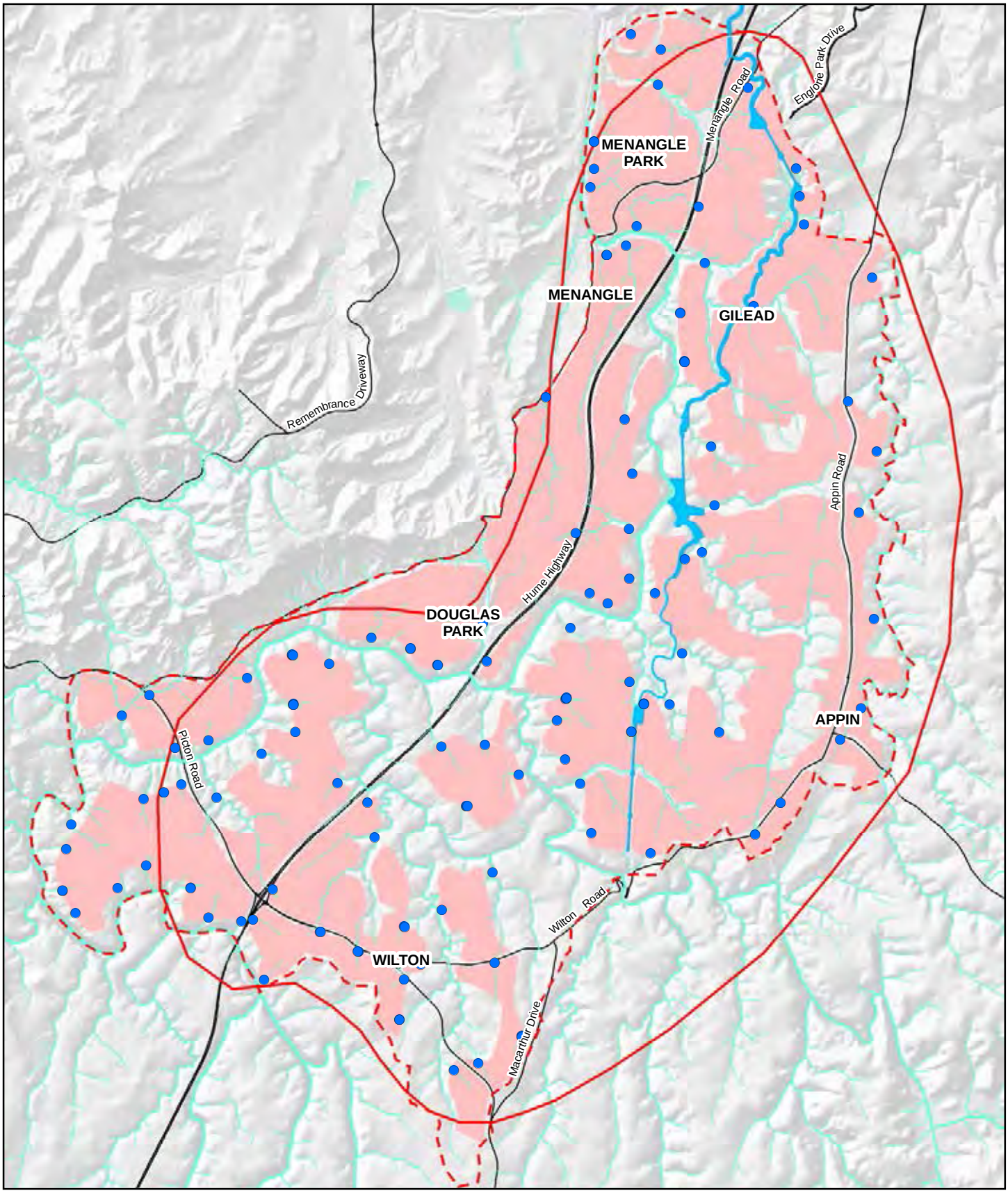
The incorporation of pocket parks and landscape features that double as stormwater storages will include the system performance.

Water quality treatment would be achieved through the provision of a bioretention area at each discharge point from the development footprint. A total of approximately 96 bioretention areas would be required unless alternate compensating works are undertaken. Where practical there has been a rationalisation of measure locations to minimise the number of facilities. Figure D-4 provides the identified discharge locations.

In general the combined detention and water quality facilities in APZs are located where stormwater will:

- Discharge from the development footprint in watercourses having a catchment larger than 10 ha
- Discharge onto existing major roadways
- Discharges past the Upper Canal.

In areas where this is not done, the flows will pass into combined stormwater and water quality facilities further downstream along the watercourses.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty
- Upper Canal

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Strategy 3 - Potential Dentention and Water Quality Facility Locations

Figure D-4

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D004_Strategy3_WQ_locationsA.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

Analysis of the topography has shown that the number of bioretention areas could be reduced by the construction of longer perimeter roads or flow conveyance paths along the APZs but this would in many locations require the acquisition of a wider APZ that that currently identified in a concurrent study.

The detention or flow control function would be provided in a regional facility collocated with each bioretention area in the APZ.

This strategy would have the disadvantage that each structure that was constructed on a creekline would lead to an almost complete severing of the vegetated corridor along the creekline. This would occur as a result of:

- The relatively large footprint required for construction of the embankments across the creekline:
- The need to clear the footprint of the online storages for construction of the bioretention area within each structure.

In addition, these online creekline structures would have:

- An increased operational risks of failure due to the amount of tree and vegetation debris that could block any lower flow outlets during times of flood. This could be partially designed out at detailed design but there would be a residual higher failure risk unless a large and robust trash rack was provided upstream of each low flow outlet
- The area lateral to the structures would need to be cleared to improve visual lines of sight from the residential areas to the basins to improve personal safety, provide an enhanced integration of the systems into the built form and encourage maintenance of the constructed systems

Land Take

This strategy would not have a reduced land take as compared to the other two strategies since some of eth structure that were previously located adjacent to the perimeter road would be removed from the urban footprint and relocated into the creekline corridors.

The indicative land take for the identified infiltration areas would total approximately 110 ha at the APZ.

Costs Estimate

A preliminary cost estimate has not been prepared for this strategy due to the significant potential impacts of the strategy.

Implementation

Implementation of the WSUD strategy would not be significantly impacted by the direction of servicing being either north to south or south to north.

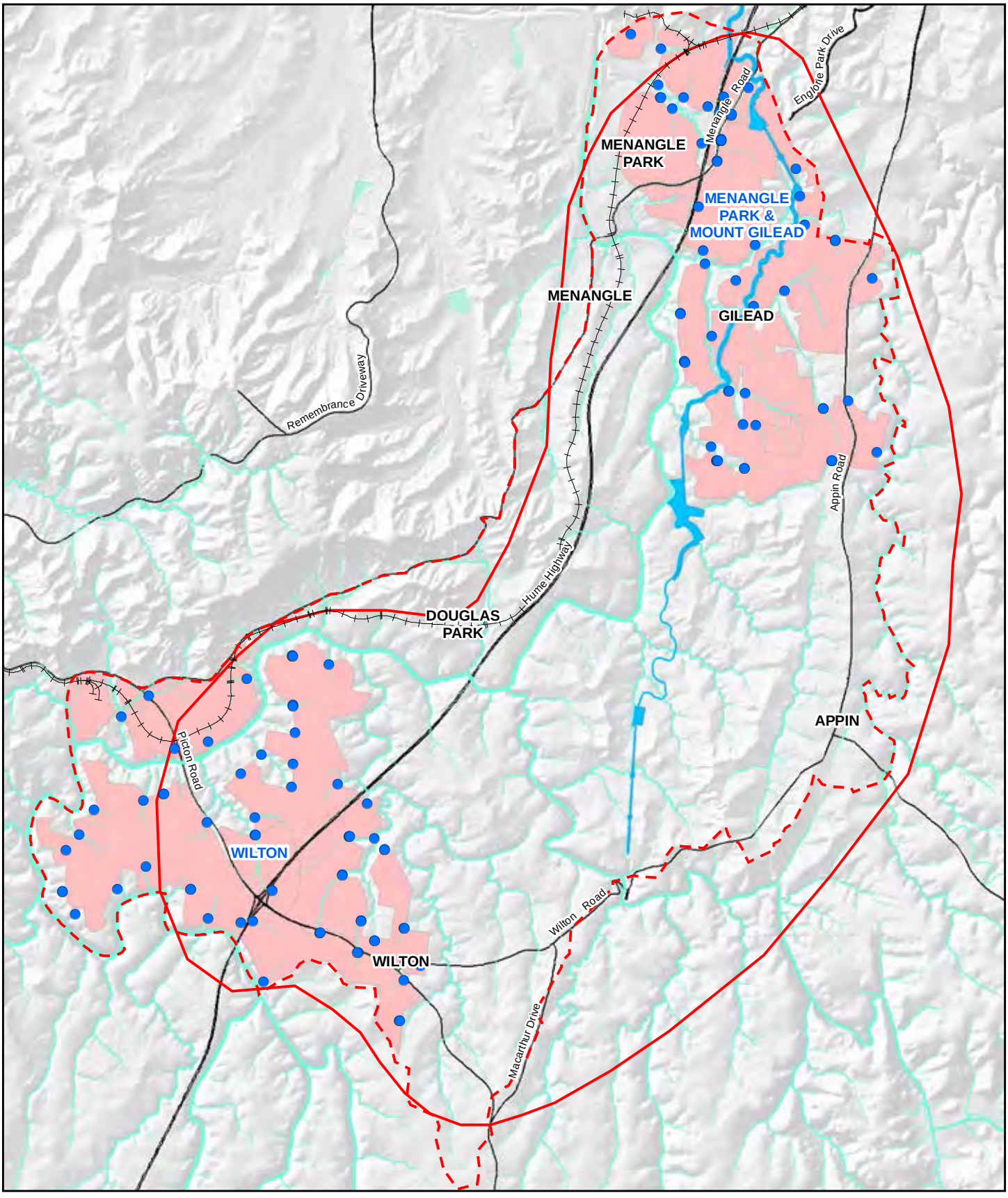
The main implementation issue would be the amount of mature vegetation that would need to be removed and the potential adverse community reaction to that works.

D.11 Refined Strategy Implementation

D.11.1 Strategy

The preferred strategy was that defined in Strategy 2. During the evaluation there was a staging for potential development of the study area prepared. That staging is shown in Figure D-5.

The breakdown in capital and operating and maintenance costs for the stages are given in Table D.2 using the assumptions identified in Appendix K.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Developable Areas
- Road
- Railway
- Watercourse
- Waterbody
- Potential water quality treatment facilty
- Upper Canal

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Potential WSUD Strategy for Developable Areas

Job Number 22-17728
Revision 0
Date 27 Aug 2015

Figure D-5

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_D\2217728_D006_Potential_WSUD_WQ_locations_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

Table D.2 Staging estimated costs

Stage	No Structures	Bioretention Area (m^2)	Detention Volume (m^3)	Capital Cost ($m)	O&M Cost ($m/a)
Menangle Park to Mount Gillead	39	200,692	453,773	70.1	0.62
Wilton	44	266,840	965,216	75.1	0.56

D.11.2 Costs for Developable Areas

The costs were then scaled to reflect those for the two developable areas shown in Figure D.5 and are shown in Table D. 3.

Table D.3 Capital and operating costs

Parameters	Menangle Park & Mount Gilead	Wilton
Capital cost for upgrade of perimeter road ($m)	2.57	2.00
Capital cost of combined bioretention and detention structures at APZ ($m)	67.60	73.10
Total capital cost ($m)	**$70.10**	**$75.10**
O&M costs for additional works on perimeter road ($m/a)	0.04	0.05
O&M costs for combined bioretention and detention structures at APZ ($m/a)	0.58	0.51
Total O&M costs ($m/a)	**0.62**	**0.56**

Appendix E – Hydrologic and hydraulic analysis

E.1 Introductory Material

E.1.1 General

The purpose of this Appendix is to provide the hydrologic and hydraulic assessment methodology, hydrology results and overview of the hydraulic results for the Greater Macarthur development area.

Details mapping of the hydraulic results from the investigation are provided in Appendices F (flood level mapping), G (velocity mapping), H (flood hazard mapping), I (flood classification mapping) and J (flood level profiles).Tabulated flood modelling results are provided at the end of this Appendix.

The study area identified for the project is provided on Section 2 of this report.

E.1.2 Scope and limitations

The scope of this assessment is provided below:

- Determine the existing hydrological response for the catchments within the study area. The events to be assessed will consider the peak 100 year Average Recurrence Interval (ARI) and Probable Maximum Precipitation and Flow (PMP/PMF) events.
- Identify watercourses to be assessed for hydraulic categorisation and establish existing hydraulic conditions for selected trunk watercourses within the study area.
- Assess sensitivities on hydrologic and hydraulic conditions with variations on the models inputs and boundary conditions considering various hydrologic and hydraulic scenarios of coincident flooding between local and regional perspectives.
- Consider climate change scenarios on the flooding regime and extent where intensity-frequency-duration data is increased by 10, 20 and 30%.
- Assess the effect of development on the catchment from the perspective of increased flow rates varying the extent of inundation predicted.

E.1.3 Assumptions

The following assumptions have been made in the preparation of the undertaking of the assessment include:

- Uniform catchment characteristics including, Manning roughness within creeks, catchment roughness and impervious percentages were adopted die to the lack of more detailed site development information and the need to undertake the assessment based upon air imagery and information available for catchment viewing from the public spaces.
- Flow attenuation caused by structures, within and adjacent to the Study Area, have been ignored.
- LIDAR information has been adopted for the definition of watercourses within the Study Area as watercourse survey was generally not available.
- 1 dimensional flooding has been adopted as many watercourses as confined due to incision. Extension of the previous 2 dimensional flood modelling along the lower reaches of the Nepean River would be prudent, should the development proceed.
- The operation of offtake structures present within the Nepean River through weir and pipeline systems managed by Sydney Water and/or Water NSW.

E.2 Hydrologic analysis

E.2.1 Terminology

Within this study there are two types of flow modelling. They are defined as:

- Local catchment – rainfall induced flows emanating from within the Study Area
- External (or upstream) flows – these emanate from either further upstream within the Upper Nepean catchment or from tributaries of the Nepean River that have their headwaters outside the Study Area. Examples of external catchments are the Avon, Cordeaux, Cataract and Bargo rivers.

E.2.2 Adopted hydrology model

An assessment on existing catchment hydrology of the Study Area was completed using XP-RAFTS, a non-linear runoff routing model with flow from the external (upstream) catchments extracted from a Nepean River model and added into the XP-RAFTS model. The model was used to simulate the rainfall runoff process and generate both flow hydrographs for use in the hydraulic model.

E.2.3 Terrain and catchment areas

A digital elevation model of the Study Area was created by GHD using LIDAR and contour information from the NSW Department of Lands.

Catchments present within the Study Area were determined through the interrogation of a DEM developed. Using GIS, catchment generation was automated through a process of filling sinks, calculating flow accumulation and stream definition.

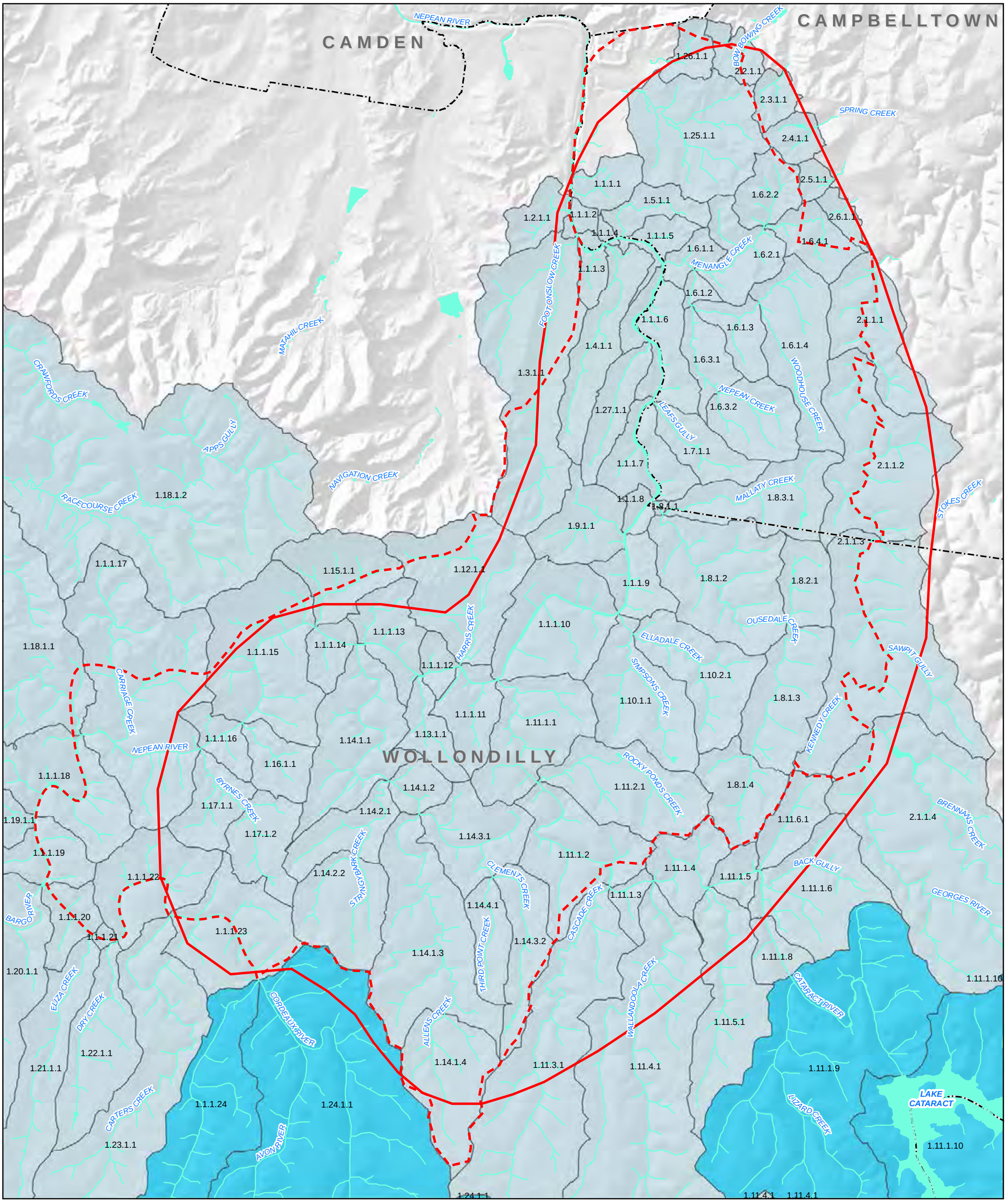
The Study Area was subdivided into approximately 80 catchments with many sub-catchments sized between approximately 500 and 1,000 ha for the major named creeks.

A catchment plan for the Study Area is provided in Figure E-1 with the XP-RAFTS model framework provided in Figure E-2.

Catchment characteristics adopted for use within the XP-RAFTS hydrological model are provided within this Appendix in Section in Section E.8

E.2.4 Flow scenarios for existing land use

The existing land use scenarios considered as part of the hydrological assessment are provided in Table E-1.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- LGA
- Watercourse
- Waterbody
- Modelled Catchments
- Hydrograph Inputs

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Sub Catchment Plan

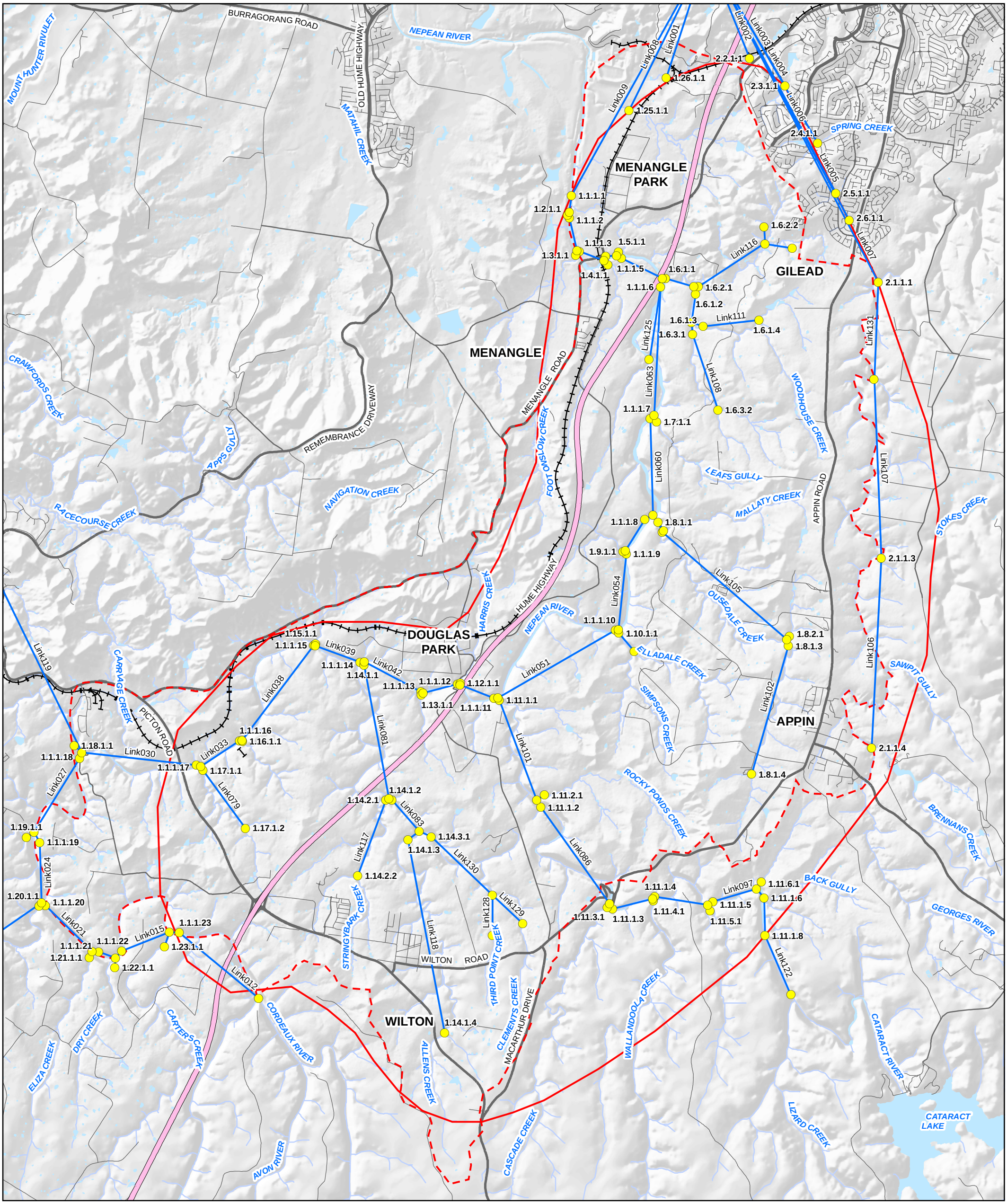
Figure E-1

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_E\2217728_E013_SubCatchments_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Railway
- Motorway
- Primary Road
- Distributor Road
- Local Road
- Watercourse
- Waterbody
- Node
- Linkage

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Hydrology Model Development

Figure E-2

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_E\2217728_E014_HydrologyModel_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

Table E-1 Existing scenarios considered

Defined Events	Locally Modelled Event	Regional Hydrographs
2 Year ARI	2 Year ARI	No hydrograph
20 Year ARI	20 Year ARI	Peak 20 Year ARI
100 Year ARI, 20 Year ARI Nepean River	100 Year ARI	Peak 20 Year ARI
100 Year ARI, 20 Year ARI Nepean River – Climate Change 10%	100 Year ARI + 10% IFD Data	Peak 20 Year ARI
100 Year ARI, 20 Year ARI Nepean River – Climate Change 20%	100 Year ARI + 20% IFD Data	Peak 20 Year ARI
100 Year ARI, 20 Year ARI Nepean River – Climate Change 30%	100 Year ARI + 30% IFD Data	Peak 20 Year ARI
100 Year ARI, 100 Year ARI Nepean River	100 Year ARI	Peak 100 Year ARI
PMP	PMP	Peak 100 Year ARI

E.2.5 Rainfall data – up to 100 year ARI events

The flood assessment for the local events within the Study Area considered events up to the 100 year ARI magnitude using intensity frequency duration (IFD) data for the flooding assessment was based on Bureau of Meteorology 1987 coefficients output from the Camden (Brownlow Hill. Station 68007) rainfall station located at 150.65 degrees east and 34.03 degrees south.

Flows from external to the local catchment were extracted from the RORB model developed for the Nepean River Flood Study.

E.2.6 Rainfall data Probable Maximum Precipitation event

Evaluation of the PMP event was undertaken to understand how a rare rainfall and runoff events could impact the Study Area, identify potential hazards and to identify evacuation routes. The PMP event was determined using both the GSDM (for storm durations up to 6 hours) and the GSAM, (for storm durations greater than 12 hours). Since the predicted peak flow rates as a result of a PMP event, occur in events less than the 6 hour event for local catchment runoff, only use of the GSDM was required to determine PMP results for the local catchment runoff events.

The runoff as a result of a PMP event was estimated for the local catchments within the Study Area was modelled using the XP-RAFTS model.

The Nepean River PMP flow was derived from modelling undertaken as part of the 1995 *Upper Nepean Flood Study*. These hydrographs were applied at two locations, Pheasants Nest Weir (located at the Study Area boundary on the Nepean River) and Cataract River (located on the Cataract River to the east of the Study Area boundary). The Upper Nepean Flood Study (1995) indicated that, typically, from a regional perspective, the 12 hour storm event was critical with PMP flow peaks four to six times that of the 100 year ARI. Since this time to peak flow was

significantly longer than the PMP response from the local catchments there was not a reasonable probability of both the local and external PMP events being co-incident.

E.2.7 Loss rates

Loss rates for the hydrological modelling have been based on the default values derived by Australian Rainfall and Runoff (Institution of Engineers Australia 1987) for eastern New South Wales catchments. It is acknowledged that various loss rates have been adopted within other assessments; however considering the scale of this assessment the loss rates provided in Table E-2 have been adopted.

Table E-2 Adopted loss rates

	Initial Loss	Continuing Loss
Pervious	10 mm	2.5 mm/hour
Impervious	1 mm	0 mm/hour
Probable Maximum Precipitation (all catchment types)	0.1 mm	1.0 mm

Adopted loss rates are generally consistent with the Council nominated values.

E.2.8 Catchment roughness

The catchment roughness adopted as part of this assessment, again consider the broad scale required for the Study Area however they acknowledge the pervious catchments which are likely to be undeveloped, densely vegetated, but also rocky. Impervious areas within the catchment are likely to represent roadways, railways, and urban development.

Table E-3 summarises the range of Manning's n values adopted in the assessment.

Table E-3 Adopted catchment roughness values

	Manning's n values Adopted
Pervious	0.05 – 0.1
Impervious	0.013 - 0.015

Chow (1959) supports the values considered in the assessment with pervious values representing natural streams of varying vegetation density and the impervious values representing a concrete or asphalt surface.

E.2.9 Impervious fraction for existing land uses

The catchment area is largely undeveloped with rural, rural residential, and dense vegetation and limited extractive industries best describing the areas outside the scattered townships. Table E-4 provides the assumed impervious fraction adopted for varying identified land uses within the catchment.

Table E-4 Existing impervious fraction

Land use Categories	Impervious Fraction
Agricultural / Vegetation	0.05
Commercial / Industry	0.9
Residential	0.6

Each of these land use categories were identified from aerial imagery available from Department of Lands. An intercept process was done in GIS between sub-catchments and census data available from Australian Bureau of Statistics (ABS) to determine the proportion that each sub-catchment had of each land use category. The majority of sub-catchments within the Study Area represented an underdeveloped area with average impervious fraction of 0.1.

E.2.10 Regional hydrology - Nepean River

External catchments that contribute to Nepean River outside of the study area were considered on the basis of historical RORB modelling available as part of the Upper Nepean Flood Study.

This model developed in 1995 considered the Nepean river catchments that extend to the south and east of the Study Area. These catchments also include the presence of the Sydney Catchment Authority (SCA) water supply dams, including the Cordeaux, Avon, Nepean and Cataract Dams.

The use of the RORB model results allows for the consideration of the three major dams that exist.

It must be noted that the modelling undertaken in 1995 did not consider the operational influence of other major water supply infrastructure of the SCA that exists around Pheasants Nest and Broughtons Pass with transfer of river water to the Macarthur water quality treatment plant for potable consumption. It is expected that in the event of a 100 year ARI event that the operational of this system would be not influence the flow rates being experienced within the Nepean or Cataract River.

E.2.11 Climate change

Seasonal trends

Recent data available from NARCliM modelling work (http://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/Download-datasets - accessed 19 April 2015) has shown the rainfall projections, as compared to that for 1990 – 2009) shown in Table E-5.

Table E-5 NARClim rainfall projections

Season	2020 - 2039	2060 - 2079
All year	0% – 5%	Northern area in 5% - 10% Southern area 0% – 5%
Summer	0% – 5%	Northern area in 5% - 10% Southern area 0% – 5%
Autumn	Mostly 0% – 5% part of area in 5% - 10%	Eastern and southern area -0% - 5% North western area 5% – 10%
Winter	-5% - 0%	Eastern and southern area -5% - 0 North western area 0% – 5%
Spring	-5% - 0%	Most area - -5% - 0%

Event trends

McLukie (2007) indicates that climate change is not only likely to influence future sea levels but also rainfall intensities. McLukie recommends the assessment of rainfall intensities as part of climate change specific sensitivities. This includes:

- Increase of 10% in peak rainfall volume
- Increase of 20% in peak rainfall volume
- Increase of 30% in peak rainfall volume

As specified within the project brief, the design rainfall IFD data was scaled using the factors on McLuckie (2007) to account for the nominated increases in peak rainfall intensities for different climate projections.

Assuming that the annual number of significant rainfall events remains approximately the same as current, then the two climate projections are relatively consistent.

Tailwater conditions for the model remained unchanged from those for the existing conditions.

E.3 Existing land use hydrologic predictions

The results of the existing land use hydrological modelling for the 2, 20, 100 year ARI events are given in Table E-6 while those for the PMP (PMF) event are provided in Table E-7. Tables E-6 and E-7 both provide the design flow rates and the critical storm duration for each location and each event.

Table E-6 Hydrological results – events to 100 year ARI

Confluences	2 Year ARI – with no Nepean River flow (Critical Storm Event)	20 Year ARI (m^3/s) – with Nepean River 20 year ARI flows (Critical Storm Event)	100 Year ARI (m^3/s) - with Nepean River 20 year ARI flows (Critical Storm Event)
Nepean River at Bargo River	419.9 (720 min)	4628.4 (2160 min)	4749.3 (2160 min)
Nepean River at Myrtle Creek	443.6 (720 min)	4637.4 (2160 min)	4764.1 (2160 min)
Nepean River at Redbank / Stone quarry Creek	660.6 (720 min)	4758 (2160 min)	4941.3 (2160 min)
Nepean River at Allens Creek	701.5 (720 min)	4797 (2880 min)	5004.5 (2880 min)
Nepean River at Cataract River	795.1 (720 min)	5608.6 (2880 min)	5869.7 (2880 min)
Nepean River at Ousedale Creek	809.2 (720 min)	5615.4 (2880 min)	5892.6 (2880 min)
Nepean River at Menangle Creek	812.0 (720 min)	5617.3 (2880 min)	5897.3 (2880 min)
Nepean River at Foot Onslow Creek	813.4 (720 min)	5618.7 (2880 min)	5899.6 (2880 min)

Confluences	2 Year ARI – with no Nepean River flow (Critical Storm Event)	20 Year ARI (m^3/s) – with Nepean River 20 year ARI flows (Critical Storm Event)	100 Year ARI (m^3/s) - with Nepean River 20 year ARI flows (Critical Storm Event)
Byrnes Creek	17.0 (360 min)	38.8 (120 min)	55.9 (120 min)
Allens Creek	93.7 (360 min)	205.2 (360 min)	285.5 (360 min)
Ousedale Creek	92.2 (90 min)	192.6 (90 min)	259.6 (90 min)
Menangle Creek	60.3 (360 min)	139.0 (120 min)	200.3 (120 min)
Foot Onslow Creek	32.6 (360 min)	75.5 (360 min)	109.8 (360 min)
Cataract River Wallandoola Creek	149.9 (360 min)	1168.6 (2160 min)	1200.0 (2160 min)
Cataract River River outfall	204.2 (360 min)	1190.4 (2160 min)	1233.9 (2160 min)
Georges River Study Area outfall	103.1 (720 min)	209.1 (720 min)	277.3 (720 min)
Spring Creek Study Area outfall	12.4 (25 min)	22.8 (90 min)	29.4 (90 min)
Bow Bowing Creek Study Area outfall	6.4 (90 min)	17.7 (90 min)	20.5 (90 min)

Tables E-6 and E-7 clearly demonstrate the difference in the critical storm duration – that for local catchments within the Study Area is typically around 90 to 120 minutes for the 20 and 100 year ARI events while that for the larger upstream catchments is much longer. This difference in critical storm duration confirms that the 100 year ARI event is not realistically represented by a 100 year ARI local catchment superimposed upon the regional 100 year ARI event as the times of peak flow are significantly different.

As expected the critical storm durations of the hydrological predictions are driven by the input hydrographs (critical duration of 36 hrs for Nepean River and 48 hrs for Cataract River).

Many of the local catchments contributing along the Nepean are consumed by the mass of flow within the Nepean River. This is exemplified by the minimal change between the peak 20 year and 100 year ARI flows.

Table E-7 Hydrological results – PMP event

Confluences	PMP Event (m^3/s) – with Nepean River 100 year ARI flows (Critical Storm Event)
Nepean River at Bargo River	4635.6 (5 hrs)
Nepean River at Myrtle Creek	4750.2 (5 hrs)
Nepean River at Redbank / Stone quarry Creek	7753.7 (1 hr)

Confluences	PMP Event (m^3/s) – with Nepean River 100 year ARI flows (Critical Storm Event)
Nepean River at Allens Creek	8018.7 (5 hrs)
Nepean River at Cataract River	9039.2 (5 hrs)
Nepean River at Ousedale Creek	9054 (5 hrs)
Nepean River at Menangle Creek	9056.4 (5 hrs)
Nepean River at Foot Onslow Creek	9057.6 (5 hrs)
Byrnes Creek	262.3 (1 hr)
Allens Creek	1270.6 (1 hr)
Ousedale Creek	1150.2 (1 hr)
Menangle Creek	917.3 (1 hr)
Foot Onslow Creek	570.4 (1 hr)
Cataract River at Wallandoola Creek	2572.4 (1 hr)
Cataract River at River outfall	3040.4 (1 hr)
Georges River at Study Area outfall	1857.7 (4 hrs)
Spring Creek at Study Area outfall	133.4 (1 hr)
Bow Bowing Creek at Study Area outfall	136.2 (1 hr)

The results of the coinciding 100 year ARI Nepean River flow and Study Area localised PMF event (of no greater than a 6 hour duration) have indicated that a slight reduction occurs in a few of the southern model nodes occurred, namely the confluence with the Bargo and Myrtle Creeks. The model scenario considering a regional PMP event indicated a peak flow at these locations of 8659.2 and 8072.4 m^3/s in a six hour event, respectively.

A set of comparative graphs have been provided in Figure E-3 to illustrate the response time of the average local catchment compared with the regional flow of the Nepean River.

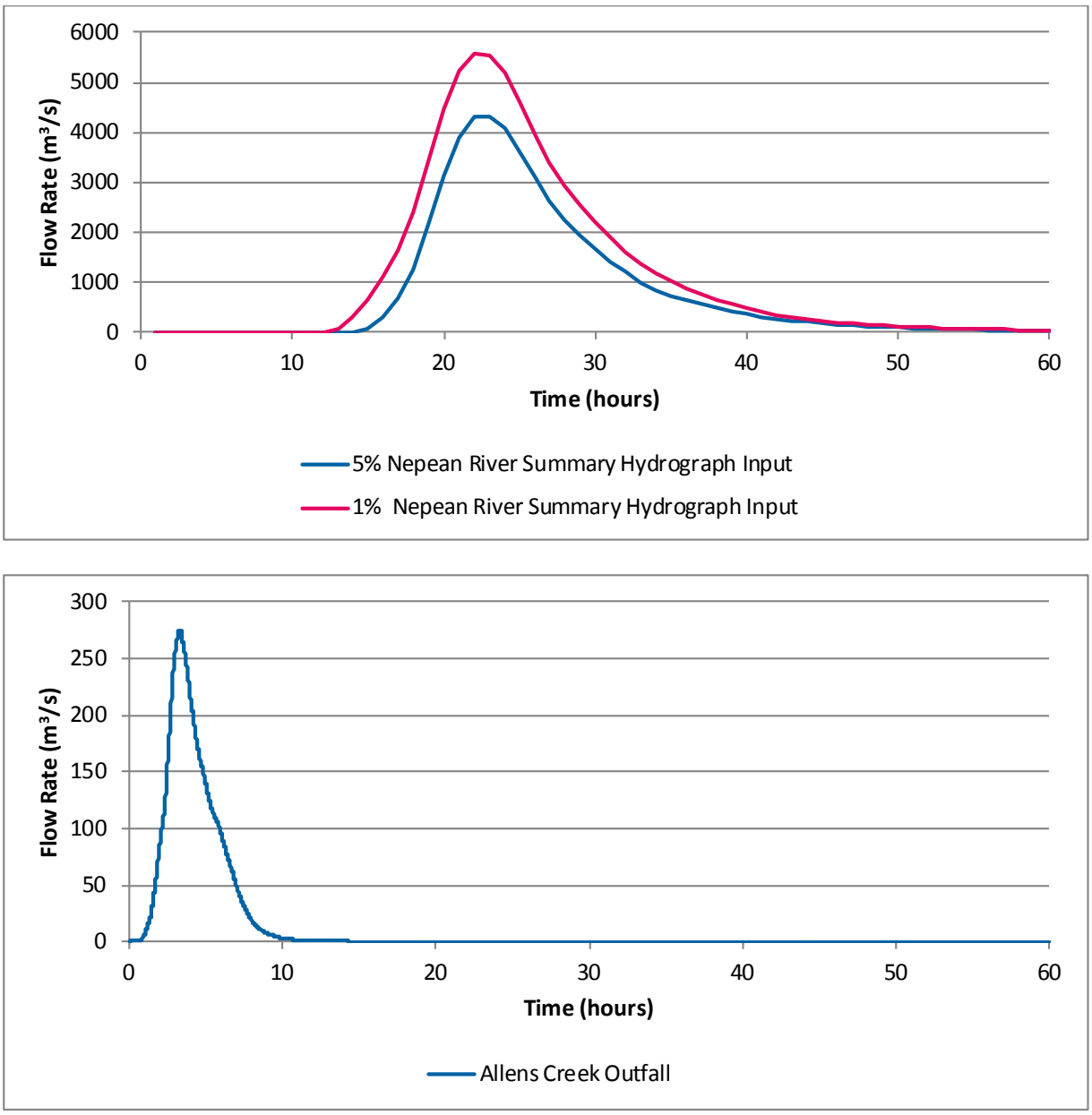


Figure E-3 Comparative hydrograph for local catchment runoff (bottom) versus regional Nepean River flow (top)

E.3.1 Climate change scenarios

The climate change scenario was run for the existing 100 year local runoff and 20 year Nepean River hydrological scenario and for each of recommended McLukie (2007) IFD percentage increases.

Table E-8 summarises the existing hydrologic results for the climate change scenarios.

Table E-8 Climate change hydrological model results

Confluences	100 Year ARI (m^3/s) (Critical Storm Event)		
	+ 10 % IFD	+ 20% IFD	+ 30% IFD
Nepean River at Bargo River	4800.7	4851.7	4899.5
Nepean River at Myrtle Creek	4817.3	4870.2	4919.8
Nepean River at Redbank / Stone quarry Creek	5015.4	5088.6	5158.2
Nepean River at Allens Creek	5088.5	5170.4	5248
Nepean River at Cataract River	5997.7	6128.9	6267.1
Nepean River at Ousedale Creek	6023.2	6165.6	6308.8
Nepean River at Menangle Creek	6028.6	6173.6	6318.1
Nepean River at Foot Onslow Creek	6031.5	6177.8	6323.1
Cataract River at Wallandoola Creek	1212	1224.1	1236.5
Georges River Study Area outfall	310.5	342.9	376.6
Spring Creek Study Area outfall	32.8	36.4	39.9
Bow Bowing Creek Study Area outfall	23.6	26.7	29.8

The results of Table E-8 indicate an average variation of peak flow rates for the selected results of up to 14%. Greater influence was shown in the smaller, independent catchments of the model such as Bow Bowing Creek which indicated a 45% increase in peak flow rates as a result of the 30% increase in standard IFD data.

E.4 Proposed development hydrologic predictions

E.4.1 Changes in catchment properties

The assessment of hydrological response to development of the Study Area was assessed through the modification of broad scale impervious area. To determine the amount of impervious area likely to occur as a result of proposed development within the Study Area, required, the assessment of land that did not meet the developable criteria was filtered out from the study area. The criteria considered such areas as existing vegetation, including ecologically endangered communities (EEC's), protected areas such as the SCA special areas, riparian protection zones (RPZ) and areas of steep terrain.

The process of filtering out areas not appropriate left the available developable land within each of the defined sub-catchments. On this available developable land, an assumed impervious fraction of 0.6 was applied.

The proposed development extent considered as part of the hydrologic model is shown in Figure E-4. Each sub-catchments potential developable area is summarised in Section E-8.

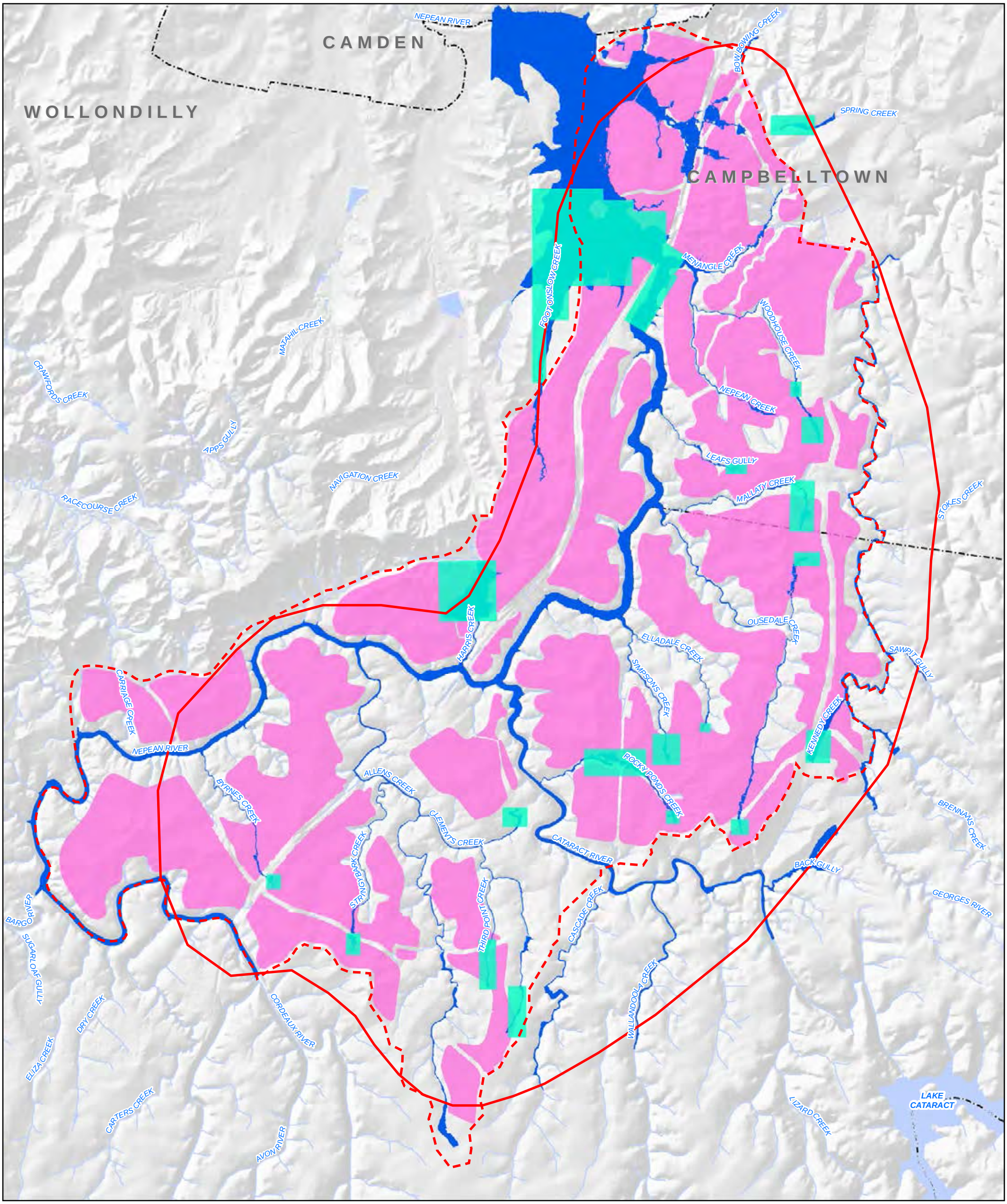
Potential development induced increases in peak flow within the watercourses of the Study Area, are unlikely to eventuate as predicted as part of the development scenario predicted within this assessment. This is due to the fact of the adoption of detention basins, either regionally or local, that will be required in any potential development within the Study Area to mitigate development peak flows back to predevelopment.

The assessment of hydrological response to development of the Study Area was assessed through the modification of broad scale impervious area. To determine the amount of impervious area likely to occur as a result of proposed development within the Study Area, required, the assessment of land that did not meet the developable criteria was filtered out from the study area. The criteria considered such areas as existing vegetation, including ecologically endangered communities (EEC's), protected areas such as the SCA special areas, riparian protection zones (RPZ) and areas of steep terrain.

The process of filtering out areas not appropriate left the available developable land within each of the defined sub-catchments. On this available developable land, an assumed impervious fraction of 0.6 was applied.

The proposed development extent considered as part of the hydrologic model is shown in Figure E-4.

Potential development induced increases in peak flow within the watercourses of the Study Area, are unlikely to eventuate as predicted as part of the development scenario predicted within this assessment. This is due to the fact of the adoption of detention basins, either regionally or local, that will be required in any potential development within the Study Area to mitigate development peak flows back to predevelopment.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- LGA
- Watercourse
- Waterbody
- Potential Waterway Blockage
- DevelopmentArea
- Flood Extent

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Potential Areas of Waterway Blockage

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Figure E-4

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_E\2217728_E019_PotentialWaterwayBlocks_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

E.4.2 Consideration of watercourse blockages as a result of development

With the development of the catchment considered, the existing hydraulics model needed modification to consider potential development that may impinge on the existing flood extents.

As the proposed development extents will not be able to remove any trees or impact on EEC communities that are prevalent within the Study Area, the consideration of water blockage as a result of development is isolated to a small area typically on specific watercourses or within the upper reaches.

The results of the existing hydraulic assessment of the Study Area indicated that the majority of watercourses have flood waters that are contained within the incised channels typical of the Study Area; however there are some areas that this is not the case and these areas correspond with sparse vegetation as well.

As part of this assessment potential watercourse blockage has not been assessed for potential afflux impact created by such blockage, however we have identified the areas that may be subject to future sensitivities. These areas of potential watercourse blockage are shown on Figure E-4.

Given the need to limit development outside of RPZ's the comparison between the predicted 100 year ARI flood extent and RPZ's need to be considered in the areas where vegetation is not a limiting factor. When this comparison was completed it was clear that there were no areas where the consideration of watercourse blockage required consideration.

E.5 Proposed development - development hydrologic predictions

The results for modelling of development considerations on the hydrological model is presented in Table E-9 for the same reporting locations as the existing conditions for events up to the 100 year ARI magnitide.

Table E-9 Developed local flooding results – 100 year ARI local / Nepean River 20 year ARI

Confluences	2 Year ARI (m^3/s) – with no Nepean River flow (Critical Storm Event)	20 Year ARI (m^3/s) – with Nepean River 20 year ARI flows (Critical Storm Event)	100 Year ARI (m^3/s) - with Nepean River 20 year ARI flows (Critical Storm Event)
Nepean River at Bargo River	422.2 (720 min)	4627.8 (2160 min)	4748.8 (2160 min)
Nepean River at Myrtle Creek	446.0 (720 min)	4636.9 (2160 min)	4763.6 (2160 min)
Nepean River at Redbank / Stone quarry Creek	663.1 (720 min)	4757.5 (2160 min)	4940.7 (2160 min)
Nepean River at Allens Creek	700.9 (720 min)	4804.4 (2880 min)	5011.2 (2880 min)
Nepean River at Cataract River	816.8 (720 min)	5614.8 (2880 min)	5884.2 (2880 min)
Nepean River at	827.8 (720 min)	5623.8 (2880 min)	5904.7 (2880 min)

Confluences	2 Year ARI (m^3/s) – with no Nepean River flow (Critical Storm Event)	20 Year ARI (m^3/s) – with Nepean River 20 year ARI flows (Critical Storm Event)	100 Year ARI (m^3/s) - with Nepean River 20 year ARI flows (Critical Storm Event)
Ousedale Creek			
Nepean River at Menangle Creek	829.1 (720 min)	5628.9 (2880 min)	5913.3 (2880 min)
Nepean River at Foot Onslow Creek	829.8 (720 min)	5632.9 (2880 min)	5918.3 (2880 min)
Byrnes Creek	40.3 (360 min)	78.5 (120 min)	103.2 (120 min)
Allens Creek	283.1 (360 min)	376.8 (360 min)	376.8 (360 min)
Ousedale Creek	192.6 (90 min)	259.7 (90 min)	259.7 (90 min)
Menangle Creek	231.9 (360 min)	307.3 (120 min)	307.3 (120 min)
Foot Onslow Creek	67.6 (360 min)	131.0 (360 min)	171.7 (360 min)
Cataract River Wallandoola Creek	149.9 (360 min)	1168.6 (2160 min)	1200.0 (2160 min)
Cataract River River outfall	203.7 (360 min)	1192.1 (2160 min)	1236.0 (2160 min)
Georges River Study Area outfall	112.5 (720 min)	211.6 (720 min)	278.9 (720 min)
Spring Creek Study Area outfall	13.1 (25 min)	23.9 (90 min)	30.6 (90 min)
Bow Bowing Creek Study Area outfall	11.6 (90 min)	22.8 (90 min)	30.0 (90 min)

The results presented in Table E-9 indicate similar critical storm durations to that of the existing with both a positive and negative variance in peak flows. Increases in flow rates were experienced in model results as the Nepean transverse further through the Study Area. Generally increases in flow rates within the Nepean were noted most at the Cataract confluence, with design rates compared with existing becoming less significant towards Menangle. This is due to much of the faster responding developed areas being lost within the longer duration, more significant flows.

The likely developed conditions will require detention basins to be considered as part water management. The use of detention basins to detain post development flows back to predevelopment will most likely increase the catchment response time. This has not been assessed as part of this assessment but should be considered specifically in the development of each area.

The results of the hydrologic assessment on a developed catchment for the PMP event has been summarised in Table E-10.

Table E-10 Developed local flooding results – PMP local / Nepean River 100 year ARI

Confluences	PMP Event (m^3/s) – with Nepean River 100 year ARI flows (Critical Storm Duration)
Nepean River at Bargo River	4631.8 (5 hrs)
Nepean River at Myrtle Creek	4746.1 (5 hrs)
Nepean River at Redbank / Stone quarry Creek	7751.2 (1 hr)
Nepean River at Allens Creek	7925.4 (5 hrs)
Nepean River at Cataract River	8945.7 (5 hrs)
Nepean River at Ousedale Creek	8952.1 (5 hrs)
Nepean River at Menangle Creek	8953.1 (5 hrs)
Nepean River at Foot Onslow Creek	8953.7 (5 hrs)
Byrnes Creek	305.7 (1 hr)
Allens Creek	1361.5 (1 hr)
Ousedale Creek	1150.2 (1 hr)
Menangle Creek	1022.9 (1 hr)
Foot Onslow Creek	583.7 (1 hr)
Cataract River at Wallandoola	2572.3 (1 hr)
Cataract River River outfall	3017.2 (1 hr)
Georges River Study Area outfall	1848.1 (5 hrs)
Spring Creek Study Area outfall	143.1 (1 hr)
Bow Bowing Creek Study Area outfall	139.7 (1 hr)

The results of Table E-10 further indicate the effects of partial development of the catchment actually resulting in an overall reduction in peak runoff rates. This was shown in results taken at the Nepean River for Allens Creek, Cataract River, Ousedale Creek, Menangle Creek, Foot Onslow Creek and Georges River

E.6 Hydraulic analysis method

E.6.1 Model

The HEC-RAS hydraulic model was adopted for use in this analysis where flows could realistically be represented as being one dimensions.

E.6.2 Extent of hydraulic analysis

Flood levels have been predicted for the main watercourses within the study area. The extent of the assessment was determined based upon the stream order and the contributing catchment areas.

Results from the hydraulic analysis are presented as follows:

- Appendix F – Flood level mapping
- Appendix G – Flood velocity mapping
- Appendix H – Flood Hazard mapping
- Appendix I – Flood level classification
- Appendix J – Flood Level profiles

E.6.3 Terminology

The hydraulic models were labelled using the watercourse name and, for the longer watercourses, a numeric segment number.

Figure E-5 shows the watercourse labelling and locations of the various watercourse segments.

E.6.4 Watercourse cross sections

Cross sections were extracted generally at a spacing of approximately 50 m with additional cross sections extracted near structures to provide an enhances watercourse definition.

E.6.5 Existing hydraulics

To determine flood regimes within the Study Area a hydraulic model was established for existing conditions of selected watercourses. Watercourses were selected on the basis of significance (being named), order and catchment area contributing to its watershed. A list of watercourses that were assessed for hydraulic condition is provided in Appendix F.

Hydraulic predictions were determined through the development of a one dimensional HEC-RAS model. HEC-RAS is a steady state model that allows for hydraulic calculations to be made on a full network of natural and constructed channels capable of modelling subcritical, supercritical and mixed flow regimes. The model considers both hydraulic through energy and momentum equations depending model conditions.

E.6.6 Scenarios considered and boundary conditions

Boundary conditions adopted for the hydraulic modelling considered both localised and regional considerations.

E.6.7 Adopted hydraulic model conditions

Localised boundary conditions

All assessed watercourses considered an up and downstream boundary condition. A normal depth boundary condition was considered equal to the average bed gradient of each corresponding creek.

LEGEND

- Allens Seg 1
- Allens Seg 2
- Allens Seg 3
- Back
- Bow Bowing
- Brennans
- Byrnes
- Cascade
- Cataract Seg 1
- Cataract Seg 2
- Cataract Seg 3
- Cataract Seg 4
- Cataract Seg 5
- Clements Seg 1
- Clements Seg 2
- Elladale Seg 1
- Elladale Seg 2
- Foot Onslow
- Georges Seg 1
- Georges Seg 2
- Georges Seg 3
- Georges Seg 4
- Harris
- Kennedy
- Leaps
- Lily Ponds
- Mallaty
- Menangle Seg 1
- Menangle Seg 2
- Nepean Seg 1
- Nepean Seg 10
- Nepean Seg 2
- Nepean Seg 3
- Nepean Seg 4
- Nepean Seg 5
- Nepean Seg 6
- Nepean Seg 7
- Nepean Seg 8
- Nepean Seg 9
- NepeanCk Seg 1
- NepeanCk Seg 2
- Ousedale Seg 1
- Ousedale Seg 2
- Ousedale Seg 3
- Rocky Ponds
- Sandy Seg 1
- Sandy Seg 2
- Sawpit
- Simpsons
- Spring
- Stringybark
- Third Point
- Wallandoola
- Woodhouse

MENANGLE PARK
MENANGLE
GILEAD
APPIN
DOUGLAS PARK
WILTON
CATARACT LAKE
MENANGLE ROAD
APPIN ROAD
WILTON ROAD
REMEMBRANCE DRIVEWAY
PICTON ROAD
HUME HIGHWAY
MACARTHUR DRIVE

LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Railway
- Motorway
- Primary Road
- Distributor Road
- Local Road
- Watercourse
- Waterbody

Paper Size A3

0 0.4 0.8 1.6 2.4 3.2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Hydraulic Model Plan and Sections

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Figure E-5

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_E\2217728_E017_Hydraulic_ModelProfiles_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015). Created by: gmcdiarmid, tmorton

Regional boundary conditions

Historically flood assessments have indicated that the Nepean River is likely to be in flood in line with local catchments. As part of this assessment the consideration of these concurrent flood conditions have been considered but also instances where flooding does not happen concurrently. The GHD flood study for the Menangle development considered a 5 year, 20 year and 100 year Nepean River flood coinciding with a local 2 year, 100 year and PMP events. To consider regional influences, the hydrologic and hydraulic model considers various inflow hydrographs and downstream flooding conditions for the Nepean River within the hydraulic modelling undertaken.

A summary of the scenarios considered for the hydraulic modelling scenarios undertaken are provided in Table E-11.

Table E-11 Existing Hydraulics scenario

Scenario	Locally Modelled Event	Regional Hydrographs	Downstream Boundary Condition
2 Year ARI	2 Year ARI	No hydrographs	5 Year ARI Nepean River (consistent with GHD (2008))
20 Year ARI	20 Year ARI	Peak 20 Year ARI	20 Year ARI Nepean River
100 Year ARI, 20 Year ARI Nepean River	100 Year ARI	Peak 20 Year ARI	20 Year ARI Nepean River (consistent with GHD (2008))
100 Year ARI, 100 Year ARI Nepean River	100 Year ARI	Peak 100 Year ARI	100 Year ARI Nepean River
PMP Event	PMP Event	Peak 100 Year ARI	100 Year ARI Nepean River
PMP, PMP Nepean River	PMP Event	PMP Event Nepean River	PMP Event

Downstream boundary conditions

The downstream boundary flood heights corresponding to each of the scenarios is outlined in Table E-12 and discussed in the following section.

Nepean at Menangle Park is a low gradient flood plain environment that was assessed by GHD in 2008 for development. The Nepean River and associated tributaries in this location were modelled in Tuflow for the 5, 20, 100 and PMF events. For this assessment, given the adoption of a one dimensional model, the incorporation of two dimensional flooding results (taken from the existing scenario) will be considered for sections downstream of the Foots Onslow Creek and Nepean River confluence.

Table E-12 presents the adopted downstream boundary conditions. The downstream boundary conditions are the result from the incorporation of the two dimensional flooding outcomes in Menangle (GHD; 2008).

Table E-12 Downstream boundary flood levels (GHD; 2008)

Scenario	Event Considered	Flood Level (mAHD)
2 Year	5 YR at Nepean River and Foot Onslow Creek, Menangle	73.5
20 Year and 100 Year	20 YR at Nepean River and Foot Onslow Creek, Menangle	75.8
100 Year and PMP	100 YR at Nepean River and Foot Onslow Creek, Menangle	77.3
PMP	PMP at Nepean River and Foot Onslow Creek, Menangle	81.5

Modelled flow regime

Within HEC-RAS, a mixed flow regime was used considering using a normal depth on up and downstream boundaries. A mixed flow regime is the most appropriate model run in instances where there are known sections of watercourse that are likely to experience supercritical flow regimes. Within the Study Area, the presence of online weir structures is likely to create sections of supercritical flow as flow passes over the weir.

Sections of watercourses that form tributaries of the Nepean River, may experience supercritical flows also as they proceed from elevated areas.

Bank stations

In the development of the HEC-RAS model, bank stations are typically used to represent the channel, left and right overbank areas. For this assessment bank stations have been developed to identify the typical watercourse present within each section. Typical initial estimates of the bank station width for the major watercourses assessed are presented in Table E-13. In local areas where the predicted flow went outside these initial estimates of the bank then the stations were reloated further from the watercourse centreline.

Table E-13 Bank stations

Creek	Bank Stations for Creek Channel
Georges River	15 metres
Cataract River	20 metres
Nepean River	45 to 60 metres

Automated cross section generation

Model cross sections were automatically generated in a first pass for the study area. This was improved through manual editing to form the final cross section geometries. Aspects that were considered in the editing of cross sections included:

- Presence of watercourse infrastructure (visible in aerial imagery).
- No overlapping sections.
- Sections parallel to watercourse infrastructure.

Typically cross sections were at intervals of between 50 to 100 metres.

Channel roughness / Manning's n definition

There are three predominate land uses were watercourses pass through for assessed watercourses. These were:

- Pastoral/cleared land.
- Heavy vegetation.
- Urban areas.

Typically the main watercourses within the Study Area (Nepean, Cataract and Georges Rivers) are bed rock defined incised channels. On this basis many of the watercourses have a well-defined channel typical of a roughness of 0.05. Outside of the channel, watercourses are extensively lined with dense riparian vegetation. It has been considered that this dense riparian vegetation would represent a Manning's n value of typically 0.1. Manning's n has been based on typical values defined by Chow (1959).

Online weirs / storages

Given the positioning of Pheasants Nest and Maldon Weir is there any attenuation or flooding behind these weirs that may cause an impediment to flooding. From further review of available elevation data, it is clear that the configuration of the Pheasants Nest Weir is a weir structure and a spillway to the south west of the weir. At present, this assessment has considered only the geometry of the weir as it is represented in the elevation model developed.

Table E-14 summarises on line structures present within the Study Area. Figure A-1 presents the location of the main stream gauging sites within the Study Area.

Table E-14 Nepean River stream gauging sites (Department Land & Water Conservation 1995)

Station ID / Station No.	Watercourse	Purpose	Catchment (km^2)	Structure Level (mAHD)	Gauge Zero (mAHD)
Pheasants Nest / 212203	Nepean River	Offtake / Diversion Weir (SCA Asset contributing to Nepean Tunnel and Macarthur Water Filtration Plant)	686	130	133.518
Maldon Weir / 212208	Nepean River	Flow Gauge – Previously used as an offtake /diversion weir.	865	90	14.950 (assumed datum)
Broughtons Pass / 212230	Cataract River	Offtake / Diversion Weir (SCA Asset contributing to Nepean Tunnel and Macarthur Water Filtration Plant)	200	130	133.609
Jordans Pass / 212231	Cataract River	Flow Gauge	160	160	NA
Douglas Park Weir /	Harris Creek	Flow Gauge	NA	75	8.565 (assumed

Station ID / Station No.	Watercourse	Purpose	Catchment (km^2)	Structure Level (mAHD)	Gauge Zero (mAHD)
212235					datum)
Menangle Weir / 212238	Nepean River	Flow Gauge	1220	70	60.609

Flood hazard

Flood hazard was determined for the existing and proposed conditions in accordance with the NSW Floodplain Development Manual. Since the majority of floodwaters are deeper than 1 metre, the majority of the assessed watercourses are categorised as high hazard.

The definition of hazard levels are summarised in Table E-15.

Table E-15 Definition of flood hazard (Australian Emergency Management Institute 2014)

Hazard	Depth Velocity Product	Depth (m)	Velocity (m/s)
H1	Less than or equal to 0.3	0.3	2.0
H2	Less than or equal to 0.6	0.5	2.0
H3	Less than or equal to 0.6	1.2	2.0
H4	Less than or equal to 1.0	2.0	2.0
H5	Less than or equal to 4.0	4.0	4.0
H6	Greater than 4.0	Greater than 4.0	Greater than 4.0

E.6.8 Flood category

Flood Category, that is, the categorisation of floodway, flood storage and flood fringe lands has been assessed on the basis of the outcomes provided in Table E-16.

Table E-16 Flood categorisation

Category	100 year ARI Conditions	PMP Conditions
Floodway	velocity x depth >0.3 or velocity > 4 m/s	velocity x depth >1.0 or velocity > 4 m/s
Flood Storage	velocity x depth <0.3 and depth >0.5 m	velocity x depth <1.0 and depth >1.0 m
Flood Fringe	velocity x depth <0.3 and depth <0.5 m	velocity x depth <1.0 and depth <1.0 m

Due to the nature of the topography of the Study Area and the one dimensional modelling it is unlikely that many areas will be categorised as flood storage and the majority of watercourses being floodway.

E.6.9 Existing hydraulics

The results from the hydrological modelling were incorporated into the hydraulic modelling of watercourses within the Nepean River, Georges River, Bow Bowing Creek and Spring Creek

catchments. The results of the hydraulic modelling have been presented in various formats to provide an adequate level of understanding for planning future developments. The following outcomes have been prepared from the hydraulic modelling undertaken:

Flood levels

The flood levels predicted from the hydraulic modelling have been summarised for selected river stations corresponding to flow locations have been provided in Table E-17 for events up to the 100 year ARI magnitude and Table E-18 for the PMF event. A full set of results have been provided in Appendix F with detailed flood profiles contained within Appendix J.

Table E-17 Hydraulic results – events up to 100 year ARI

Confluences	River Segment (Station)	2 Year ARI – with no Nepean River flow (mAHD) (Average Velocity)	20 Year ARI – with Nepean River 20 year ARI flows (mAHD) (Average Velocity)	100 Year ARI - with Nepean River 20 year ARI flows (mAHD) (Average Velocity)
Nepean River at Bargo River	Segment 1 (7015.94)	103.1 (0.1 m/s)	113.2 (1.1 m/s)	113.4 (1.0 m/s)
Nepean River at Myrtle Creek	Segment 1 (5593.51)	96.2 (1.2 m/s)	108.1 (2.2 m/s)	108.3 (2.2 m/s)
Nepean River at Redbank / Stone quarry Creek	Segment 1 (2662.05)	88.1 (0.4 m/s)	100.3 (1.0 m/s)	100.6 (1.0 m/s)
Nepean River at Allens Creek	Segment 3 (2217.33)	74.9 (0.7 m/s)	86.5 (1.5 m/s)	87.0 (1.5 m/s)
Nepean River at Cataract River	Segment 5 (3402.34)	74.3 (0.6 m/s)	84.3 (1.9 m/s)	84.7 (1.9 m/s)
Nepean River at Ousedale Creek	Segment 7 (2249.18)	73.9 (0.7 m/s)	80.9 (2.4 m/s)	81.2 (2.5 m/s)
Nepean River at Menangle Creek	Segment 2 (2159.32)	73.6 (0.5 m/s)	77.8 (2.5 m/s)	78.0 (2.6 m/s)
Nepean River at Foot Onslow Creek	Segment 10 (3363.52)	73.5 (0.7 m/s)	75.8 (1.0 m/s)	75.8 (1.1 m/s)
Cataract River at Wallandoola Creek	Segment 3 (199.74)	140.6 (2.4 m/s)	142.1 (9.6 m/s)	142.2 (9.6 m/s)
Georges River	Segment 3 (1700)	215.4 (1.3 m/s)	216.4 (1.5 m/s)	217.0 (1.6 m/s)
Georges River	Segment 4 (3050)	139.7 (2.7 m/s)	140.2 (3.1 m/s)	140.8 (2.8 m/s)
Spring Creek	(1150)	141.2 (3.2 m/s)	141.4 (3.8 m/s)	141.4 (4.0 m/s)
Spring Creek	(400)	131.5 (0.3 m/s)	131.7 (0.4 m/s)	131.7 (0.5 m/s)
Bow Bowing Creek	(550.6)	96.7 (1.2 m/s)	96.8 (1.5 m/s)	96.8 (1.7 m/s)
Bow Bowing Creek	(90.54)	90.13 (0.3 m/s)	90.4 (0.4 m/s)	90.5 (0.5 m/s)

From the results provided in Table E-17 the influence of the regional Nepean River flows is significant as is shown in the comparison of flow rates and levels from the 2 year ARI and the 20 year ARI, with an average of 11.5 metres being the difference between the 2 and 20 year ARI events within the upper sections of Nepean River. Furthermore, the difference between the 20 and 100 year ARI flood levels suggests that the localised catchment contribution to the Nepean River is insignificant when compared with the influence of regional flows, supported by an average with a depth change between the two events of 0.3 metres.

Considering a regional Nepean River flow of 100 year ARI and a 100 year ARI tail water condition, the increase in water surface level compared with the 20 year ARI increases to 2.5 metres. The tailwater conditions of the Nepean River effects most significantly the flooding levels of Foot Onslow Creek, Menangle Creek and areas fronting the most downstream segment of the Nepean River.

The watercourses outside of the Nepean River presented hydraulic conditions that varied depending on watercourse grade and bank conditions. Georges River indicated similar characteristics to that of the Nepean River with an incised channel in rock making up the majority of the Georges River.

Bow Bowing Creek indicated results that suggest a wide undefined channel with only minor increases in water level between design events assessed, in the order of 100 mm between the 2 and the 100 year ARI. Spring Creek in comparison indicated a higher velocity, man-made style channel where an existing dam influenced the results of the hydraulic modelling where the dam represented a wide watercourse into a narrow spillway. The predicted change in water level between the 2 and 100 year ARI events was in the order of 0.2 to 0.3 metres.

Table E-18 Hydraulics results - PMF

Confluences	River Segment (Station)	PMP Event – with Nepean River 100 year ARI flows (mAHD) (Average Velocity)
Nepean River at Bargo River	Segment 1 (7015.94)	113.5 (0.3 m/s)
Nepean River at Myrtle Creek	Segment 1 (5593.51)	109.3 (2.0 m/s)
Nepean River at Redbank / Stone quarry Creek	Segment 1 (2662.05)	105.6 (0.8 m/s)
Nepean River at Allens Creek	Segment 3 (2217.33)	92.1 (1.8 m/s)
Nepean River at Cataract River	Segment 5 (3402.34)	89.1 (2.3 m/s)
Nepean River at Ousedale Creek	Segment 7 (2249.18)	84.7 (3.1 m/s)
Nepean River at Menangle Creek	Segment 2 (2159.32)	80.2 (3.4 m/s)
Nepean River at Foot Onslow Creek	(3363.52)	77.3 (1.3 m/s)
Cataract River at Wallandoola Creek	(199.74)	143.8 (12.7 m/s)
Georges River	Segment 3 (1700)	223.6 (2.0 m/s)
Georges River	Segment 4 (3050)	147.3 (3.0 m/s)

Confluences	River Segment (Station)	PMP Event – with Nepean River 100 year ARI flows (mAHD) (Average Velocity)
Spring Creek	(1150)	142.3 (4.6 m/s)
Spring Creek	(400)	132.6 (1.2 m/s)
Bow Bowing Creek	(550.6)	97.5 (2.7 m/s)
Bow Bowing Creek	(90.54)	91.8 (1.2 m/s)

The results in Table E-18 indicate flood levels for the PMP events associated with a 100 year regional Nepean River flow and a 100 year tailwater condition. In the Nepean River, the water levels are on average 4.0 metres above the 100 year ARI event. Despite this the majority of the Nepean River remains contained within the gorge style watercourse that is the Nepean River.

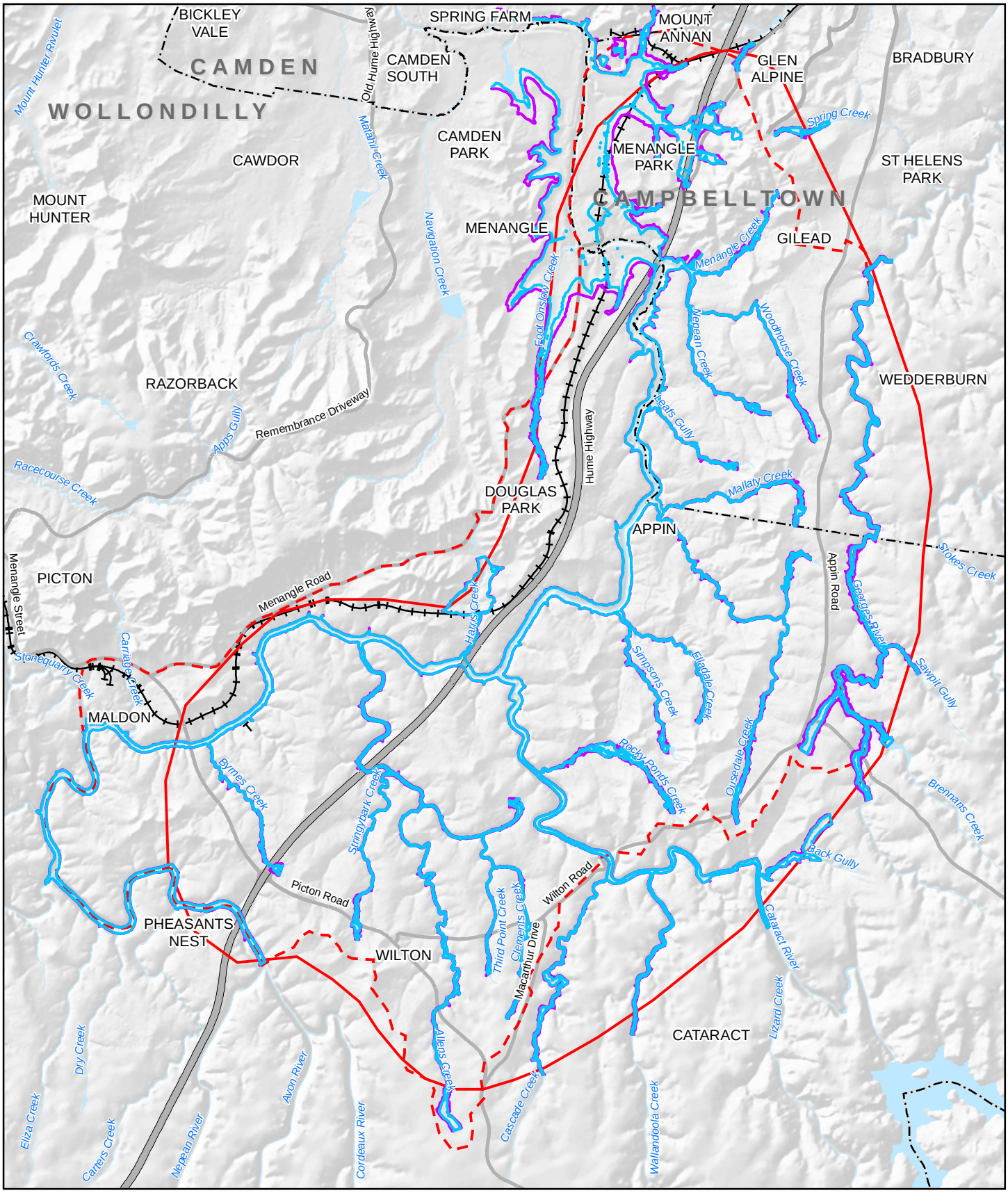
Sensitivities in the boundary conditions adopted for the PMP with 100 year inflows and the PMP with PMP inflows only influenced the furthest upstream and downstream areas of the modelling. Within the Nepean River, flood levels were influence at Bargo River and Myrtle Creek confluences, with only minor increases through the Nepean River gradually increasing northward, and a depth increase of between 2 to 4 metres at Menangle and Foot Onslow Creeks respectively.

Georges River has two areas that have responded differently in the hydraulic conditions of a PMP event. The upper section of Georges River (above segment 4 river station 9249.55) indicated a wider flood profile typically in the order of 200 metres wide. The upper section indicated a number of small tributary confluences, represented by a number of extended flood widths. In comparison, the lower segments of the Georges River indicated a more incised channel and hence a narrower flood profile with little difference between the flood events assessed. The flow width through the lower section was predicted to be in the order of 40 to 50 metres and uniform. Typically the PMP event predicted flood levels that were 7.0 metres above the 100 year ARI.

On Bow Bowing Creek the PMP event varied from the 100 year ARI from 0.7 to 1.3 metres in water level with a relatively quicker velocity at double the 100 year ARI flow. Flow widths in the PMP event were predicted at between 50 to 70 metres.

The results of the PMP at Spring Creek indicated a flood level that was on average 0.9 metres above the 100 year. Due to the existing development surrounding Spring Creek the confinement of the PMP event is similar to that of the 2 year ARI. Hydraulic predictions are also influenced by the dam present along the creek, of which in the PMP event indicated overtopping of the structure via an assumed overflow structure positioned on the dam's southern side. PMP flood widths were estimated at 160 metres in the upstream and 90 metres in the downstream sections.

A comparison of the 100 year ARI and PMF flood extents is provided in Figure E6.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway
- 100 year flood extent
- PMF extent

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Comparison of PMF and 100 year Flood Extents

Figure E-6

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_E\2217728_E020_100yrPMF_Extents_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012. Created by: tmorton

Flooded area

Table E-19 indicates the approximate flooded areas predicted within the Study Area for different events assessed.

Table E-19 Existing flood areas

	2 year (ha)	20 year (ha)	100 year / 20 year (ha)	PMP Event / 100 year (ha)
Nepean River Catchment	791	1,131	1,164	1,382
Georges River, Bow Bowing and Spring Creek	65	83	91	172

The results indicated in Table E-19 show flooded areas of the Nepean River catchment are similar between the 20 year ARI and 100 year ARI events. This suggests that the localised 100 year event is largely still contained within the channelised network of existing watercourses.

Considering variations in the tailwater and inflow boundary conditions of the Nepean River 100 year and PMP events, predicted flooded area may increase to 1,238 ha and 1,460 ha respectively, with a majority of this increased area of inundation occurring in the northern extents of the Nepean River.

Climate change

The assessment of climate change flows were considered in the hydraulic modelling of the assessed watercourses within the Study Area. Generally the results of the assessment indicated minimal change in flood level as a result of the adoption of climate change flow rates within all watercourses.

Table E-20 indicates the results of the assessment compared with the existing results for the confluence of Cataract River and Wallandoola Creek.

Table E-20 Climate change hydraulic results

Scenario	Existing	Climate Change Scenarios		
	100 Year ARI	**+10%**	**+20%**	**+30%**
Water Level (m AHD)	142.2	142.2	142.2	142.3
Velocity (m/s)	9.6	9.5	9.5	9.6
Water Level Variance (m AHD)	0	0	0	+0.1

As the results of Table E-20 have indicated the sensitivity of hydraulic results from adopting an increase in rainfall intensities up to 30% is only likely to result in water levels increasing by in the order of 100 mmExisting Hazard

The existing conditions have been defined for flood hazard and category for the 100 year and PMP events. The results have been presented in Appendix H.

The results for the existing conditions indicate for flood hazard:

- Majority of watercourses are classed as high hazard (H6) (not suitable for people, vehicles or buildings) in a 100 year ARI with the exception of Byrnes Creek, Stringybark Creek, Third Point Creek, Cascade Creek, Rocky Ponds Creek, Elladale Creek, Mallaty Creek, Nepean Creek, Woodhouse Creek, Harris Creek, Spring Creek and Bow Bowing Creek.
- Those watercourses not high hazard are typically a hazard rating no less than H4 (unsafe for people and vehicles) where hazard is typically a function of watercourse grade and flow.
- PMP event indicates that the majority of watercourses are high hazard.
- In both the 100 year ARI and PMP event, no hazard ramp is predicted at the edges of the watercourse for Nepean and Cataract River which is a function of the slopes present on these watercourses.

Flood category

Flood category was mapped for the Study Area and indicated the following results:

- Most of the assessed watercourse area was classified in the floodway category
- There was only relatively small areas where the depth was sufficiently small or the velocity sufficiently low to be classified as other than floodway

Limitations of modelling results

The following limitations were identified as a result of modelling the existing hydraulics scenarios assessed. The following outcomes are recommended for further refinement in future hydraulic assessments.

- Only select watercourses have been hydraulically assessed as part of this Project. Future development of the Study Area should be considered on a case by case basis with regarding the level and detail of the hydraulic assessment to be considered.
- Assessment of online storages and other infrastructure that may influence both hydrology and hydraulic operation.
- Greater section intervals are required to present improved mapping outcomes for low flow events such as the 2 year ARI.
- Upper extent of Georges River, Spring Creek, downstream extent of Nepean River around Menangle, and Harris Creek all have indicated mapping imperfections. Despite the imperfections the impact of these on hydraulic outcomes is unlikely.
- Two dimensional modelling would present more suitable results at Rocky Ponds Creek, Menangle Creek, Lily Ponds Creek and Foot Onslow Creek.

E.6.10 Proposed development hydraulics – no flow mitigation

The consideration of a developed catchment extended to include what influence increased flow rates would have on hydraulic performance. Table E-21 and Table E-22 summarises the results from hydraulic modelling considering a developed catchment flow rate.

Table E-21 Developed local hydraulic results

Confluences	River Segment (Station)	2 Year ARI (mAHD) – with no Nepean River flow (Average Velocity)	20 Year ARI (mAHD) – with Nepean River 20 year ARI flows (Average Velocity)	100 Year ARI (mAHD) - with Nepean River 20 year ARI flows (Average Velocity)
Nepean River at Bargo River	Segment 1 (7015.94)	103.1 (0.1 m/s)	113.2 (1.1 m/s)	113.4 (1.0 m/s)
Nepean River at Myrtle Creek	Segment 1 (5593.51)	96.3 (1.2 m/s)	108.1 (2.2 m/s)	108.3 (2.2 m/s)
Nepean River at Redbank / Stone quarry Creek	Segment 1 (2662.05)	88.1 (0.4 m/s)	100.3 (1.0 m/s)	100.6 (1.0 m/s)
Nepean River at Allens Creek)	Segment 3 (2217.33)	74.9 (0.7 m/s)	86.6 (1.5 m/s)	87.0 (1.5 m/s)
Nepean River at Cataract River	Segment 5 (3402.34)	74.4 (0.6 m/s)	84.3 (1.9 m/s)	84.7 (1.9 m/s)
Nepean River at Ousedale Creek	Segment 7 (2249.18)	73.9 (0.7 m/s)	80.9 (2.4 m/s)	81.2 (2.5 m/s)
Nepean River at Menangle Creek	Segment 2 (2159.32)	73.6 (0.5 m/s)	77.82 (2.5 m/s)	78.0 (2.6 m/s)
Nepean River at Foot Onslow Creek	(3363.52)	73.5 (0.2 m/s)	75.8 (1 m/s)	75.8 (1.1 m/s)
Cataract River at (Wallandoola Creek	(199.74)	140.6 (2.4 m/s)	142.1 (9.6 m/s)	142.2 (9.6 m/s)
Georges River	Segment 3 (1700)	215.4 (1.3 m/s)	216.4 (1.5 m/s)	216.9 (1.6 m/s)
Georges River	Segment 4 (3050)	139.7 (2.8 m/s)	140.2 (3.1 m/s)	140.8 (2.8 m/s)
Spring Creek	(1150)	141.2 (3.3 m/s)	141.4 (3.8 m/s)	141.5 (4.0 m/s)
Spring Creek	(400)	131.5 (0.3 m/s)	131.7 (0.5 m/s)	131.8 (0.5 m/s)
Bow Bowing Creek	(550.6)	96.7 (1.4 m/s)	96.9 (1.7 m/s)	96.9 (1.9 m/s)
Bow Bowing Creek	(90.54)	90.3 (0.4 m/s)	90.6 (0.5 m/s)	90.7 (0.6 m/s)

Table E-22 Developed local extreme event hydraulics results

Confluences	River Segment (Station)	PMP Event (mAHD) – with Nepean River 100 year ARI flows (Average Velocity)
Nepean River at Bargo River	Segment 1 (7015.94)	113.5 (0.3 m/s)
Nepean River at Myrtle Creek	Segment 1 (5593.51)	109.3 (2.0 m/s)
Nepean River at Redbank / Stone quarry Creek	Segment 1 (2662.05)	105.6 (0.8 m/s)

Confluences	River Segment (Station)	PMP Event (mAHD) – with Nepean River 100 year ARI flows (Average Velocity)
Nepean River at Allens Creek	Segment 3 (2217.33)	92.0 (1.8 m/s)
Nepean River at Cataract River	Segment 5 (3402.34)	89.0 (2.3 m/s)
Nepean River at Ousedale Creek	Segment 7 (2249.18)	84.6 (3.1 m/s)
Nepean River at Menangle Creek	Segment 2 (2159.32)	80.1 (3.4 m/s)
Nepean River at Foot Onslow Creek	Segment ?? (3363.52)	77.3 (1.3 m/s)
Cataract River at Wallandoola Creek	Segment ?? (199.74)	143.8 (12.7 m/s)
Georges River	Segment 3 (1700)	223.5 (2.0 m/s)
Georges River	Segment 4 (3050)	147.2 (3.0 m/s)
Spring Creek	Segment ?? (1150)	142.4 (4.6 m/s)
Spring Creek	(400)	132.6 (1.3 m/s)
Bow Bowing Creek	(550.6)	97.6 (2.8 m/s)
Bow Bowing Creek	(90.54)	91.8 (1.2 m/s)

The results of Tables E-21 and E-22 indicate only minor changes (less than 0.5 metres) in hydraulic performance. This was expected from the minimal change in hydrologic condition and the resilience of watercourses within the hydraulic model to cater for increased flows.

E.7 Potential modelling refinements

The outcomes from this assessment should only be viewed as a baseline assessment for further refinement in each development.

Each development should consider the use of a two dimensional model for better characterisation of the flow regime in low gradient areas. The refinement should be focused on the hydraulic modelling of the Study Area as this has the most chance of influencing development.

The delineation of a preferred Study area is still undergoing and the final area may or may not include some watercourses.

E.8 Hydrology model data and results

E.8.1 Catchment inputs

Table E-23 Sub-catchment properties

Sub-catchment	Area (ha)	Impervious	Pervious	Slope (%)	Impervious Manning n	Pervious Manning n	Developable Area (ha)
1.1.1.1	112.10	23.5	88.6	5.6	0.015	0.05	106.6
1.5.1.1	118.64	5.9	112.7	9.3	0.015	0.05	118.6
1.1.1.2	37.13	1.9	35.3	6.0	0.015	0.05	31.7
1.1.1.4	14.90	0.7	14.2	7.3	0.015	0.05	14.9
1.2.1.1	112.36	5.6	106.7	10.4	0.015	0.05	11.1
1.6.2.2	141.46	10.3	131.1	15.0	0.015	0.05	88.6
1.6.1.1	74.78	3.7	71.0	18.4	0.015	0.05	61.5
1.6.2.1	201.65	10.1	191.6	13.8	0.015	0.05	178.5
1.1.1.5	91.31	4.6	86.7	11.8	0.015	0.05	85.8
1.1.1.3	72.00	6.4	65.6	7.5	0.015	0.05	69.2
1.6.1.2	31.63	1.6	30.0	13.6	0.015	0.05	17.5
1.6.1.3	129.57	6.5	123.1	10.1	0.015	0.05	87.7
1.6.3.1	129.99	6.5	123.5	9.5	0.015	0.05	101.5
1.6.1.4	385.90	19.3	366.6	6.1	0.015	0.05	290.1
1.6.3.2	232.46	11.6	220.8	8.7	0.015	0.05	150.0
1.4.1.1	296.18	18.1	278.1	6.4	0.015	0.05	289.8
1.1.1.6	252.09	12.6	239.5	12.3	0.015	0.05	161.5
1.7.1.1	172.55	8.6	163.9	10.7	0.015	0.05	113.1
1.1.1.7	216.84	10.8	206.0	17.7	0.015	0.05	98.6
1.1.1.8	45.73	2.3	43.4	23.8	0.015	0.05	21.6
1.3.1.1	840.82	46.7	794.2	10.7	0.015	0.05	362.7
2.1.1.1	964.00	48.2	915.8	12.9	0.015	0.05	102.9
1.9.1.1	228.95	11.4	217.5	10.3	0.015	0.05	214.2
1.1.1.9	159.96	8.0	152.0	14.1	0.015	0.05	110.6

Sub-catchment	Area (ha)	Impervious	Pervious	Slope (%)	Impervious Manning n	Pervious Manning n	Developable Area (ha)
1.15.1.1	273.12	13.7	259.5	21.8	0.015	0.05	17.4
1.8.2.1	158.96	7.9	151.0	7.3	0.015	0.05	132.0
1.8.1.1	7.18	0.4	6.8	33.0	0.015	0.05	0.0
1.12.1.1	524.99	130.2	394.8	14.8	0.015	0.05	214.2
1.1.1.10	435.85	48.2	387.7	14.5	0.015	0.05	262.4
1.1.1.14	100.65	5.0	95.6	14.8	0.015	0.05	65.5
1.1.1.12	66.94	26.5	40.4	18.1	0.015	0.05	40.0
1.1.1.13	202.36	33.5	168.9	16.9	0.015	0.05	86.2
1.1.1.15	597.58	29.9	567.7	18.7	0.015	0.05	239.8
1.10.1.1	395.50	19.8	375.7	11.3	0.015	0.05	251.3
1.8.1.2	539.67	27.0	512.7	11.8	0.015	0.05	355.2
1.1.1.11	182.33	61.3	121.1	12.1	0.015	0.05	103.9
1.1.1.16	107.76	5.4	102.4	18.6	0.015	0.05	56.3
1.13.1.1	126.91	6.3	120.6	8.1	0.015	0.05	63.3
2.1.1.2	627.61	31.4	596.2	11.9	0.015	0.05	228.5
1.16.1.1	148.22	7.4	140.8	9.8	0.015	0.05	105.8
1.11.1.1	386.49	36.3	350.2	15.1	0.015	0.05	252.9
1.18.1.1	1,650.94	302.1	1348.8	15.5	0.015	0.05	0.0
1.14.1.2	94.25	4.7	89.5	14.5	0.015	0.05	24.2
1.1.1.17	1,004.63	50.2	954.4	18.3	0.015	0.05	94.1
1.18.1.2	8,104.62	628.1	7476.5	15.5	0.015	0.05	0.0
1.11.2.1	408.92	20.4	388.5	9.2	0.015	0.05	365.9
1.8.1.3	351.45	38.8	312.7	7.6	0.015	0.05	231.5
1.14.1.1	458.61	22.9	435.7	13.8	0.015	0.05	190.3
1.17.1.1	183.63	9.2	174.5	13.8	0.015	0.05	111.2
1.1.1.18	442.72	22.1	420.6	17.4	0.015	0.05	0.0
1.11.6.1	161.12	8.1	153.1	9.5	0.015	0.05	0.0
1.14.2.1	203.34	10.2	193.2	11.3	0.015	0.05	151.0

Sub-catchment	Area (ha)	Impervious	Pervious	Slope (%)	Impervious Manning n	Pervious Manning n	Developable Area (ha)
1.1.1.19	197.39	9.9	187.5	19.6	0.015	0.05	0.0
1.19.1.1	936.10	129.2	806.9	7.7	0.015	0.05	0.0
1.17.1.2	214.13	10.7	203.4	6.5	0.015	0.05	199.8
1.11.1.5	80.54	4.0	76.5	20.8	0.015	0.05	0.0
1.11.1.2	405.34	20.3	385.1	17.6	0.015	0.05	139.6
1.11.1.4	187.22	9.4	177.9	16.9	0.015	0.05	0.0
1.11.1.3	64.33	3.2	61.1	23.9	0.015	0.05	0.0
1.1.1.22	355.33	17.8	337.6	16.8	0.015	0.05	100.6
1.1.1.21	15.25	0.8	14.5	47.2	0.015	0.05	0.0
1.11.1.6	431.58	21.6	410.0	10.5	0.015	0.05	0.0
1.14.2.2	329.17	16.5	312.7	7.6	0.015	0.05	286.1
1.1.1.20	130.16	6.5	123.7	22.9	0.015	0.05	0.0
2.1.1.3	924.05	85.1	838.9	9.3	0.015	0.05	364.2
1.1.1.23	422.30	21.1	401.2	15.3	0.015	0.05	197.2
1.14.1.3	670.25	59.3	610.9	9.7	0.015	0.05	376.2
1.14.3.1	292.05	14.6	277.5	13.2	0.015	0.05	97.2
1.11.5.1	455.01	22.8	432.3	8.1	0.015	0.05	0.0
1.22.1.1	362.21	18.1	344.1	7.5	0.015	0.05	0.0
1.14.1.4	375.73	18.8	356.9	5.6	0.015	0.05	146.2
1.11.3.1	1,018.73	50.9	967.8	8.0	0.015	0.05	0.0
1.21.1.1	476.17	23.8	452.4	8.0	0.015	0.05	0.0
1.23.1.1	1,007.97	50.4	957.6	7.7	0.015	0.05	0.0
1.20.1.1	5,239.74	550.2	4689.6	10.1	0.015	0.05	0.0
1.11.1.8	95.97	4.8	91.2	26.6	0.015	0.05	0.0
1.11.4.1	3,336.44	166.8	3169.6	9.7	0.015	0.05	0.0
1.11.1.9	2,343.63	117.2	2226.5	12.8	0.015	0.05	0.0
1.20.1.2	7,762.50	772.4	6990.1	15.5	0.015	0.05	0.0
1.24.3.1	8,648.39	1089.7	7558.7	19.9	0.015	0.05	0.0

Sub-catchment	Area (ha)	Impervious	Pervious	Slope (%)	Impervious Manning n	Pervious Manning n	Developable Area (ha)
1.24.2.1	14,248.13	1659.9	12588.2	22.4	0.015	0.05	0.0
1.1.1.25	31,749.61	8223.1	23526.5	17.1	0.015	0.05	0.0
1.26.1.1	85.49	4.3	81.2	13.3	0.015	0.05	43.4
2.2.1.1	91.16	17.6	73.6	10.7	0.015	0.05	57.4
2.3.1.1	76.48	36.6	39.8	13.0	0.015	0.05	74.8
2.4.1.1	82.52	46.1	36.4	7.7	0.015	0.05	69.5
1.25.1.1	526.23	35.0	491.2	9.5	0.015	0.05	476.4
2.5.1.1	42.02	24.5	17.5	5.5	0.015	0.05	41.9
2.6.1.1	52.88	27.7	25.2	4.3	0.015	0.05	44.1
1.10.2.1	346.93	17.3	329.6	12.1	0.015	0.05	199.5
1.14.3.2	242.32	12.1	230.2	8.2	0.015	0.05	125.6
1.14.4.1	157.75	7.9	149.9	6.5	0.015	0.05	105.1
1.27.1.1	166.11	8.3	157.8	8.1	0.015	0.05	129.3
1.6.4.1	152.91	8.9	144.0	7.9	0.015	0.05	105.5
1.8.1.4	231.56	11.6	220.0	7.2	0.015	0.05	210.0
1.8.3.1	328.02	16.4	311.6	9.9	0.015	0.05	263.1
2.1.1.4	1,357.89	67.9	1290.0	11.5	0.015	0.05	31.1

E.8.2 Design intensity frequency duration data

Table E-24 IFD Data at Camden (Brownlow Hill, Station 68007)

Event	1 Year ARI	2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
5 min	74.9	97.0	127.0	144.0	167.0	197.0	220.0
6 min	70.1	90.8	118.0	135.0	156.0	184.0	206.0
10 min	57.3	74.2	96.7	110.0	127.0	150.0	168.0
20 min	41.8	54.0	70.3	80.0	92.6	109.0	122.0
30 min	33.9	43.8	57.0	64.9	75.1	88.6	98.9
1 hr	22.9	29.6	38.5	43.8	50.8	59.9	66.9
2 hr	15.0	19.4	25.3	28.7	33.3	39.3	43.9

Event	1 Year ARI	2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
3 hr	11.6	15.0	19.6	22.3	25.8	30.5	34.0
6 hr	7.5	9.7	12.6	14.4	16.6	19.7	22.0
12 hr	4.8	6.2	8.2	9.3	10.8	12.8	14.3
24 hr	3.1	4.0	5.3	6.1	7.1	8.4	9.4
48 hr	1.9	2.5	3.3	3.9	4.5	5.4	6.1
72 hr	1.4	1.8	2.5	2.9	3.4	4.1	4.6

E.8.3 Lag estimates

Lag times between catchments were based on velocities estimated from watercourse grades and an average cross sectional area of watercourse. Flow velocities varied from 1 to 3 m/s.

E.8.4 Input hydrographs

To consider the hydrological response of the Nepean River catchment that extends beyond the Study Area, the extraction of hydrographs for the critical storm from the existing 1995 RORB model was undertaken. Hydrographs were extracted at two key locations to consider the southern and eastern Nepean catchments. These hydrograph inputs also consider the hydrological response of the Dams present within the Nepean Catchment including:

- Cataract Dam
- Avon Dam
- Nepean Dam
- Cordeaux Dam

Hydrographs were extracted for the peak 100 year ARI, 20 year ARI and PMF events. While the flooding assessment considers only the catchments hydrological response from the 100 year ARI and PMF event, the 20 year was also considered for the purposes of considering a variance between events occurring on regional and local scale. The base scenario considered for the flood assessment of the Study Area were a 20 year ARI regional event occurred combined with a 100 year ARI local event.

The flood hydrographs considered for the assessment are shown below in Figure E-7 and Figure E-8.

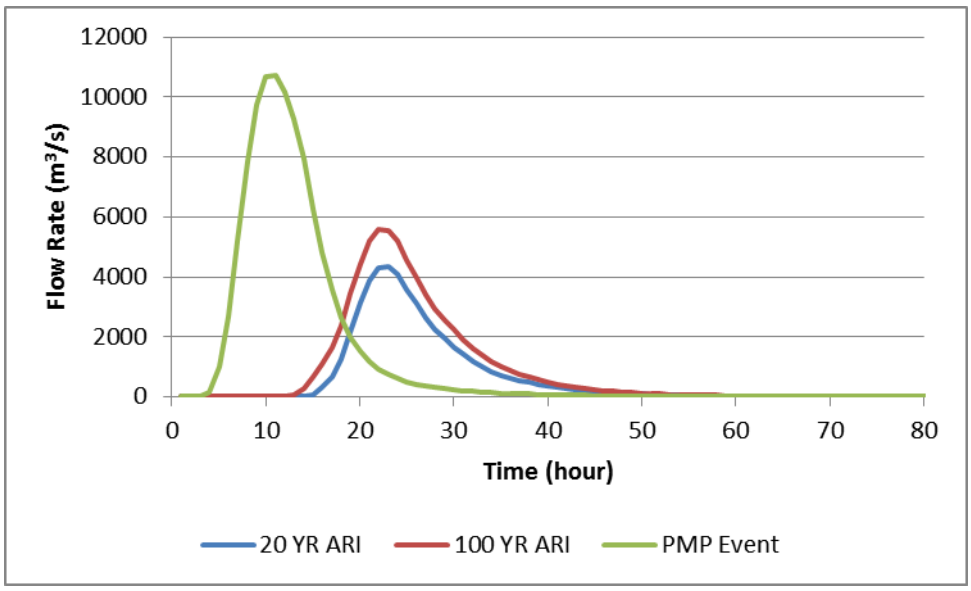


Figure E-7 Location 1 – Pheasants Nest gauge representing the southern Nepean catchment for the critical 20 year ARI, 100 year ARI and PMP events

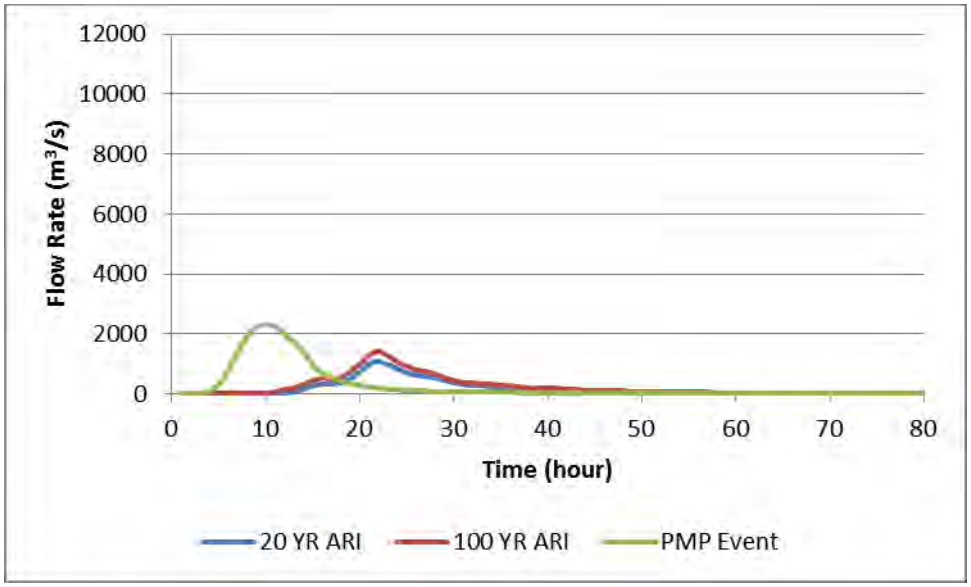


Figure E-8 Location 2 – Cataract River representing the eastern catchments contributing to Nepean River via Cataract River for the critical 20 year ARI, 100 year ARI and PMP events.

From the hydrographs presented in Figures E-7 and E-8, it is clear that more flow contributes in location 1 then at location 2. This can be largely attributed to catchment area and the presence of three dams that contribute to location 1. Location 2 had a critical duration greater than that of location 1 at 48 hours compared with 36 hours and also presented a smaller variance between the flow rates predicted in the 100 year ARI compared with the PMP event.

E.8.5 Probable maximum precipitation

The PMP event was determined using both the GSDM (for storm durations up to 6 hours) and the GSAM method (for storm durations greater than 12 hours). This assessment considered PMP events up to and including the 6 hour event.

A PMP hydrograph was input upstream of the XP-RAFTS model for the purposes of identifying the potential flows contributing to the Study Area from both the southern and eastern

catchments. This hydrograph had a critical duration of 12 hours for both southern and eastern external catchments.

E.8.6 Sensitivity considerations

The sensitivities of model variables were tested on the base hydrologic model, that is the model considering the 100 year local runoff and 20 year routed Nepean flow scenario.

Model variables tested considered catchment lag speed, Manning's n values, and initial and continuing loss. The last two of these parameters were specifically subject to a wide range of variance in historical assessments within in the area.

For the testing location of flows from the model, the confluence of the Cataract and Nepean Rivers was considered. Whilst these two rivers are largely dominated by flow derived from input hydrographs, the flow reporting location is well suited as having the largest contiguous sub-catchment contributing to the Nepean River within the Study Area.

Table E-25 presents a summary of the results of the sensitivity assessment for the model node junction of DUM16.

Table E-25 Sensitivity assessment

	Flow Rate (m^3/s)	Critical Duration (hrs)	Flow Variance from Existing Scenario	Critical Duration Variance from Existing Scenario (min)
Existing	5869.7	24.7	NA	NA
Sensitivity 1 (half Lag Times)	6226.6	24.6	+356.9	-4
Sensitivity 2 (double Lag Times)	5619.2	32.1	-250.5	445
Sensitivity 3 (decrease Manning's N roughness)	5805.6	27.0	-64.1	143
Sensitivity 4 (increase Manning's N roughness)	6072.6	27.0	+202.9	143
Sensitivity 5 (decrease losses)	5869.7	27.0	0	143
Sensitivity 6 (increase losses)	5869.7	27.0	0	143

The result of Table E-25 indicates the model has a greater sensitivity to lags and Manning's n assumptions. Due to the input hydrographs representing the southern and eastern sections of the Nepean River catchment, the response of the local catchments complicate the expected results. This is shown in the decrease of catchment roughness which would typically correspond in an increase of runoff speed indicating generally a decrease in peak flow volume at node DUM16. This is due to the change in critical storm events that produce the peak also. Future refinements should consider more hydrological models of the Study Area catchments considering no Nepean River Flow.

To assess for the models precision, a check was undertaken on how upper catchment runoff was represented in XP-RAFTS compared with the probabilistic rational method (PRM) (IEAUST, 1997). This check was performed on 10 sample catchments well distributed through the Study Area varying in catchment area and slope.

A summary of the comparison between the base model and PRM method has been provided in Table E-26.

Table E-26 Comparisons of modelled flows to PRM calculated flows

Catchment ID	XP-RAFTS (m^3/s) / Critical Storm	PRM Flow (m^3/s) / Time of Concentration	Percentage Difference
1.23.1.1	110.9	140.5	-21%
1.19.1.1	111.6	132.7	-16%
1.9.1.1	36.5	45.1	-19%
1.8.1.4	33.0	45.5	-27%
1.14.3.2	35.9	47.1	-24%
1.14.2.2	45.0	59.6	-25%
1.10.2.1	54.8	62.1	-12%
1.6.4.1	23.8	32.9	-28%
2.3.1.1	27.5	19.2	+43%
2.1.14	163.3	176.2	-7%

Table E-27 indicates that results of the XP-RAFTS model and PRM flow are comparable. On average the results indicate a percentage difference of model to calculated of-22% with the exception of 2.3.1.1. Catchment 2.3.1.1 indicated a greater runoff predicted then estimated using the PRM which could be contributed to its catchment size which was much smaller than the other sample catchments.

Contributing factors to the difference were also identified as the consideration of catchment loss and catchment roughness values considered in the modelling compared with the PRM calculation which utilised a significantly higher runoff coefficient (C_{10} – 0.8) (IEAust; 1997) given the Study Areas location nearby the Wollongong Escarpment.

E.8.7 XP-RAFTS hydrographs

Hydrographs from the existing modelling have been presented for the following XP-RAFTS model locations:

- 2.1.1.1 – Georges River
- 2.4.1.1 – Spring Creek
- 2.2.1.1 – Bow Bowing Creek
- DUM05 – Nepean River and Bargo River
- DUM07 – Nepean River and Myrtle Creek
- DUM09 – Nepean River and Redbank/Stone Quarry Creek
- DUM13 – Nepean River and Allens Creek
- DUM16 – Nepean River and Cataract River
- DUM19 – Nepean River and Ousedale Creek
- DUM21 – Nepean River and Menangle Creek
- DUM24 – Nepean River and Foot Onslow Creek
- DUM28 – Cataract River and Wallandola Creek

Comparative hydrographs were also provided for the alternate boundary conditions on the Nepean River where:

- 100 year ARI event was assessed for local catchments considering a 100 year ARI inflow from regional catchments

- PMP event was assessed for local catchments considering a PMP event inflow from regional catchments.

E.8.8 Design flood hydrograph

Graphs of design hydrographs are provided below at the end of this Appendix.

E.8.9 Watercourse grades

Watercourse grades (slopes) were determined from the terrain model and are shown in Table E-27 wor the individual watercourses.

Table E-27 Bed grade

Creek	Bed Grade (%)
Allens Creek	1.6
Back Gully	3.3
Bow Bow ing Creek	1.5
Byrnes Creek	3.2
Cascade Creek	2.2
Cataract River	1.0
Clements Creek	2.1
Elladale Creek	2.8
Foot Onslow Creek	0.8
Georges River	0.75
Harris Creek	2.5
Leaps Gully	4.4
Lily Pond Gully	2.5
Mallaty Creek	3.4
Menangle Creek	1.5
Nepean Creek	1.9
Nepean River	0.2
Ousedale Creek	1.8
Rocky Ponds Creek	2.6
Sandy Gully	1.4
Simpsons Creek	3.2
Spring Creek	1.4

Stringybark Creek	2.5
Third point Creek	3.0
Wallandoola Creek	2.3
Woodhouse Creek	2.4

Bed grade was considered in the estimation of the normal depth boundary condition.

E.8.10 Long section profiles and design flood profiles

Flood profiles area provided in the appendices for each of the following watercourses:

- Allens Creek
- Back Gully
- Bow Bowing Creek
- Byrnes Creek
- Cascade Creek
- Cataract River
- Clements Creek
- Elladale Creek
- Foot Onslow Creek
- Georges River
- Harris Creek
- Leaps Gully
- Lily Pond Gully
- Mallaty Creek
- Menangle Creek
- Nepean Creek
- Nepean River
- Ousedale Creek
- Rocky Ponds Creek
- Sandy Gully
- Simpsons Creek
- Spring Creek
- Stringybark Creek
- Third point Creek
- Wallandoola Creek
- Woodhouse Creek

Appendix F – Flood level mapping

F.1 Result presentation

Design flood levels have been calculated for the 2, 20, and 100 year ARI existing conditions design events together with a PMF event as described in Appendix E.

For each event the results are provided as follows:

- An overall image
- Six detail sheets.

The overall image shows the predicted flood extent by the width of the central light blue area identified as “Flood extent” in the legend. The flood level is then shown by a colour shading each side of the Flood extent. To facilitate the definition of the flood levels it has been found appropriate to adopt a “flood level colour ramp” that varies the in the magnitude of the depth change as the colour gradation changes. This was necessary to provide adequate flood level definition along the Nepean River while in the steeper tributary areas the band level change width was made larger.

The series of six detail sheets, using the same colour ramp definition, were then provided to give an enhanced definition of the levels across the Subject Site.

Detailed flood profiles, together with tabulated design flood levels are provided in Appendix J.

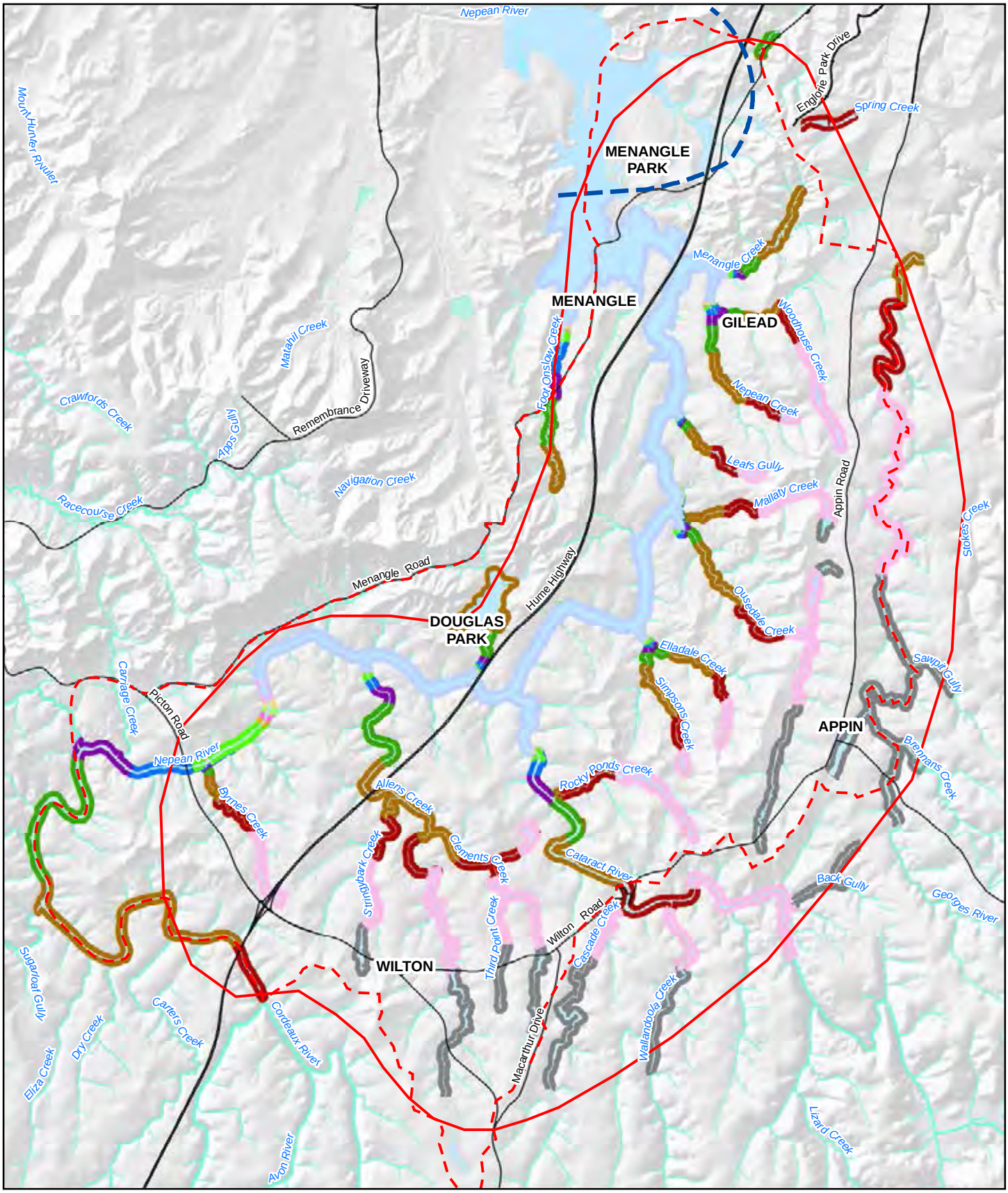
F.2 Flood level comparisons

The colour ramp was selected to permit the use of the same colour ramp on all flood maps. This permits a relatively quick comparison of the flood levels for the 2, 20 and 100 year ARI events together with the PMF can be determined by comparing the location of the colour banding along the watercourses shown on Figures F-1, F-3, F-5 and F-7.

F.3 Interpretation

As anticipated the flood level along the lower reaches of the Nepean River was relatively flat downstream of approximately Douglas Park for the 2 year ARI event. Upstream of this location there was a more noticeable flood gradient. All modelled tributaries demonstrated a significant flood gradient for the 2 year ARI event due to the topographic slope.

As the flow rate in the Nepean River was increased, with the larger events, the flood gradient in the Nepean River became more significant. The flood gradient in the tributaries did not change as markedly as the flow rates were increased.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 2 year Flood Levels and Extents - Overall

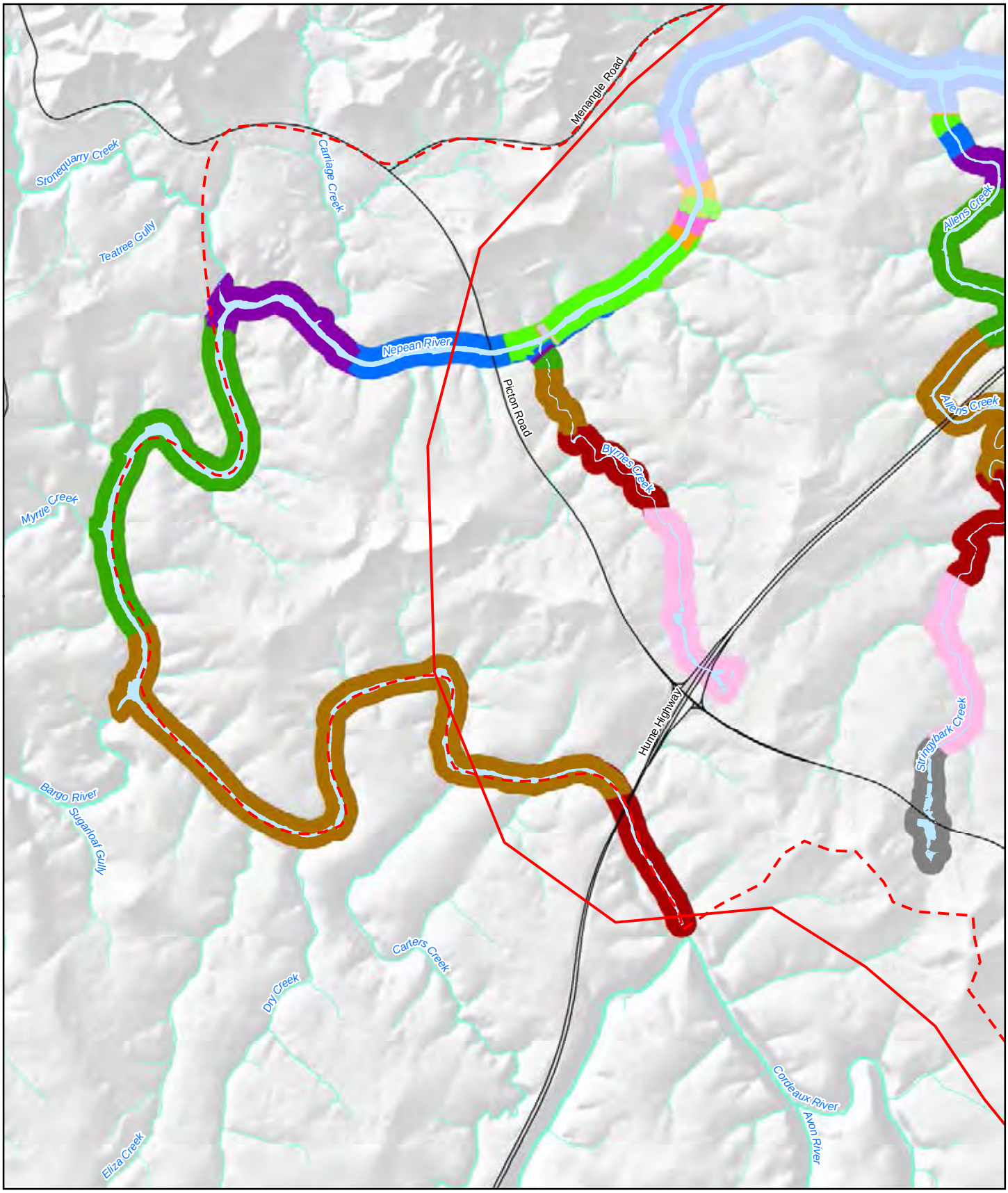
Figure F-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F001_Existing_2YR_Overall_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

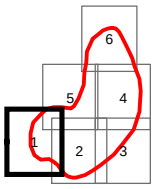


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 2 year Flood Levels and Extents - Sheet 1

Job Number	22-17728
Revision	0
Date	23 Jun 2015

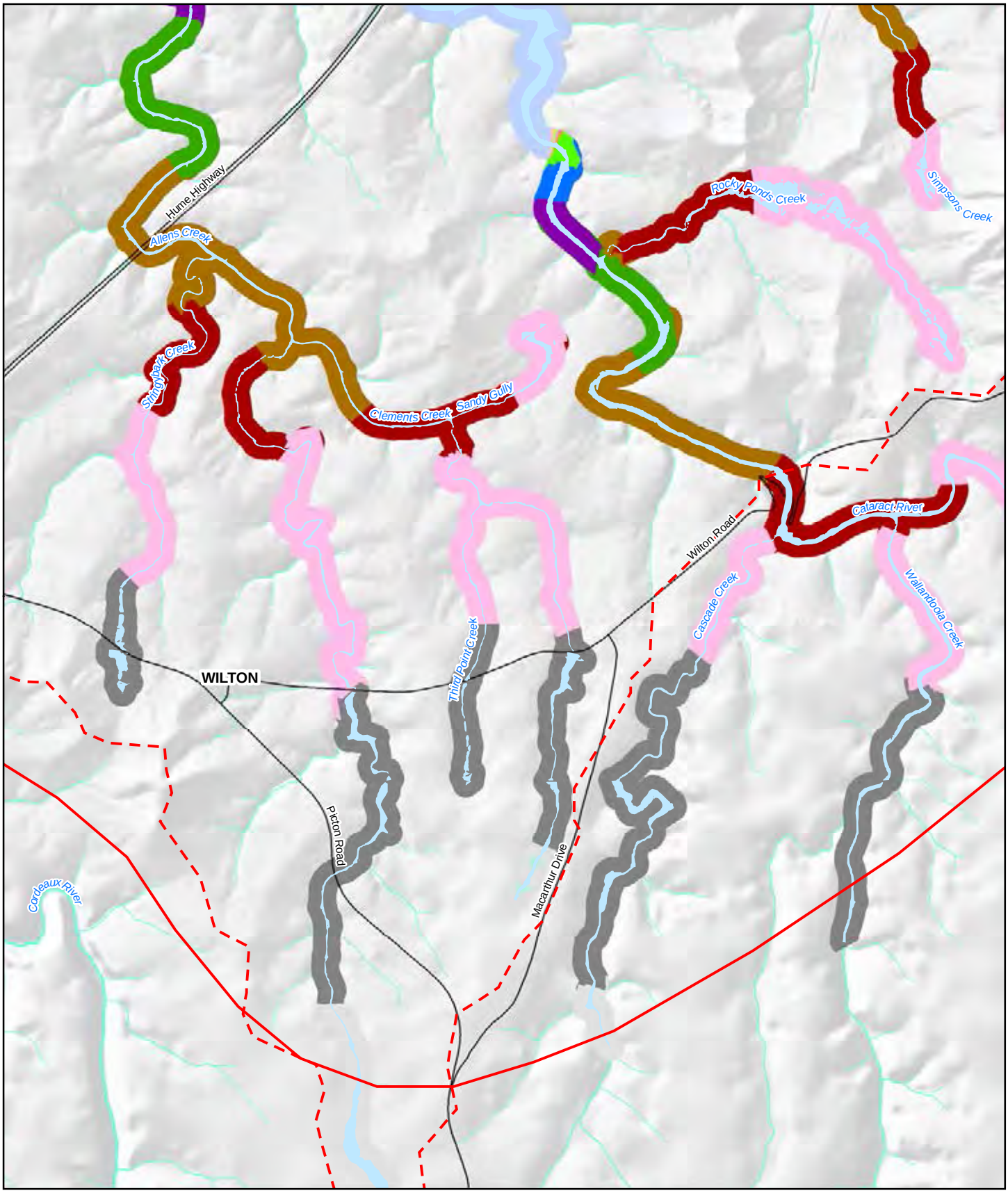
Figure F-2a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F002_DDP_Existing_2YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

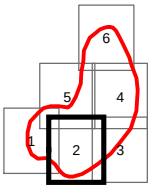


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 2 year Flood Levels and Extents - Sheet 2

Job Number	22-17728
Revision	0
Date	23 Jun 2015

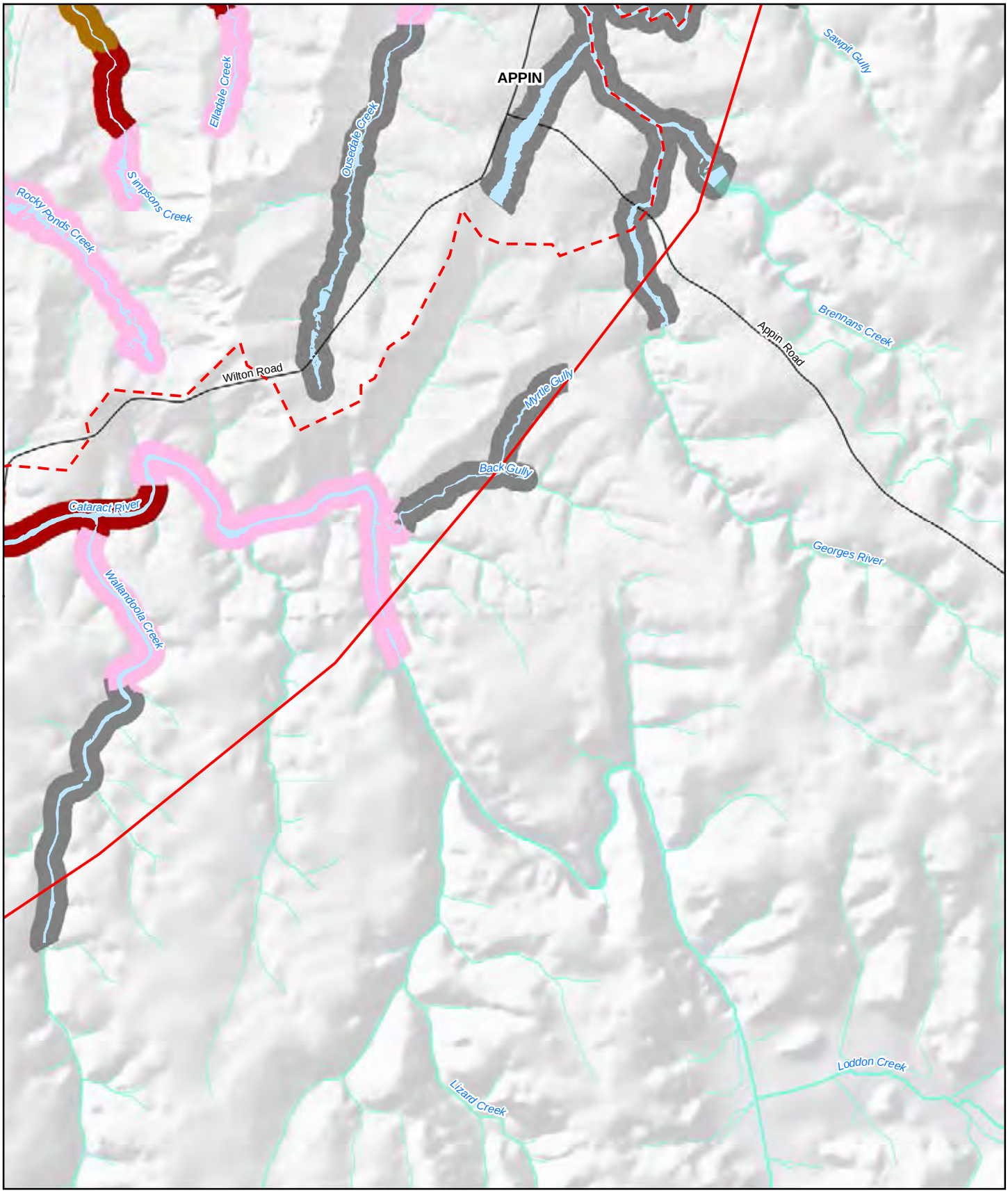
Figure F-2b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F002_DDP_Existing_2YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

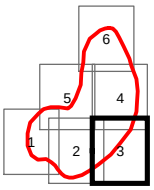


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 2 year Flood Levels and Extents - Sheet 3

Job Number 22-17728
Revision 0
Date 23 Jun 2015

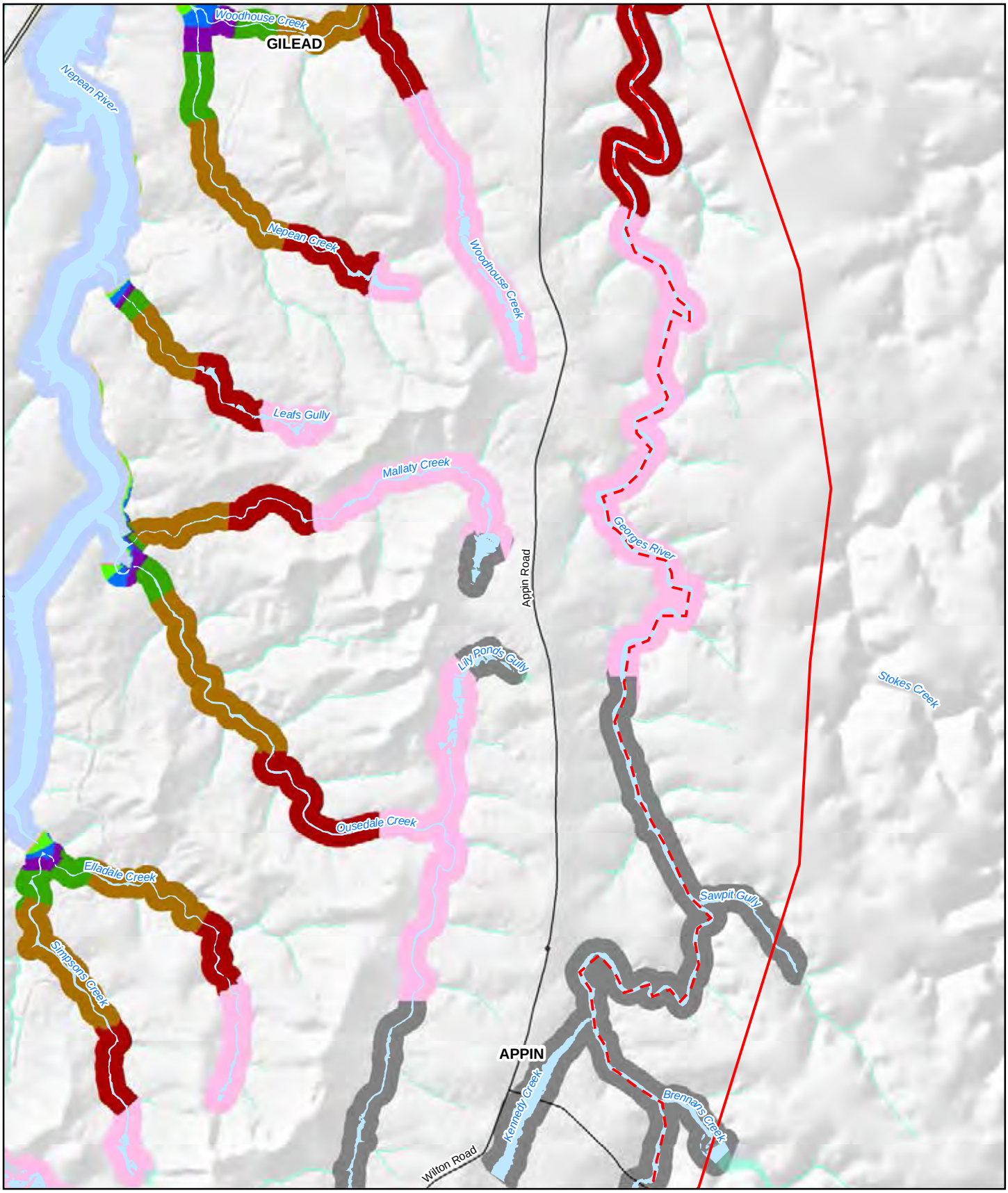
Figure F-2c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F002_DDP_Existing_2YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

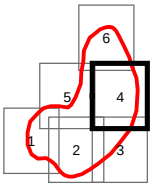


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 2 year Flood Levels and Extents - Sheet 4

Job Number 22-17728
Revision 0
Date 23 Jun 2015

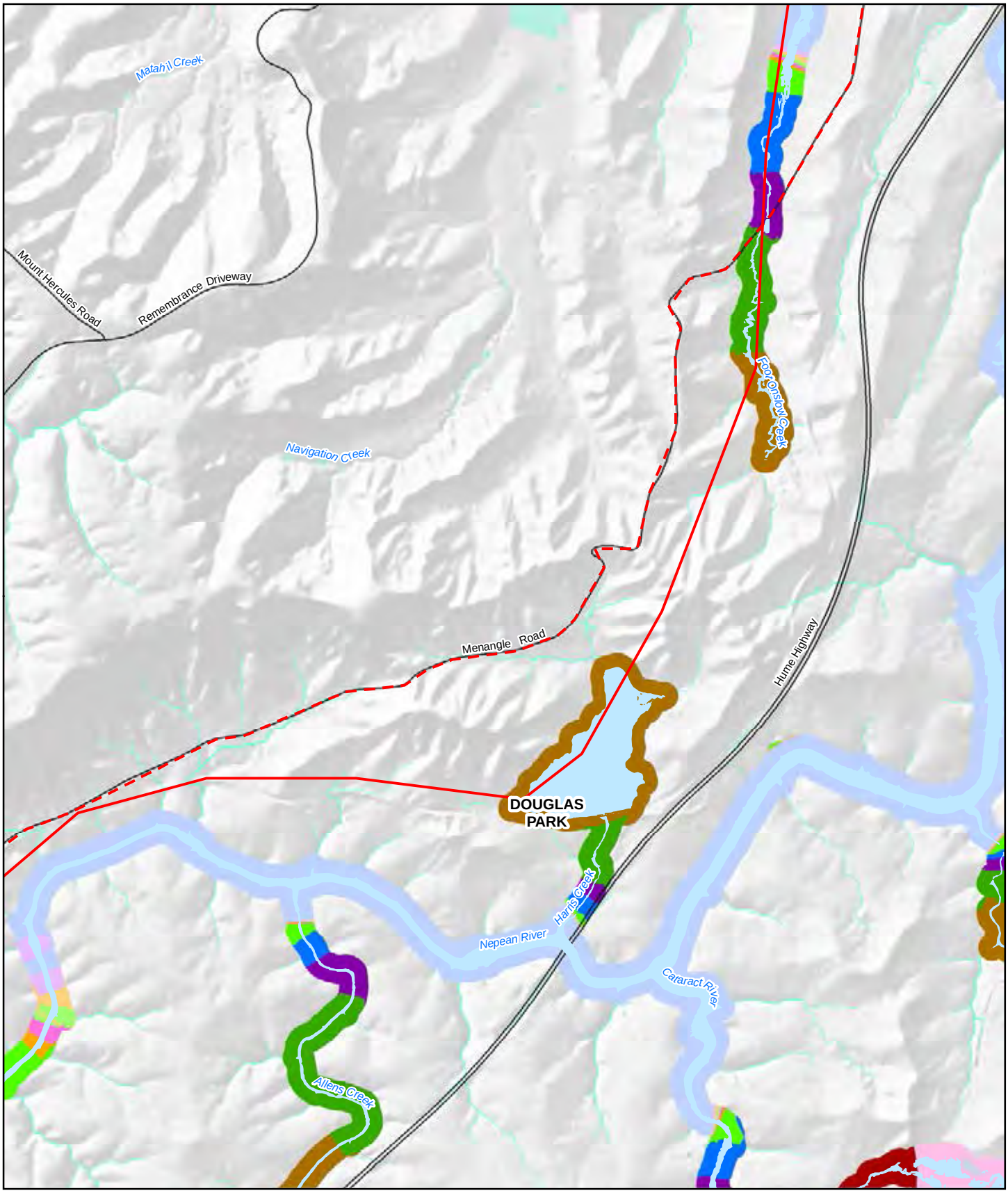
Figure F-2d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F002_DDP_Existing_2YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

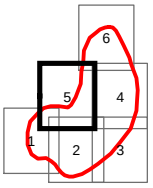


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 2 year Flood Levels and Extents - Sheet 5

Job Number 22-17728
Revision 0
Date 23 Jun 2015

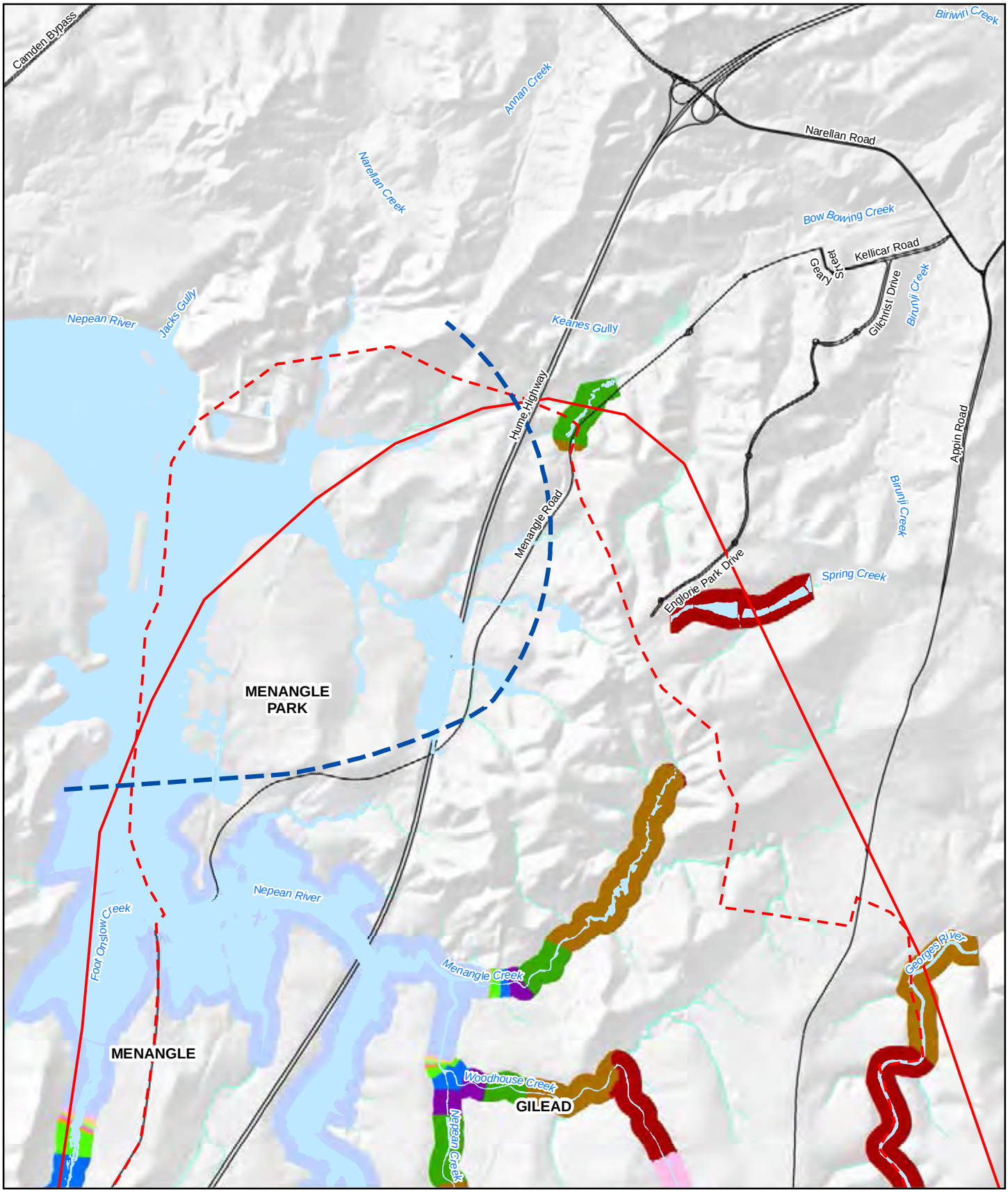
Figure F-2e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F002_DDP_Existing_2YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

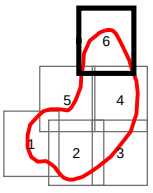


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 2 year Flood Levels and Extents - Sheet 6

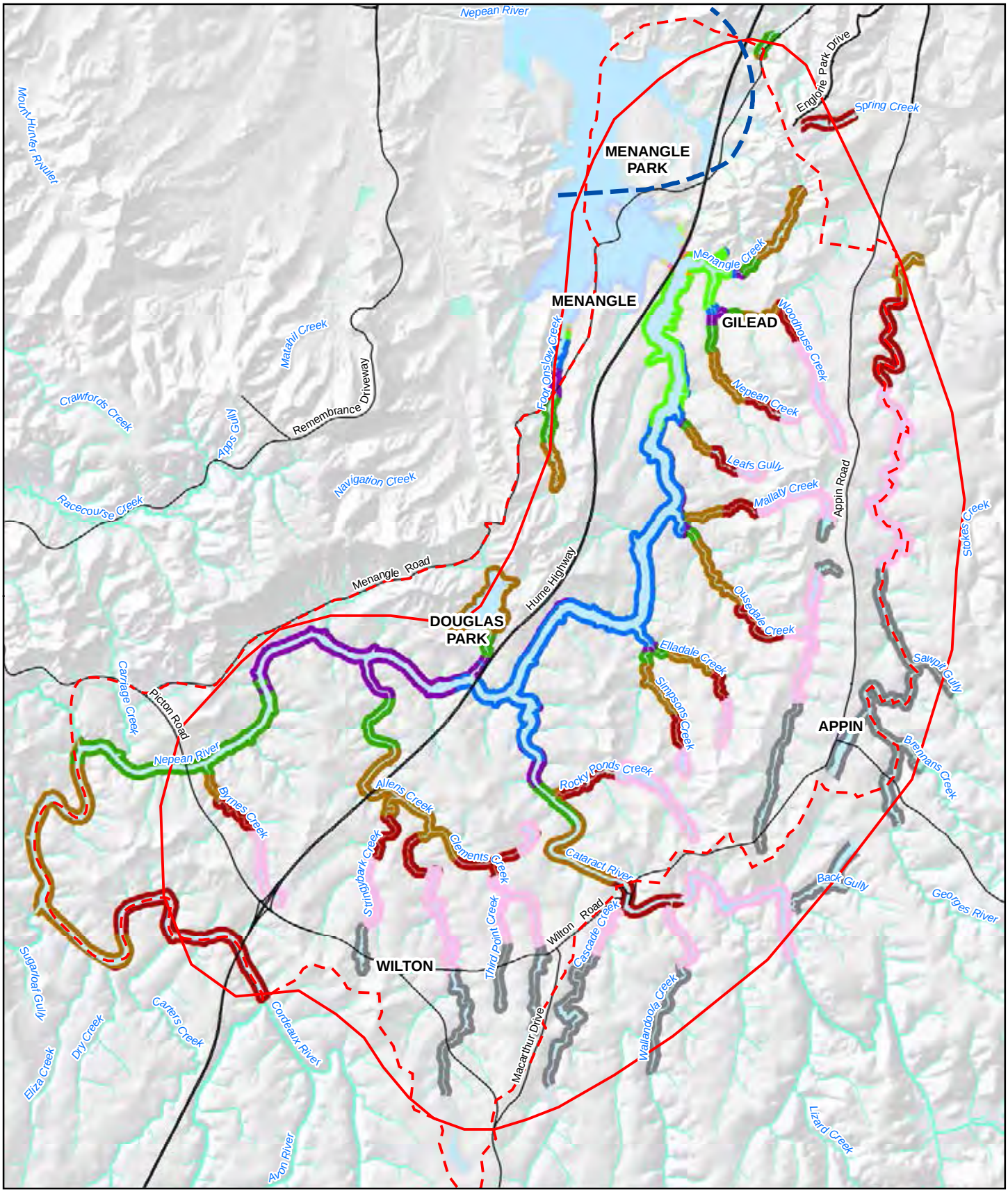
Figure F-2f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F002_DDP_Existing_2YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 20 year Flood Levels and Extents - Overall

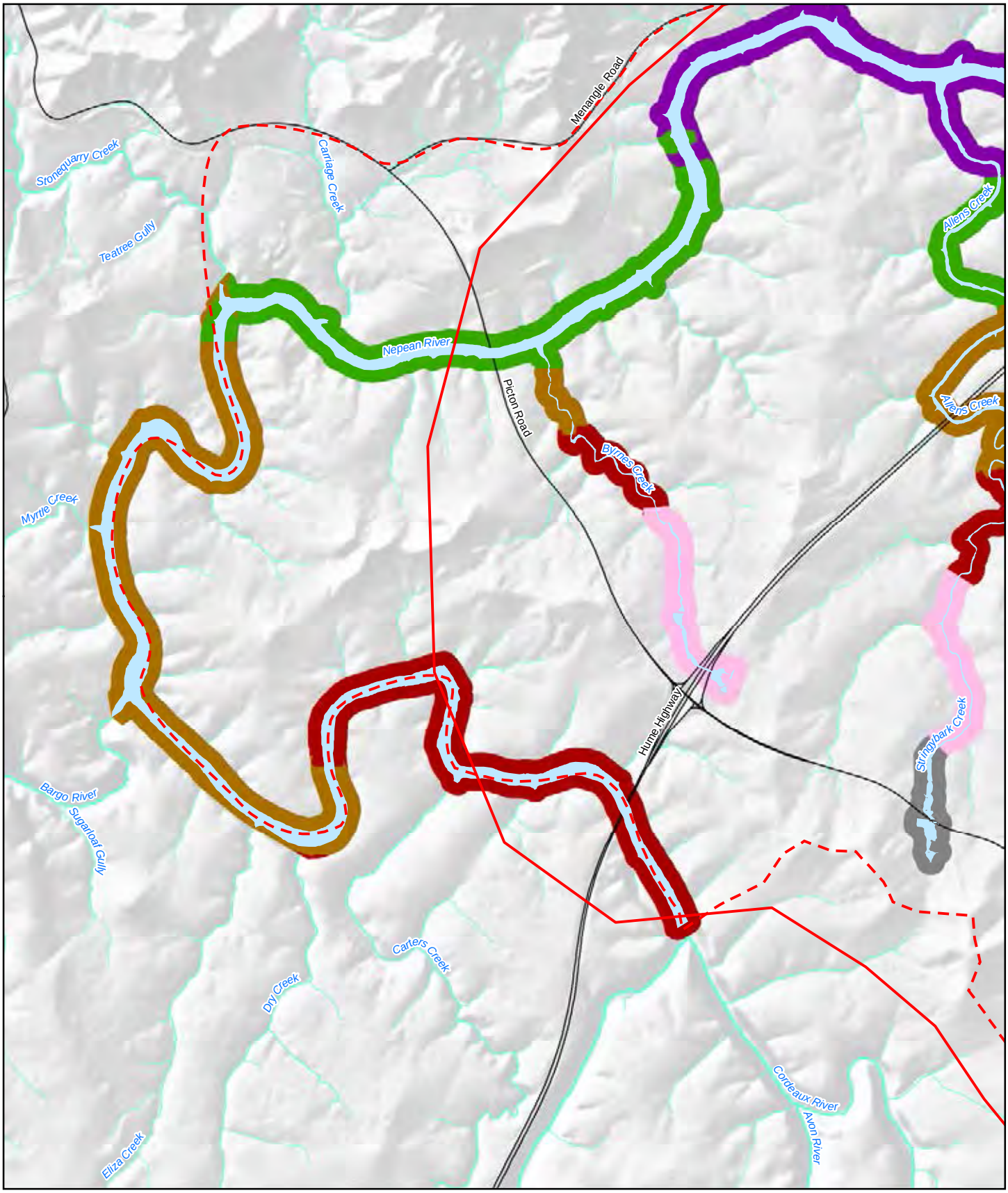
Figure F-3

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F003_Existing_20YR_Overall_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

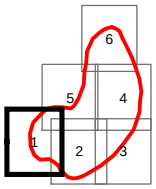


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 20 year Flood Levels and Extents - Sheet 1

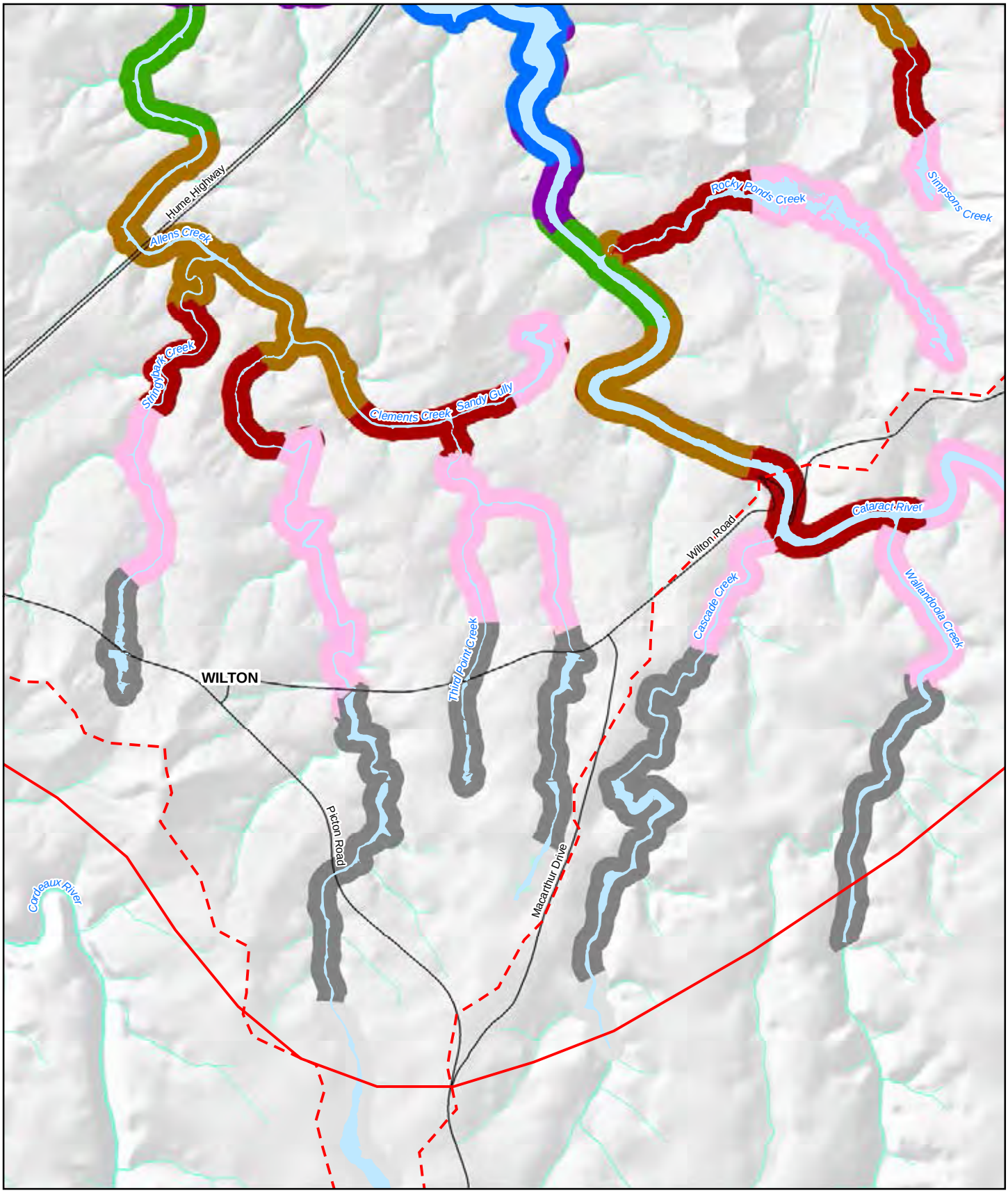
Figure F-4a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F004_DDP_Existing_20YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

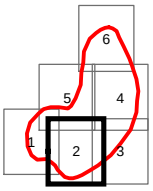


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 20 year Flood Levels and Extents - Sheet 2

Job Number	22-17728
Revision	0
Date	23 Jun 2015

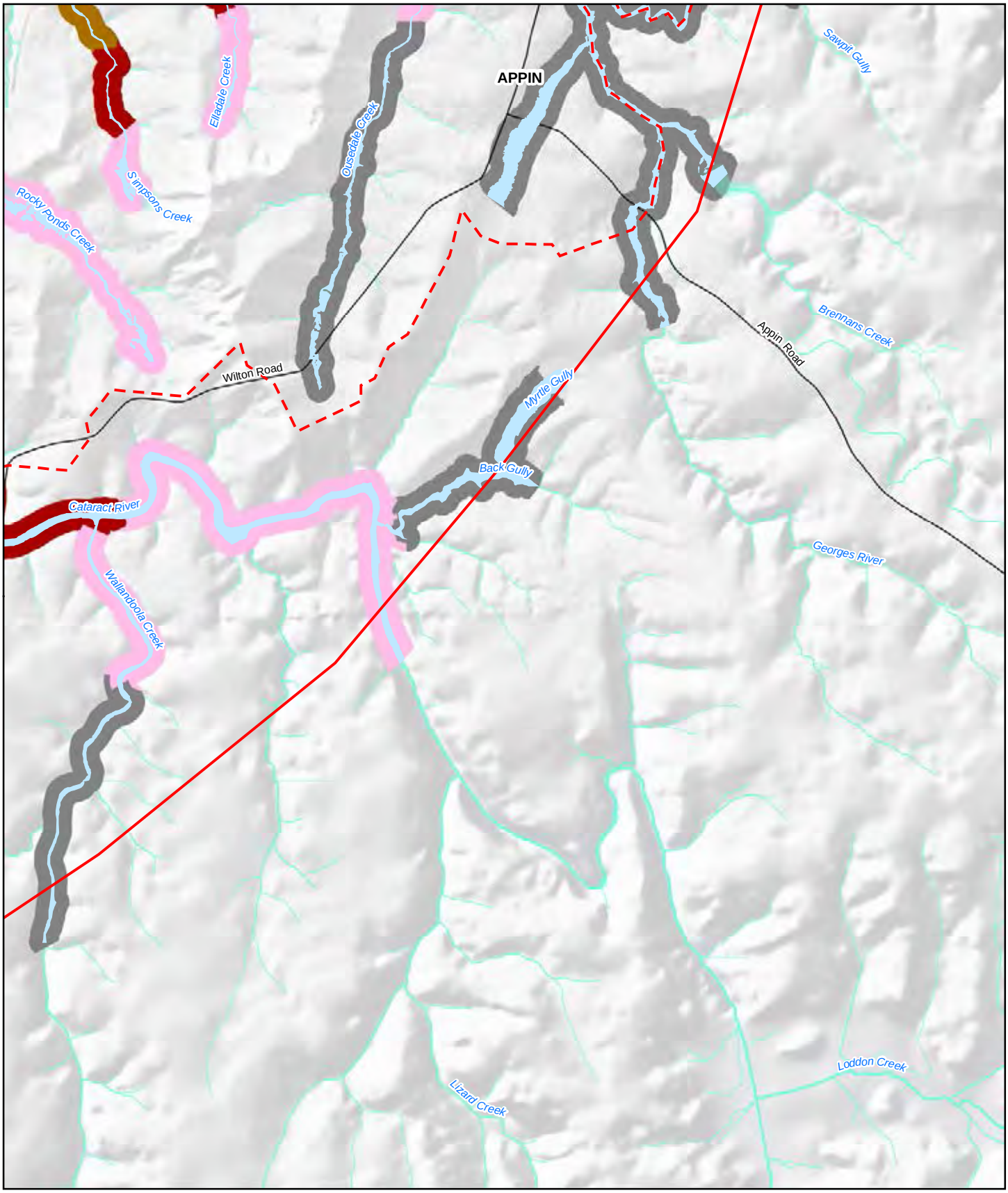
Figure F-4b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F004_DDP_Existing_20YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

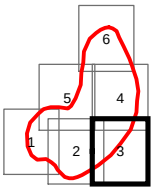


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 20 year Flood Levels and Extents - Sheet 3

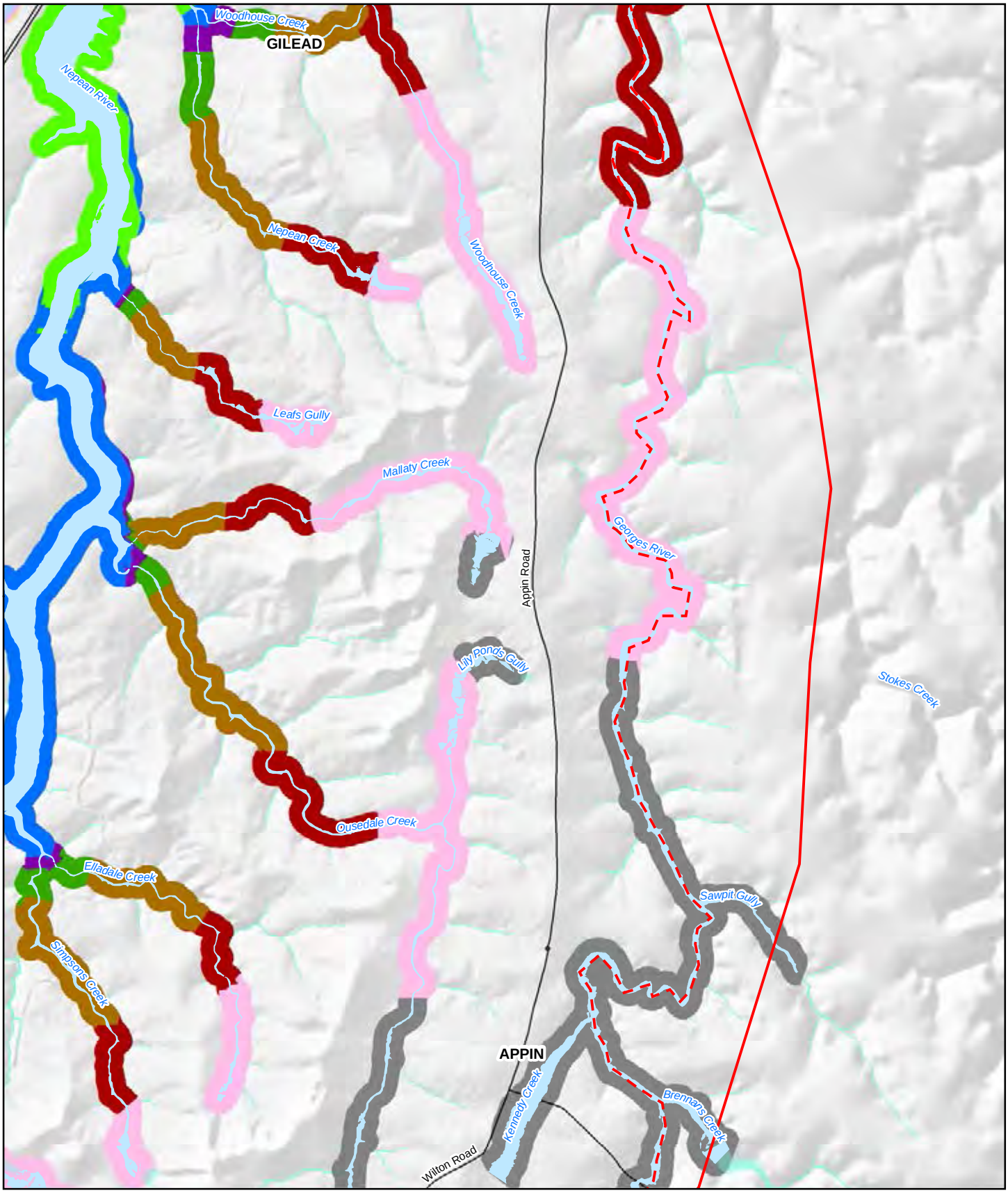
Figure F-4c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F004_DDP_Existing_20YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

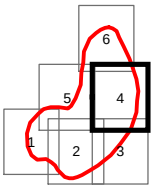


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 20 year Flood Levels and Extents - Sheet 4

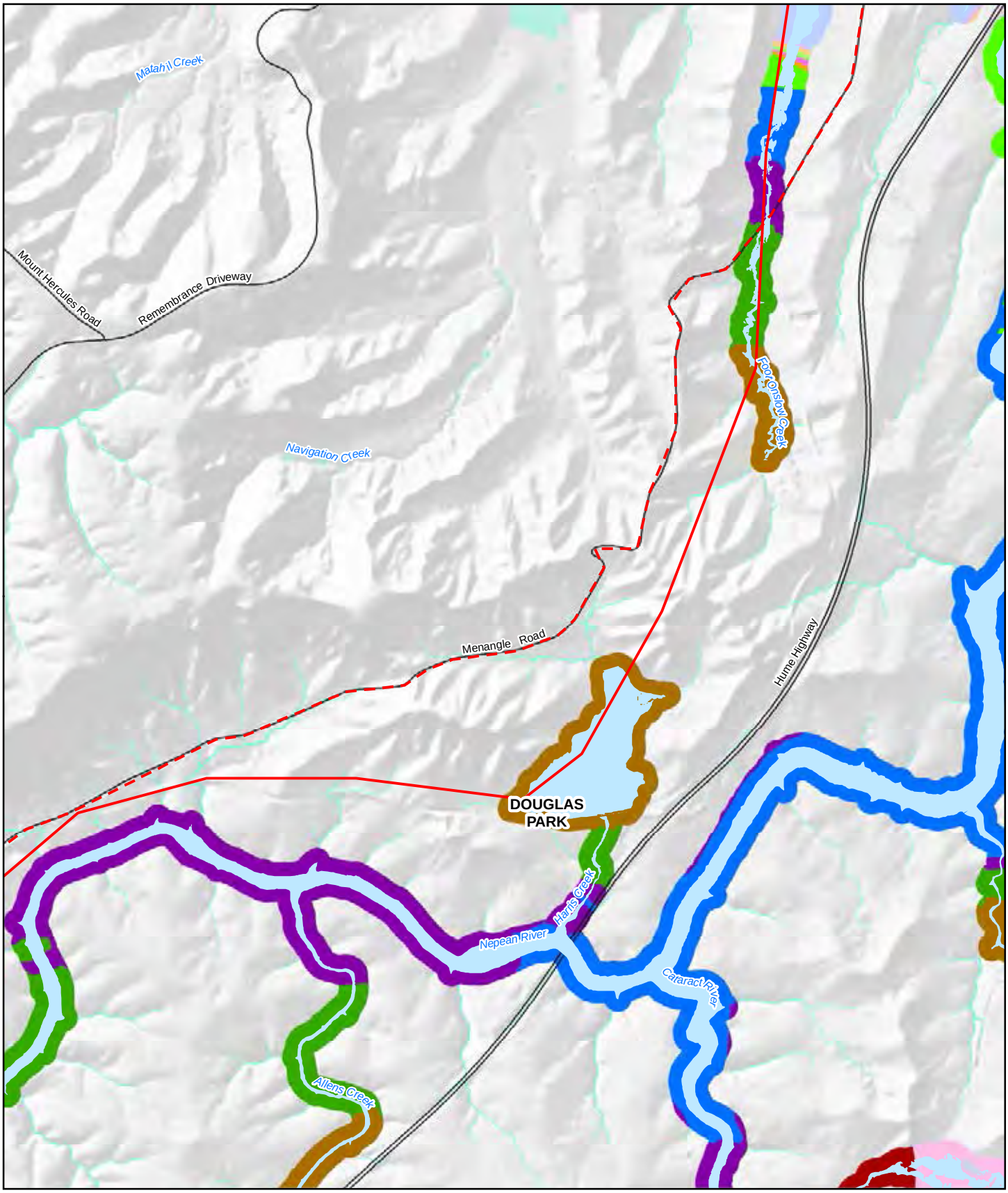
Figure F-4d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F004_DDP_Existing_20YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

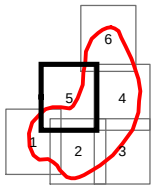


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 20 year Flood Levels and Extents - Sheet 5

Job Number	22-17728
Revision	0
Date	23 Jun 2015

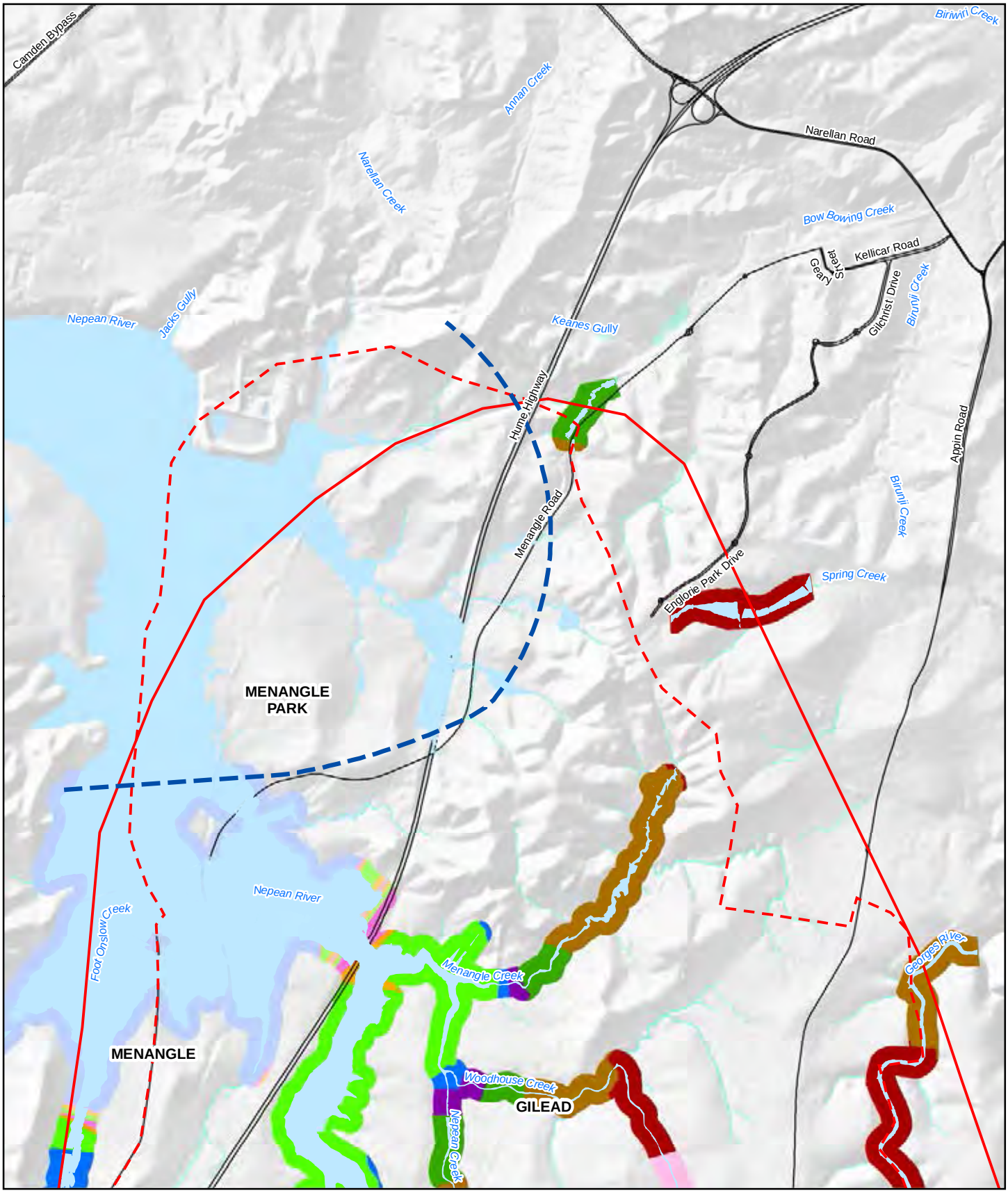
Figure F-4e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F004_DDP_Existing_20YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

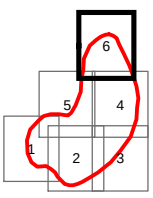


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 20 year Flood Levels and Extents - Sheet 6

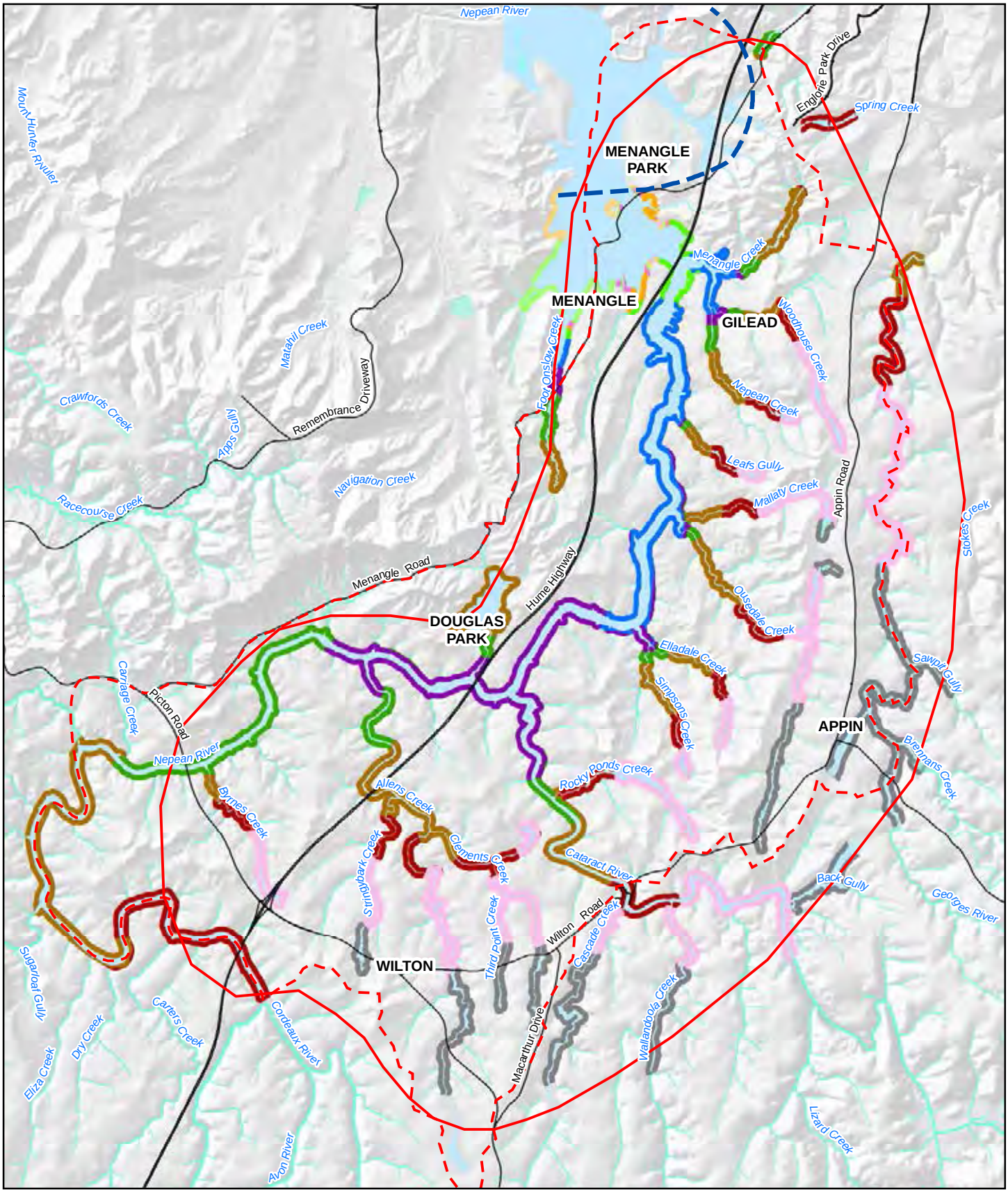
Figure F-4f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F004_DDP_Existing_20YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 100 year Flood Levels and Extents - Overall

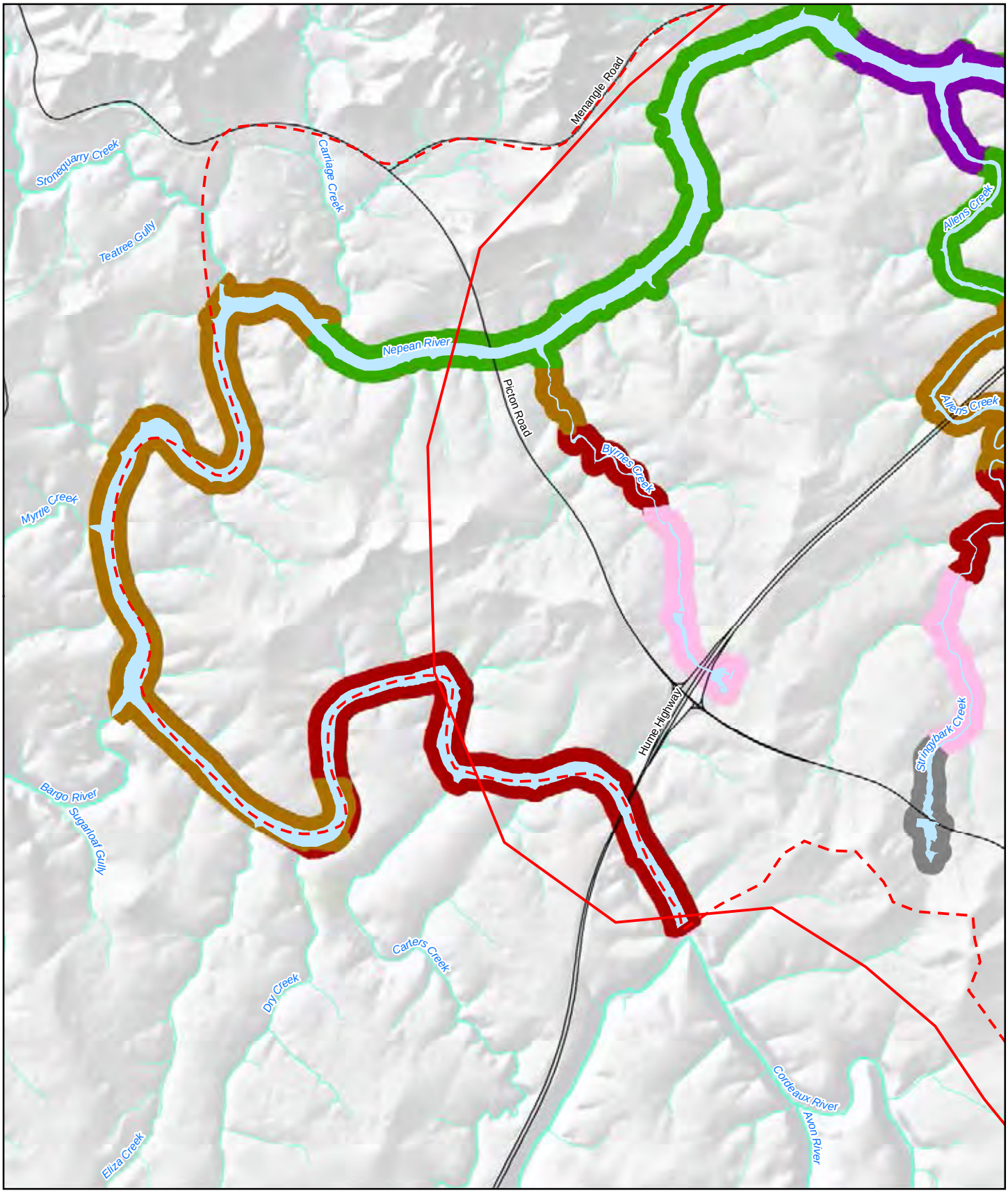
Figure F-5

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F005_Existing_100YR_Overall_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

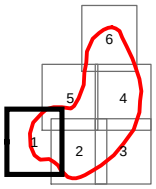


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 100 year Flood Levels and Extents - Sheet 1

Job Number 22-17728
Revision 0
Date 23 Jun 2015

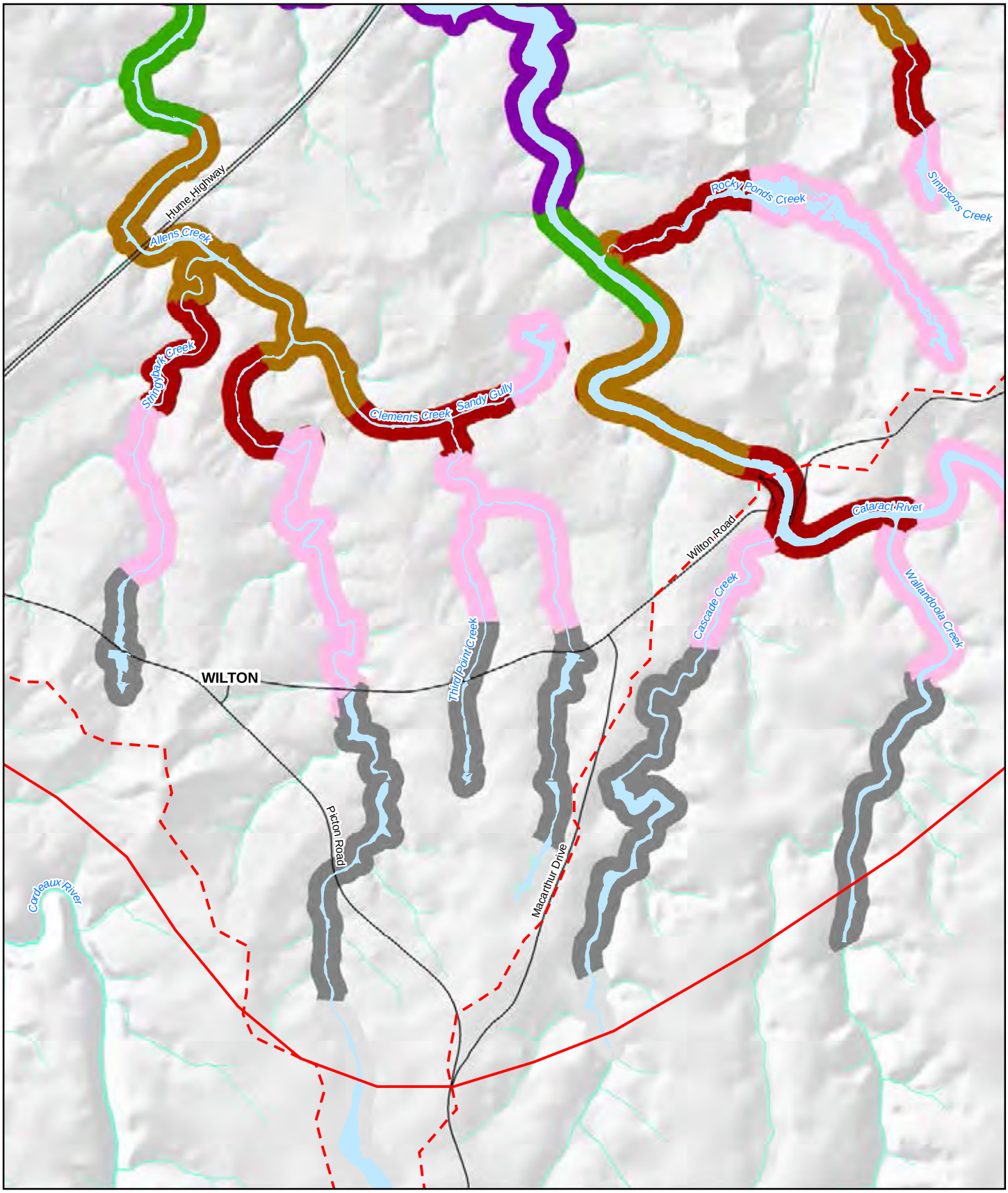
Figure F-6a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F006_DDP_Existing_100YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

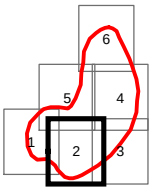


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 100 year Flood Levels and Extents - Sheet 2

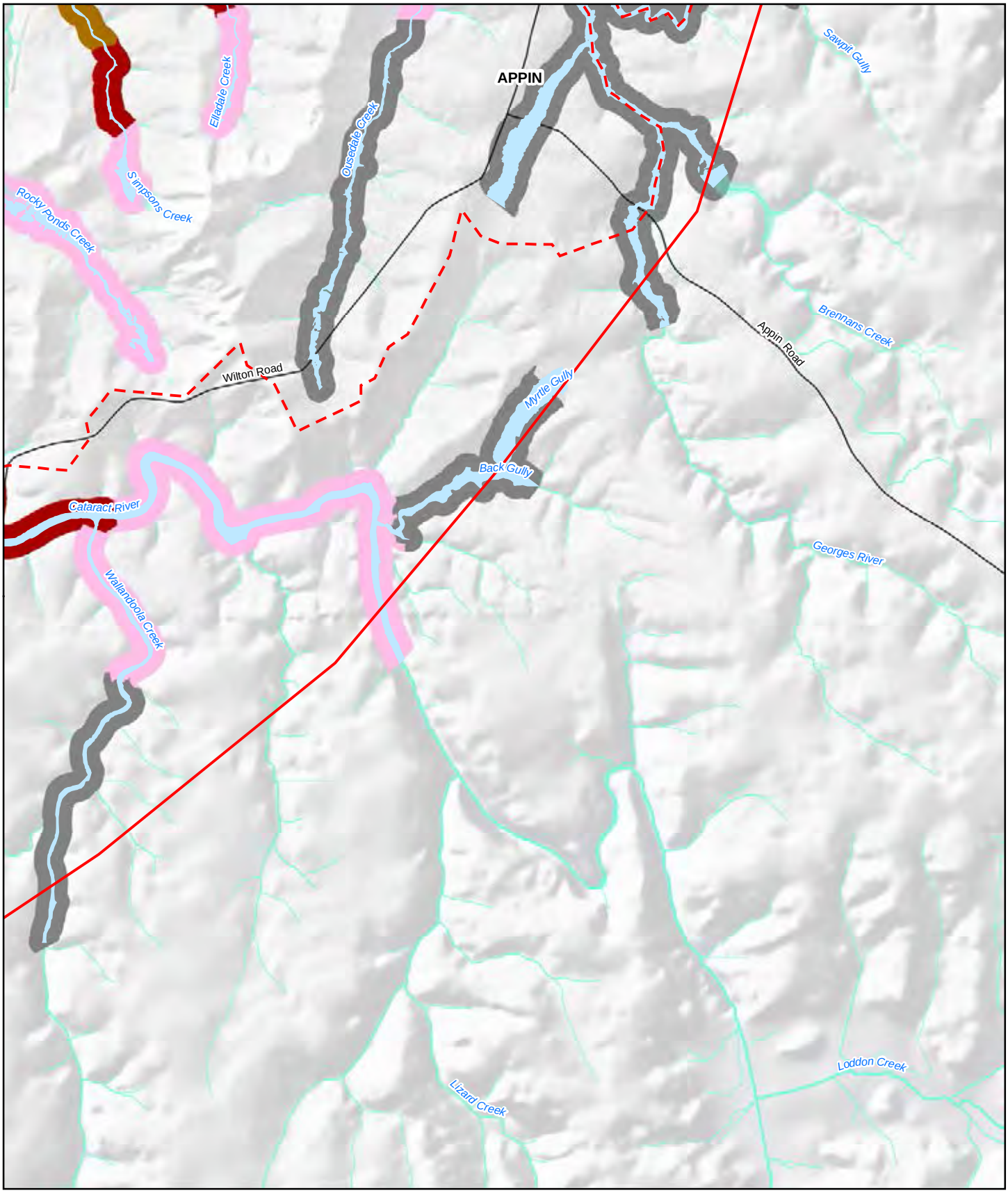
Figure F-6b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F006_DDP_Existing_100YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

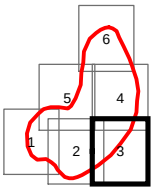


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 100 year Flood Levels and Extents - Sheet 3

Job Number	22-17728
Revision	0
Date	23 Jun 2015

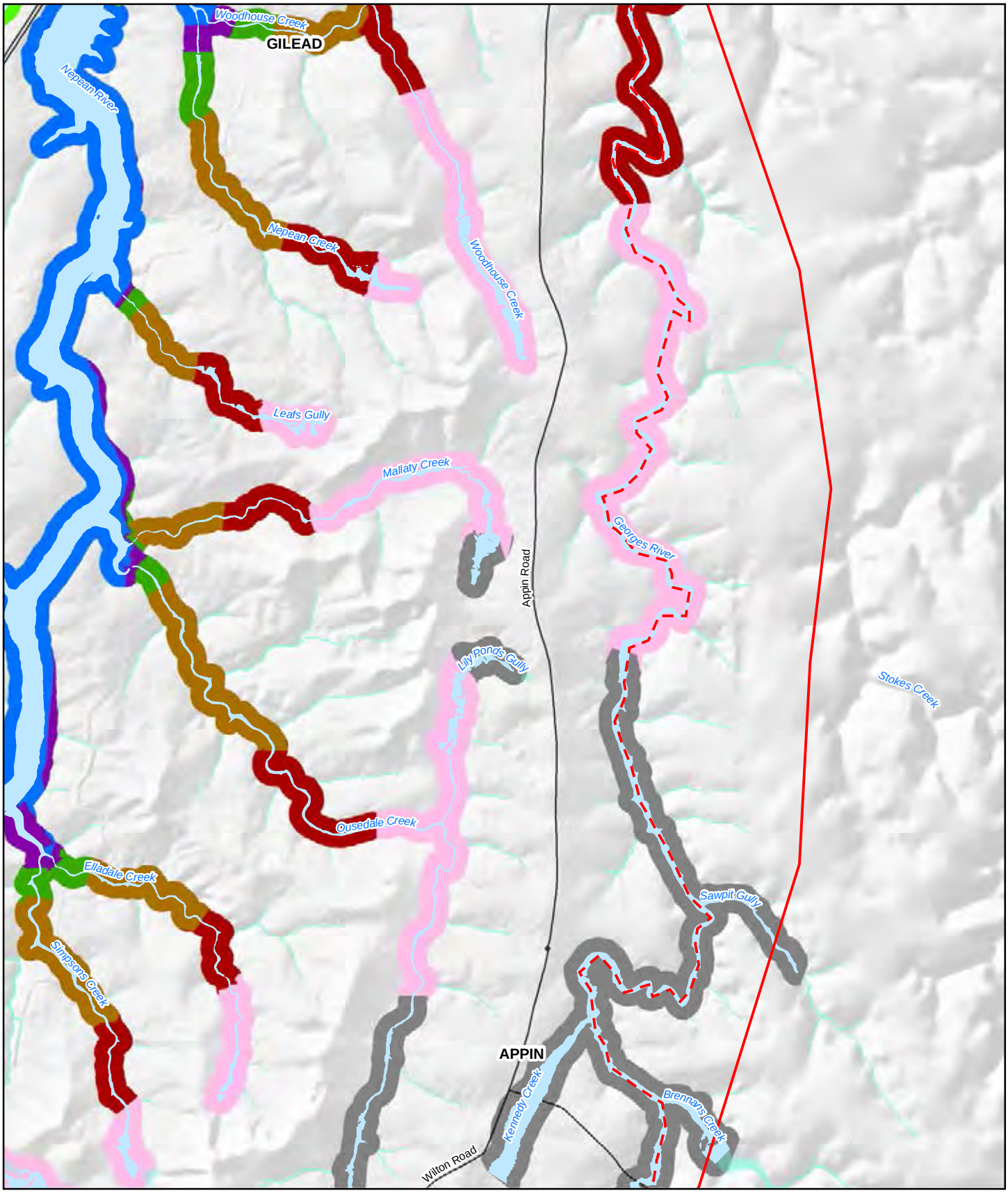
Figure F-6c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F006_DDP_Existing_100YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

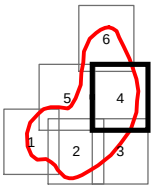


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 100 year Flood Levels and Extents - Sheet 4

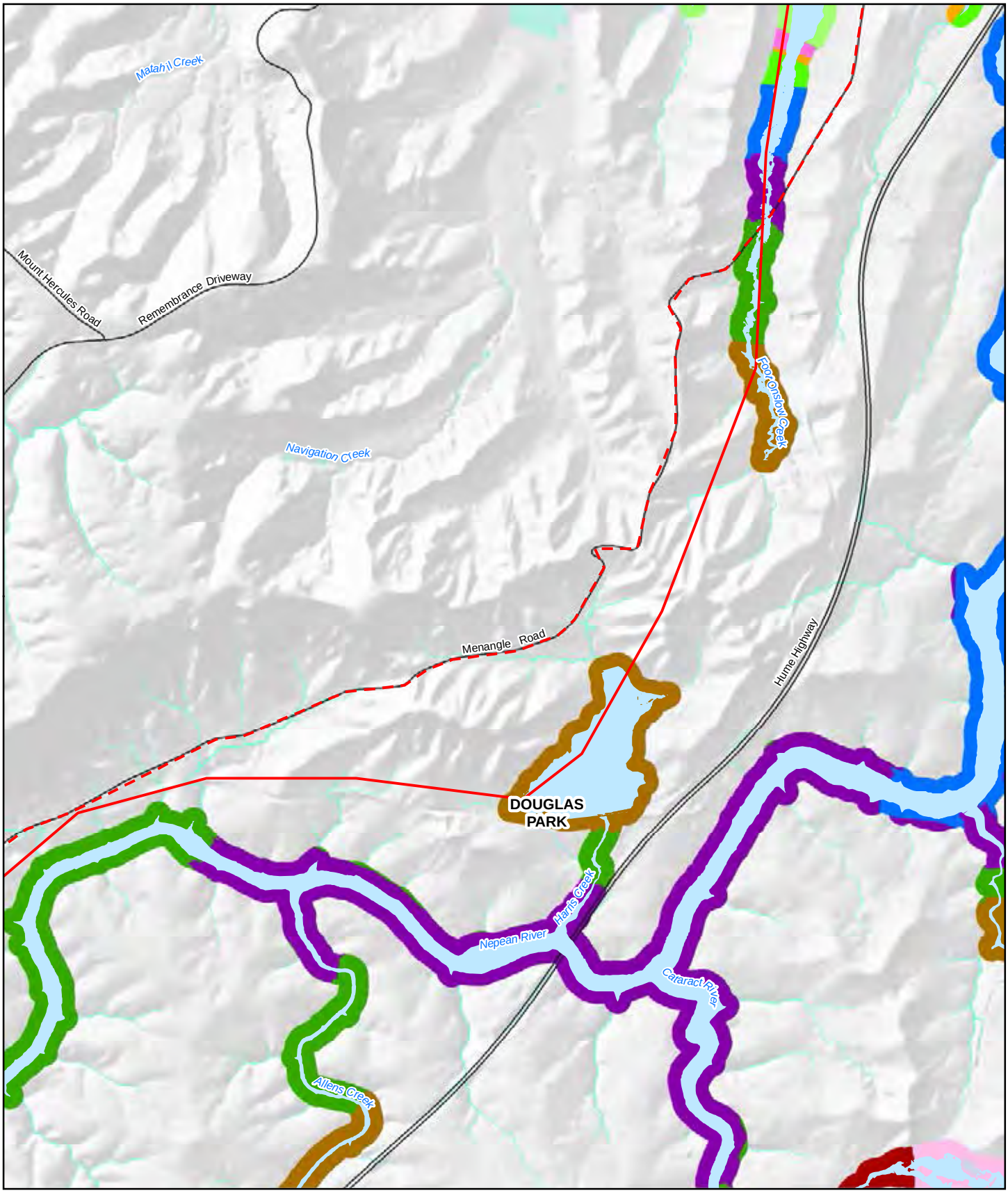
Figure F-6d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F006_DDP_Existing_100YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

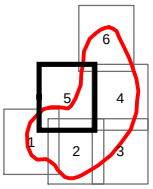


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 100 year Flood Levels and Extents - Sheet 5

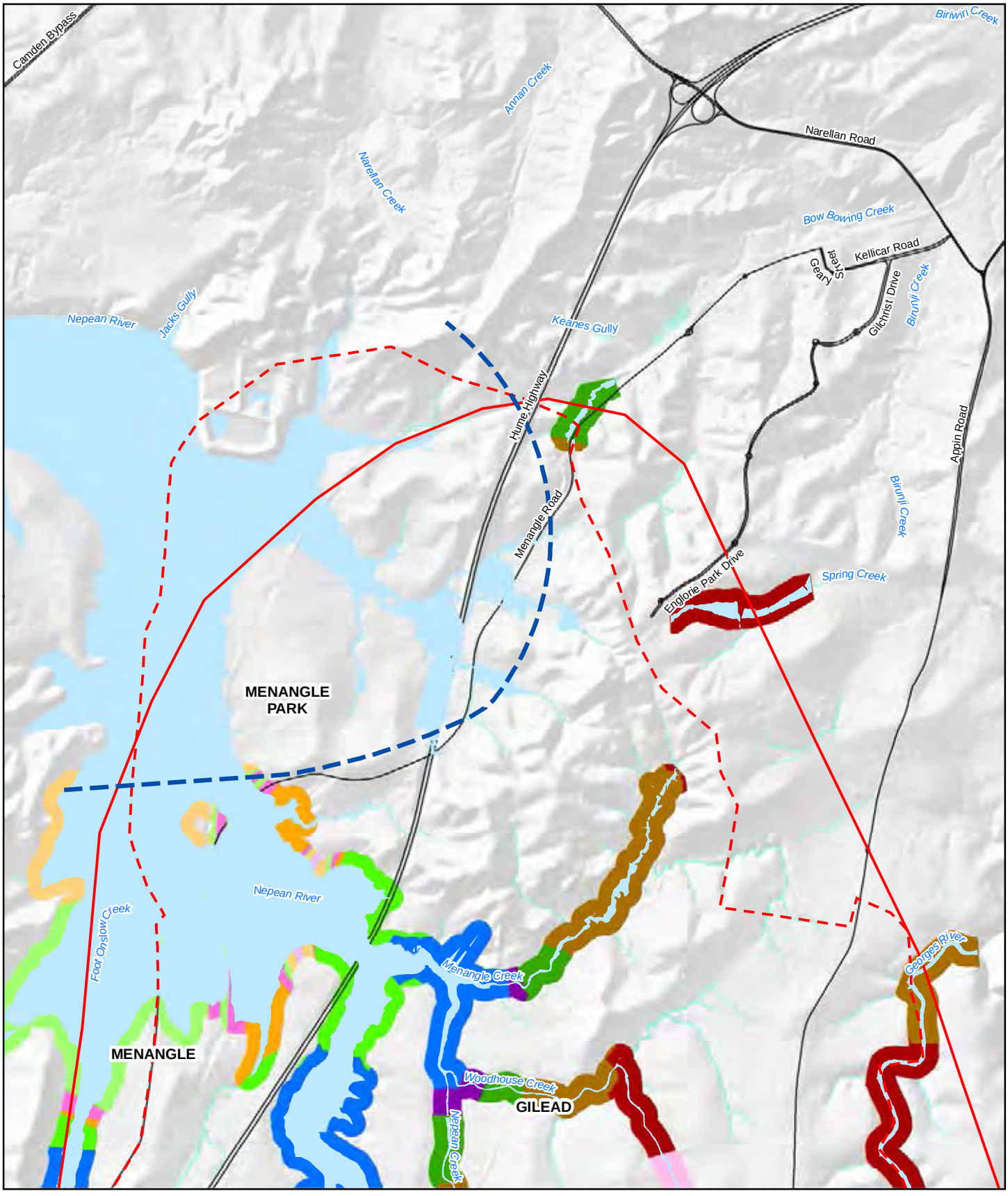
Figure F-6e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F006_DDP_Existing_100YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

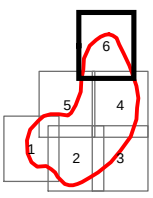


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 100 year Flood Levels and Extents - Sheet 6

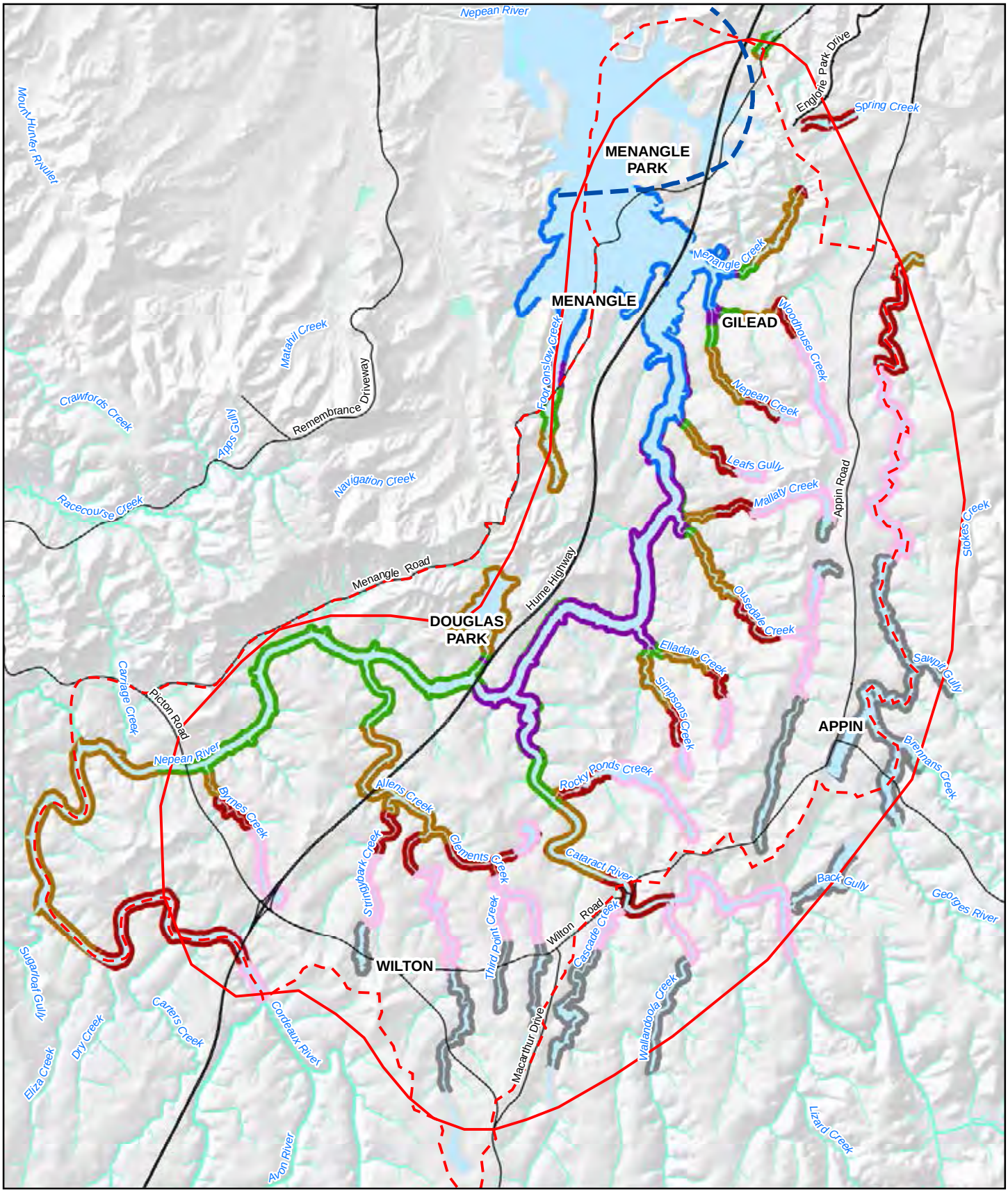
Figure F-6f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F006_DDP_Existing_100YR_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing PMF
Levels and Extents - Overall

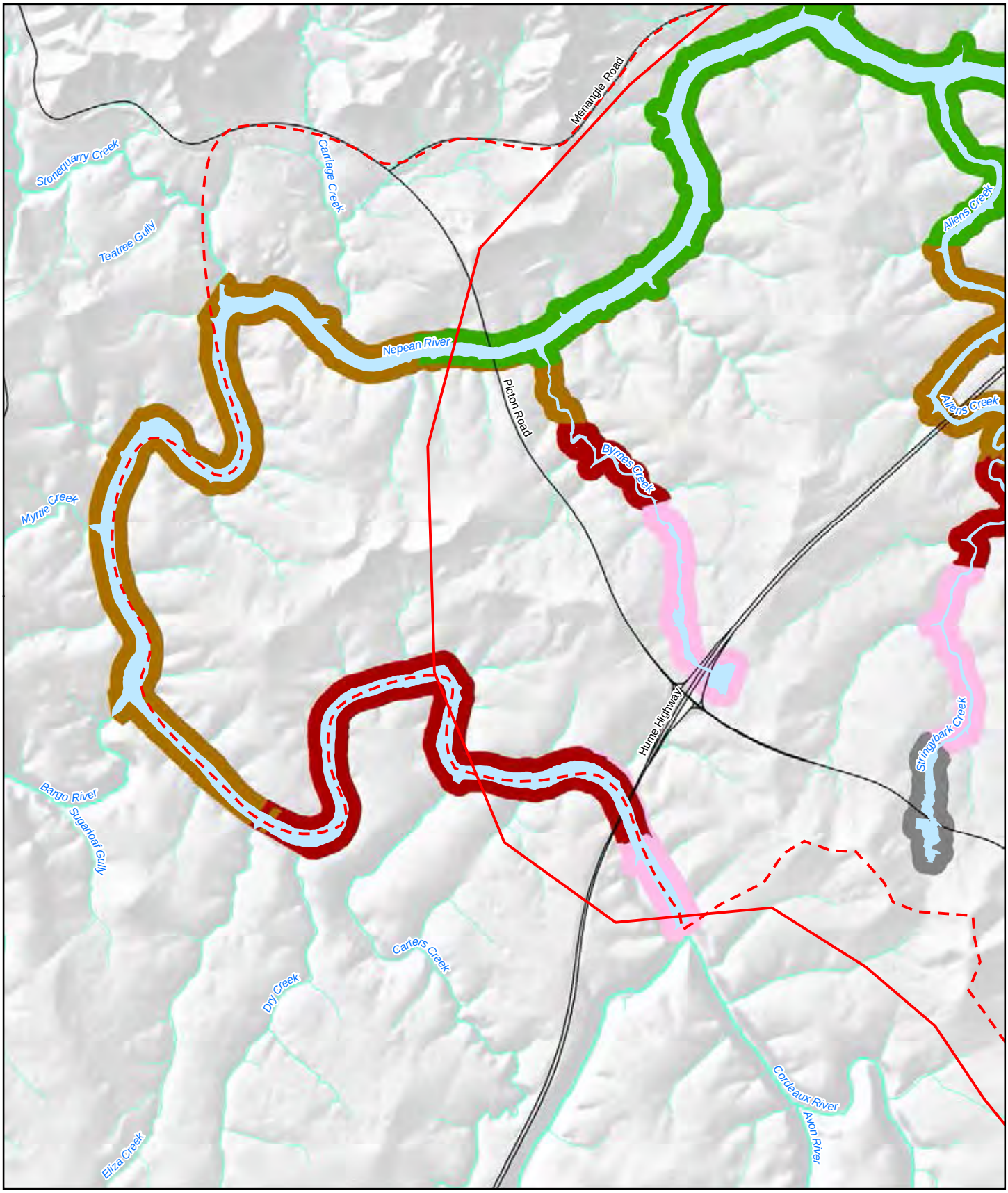
Figure F-7

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F007_Existing_PMF_Overall_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

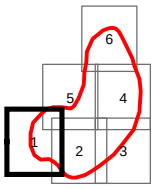


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing PMF Levels and Extents - Sheet 1

Job Number 22-17728
Revision 0
Date 23 Jun 2015

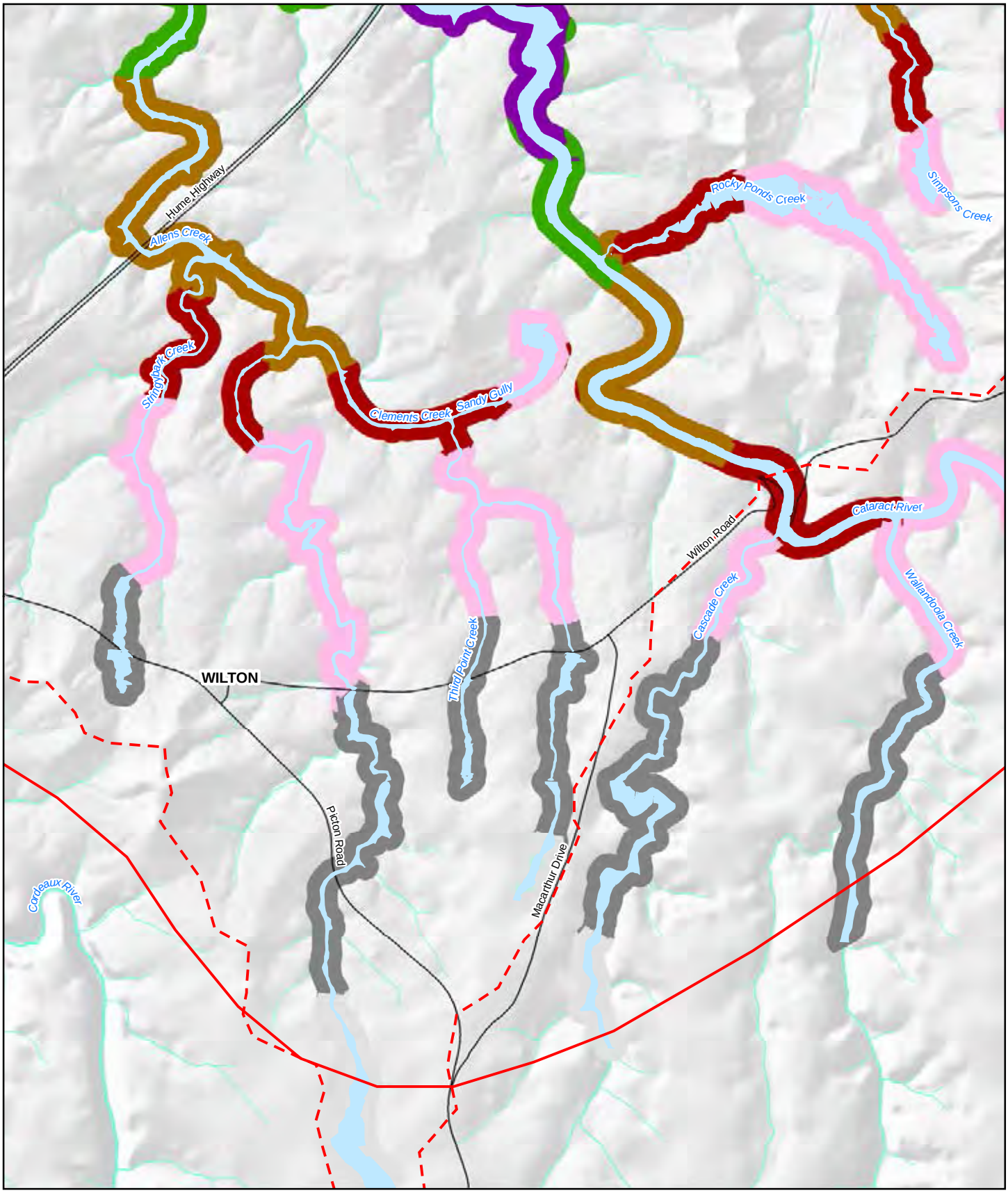
Figure F-8a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F008_DDP_Existing_PMF_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

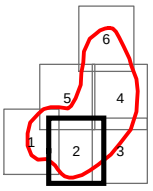


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing PMF Levels and Extents - Sheet 2

Job Number	22-17728
Revision	0
Date	23 Jun 2015

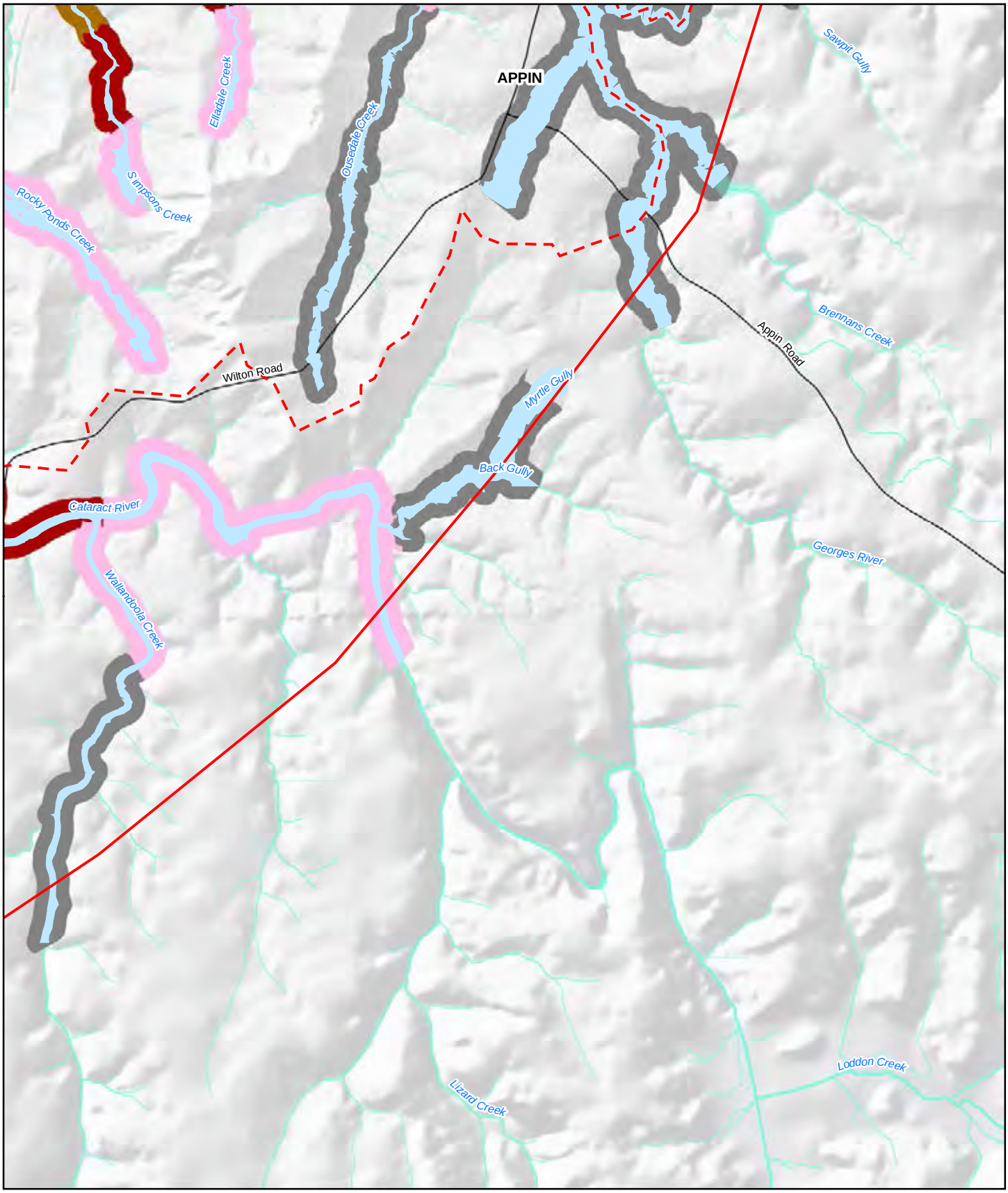
Figure F-8b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F008_DDP_Existing_PMF_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

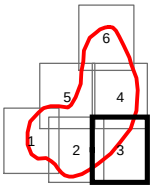


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing PMF Levels and Extents - Sheet 3

Job Number 22-17728
Revision 0
Date 23 Jun 2015

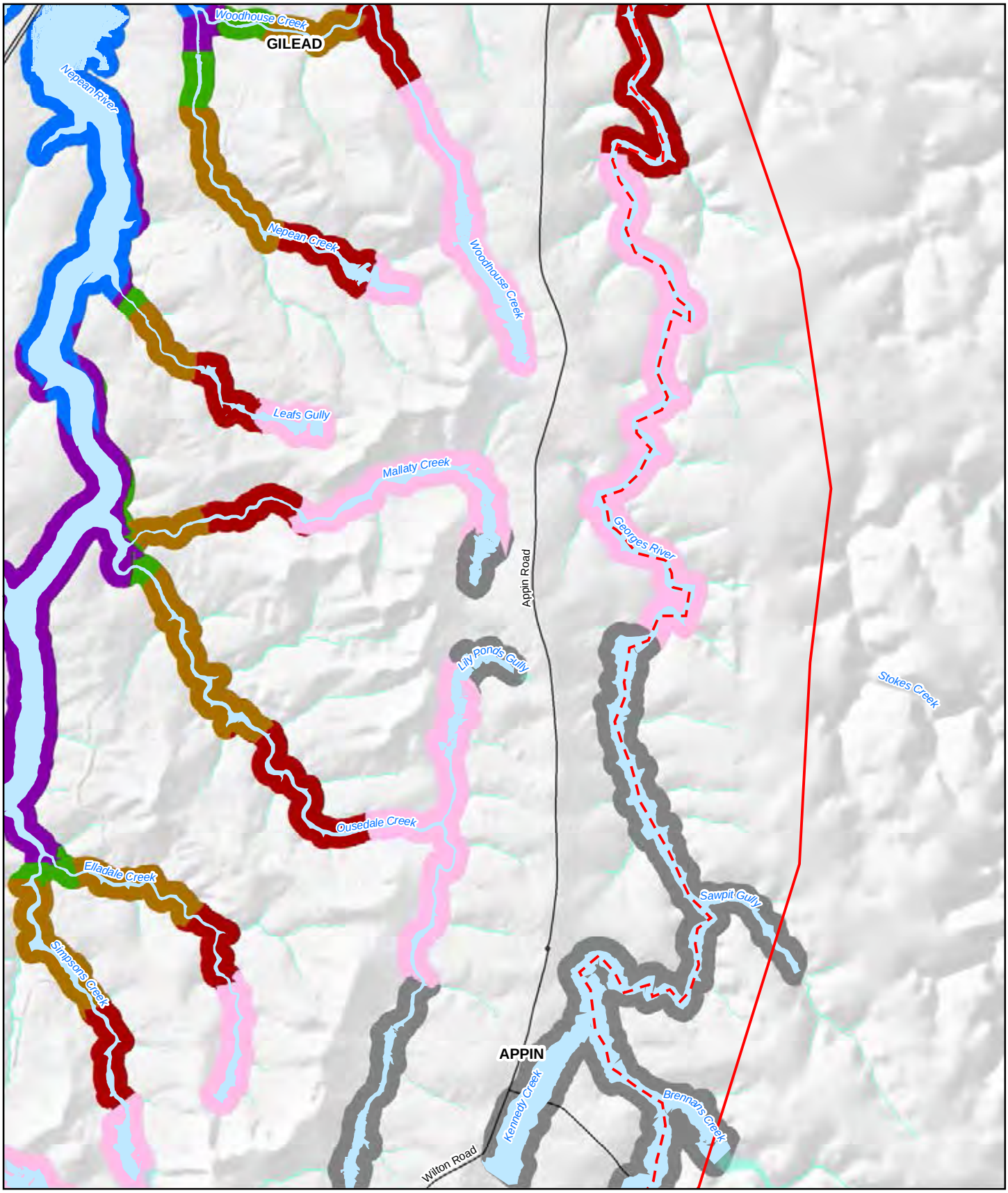
Figure F-8c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F008_DDP_Existing_PMF_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

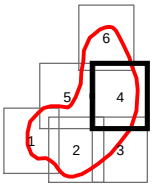


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Existing PMF Levels and Extents - Sheet 4

Job Number 22-17728
Revision 0
Date 23 Jun 2015

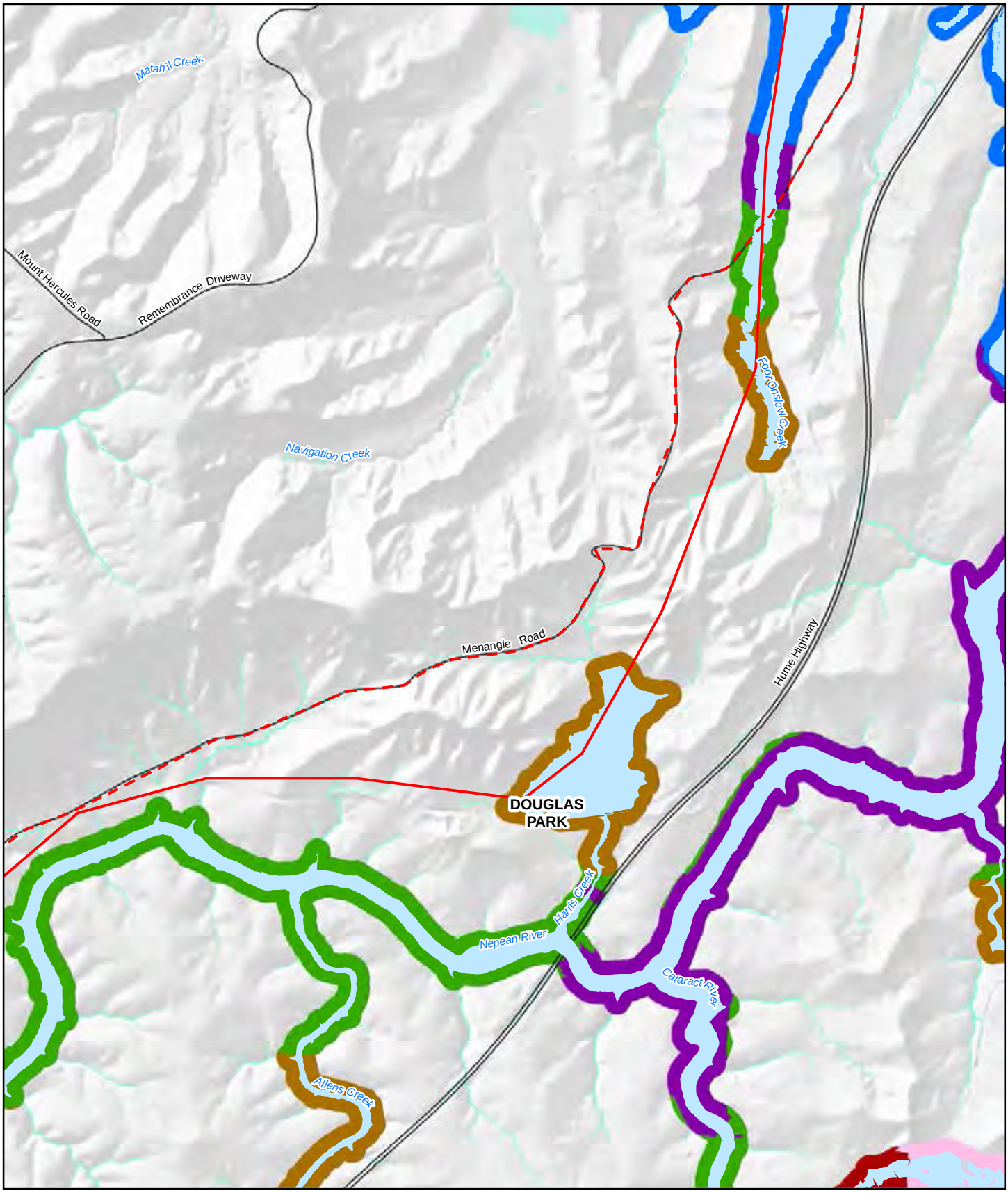
Figure F-8d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F008_DDP_Existing_PMF_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

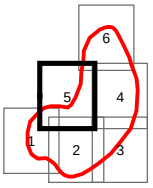


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing PMF Levels and Extents - Sheet 5

Job Number 22-17728
Revision 0
Date 23 Jun 2015

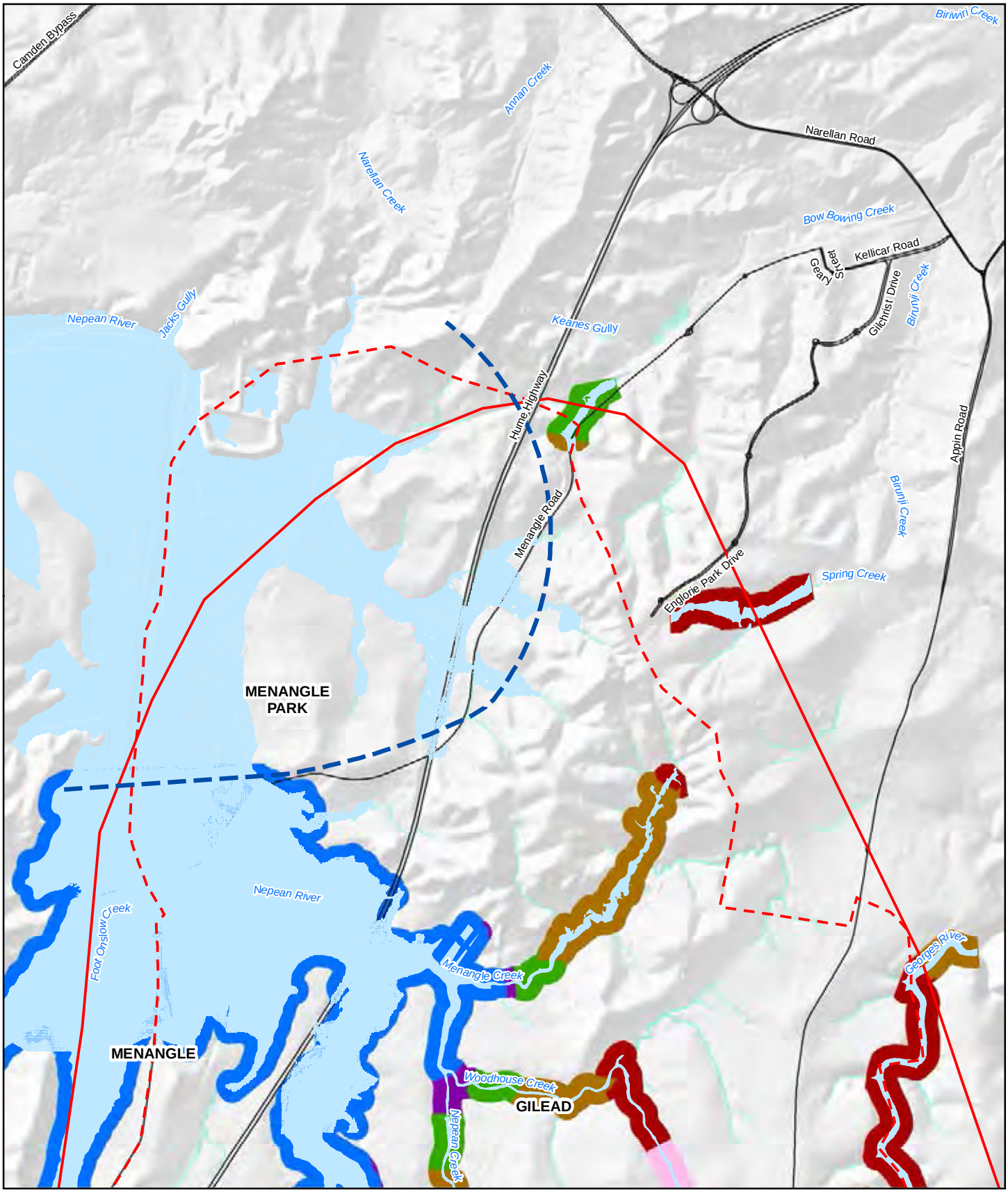
Figure F-8e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F008_DDP_Existing_PMF_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

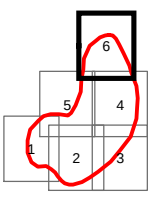


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Flood extent
- TuFlow Results Extent

Flood Level

< 77	77 - 77.2	77.2 - 77.4	77.4 - 77.6	77.6 - 77.8	77.8 - 78	78 - 80	80 - 85	85 - 90	90 - 100	100 - 125	125 - 150	150 - 200	200 - 250	> 250



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing PMF Levels and Extents - Sheet 6

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Figure F-8f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_F\2217728_F008_DDP_Existing_PMF_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

Appendix G – Velocity mapping

G.1 Result presentation

Design average flow velocities have been calculated for the 2, 20, and 100 year ARI existing conditions design events together with a PMF event as described in Appendix E.

For the 20 and 100 year ARI events and the PDF event the results are provided as follows:

- An overall image
- Six detail sheets

The overall image shows the predicted flow velocities in 1m/s increments up to 4 m/s with all velocities in excess of that value being shown as greater than 4 m/s.

The post processing of the hydraulic analysis results has permitted the estimation of the flow velocity across each cross-section where the HEC-RAS model was used to quantify the flood behaviour. This has resulted in the prediction of varying flow velocities across most cross sections.

On the figures in this Appendix the width of the flow is shown by the width of the colour shading at each cross section. All the figures use the same colour ramp.

The series of six detail sheets, using the same colour ramp definition, were then provided to give an enhanced definition of the levels across the Subject Site.

Detailed flood profiles, together with tabulated design flood levels are provided in Appendix J.

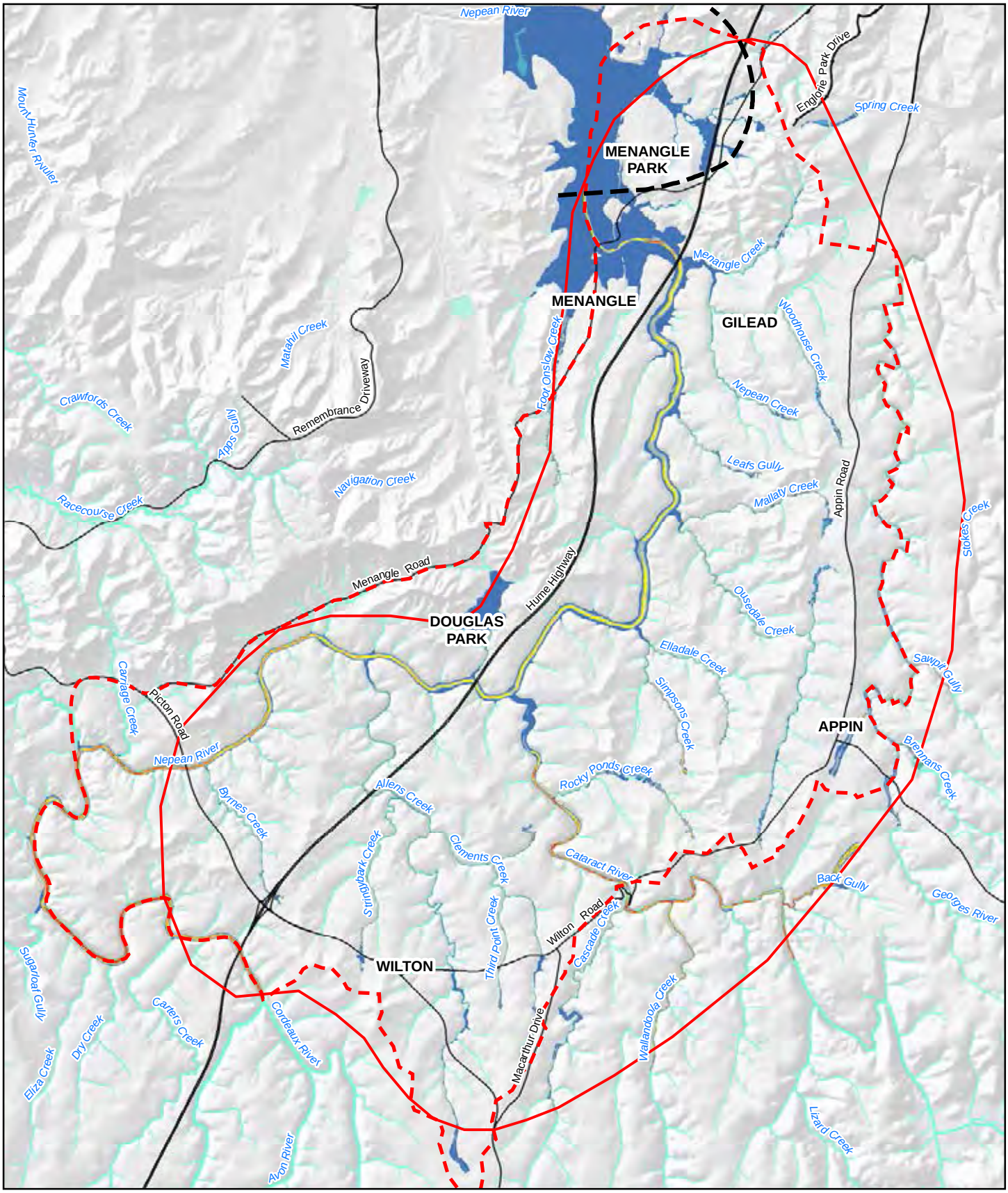
G.2 Flow velocity comparisons

The colour ramp was selected to permit the use of the same colour ramp on all flood maps. This permits a relatively quick comparison of the change in flow velocities and the distribution of flow velocities for the 20 and 100 year ARI events together with the PMF can be determined by comparing the location of the colour banding along the watercourses shown on Figures G-1, G-3 and G-5. More detailed results for the velocities are shown on Figures G-2, G-4 and G-6.

G.3 Interpretation

The flow velocity along the lower reaches of the Nepean River was relatively low, for all events, compared to the velocity in the tributary watercourses.

There were a significant number of locations where the flow velocity was predicted to exceed a value of 4 m/s.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent

Velocity

<1	1 - 2	2 - 3	3 - 4	>4

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

20 Year ARI Flood Velocities

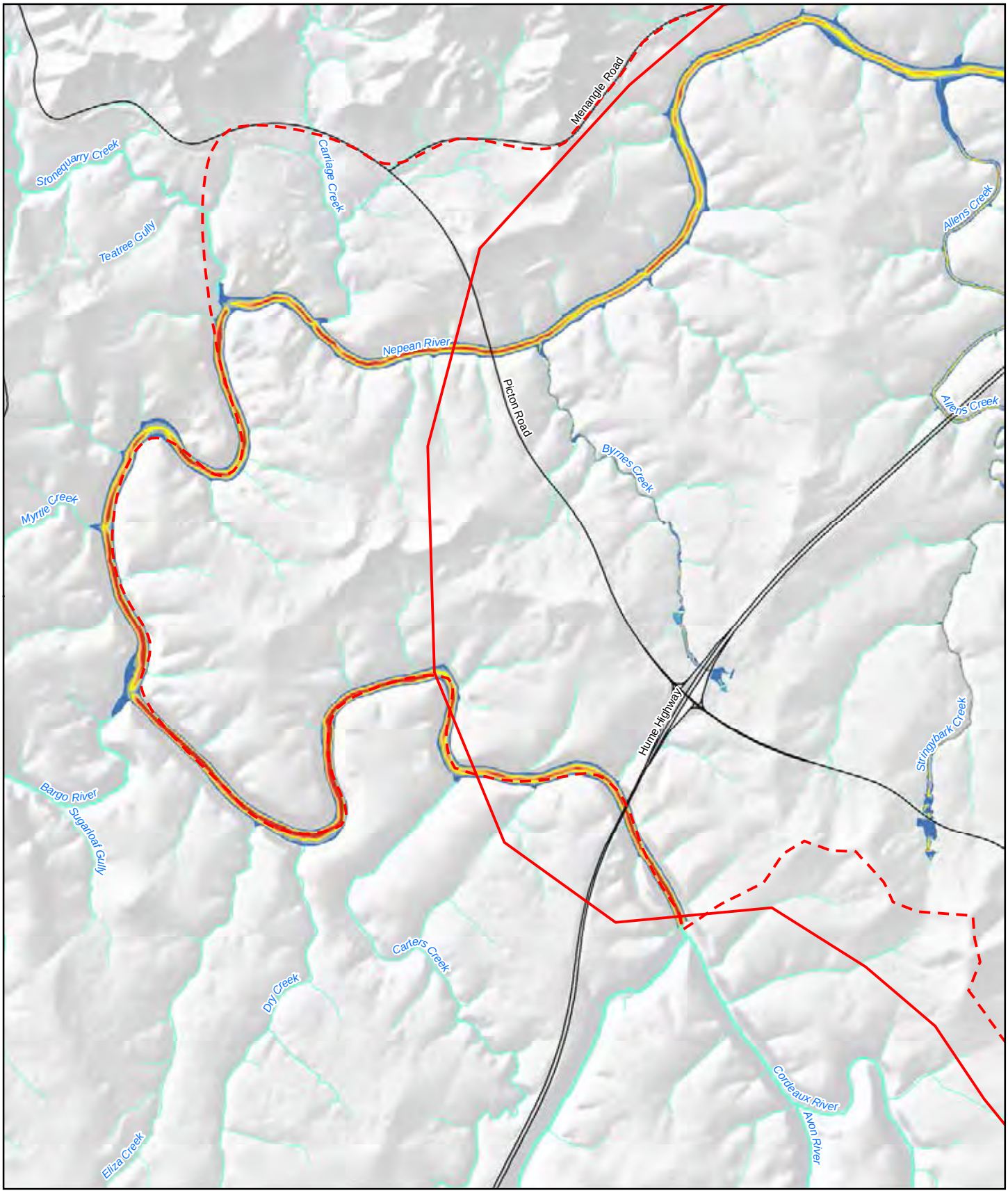
Figure G-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G003_20YR_Velocity_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

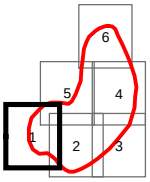


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

20 Year ARI Flood Velocities

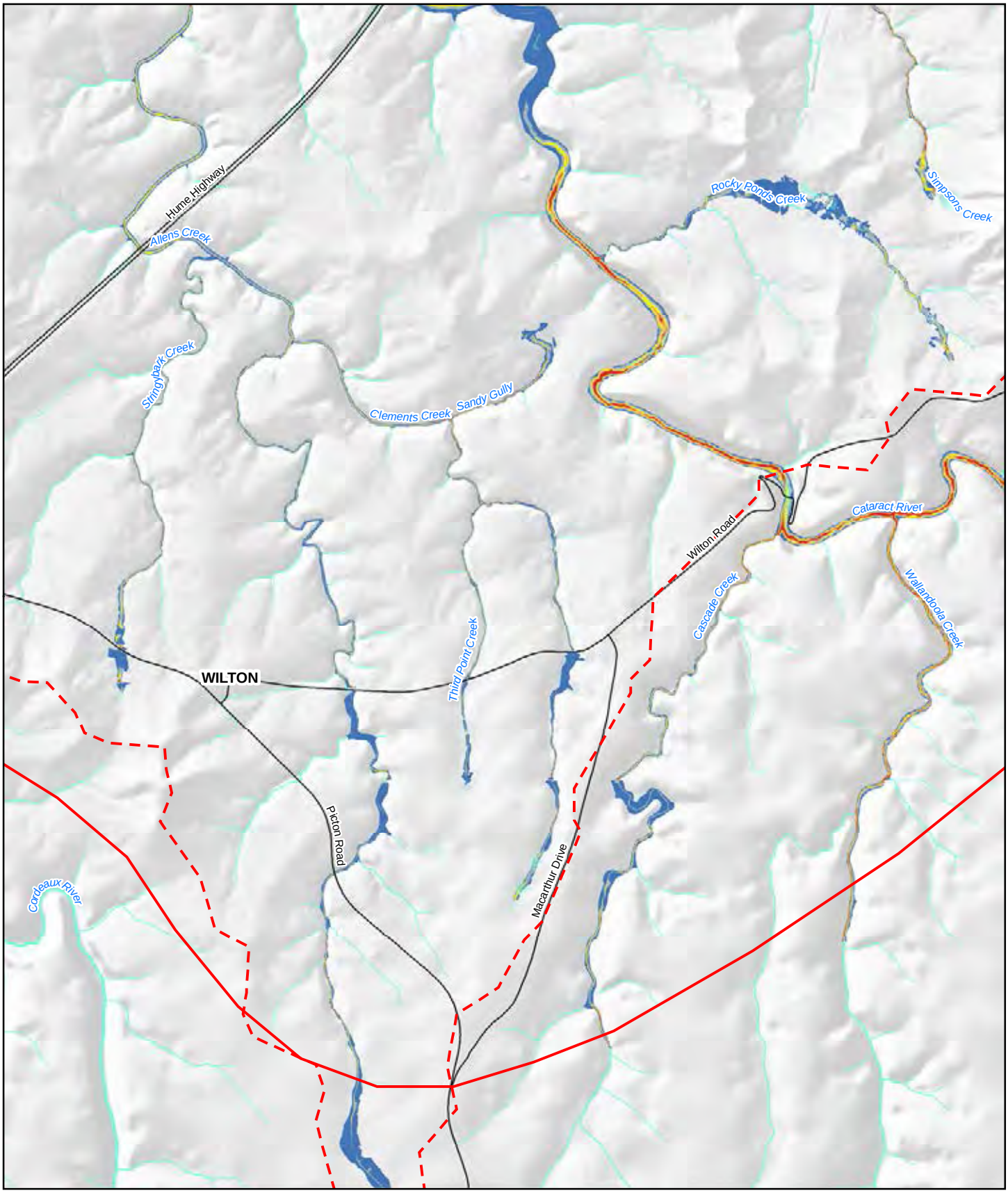
Figure G-2a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G004_DDP_Existing_20YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

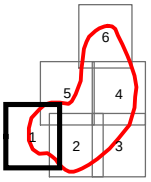


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

20 Year ARI Flood Velocities

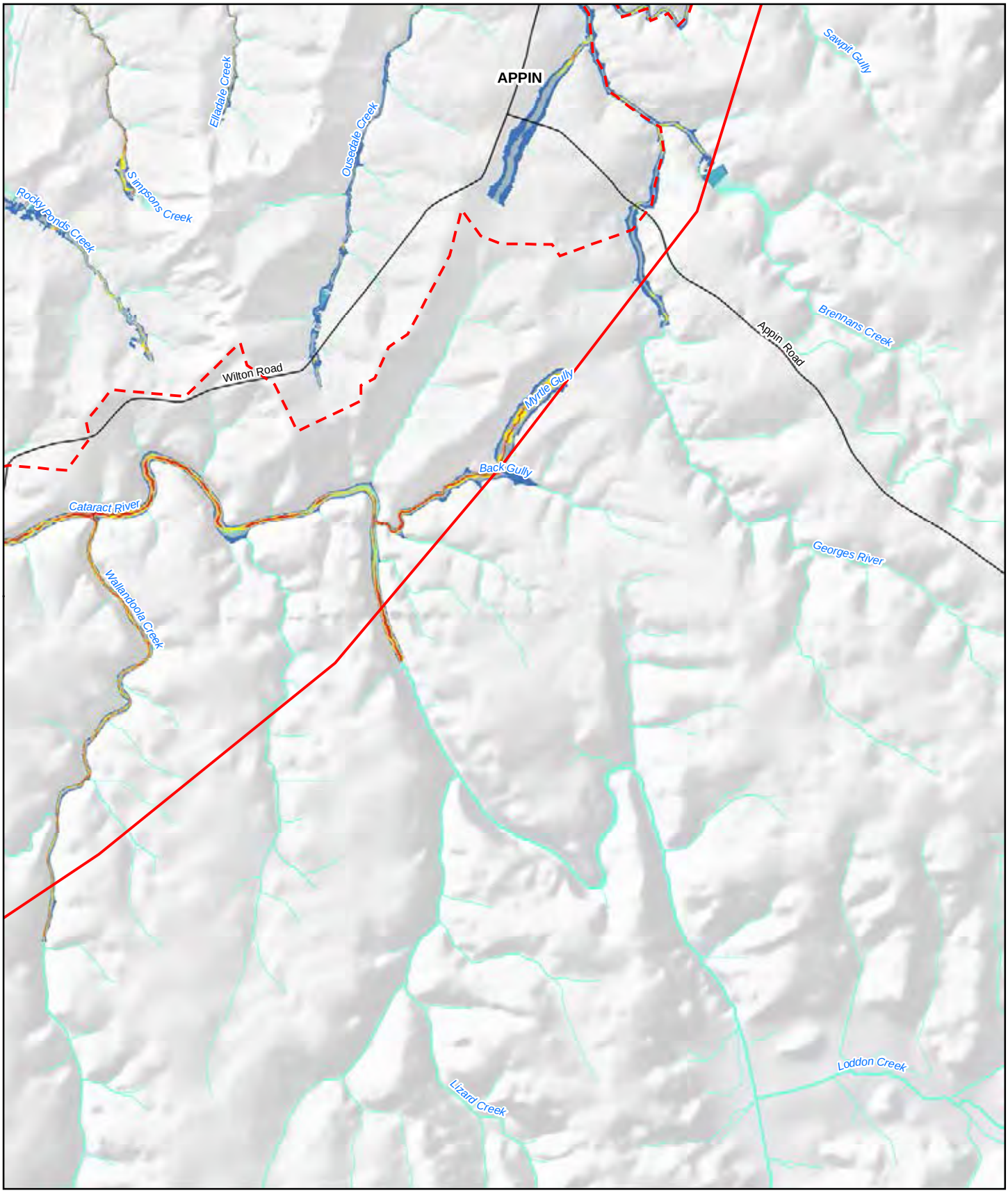
Figure G-2b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G004_DDP_Existing_20YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

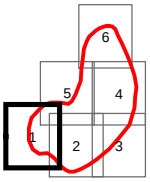


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

20 Year ARI Flood Velocities

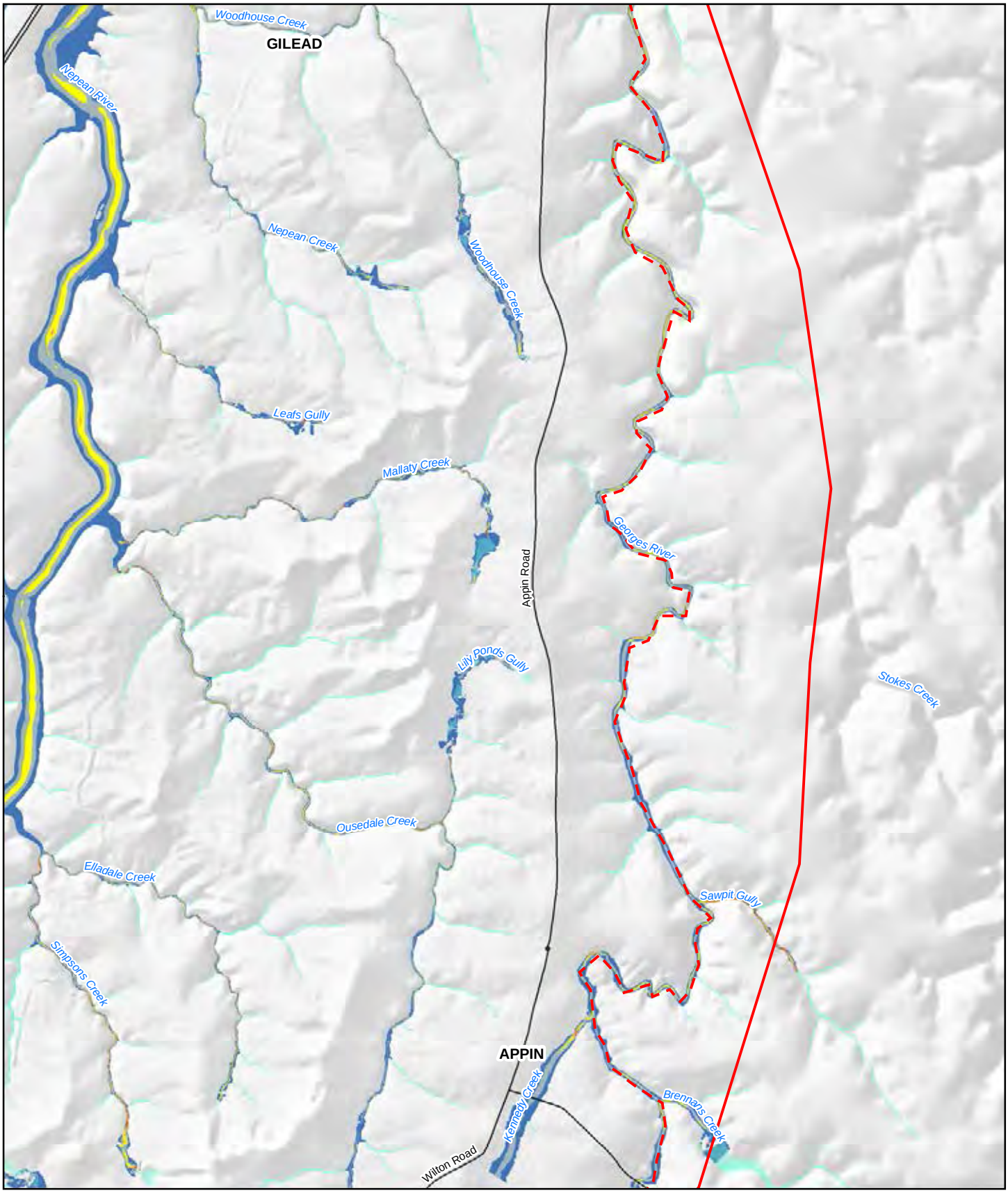
Figure G-2c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G004_DDP_Existing_20YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

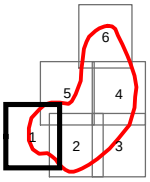


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

20 Year ARI Flood Velocities

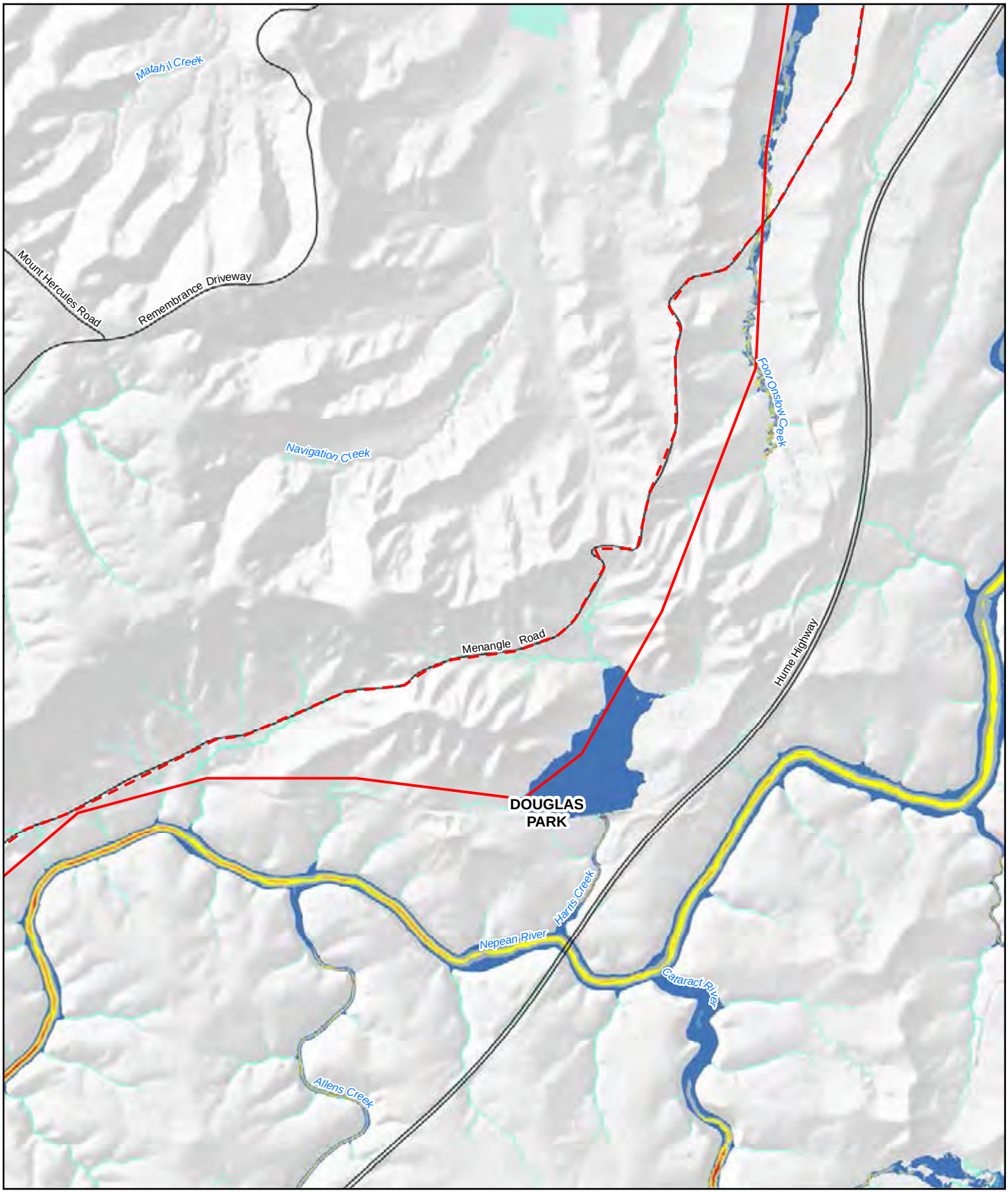
Figure G-2d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G004_DDP_Existing_20YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

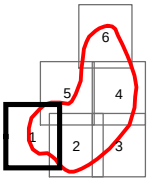


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

20 Year ARI Flood Velocities

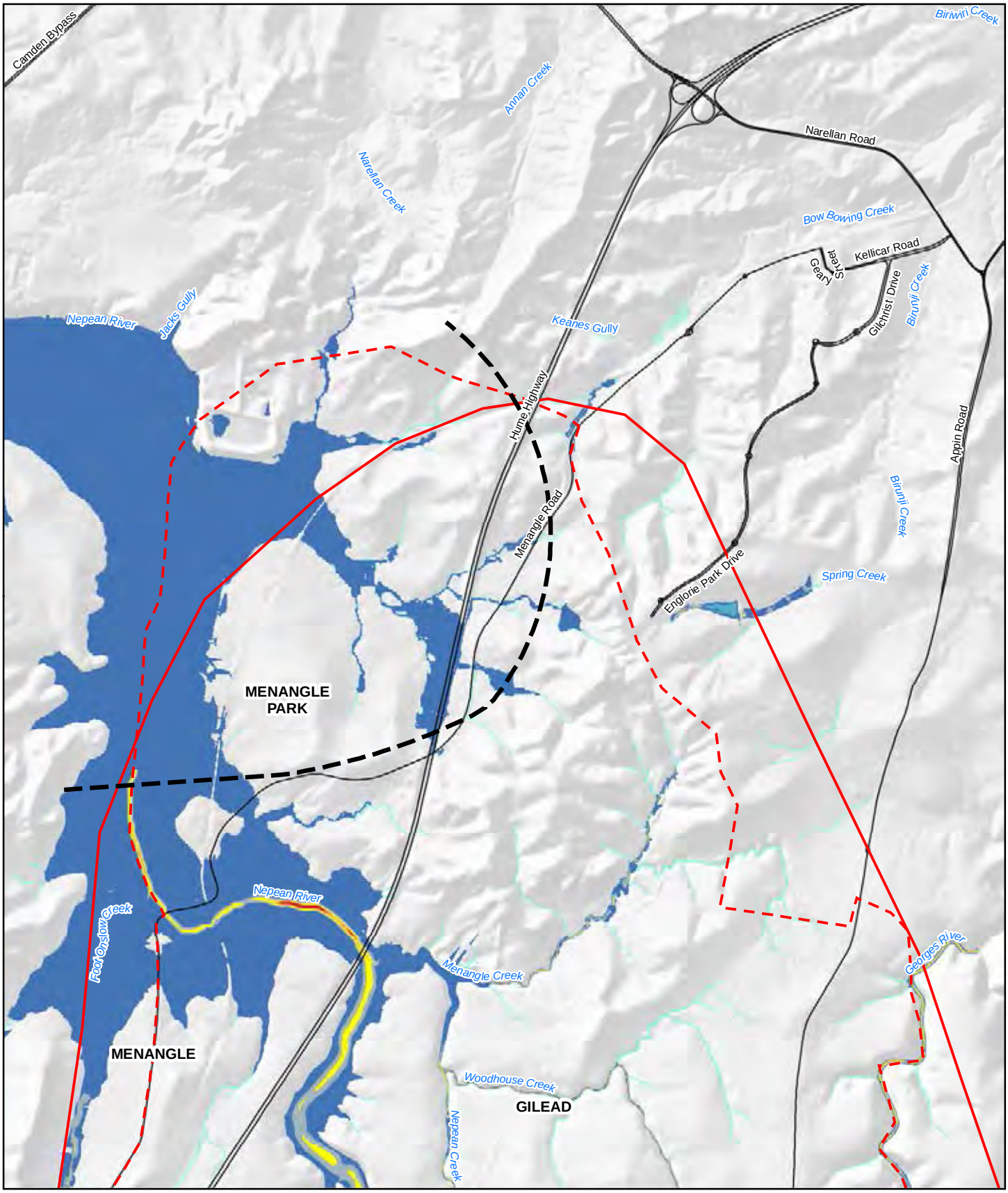
Figure G-2e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G004_DDP_Existing_20YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

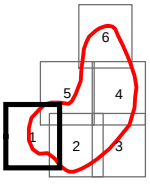


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

20 Year ARI Flood Velocities

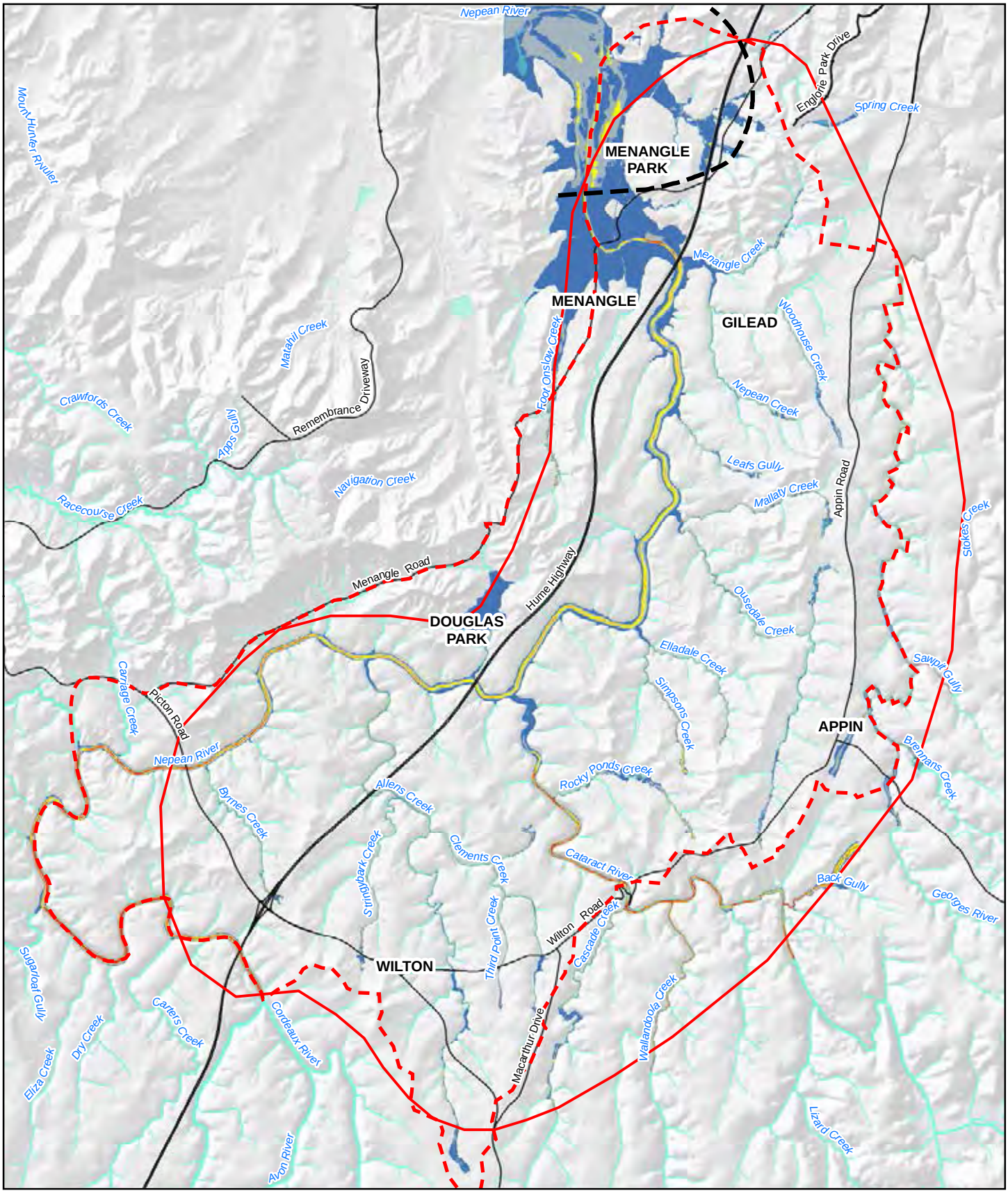
Figure G-2f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G004_DDP_Existing_20YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent

Velocity

<1	1 - 2	2 - 3	3 - 4	>4

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

100 Year ARI Flood Velocities

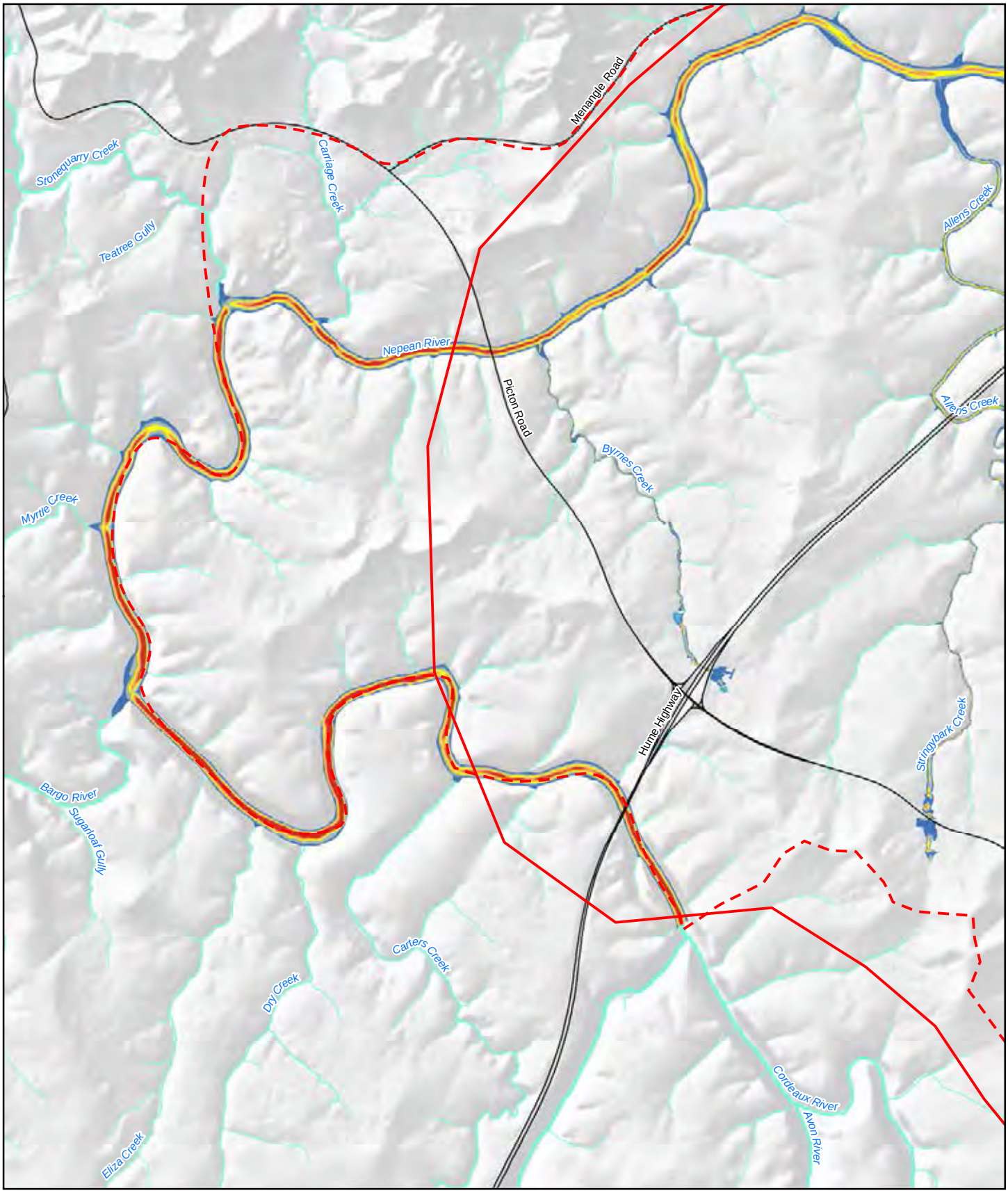
Figure G-3

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G005_100YR_Velocity_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

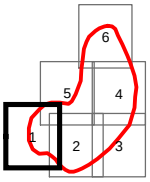


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flood Velocities

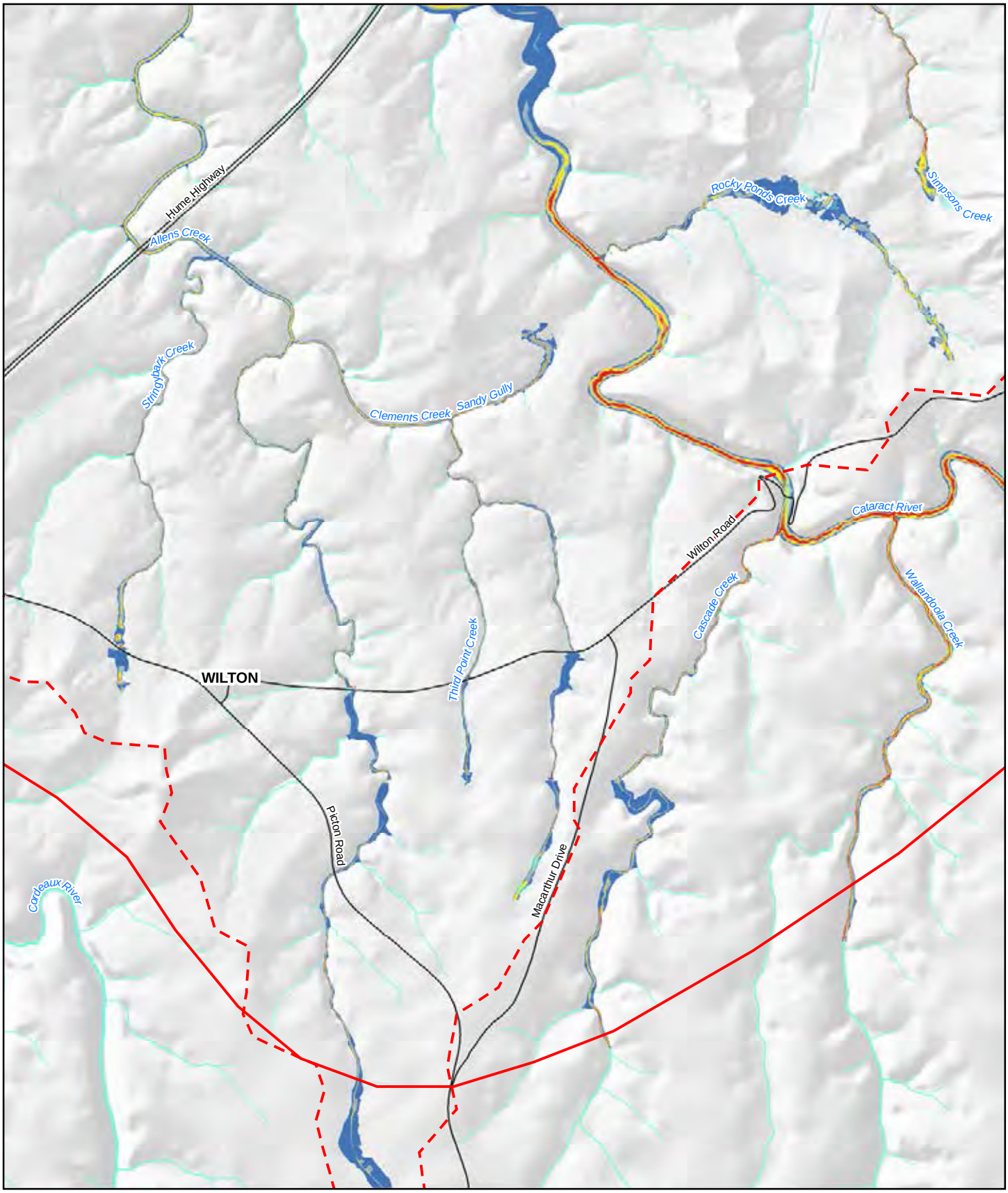
Figure G-4a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G006_DDP_Existing_100YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

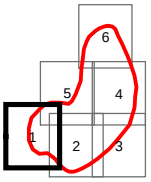


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

100 Year ARI Flood Velocities

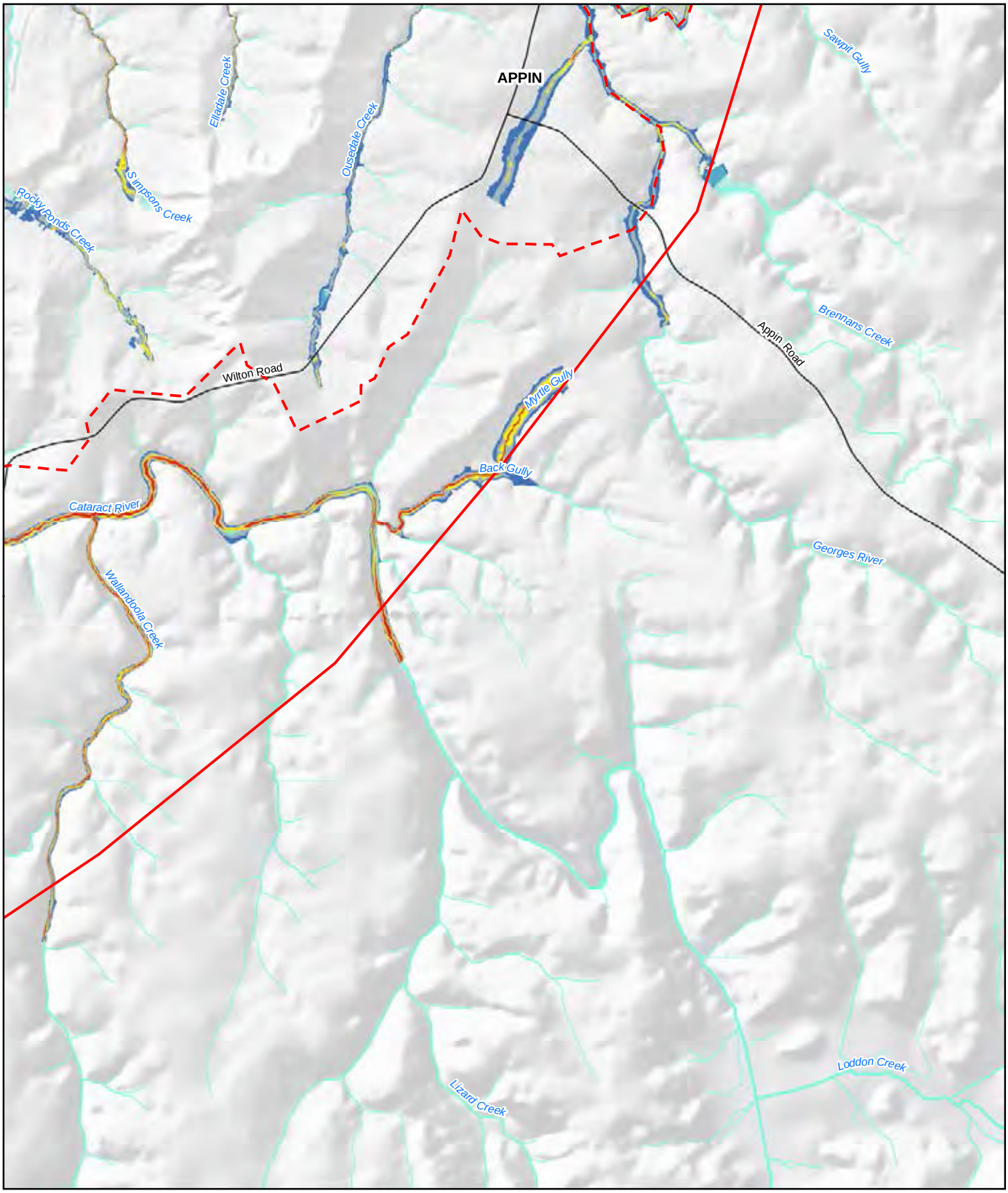
Figure G-4b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G006_DDP_Existing_100YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

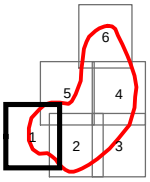


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flood Velocities

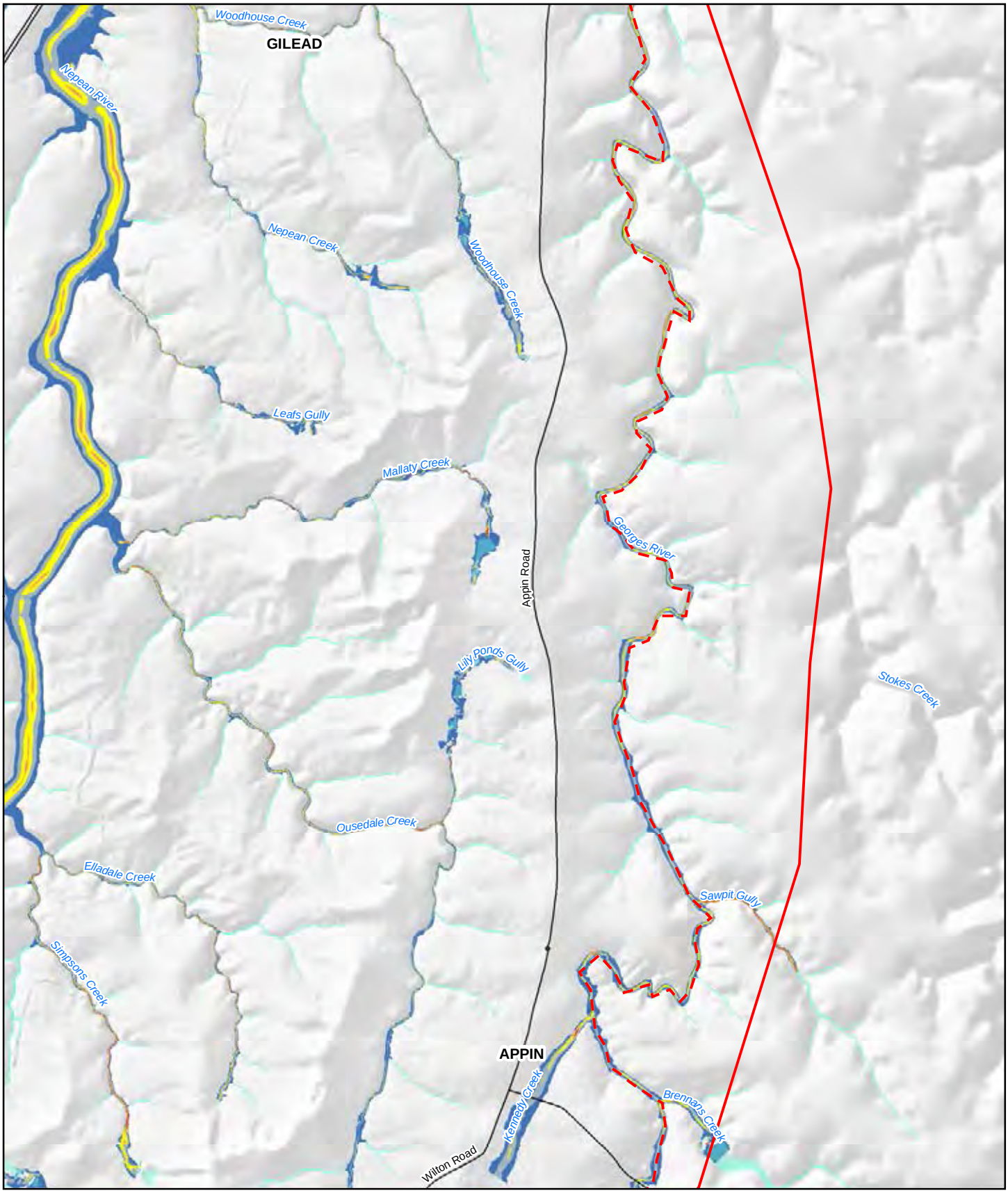
Figure G-4c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G006_DDP_Existing_100YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

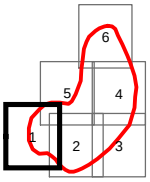


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

100 Year ARI Flood Velocities

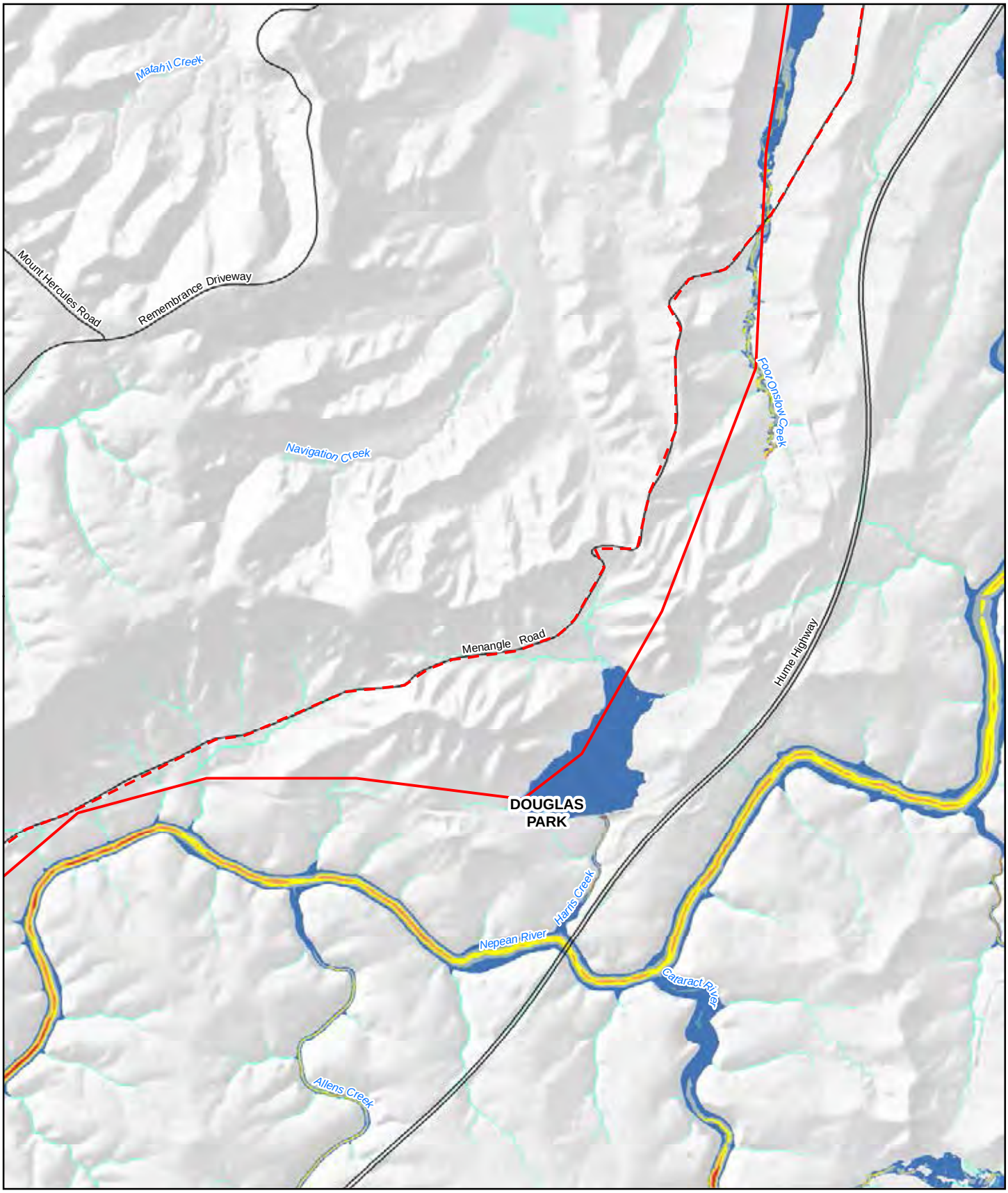
Figure G-4d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G006_DDP_Existing_100YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

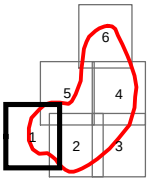


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

100 Year ARI Flood Velocities

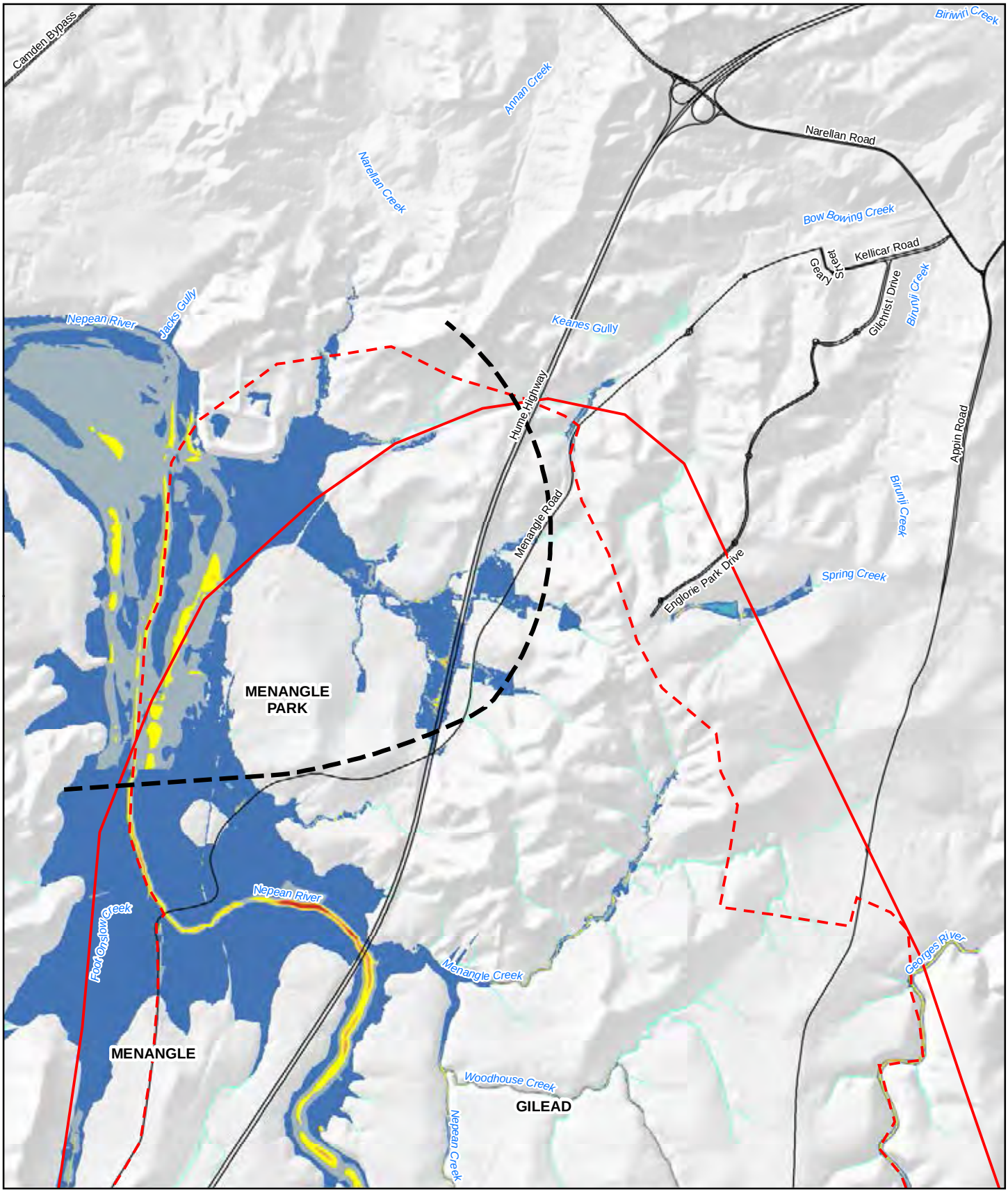
Figure G-4e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G006_DDP_Existing_100YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

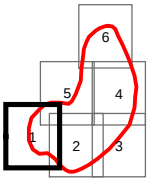


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

100 Year ARI Flood Velocities

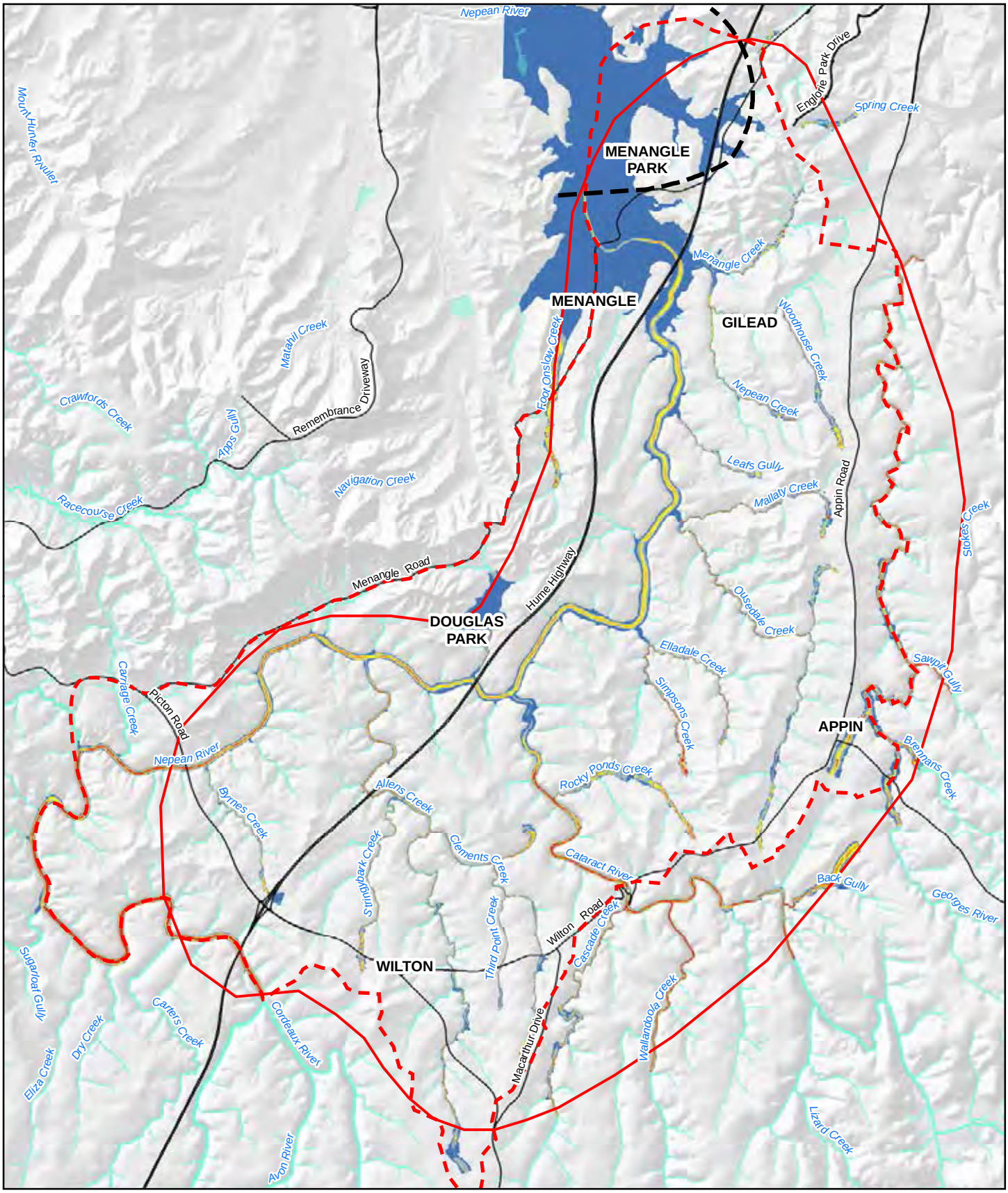
Figure G-4f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G006_DDP_Existing_100YR_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent

Velocity

<1	1 - 2	2 - 3	3 - 4	>4

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

PMF Velocities

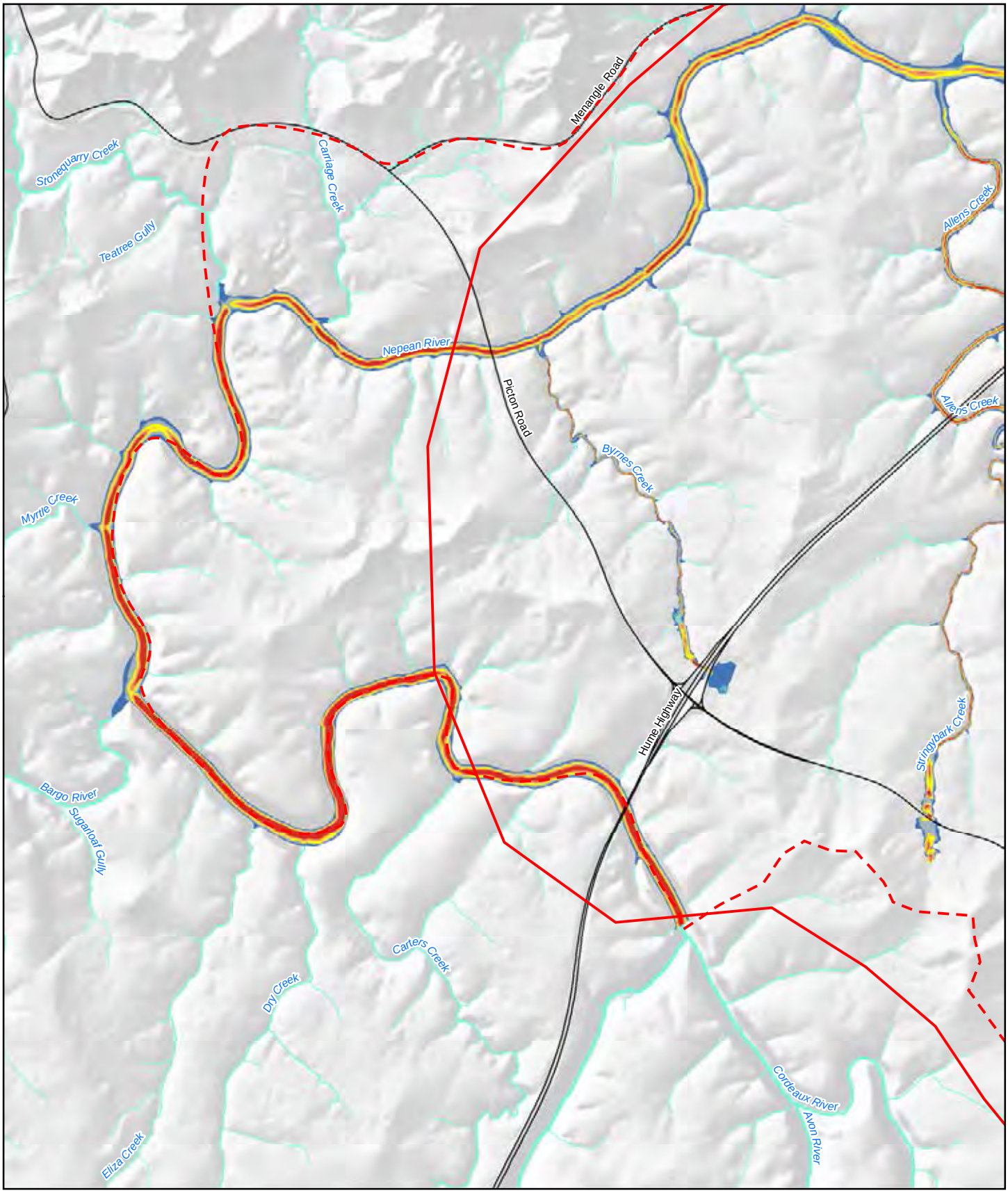
Figure G-5

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G007_PMF_Velocity_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

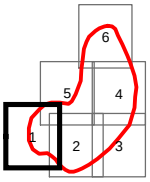


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

PMF Velocities

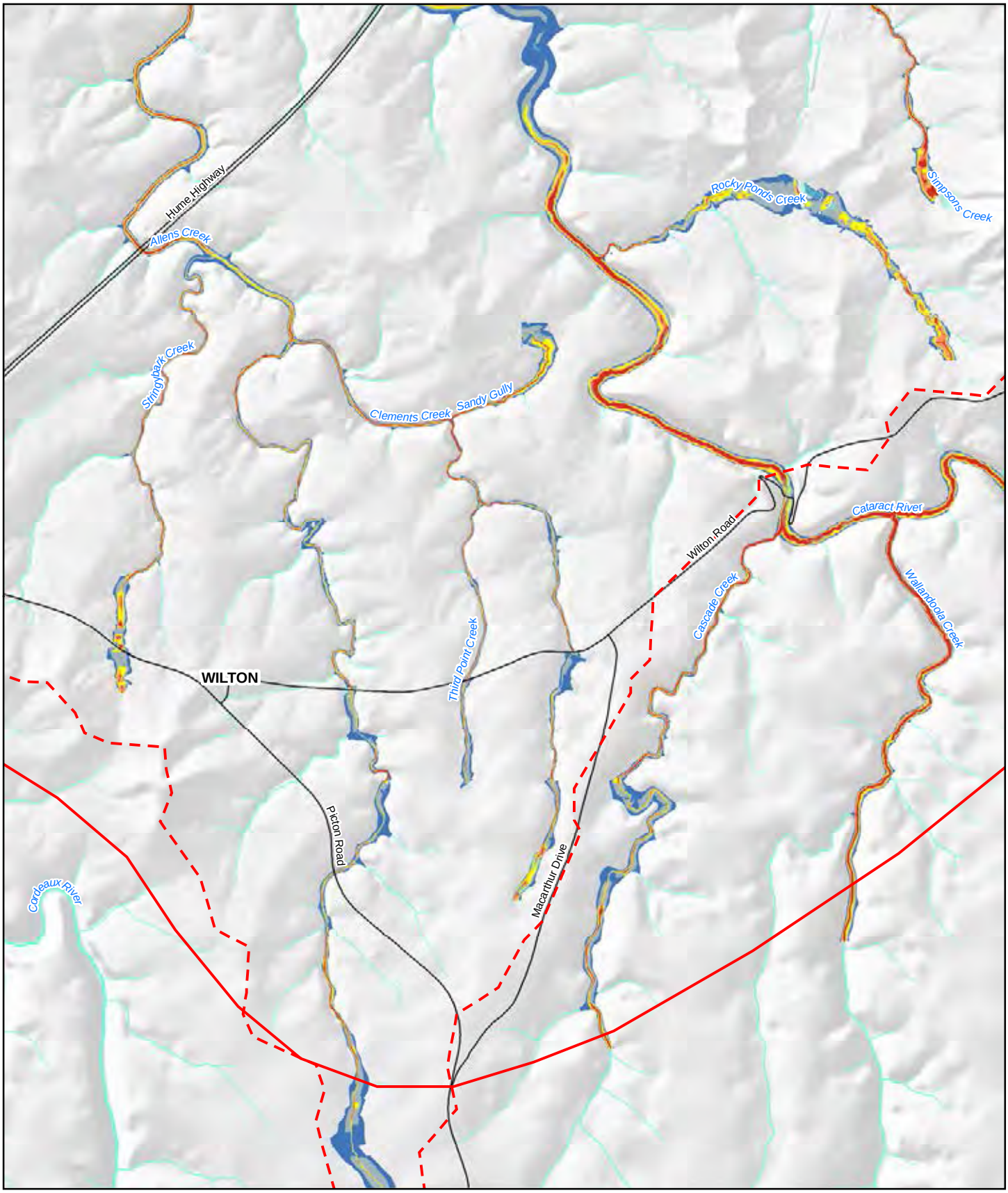
Figure G-6a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G008_DDP_Existing_PMF_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

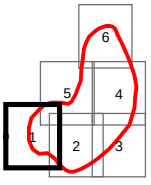


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

PMF Velocities

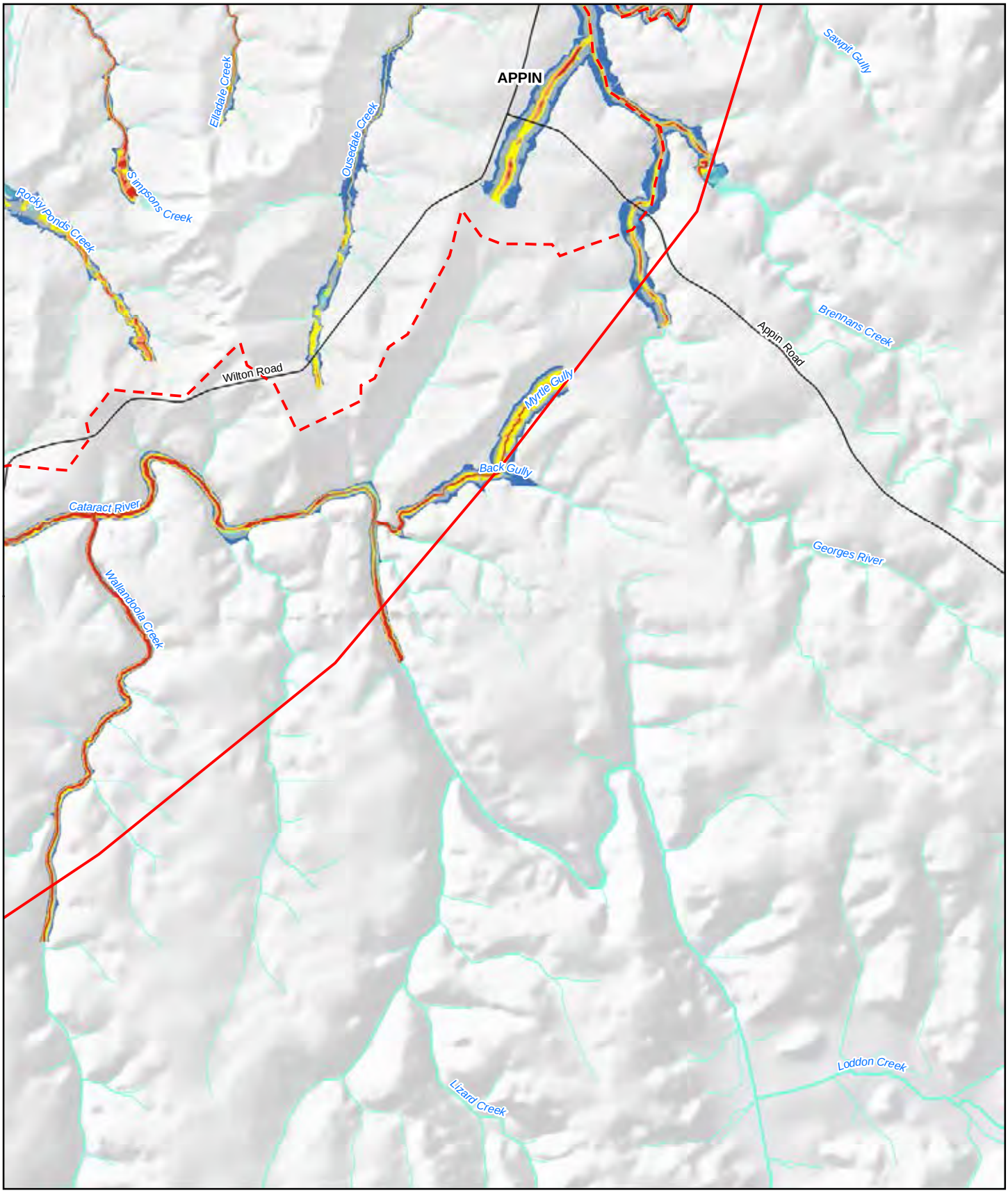
Figure G-6b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G008_DDP_Existing_PMF_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

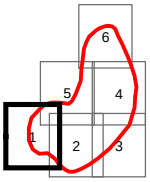


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

PMF Velocities

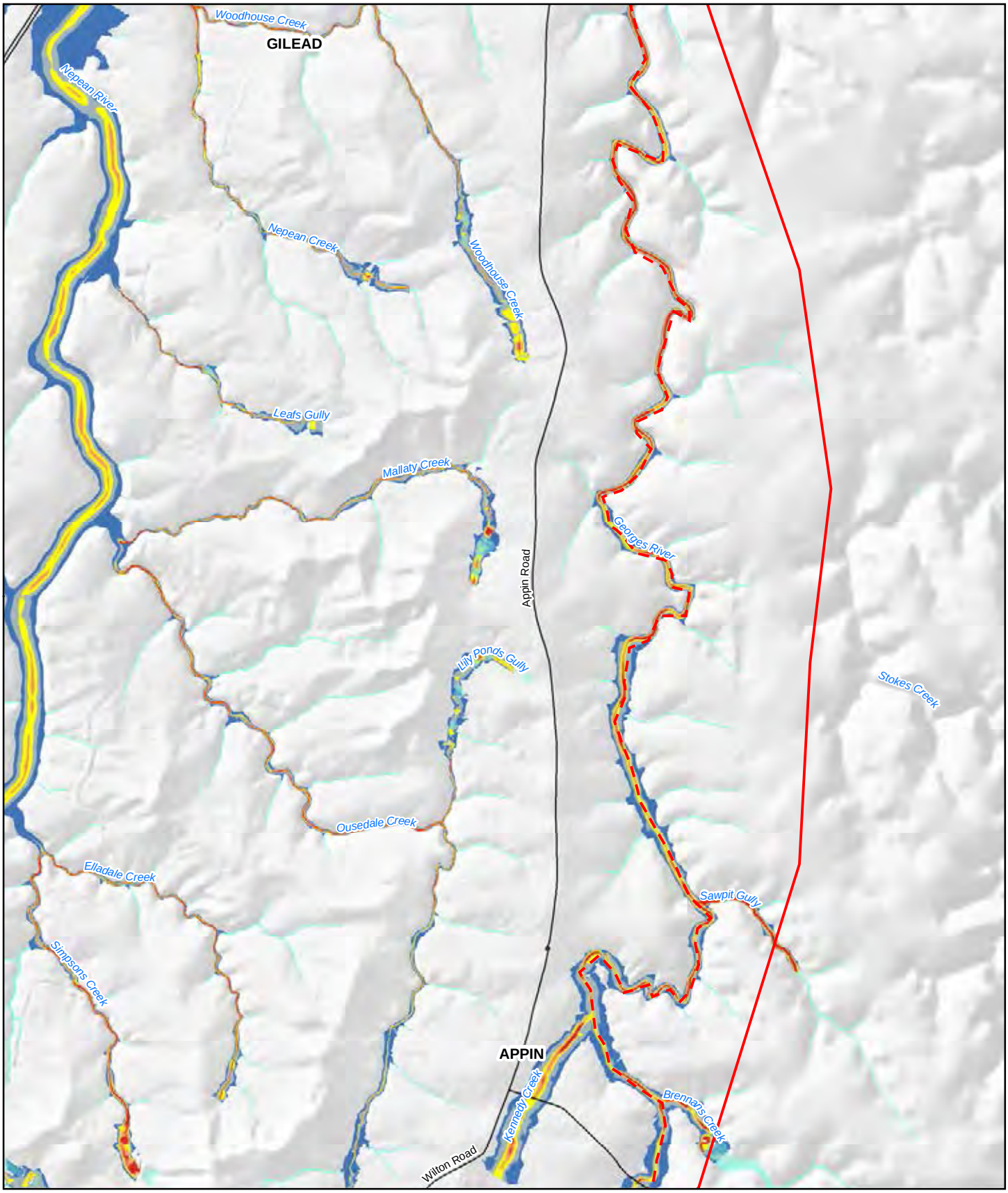
Figure G-6c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G008_DDP_Existing_PMF_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

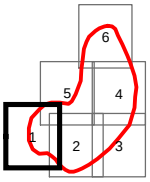


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

PMF Velocities

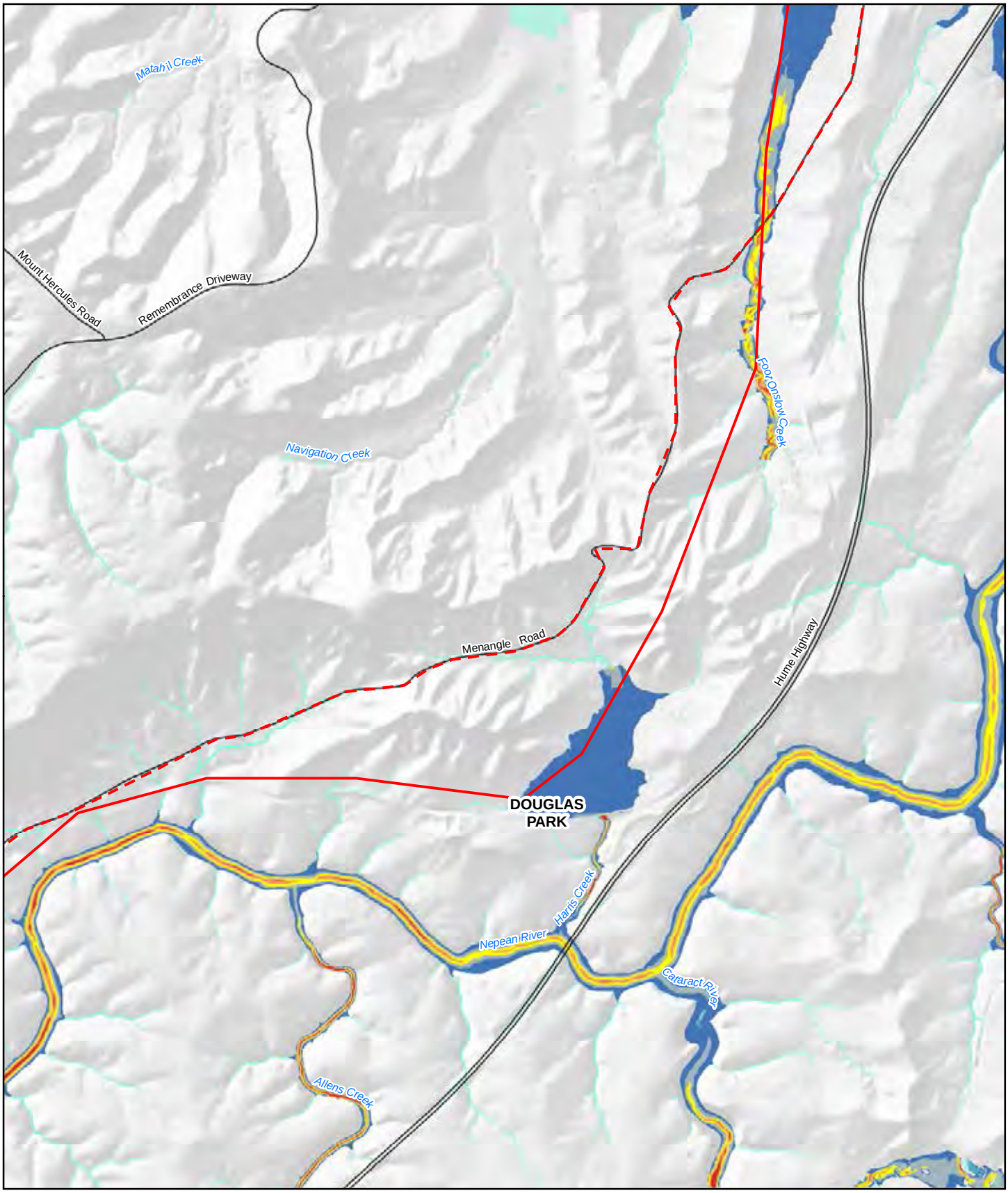
Figure G-6d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G008_DDP_Existing_PMF_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

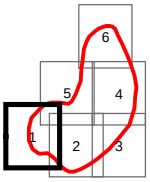


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

PMF Velocities

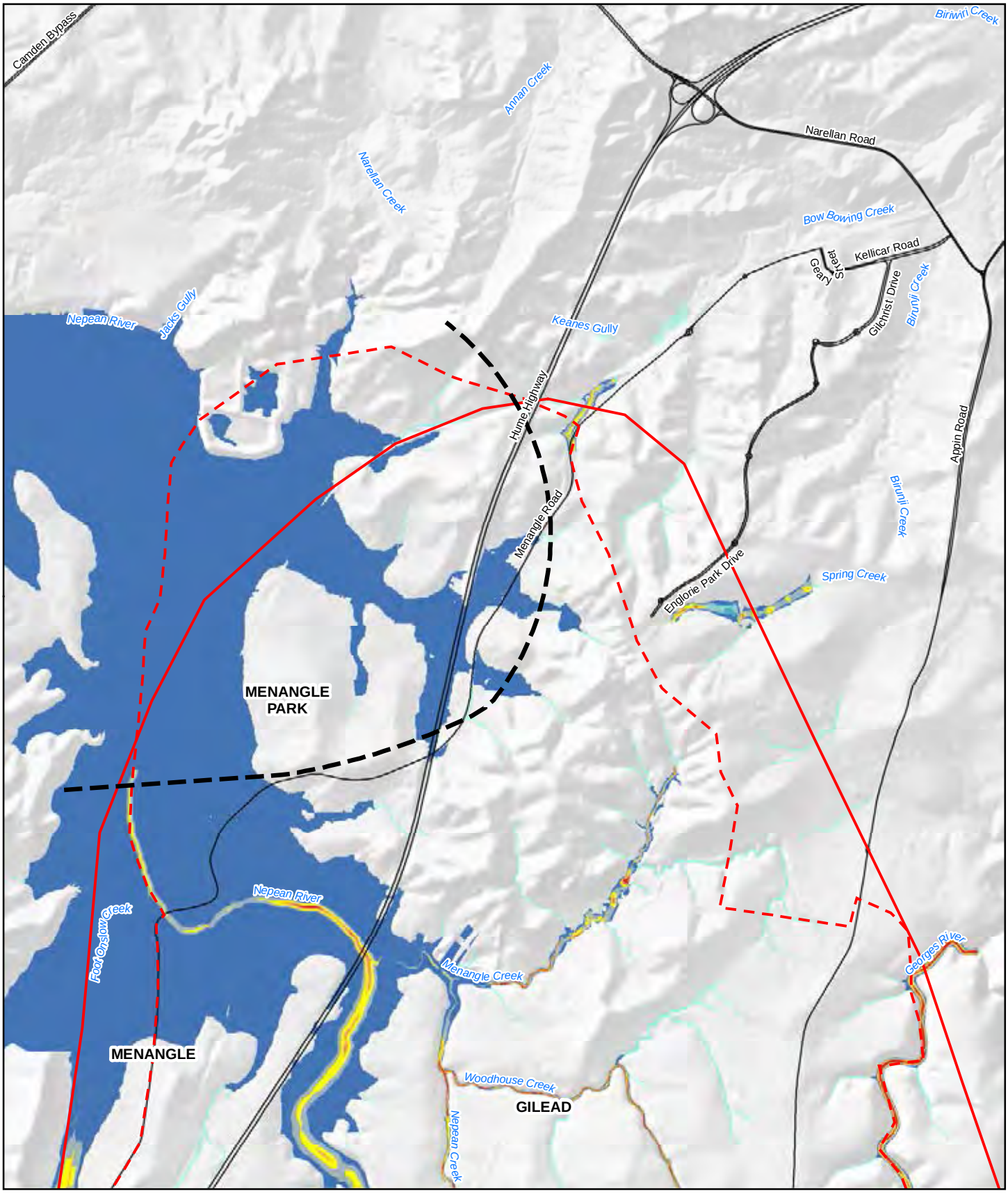
Figure G-6e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G008_DDP_Existing_PMF_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

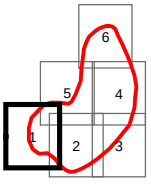


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent

Velocity

<1	1 - 2	2 - 3	3 - 4	>4



Paper Size A4

0 150 300 600 900 1,200 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number	22-17728
Revision	0
Date	23 Jun 2015

PMF Velocities

Figure G-6f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_G\2217728_G008_DDP_Existing_PMF_Vel_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

Appendix H – Flood hazard mapping

H.1 Result presentation

Design hazard values have been calculated for the 100 year ARI existing flows.

The results are provided as follows:

- An overall image
- Six detail sheets.

The overall image shows the predicted hazard value in a classification of H1 to H6 using the classification as shown in Table H-1.

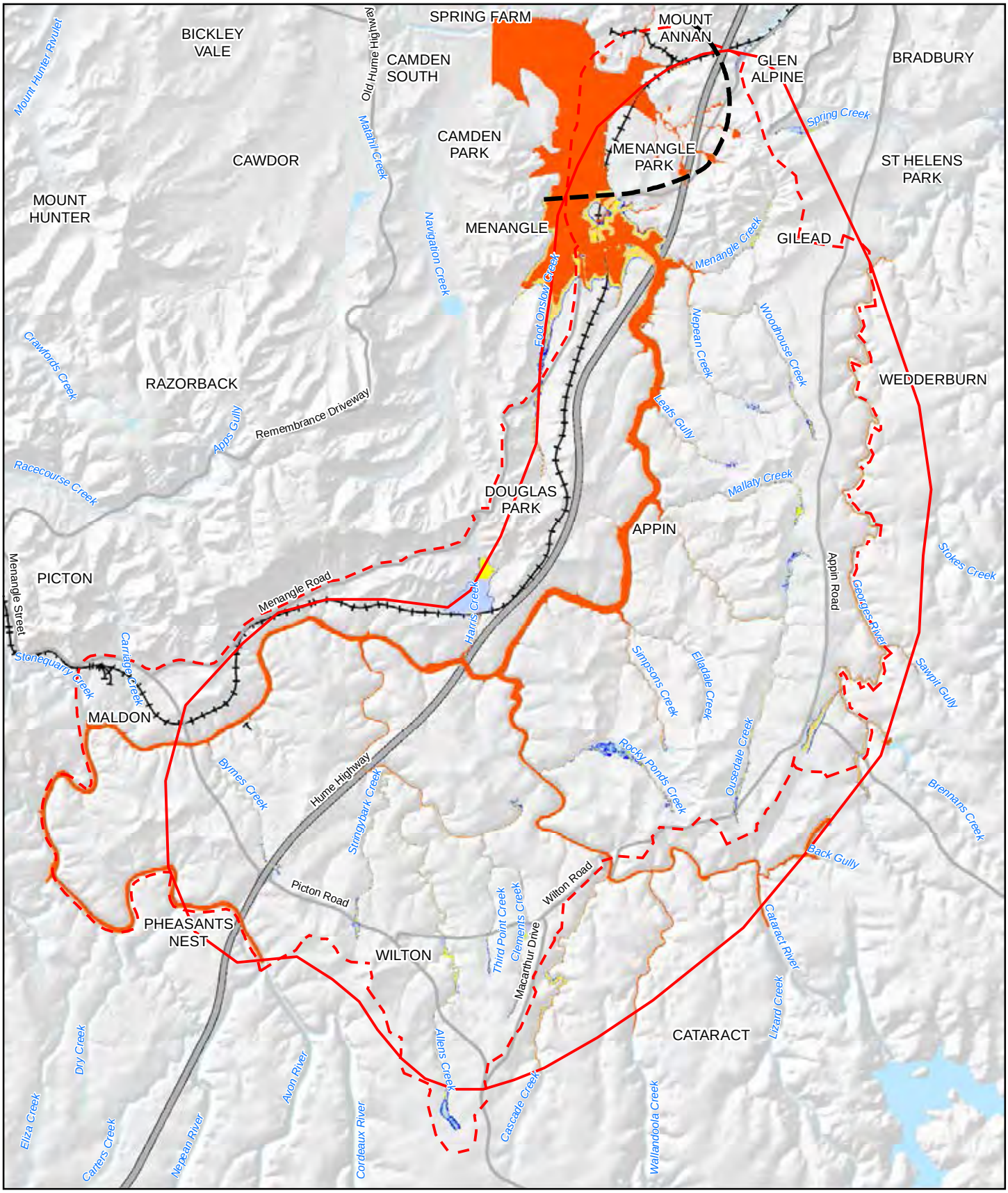
Table H-1 Definition of flood hazard (Australian Emergency Management Institute; 2014)

Hazard	Depth Velocity Product	Depth (m)	Velocity (m/s)
H1	Less than or equal to 0.3	0.3	2.0
H2	Less than or equal to 0.6	0.5	2.0
H3	Less than or equal to 0.6	1.2	2.0
H4	Less than or equal to 1.0	2.0	2.0
H5	Less than or equal to 4.0	4.0	4.0
H6	Greater than 4.0	Greater than 4.0	Greater than 4.0

A series of six detail sheets provide an enhanced definition of the levels across the Subject Site.

H-2 Interpretation assumptions

The majority of the flow area is shown as being H6 category hazard with only fringing flow areas having a lower hazard category.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway

Hazard

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings
- TuFlow Results Extent

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Existing 100 year Hazard Overall

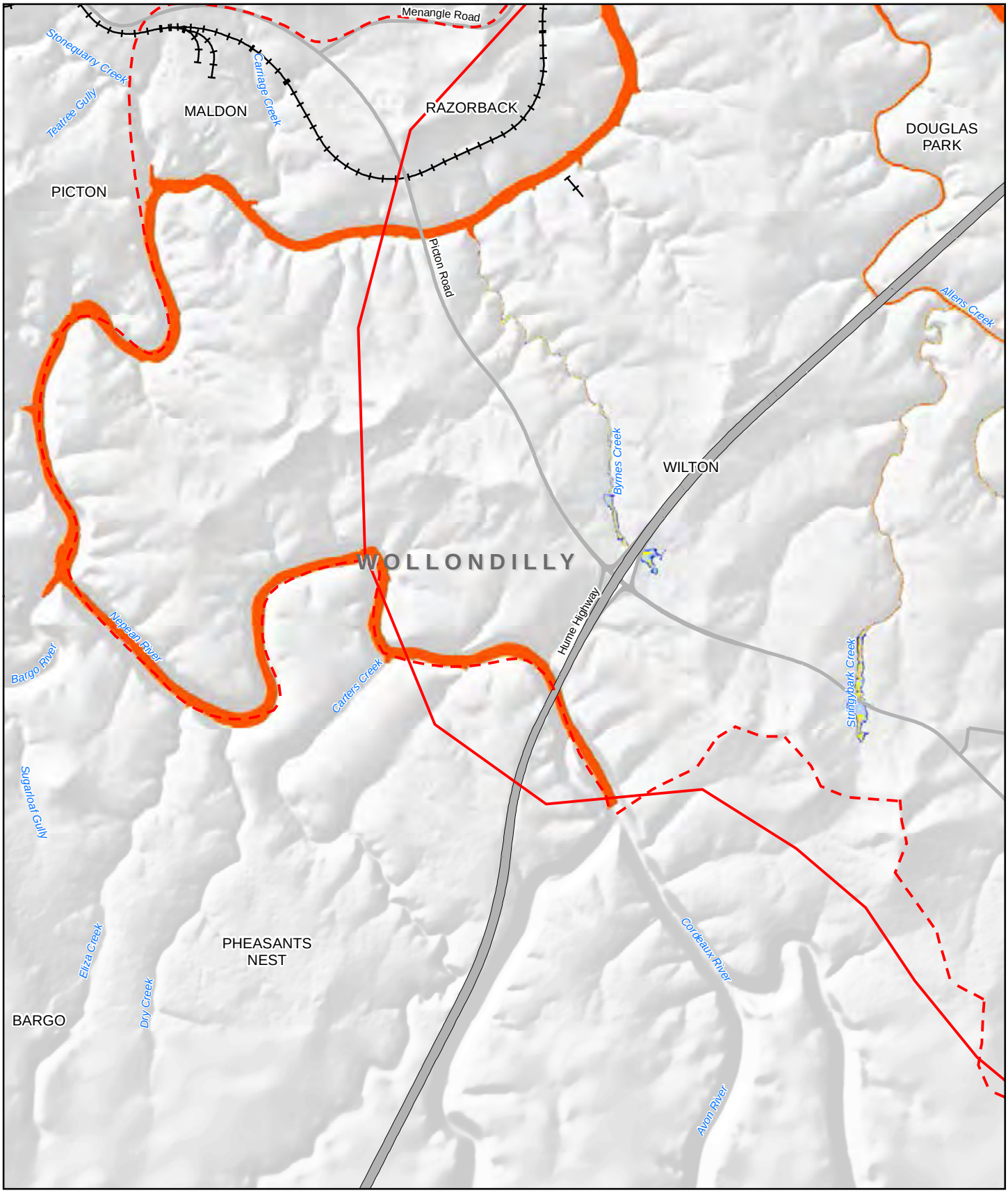
Figure H-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_H\2217728_H001_Exg_Hazard_FloodExtents_Overall_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton

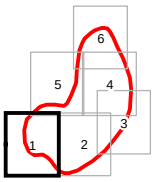


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway

Hazard

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Existing 100 year Hazard
Sheet 1

Job Number	22-17728
Revision	0
Date	23 Jun 2015

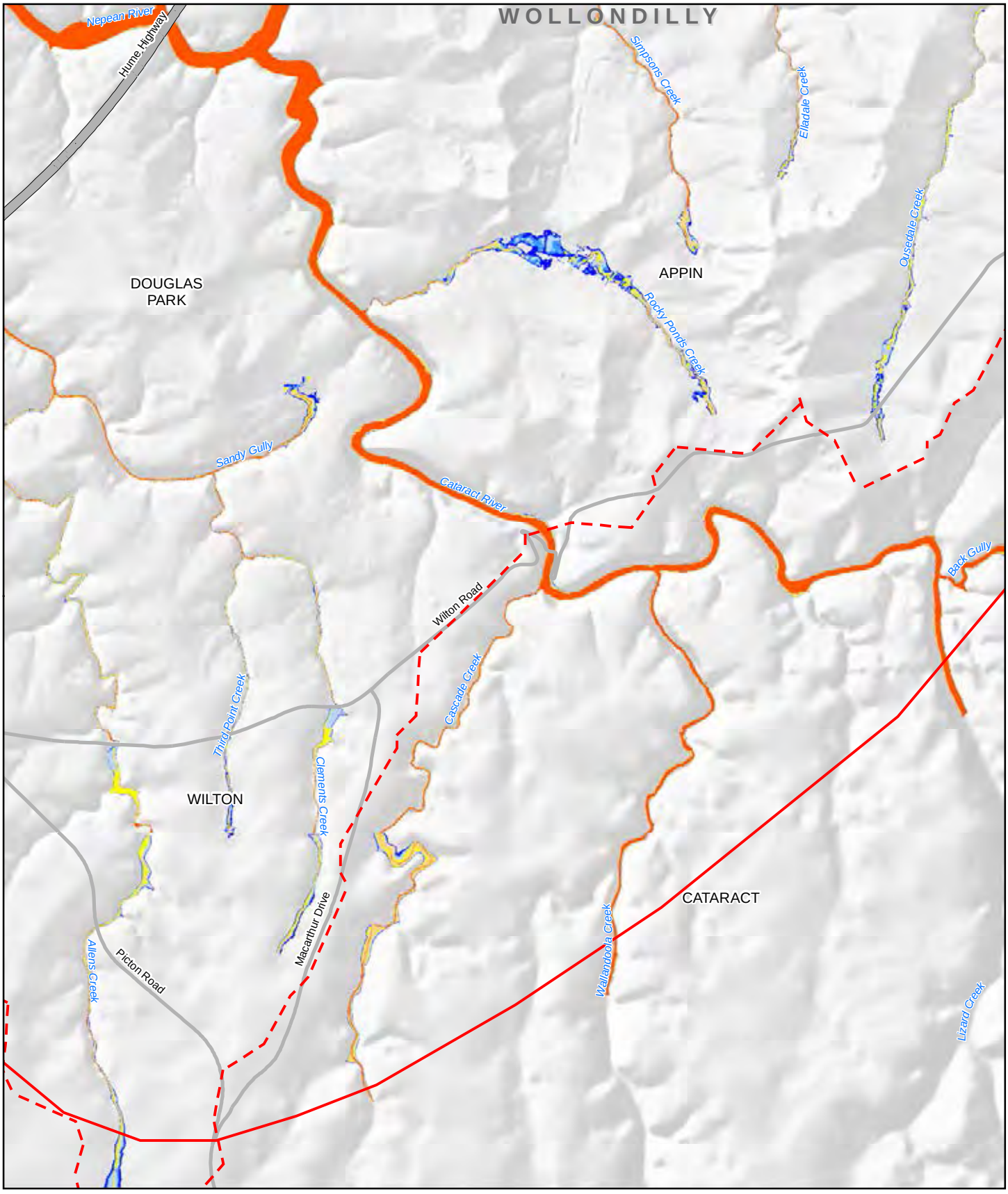
Figure H-2a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_H\2217728_H002_DDP_Exg_Hazard_FloodExtents_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton

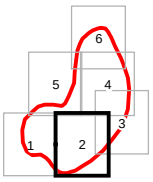


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road

Hazard

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 100 year Hazard
Sheet 2

Job Number	22-17728
Revision	0
Date	23 Jun 2015

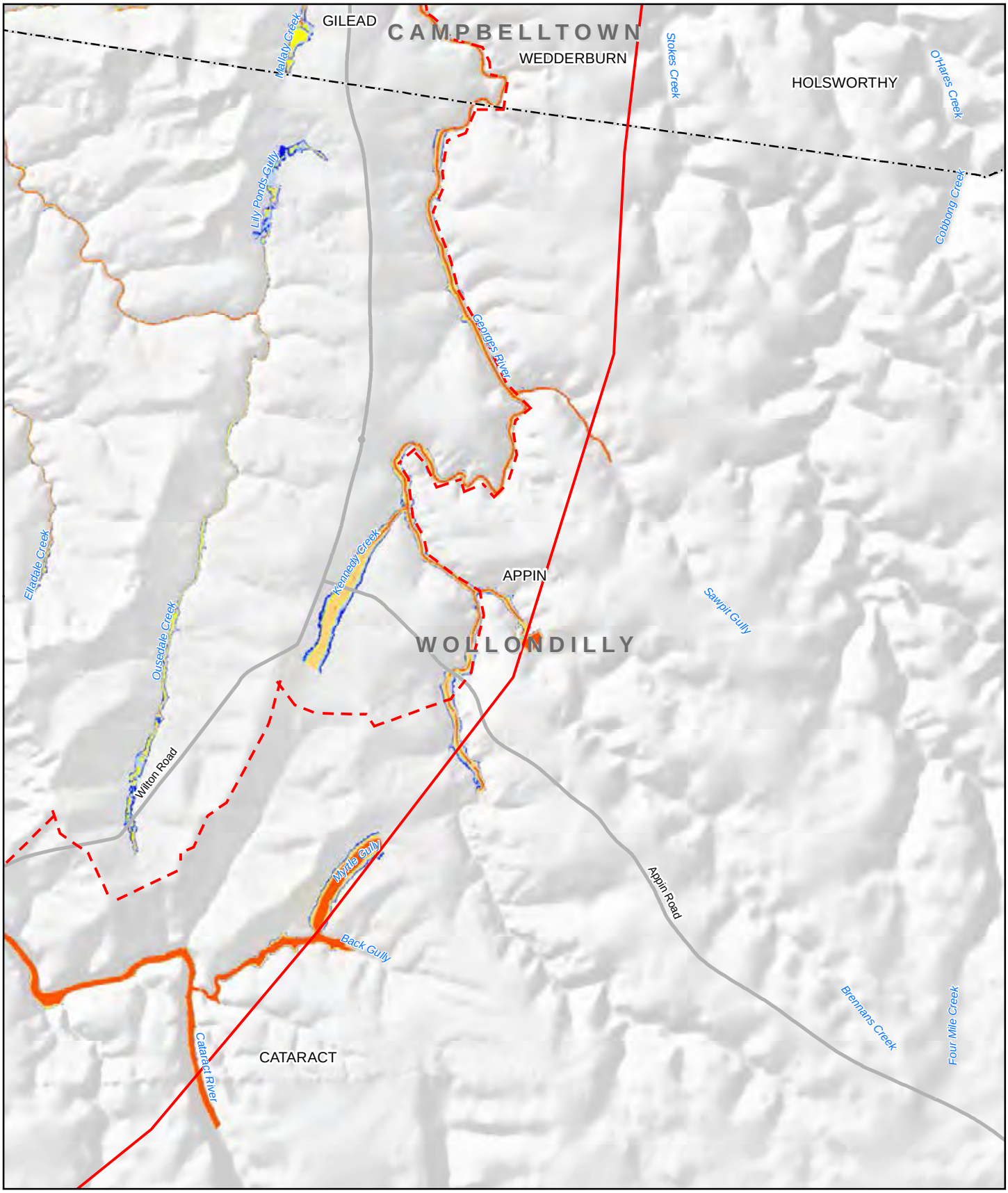
Figure H-2b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_H\2217728_H002_DDP_Exg_Hazard_FloodExtents_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton

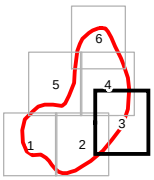


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Primary Road

Hazard

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Existing 100 year Hazard
Sheet 3

Job Number	22-17728
Revision	0
Date	23 Jun 2015

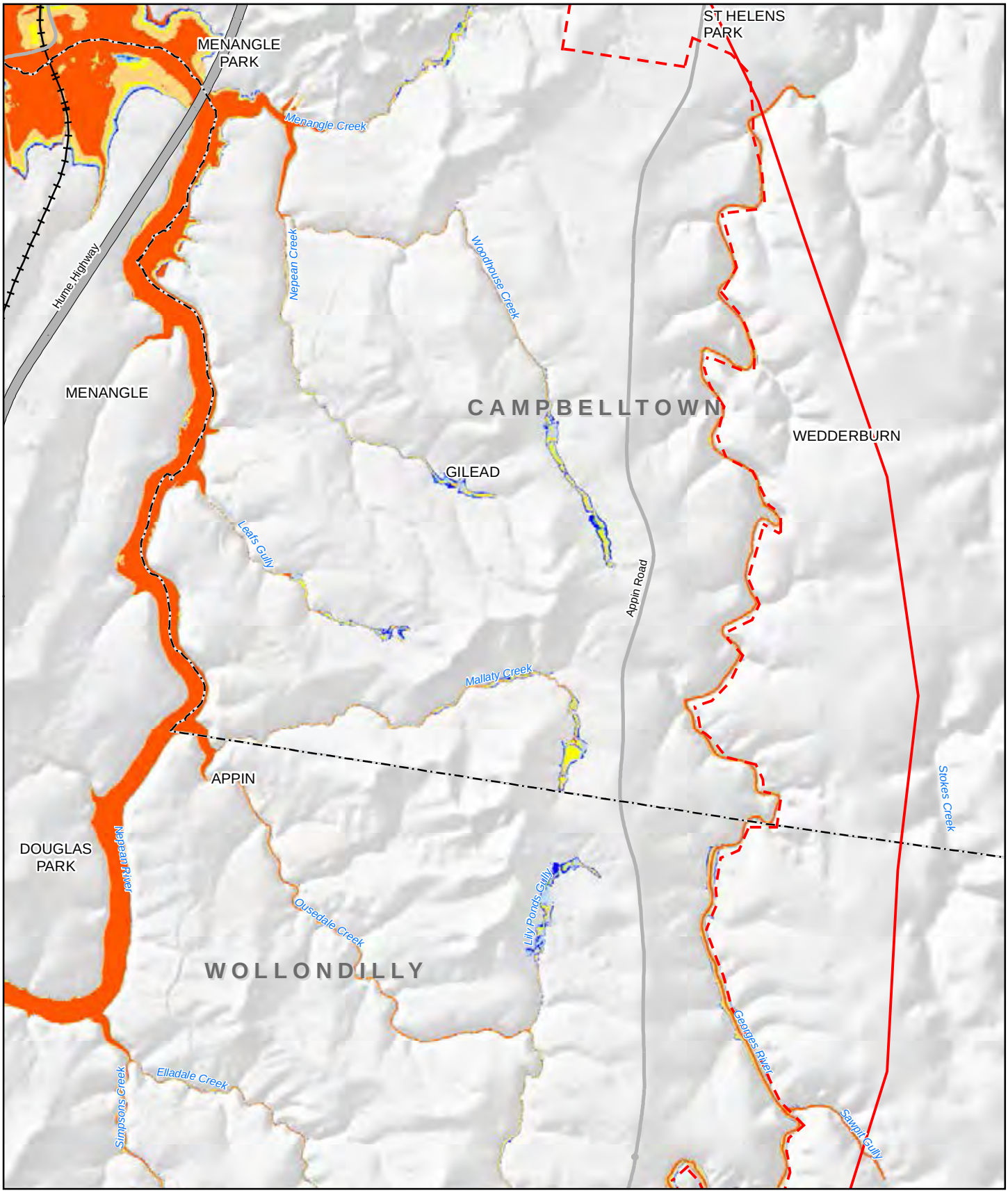
Figure H-2c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_H\2217728_H002_DDP_Exg_Hazard_FloodExtents_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton

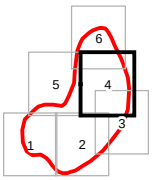


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway

Hazard

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 100 year Hazard
Sheet 4

Job Number	22-17728
Revision	0
Date	23 Jun 2015

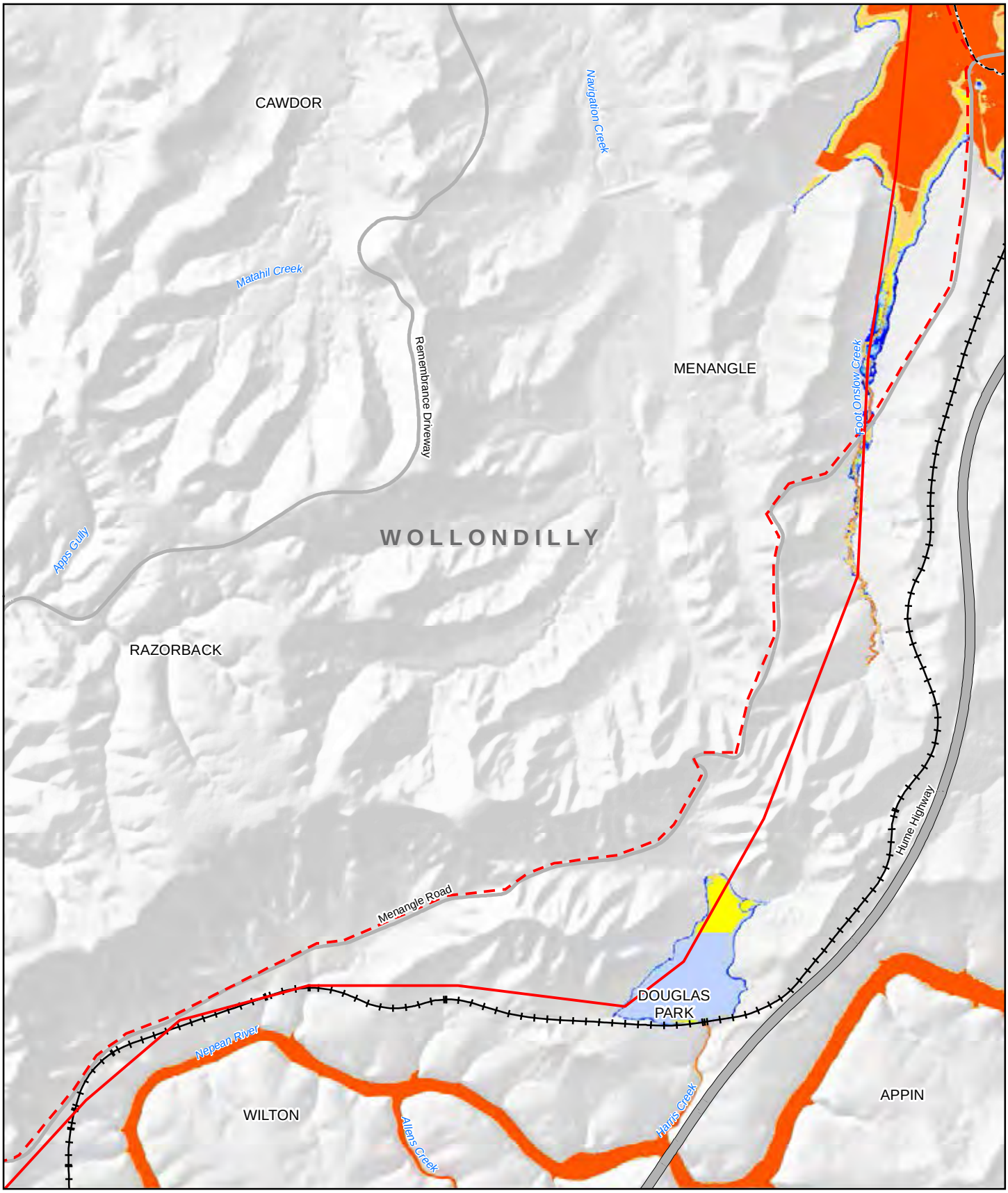
Figure H-2d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_H\2217728_H002_DDP_Exg_Hazard_FloodExtents_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton

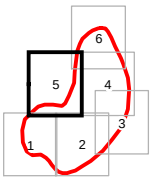


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway

Hazard

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Existing 100 year Hazard
Sheet 5

Job Number	22-17728
Revision	0
Date	23 Jun 2015

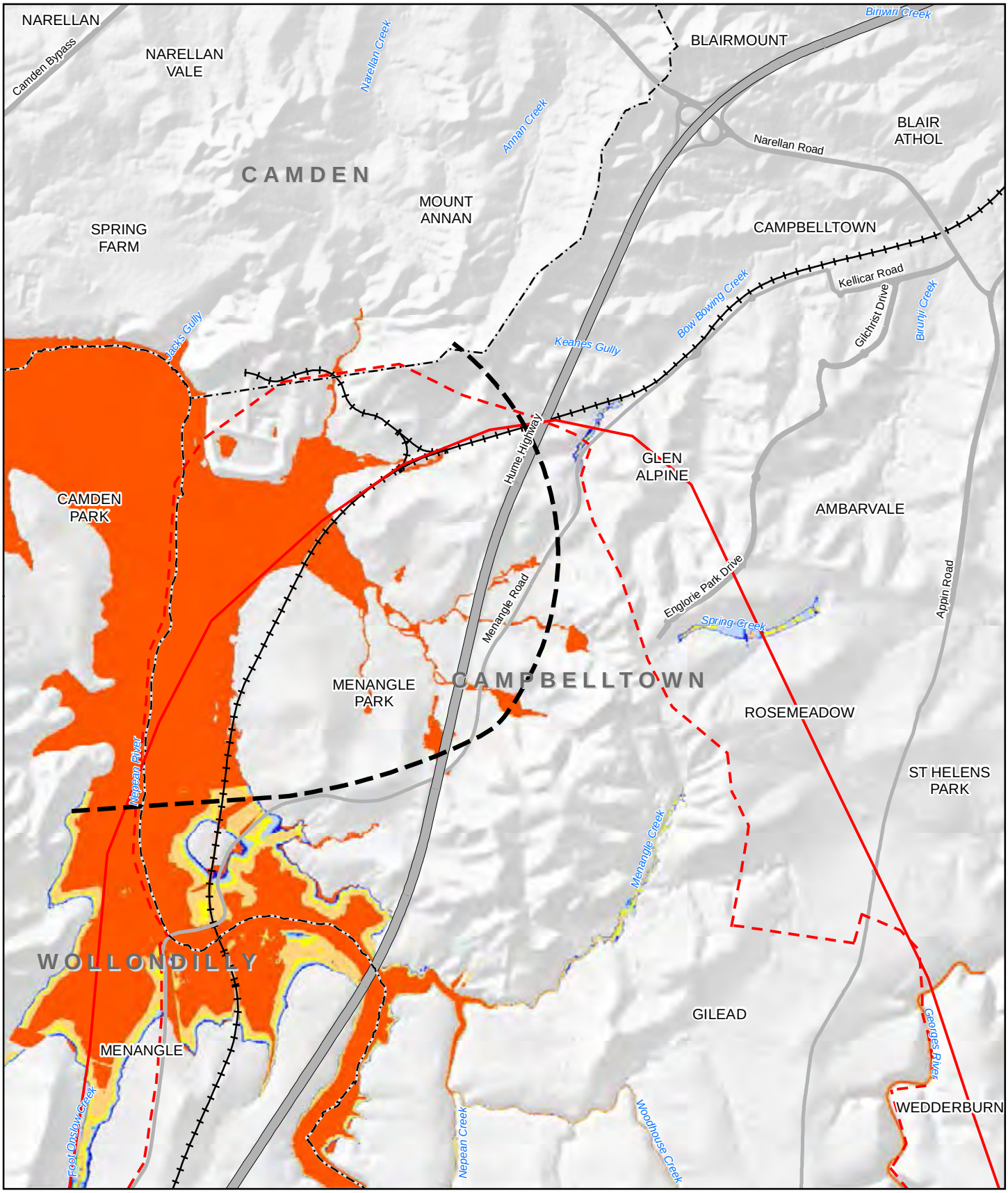
Figure H-2e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_H\2217728_H002_DDP_Exg_Hazard_FloodExtents_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton

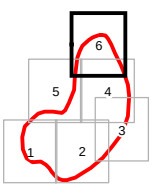


LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway

Hazard

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings
- TuFlow Results Extent



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Existing 100 year Hazard
Sheet 6

Job Number	22-17728
Revision	0
Date	23 Jun 2015

Figure H-2f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_H\2217728_H002_DDP_Exg_Hazard_FloodExtents_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton

Appendix I – Flood classification mapping

I.1 Result presentation

Design flood categories have been calculated for the 100 year ARI existing flows.

The results are provided as follows:

- An overall image
- Six detail sheets

The overall image shows the predicted flow category based upon the classification shown in Table I-1.

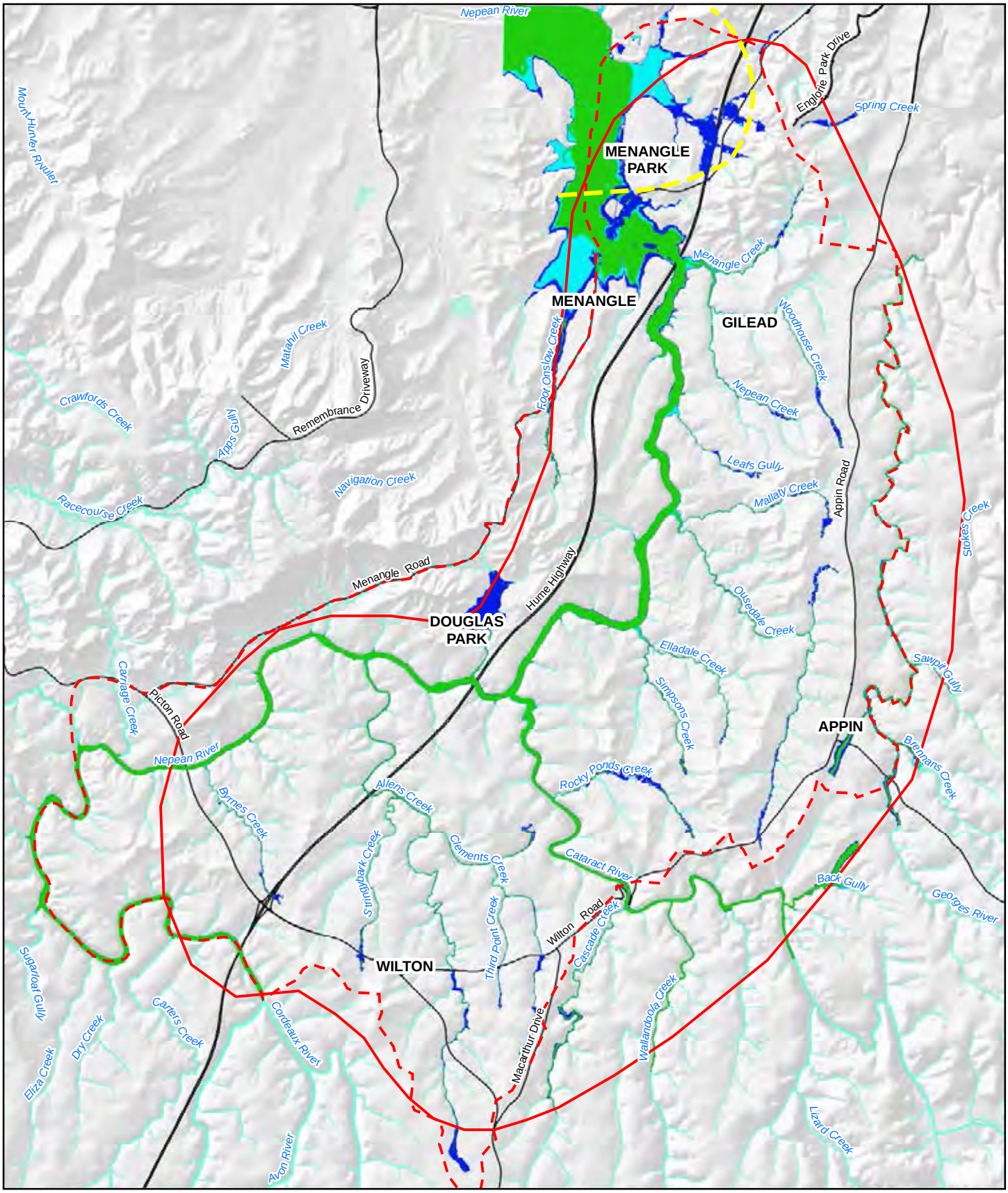
Table I-1 Flood categorisation

Category	100 year ARI Conditions	PMP Conditions
Floodway	velocity x depth >0.3 or velocity > 4 m/s	velocity x depth >1.0 or velocity > 4 m/s
Flood Storage	velocity x depth <0.3 and depth >0.5 m	velocity x depth <1.0 and depth >1.0 m
Flood Fringe	velocity x depth <0.3 and depth <0.5 m	velocity x depth <1.0 and depth <1.0 m

A series of six detail sheets provide an enhanced definition of the levels across the Subject Site.

I.2 Interpretation

As can be seen from the figures the majority of the flow area is classified as floodway.



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- TuFlow Results Extent
- Floodway
- Flood storage
- Flood fringe

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flow Classification

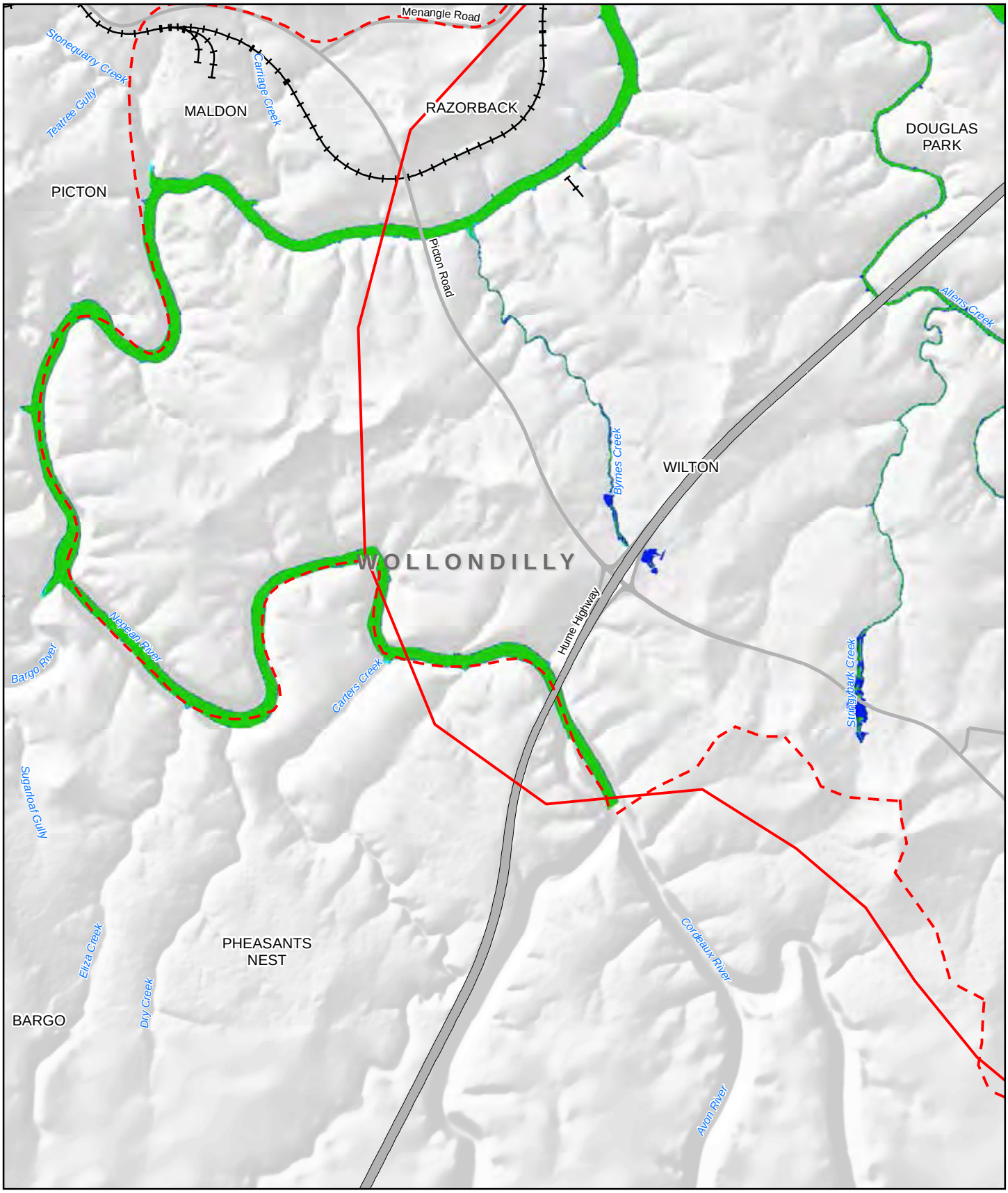
Figure I-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_I\2217728_I001_100YR_Classification_0.mxd

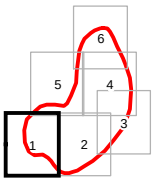
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway
- Floodway
- Flood storage
- Flood fringe



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flow Classification Sheet 1

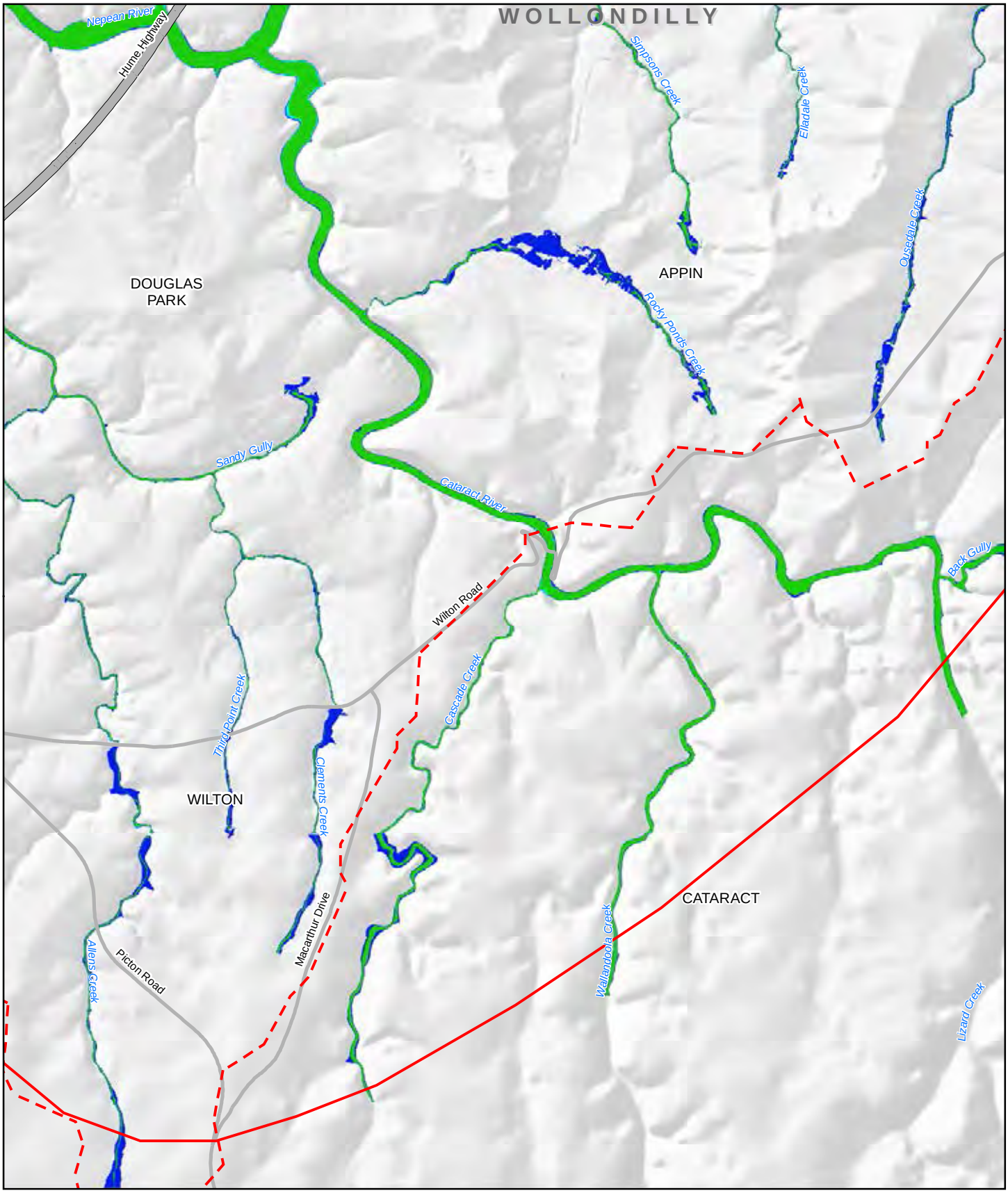
Figure I-2a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_I\2217728_I002_DDP_100YR_Classification_0.mxd

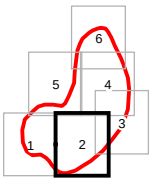
© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Floodway
- Flood storage
- Flood fringe



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flow Classification Sheet 2

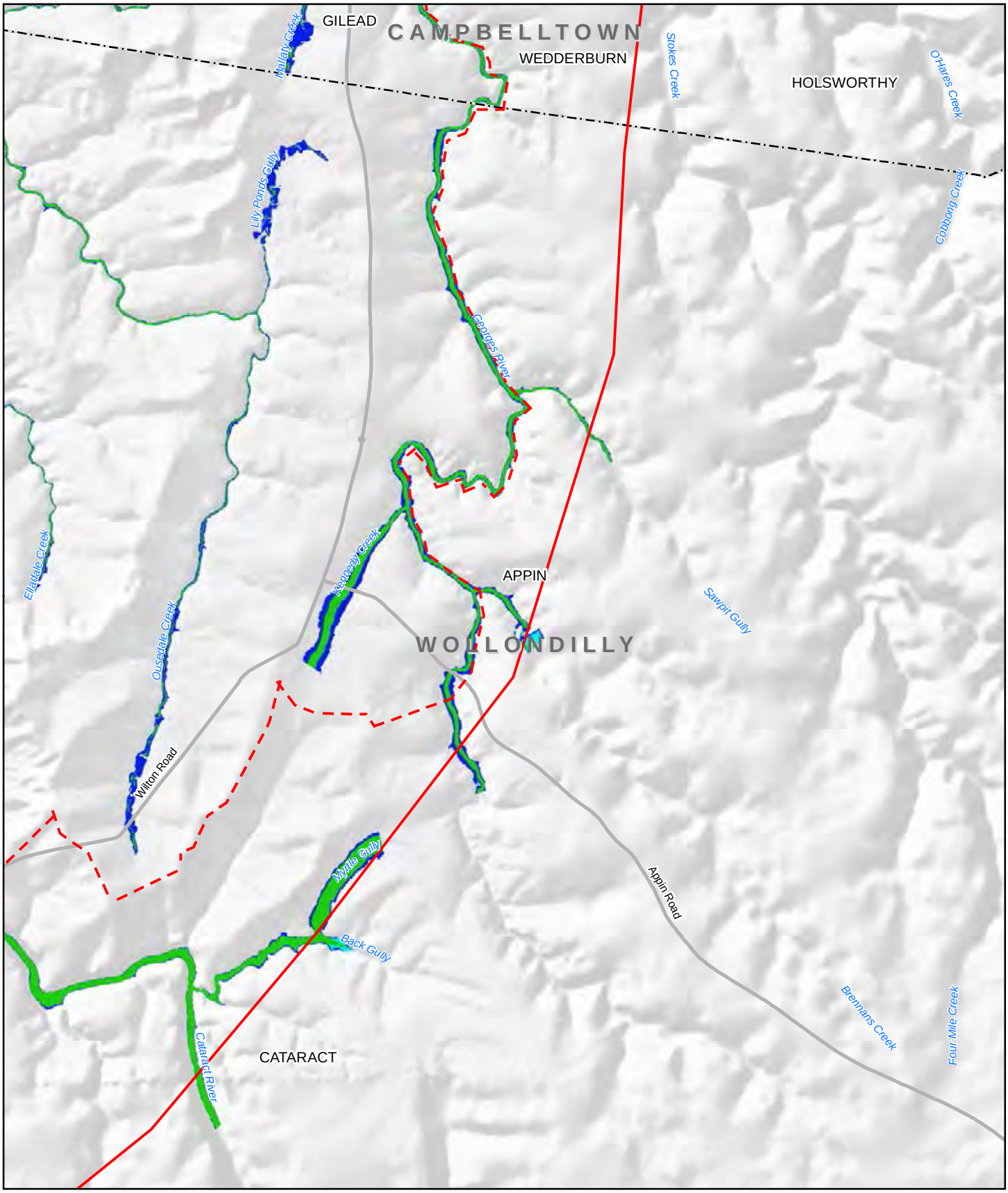
Figure I-2b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_I\2217728_I002_DDP_100YR_Classification_0.mxd

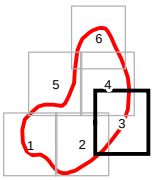
© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Primary Road
- Floodway
- Flood storage
- Flood fringe



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flow Classification Sheet 3

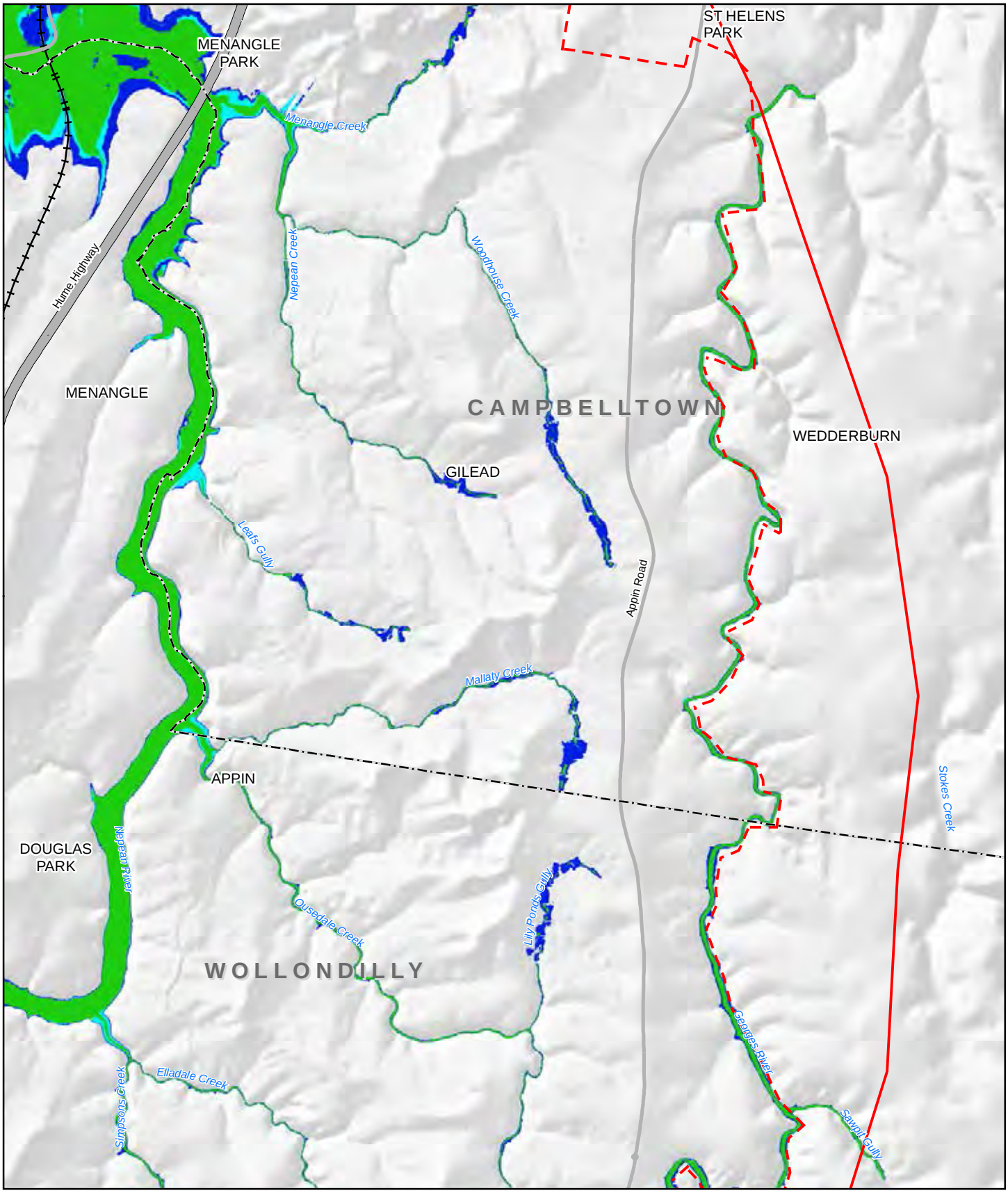
Figure I-2c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_I\2217728_I002_DDP_100YR_Classification_0.mxd

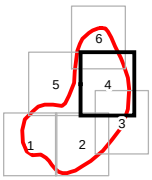
© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway
- Floodway
- Flood storage
- Flood fringe



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flow Classification
Sheet 4

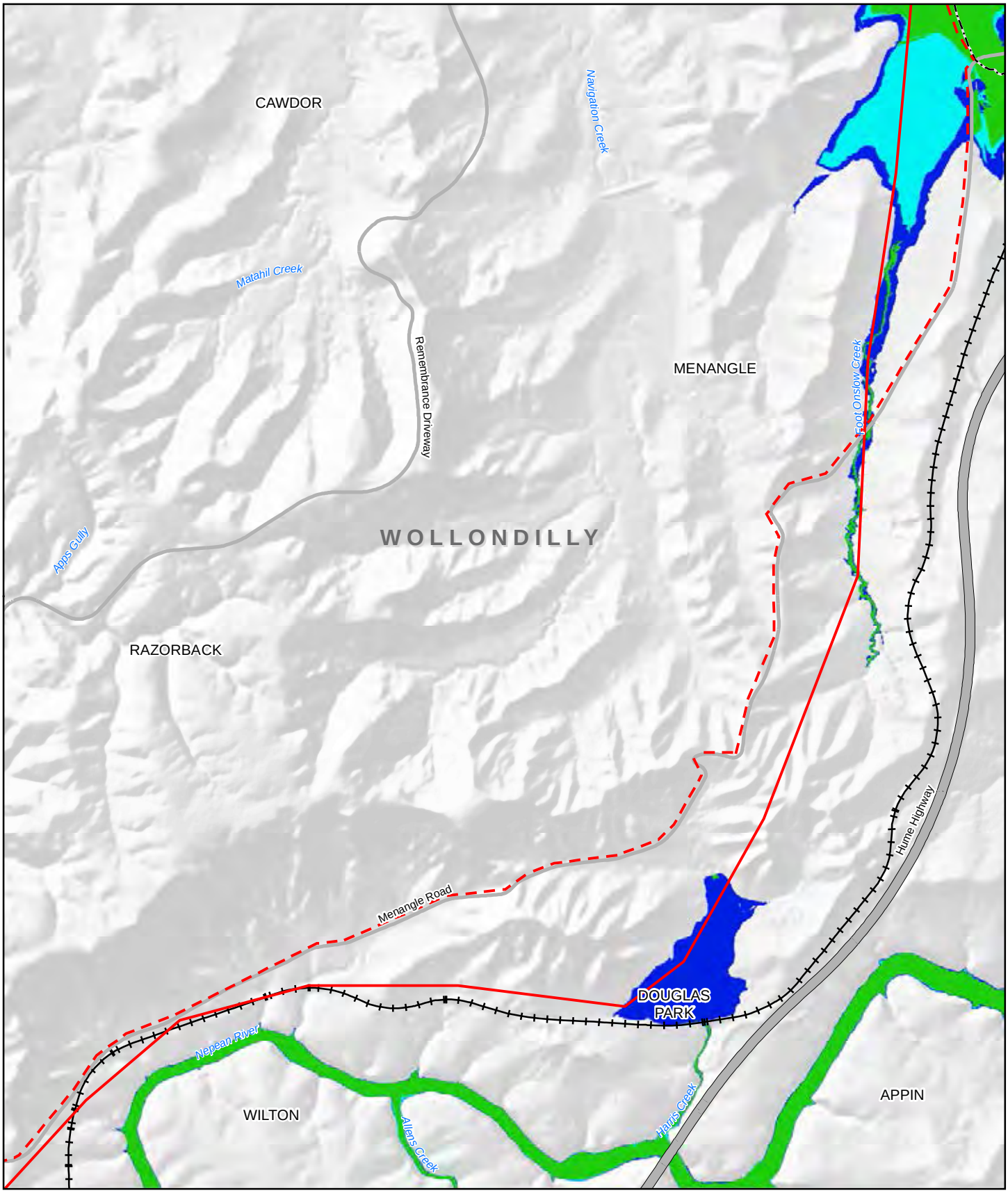
Figure I-2d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_I\2217728_I002_DDP_100YR_Classification_0.mxd

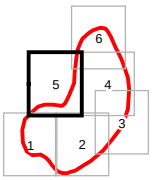
© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway
- Floodway
- Flood storage
- Flood fringe



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flow Classification Sheet 5

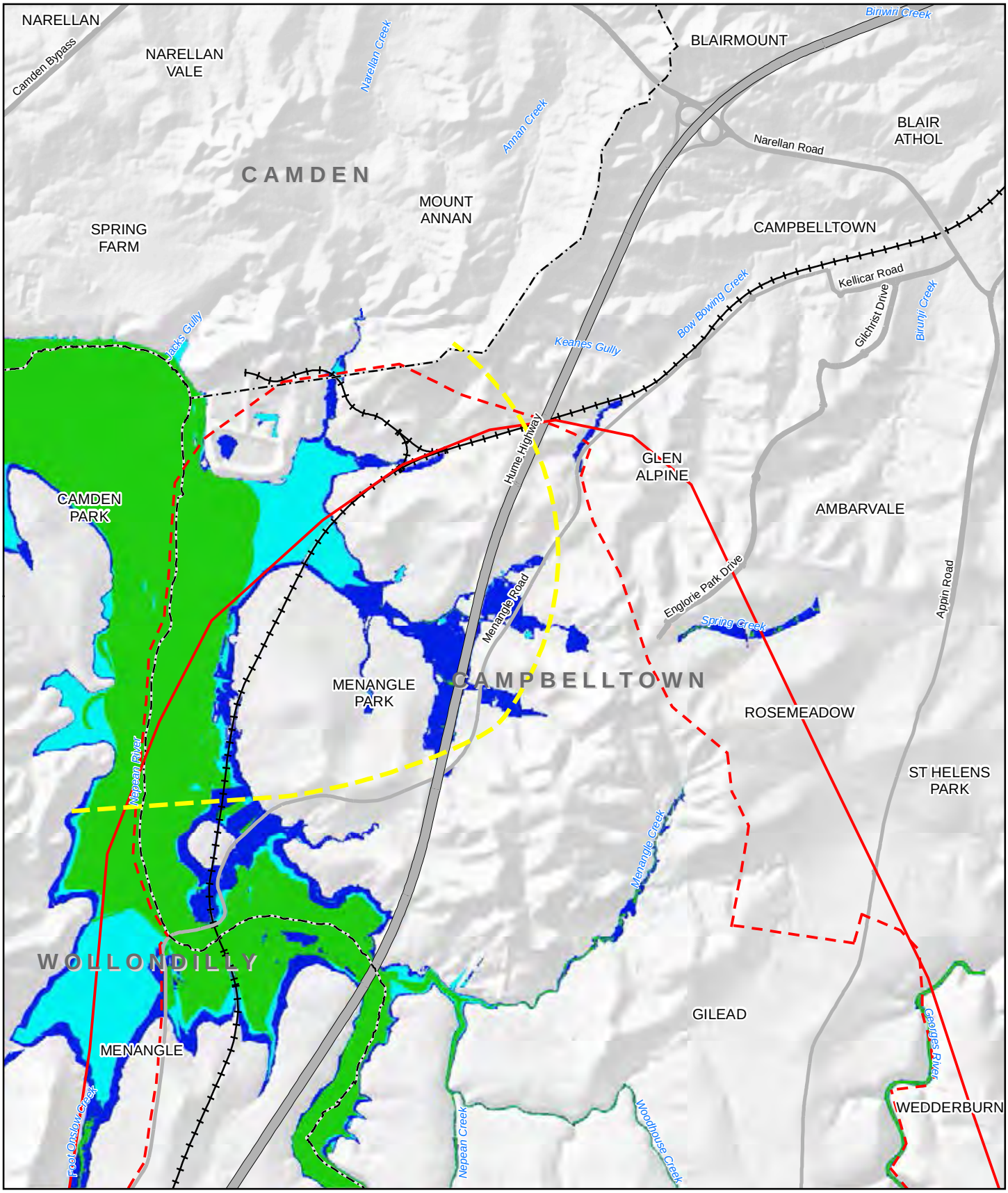
Figure I-2e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_I\2217728_I002_DDP_100YR_Classification_0.mxd

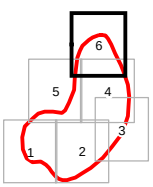
© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Motorway
- Primary Road
- Railway
- TuFlow Results Extent
- Floodway
- Flood storage
- Flood fringe



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

100 Year ARI Flow Classification Sheet 6

Figure I-2f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_I\2217728_I002_DDP_100YR_Classification_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD and LPI make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI: DCDB/DTDB, 2012; Sixviewer, 2015. Created by: tmorton

Appendix J – Flood level profiles

J.1 Results presentation

Design flood categories have been calculated for the 2, 20 and 100 year ARI existing flows together with the PMF event.

The results are provided as follows:

- An overall image of the study area that shows the watercourse segment names and numbers
- Six detail sheets that provide the chainage locations along the various segments of the watercourses

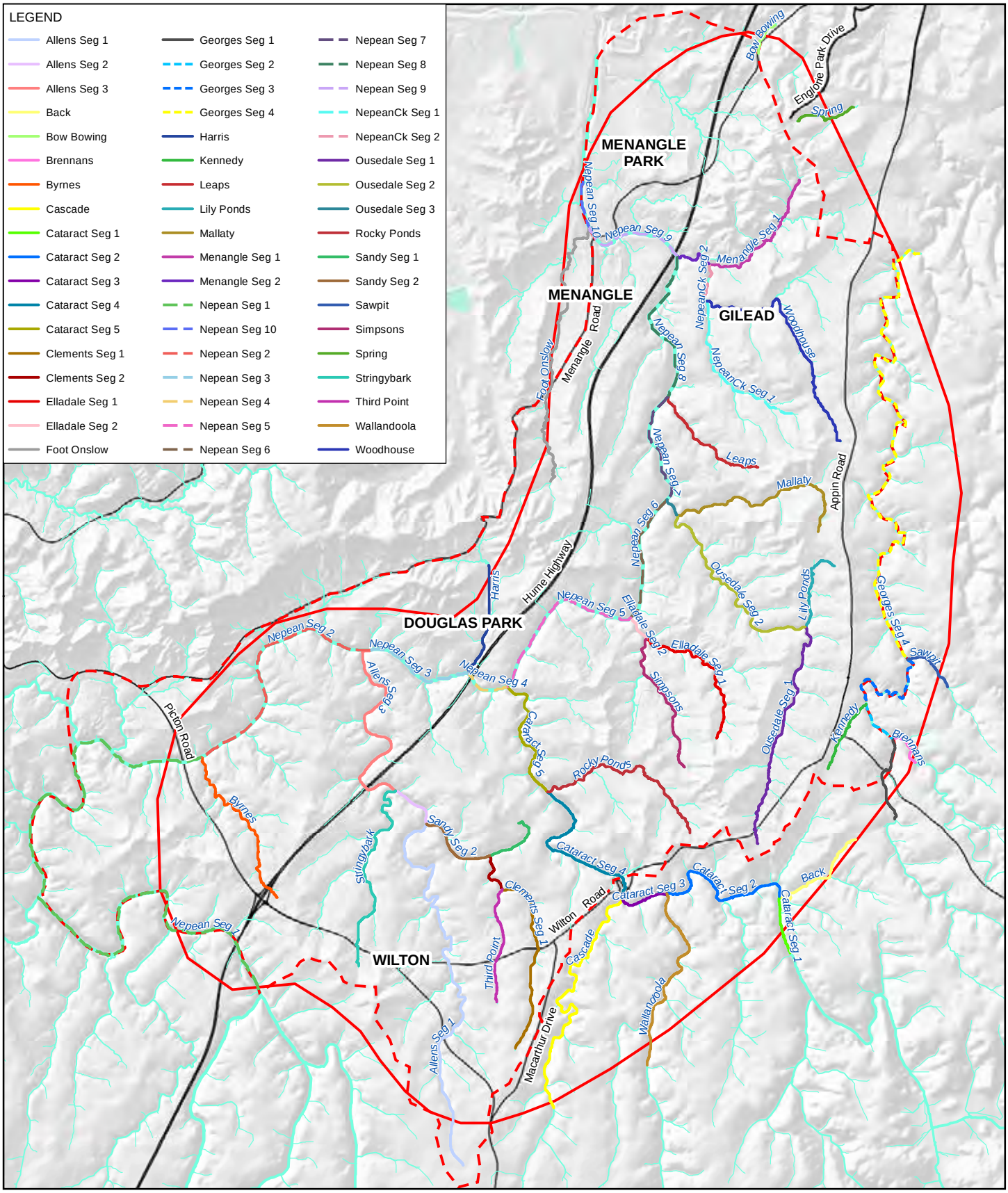
The overall image, Figure J-1, shows the watercourse names and segment numbers together with the location (by means of the line colour and style) within the Study Area. Figure J-2 then provides enlarged views of the Study Area indicating chainages within each of the watercourse segments. The chainages are provided to assist the user in obtaining a location and thence either determining the design flood level off the included flood profiles or reading numerical values of flood level from the tabulated flood levels at the end of this Appendix.

J.2 Long section profiles and design flood profiles

Long section profiles are provided in graphical form for each of:

- Allens Creek
- Back Gully
- Bow Bowing Creek
- Byrnes Creek
- Cascade Creek
- Cataract River
- Clements Creek
- Elladale Creek
- Foot Onslow Creek
- Georges River
- Harris Creek
- Leaps Gully
- Lily Pond Gully
- Mallaty Creek
- Menangle Creek
- Nepean Creek
- Nepean River
- Ousedale Creek
- Rocky Ponds Creek
- Sandy Gully
- Simpsons Creek

- Spring Creek
- Stringybark Creek
- Third point Creek
- Wallandoola Creek
- Woodhouse Creek



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody

Paper Size A4

0 400 800 1,600 2,400 3,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Modelled Watercourses

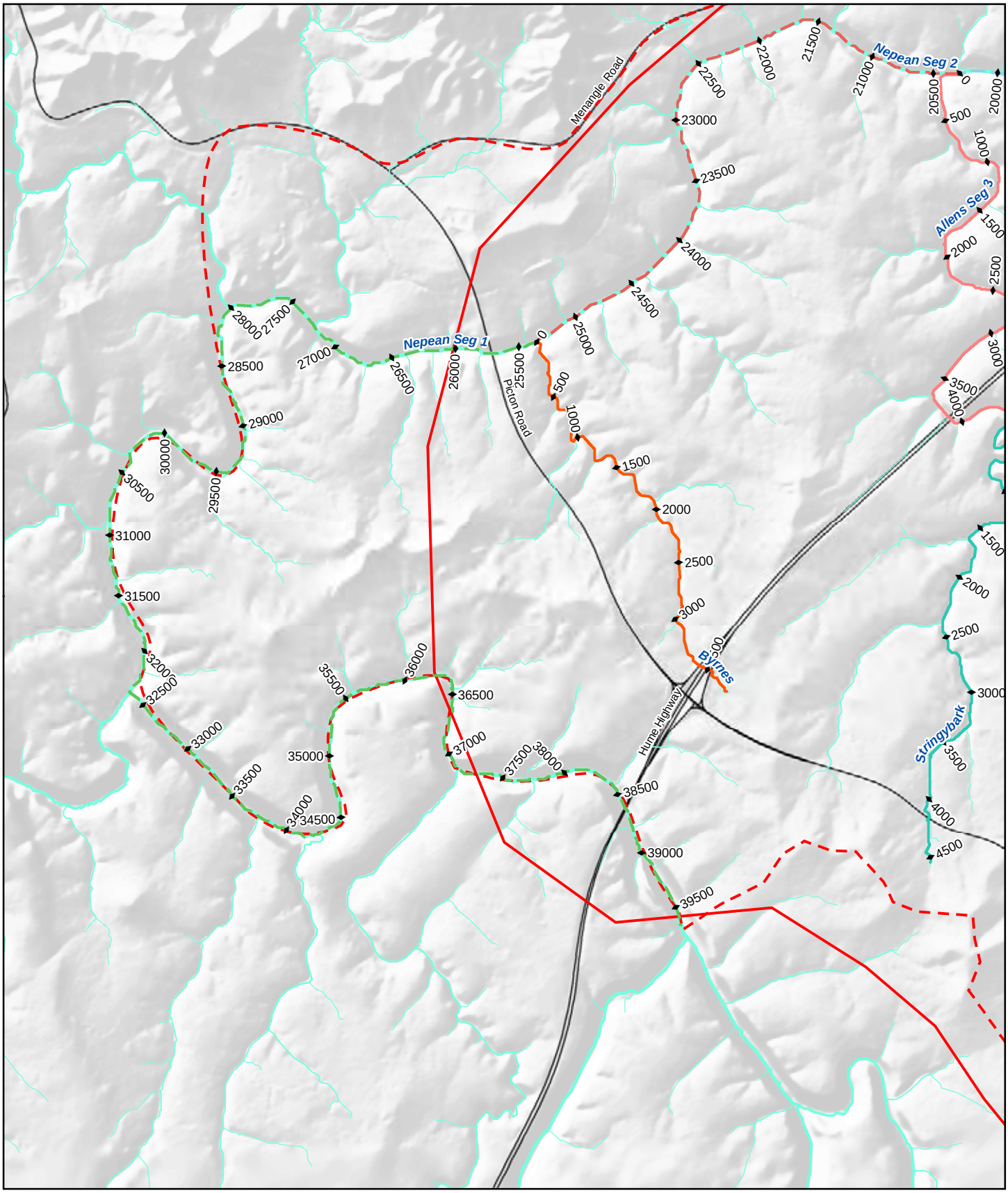
Figure J-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_J\2217728_J001_Profiles_Overall_0.mxd

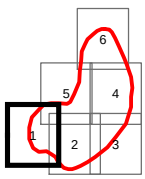
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Allens Seg 3
- Byrnes
- Nepean Seg 1
- Nepean Seg 2
- Nepean Seg 3
- Stringybark



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Hydraulic Model Plans
Sheet 1

Job Number 22-17728
Revision 0
Date 23 Jun 2015

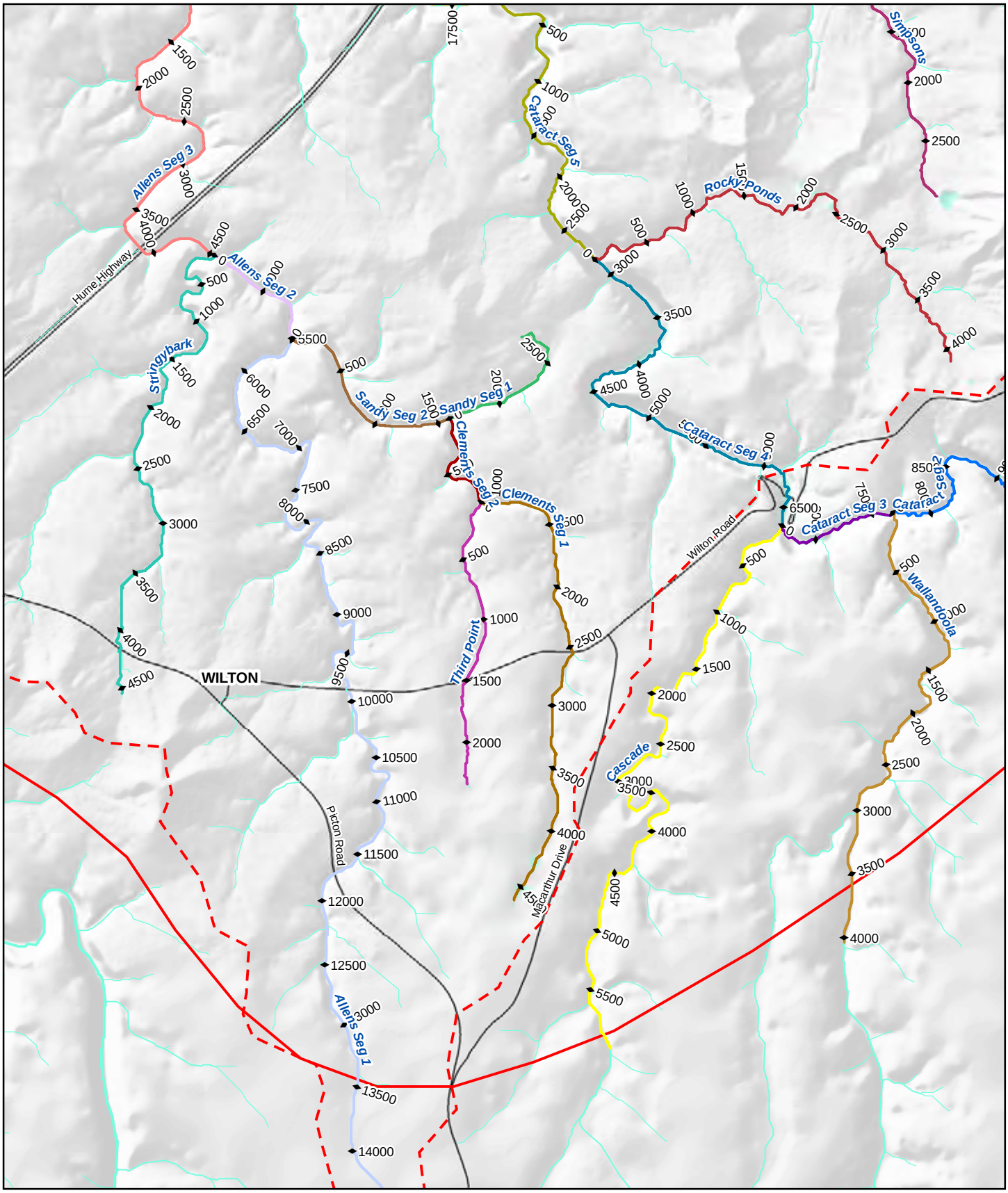
Figure J-2a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_J\2217728_J002_DDP_Profiles_Overall_0.mxd

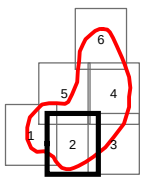
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Allens Seg 1
- Allens Seg 2
- Allens Seg 3
- Cascade
- Cataract Seg 2
- Cataract Seg 3
- Cataract Seg 4
- Cataract Seg 5
- Clements Seg 1
- Clements Seg 2
- Nepean Seg 4
- Rocky Ponds
- Sandy Seg 1
- Sandy Seg 2
- Simpsons
- Stringybark
- Third Point
- Wallandoola



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Hydraulic Model Plans
Sheet 2

Job Number	22-17728
Revision	0
Date	23 Jun 2015

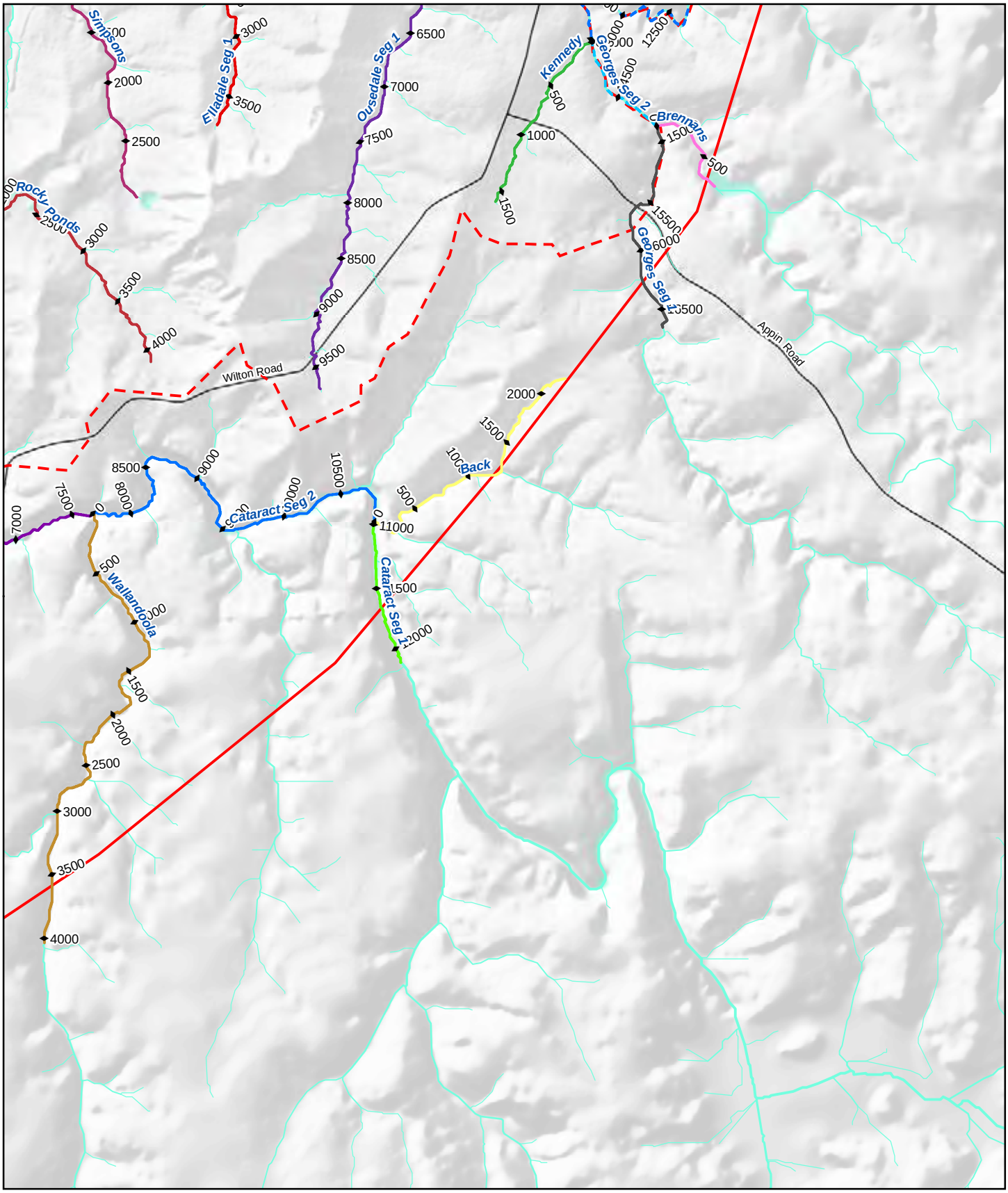
Figure J-2b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_J\2217728_J002_DDP_Profiles_Overall_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Back
- Brennans
- Cataract Seg 1
- Cataract Seg 2
- Cataract Seg 3
- Elladale Seg 1
- Georges Seg 1
- Georges Seg 2
- Georges Seg 3
- Kennedy
- Ousedale Seg 1
- Rocky Ponds
- Simpsons
- Wallandoola

Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Hydraulic Model Plans
Sheet 3

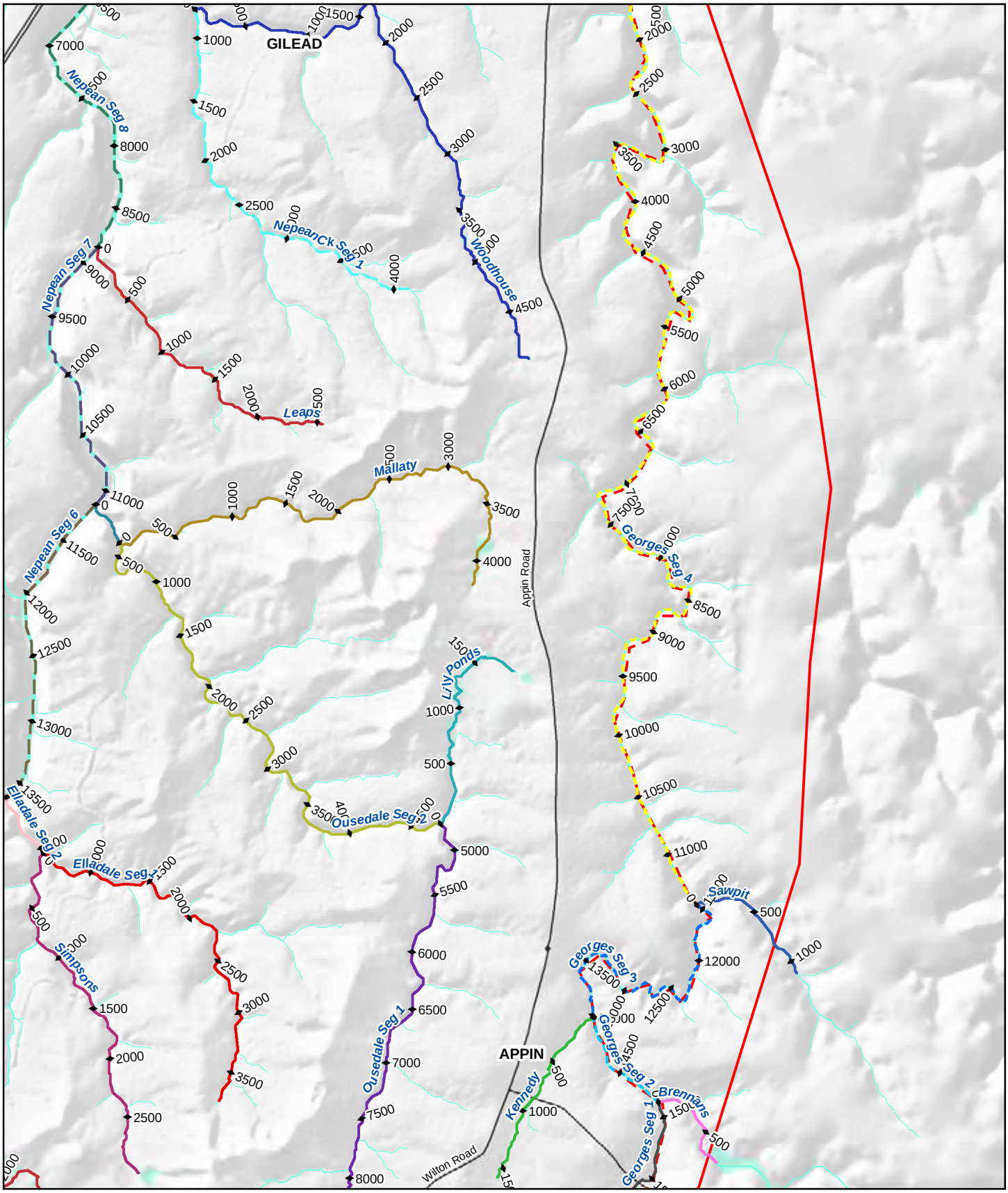
Figure J-2c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_J\2217728_J002_DDP_Profiles_Overall_0.mxd

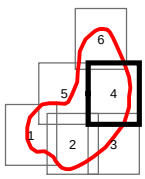
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Hydraulic Model Plans
Sheet 4

Job Number	22-17728
Revision	0
Date	23 Jun 2015

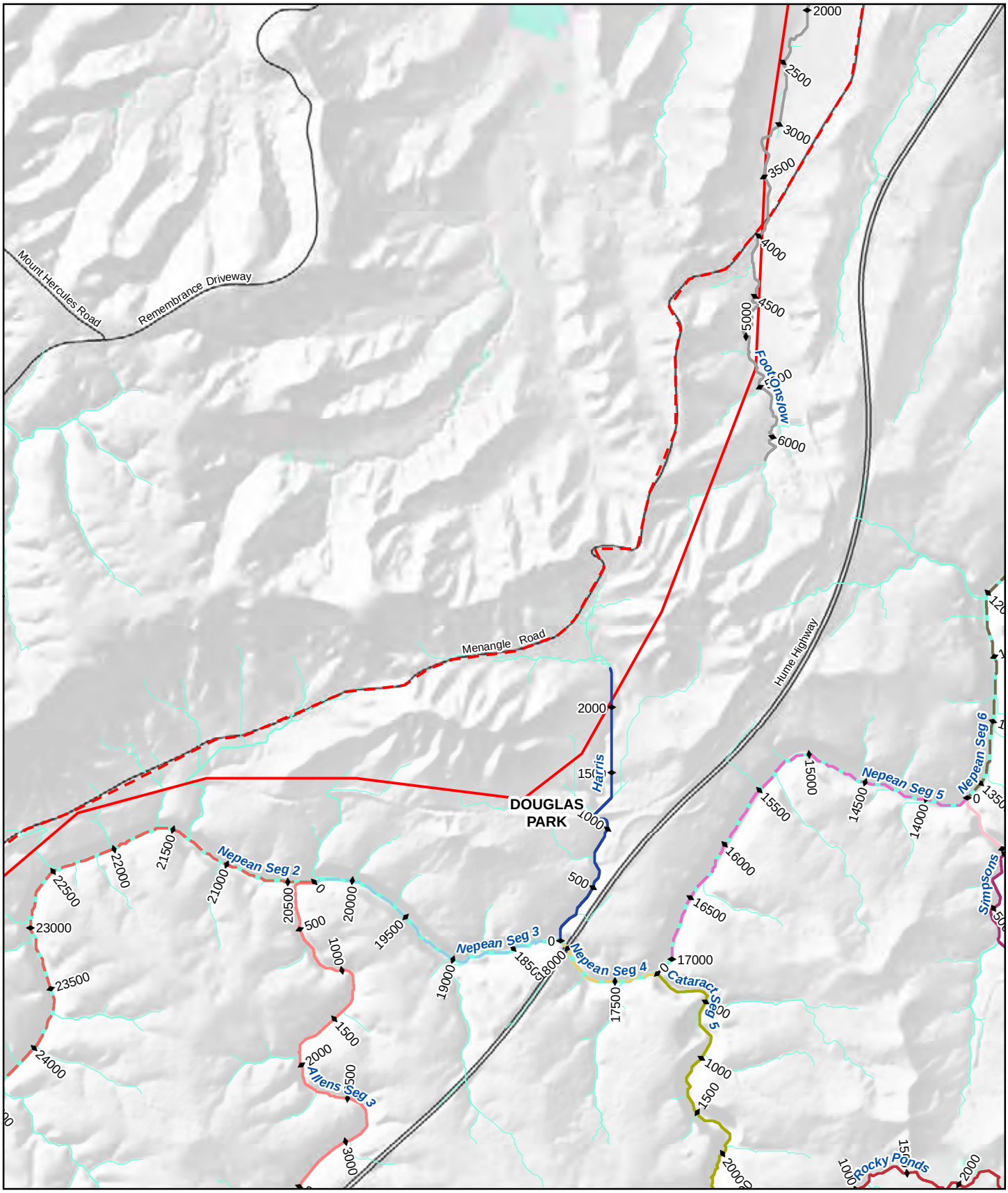
Figure J-2d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_J\2217728_J002_DDP_Profiles_Overall_0.mxd

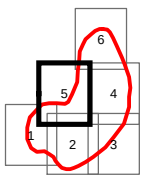
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Allens Seg 3
- Cataract Seg 5
- Elladale Seg 1
- Elladale Seg 2
- Foot Onslow
- Harris
- Nepean Seg 2
- Nepean Seg 3
- Nepean Seg 4
- Nepean Seg 5
- Nepean Seg 6
- Rocky Ponds
- Simpsons



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Hydraulic Model Plans
Sheet 5

Job Number 22-17728
Revision 0
Date 23 Jun 2015

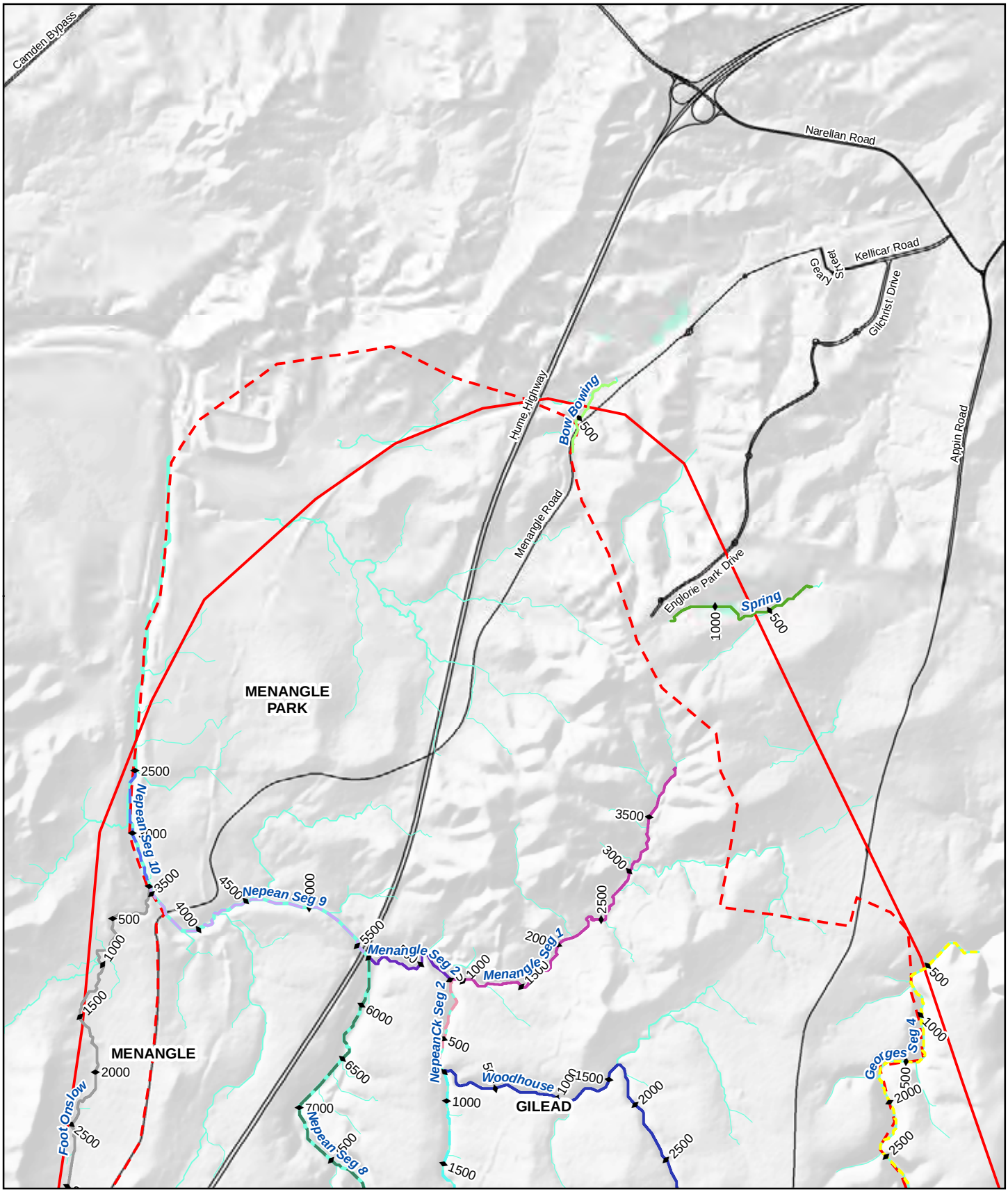
Figure J-2e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_J\2217728_J002_DDP_Profiles_Overall_0.mxd

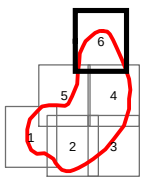
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Road
- Watercourse
- Waterbody
- Bow Bowing
- Foot Onslow
- Georges Seg 4
- Menangle Seg 1
- Menangle Seg 2
- Nepean Seg 10
- Nepean Seg 8
- Nepean Seg 9
- NepeanCk Seg 1
- NepeanCk Seg 2
- Spring
- Woodhouse



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Hydraulic Model Plans
Sheet 6

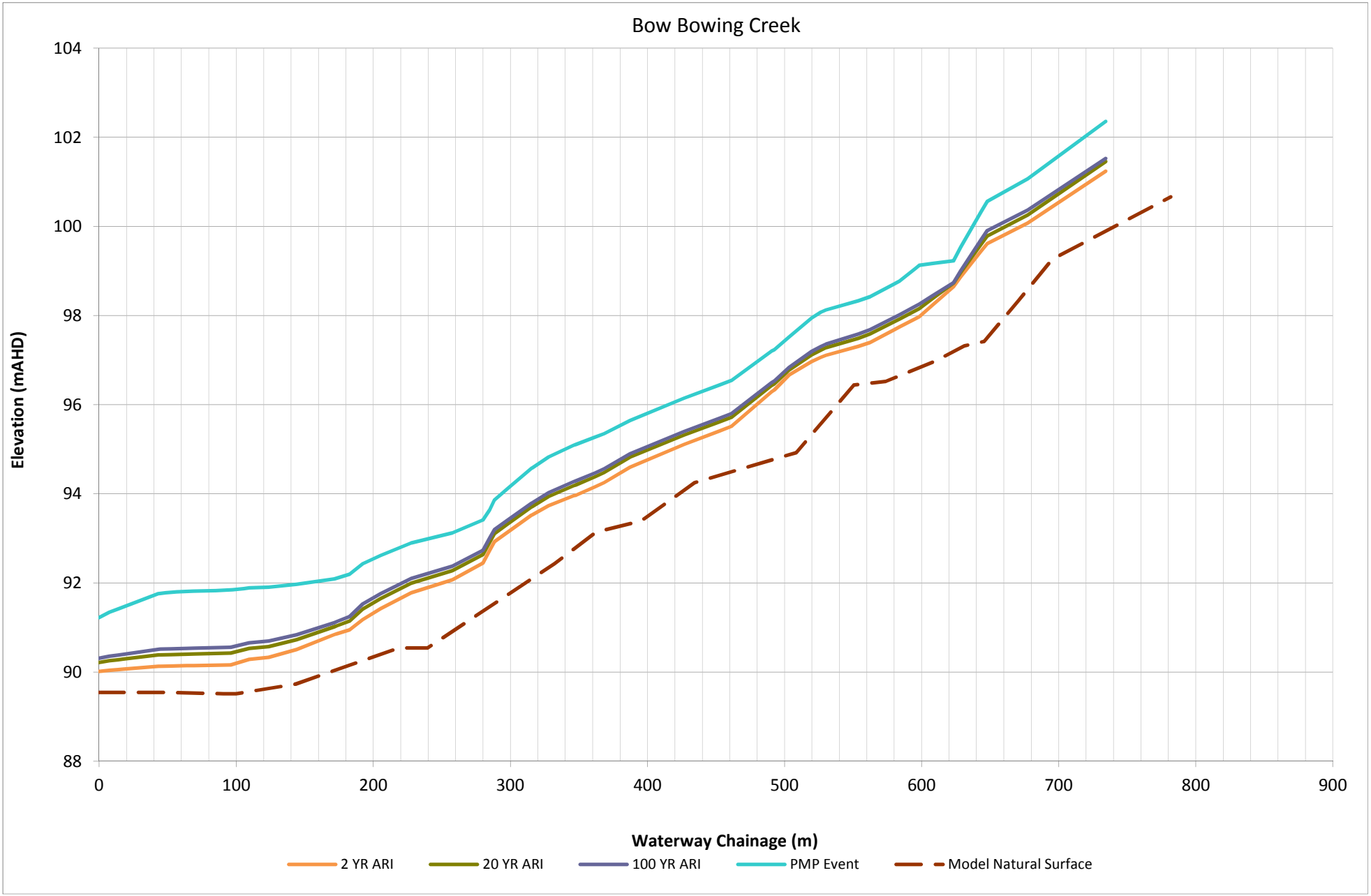
Figure J-2f

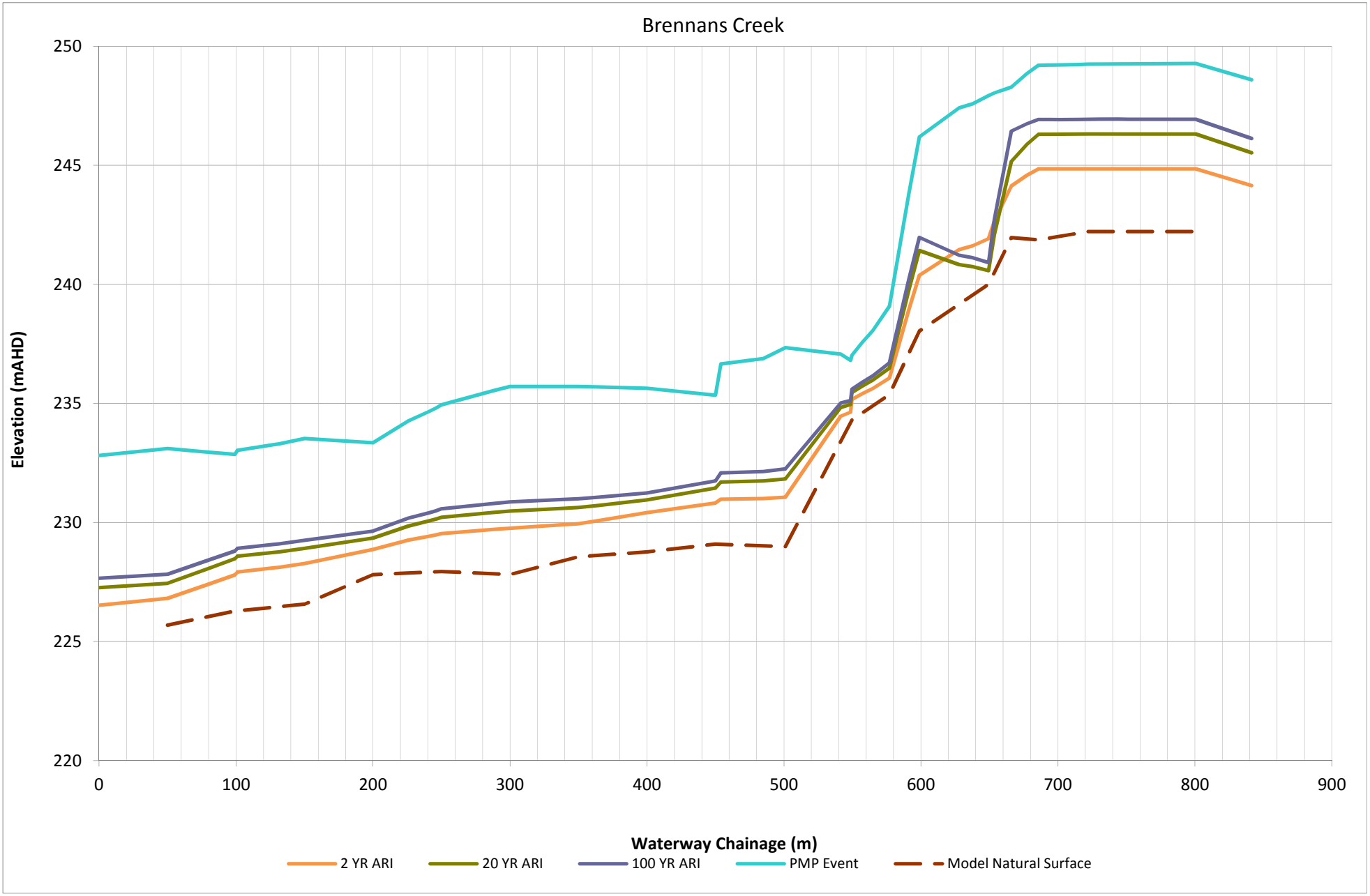
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

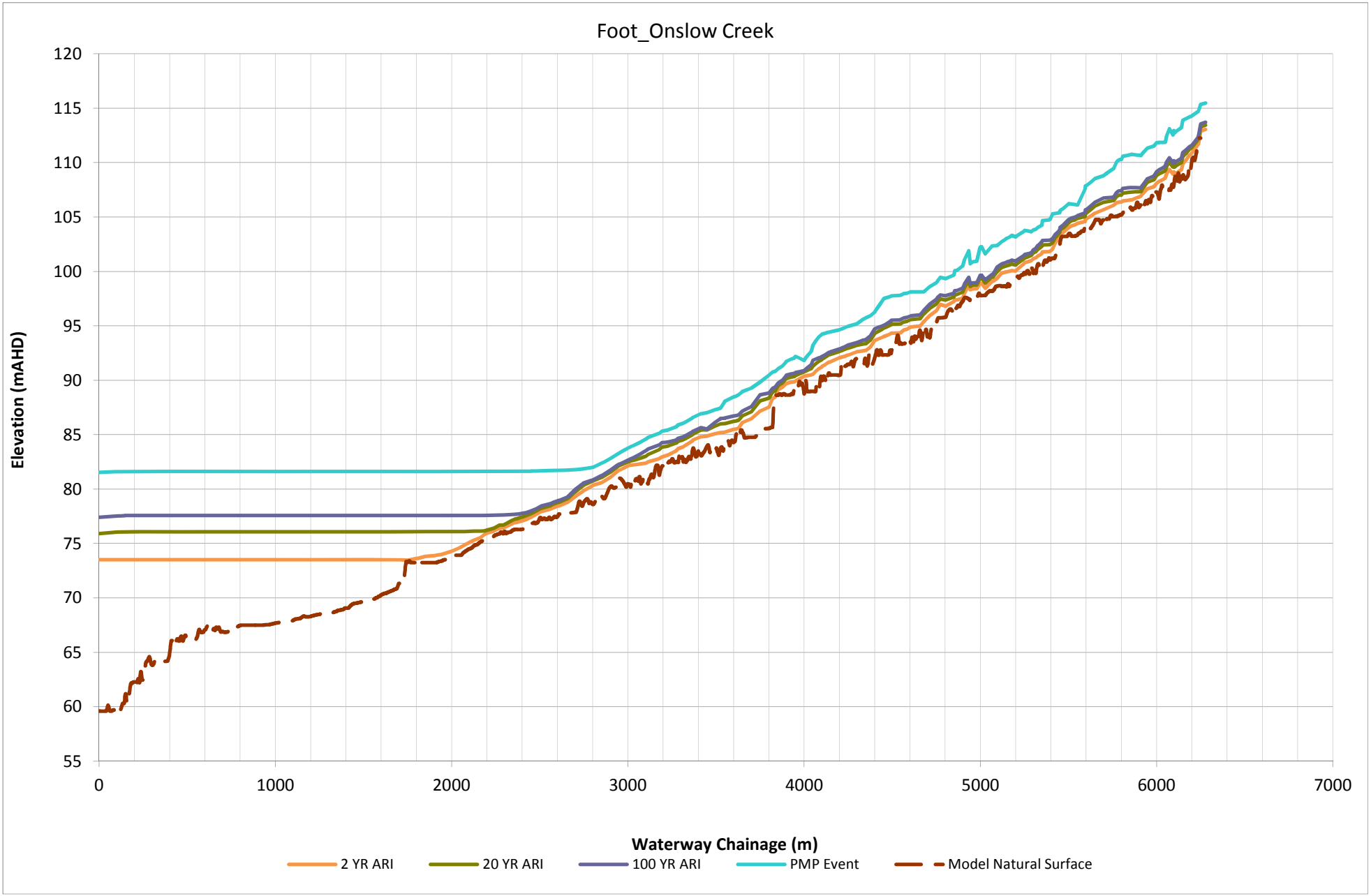
G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_J\2217728_J002_DDP_Profiles_Overall_0.mxd

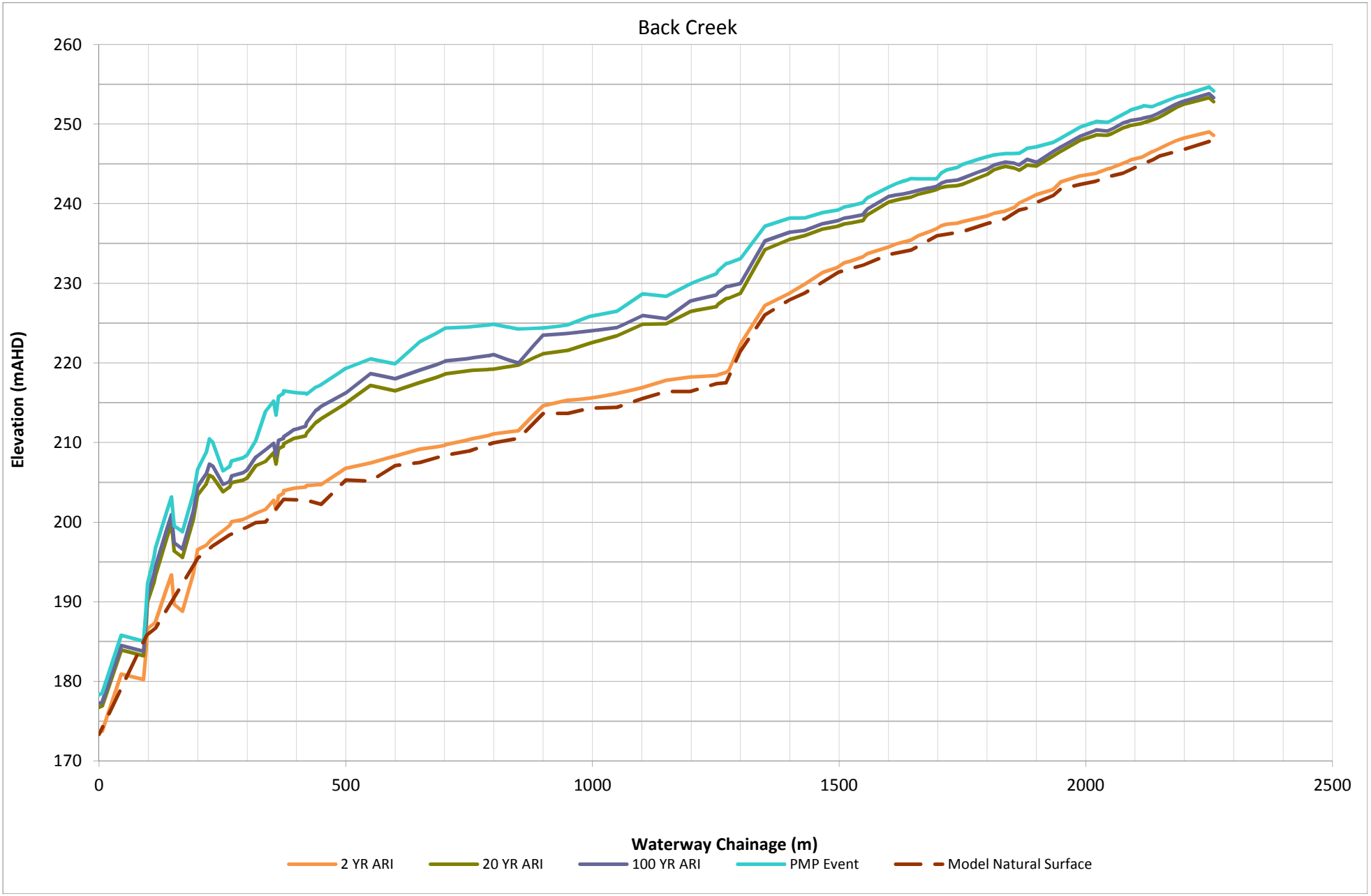
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

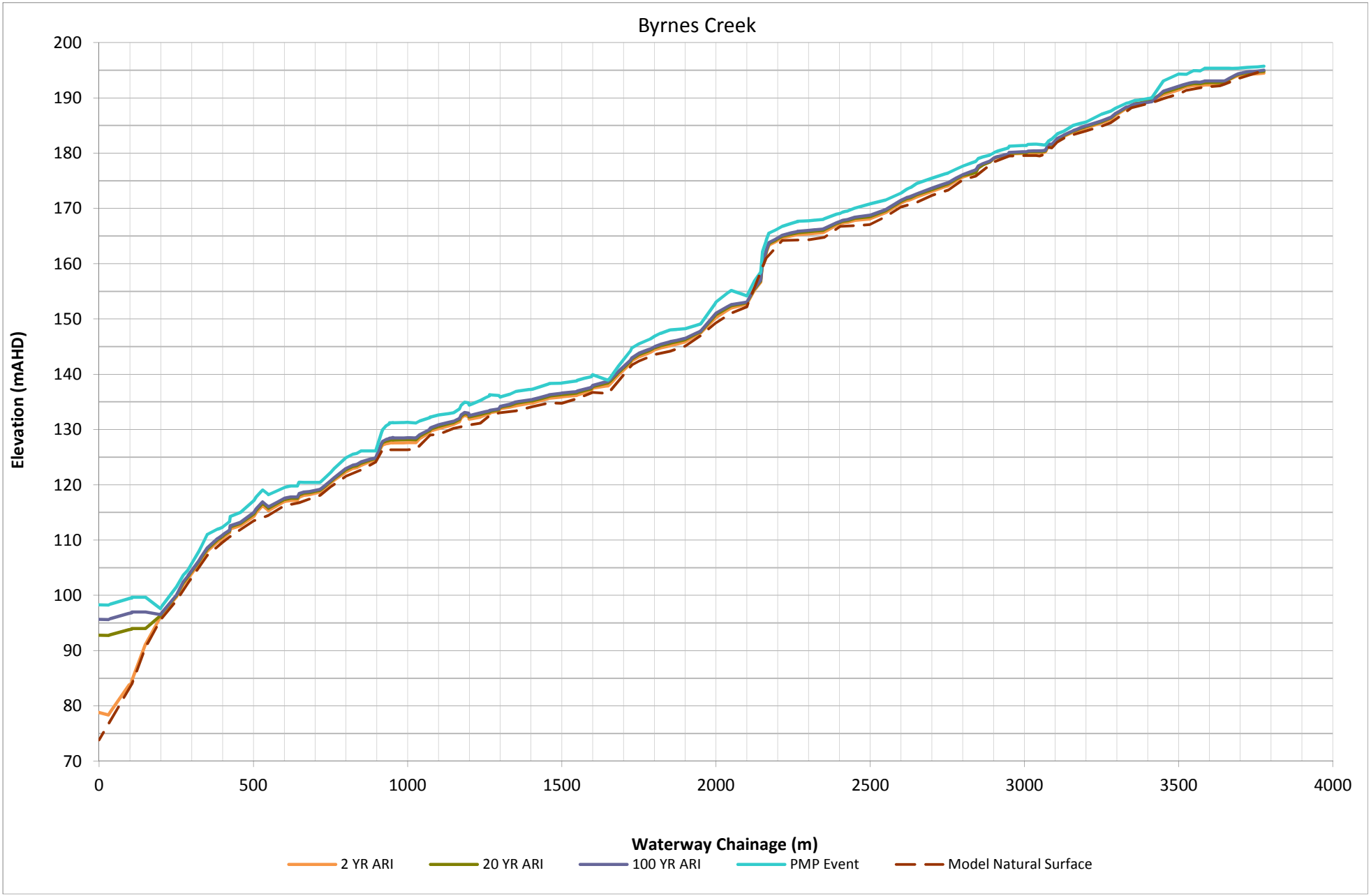
Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

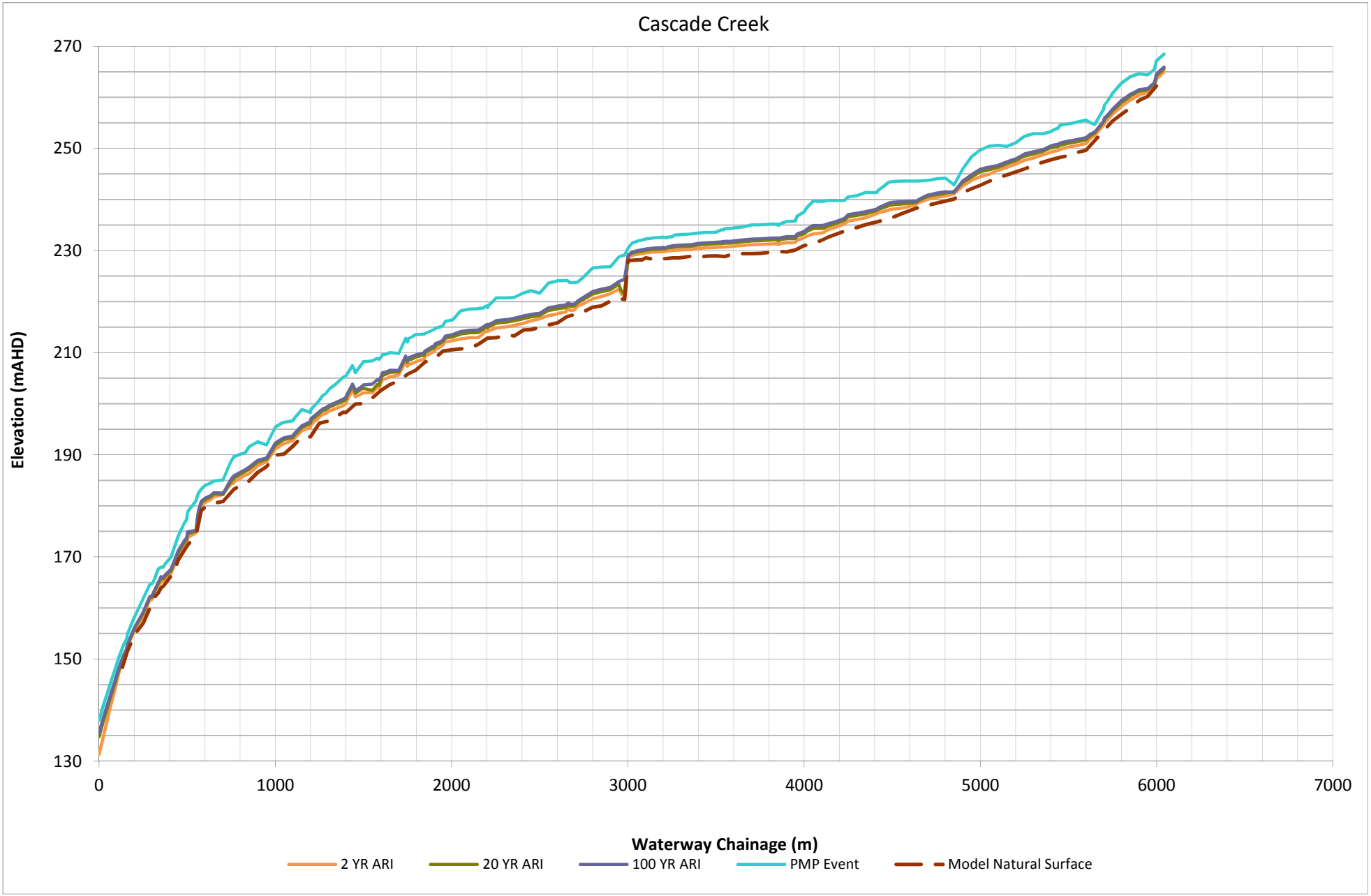

Bow Bowing Creek
104
102
100
98
96
94
92
90
88
Elevation (mAHD)
0
100
200
300
400
500
600
700
800
900
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

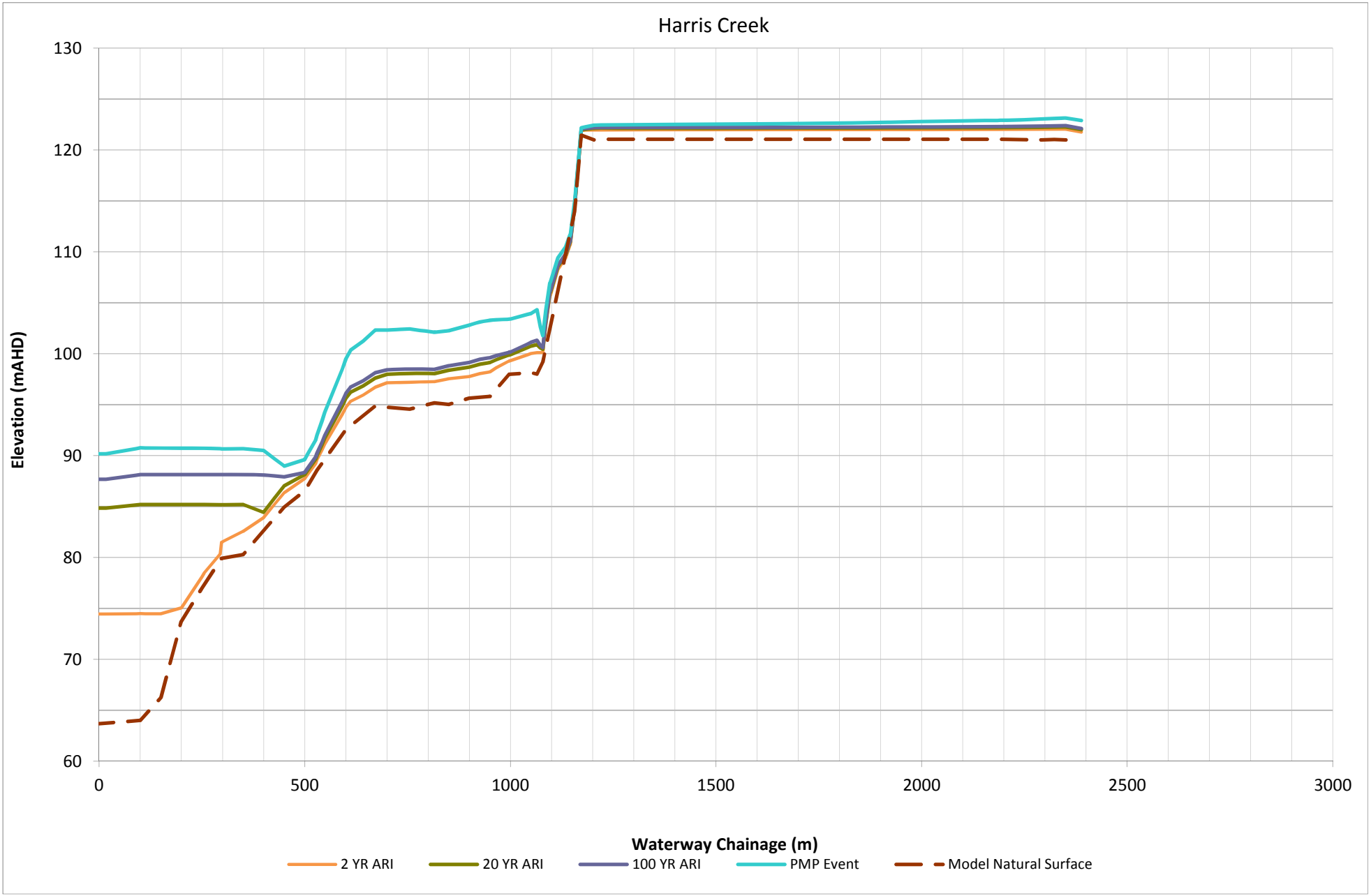

Brennans Creek
250
245
240
235
230
225
220
Elevation (mAHD)
0
100
200
300
400
500
600
700
800
900
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

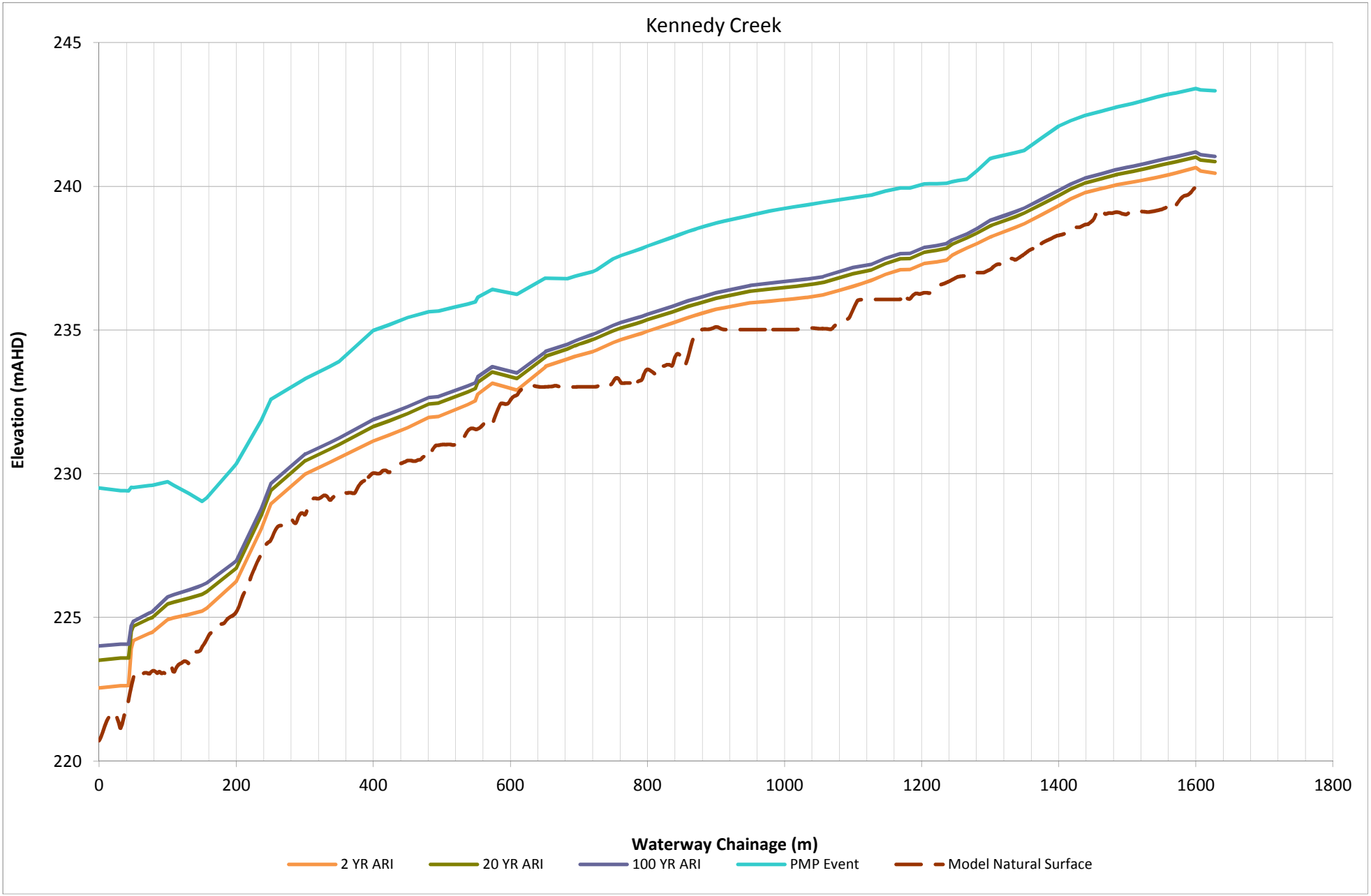

Foot_Onslow Creek
120
115
110
105
100
95
90
85
80
75
70
65
60
55
Elevation (mAHD)
0
1000
2000
3000
4000
5000
6000
7000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

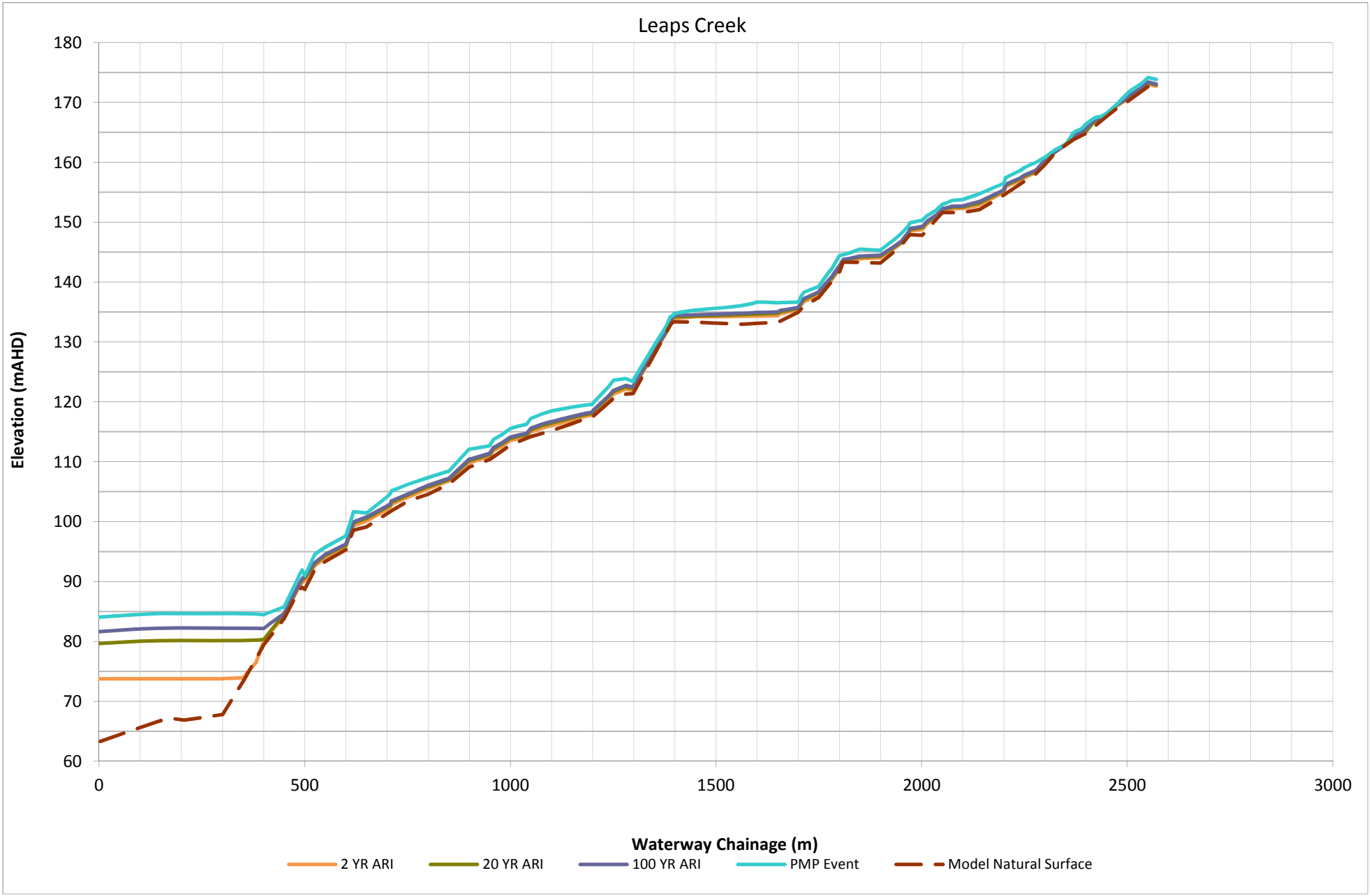

Back Creek
260
250
240
230
220
210
200
190
180
170
Elevation (mAHD)
0
500
1000
1500
2000
2500
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

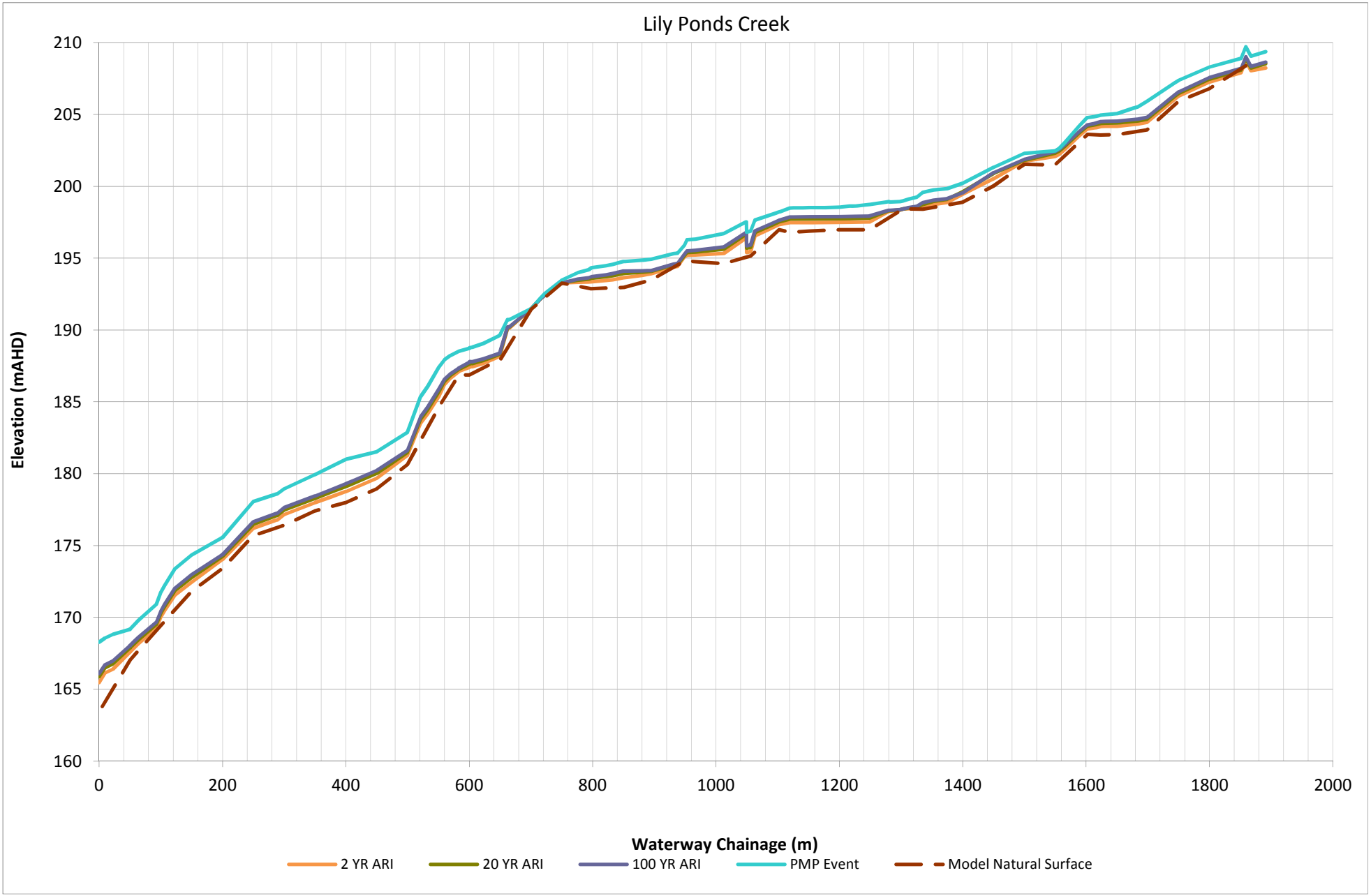

Byrnes Creek
Elevation (mAHD)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
0
500
1000
1500
2000
2500
3000
3500
4000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

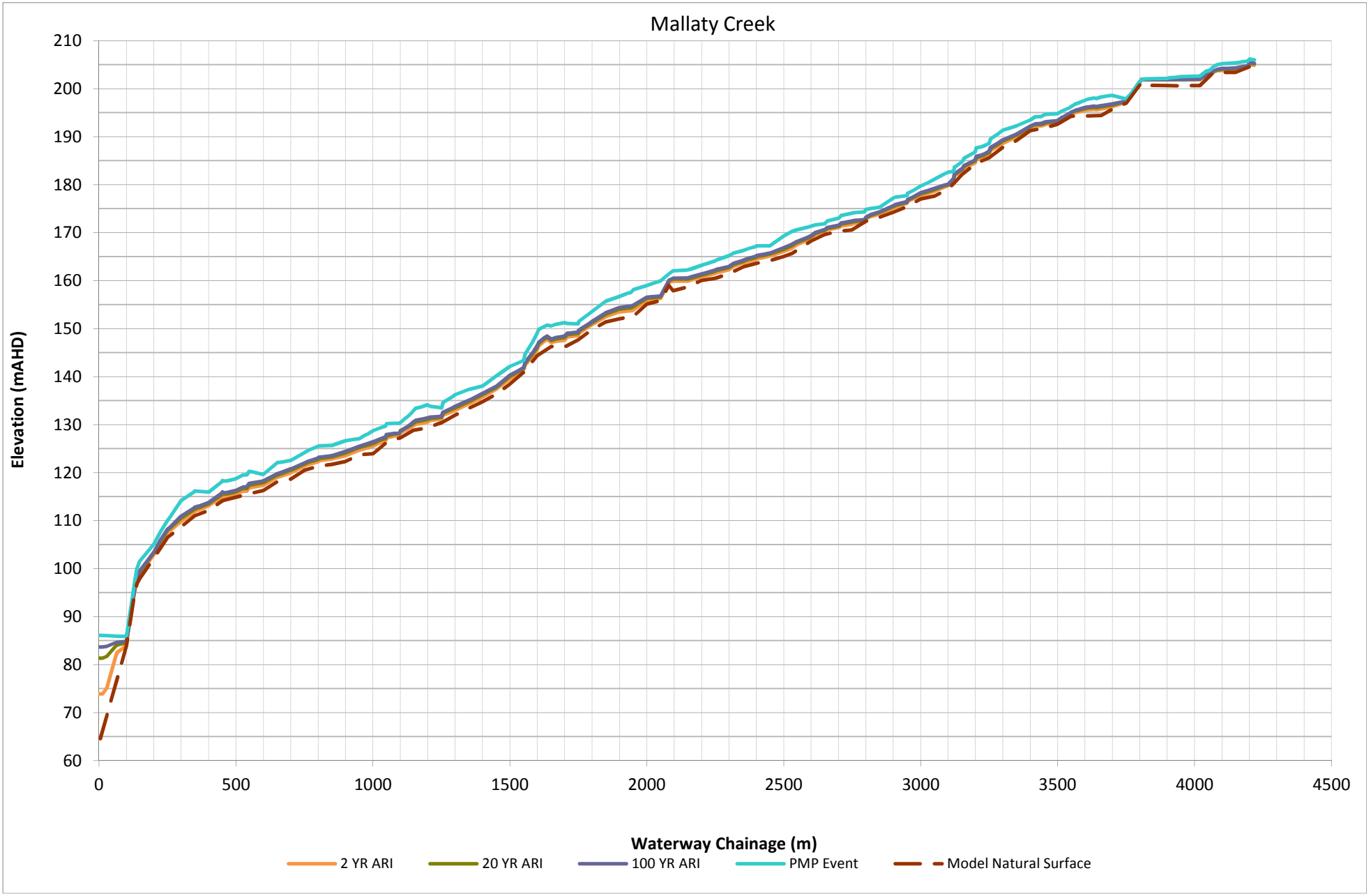

Cascade Creek
270
250
230
210
190
170
150
130
Elevation (mAHD)
0
1000
2000
3000
4000
5000
6000
7000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

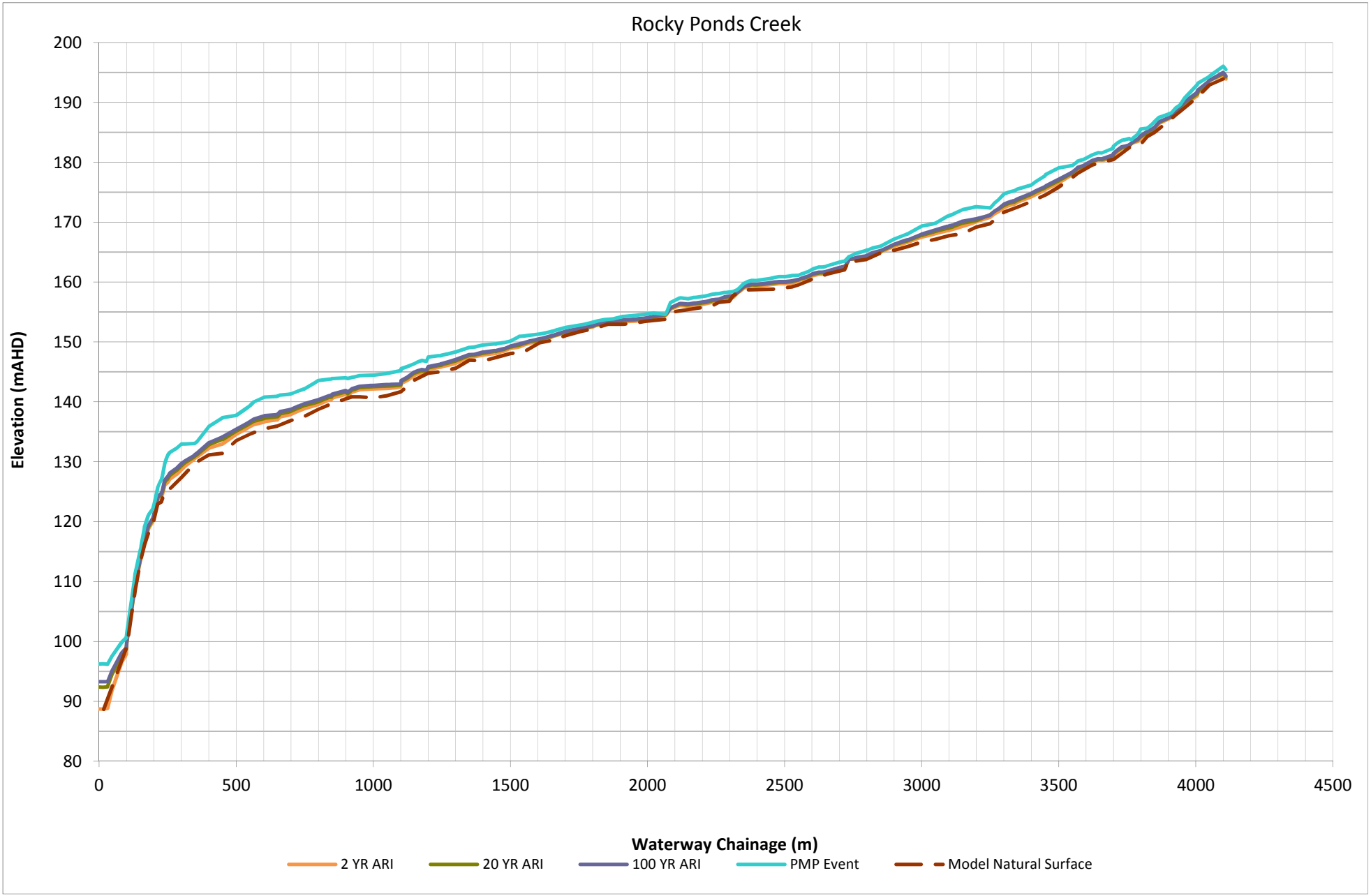

Harris Creek
Elevation (mAHD)
130
120
110
100
90
80
70
60
0
500
1000
1500
2000
2500
3000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

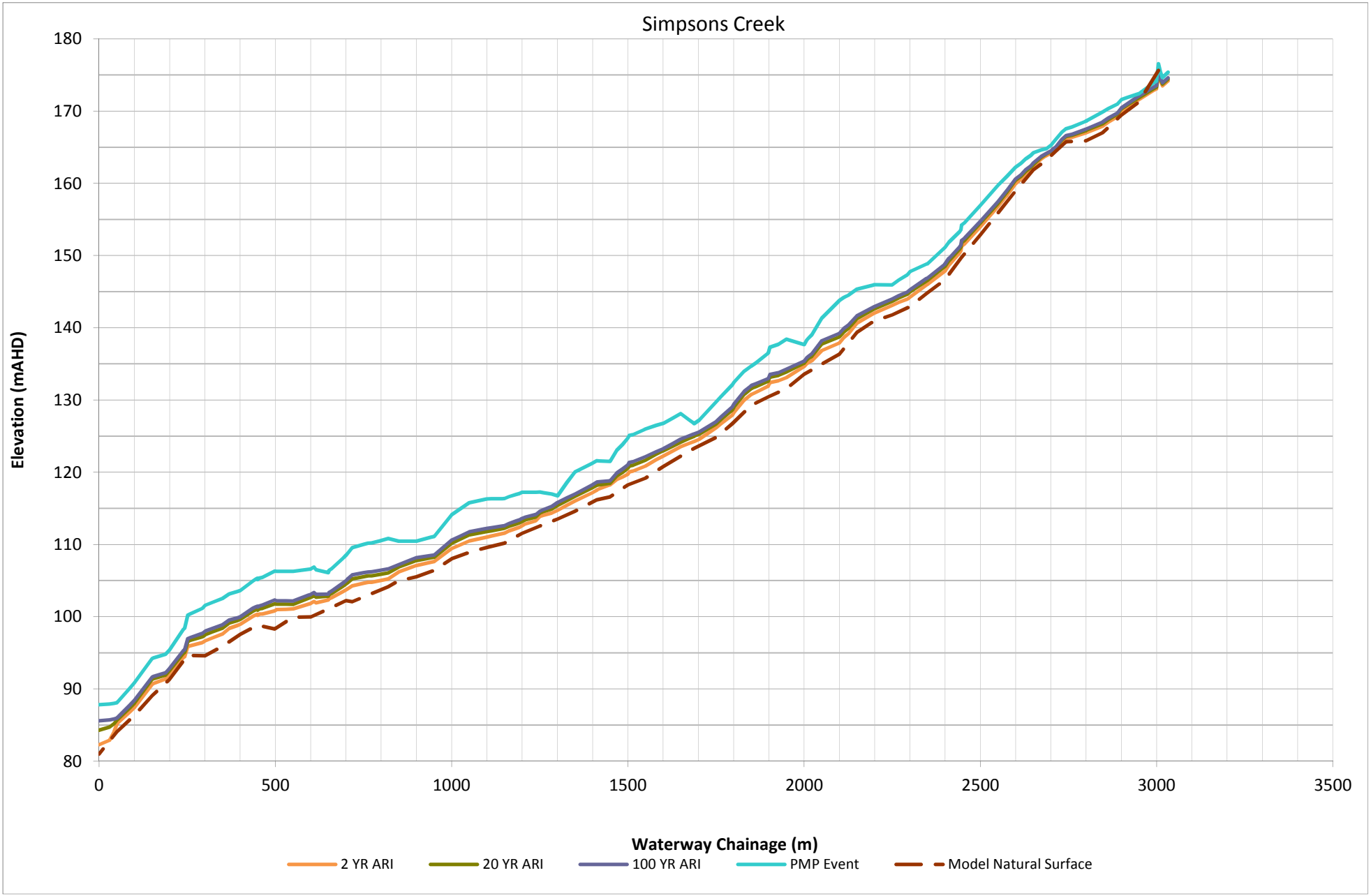

Kennedy Creek
245
240
235
230
225
220
Elevation (mAHD)
0
200
400
600
800
1000
1200
1400
1600
1800
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

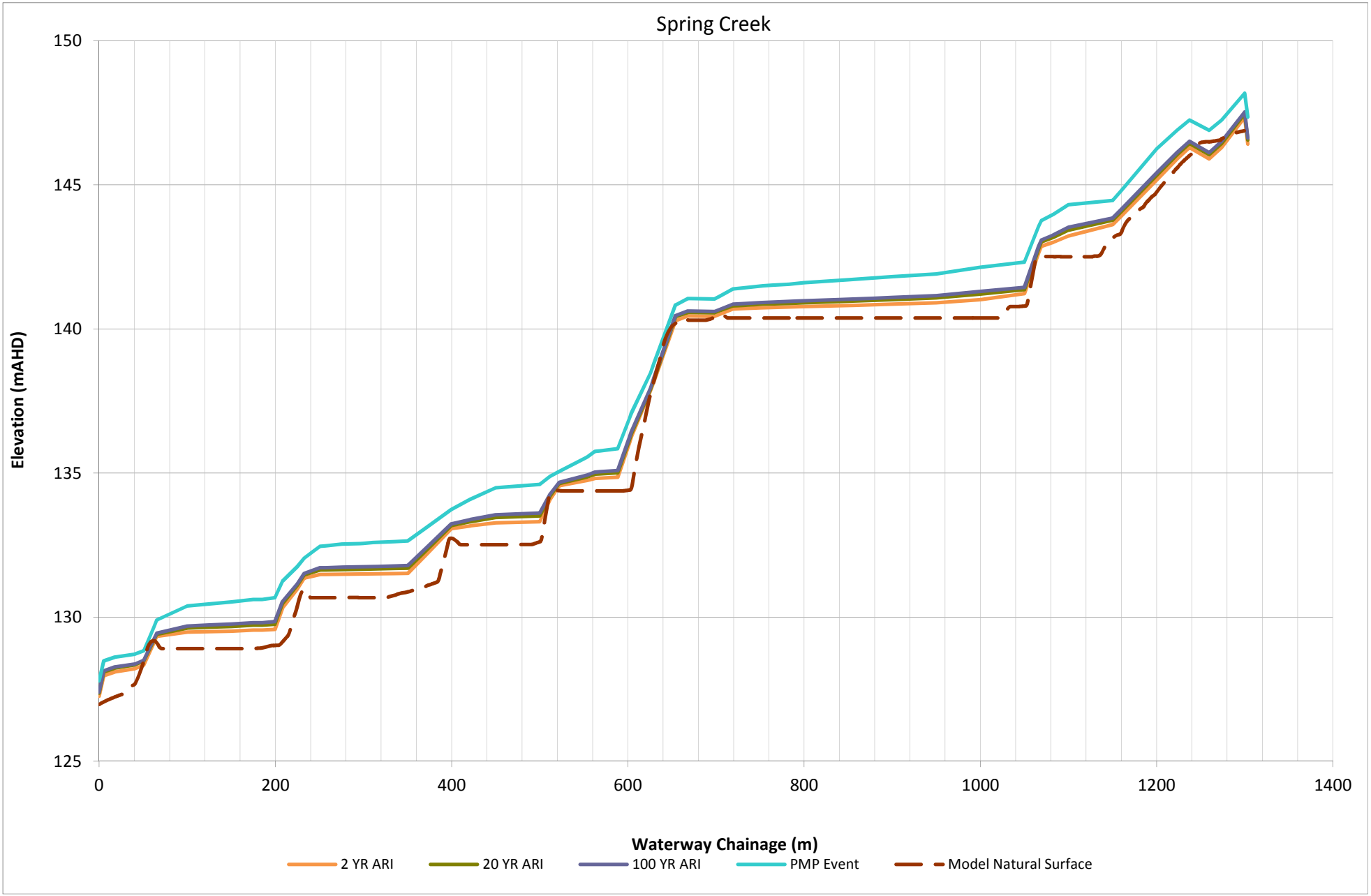

Leaps Creek
Elevation (mAHD)
180
170
160
150
140
130
120
110
100
90
80
70
60
0
500
1000
1500
2000
2500
3000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

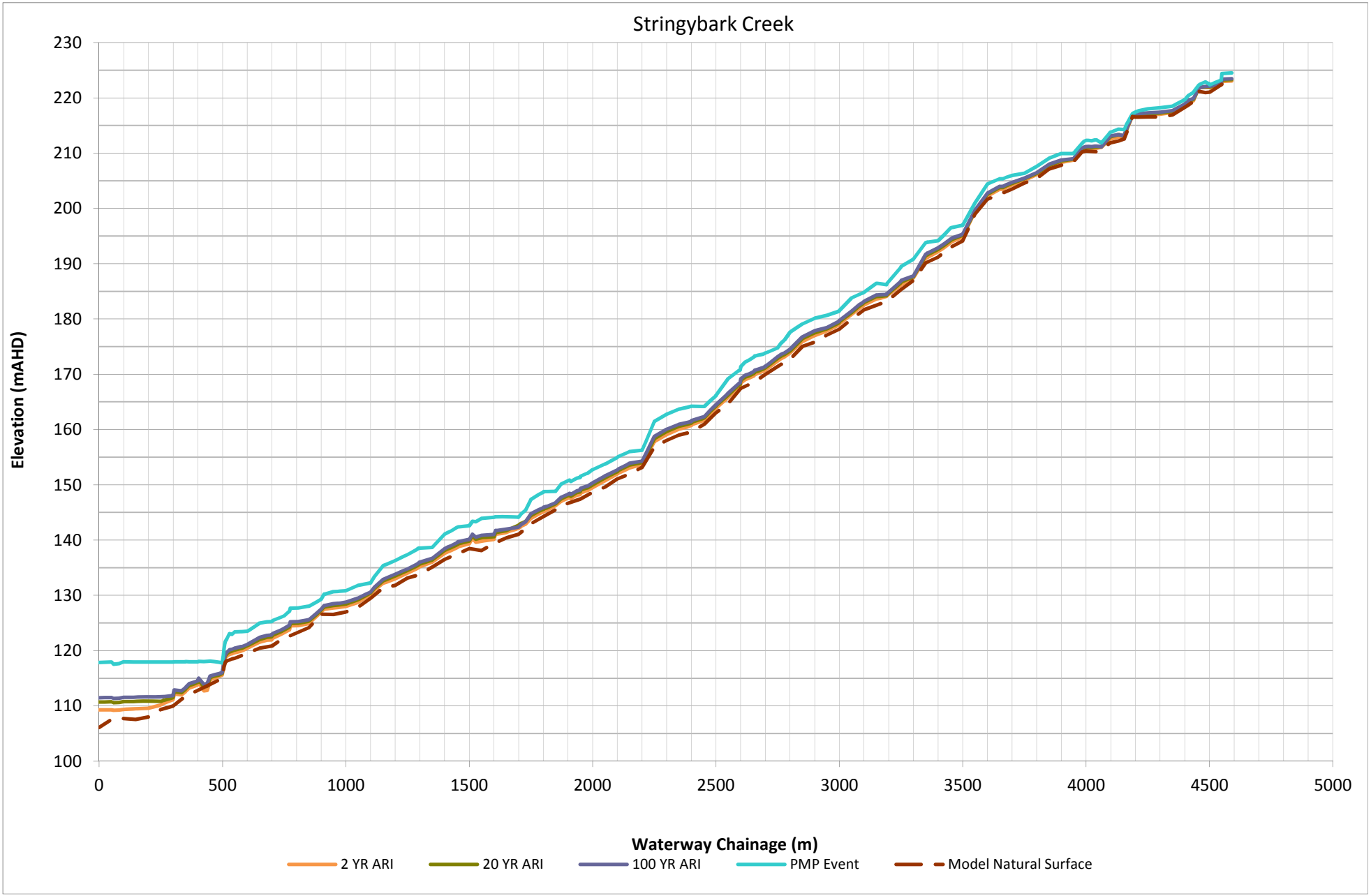

Lily Ponds Creek
Elevation (mAHD)
210
205
200
195
190
185
180
175
170
165
160
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

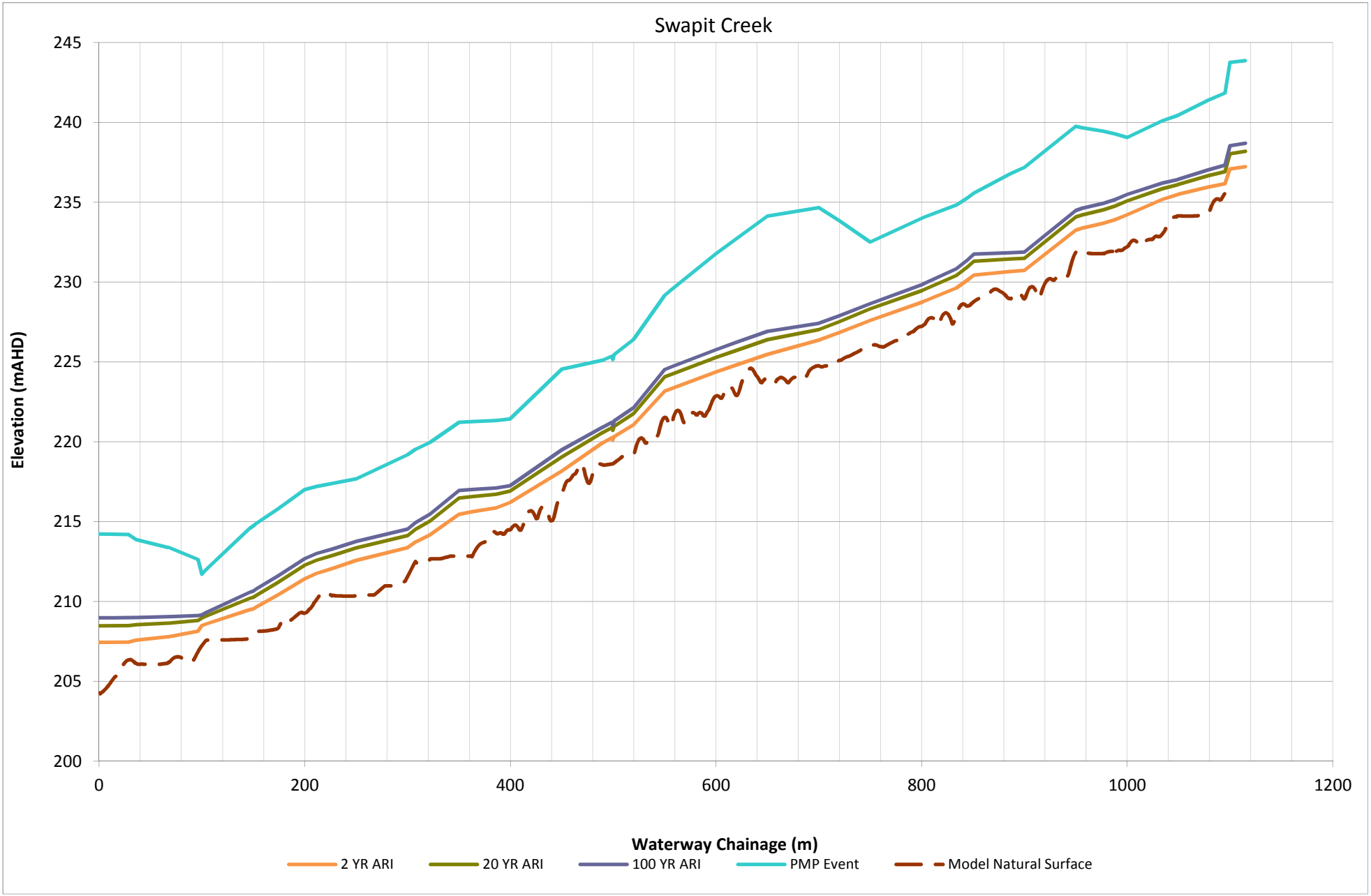

Mallaty Creek
Elevation (mAHD)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

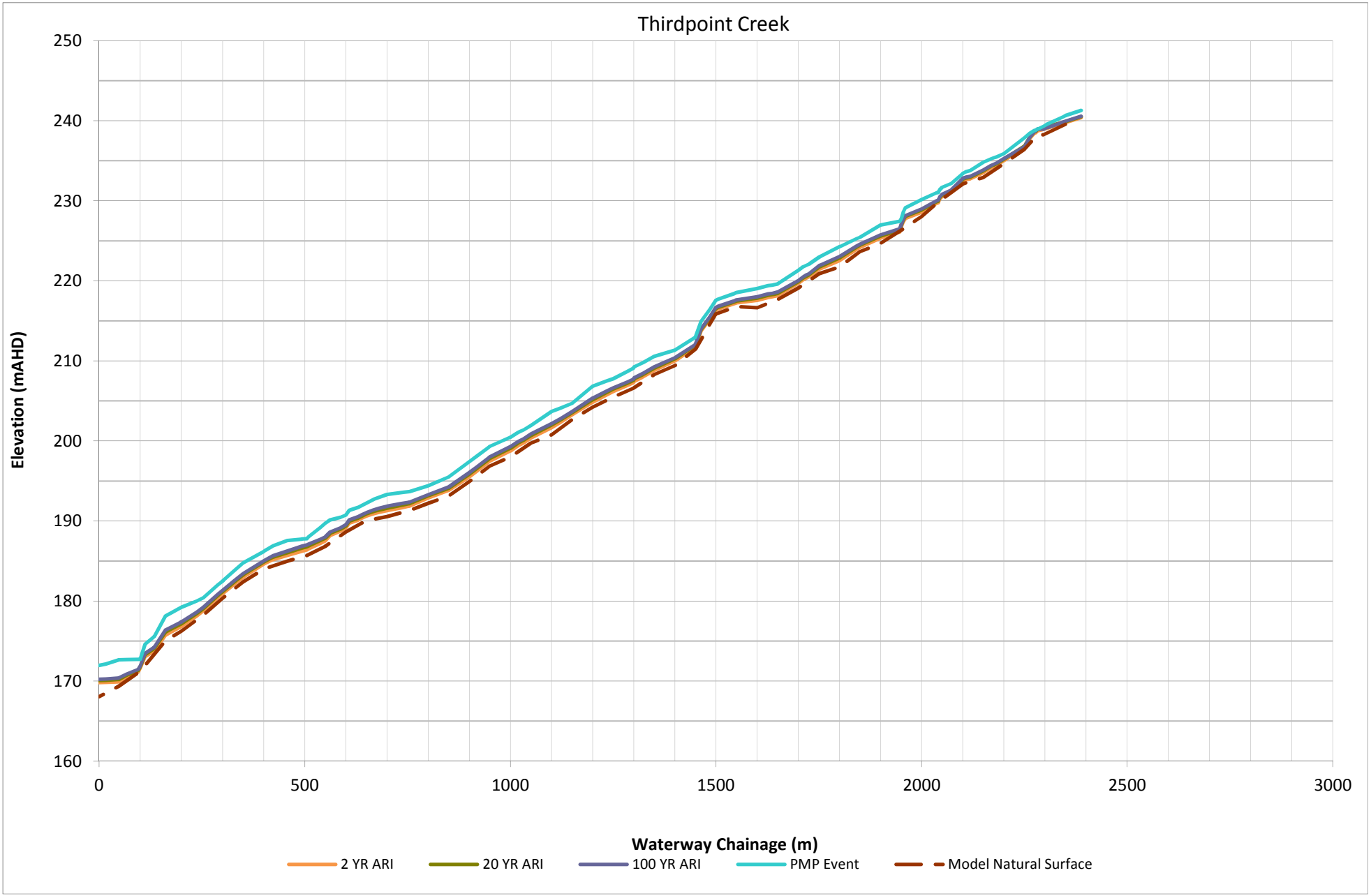

Rocky Ponds Creek
Elevation (mAHD)
200
190
180
170
160
150
140
130
120
110
100
90
80
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

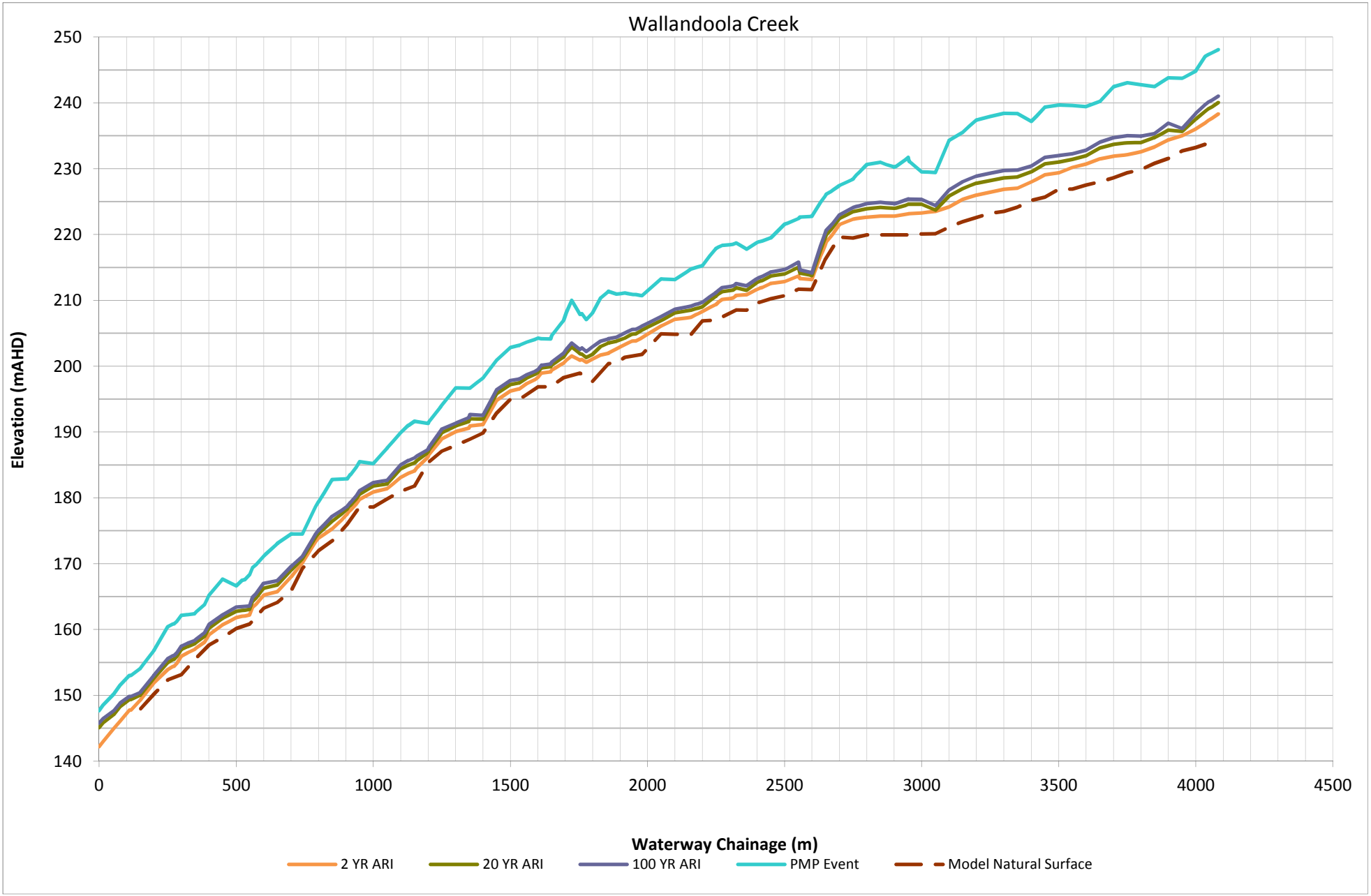

Simpsons Creek
Elevation (mAHD)
180
170
160
150
140
130
120
110
100
90
80
0
500
1000
1500
2000
2500
3000
3500
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

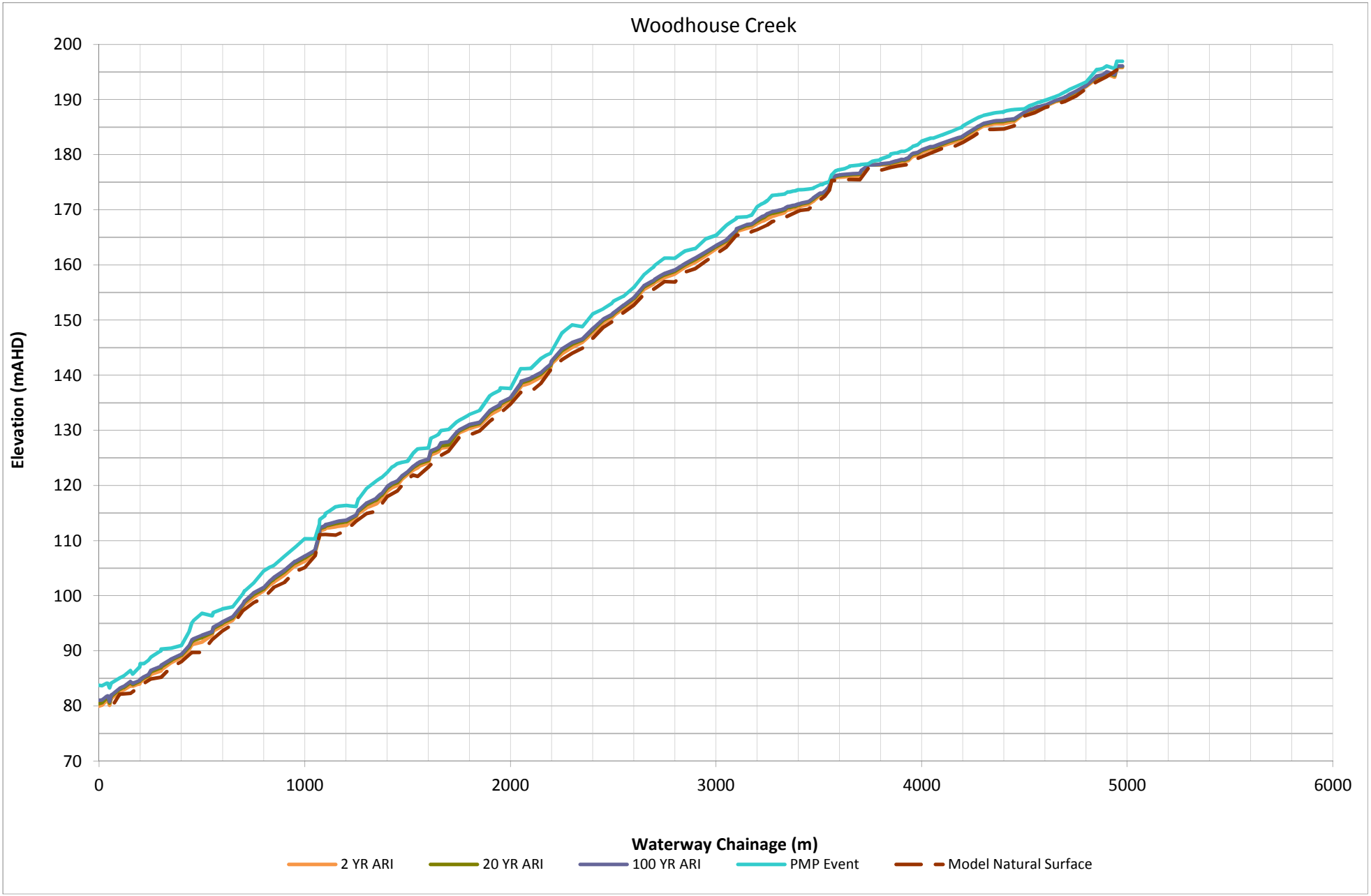

Spring Creek
150
145
140
135
130
125
Elevation (mAHD)
0
200
400
600
800
1000
1200
1400
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

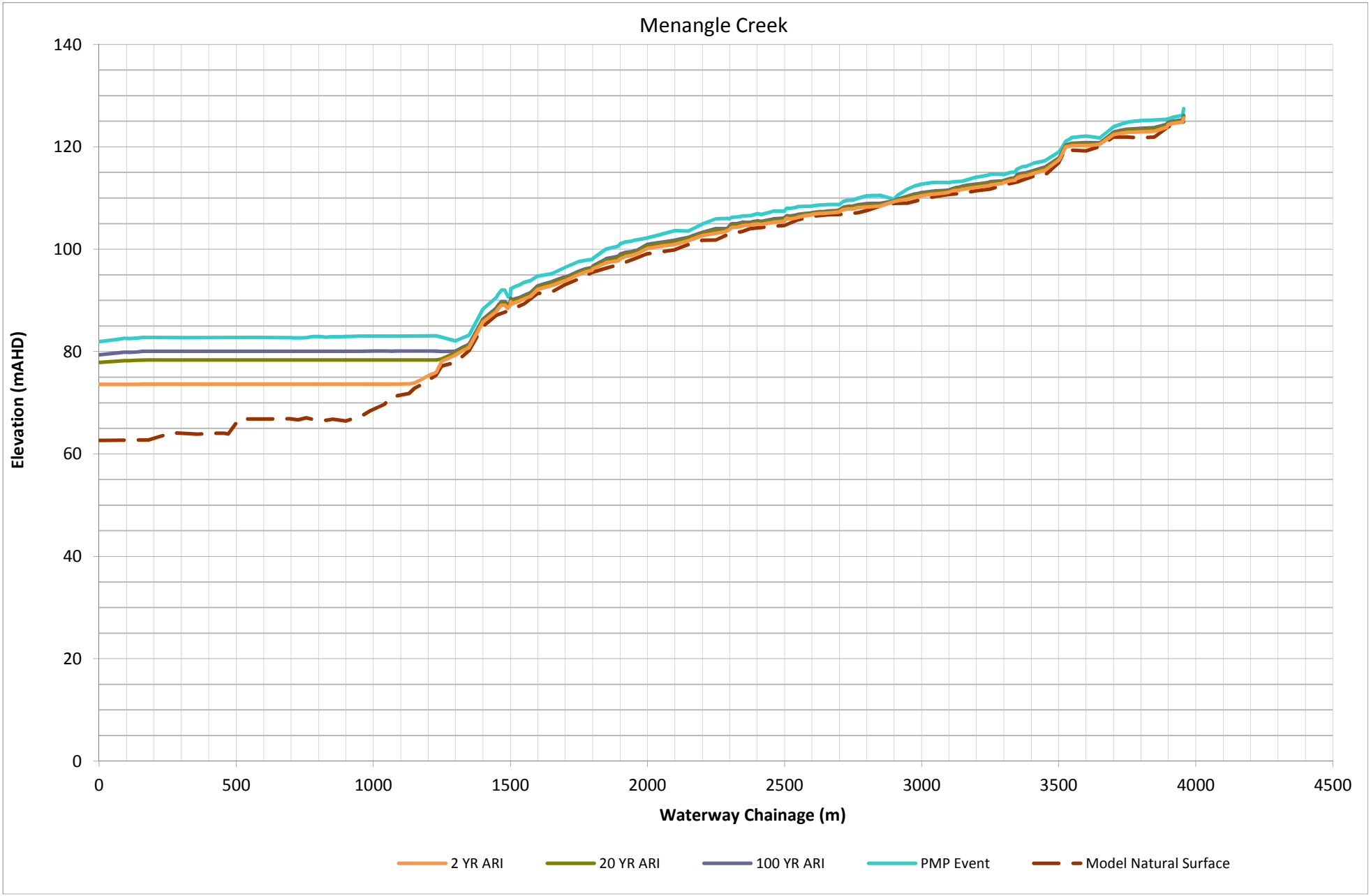

Stringybark Creek
Elevation (mAHD)
230
220
210
200
190
180
170
160
150
140
130
120
110
100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

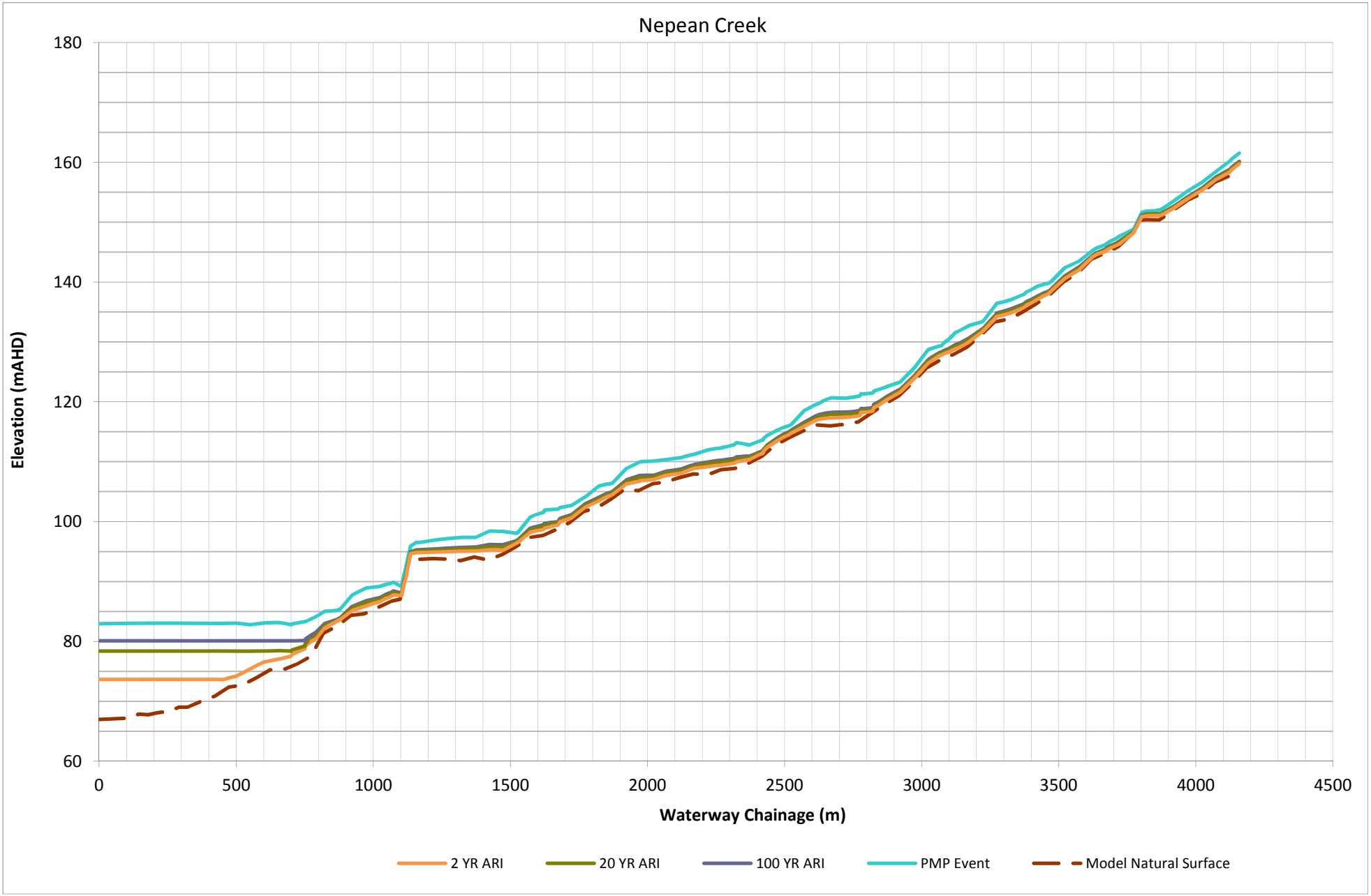

Swapit Creek
245
240
235
230
225
220
215
210
205
200
Elevation (mAHD)
0
200
400
600
800
1000
1200
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

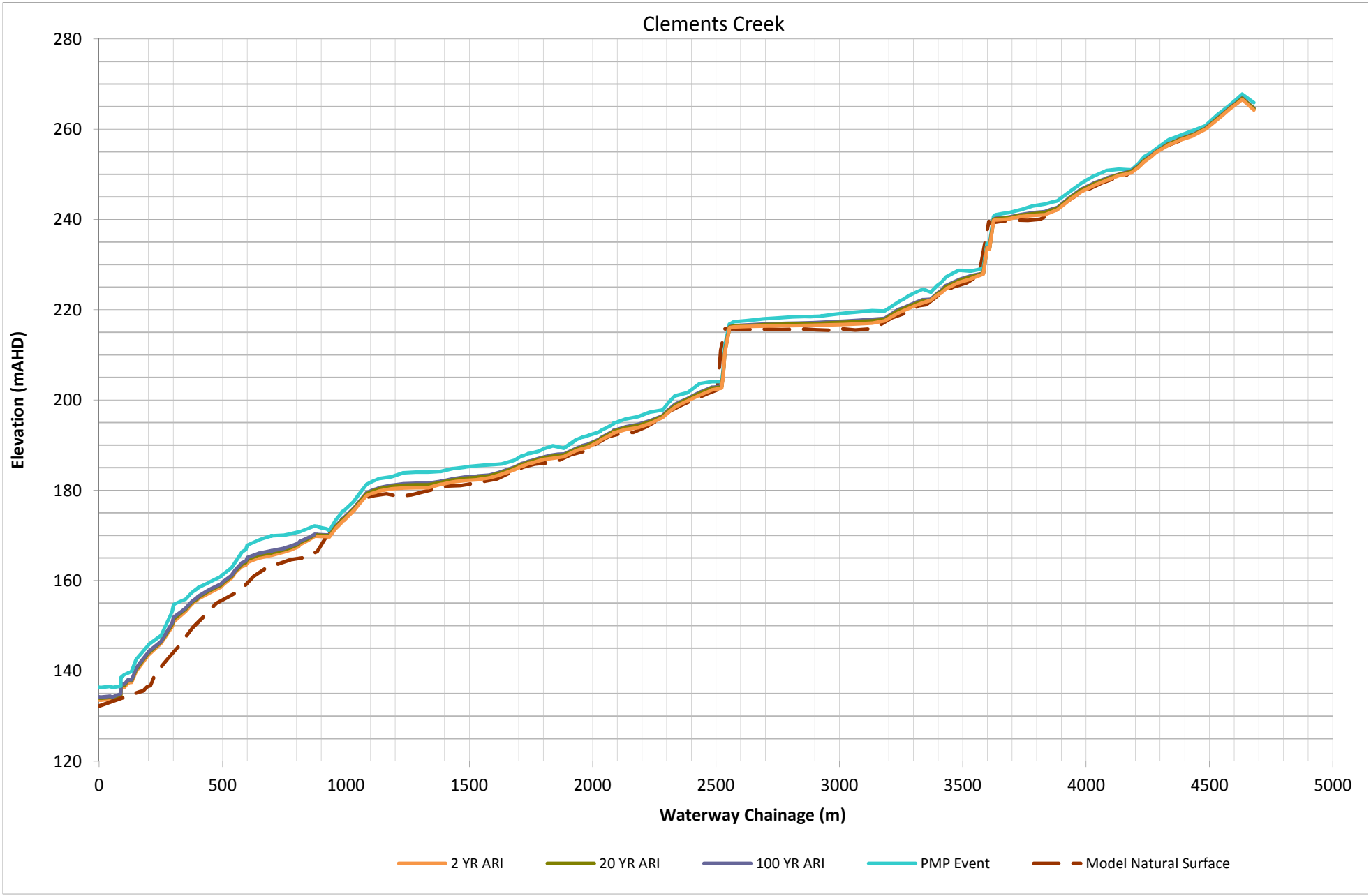

Thirdpoint Creek
250
240
230
220
210
200
190
180
170
160
Elevation (mAHD)
0
500
1000
1500
2000
2500
3000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

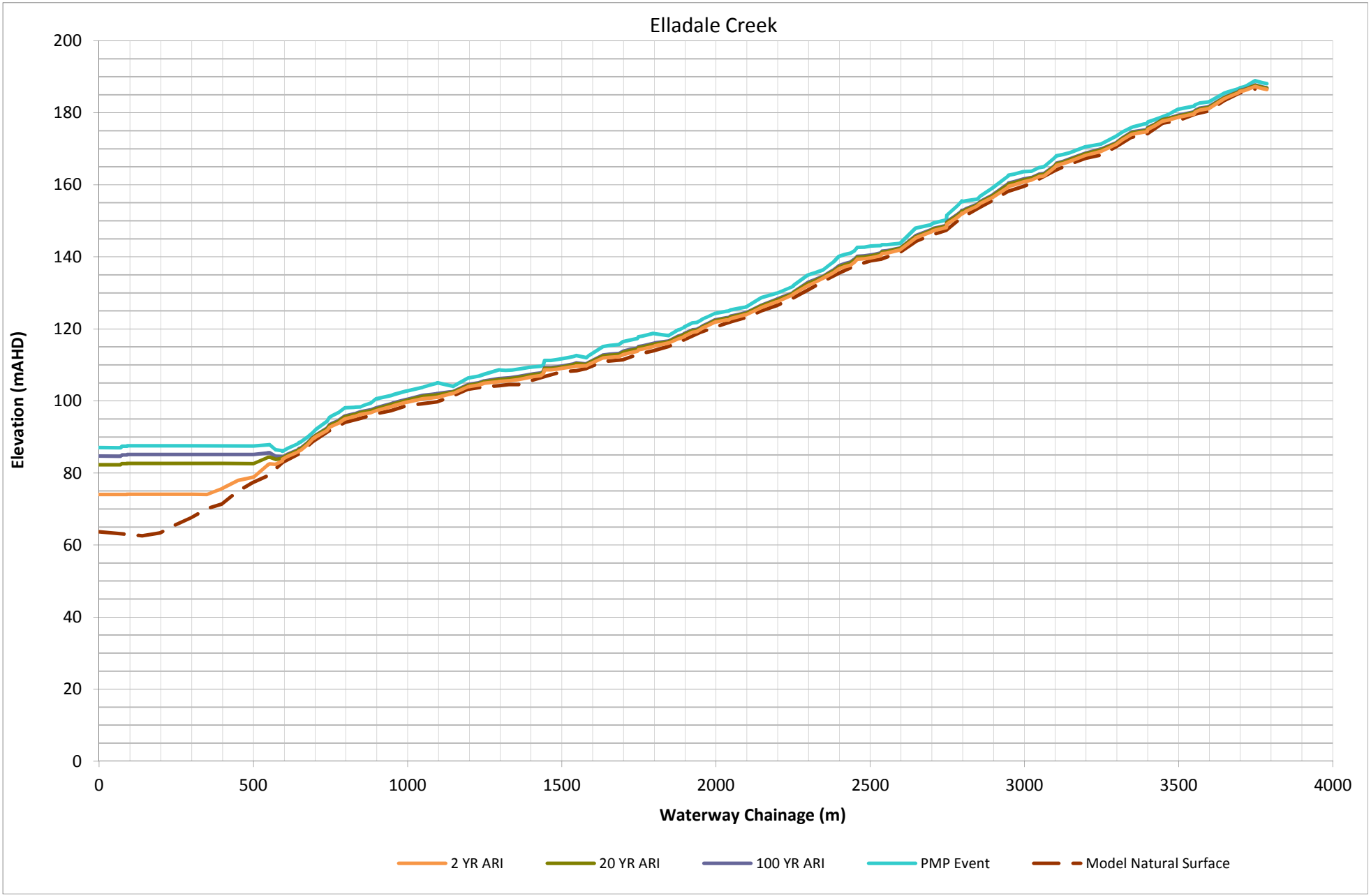

Wallandoola Creek
Elevation (mAHD)
250
240
230
220
210
200
190
180
170
160
150
140
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

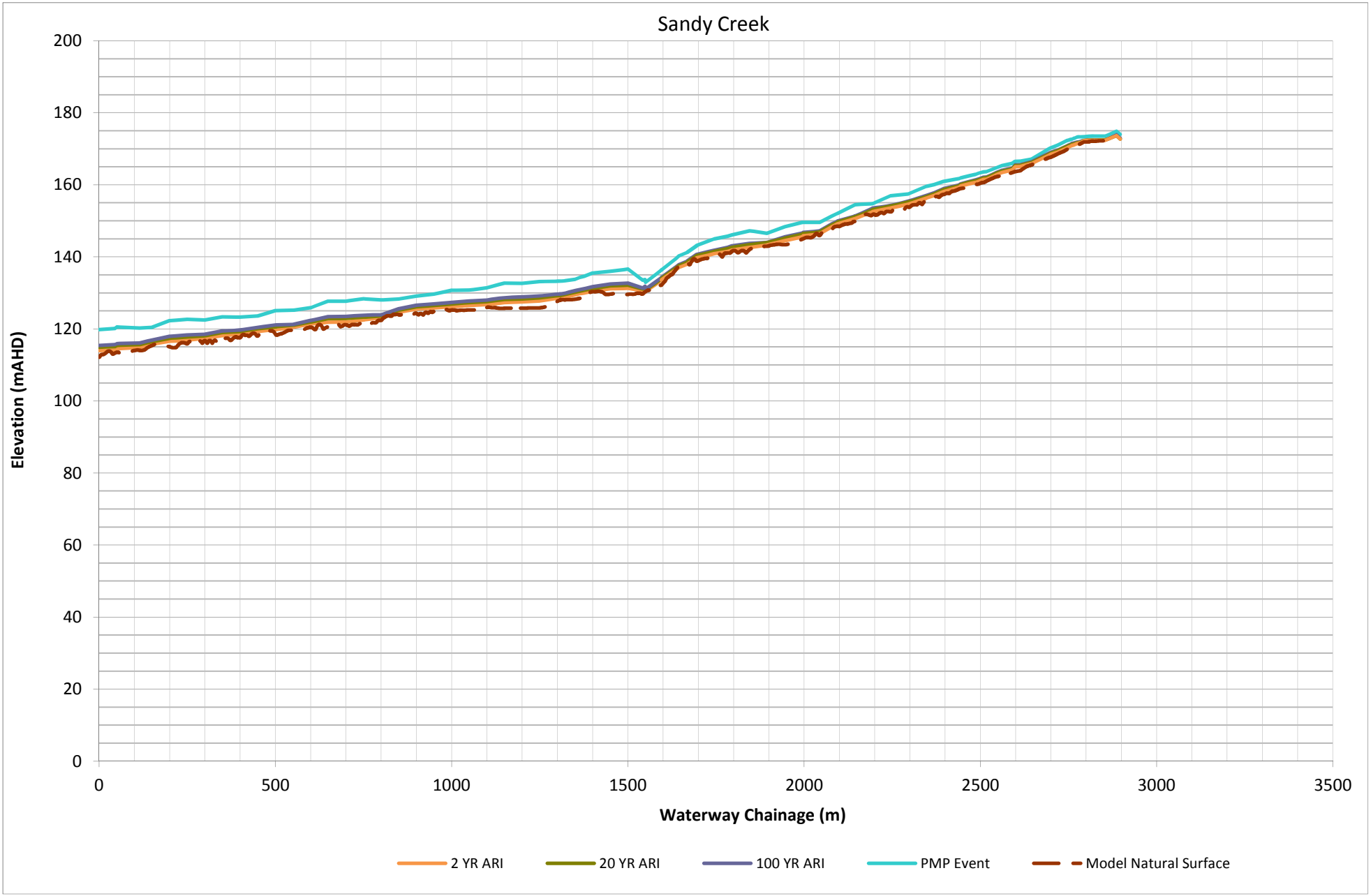

Woodhouse Creek
Elevation (mAHD)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
0
1000
2000
3000
4000
5000
6000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

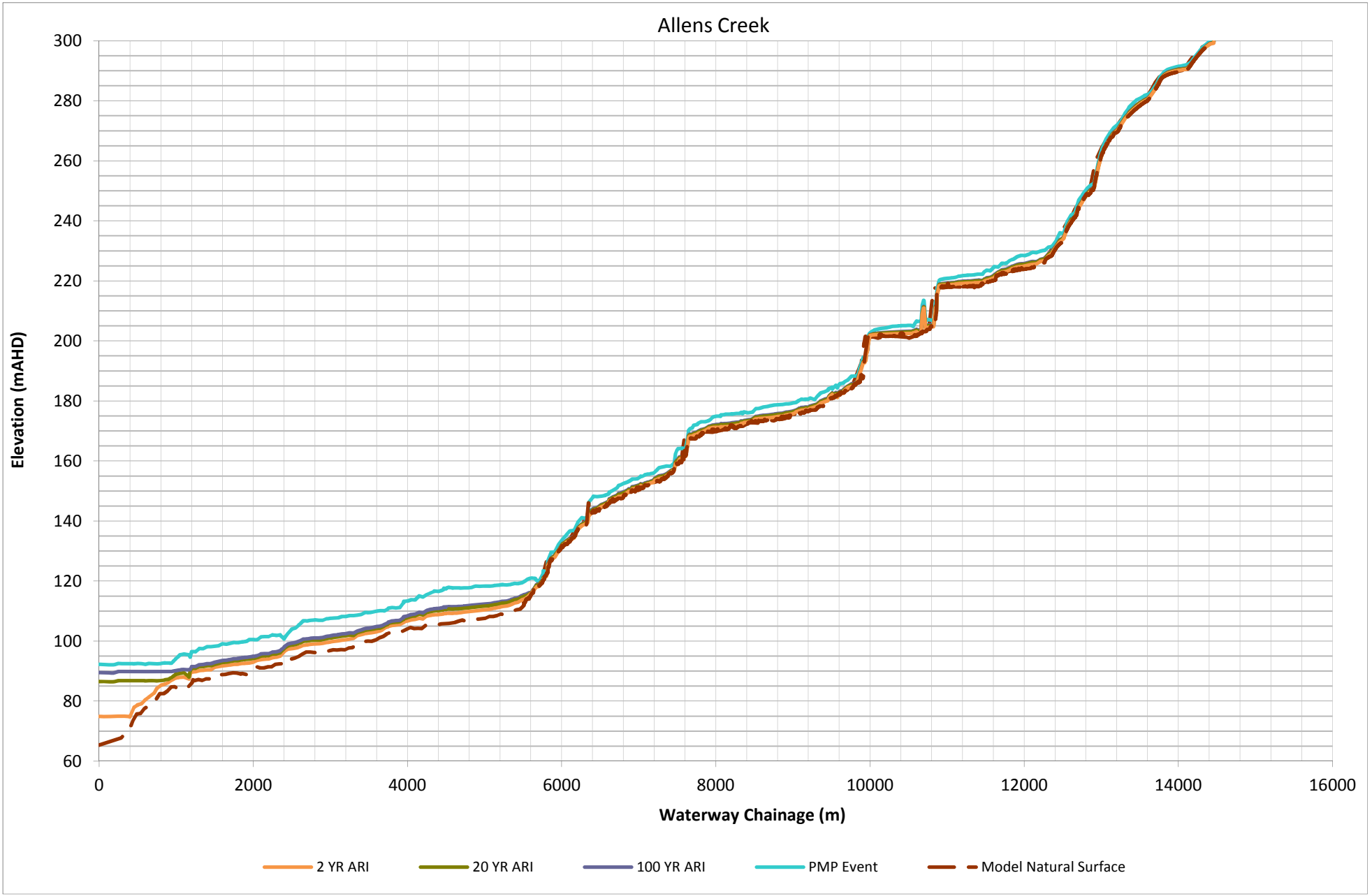

Menangle Creek
Elevation (mAHD)
140
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

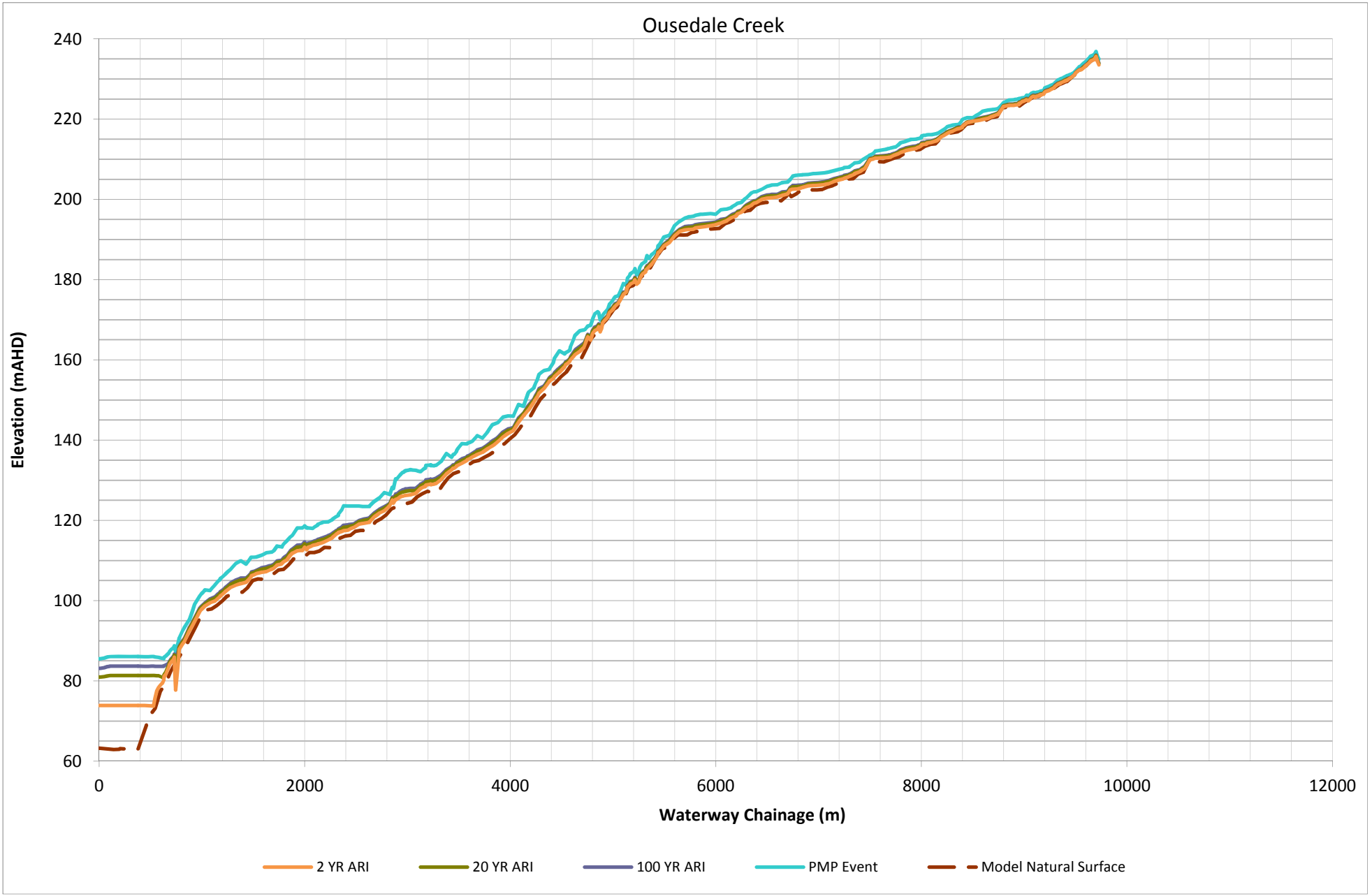

Nepean Creek
180
160
140
120
100
80
60
Elevation (mAHD)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

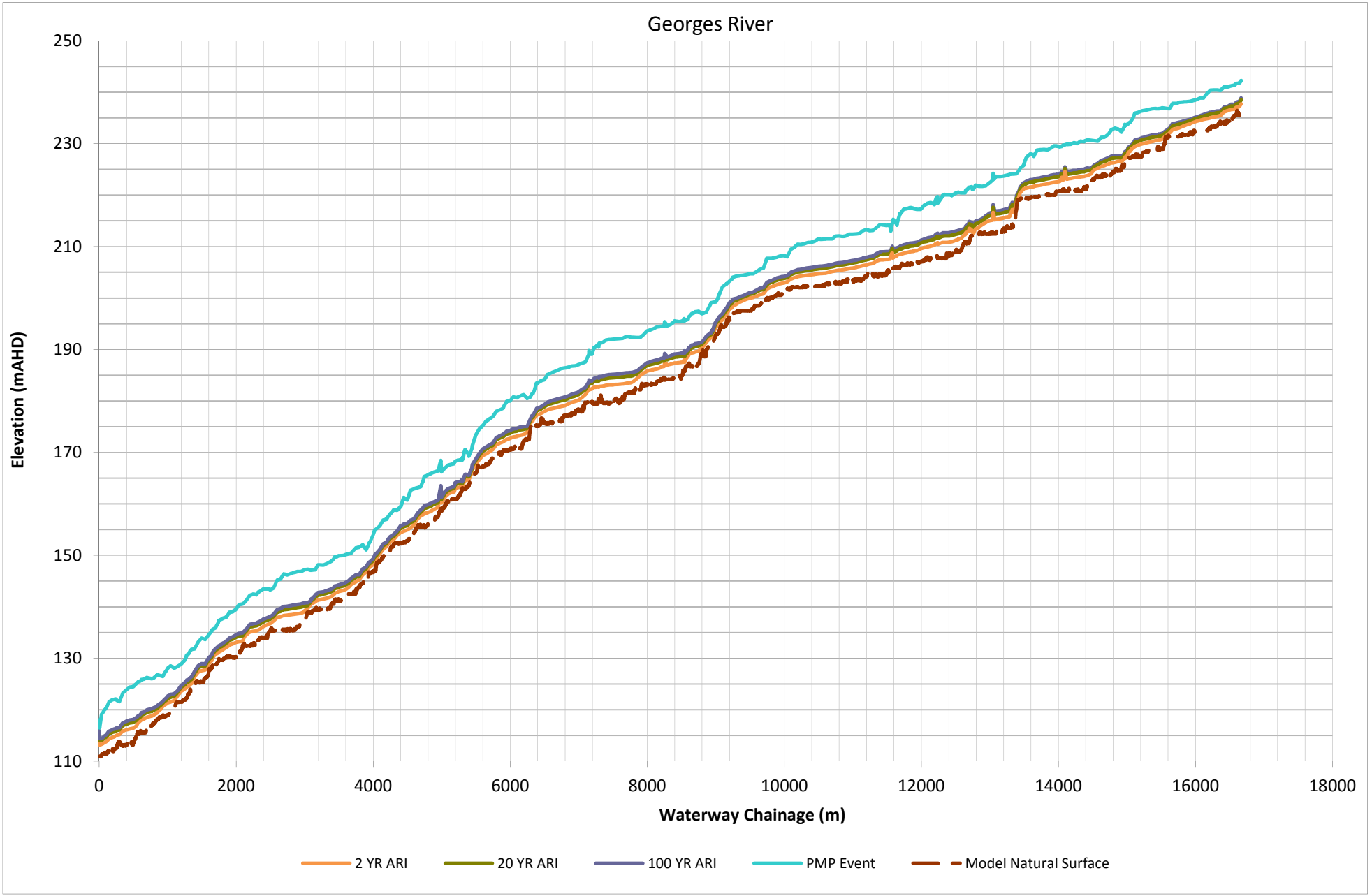

Clements Creek
Elevation (mAHD)
280
260
240
220
200
180
160
140
120
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

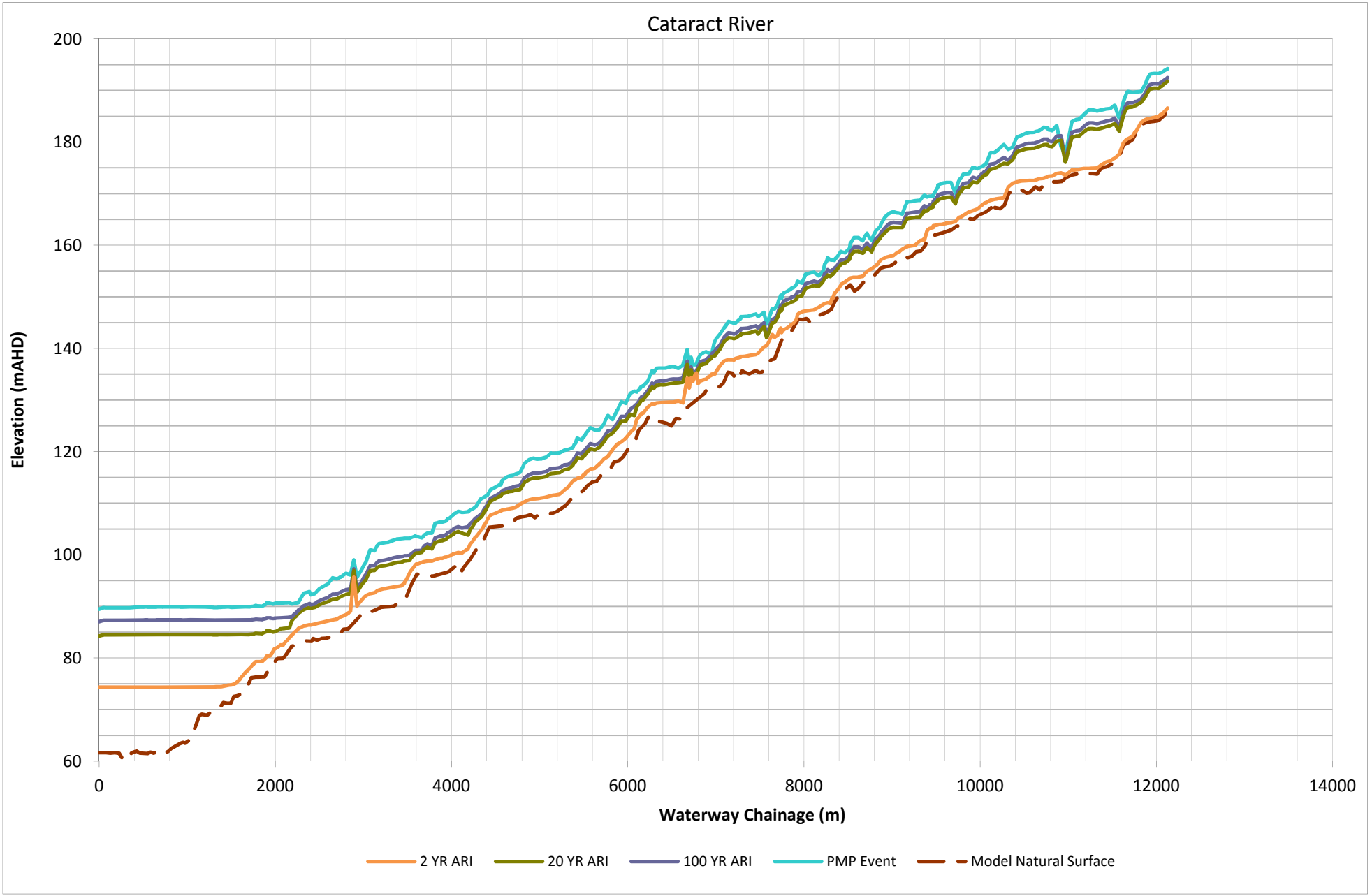

Elladale Creek
Elevation (mAHD)
200
180
160
140
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
4000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

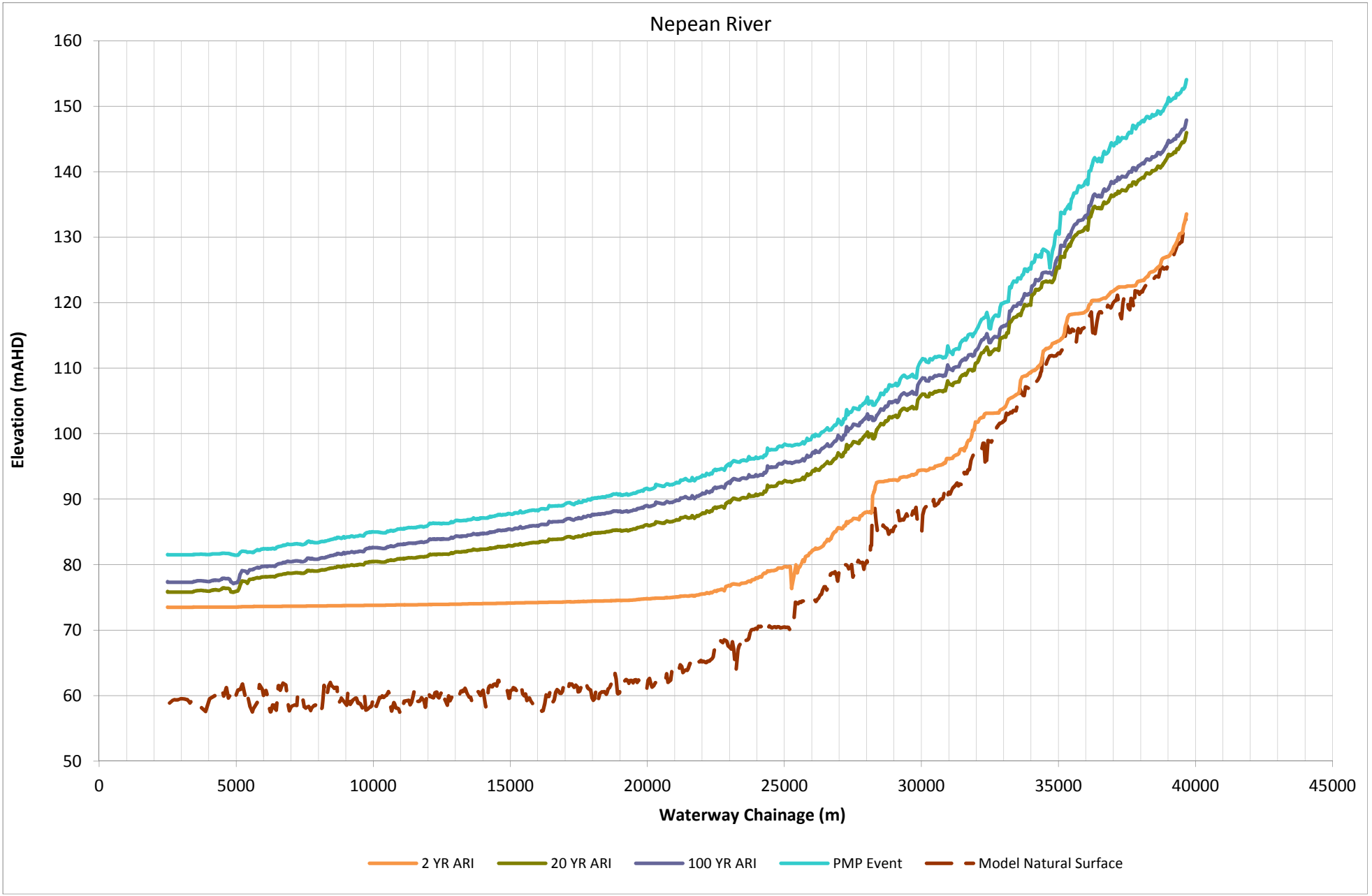

Sandy Creek
Elevation (mAHD)
200
180
160
140
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface


Allens Creek
Elevation (mAHD)
300
280
260
240
220
200
180
160
140
120
100
80
60
0
2000
4000
6000
8000
10000
12000
14000
16000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface


Ousedale Creek
240
220
200
180
160
140
120
100
80
60
Elevation (mAHD)
0
2000
4000
6000
8000
10000
12000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface


Georges River
250
230
210
190
170
150
130
110
Elevation (mAHD)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface


Cataract River
200
180
160
140
120
100
80
60
Elevation (mAHD)
0
2000
4000
6000
8000
10000
12000
14000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface


Nepean River
160
150
140
130
120
110
100
90
80
70
60
50
Elevation (mAHD)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
Waterway Chainage (m)
2 YR ARI
20 YR ARI
100 YR ARI
PMP Event
Model Natural Surface

Appendix K – Cost estimates

K.1 Background

Capital and operating cost estimates have been prepared for the three WSUD strategies that have been considered in this report.

K.2 Assumptions

Assumptions around the estimates include:

- The estimates are based upon concept level information only.
- Assumptions have been made that include application of a uniform lot size across the development footprint and a uniform development form across the development footprint
- Unit rates for construction and maintenance works have been adopted from sources identified within the attached costing tables
- Works that are common to all three options (ie rainwater tanks and water efficient fittings) have not been considered in developing the cost estimates
- No consideration has been included for the land values for the construction works
- All costs are in 2015 values and do not include consideration of inflation

K.3 Estimates

Many reports and technical papers have provided generalised information on the capital cost and maintenance cost of WSUD measures. Examples of some of the more recent documents include Taylow (2005), Taylor and Fletcher (2007), Thomson and Leinster (2007), Landcom (2009) and Melbourne Water (2013). Information from those sources was reviewed to select unit cast rates for adoption.

The cost rates from Landcom (2009) were adopted and supplemented by additional rates shown on Sheet 1 of the attached costing.

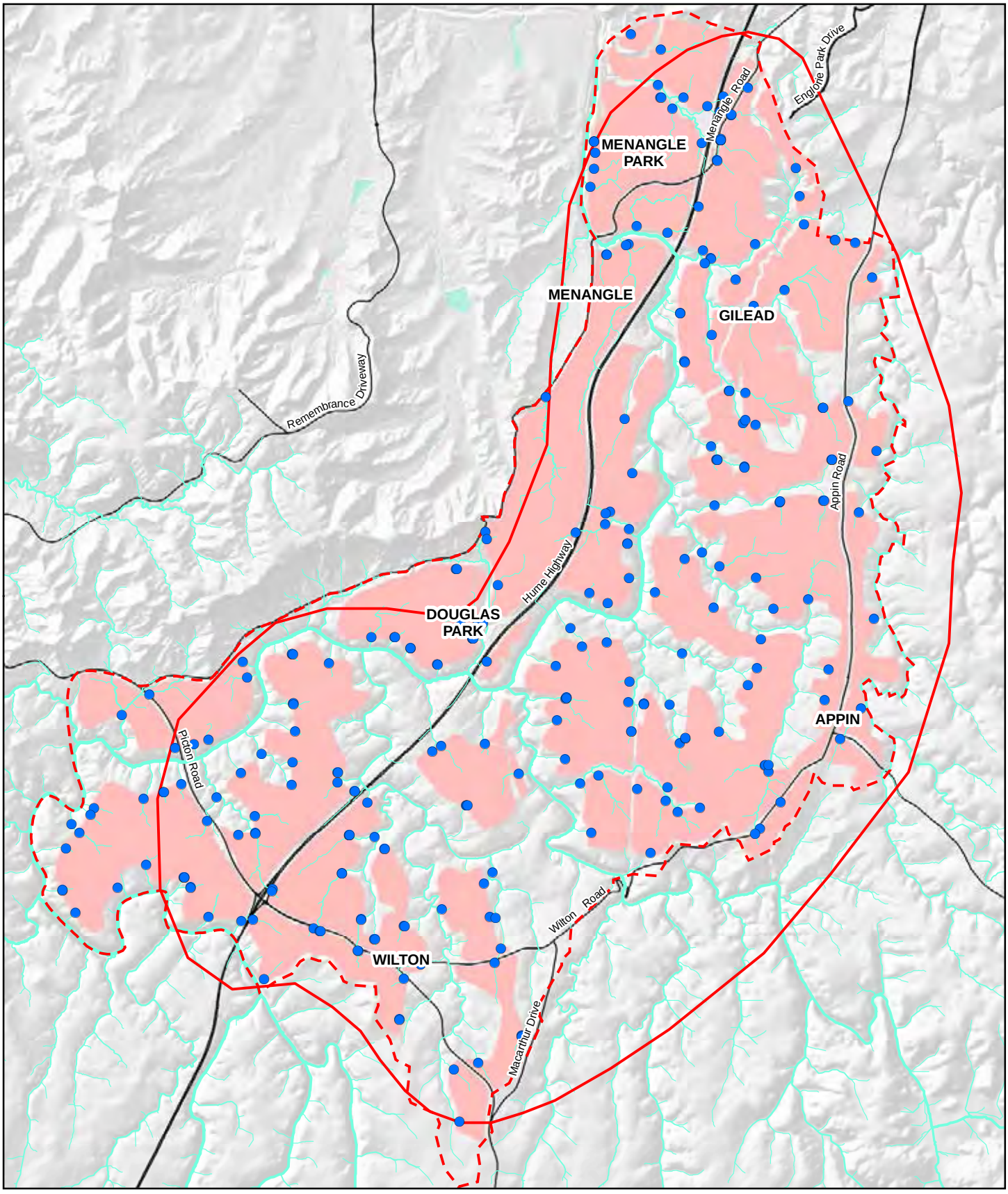
K.4 Comparison of WSUD strategy cost estimates

Comparative cost estimates were developed for two strategies and are summarised in Table K-1. Costs shown in Table K-1 have been rounded from those shown in the spreadsheets.

Table K-1 Cost estimates for WSUD strategies

Parameters	Strategy 1	Strategy 2 (Preferred)
Capital cost of onsite detention ($m)	1,110	-
Capital cost for upgrade of perimeter road ($m)	10	10
Capital cost bioretention at APZ ($m)	220	-
Capital cost of combined bioretention and detention structures at APZ ($m)	-	310
Total capital cost ($m)	**1,340**	**310**
O&M costs direct foe onsite detention ($m/a)	7.0	-
O&M costs for additional works on perimeter road ($m/a)	0.2	0.2

Parameters	Strategy 1	Strategy 2 (Preferred)
O&M costs for bioretention at APZ ($m/a)	1.6	-
O&M costs for combined bioretention and detention structures at APZ ($m/a)	-	2.5
Total O&M costs ($m/a)	**8.8**	**2.7**



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Potential Detention / Water Quality Facilities

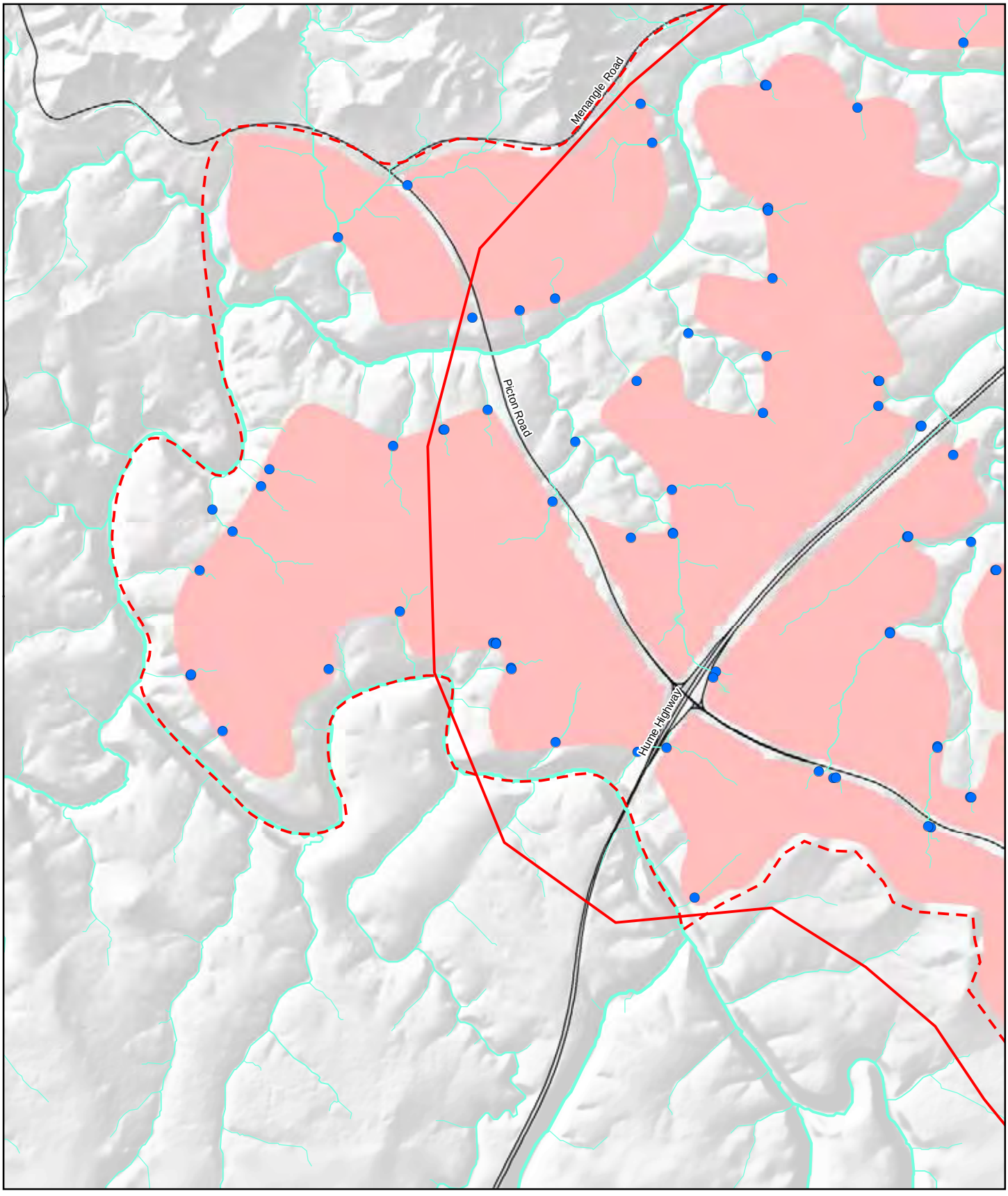
Figure K-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_K\2217728_K001_Detention_0.mxd

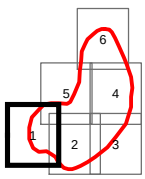
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Potential Detention / Water Quality Facilities - Sheet 1

Job Number 22-17728
Revision 0
Date 23 Jun 2015

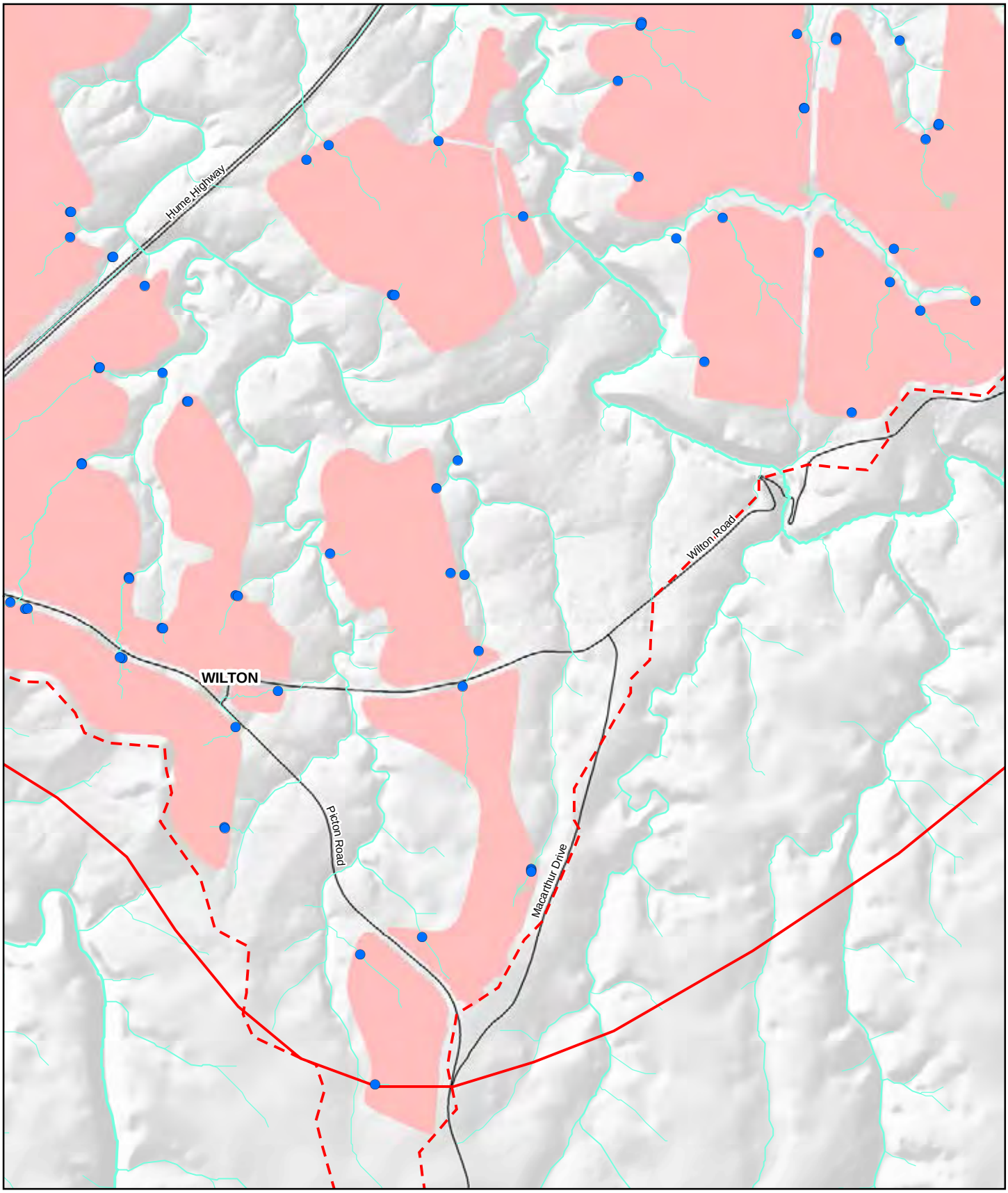
Figure K-2a

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_K\2217728_K002_DDP_Detention_0.mxd

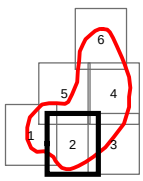
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Potential Detention / Water Quality Facilities - Sheet 2

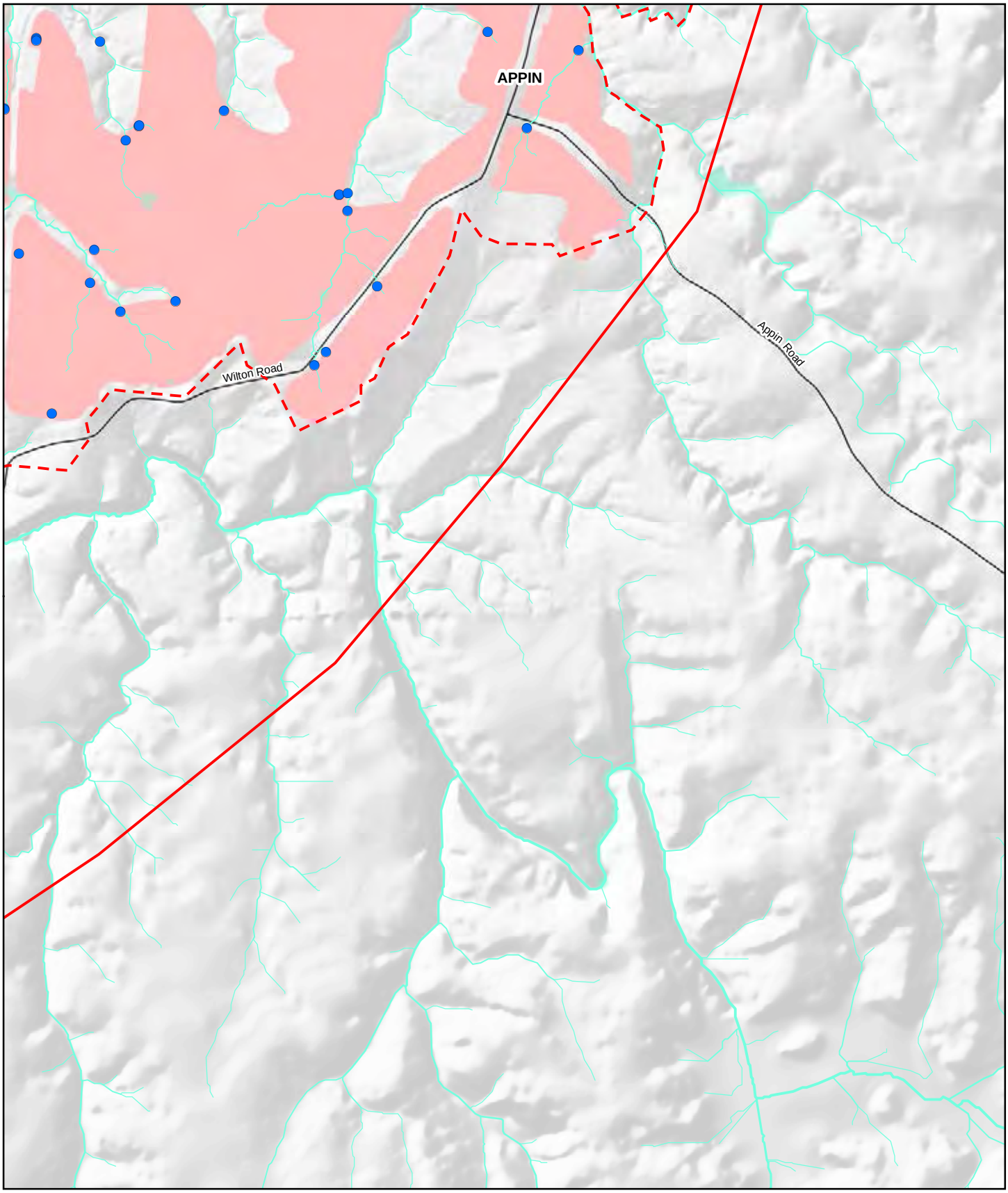
Figure K-2b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_K\2217728_K002_DDP_Detention_0.mxd

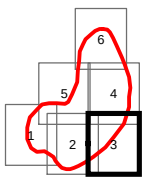
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Potential Detention / Water Quality Facilities - Sheet 3

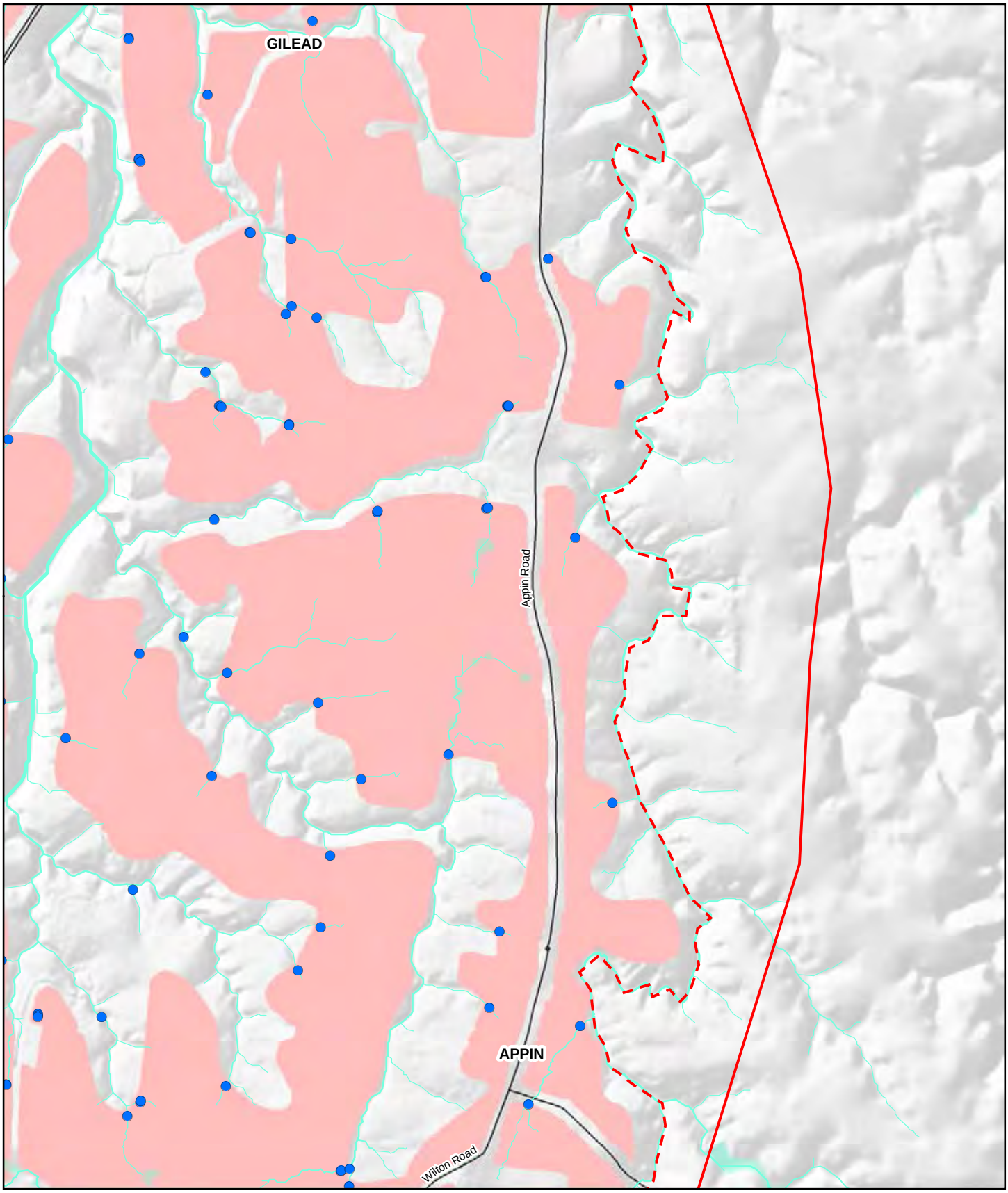
Figure K-2c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_K\2217728_K002_DDP_Detention_0.mxd

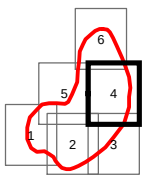
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Potential Detention / Water Quality Facilities - Sheet 4

Job Number 22-17728
Revision 0
Date 23 Jun 2015

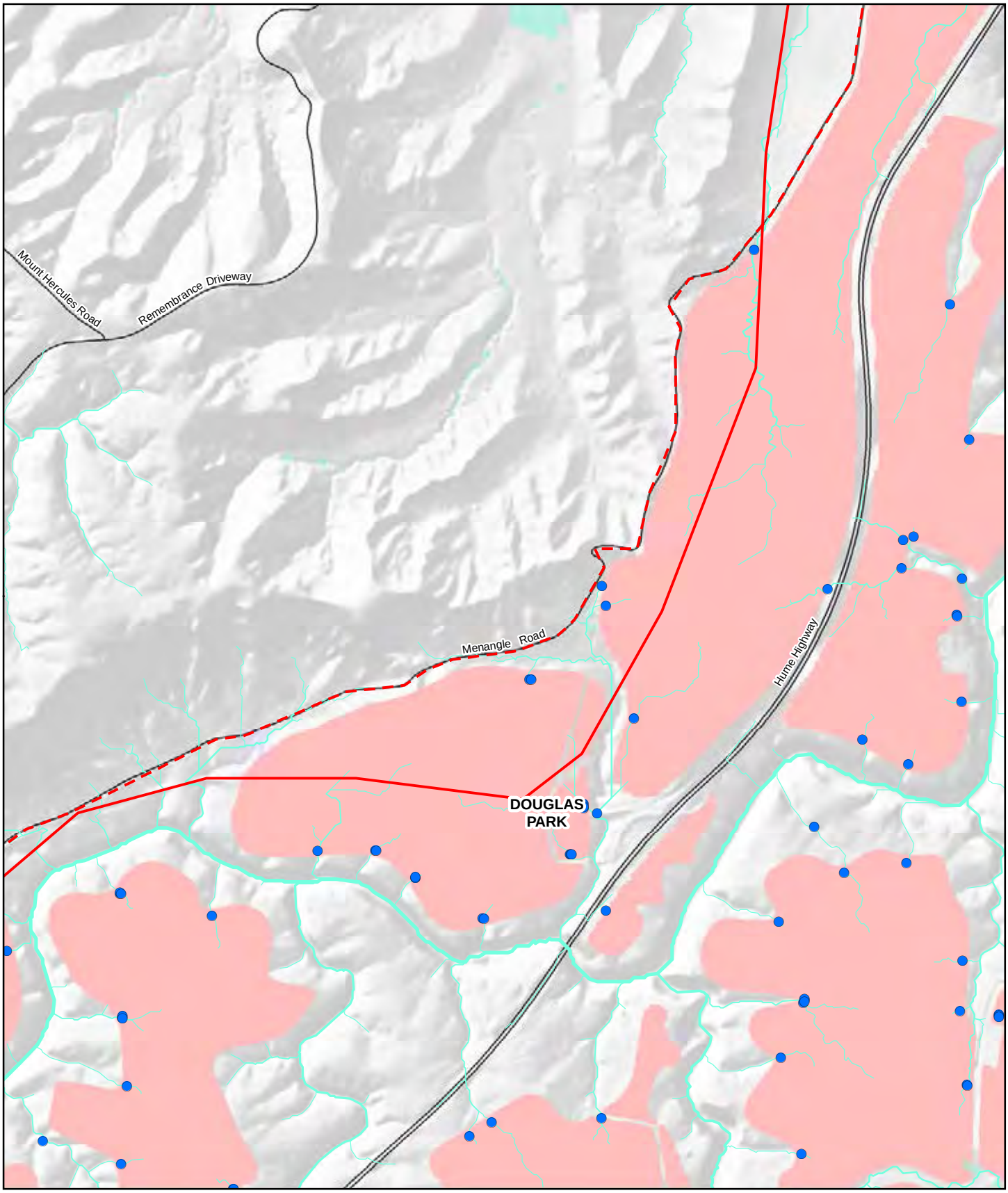
Figure K-2d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_K\2217728_K002_DDP_Detention_0.mxd

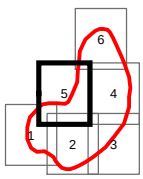
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Potential Detention / Water Quality Facilities - Sheet 5

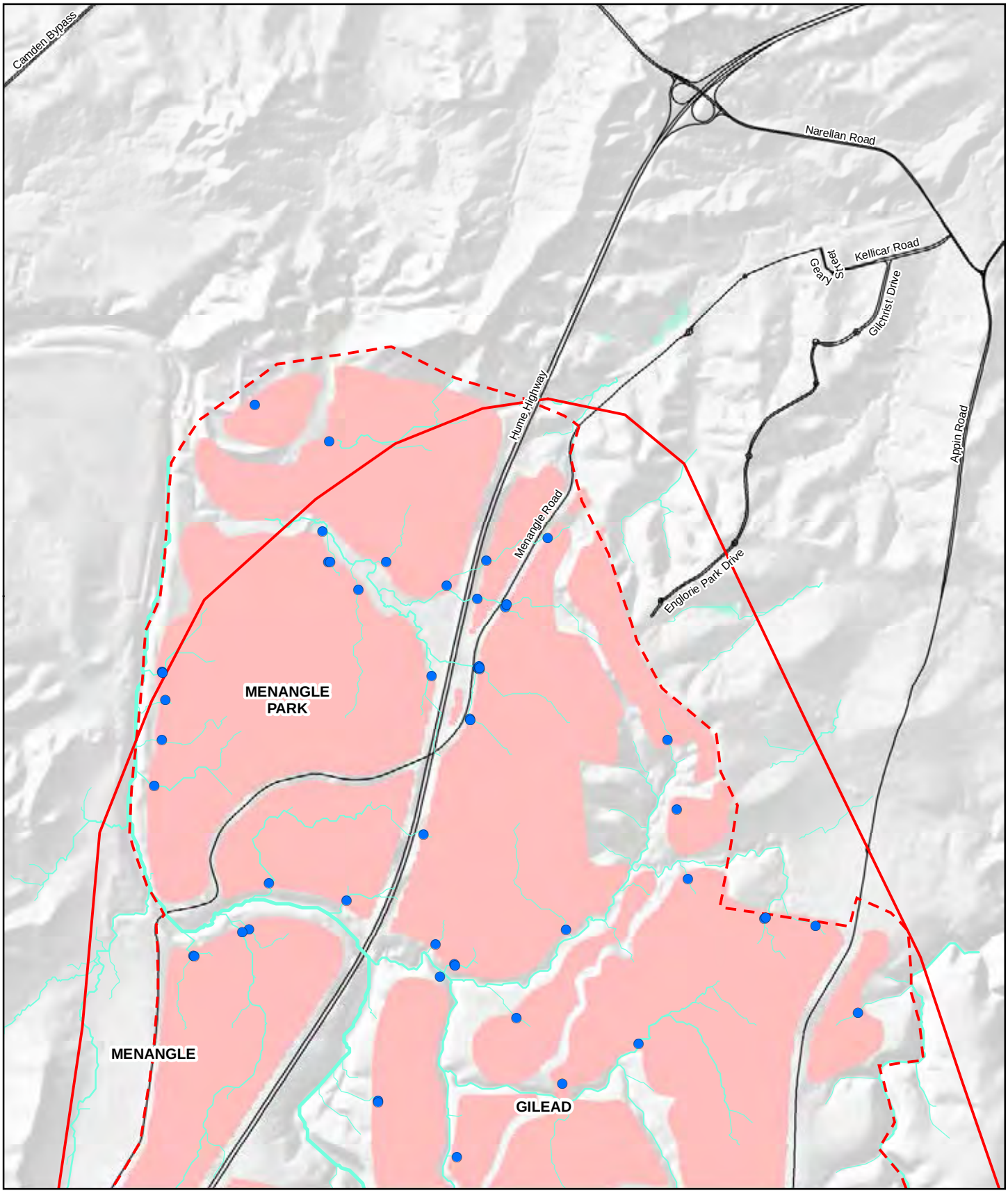
Figure K-2e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_K\2217728_K002_DDP_Detention_0.mxd

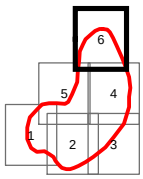
© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty



Paper Size A4

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Planning and Environment
Greater Macarthur Water Management

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Potential Detention / Water Quality Facilities - Sheet 6

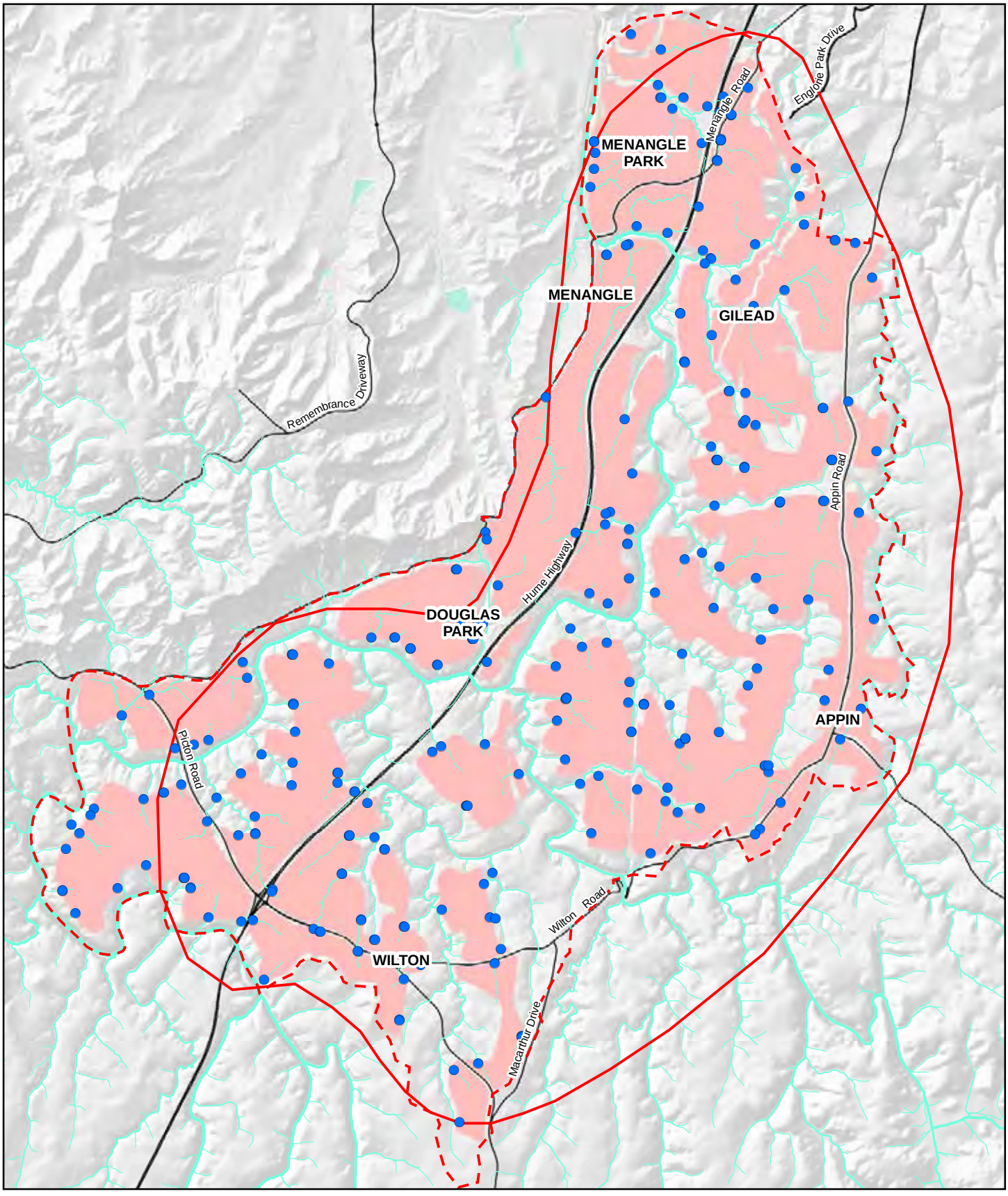
Figure K-2f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_K\2217728_K002_DDP_Detention_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton



LEGEND

- Investigation Area Boundary
- Urban Capable Boundary
- Development extent
- Road
- Watercourse
- Waterbody
- Potential combined detention / water quality treatment facilty

Paper Size A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Planning and Environment
Greater Macarthur Water Management

Recommended Stormwater Strategy

Job Number 22-17728
Revision 0
Date 23 Jun 2015

Figure K-3

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17728\GIS\Maps\Deliverables\WaterManagement\Appendix_K\2217728_K003_Strategy_0.mxd

© 2015. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: LPI, DTDB (2012) /Aerial imagery (2015) Created by: tmorton

Project: Macarthur Water Management
Number: 22/17728

Description: Development of base estimates for Strategies

Assumptions:

Development area -	9,228	ha
Dwelling area -	60	% of Development are
Average lot area -	450	m2
Number ot lots -	138,413	
Lots per hectare -	15.00	
Potential population (at 2.7/lot)	401,398	
Detention for OSD -	15.3	m3/lot
Biofiltration area -	1.2	% catchment area
Detention volume -	230	m3/ha
Depth excavation of rbioretention -	0.5	m3/ha
Capit and O&M costs from Landcom (2009)		
All values are in 2015 dollars - no inflation allowance provided		
Maximum detention basin allowed -	2	m

Adopted Unit Rates:

Construction of onsite detention facilities -	8,000	$
O&M for onsite detention facilities -	5	$/a
Contribution to perimeter road drainage upgrade to 100 year ARI -	150	$/m
Contribution to O&M for additionaal drainage maintenance along perimeter road -	3	

Option: **Strategy 1**

			Onsite detention on lots (OSD)			Perimeter Road		Biofiltration (only) at perimeter road			Bioretention and detention at perimeter road				
Area label	Area (ha)	Perimeter road length (m)	Number of lots	Capital cost ($m)	O&M cost ($m/a)	Capital cost ($m)	O&M cost ($m/a)	Biofiltration area (m2)	Capital cost ($m)	O&M cost ($m/a)	Biofiltration area (m2)	Detention Volume (m3)	Detention Area (m2)	Capital cost ($m)	O&M cost ($m/a)
A	27	624	406	3.2	0.02	0.09	0.00	3,250	0.7	0.02	3,250	6,229	3,426	1.1	0.03
B	98	1,190	1,475	11.8	0.07	0.18	0.00	11,802	2.4	0.03	11,802	22,621	12,442	3.5	0.05
C	121	1,322	1,822	14.6	0.09	0.20	0.00	14,574	2.9	0.03	14,574	27,934	15,364	4.3	0.05
D	156	1,496	2,333	18.7	0.12	0.22	0.00	18,662	3.7	0.04	18,662	35,768	19,673	5.4	0.06
E	332	2,186	4,977	39.8	0.25	0.33	0.01	39,814	8.0	0.05	39,814	76,310	41,970	11.0	0.08
F	366	2,296	5,490	43.9	0.27	0.34	0.01	43,920	8.8	0.06	43,920	84,180	46,299	12.1	0.09
G	77	1,052	1,153	9.2	0.06	0.16	0.00	9,226	1.9	0.03	9,226	17,682	9,725	2.8	0.04
H	204	1,714	3,061	24.5	0.15	0.26	0.01	24,491	4.9	0.04	24,491	46,941	25,817	7.0	0.07
I	558	2,835	8,372	67.0	0.42	0.43	0.01	66,974	13.4	0.07	66,974	128,368	70,602	18.0	0.11
J	216	1,765	3,246	26.0	0.16	0.26	0.01	25,969	5.2	0.04	25,969	49,773	27,375	7.4	0.07
K	164	1,534	2,453	19.6	0.12	0.23	0.00	19,620	3.9	0.04	19,620	37,606	20,683	5.7	0.06
L	198	1,687	2,965	23.7	0.15	0.25	0.01	23,719	4.8	0.04	23,719	45,461	25,003	6.8	0.07
M	149	1,463	2,229	17.8	0.11	0.22	0.00	17,835	3.6	0.04	17,835	34,184	18,801	5.2	0.06
N	599	2,938	8,992	71.9	0.45	0.44	0.01	71,936	14.4	0.07	71,936	137,878	75,833	19.3	0.11
O	616	2,979	9,241	73.9	0.46	0.45	0.01	73,932	14.8	0.07	73,932	141,703	77,937	19.8	0.11
P	429	2,486	6,439	51.5	0.32	0.37	0.01	51,513	10.3	0.06	51,513	98,733	54,303	14.1	0.09
Q	233	1,830	3,488	27.9	0.17	0.27	0.01	27,905	5.6	0.05	27,905	53,484	29,416	7.9	0.07
R	78	1,062	1,175	9.4	0.06	0.16	0.00	9,397	1.9	0.03	9,397	18,012	9,907	2.9	0.04
S	148	1,459	2,216	17.7	0.11	0.22	0.00	17,728	3.6	0.04	17,728	33,978	18,688	5.2	0.06
T	146	1,451	2,195	17.6	0.11	0.22	0.00	17,557	3.5	0.04	17,557	33,651	18,508	5.1	0.06
U	246	1,882	3,691	29.5	0.18	0.28	0.01	29,529	5.9	0.05	29,529	56,598	31,129	8.3	0.07
V	405	2,414	6,070	48.6	0.30	0.36	0.01	48,563	9.7	0.06	48,563	93,078	51,193	13.3	0.09
W	123	1,330	1,843	14.7	0.09	0.20	0.00	14,747	3.0	0.03	14,747	28,265	15,546	4.4	0.05
X	115	1,285	1,720	13.8	0.09	0.19	0.00	13,758	2.8	0.03	13,758	26,369	14,503	4.1	0.05
W	65	965	970	7.8	0.05	0.14	0.00	7,760	1.6	0.03	7,760	14,873	8,180	2.4	0.04
Z	238	1,852	3,573	28.6	0.18	0.28	0.01	28,581	5.7	0.05	28,581	54,780	30,129	8.1	0.07
AA	952	3,702	14,275	114.2	0.71	0.56	0.01	114,203	22.9	0.09	114,203	218,889	120,389	29.9	0.14
AB	466	2,590	6,989	55.9	0.35	0.39	0.01	55,911	11.2	0.06	55,911	107,162	58,939	15.2	0.10
AC	57	904	851	6.8	0.04	0.14	0.00	6,805	1.4	0.02	6,805	13,043	7,173	2.1	0.04
AD	469	2,599	7,034	56.3	0.35	0.39	0.01	56,270	11.3	0.06	56,270	107,850	59,318	15.3	0.10
AE	163	1,533	2,447	19.6	0.12	0.23	0.00	19,573	3.9	0.04	19,573	37,514	20,633	5.7	0.06
AF	127	1,353	1,907	15.3	0.10	0.20	0.00	15,254	3.1	0.04	15,254	29,237	16,080	4.5	0.05
AG	495	2,670	7,427	59.4	0.37	0.40	0.01	59,419	11.9	0.06	59,419	113,887	62,638	16.1	0.10
AH	301	2,081	4,512	36.1	0.23	0.31	0.01	36,095	7.2	0.05	36,095	69,182	38,050	10.1	0.08
Ai	55	893	831	6.6	0.04	0.13	0.00	6,647	1.3	0.02	6,647	12,740	7,007	2.1	0.04
AJ	36	724	546	4.4	0.03	0.11	0.00	4,368	0.9	0.02	4,368	8,372	4,605	1.4	0.03
Total	9,228	64,148	138,413	1,107	6.92	9.6	0.19	1,107,306	222.0	1.61	1,107,306	2,122,336	1,167,285	307.5	2.50

GHD

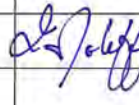
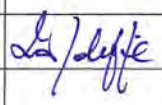
Level 3 GHD Tower 24 Honeysuckle Drive Newcastle NSW 2300
PO Box 5403 Hunter Region Mail Centre NSW 2310
T: (02) 4979 9999 F: (02) 4979 9988 E: ntlmail@ghd.com

© GHD 2015

This document is and shall remain the property of GHD. The document may only be used for the purpose for which it was commissioned and in accordance with the Terms of Engagement for the commission. Unauthorised use of this document in any form whatsoever is prohibited.

G:\22\17728\WP\109007.docx

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	I Joliffe	I Joliffe	Signed	I Joliffe	Signed	26/06/15
B	I Joliffe	I Joliffe		I Joliffe		28/8/15

www.ghd.com

