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Our Ref: DJL: L.T2672.002.docx

07 February 2025
Oak Property Investments Pty Ltd
c/o Clint Ballard
PO Box 1157,
Double Bay NSW 1360

Dear Clint

RE: FLOOD IMPACT AND RISK ASSESSMENT FOR PROPOSED SUBDIVISION OF LOT 1 DP995228, HUNTER STREET, MUSWELLBROOK, NSW

Background

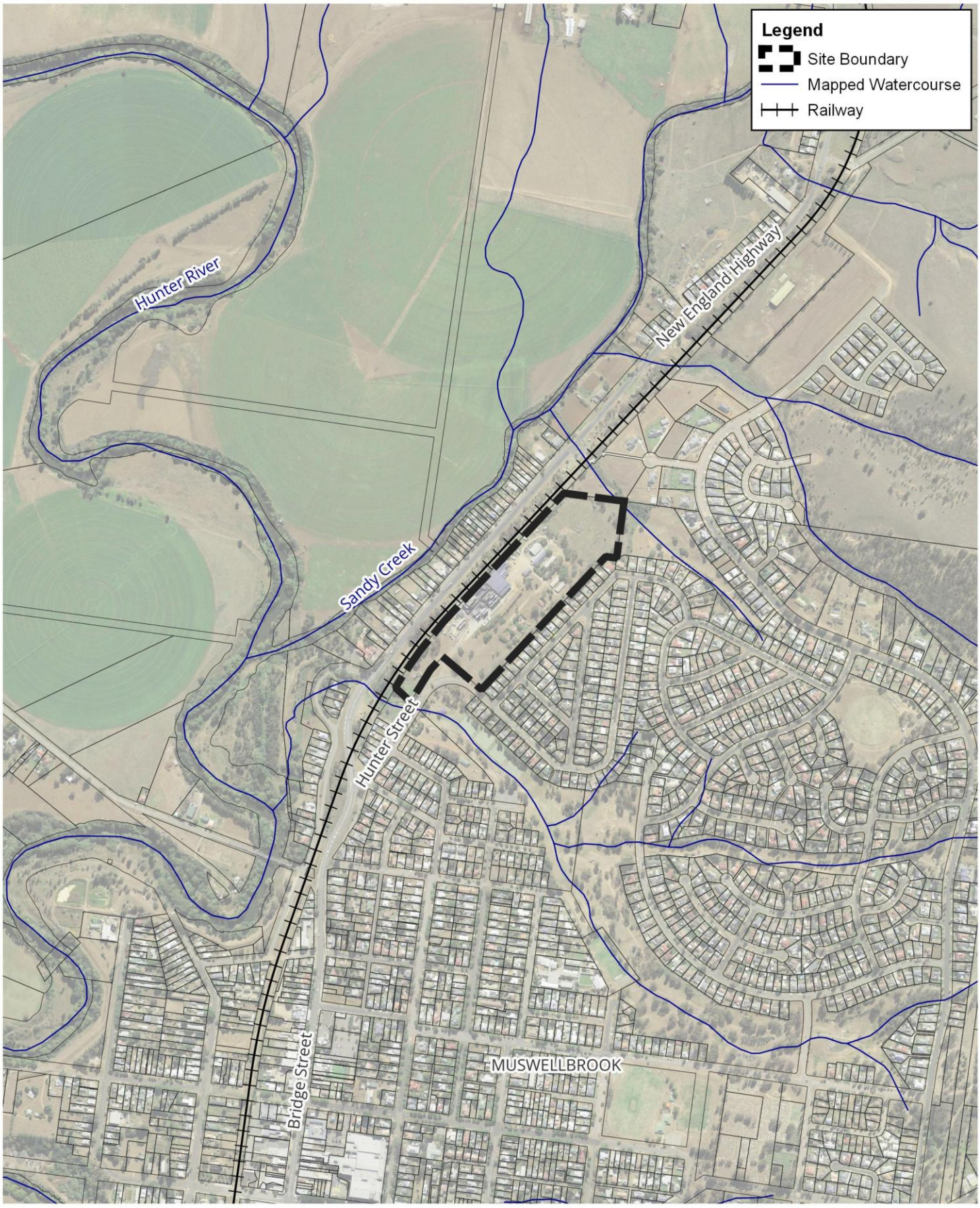
Torrent Consulting was engaged to undertake a Flood Impact and Risk Assessment (FIRA) to assist in the development and planning process for the proposed subdivision of Lot 1 DP995228, Hunter Street, Muswellbrook NSW (the Site). The Site location is shown in Figure 1 with reference to the local watercourse network.

The Site is located within the local catchment of an unnamed watercourse that runs through Karoola Park and adjacent to the southern boundary of the Site. The watercourse then crosses Hunter Street, the Main Northern Railway and the New England Highway in discharging to the Hunter River downstream. A second minor watercourse draining a small local catchment runs along the northern Site boundary before crossing the railway and highway before discharging to Sandy Creek.

It is understood that there is no existing flood information for the local watercourse catchments. The Muswellbrook Floodplain Risk Management Study and Plan (FRMSP) (Royal HaskoningDHV, 2019) prepared on behalf of Muswellbrook Shire Council (Council) includes detailed mapping of the mainstream Hunter River flooding condition. An extract of this mapping in the Site locality is shown in Figure 2 for the 1% Annual Exceedance Probability (AEP) design flood condition. The 1% AEP and Probable Maximum Flood (PMF) design flood levels for the Hunter River adjacent to the Site are:

- 1% AEP ~149.0m AHD
- PMF ~ 151.5m AHD

The mapping shows no flood affectation to the Site for Hunter River flooding for the 1% AEP design event. Review of the FRMSP flood information indicates that the Site is subject to backwater flood inundation from the Hunter River, albeit for PMF event. The FRMS mapping shows no inundation of the Site at the PMF level, however, this is only due to a limitation in the model extent. The cross-drainage culverts on the Karoola Park watercourse are not in the FRMS modelling, and accordingly, there is no connectivity of the backwater inundation from the Hunter River through the various road and rail embankments upstream. The Hunter River PMF level will provide for some limited inundation in the southern part of the Site at the lowest topography. The Hunter River PMF flooding condition is considered further in the assessment in conjunction with the local catchment contribution.



Title:

Site Locality

0 300 600 m

approx. scale

Figure: 1

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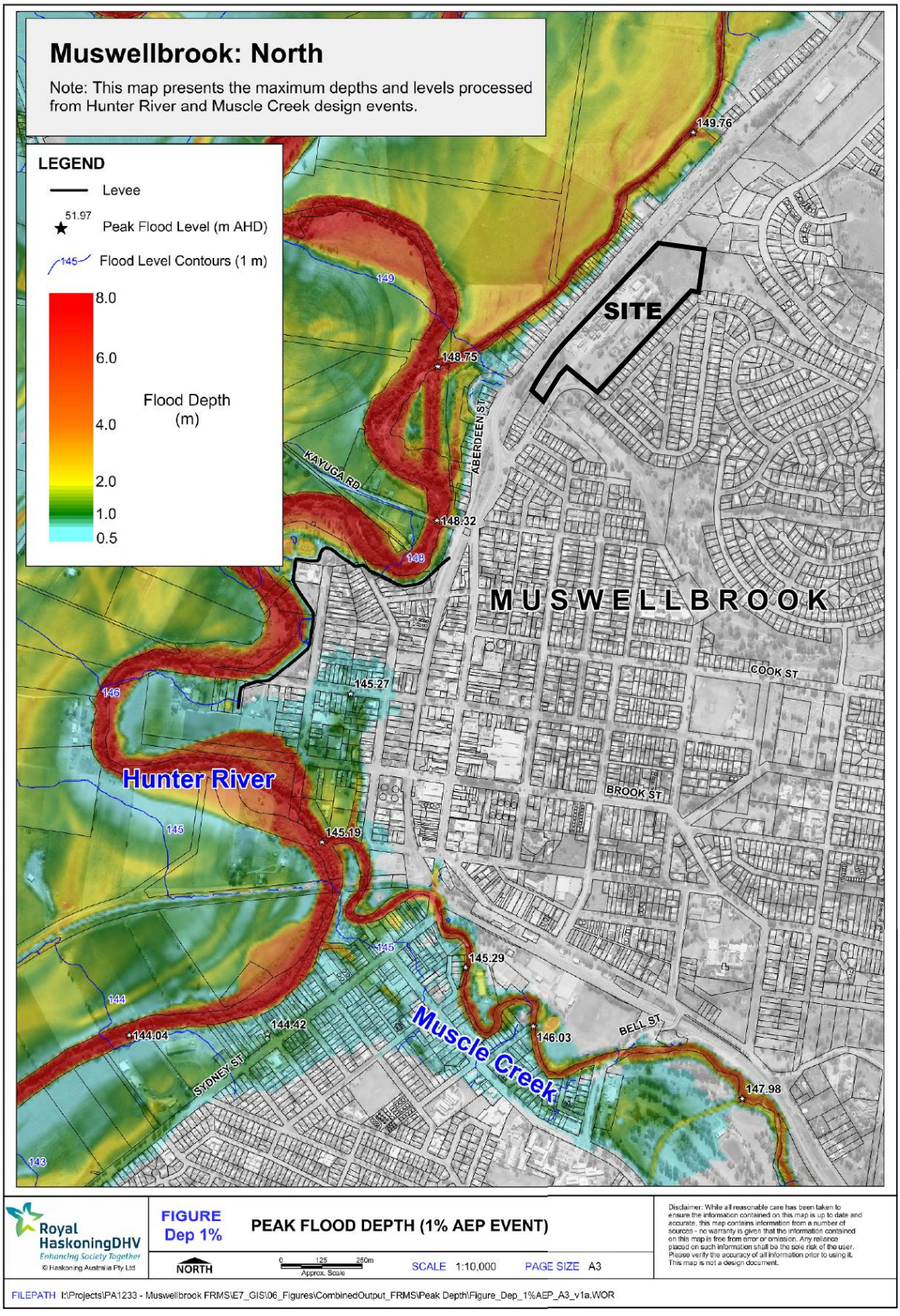


Figure 2 – 1% AEP Design Event Hunter River Flood Conditions (from FRMSP)

There is no specific flood mapping for the local catchment environment. Accordingly, this assessment includes the development of a TUFLOW model of local catchment contributing to flow at the Site. The developed model provides a platform to assess the potential flood constraints for the proposed subdivision and future development.

Site Details

The Site comprises the existing 9.63 ha single Lot 1 DP995228. The existing layout of the Site and local geographical context is shown in Figure 3. The proposed lot subdivision is shown for reference with the new lots occupying the land area adjacent to the railway line.

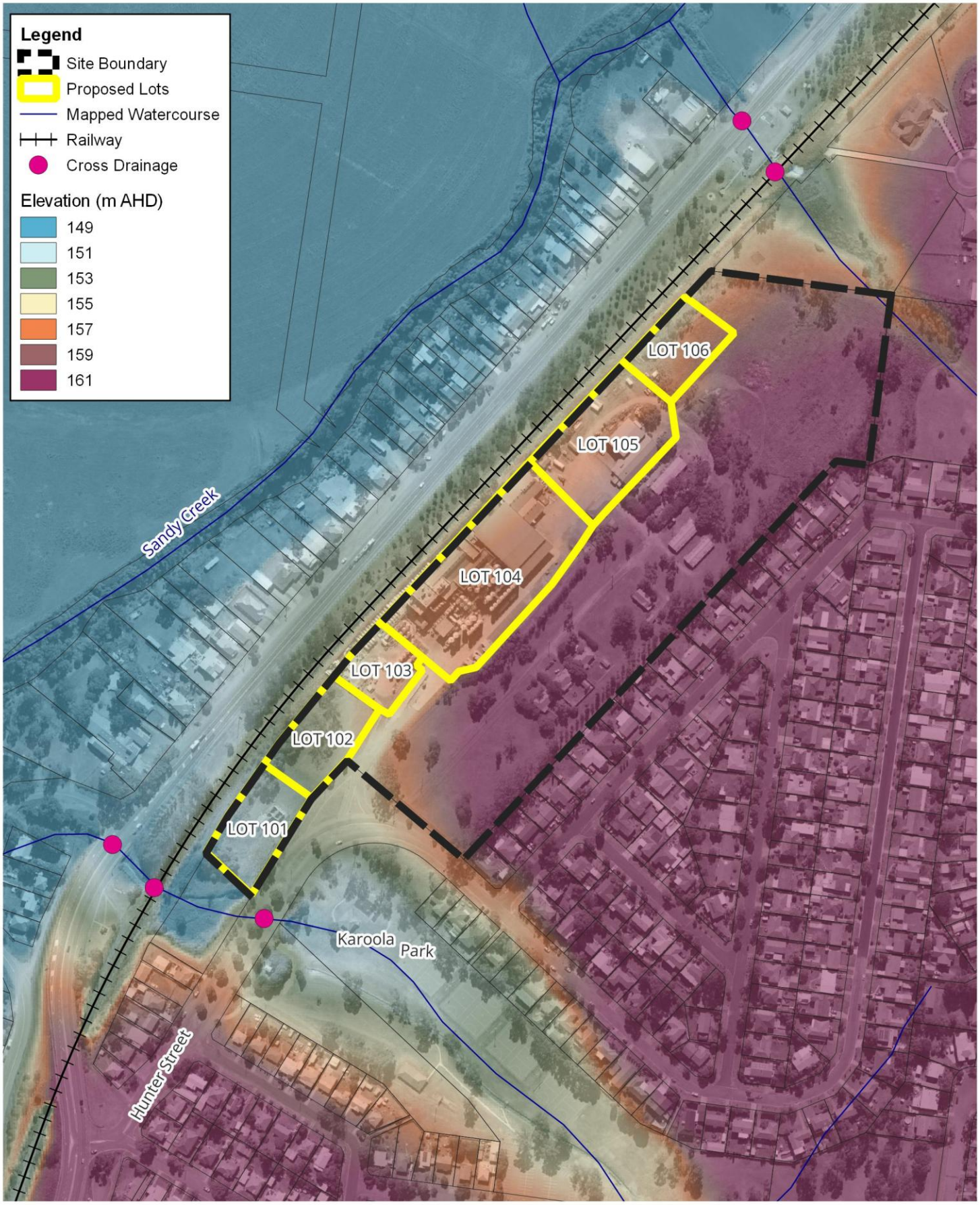
The local watercourse/overland flowpath alignments run either side of the Site boundary, with the southern alignment being the principal watercourse draining through Karoola Park.

The detailed local topography is represented by the NSW Spatial Services LiDAR data product, downloaded via the ELVIS Foundation Spatial Data.

Elevations on the Site vary from around 150m AHD to 169m AHD. The lowest elevations are at the southwestern boundary adjacent to the Karoola Park watercourse, with the highest Site elevations along the eastern boundary adjacent to the Cousins Street residential properties.

The watercourses traverse a number of road and rail embankments via cross drainage culverts including at Hunter Street, the Mian Northern Railway and the New England Highway. The approximate location of the culvert structures relevant to the assessment are shown on Figure 3. In particular, the Main Northern Railway structure on the Karoola Park waterway is a key hydraulic control being located immediately downstream of the Site. Photograph1 shows the culvert viewed looking upstream, depicting the restricted waterway provided by the culvert opening relative to the floodplain obstruction of the elevated rail embankment.

Photograph 1 – Main Northern Railway Culvert (looking upstream)



Title:

Site Detail

0 100 200 m

approx. scale

Figure: 3

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Model Development

Model Extent and Topography

A TUFLOW hydraulic model was developed covering the local catchment upstream of the Site, representing a contributing catchment area of around 50 ha. The modelled catchment area and topography is shown in Figure 1. The model utilises the NSW Spatial Services LiDAR data product to define the local topography. The LiDAR survey was acquired in 2018, with a Digital Elevation Model (DEM) available at a 2 m resolution.

The catchment extends from approximately 2km east of the Site, in the general locality of the Muswellbrook Waste and Recycling Facility, to the confluence with Sandy Creek and the Hunter River. The highest elevations are along the upper catchment boundary with Muscle Creek at around 310m AHD. Whilst there has been some disturbance to the natural gully lines in the upper catchment due to earthworks (landfill, mining activity), the upper catchment provides for relatively steep drainage profiles through to the start of the existing urban residential area predominantly west of Queen Street. Drainage corridors have been retained in the urban areas along the main waterway alignments, with Karoola Park being the principal drainage alignment in the catchment.

The model boundary has been extended downstream of King Street to ensure the adopted boundary condition does not influence design flood conditions at the Site. The invert level of the King Street Branch channel at the downstream boundary is around 4m AHD. The Sandy Creek confluence with the Hunter River is only around 300m from the Site. Hunter River flooding regimes are not considered in the current assessment with the existing Council flood study mapping as discussed previously.

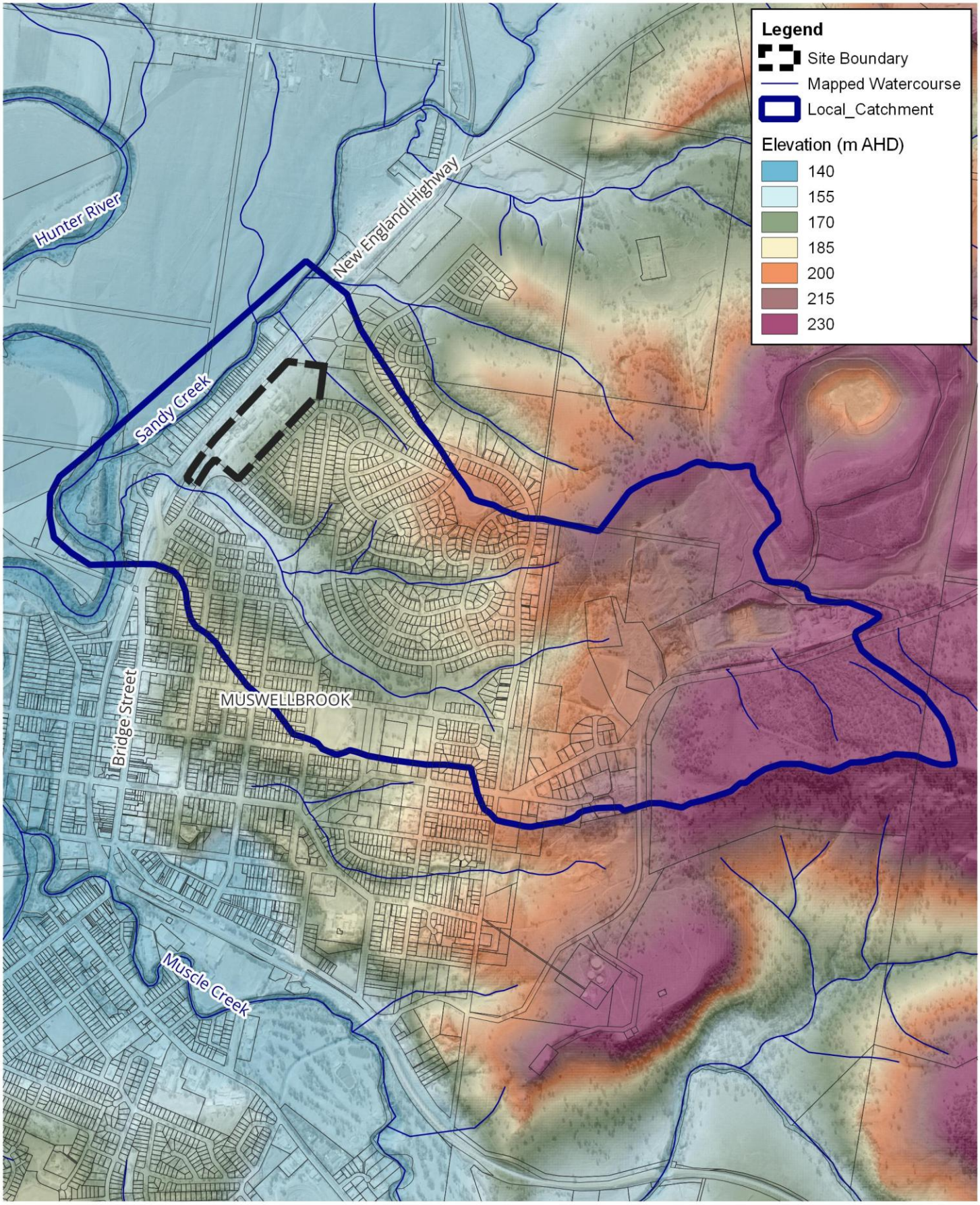
The adopted TUFLOW grid model resolution is 2m consistent with the available LiDAR DEM resolution. This adopted model resolution is sufficient to model the overland flow distribution through the catchment, and overall conveyance of flood water to the Site.

Hydraulic Structures

Any local stormwater network (pits and pipes) would provide some conveyance of local street drainage in the urban residential areas. However, the limited capacity of the subsurface network would not have any significant influence on overland flood conditions at the Site. The majority of catchment runoff is conveyed as overland flow paths as dictated by the local topography. Accordingly, local subsurface stormwater infrastructure is not included in the model.

The cross-drainage infrastructure at the numerous road and rail embankment locations as identified in Figure 2 have been included in the model. The modelled culverts include:

- Karoola Park channel
    - Hunter Street
    - Main North Railway
    - New England Highway
    - Aberdeen Street
- Channel at north of Site
    - Main North Railway
    - New England Highway



Title:

Local Catchment and Topography

0 0.5 1 km

approx. scale

Figure: 3

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Hydraulic Roughness

The development of the TUFLOW model requires the assignment of different hydraulic roughness zones. These zones are delineated from aerial photography and cadastral data identifying different land-uses (e.g., roads, urban areas, park lands, open space etc.) for modelling the variation in flow resistance.

Table 1 summarises the adopted Manning's 'n' coefficients for hydraulic roughness based on the land use. Whilst there is no specific calibration data available for catchment, the adopted values are within typical industry adopted ranges.

Table 1 – Hydraulic Roughness Parameters

Land Use	Manning's 'n'
Woodland/Riparian Vegetation	0.10
Cleared floodplain	0.05
Roadways / hardstand	0.02
Urban lots	0.07
Culverts	0.015

Design Hydrology Inputs

This study has adopted the direct rainfall approach for modelling the catchment hydrology and therefore only a single TUFLOW model has been developed, which implicitly performs both hydrologic and hydraulic computation. The release of the Australian Rainfall and Runoff 2019 guidelines provides updated procedures for design flood estimation. This includes updated intensity-frequency-duration (IFD) rainfall estimates and application of a suite of revised temporal patterns for establishing critical design flood conditions. The design rainfall depths were sourced from the BoM IFD portal and are summarised in Table 2 for various design event magnitudes and storm durations.

Design rainfall losses considered the recent NSW-specific guidance with an initial loss of around 5-10 mm (depending on storm event as extracted from ARR Datahub) and a continuing loss of 0.9 mm/h for the undeveloped catchment. For developed urban areas these losses were reduced to 2.2 mm and 0.45 mm/h, and for road corridors reduced to 1 mm and 0 mm/h.

The ARR 2019 guidelines ensemble method to design flood hydrology involves the simulation of ten rainfall temporal patterns for each design event magnitude and duration, with the average condition of the ten being adopted for design purposes. The point rainfall temporal patterns provided for the East Coast South temporal rainfall region were adopted for the ensemble method accordingly.

The TUFLOW model was simulated (using the HPC solver) for the 1% AEP design rainfall event for storm durations ranging from ten minutes to 360 minutes. The peak flow results were analysed at the Site to identify the critical duration. The 60-minute duration was identified as being critical for the 1% AEP event, with the design temporal pattern ID 4558 (TP07) was selected as producing hydrographs most representative of the mean design condition from the results of the ensemble method. For the 5% AEP event, the 60-minute duration with design temporal pattern ID 4568 (TP06) was identified as the critical design event.

Table 2 – Design IFD Rainfall

Duration (mins)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
10	12.7	15.1	17.6	21.1	23.9	26.4	30.4
15	16.1	19.3	22.4	26.9	30.5	33.6	38.7
20	18.6	22.2	25.8	31.1	35.2	38.9	44.8
25	20.6	24.6	28.6	34.2	38.7	42.8	49.3
30	22.2	26.5	30.8	36.7	41.5	46	53
45	25.8	30.6	35.5	42.1	47.5	52.7	60.6
60	28.4	33.6	38.7	45.8	51.5	57.2	65.8
90	32	37.7	43.5	51.2	57.3	63.5	73.1
120	34.8	41	47.1	55.3	61.7	68.3	78.4
180	39.4	46.1	52.9	62	69.1	76.1	87.3
270	44.9	52.4	60.2	70.6	78.9	86.6	99.7
360	49.5	58	66.6	78.5	87.9	96.4	110.8

The PMF event rainfall was appropriately derived using the “The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method’’ (2001). The derived 30-minute duration PMP was found to be the critical duration for catchment.

Model Results

The developed model has been simulated for the 5% AEP, 1% AEP and PMF design flood condition. The model output includes the peak flood inundation extents and levels, peak flood depth, velocity, and flood hazard distributions. A full suite of mapping is included in Appendix A.

The flood hazards have been determined in accordance with Guideline 7-3 of the Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR, 2017). This produces a six-tier hazard classification, based on modelled flood depths, velocities, and velocity-depth product. The hazard classes relate directly to the potential risk posed to people, vehicles, and buildings, as presented in Figure 4.

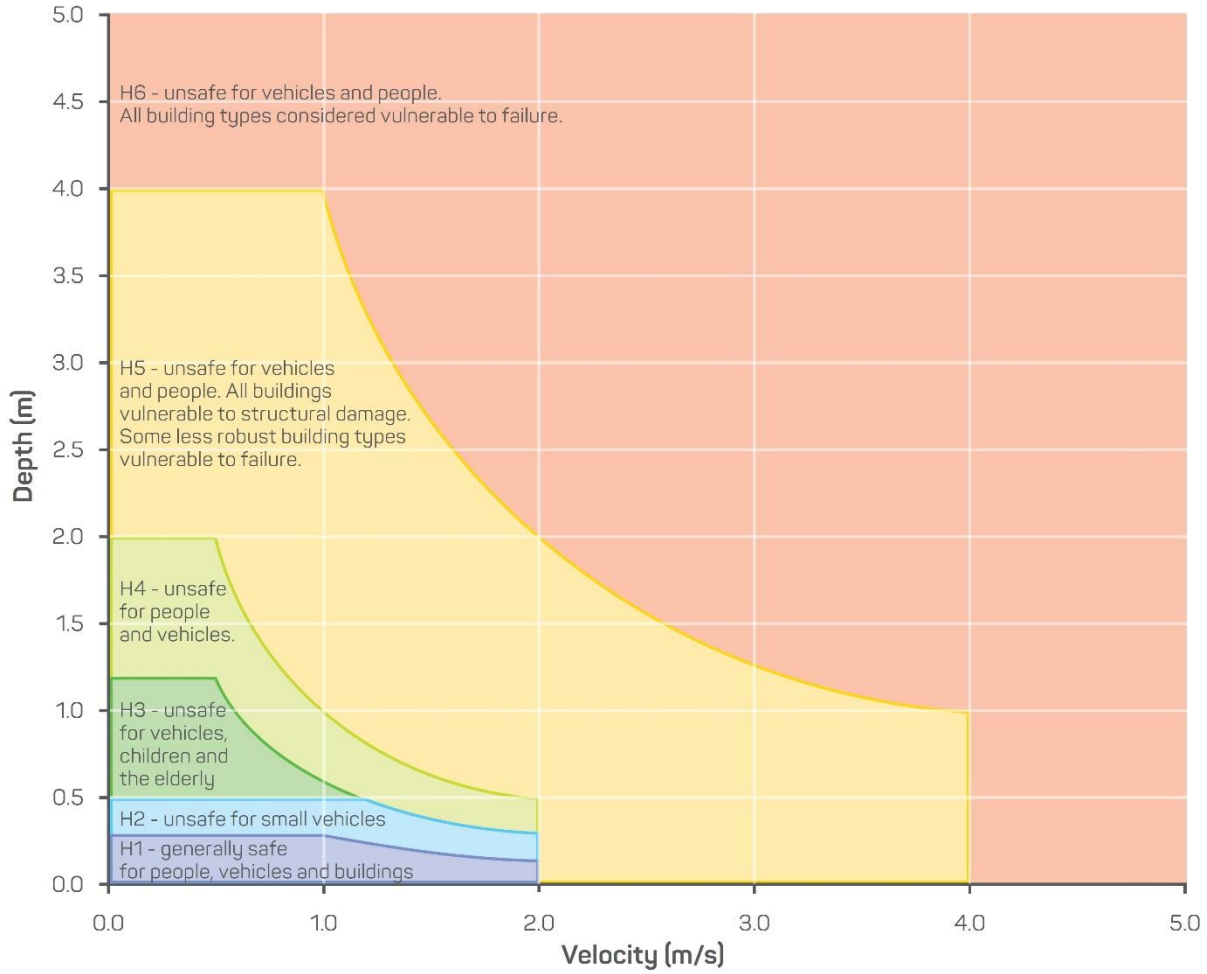


Figure 4 – General Flood Hazard Vulnerability Curves (AIDR, 2017)

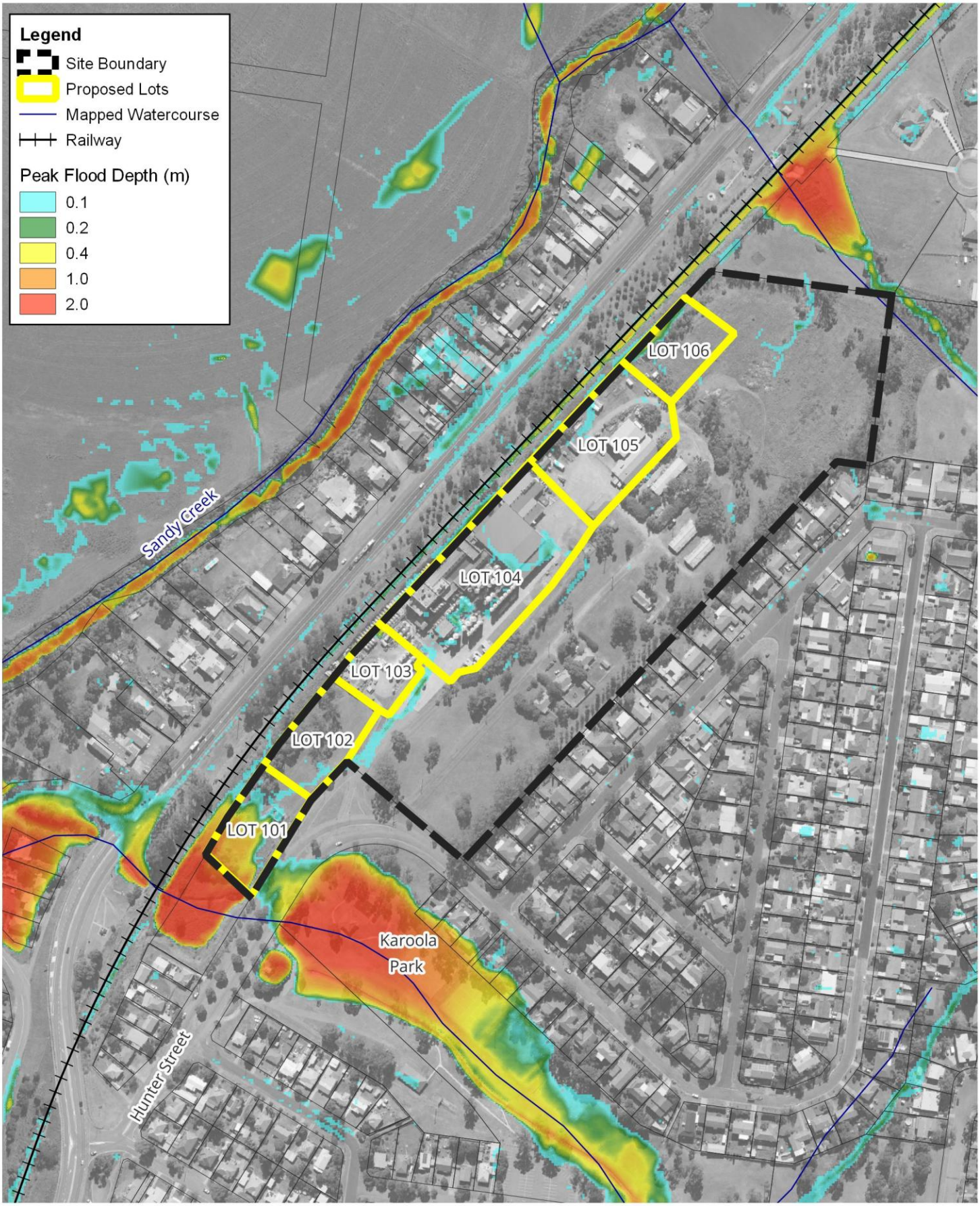
The simulated peak 1% AEP flood inundation extents and flood depth distribution for existing conditions is shown in Figure 5 in the vicinity of the Site. Note the mapping represents the flooding conditions in the local catchment only independent of flooding in the broader Sandy Creek and Hunter River catchments.

The Site is mostly flood free at the 1% AEP design flood level with the exception of an area at the southern boundary adjacent to the Karoola Park waterway. The inundation is limited in extent to within the proposed future lot labelled Lot 101 and corresponds to the area of lowest ground elevation as shown in Figure 3. Note the other minor inundation shown within the Site is a function of the direct rainfall approach and represents only local runoff and pondage in depressions.

The Site flood inundation is contributed to by two main flooding mechanisms:

- Overtopping of Hunter Street with the overflow from the Karoola Park detention basin – note that the low point in Hunter Street adjacent to the Site.
- Backwater inundation behind the Main North Railway embankment – the extent of inundation on the Site directly controlled by the performance of the rail culvert.

The corresponding flood hazard classification fin the vicinity of the Site for the 1% AEP event is shown in Figure 6.



Title:

Peak 1% AEP Flood Depth

0 100 200 m

approx. scale

Figure: 5

Revision: A

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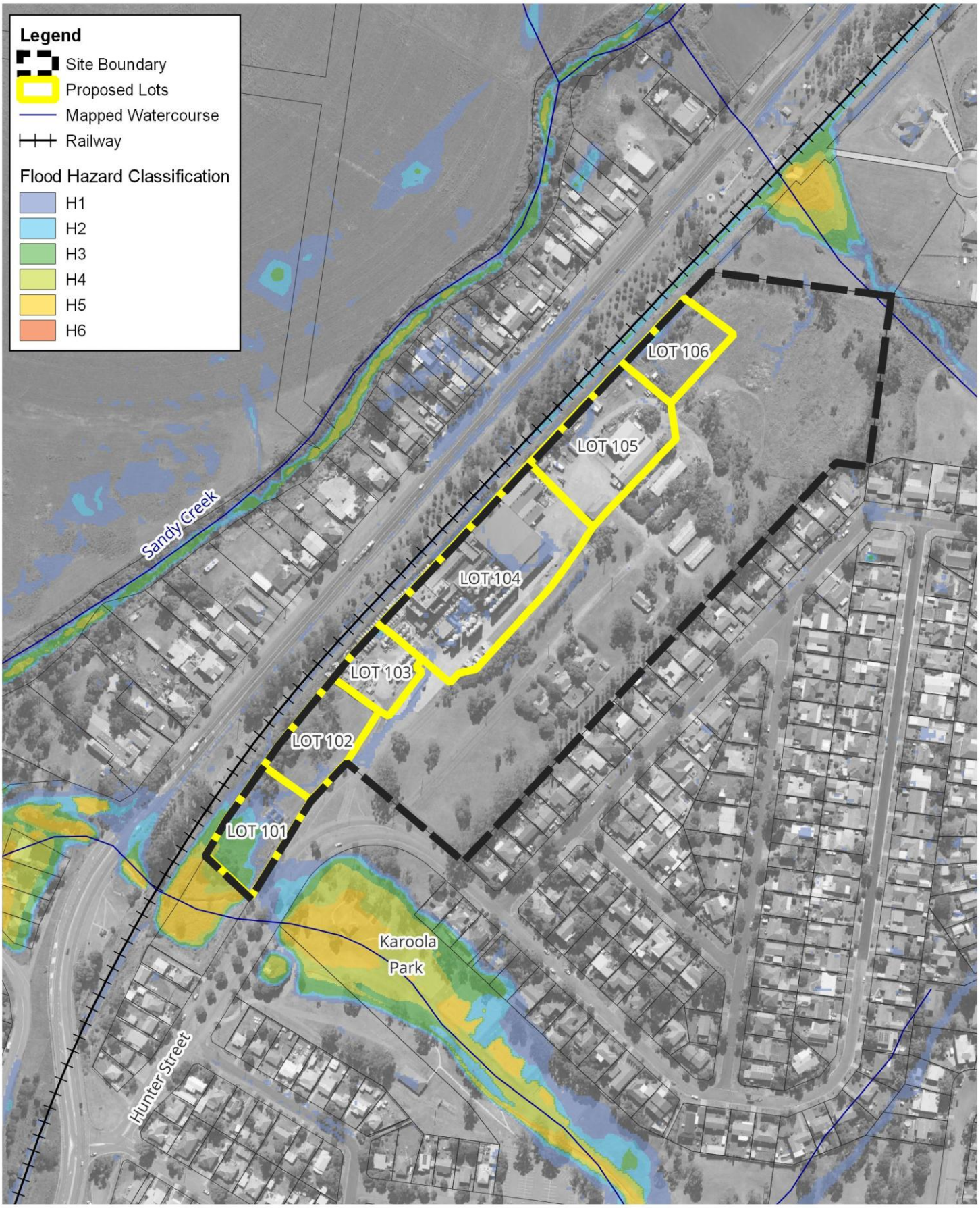

Title:

Peak 1% AEP Flood Hazard Classificaiton

0 100 200 m

approx. scale

Figure: 6

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The flood hazard classification is a function of the peak flood depth and velocity as shown in Figure 4. The flood hazard classification for the Site is largely H4. This corresponds to the peak depth of flooding in the flood affected region being of the order of 1m.

The inundation extents and flood depth distribution for the PMF event is shown in Figure 6. Similar to the 1% AEP event, the major flooding is largely limited to along the mapped watercourse albeit with increasing flood depth and extent. Peak flood depths exceed 4m on the lowest parts of the Site.

The Main North Railway embankment is overtopped under the PMF condition providing for a significant backwater inundation of the Site extending across the proposed Lot 101 and Lot 102. Notwithstanding the rail overtopping, the Site would still be subject to inundation from the overflow across Hunter Street from the Karoola Park detention basin.

Flood Planning Requirements

The Muswellbrook LEP 2009 provides a framework for development of land and land use in the Muswellbrook LGA. Clause 5.21 relates to flood planning which states the following objectives:

a) to minimise the flood risk to life and property associated with the use of land;

b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change;

c) to avoid adverse or cumulative impacts on flood behaviour and the environment;

d) to enable the safe occupation and efficient evacuation of people in the event of a flood.

In supporting these objectives, the LEP includes provision that development consent must not be granted unless the consent authority is satisfied that the development:

a) is compatible with the flood function and behaviour on the land; and

b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties; and

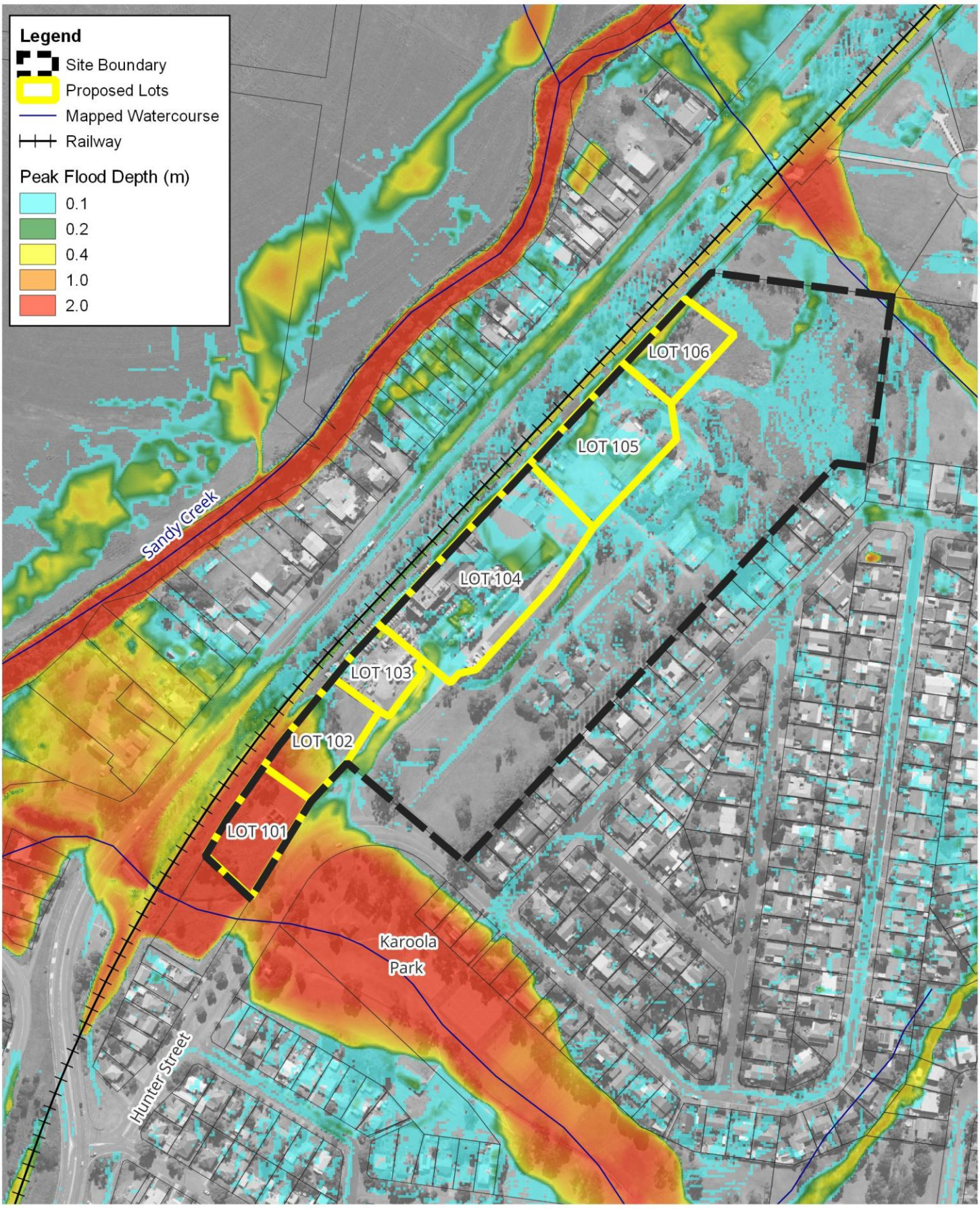
c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood; and

d) incorporates appropriate measures to manage risk to life in the event of a flood; and

e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.

NSW Planning has prepared a Special Flood Considerations Clause as an optional clause to include in LEPs in order to better protect and manage new development in areas that could be at risk during floods. The special flood considerations clause would apply to:

- sensitive and hazardous development, such as caravan parks, hospitals and seniors housing, between the flood planning area and the probable maximum flood level
- development that is not sensitive or hazardous on land that the consent authority considers that, in a flood, may pose a particular risk to life and where people may need to evacuate, or where there are other safety concerns.



Title:

Peak PMF Flood Depth

0 100 200 m

approx. scale

Figure: 7

Revision: A

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The Special Flood Considerations clause has been adopted in MLEP 2009. Accordingly, a development proposal may need to consider potential flood risk to future occupation of the floodplain for all events up to and including the PMF. The future industrial or commercial land use would not be considered a sensitive land use for this location. However, the PMF conditions on the lower portion of the Site may constitute a risk to life hazard and would need to be appropriately addressed via a Flood Emergency Response Plan.

Specific planning controls are outlined in the Muswellbrook DCP 2009 Section 13 – Floodplain Management. The following objectives are noted in the DCP:

- Establish guidelines for the development of flood prone land that are consistent with the NSW Flood Policy and NSW Floodplain Development Manual (2005) (noting this is now Flood Risk Management Manual 2023) and as updated by the associated Floodplain Risk Management Guides.
- Limit the intensification of residential uses and other inappropriate uses in flood affected areas.
- Promote flood compatible design and building that considers requirements for the development of flood prone land and does not adversely impact on adjoining properties or pose unnecessary risk or cost to the public or emergency services.
- Ensure measures are implemented to reduce private and public losses resulting from flooding and manage risks to property and life from flood events.
- Ensure that the development or use of floodplains waterways and riparian corridors does not adversely impact upon aesthetic, recreational and ecological values and takes into account potential changes resulting from climate change; and
- Provide guidance for assessing the LEP criteria for Development Consent, considering Council's responsibilities for floodplain management and flood related development standards as specified in other relevant legislation including the Local Government Act 1993 and Water Management Act 2000.

The flood modelling and mapping identifies most of the Site to be flood free at the PMF level with only Lot 101 within the 1% AEP extent, and Lot 101 and Lot 102 within the PMF extent. There would be no flood related development constraint for the proposed lots outside of the PMF extent.

Similarly, there would appear to be limited constraint for potential development on Lot 102 given that is outside the 1% AEP flood extent and a large proportion of the lot area is flood free up to the PMF level, with flood free access to Hunter Street. Accordingly, it would be expected that Risk to Life is appropriately managed.

The Site flooding constraints predominantly affect potential development on Lot 101. Section 13.6 of the DCP details specific controls for development on flood prone land. The controls are outlined below with a response on the implications for proposed development on the Site.

1. *Development must be consistent with the current version of the NSW Floodplain Development Manual, any relevant local flood study, floodplain management study and plan applying to the land that has been endorsed by Council, or the recommendations of a Flood Impact & Risk Assessment completed for the development.*

Response: The modelling undertaken in this FIRA is consistent with these guidelines and would underpin the flood related DA documentation.

1. *Generally, buildings and other structures, including fences, must be designed so as not to impede the flow of floodwaters or entrap debris.*

Response: This would be addressed at detailed design. The models developed in this assessment may assist in demonstrating compatible design.

2. *Filling within the floodplain must be supported by a detailed flood risk & impact assessment certified by a suitably qualified consulting engineer that can adequately demonstrate:*

   a) Filling is not within a core riparian zone.

   b) Filling will not substantially impede the flow of floodwater and not contribute to flooding or ponding of water on any other property; and

   c) For a dwelling pad in a rural area, filling is minimal and is balanced by a borrow pit on the same site, and neither are situated in high hazard floodwaters (H3 or higher in a 1% AEP flood).

Response: There is flood area at the 1% AEP event flood in Lot 101 such that future development may not require any filling. The flood affected area typically has flood depths in excess of 0.5m such that extensive filling is unlikely to be viable in any case. Some limited filling on the edge of the flood affected area may be possible subject to confirmation of acceptable impacts via the developed models.

3. *New structures are to meet the flood planning levels and floor heights specified in the Table 2 below*.

Response: Commercial and industrial development types require minimum floor height of the 1% AEP flood level. This achievable on all proposed lots.

4. *Flood planning levels and floor heights for additions or alterations to existing residential development will be assessed on the merits of the situation, having regard to meeting an acceptable level of risk to life and flood damage. In general, additions that will increase the existing floor area by more than 20% as it existed on 1 January 2022 will be required to meet the floor heights in Table 2*.

Response: Not applicable for this proposal.

5. *The construction methods and materials that form part of the development that will be below the flood planning level, including filling, must be capable of withstanding the force of flowing floodwaters, including debris and buoyancy forces and immersion for a prolonged period.*

Response: To be addressed at detailed design.

6. *Development on land below the 1% AEP will only be permitted where effective warning time and reliable access is available for evacuation to an area free of risk from flooding. Evacuation should be consistent with any relevant flood evacuation strategy.*

Response: It is anticipated there will be no development below the 1% AEP flood level. However, it is noted that flood free access to Hunter Street is available for all lots fort the 1% AEP event.

7. *Evacuation Plans, when required, are to be prepared to Council's satisfaction demonstrating the Plan provides for:*

   a) Low flood hazard emergency vehicle road access (NSW SES, NSW RFS) during a 1% AEP flood event; and

b) Failsafe, comprehensive flood-alert measures. Alternative shelter in place arrangements will need to be justified and comply with guidance issued by NSW SES, DPIE or equivalent agencies.

Response: As noted, all lots have flood free access to Hunter Street for the 1% AEP event. This is also the case at the PMF event for all lots except Lot 101. Lot 101 does have continually rising access to flood free area above the PMF and an appropriate Flood Emergency Response Plan would be required to support a development application.

8. No Torrens Title subdivision that may result in intensification of development is to occur on land wholly inundated by flooding during the PMF event, unless it is demonstrated that:

   a) The risk of flooding can be effectively and appropriately mitigated without impacting the adjacent floodplain or unnecessary risk or cost to the public or emergency services.

   b) There is adequate flood free land above the 1% AEP flood level suitable for the development, vehicle parking and effluent disposal (if applicable); and

   c) There is flood free access to each lot or a satisfactory Flood Evacuation Plan.

Response: Only Lot 101 is wholly inundated during the PMF flood event. A single industrial/commercial development of the land would provide for new development on the Lot; however, it is possible this is not considered “intensification”. Notwithstanding, as per previous comments a Flood Emergency Response Plan is expected to address this control and demonstrate risk to life is appropriately managed.

Conclusion

Torrent Consulting was engaged to undertake a Flood Impact and Risk Assessment to assist in the development and planning process for the proposed subdivision of Lot 1 DP995228, Hunter Street, Muswellbrook NSW (the Site). This assessment has included development of a TUFLOW model for the local catchment runoff and has simulated design flood conditions in accordance with the ARR 2019 guidelines, specifically the ensemble method for design flood hydrology.

The modelling has established design flood conditions to assess the flood planning requirements for the development and consider potential flood impacts. The key findings of the assessment include:

- Flood inundation of the Site in the 1% AEP event is limited to a partial area of the proposed Lot 101. All other lots are flood free at the 1% AEP level and expected to provide minimal flood planning constraint to future development.
- Flood inundation of the Site in the PMF event is limited to a partial area of the proposed Lot 102, and the full area of Lot 101. Lot 102 has flood free area above the PMF and flood free access to Hunter Street which is expected to readily address risk to life concerns. Peak PMF flood depths are typically over 3m across all of Lot 101. There is continuously rising flood egress opportunity within the lot to flood free area above the PMF. A Flood Emergency Response Plan would be required to demonstrate risk to life is appropriately managed.

The Flood Impact and Risk Assessment has demonstrated potential development opportunity and constraints across the Site. Refinement of the assessment would be required to support future applications once development proposal design is finalised.

We trust that this report meets your requirements. For further information or clarification please contact the undersigned.

Yours faithfully

Torrent Consulting

Darren Lyons
Principal Water Resources Engineer
CPEng MIEAust

References:

AIDR (2017). *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*. Australian Institute for Disaster Resilience, Commonwealth Government of Australia.

Muswellbrook Shire Council (2009) *Muswellbrook Local Environmental Plan*

Muswellbrook Shire Council (2009) *Muswellbrook Shire Development Control Plan*

Royal Haskoning DHV (2019) *Muswellbrook Floodplain Risk Management Study and Plan*.

APPENDIX A - Flood Mapping