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NSW DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT

PARKES SPECIAL ACTIVATION PRECINCT

FLOOD AND WATER QUALITY MANAGEMENT STUDY REPORT

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Parkes Special Activation Precinct

Flood and Water Quality Management Study Report

NSW Department of Planning, Industry and Environment

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GLOSSARY

1D	One dimensional
2D	Two dimensional
AEP	Annual Exceedance Probability
ANZECC	Australian and New Zealand Environment and Conservation Council
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
ARR 2016	Australian Rainfall and Runoff 2016
BX	Storage coefficient multiplication factor – a RAFTS model parameter
CL	Continuing loss (rainfall) – a RAFTS model parameter
DCP	Development Control Plan
DEM	Digital Elevation Model
DPIE	NSW Department of Planning, Industry and Environment
DRAINS	A hydrological and hydraulic modelling software program
DSC	Dam Safety Committee
DTM	Digital Terrain Model
EIS	Environmental Impact Statement
EPA	NSW Environment Protection Authority
EY	Exceedances per Year
GIS	Geographical Information System
GSAM	Generalised Southeast Australia Method
GSDM	Generalised Short Duration Method
HPC	Heavily Parallelised Computations
IFD	Intensity-Frequency-Duration
IL	Initial loss (rainfall) – a RAFTS model parameter
IR	The Inland Rail project
kg	Kilogram
kg/year	Kilograms per year
LX	Level Crossing
LiDAR	Light Detection and Ranging

m AHD	Metres above Australian Height Datum
m/s	Metres per second
m^2/s	Square metres per second
m^3/s	Cubic metres per second
ML	Megalitre
ML/year	Megalitres per year
MUSIC	Model for Urban Stormwater Improvement Conceptualisation – a stormwater quality modelling software program
NWQMS	National Water Quality Management Strategy
OEH	NSW Office of Environment and Heritage
P2N	The Parkes to Narromine section of the Inland Rail program
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RAFTS	A hydrological modelling software program
RFFE	Regional Flood Frequency Estimation
SAP	Special Activation Precinct
SEPP	State Environmental Planning Policy
SRTM	Shuttle Radar Topography Mission
TIN	Triangular Irregular Network
TUFLOW	A hydraulic modelling software program
WSUD	Water Sensitive Urban Design

1 INTRODUCTION

The Parkes Special Activation Precinct (the SAP) is a joint Government Agency initiative, announced by the Deputy Premier, the Hon John Barilaro MP, to create a 20-year vision for job creation and regional development. The Department of Premier and Cabinet and the Department of Planning, Industry and Environment are leading the creation of the Parkes SAP.

Parkes is a location of State and regional significance and the SAP is an economic enabler that will address market failures and leverage catalyst opportunities. The SAPs are a place-based approach to 'activate' this strategic location.

The Parkes SAP was selected because of the economic opportunities associated with the construction of an Inland Rail from Brisbane to Melbourne and the existing east-west Sydney to Perth/Adelaide Rail corridor which cross at Parkes creating an opportunity for an Inland Port.

The Parkes SAP will lead to investment in common-use infrastructure, including roads infrastructure, water, electricity, telecommunication, gas systems and services, high speed internet and data connections and facilities, and other possible infrastructure or services.

A SAP contains five core components and this plan (government led studies) will inform fast track planning for the Precinct and potential future infrastructure investment and government led development:

1.1 REGIONAL AND LOCAL CONTEXT

Parkes local government area (LGA) is located approximately 350 kilometres west of Sydney, in the Central West and Orana Region. The main townships and settlements in the LGA include Alectown, Bogan Gate, Cookamidgera, Parkes, Peak Hill, Trundle and Tullamore. Other major centres in the region include Condobolin, Cowra, Dubbo, Forbes and Orange.

The Parkes township has a stable population of approximately 11,500 people (ABS, 2016), with around 5,000 dwellings. An industrial estate (zoned IN1 – General Industrial) is located south of the town, adjoining the Newell Highway. The town is serviced by an existing local centre, mixed use areas that contain both commercial, business and retail use. A new hospital and associated health Precinct is located towards the southern end of the town. The Parkes Regional Airport is located east of town, with the Parkes National Logistics Hub located to the west.

The Central West and Orana Regional Plan 2036 identifies the following key features about Parkes:

- development and settlement is clustered around key corridors, including the twin centres of Parkes and Forbes
- Parkes, along with Dubbo, is a major freight hub particularly in the selling, processing, manufacturing and transporting of livestock and agricultural produce
- TransGrid's NSW Connection Opportunities identifies Parkes as having capacity for renewable energy generation; and
- existing regional mining operations (North Parkes Mines and Tomingley) near Parkes.

The establishment of a Parkes SAP is consistent with Parkes Shire Council's vision and strategic planning for the locality.

1.2 PARKES SPECIAL ACTIVATION PRECINCT

The Parkes SAP covers an area of about 5000 hectares and is located to the west of the Parkes township (see Figure 1.1). The Parkes SAP is strategically located at the intersection of:

- the Brisbane to Melbourne Inland Rail
- the Sydney to Perth/Adelaide Rail corridor; and
- is in close proximity to the junction of the Henry Parkes Way and Newell Highway.

The Inland Rail project has received $9.3 billion in funding from the Commonwealth Government to support the upgrade to the freight network from Brisbane the Melbourne. It is projected that the first train will run between the two capital cities in 2025. Parkes is an important connection for the Inland Rail project, as it is the epicentre of inland freight.

The Parkes SAP area is predominantly occupied by agricultural land, with a solar energy facility located in the north-western corner and an existing quarry operation located in the south-eastern area of the Precinct.

The existing primary industries in Parkes are focused around freight and logistics, agribusiness and mining. Parkes strategic location within Regional NSW provides the opportunity to capitalise on these industries, along with the potential to expand into warehousing, advanced food manufacturing and renewable energy uses.

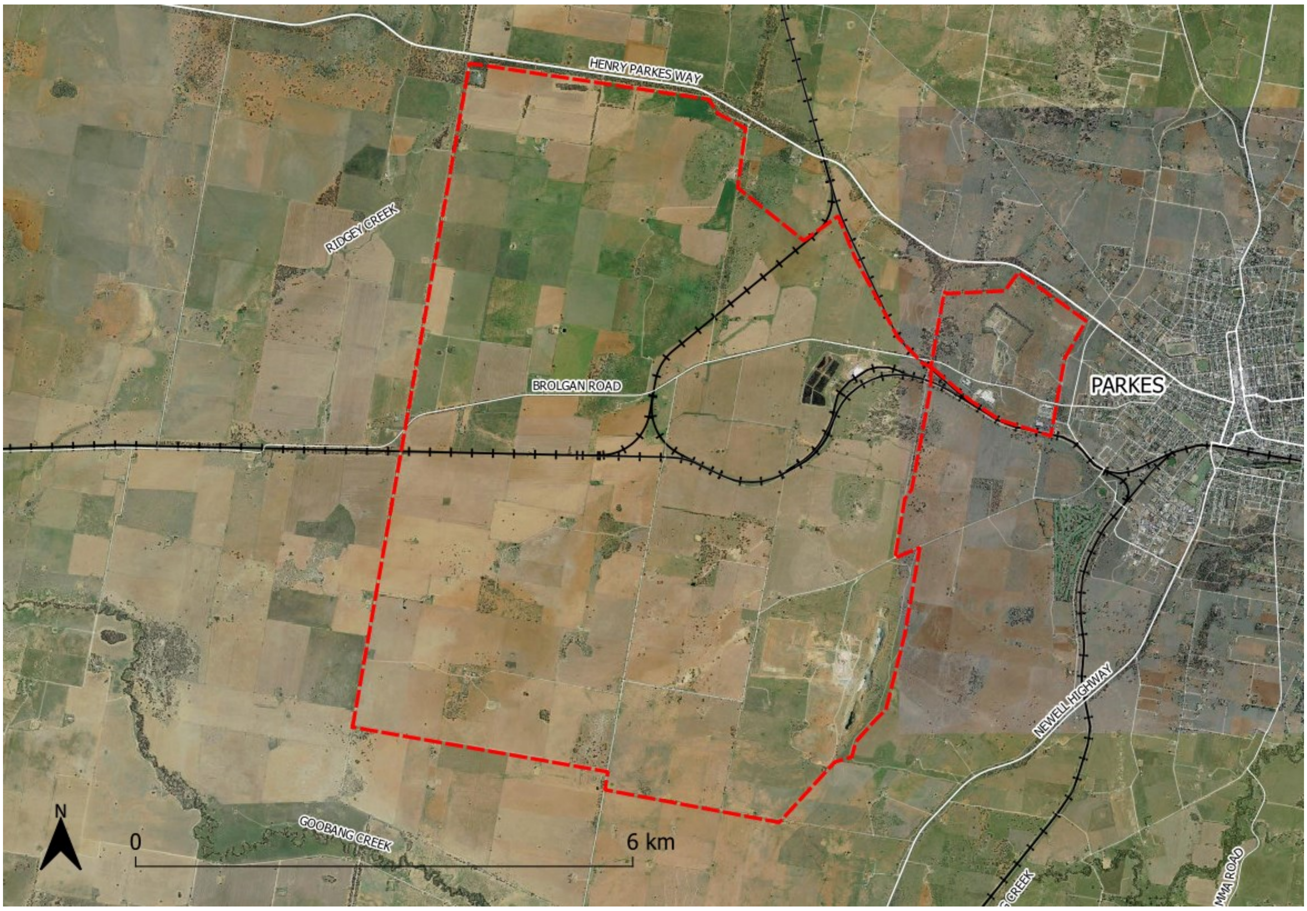

Figure 1.1 Indicative location of the Parkes SAP

1.3 PLANNING FRAMEWORK

Currently under the Parkes Local Environmental Plan (LEP) 2013, the Parkes SAP area is zoned:

- RU1 – Primary Production
- SP1 – Special Activities; and
- SP2 – Infrastructure.

The land zoned SP1 – Special Activities has been identified as the Parkes National Logistics Hub. The Logistics Hub covers approximately 600 hectares. The land includes the Pacific National and SCT Logistics sites among other landholdings. The locality provides the opportunity to create an intermodal site serviced by rail and road connections.

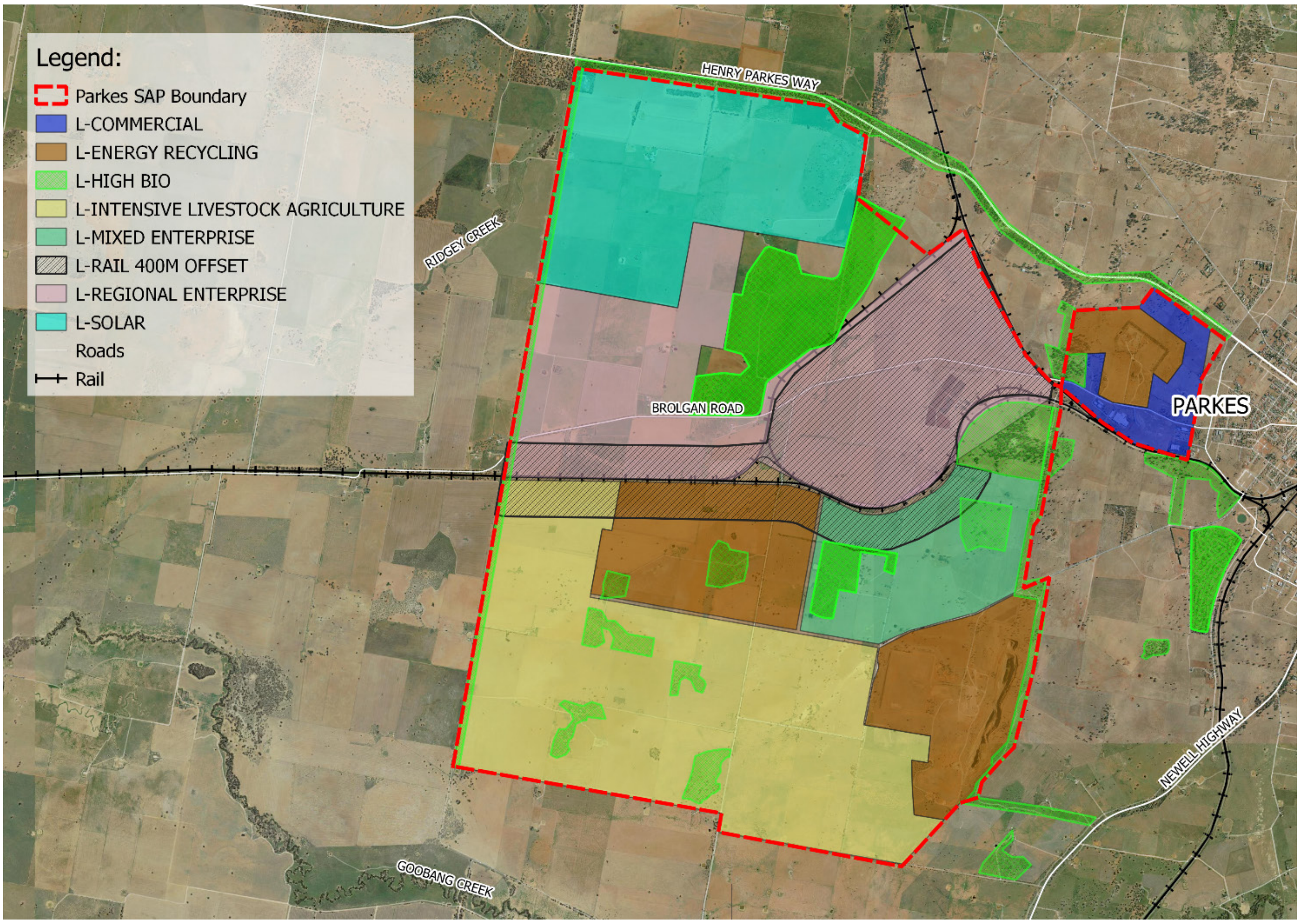

Figure 1.2 Land use zoning

1.4 PURPOSE AND SCOPE OF STUDY

The purpose of the study is to establish a detailed understanding of the flooding and stormwater characteristics of the Parkes SAP and surrounding area to inform the development of the Parkes SAP Master Plan. The characteristics of interest are the flooding and drainage processes internally within the SAP and how these interact with the surrounding environment. The outputs of the study are required to define the following:

- the flood behaviour and drainage patterns of the existing SAP area and surrounding catchments
- the water quality characteristics of the existing surface runoff within the SAP area and surrounding catchments
- the constraints that the existing flooding, drainage and water quality characteristics pose on the Master Plan
- the potential impacts of the Master Plan on the flooding, drainage and water quality regime in the surrounding catchments that have a hydrologic interaction with the SAP; and
- mitigation measures, including the potential to incorporate Water Sensitive Urban Design (WSUD) principles and measures within the Master Plan, to manage flooding, stormwater quality and stormwater harvesting and re-use.

The key elements of the study scope are as follows:

- develop a set of hydrologic models capable of defining flood flows, levels, depths, velocities and hazard categories within the SAP and surrounding catchments for existing conditions and the Master Plan scenario
- use the hydrologic model outputs to map flood risk parameters for the 10%, 1% and 0.2% Annual Exceedance Probabilities (AEP) and the Probable Maximum Flood (PMF) for both existing conditions and the Master Plan scenario

- use the hydrologic models to determine the flood risk management strategy for the SAP, based on analysis of flood attenuation/detention requirements and other best practice measures to maximise the developable land area within the SAP and to protect existing assets and adjacent land from adverse flooding impacts
- develop a stormwater quality model capable of defining sub-catchment flow rates, flow volumes and water quality parameters within the SAP and surrounding catchments for existing conditions and the Master Plan scenario; and
- use the water quality model to:
  - determine harvestable volumes of stormwater that can contribute to meeting the non-potable water demand for the SAP
  - determine the limits on stormwater harvesting within the SAP to maintain the current flow regime in the receiving catchments downstream of the SAP; and
  - identify measures for treating runoff from the SAP to maintain the current water quality regime in the receiving catchments downstream of the SAP.

1.5 REPORT STRUCTURE

The report is structured as follows:

- Section 2 describes the SAP study area and catchment and climate characteristics.
- Section 3 provides an overview of relevant legislation and policies.
- Section 4 describes the flooding assessment, including the hydrological and hydraulic modelling methodologies and summaries of the flooding characteristics for existing and future conditions.
- Section 5 describes the water quality assessment, including the water quality modelling methodology and summaries of the water quality characteristics for existing and future conditions.
- Section 6 provides key conclusions from the study.
- Appendix A provides a plan of the study area and layouts of the hydrological and hydraulic models.
- Appendix B provides the existing conditions flood maps for extent and depth, velocity, hazard and hydraulic categorisation.
- Appendix C provides the Master Plan scenario water management infrastructure layout and the flood maps for extent and depth, velocity, hazard and hydraulic categorisation.

2 EXISTING ENVIRONMENT

2.1 STUDY AREA

The study area incorporates the Parkes SAP and the surrounding surface water catchments that affect flooding, drainage and water quality processes within the SAP. The study covers all areas which could be affected by modifications to the surface water regime as a result of the SAP development. Refer to Figure 1.1 for the indicative location of the Parkes SAP.

The SAP spans two local catchments with most of the area falling within the headwaters of the Ridgey Creek system, which drains the area north and west of Parkes and forms a tributary of Goobang Creek. The south eastern part of the SAP drains downstream towards Goobang Creek which is a significant creek system draining the area south and east of Parkes with headwaters located at least 30km east of Parkes. Lake Endeavour Dam is located on Goobang Creek approximately 25 km east of Parkes.

The SAP is within the broader Lachlan River catchment which forms part of the Murray Darling Basin. Goobang Creek joins the Lachlan River at Condoblin approximately 100 km west of Parkes. The Lachlan River is a major regional river and floodplain system but the SAP and Parkes are located well out of the Lachlan regional floodplain. The flooding processes of relevance to the project are therefore local catchment flooding within the Ridgey Creek and Goobang Creek systems. Photos 2.1 and 2.2 below show flooding that occurred within the SAP during a moderate flood event in September 2016.

Photo 2.1 Flooding on Coopers Road (looking south) during September 2016 flood event

Photo 2.2 Flooding west of Coopers Road during September 2016 flood event

The southern boundary of the SAP is located approximately 2 km from the main Goobang Creek channel. Therefore, flooding in the Goobang system is unlikely to affect the SAP, instead flooding within the SAP will be governed by shallow overland flow paths and minor drainage lines associated with the Ridgey Creek system and minor sub-catchments of the Goobang Creek system. A significant topographic divide exists between the Ridgey Creek system and the Goobang Creek system running south to north through Parkes and therefore failure of the Lake Endeavour Dam would not influence flood levels throughout the SAP, but may result in elevated tailwater conditions in the Goobang Creek channel and floodplain south of the SAP that may have some effect on drainage patterns within and south of the SAP.

2.2 LAND USE AND INFRASTRUCTURE

Key features and topography of the SAP and surrounding area are shown on Figures A1 and A3 in Appendix A. Most of the SAP land use consists of cleared rural-agricultural land with several rural properties located throughout the area. The land is used for a combination of mixed agricultural activities including cropping and livestock, with small pockets of uncleared native vegetation remaining in addition to numerous small farm dams across the area. The West Lime Quarry is located in the lower south-eastern half of the SAP and several industrial sites including the Goonumbla Solar Farm and Pacific National regional rail depot are located at the northern half of the SAP. The Orange to Broken Hill rail line bisects the SAP from east to west and the SCT Logistics train yard is located off this rail line on the eastern boundary of the SAP. This rail line meets the Parkes to Narromine rail line at the Goobang Junction at the north-eastern boundary of the SAP.

The land to the north, south and west of the SAP consists of cleared agricultural land with rural properties scattered throughout. The Parkes Golf Course and a low density residential area are located to the east of the SAP.

2.3 CLIMATE AND RAINFALL

Parkes has a warm temperate climate, with large temperature variation between the summer and winter months. Parkes receives an annual average of 587.5 mm of rainfall with January as the wettest month and June the driest. Rainfall in spring and summer usually falls as thunderstorms. Mean monthly rainfall and evapotranspiration as recorded at Parkes Airport are shown in Figure 2.1 below.

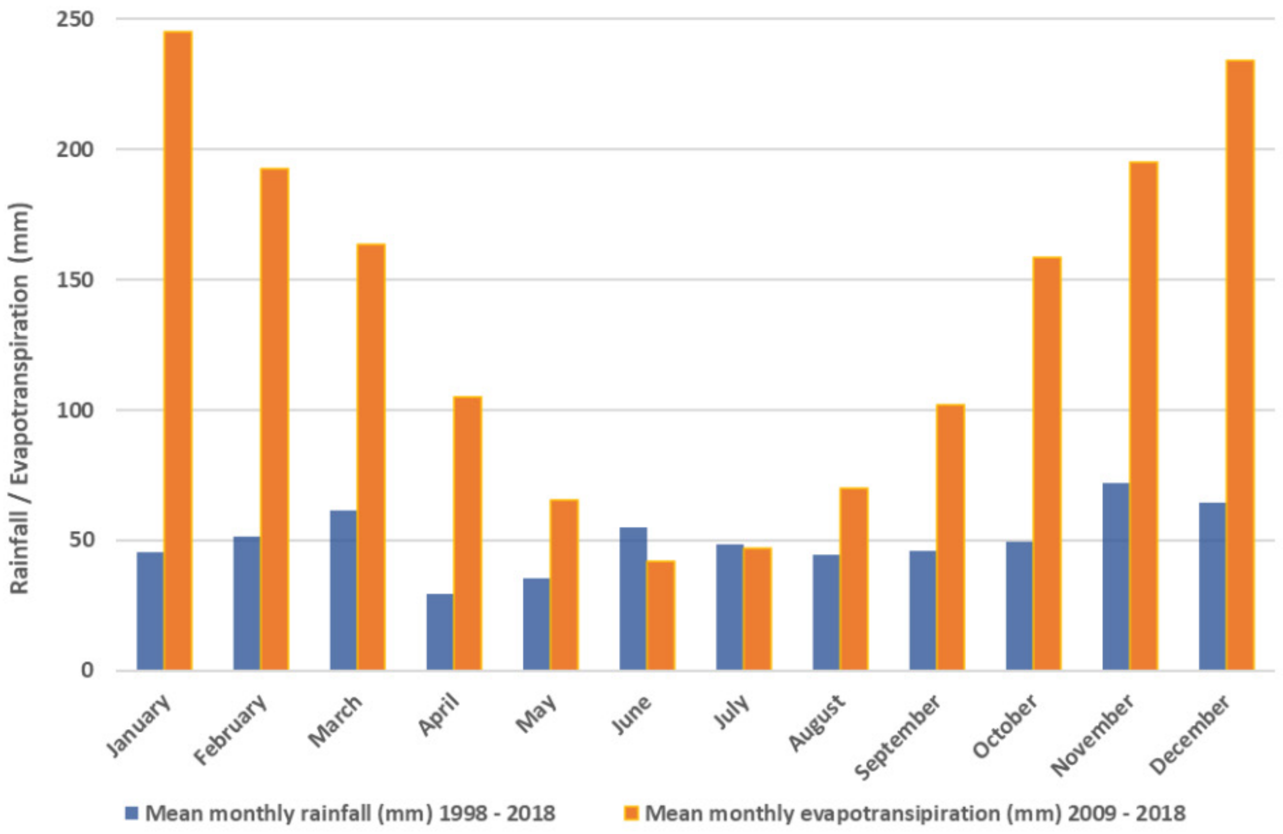

Figure 2.1 Mean monthly rainfall and evapotranspiration recorded at Parkes Airport (Bureau of Meteorology 065068)

2.4 TOPOGRAPHY AND SOILS

The SAP topography varies across the area but generally slopes to the west, with a small localised catchment sloping to the south-east (refer to Figure A3 in Appendix A). The SAP elevation ranges from approximately 263 metres above Australian Height Datum (mAHD) in the west to 351 mAHD in the east.

The soil landscape is described as level to gently undulating plains west of Parkes with the dominant soils being non-calcic browns, red podzolic soils, red earths, yellow solodic soils and brown clays. The area is described as being a foundation hazard and can be subject to seasonal water logging. Further it is noted that the soil fertility is low to very low, the topsoils have a high erodibility and are generally unsuitable for structural earthworks.

2.5 CATCHMENTS AND WATERWAYS

The SAP is located within the Lachlan River Catchment. There are no permanent waterways in the SAP, but it does contain several ephemeral waterways. The major receiving waterways are Goobang Creek located approximately 1.5 km to the south and west and Ridgey Creek to the west. Goobang Creek has permanent waterholes, however, it is ephemeral in nature and generally only flows after good seasonal rainfall. The banks of Goobang creek exhibit a slightly increased elevation compared to the immediately surrounding farmland, likely due to natural sediment deposits from the creek. The creek flows to the west and eventually into the Lachlan River approximately 85 km west of the SAP.

There are farm dams present throughout the SAP. Six man-made dams are present in the SCT Logistics site next to the Orange to Broken Hill rail line. Several large dams are also present within the West Lime quarry site in the south-eastern corner of the SAP.

2.6 SURFACE WATER QUALITY

There is no existing water quality data for the watercourses crossing the SAP due to the ephemeral nature of the watercourses. The Parkes Urban Stormwater Management Plan (Parkes Shire Council, 2001) provides the following summary of the water quality within the Goobang Creek system:

- A study that rated the condition of the Goobang Creek catchment riverine corridor was carried out in 1998 (Massey 1998). While the study did not involve the monitoring of water quality it provided a description of the existing condition of the Goobang Creek catchment.
- The reach environment was rated as moderate with 70% of this environment, suffering moderate to extreme disturbance. Most of the disturbance was attributed to the clearing of native vegetation, grazing, bridges and roads. The land use adjacent to streams have affected the quality of this environment including urban development.
- Over 80% of the entire length was within the good stability range for bank condition. The main causes of bank instability were domestic stock, clearing, runoff into the creek and the flow in the creek itself. Bed and bar stability was given an average stability rating. The factor was affected by stream disturbance and bed control structures such as logs and culverts.
- Aquatic habitat ranged from poor to good quality with an overall average rating falling within the moderate quality range. Areas rated as having low quality aquatic habitat are found in the upper reaches of Goobang Creek particularly near Parkes. In these areas, there was a high level of disturbance, poor depth diversity or substrate material, organic debris was minimal and there was also minimal bank and overhanging vegetation.
- Riparian Vegetation overall (95%) rated either as in poor or very poor condition (highly degraded) with clearing generally occurring to the top of banks as a result of farming operations. In some sections the vegetation was dominated by exotic species such as willows. Aquatic vegetation was in poor to very poor condition. This could be because the survey was conducted during a period of no flow. This is common for the creek, as it is ephemeral in nature generally only flowing for short periods of time.

- Overall the health of the riverine corridors in the Goobang catchment is summarised by the graph (reproduced in Figure 2.2 below) as being in moderate to poor condition.

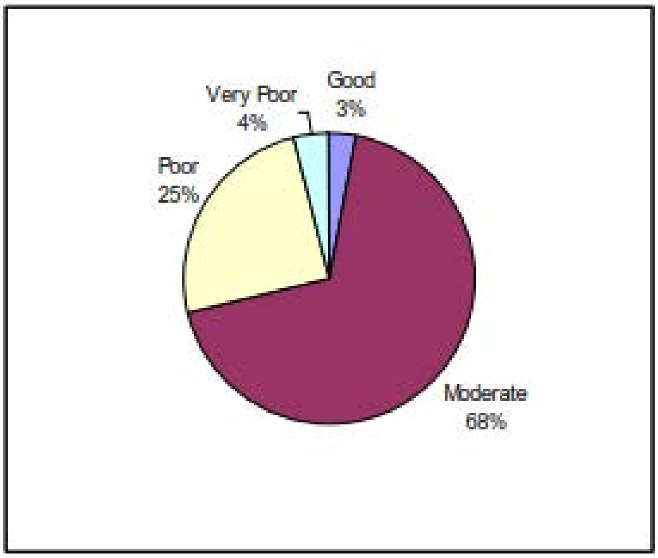

Figure 2.2 Breakdown of the health of the riverine corridors in Goobang Catchment (Massey 1998)

The National Water Quality Assessment 2011 (Sinclair Knight Merz, 2011) classified the water quality of the Lachlan River catchments as being relatively poor (refer to Table 2.1), exceeding the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, 2000) for several criteria. This was based on data from 15 sites in the Lachlan River catchment, none of which were located within the study area catchments of Goobang Creek and Ridgey Creek.

Table 2.1 Lachlan River catchment water quality condition as reported in 2011

PARAMETER	WATER QUALITY CONDITION	COMMENT
Turbidity	Fair	31% of samples exceeded guidelines values
Salinity	Fair	50% of samples exceeded guidelines values
pH	Good	85% of samples within guidelines values
Total Nitrogen	Very Poor	96% of samples did not meet guidelines values Median values at the site ranged from 456–860 ug/L
Total Phosphorus	Poor	72% of samples did not meet guidelines values Median values at the site ranged from 12–83 ug/L

The 2018 NSW State of the Environment report (NSW EPA, https://www.soe.epa.nsw.gov.au/) identifies the following for the Lachlan River:

- exceedances of the National Guidelines for Fresh and Marine Water Quality for Total Nitrogen and Total Phosphorus
- a reduction in mean daily salinity levels for the previous reporting period ending in 2014.

3 RELEVANT GUIDELINES AND POLICIES

This section provides summaries of key guidelines and policies that were used to guide the flooding and water quality analyses and the assessment of management measures.

3.1 FLOODING

3.1.1 AUSTRALIAN RAINFALL AND RUNOFF

Australian Rainfall and Runoff 2016 (Commonwealth of Australia, 2019), hereafter referred to as 'ARR 2016', is a national guideline document, data and software suite that is used for the estimation of design flood characteristics in Australia. The guideline provides recommended nationally consistent practices for the following:

- estimation of design rainfall, peak design flows and prediction of full hydrographs
- guidance on design flood estimation under changing climatic conditions
- methods for calibration and verification of design flows; and
- a source for location specific hydrology and hydraulic modelling factors.

The ARR 2016 document is used as the basis of best practices for flood modelling design, where NSW specific advice has not otherwise been provided by the NSW Office of Environment and Heritage (OEH).

3.1.2 FLOODPLAIN RISK MANAGEMENT GUIDELINES

OEH provides a number of documents designed to inform and support preparation and implementation of floodplain risk management plans. These guidelines aim to complement and clarify items within the Floodplain Development Manual (NSW Government 2005). Key documents within these guidelines include:

- Floodway Definition (OEH 2007)
- Rainwater Tanks – Limitations as Flood Risk Management Devices (OEH 2007); and
- Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in studies (State of NSW and OEH 2019).

The Floodplain Risk Management Guide contains recommendations for alternate methodologies to be adopted within NSW in lieu of the national ARR 2016 guideline. This study addresses and adopts these NSW specific recommendations where appropriate.

3.1.3 AUSTRALIAN INSTITUTE OF DISASTER RESILIENCE HANDBOOK

The Australian Institute of Disaster Resilience (AIDR) Handbook provides advice on management of flooding within the floodplains and catchments of waterways due to catchment flooding from prolonged or intense rainfall. The handbook outlines best practices for managing the flood risk to communities inhabiting floodplains in Australia. The key document within these guidelines is Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Australian Disaster Resilience Handbook Collection, Handbook 7 (AIDR 2017).

3.1.4 *FLOODPLAIN DEVELOPMENT MANUAL – THE MANAGEMENT OF FLOOD LIABLE LAND*

The Floodplain Development Manual (NSW Government 2005) provides guidance for development and implementation of detailed local floodplain risk management plans to produce robust and effective floodplain risk management outcomes. The manual provides the basis for the best practice surrounding flood risk management, however some specific methodologies are outdated in favour of more recent approaches documented in guidelines including ARR 2016, the OEH Floodplain Risk Management Guide and the AIDR Handbook 7.

3.2 WATER QUALITY

The NSW Environment Protection Authority (EPA) promotes use of a risk-based decision framework for considering water quality outcomes for strategic planning decisions. This aims to improve management of the impacts of development while supporting locally relevant management objectives and outcomes. The NSW EPA refers to the National Water Quality Management Strategy (NWQMS) for management and impact assessment of water quality in the state. The key documents under this strategy are:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (http://www.waterquality.gov.au/anz-guidelines)
- NSW Water Quality and River Flow Objectives (http://www.environment.nsw.gov.au/ieo/); and
- Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions (NSW EPA and Office of Environment and Heritage 2017).

3.2.1 *NATIONAL WATER QUALITY MANAGEMENT STRATEGY*

The NWQMS aims to protect the nation's water resources by improving water quality while supporting the businesses, industry, environment and communities that depend on water for their continued development. The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development.

The NWQMS includes water quality guidelines that define desirable ranges and maximum levels for certain parameters that can be allowed (based on scientific evidence and judgement) for specific uses of waters or for protection of specific values. They are generally set at a low level of contamination to offer long-term protection of environmental values. The NWQMS water quality guidelines include the Australian and New Zealand Guidelines for Fresh and Marine Water Quality and the Australian Drinking Water Guidelines (Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council, 2018).

3.2.2 *AUSTRALIAN AND NEW ZEALAND GUIDELINES FOR FRESH AND MARINE WATER QUALITY*

These guidelines have been prepared as part of the NWQMS. The guidelines provide a process for developing Water Quality Objectives (WQOs) required to sustain current or likely future environmental values for natural and semi-natural water resources.

3.2.3 *NSW WATER QUALITY AND RIVER FLOW OBJECTIVES*

For each catchment in NSW, the NSW Government has endorsed the community’s environmental values for water and identified water quality objectives. These were adopted following extensive consultation with the community in 1998. The NSW Water Quality and River Flow Objectives (http://www.environment.nsw.gov.au/ieo/) are the agreed environmental values and long-term goals for NSW's surface waters. They are consistent with the agreed national framework for assessing water quality established by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality and set out:

- the community's values and uses for rivers, creeks, estuaries and lakes (i.e. healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water); and
- a range of water quality indicators to help assess the current condition of waterways and whether they support those values and uses.

The water quality objectives are the specific water quality targets agreed between stakeholders, or set by local jurisdictions, that become the indicators of management performance. These limits or descriptive statements are selected to support and maintain the environmental values of the catchment.

The trigger values are concentrations that, if exceeded, would indicate a potential environmental problem, and so ‘trigger’ a management response, e.g. further investigation and subsequent refinement of the guidelines according to local conditions. Assessing whether the exceedance means a risk of impact to the Water Quality Objective requires site-specific investigation, using decision trees provided in the Australian & New Zealand Guidelines for Fresh and Marine Water Quality. If the trigger values are not exceeded, a very low risk of environmental damage can be assumed.

3.2.3.1 ENVIRONMENTAL VALUES

The identified environmental values for the Parkes SAP and immediate downstream catchments are:

- aquatic ecosystems
- visual amenity
- secondary contact recreation
- livestock water supply
- irrigation water supply
- homestead water supply; and
- aquatic foods (cooked).

3.2.3.2 WATER QUALITY OBJECTIVES

The Parkes SAP is located in the Lachlan River catchment and as such this assessment adopts the water quality objectives and trigger values for upland rivers for this catchment from the NSW Water Quality and River Flow Objectives. Table 3.1 lists the environmental values and their associated water quality objectives and trigger values for the SAP.

Table 3.1 Parkes SAP environmental values, water quality objectives and trigger values and criteria

WATER QUALITY OBJECTIVE	INDICATOR	TRIGGER VALUE OR CRITERIA
Aquatic ecosystems		
Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	Total phosphorus	20 µg/L
	Total nitrogen	250 µg/L
	Chlorophyll-a	not applicable
	Turbidity	2–25 NTU
	Salinity (electrical conductivity)	30–350 µS/cm
	Dissolved oxygen	90–110%
	pH	6.5–7.5

WATER QUALITY OBJECTIVE	INDICATOR	TRIGGER VALUE OR CRITERIA
Visual amenity		
Aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae and sewage fungus.
Secondary contact recreation		
Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed	Faecal coliforms	Median bacterial content in fresh and marine waters of <1000 faecal coliforms per 100 mL, with 4 out of 5 samples < 4000/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month).
	Enterococci	Median bacterial content in fresh and marine waters of <230 enterococci per 100 mL (maximum number in any one sample: 450–700 organisms/100 mL).
	Algae & blue-green algae	<15,000 cells/mL
	Nuisance organisms	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed values in tables 5.2.3 and 5.2.4 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC 2000).
	Visual clarity and colour	Use visual amenity guidelines.
	Surface films	Use visual amenity guidelines.
Livestock water supply		
Protecting water quality to maximise the production of healthy livestock	Algae & blue-green algae	An increasing risk to livestock health is likely when cell counts of microcystins exceed 11 500 cells/mL and/or concentrations of microcystins exceed 2.3 µg/L expressed as microcystin-LR toxicity equivalents.

WATER QUALITY OBJECTIVE	INDICATOR	TRIGGER VALUE OR CRITERIA
	Salinity (electrical conductivity)	Recommended concentrations of total dissolved solids in drinking water for livestock are given in table 4.3.1 (ANZECC 2000 Guidelines).
	Thermotolerant coliforms (faecal coliforms)	Drinking water for livestock should contain less than 100 thermotolerant coliforms per 100 mL (median value).
	Chemical contaminants	Refer to Table 4.3.2 (ANZECC 2000 Guidelines) for heavy metals and metalloids in livestock drinking water. Refer to Australian Drinking Water Guidelines (NHMRC and NRMMC 2004) for information regarding pesticides and other organic contaminants, using criteria for raw drinking water.
Irrigation water supply		
Protecting the quality of waters applied to crops and pasture	Algae & blue-green algae	Should not be visible. No more than low algal levels are desired to protect irrigation equipment.
	Salinity (electrical conductivity)	To assess the salinity and sodicity of water for irrigation use, a number of interactive factors must be considered including irrigation water quality, soil properties, plant salt tolerance, climate, landscape and water and soil management. For more information, refer to Chapter 4.2.4 of ANZECC 2000 Guidelines.
	Thermotolerant coliforms (faecal coliforms)	Trigger values for thermotolerant coliforms in irrigation water used for food and non-food crops are provided in table 4.2.2 of the ANZECC Guidelines
	Heavy metals and metalloids	Long term trigger values (LTV) and short-term trigger values (STV) for heavy metals and metalloids in irrigation water are presented in table 4.2.10 of the ANZECC 2000 Guidelines.
Homestead water supply		
Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing	Blue-green algae	Recommend twice weekly inspections during danger period for storages with history of algal blooms. No guideline values are set for cyanobacteria in drinking water. In water storages, counts of <1000 algal cells/mL are of no concern. >500 algal cells/mL – increase monitoring. >2000 algal cells/mL – immediate action indicated; seek expert advice. >6500 algal cells/mL – seek advice from health authority.
	Turbidity	5 NTU; <1 NTU desirable for effective disinfection; >1 NTU may shield some micro-organisms from disinfection. (see supporting information).

WATER QUALITY OBJECTIVE	INDICATOR	TRIGGER VALUE OR CRITERIA
	Total dissolved solids	<500 mg/L is regarded as good quality drinking water based on taste. 500–1000 mg/L is acceptable based on taste. >1000 mg/L may be associated with excessive scaling, corrosion and unsatisfactory taste.
	Faecal coliforms	0 faecal coliforms per 100 mL (0/100 mL). If micro-organisms are detected in water, advice should be sought from the relevant health authority. See also the Guidelines for Microbiological Quality in relation to Monitoring, Monitoring Frequency and Assessing Performance in the Australian Drinking Water Guidelines (NHMRC & ARMCANZ 2004).
	pH	6.5–8.5 (see supporting information)
	Chemical contaminants	See Guidelines for Inorganic Chemicals in the Australian Drinking Water Guidelines (NHMRC & NRMMC 2004).
Aquatic foods (cooked)		
Refers to protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.	Algae & blue-green algae	No guideline is directly applicable, but toxins present in blue-green algae may accumulate in other aquatic organisms.
	Faecal coliforms	Guideline in water for shellfish: The median faecal coliform concentration should not exceed 14 MPN/100 mL; with no more than 10% of the samples exceeding 43 MPN/100 mL Standard in edible tissue: Fish destined for human consumption should not exceed a limit of 2.3 MPN E Coli /g of flesh with a standard plate count of 100,000 organisms /g.
	Toxicants (as applied to aquaculture activities)	Copper: less than 5 µgm/L. Mercury: less than 1 µgm/L. Zinc: less than 5 µgm/L. Organochlorines: Chlordane: less than 0.004 µgm/L (saltwater production) PCB's: less than 2 µgm/L.
	Physico-chemical indicators (as applied to aquaculture activities)	Suspended solids: less than 40 micrograms per litre (freshwater). Temperature: less than 2 degrees Celsius change over one hour.

3.2.4 PARKES URBAN STORMWATER MANAGEMENT PLAN 2001

The Parkes Urban Stormwater Management Plan (Parkes Shire Council 2001) was developed to improve the health and quality of the Parkes urban waterways and the receiving waterway of Goobang Creek. The Plan identifies catchment (environmental) values for the waterways in the Parkes area. The Plan does not provide reduction criteria for water quality pollutants and instead states that quantitative objectives for development in Parkes will need to be set after further investigation. Table 3.2 shows the catchment (environmental) values and priorities identified for Goobang Creek in the Parkes Urban Stormwater Management Plan.

Table 3.2 Goobang Creek environmental value priorities (Parkes Urban Stormwater Management Plan)

ENVIRONMENTAL VALUES	PRIORITY
Aquatic ecosystem Secondary recreation Water birds Riparian Vegetation	High
Visual amenity Stream flow	Medium
Consumption of fish and yabbies	Low

The Plan identifies also identifies ecological, social and economic long and short-term objectives for the high priority environmental values. Table 3.3 contains the long and short-term objectives for each environmental value that are relevant to this assessment.

Table 3.3 Long and short term objectives for environmental values in the Parkes area (Parkes Urban Stormwater Management Plan 2001)

ENVIRONMENTAL VALUES	LONG TERM OBJECTIVES	SHORT TERM OBJECTIVES
Aquatic ecosystem Riparian vegetation Water birds Weed removal	Water quality meets the requirements for the protection of aquatic ecosystems (ANZECC 1992). The effectiveness of the Stormwater Management Plan in achieving the objectives should be monitored and necessary improvements identified and implemented.	Control of impacts from new and existing development in the catchment on water quality and flow volumes through consistent approaches to development approvals, regulation and education.
Visual amenity Stream flow	Improve water quality so that it meets the requirements for secondary contact recreation in the waterways of Parkes (ANZECC 1992). Maintain and enhance the ecological, visual and recreational amenities along the natural waterways. Minimise the risk of property damage from stormwater and groundwater.	Optimise opportunities for multiple use of the stormwater system. Design stormwater system to protect public health and safety. Reduce litter in waterways is to be through education and maximise capture efficiency in high litter areas.

ENVIRONMENTAL VALUES	LONG TERM OBJECTIVES	SHORT TERM OBJECTIVES
Tourism, recreation	To identify and facilitate opportunities for the sustainable development and use of resources. To ensure that the fisheries of Goobang Creek and other tributaries are protected.	Integrated approaches to stormwater management promoted to reduce resource duplication. Impacts of stormwater on habitat minimised through improved treatment of stormwater. Consistent and cost-effective stormwater management strategies developed and implemented. Multiple use of stormwater system optimised.

3.2.5 HEALTHY WATERWAY OUTCOMES IN STRATEGIC LAND USE PLANNING DECISIONS

The Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions document (NSW EPA 2017) provides a framework for decision-makers, such as councils and environmental regulators, to help manage the impact of land-use activities on the health of waterways in NSW. The Framework brings together existing principles and guidelines recommended in the NWQMS, which the federal and all state and territory governments have adopted for managing water quality.

3.2.6 MANAGING URBAN STORMWATER – SOILS AND CONSTRUCTION

The Managing Urban Stormwater – Soils and Construction series of handbooks (OEH 2004) are an element of the NSW Government's urban stormwater program specifically applicable to the construction phase of developments. These are aimed at providing guidance for managing soils in a manner that protects the health, ecology and amenity of urban streams, rivers estuaries and beaches through better management of stormwater quality.

The handbooks were produced to provide guidelines, principles, and recommended minimum design standards for good management practice in erosion and sediment control during construction projects.

3.2.7 PARKES SHIRE COUNCIL PLANNING

3.2.7.1 PARKES SHIRE COUNCIL DEVELOPMENT CONTROL PLAN 2013

The Parkes Shire Development Control Plan (DCP) 2013 (Parkes Shire Council 2013) identifies the following controls for all multi-lot developments, industrial and residential developments:

- Stormwater shall be conveyed to Council's stormwater management system where possible or otherwise to legal point of discharge
- The stormwater system design is to optimise the interception, retention and removal of water-borne pollutants using appropriate criteria prior to their discharge to receiving waters. The stormwater system design should minimise the environmental impact of urban run-off on other aspects of the natural environment (creeks and vegetation) by employing techniques which are appropriate and effective in reducing run-off and pollution.
- Drainage from development site is not in excess of drainage from the site during its pre-development state.
- Stormwater design and works are to be undertaken in accordance with Council's adopted Engineering Technical Specification policies.

For residential development, the following control is also applicable:

- Roof water is to be collected and stored onsite in suitable rainwater tanks.

The Parkes National Logistics Hub is located within the Parkes SAP and the DCP outlines a number of additional water quality and stormwater controls for this area as follows:

ADDITIONAL STORMWATER MANAGEMENT APPLICABLE TO THE 'PARKES NATIONAL LOGISTICS HUB' (ZONED SP1 SPECIAL ACTIVITIES)

A stormwater management plan must be submitted with a development application and is to address the following requirements:

- A minor drainage system collecting runoff from roads and hard stand areas must be provided. This would include a pipe drainage system designed for a 1 in 20 year storm event.
- Overland flow paths to accommodate flows in excess of the 1 in 20-year storm event must be provided.
- Retarding basins to limit post-development flows to levels no greater than those for existing development must be provided.
- Trunk drainage channels designed as wide shallow drainage channels located in drainage reserves must be provided. The trunk drainage channels should incorporate a lined low flow section or low flow pipe.
- Water quality devices will be required to ensure that water leaving a site is not contaminated by pollutants. This may include such devices as gross pollutant traps, sediment arrestors, grease and oil arrestors, and devices to remove any accumulated pollutants from stormwater before it leaves a site.
- Management of water cycle and urban salinity. This may include recycling of water onsite for watering landscape areas, collecting runoff from hardstand areas, avoiding use of soakage pits or porous pavements to dispose of stormwater, lining of permanent water storage areas and establishment of deep-rooted vegetation stands to increase evapotranspiration rates.

3.2.7.2 PARKES STORMWATER DRAINAGE DESIGN GUIDELINES (2010)

The Parkes Stormwater Drainage Design Guidelines (Parkes Shire Council 2010) provide details of requirements for stormwater management aspects of development applications and guidelines for the analysis and detailed design of stormwater management systems and drainage infrastructure. The guidelines provide more detail to developers and designers in flooding, drainage and stormwater quality management and underpin the overarching planning documents described in the previous sections.

4 FLOODING ASSESSMENT

4.1 PREVIOUS ASSESSMENTS

The following previous assessments of flooding of the SAP and surrounding area have been undertaken:

- Inland Rail Parkes to Narromine (P2N): Flood Study Report (Inland Rail Design Joint Venture 2018) – Flood study summarising the flood behaviour between Parkes and Narromine across the Macquarie, Bogan and Lachlan River floodplains including an impact assessment of the 98km brownfield rail upgrade. This study and its hydrological and hydraulic models were used as the basis for the flooding assessment for the Parkes SAP, in particular those modelled areas within the Lachlan River floodplain area.
- Lachlan Floodplain Atlas (OEH 1978) – Refer to Figure 4.1 below for key watercourses in the local area identified by this study.

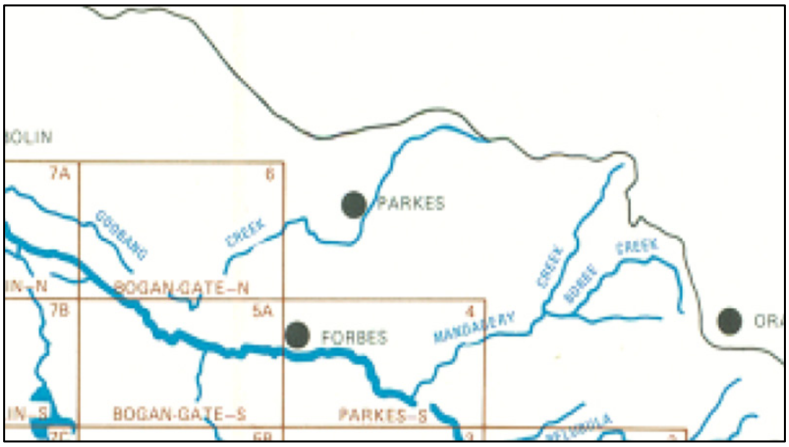

Figure 4.1 Extract from Lachlan River Floodplain Atlas (OEH 1978)

- Lachlan Valley – Flood Plain Management Studies Report (OEH 1983) – Refer to Figure 4.2 below for floodplain extents identified by this study.

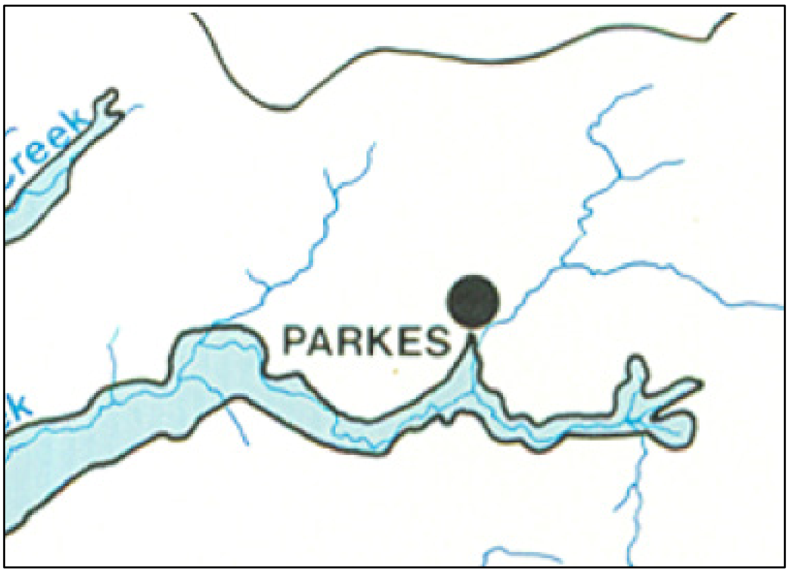

Figure 4.2 Extract from Lachlan Valley – Flood Plain Management Studies Report (OEH 1983)

4.2 PREVIOUS HYDROLOGICAL AND HYDRAULIC MODELS

The methodology for this study broadly involved extension of the 'LAC01' flood model developed for the P2N project further to the west and north of Parkes to cover the area within the Parkes SAP boundary and the receiving catchments downstream of the SAP. The flood model consists of two sub-models:

- A hydrological model that simulates the runoff response to rainfall within the study area sub-catchments. This model was developed using the RAFTS hydrological modelling module within the DRAINS software program (hereafter referred to as the 'RAFTS model'). The RAFTS model computes the runoff hydrographs for each sub-catchment which are provided as inputs to the hydraulic model.
- A hydraulic model that simulates the routing of the runoff across the terrain within the study area, including conveyance of flow within channels and overland flow paths and storage of ponded water where flow is obstructed by features in the terrain. This model was developed using the TUFLOW HPC (Heavily Parallelised Compute) software program (hereafter referred to as the 'TUFLOW model'). The TUFLOW model computes parameters that are used to map the flood behaviour, such as extents, depths, velocities, duration and hazard.

4.3 TOPOGRAPHIC DATA AND DIGITAL ELEVATION MODEL

Topographic data is a fundamental input to the flood model and is used to:

- delineate sub-catchments for the RAFTS model; and
- define the terrain data within the TUFLOW model grid.

The Parkes SAP flood models were based on the following topographic datasets:

- 2019 Parkes Town 1m Filtered Digital Terrain Model (DTM) provided for the project by the Department of Planning, Industry and Environment (DPIE).
- 2015 Light Detection and Ranging (LiDAR) survey at 0.5 m resolution covering approximately a 10 km wide strip along the rail corridor. This data was sourced from the P2N Inland Rail Project.
- 2017 LiDAR survey at 0.01 m resolution covering approximately a 100 m wide strip along the rail corridor. This data was sourced from the P2N Inland Rail Project.
- Rail corridor ground survey – detailed ground survey of levels and features within the rail corridor of the P2N Project. This data was sourced from the P2N Inland Rail Project.
- 2010 Shuttle Radar Topography Mission (SRTM) data at 30 m resolution. This is a coarse dataset only used to delineate catchments outside areas covered by the more detailed and accurate LiDAR data. This LiDAR was sourced from the Australian Government's Elevation and Depth Foundation Spatial Data service (ELVIS).

The Digital Elevation Model (DEM) used as the basis for the Parkes SAP flood models is a combination of the above datasets. The complete dataset for the 2019 Parkes Town 1m Filtered DTM is used and covers the entire SAP, with the other datasets combined in order of accuracy to cover the areas beyond the extent of the 2019 data.

4.4 HYDROLOGICAL MODELLING METHODOLOGY

4.4.1 OVERVIEW

The RAFTS hydrological model is used to simulate runoff generation and flow routing through the sub-catchments upstream, within and downstream of the Parkes SAP boundary. The RAFTS model provides critical runoff hydrographs for input into the hydraulic model of the study area.

An overview of the hydrological modelling process is as follows:

- Use the flood model DEM described in Section 4.3 to delineate the sub-catchments within and around the Parkes SAP boundary.
- Use the sub-catchment delineations and aerial photos to define the hydrological sub-catchment nodes in the RAFTS model.
- Calibrate the RAFTS model to available rainfall and streamflow gauge data for a number of historical flood events.
- Use the calibrated RAFTS model to estimate design flows for a range of events at the area of interest and compare the flow estimates to those produced by the Regional Flood Frequency Estimation (RFFE) method. The RFFE method is a statistical method of flow estimation based on the national streamflow gauge network.
- Vary the RAFTS model parameters within the recommended ranges as required to gain reasonable agreement with the RFFE flow estimates. When reasonable agreement is achieved, the RAFTS model can be considered validated against the RFFE.

The details of the process are described in the following sections.

4.4.2 MODEL CONSTRUCTION

The hydrological model was constructed in the DRAINS software program using the RAFTS storage routing methodology and the kinematic wave method. The sub-catchments were delineated using the model DEM. The sub-catchment breakdown for the local areas within the Parkes SAP and along Ridley's Creek is shown below in Figure 4.3. A more detailed hydrological model layout map is provided in Figure A2 in Appendix A.

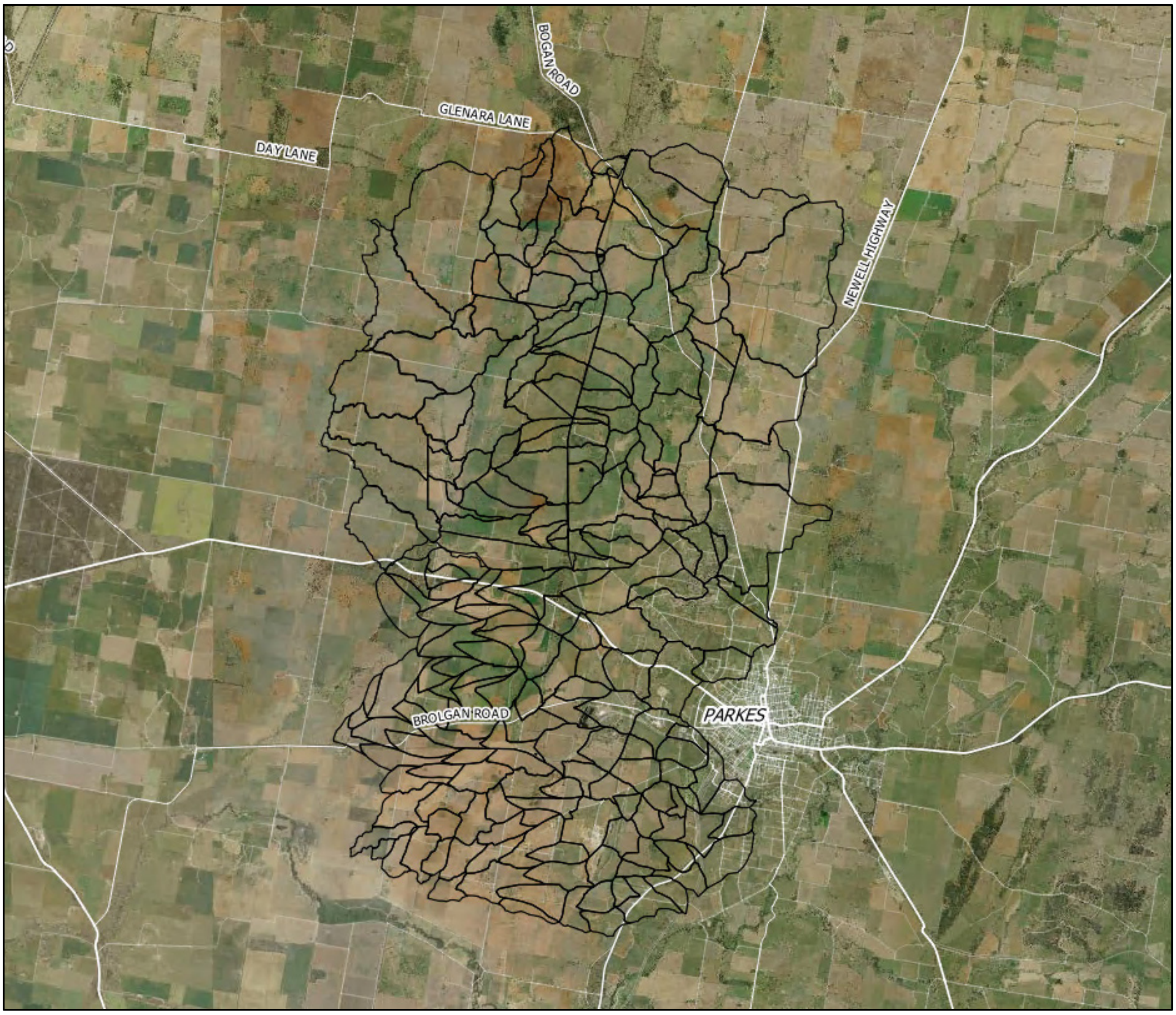

Figure 4.3 RAFTS model sub-catchments for local area flooding

It was also necessary to model the Goobang Creek catchment to define flood flows and levels in this main creek system that extends south and west of the SAP. The modelled catchment area for Goobang Creek is shown below in Figure 4.4.

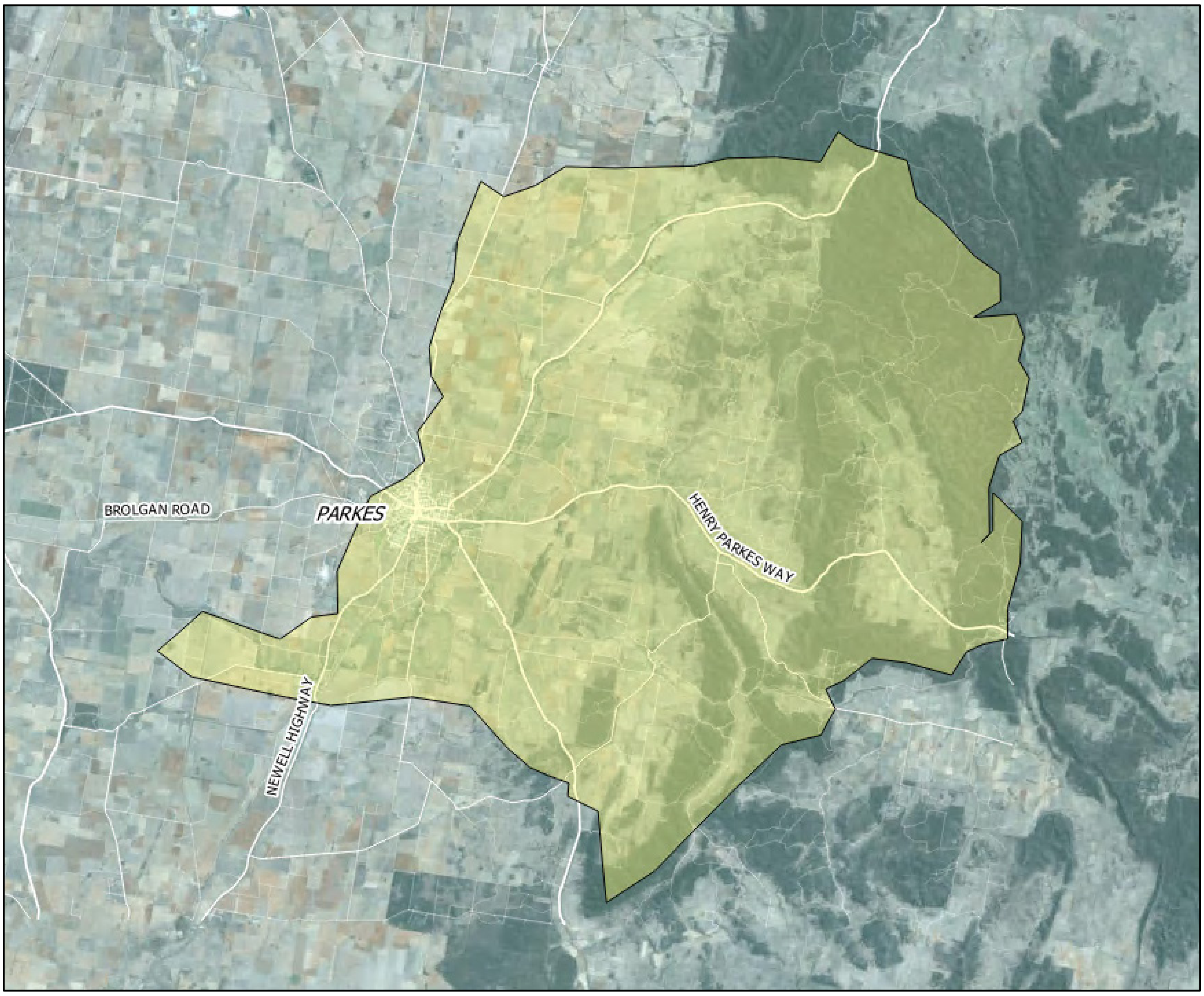

Figure 4.4 Extent of Goobang Creek catchment modelled area

4.4.3 MODEL CALIBRATION

The hydrological model calibration methodology involved the following steps:

- review flow records to identify potential previous events for calibration
- review rainfall records to identify completeness and reliability of rainfall data relating to above events
- confirm calibration events based on review of available rainfall data and determine most reliable gauges to define calibration rainfall dataset and any adjustment factors required to gauges used to fill data gaps; and
- run the models with the calibration rainfall datasets and vary the following RAFTS hydrological model parameters until a reasonable fit to the observed flow hydrographs is obtained:
  - Storage Coefficient Multiplication Factor (BX). BX is used to modify the calculated storage time delay coefficient (B) and uniformly modifies all sub-catchment Storage Time Delay Coefficient values determined from the default equation. The default value for BX is 1.0
  - Initial Loss (IL). IL is the initial rainfall lost at the start of an event to represent initial catchment wetting when no runoff is produced. IL varies by soil type and is specified in the range of 5 to 35 mm
  - Continuing Loss (CL). CL is the continuing loss rate that occurs during an event due to infiltration once the catchment is saturated. CL also varies by soil type and is specified in the range of 0.5 to 25 mm/hour.

4.4.3.1 CALIBRATION SITES

The sub-catchments within and around the Parkes SAP area are categorised as ‘local’ catchments, which are defined as small upland catchments in which the flood behaviour is governed by runoff within the catchment rather than by flooding from a larger regional system adjacent or upstream of the catchment. The Goobang Creek system is the regionally dominant floodplain system in the locality, however, it does not affect flooding processes in the local catchments around the SAP area.

It is desirable to calibrate hydrological models to a stream gauge within or close to the area of interest. No streamflow data exists within or close to the SAP area. The nearest steamflow gauge is on Goobang Creek east of Parkes, but this is not a suitable gauge for calibration of the Parkes SAP model as it is located on a large catchment containing a major storage feature (Lake Endeavour Dam) which responds differently to rainfall than the local catchments around the SAP area.

The nearest local catchment streamflow gauge is located on Gunningbland Creek at Milpose, approximately 15 km west of the SAP area (see gauge location 412138 on Figure 4.5). This gauge was selected as the most suitable for calibration of the RAFTS model.

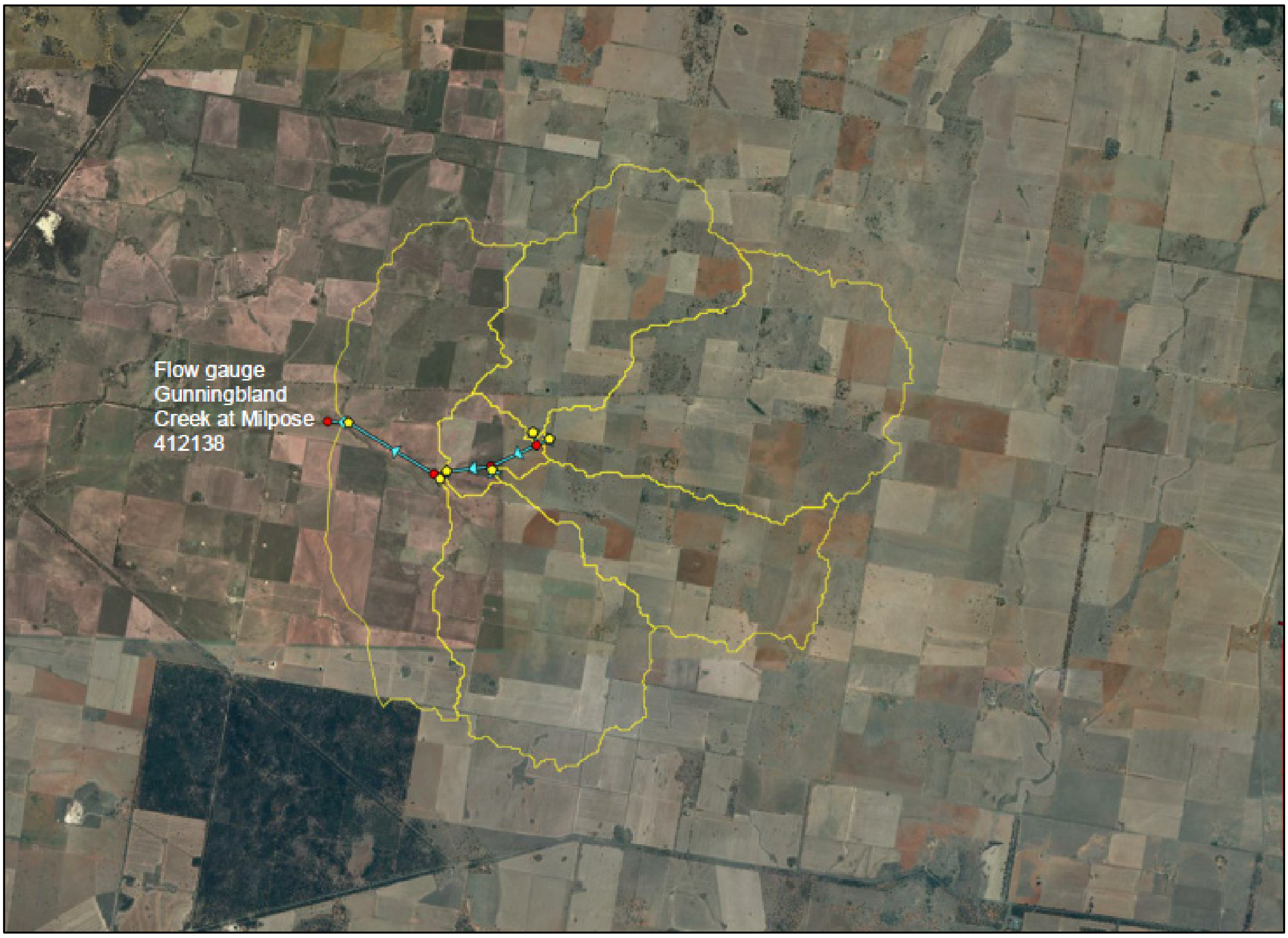

Figure 4.5 Extent of calibration hydrological model

4.4.3.2 STREAMFLOW AND RAINFALL DATA

The record for gauge 412138 was reviewed and the following features of the data were noted:

- the flow and water level record commenced in 1991 and closed in 2002 (11 year record)
- daily flow and water level data are not complete
- rainfall data was collected between 1992 and 2002 (10 year record); and
- from a review of the data, the following high flow events were notable:
  - November 1994 (record date is 01/12/1994): maximum monthly discharge was 1,200 ML and maximum monthly water level was 0.68 m. No hourly flow data is available for the event (flow data appears to be daily total/24 hr). Hourly water level data available, with a peak of 0.672 m recorded at 4:00 pm 29/11/1994
  - August 1998 (record date is 01/09/1998): maximum monthly discharge was 193 ML and maximum monthly water level was 0.4 m. Hourly water level data indicates that it was a wet period from beginning of August to end of September. No hourly flow data available. Data was found to poorly match recorded rainfall.

From the data review, the November 1994 event was the only recorded event deemed suitable for calibration. For this event, sub-daily rainfall data recorded at rainfall station 65100 approximately 2 km north of Parkes was used, with an adjustment factor applied based on daily total rainfall recorded at station 50004 located close to the steamflow gauge.

4.4.3.3 CALIBRATION RESULTS

The results of the November 1994 event RAFTS model calibration are shown in Figure 4.6. The model produced a good fit to the recorded peak flow but estimated significantly more flow volume than was recorded at the gauge. This result was based on the following RAFTS model parameter set:

- Storage coefficient multiplication factor (BX) = 0.5
- Initial Loss (IL) = 35 mm; and
- Continuing Loss (CL) = 1 mm/hour.

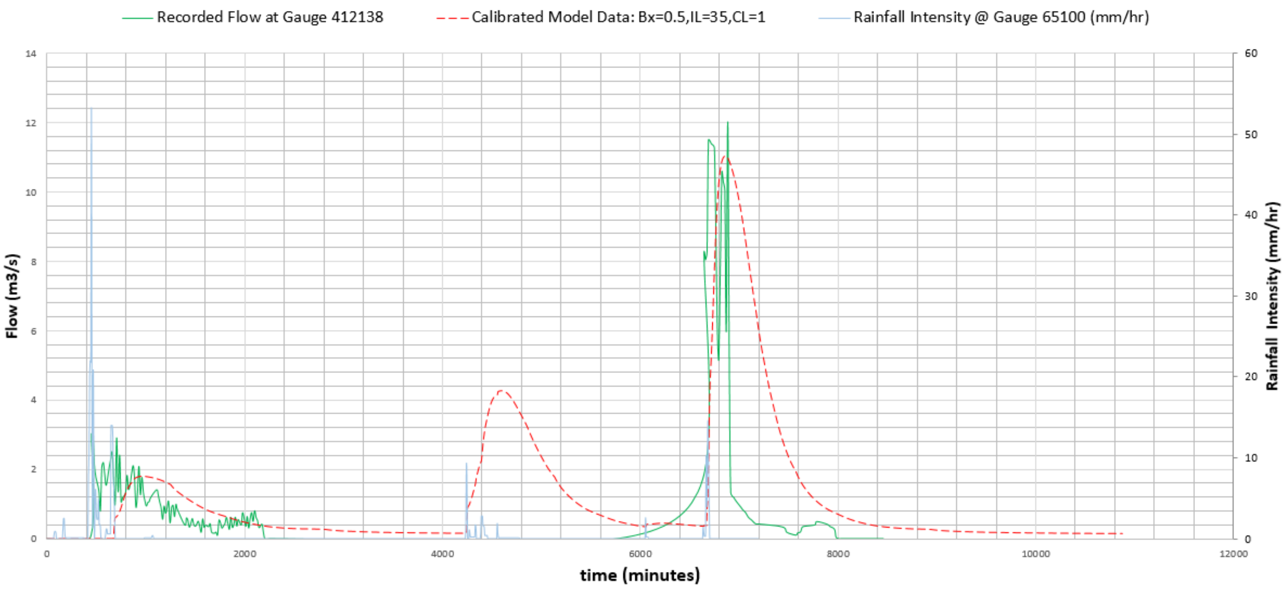

Figure 4.6 Calibration event result for November 1994 event at Milpose 412138 – to fit peak flow

A further test was attempted to get a better fit to the volume recorded at the gauge. This test did not match the peak flow recorded. This result is shown in Figure 4.7 and was based on the following parameter set:

- BX = 0.5
- IL = 34 mm; and
- CL = 3.4 mm/hour.

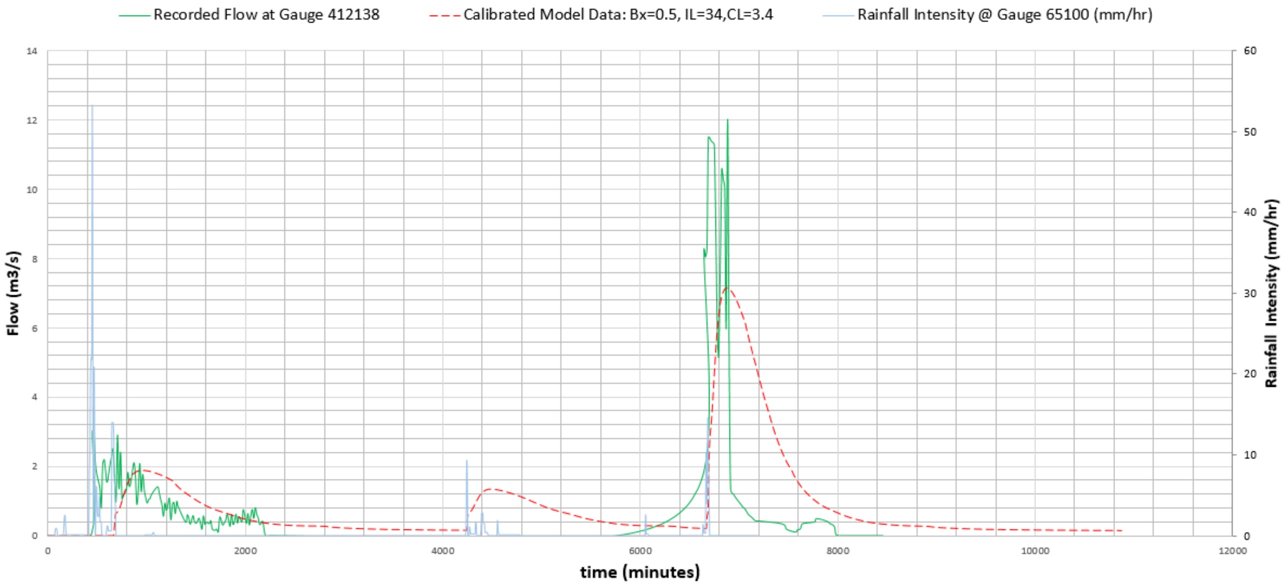

Figure 4.7 Calibration event result for November 1994 event at Milpose 412138 – to fit flow volume

The ARR 2016 recommended values for IL and CL are compared to the values used in the calibration tests in Table 4.1.

Table 4.1 Comparison of ARR 2016 recommended loss values with those adopted for RAFTS model calibration

LOSS PARAMETER	GUNNINGBLAND CREEK AT MILPOSE (GAUGE 412138)		
	ARR 2016	Calibration parameters to fit 1994 recorded peak flow	Calibration parameters to fit 1994 recorded flow volume
IL (mm)	25	35	34
CL (mm/hour)	1.1	1	3.4

Since the CL value used to get the best fit to the recorded peak flow agrees better with the ARR 2016 recommended value and the preference is to be conservative in design flow estimation, the CL value that obtained the best fit to the peak flow was adopted. The IL values required to fit the observed peak/volume did not agree with the ARR 2016 value, however, this can be attributed to the lack of pre-burst loss factored into the ARR 2016 value. The RAFTS model parameters initially chosen based on calibration and adjusted to account for pre-burst losses were as follows:

- BX = 0.5
- IL = 25 mm; and
- CL = 1 mm/hour.

These values were then reviewed against recent OEH and Parkes Shire Council recommendations on hydrological model parameters.

4.4.4 REVIEW OF HYDROLOGICAL MODEL PARAMETERS AGAINST OEH AND PARKES SHIRE COUNCIL ADVICE

The hydrological model parameters were reviewed against the recommendations of the NSW specific Floodplain Risk Management Guide (OEH 2019) and advice from Parkes Shire Council from other recent flood studies. The review found the following:

- The closest gauged catchment documented within the Floodplain Risk Management Guide (OEH 2019) was catchment G10 which reported a good fit quality for its data. The G10 catchment is located 45km to the north east of the Parkes SAP, and had a calibrated IL of 24 mm and a CL of 1.9 mm/h.
- Comments from Parkes Shire Council on the preliminary Parkes SAP flood modelling methodology noted that *"The value of 25mm for initial loss is more consistent with Parkes Shire Council RAFTS models for the Goobang System to the North East of the Parkes Urban area."*.
- Comments from OEH on the preliminary Parkes SAP flood modelling methodology recommended to use a 0.4 factor on continuing losses to manage overestimation of ARR 2016 values.

As a result of the review and above comments, the adopted RAFTS model loss parameters for the Parkes SAP flood model are as follows:

- IL = 25 mm; and
- CL = 0.4 mm/hour.

4.4.5 DESIGN MODEL DATA INPUTS AND PARAMETERS

4.4.5.1 ADOPTED RAFTS MODEL PARAMETERS

Design values for initial and continuing losses and the storage coefficient multiplication factor were determined from a review of the parameters used in calibration against those provided by the ARR 2016 datahub and those recommended by the Floodplain Risk Management Guide (OEH 2019), as discussed in Section 4.4.4. The adopted values for the 10% AEP, 1% AEP and the 0.2% AEP storm events were as follows:

- BX = 0.5
- IL = 25 mm; and
- CL = 0.4 mm/hour.

For the PMF event it is assumed that the upstream catchment is completely saturated and no initial loss occurs. The adopted values for the PMF event are as follows:

- BX = 0.5
- IL = 0 mm; and
- CL = 0.4 mm/hour.

4.4.5.2 INTENSITY-FREQUENCY-DURATION DESIGN RAINFALLS

Intensity–Frequency–Duration (IFD) design rainfall depths were specified in accordance with ARR 2016 (Book 2, Chapter 3). Rainfall depths for the 10%, 1% and the 0.2% AEP storm events were generated from the Bureau of Meteorology 2016 IFD dataset.

PMF EVENT RAINFALL

PMF event rainfall was calculated in accordance with the ARR 2016 guidelines and the NSW specific Floodplain Risk Management Guide (OEH 2019). The OEH recommendations suggest using the single storm Generalised Short Duration Method (GSDM) for short duration storms (⩽3 hrs), and using the Generalised Southeast Australia Method (GSAM)

Inland Zone for long duration storm events (⩾24 hrs). The depths for the 6 to 18hr storm durations were interpolated from the envelope of both methods. Refer to Table 4.2 for factors were used for PMF modelling.

Table 4.2 PMF model factors

FACTOR	VALUE
ZONE	GSAM Inland Zone
Catchment Size	210 km^2
Topographical adjustment factor (TAF)	1.06
Epw_autumn	57.87
Epw_annual	72.42
Moisture adjustment factor	0.69
Mean elevation	300
Terrain category (% rough):	5

4.4.5.3 PRE-BURST RAINFALL DEPTHS

Pre-burst rainfall was generated using the median data from the ARR 2016 datahub and transformed into NSW probability neutral adjusted pre-burst values in accordance with the recommendations of the Floodplain Risk Management Guide (OEH 2019). Depths were interpolated between adjacent duration values where necessary.

The ARR 2016 datahub does not provide pre-burst depths for extreme storm events. The 0.2% AEP pre-burst depths were forecast from the generated 1% AEP pre-burst depths based on a log or a power relationship (depending on fit). The PMF flood event is run assuming that there is no initial loss and therefore no pre-burst depth value is applied.

The adopted pre-burst depths are provided in Table 4.3.

Table 4.3 Adopted NSW probability neutral adjusted pre-burst rainfall depth values

STORM DURATION (MINUTES AND HOURS)	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP
60 (1.0)	2.10	0.72	0.59	0.51	0.69	0.77	0.00
90 (1.5)	4.41	1.14	0.91	0.74	0.45	0.22	0.00
120 (2.0)	6.36	1.38	1.19	0.99	0.77	0.62	0.00
180 (3.0)	8.46	1.54	1.39	1.39	0.94	0.70	0.00
270 (4.5)	9.05	1.43	1.40	1.51	3.43	4.93	5.28
360 (6.0)	7.20	1.21	1.34	1.58	6.27	9.78	12.57
540 (9.0)	5.67	1.53	2.13	2.80	7.85	11.72	31.96
720 (12.0)	0.72	1.85	3.00	4.14	9.49	13.61	20.27
1080 (18.0)	0.00	1.17	1.92	2.71	5.21	7.19	11.03
1440 (24.0)	0.00	0.09	0.10	0.25	1.51	2.45	3.40
2160 (36.0)	0.00	0.00	0.00	0.00	0.61	1.01	1.37
2880 (48.0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4.4.5.4 TEMPORAL PATTERNS

Ensemble method temporal patterns for the 10% and the 1% storm events were sourced from the ARR 2016 datahub for both point and areal catchments.

For the 0.2% AEP and the PMF events, a single temporal pattern was generated from the GSAM and the GSDM methods in accordance with the recommendations of the Floodplain Risk Management Guide (OEH 2019).

4.4.5.5 AREAL REDUCTION FACTORS

ARR 2016 (Book 2, Chapter 4) requires that hydrological models adopt Areal Reduction Factors (ARFs) when applying design rainfall depths that are estimated at point locations to entire catchments. ARR 2016 provides a method for estimating the ARF to the point of interest with the factor varying with AEP, storm duration and catchment area. ARR 2016 also states that "*There has been limited research on ARF applicable to catchments that are less than 10 km^2. The recommended procedure is to adopt an ARF of unity for catchments that are less than 1 km^2, with an interpolation to the empirically derived equations for catchments that are between 1 and 10 km^2*".

The application of a unique ARF per catchment/AEP/area combination is not available in the DRAINS software and therefore it was necessary to develop a specific approach to estimating ARF for the range of sub-catchment sizes within the area covered by the RAFTS model. The approach was as follows:

- Catchment area <1 km^2: no ARF applied consistent with ARR 2016 recommendations.
- Catchment area between 1 km^2 and 10 km^2: no ARF applied, based on the following findings:
  - ARR 2016 recommends to calculate the ARF for a 10km^2 catchment and then factor using a second equation based on the catchment area
  - Figure 4.8 below demonstrates the range of ARF for catchments <10 km^2. For more frequent events (higher AEPs), the ARF range trends towards 1. For expected catchment area and critical storm duration combinations (i.e. lower critical duration with smaller area, higher critical duration with larger area) the values trend towards >0.95
  - this suggests that ARF is in range of 0.95 to 1.0 for most catchments <10 km^2
  - given the relatively weak influence of ARF values > 0.95 on flow estimates produced by the model, a conservative approach of using ARF = 1.0 for catchments less than 10 km^2 was considered to be valid.

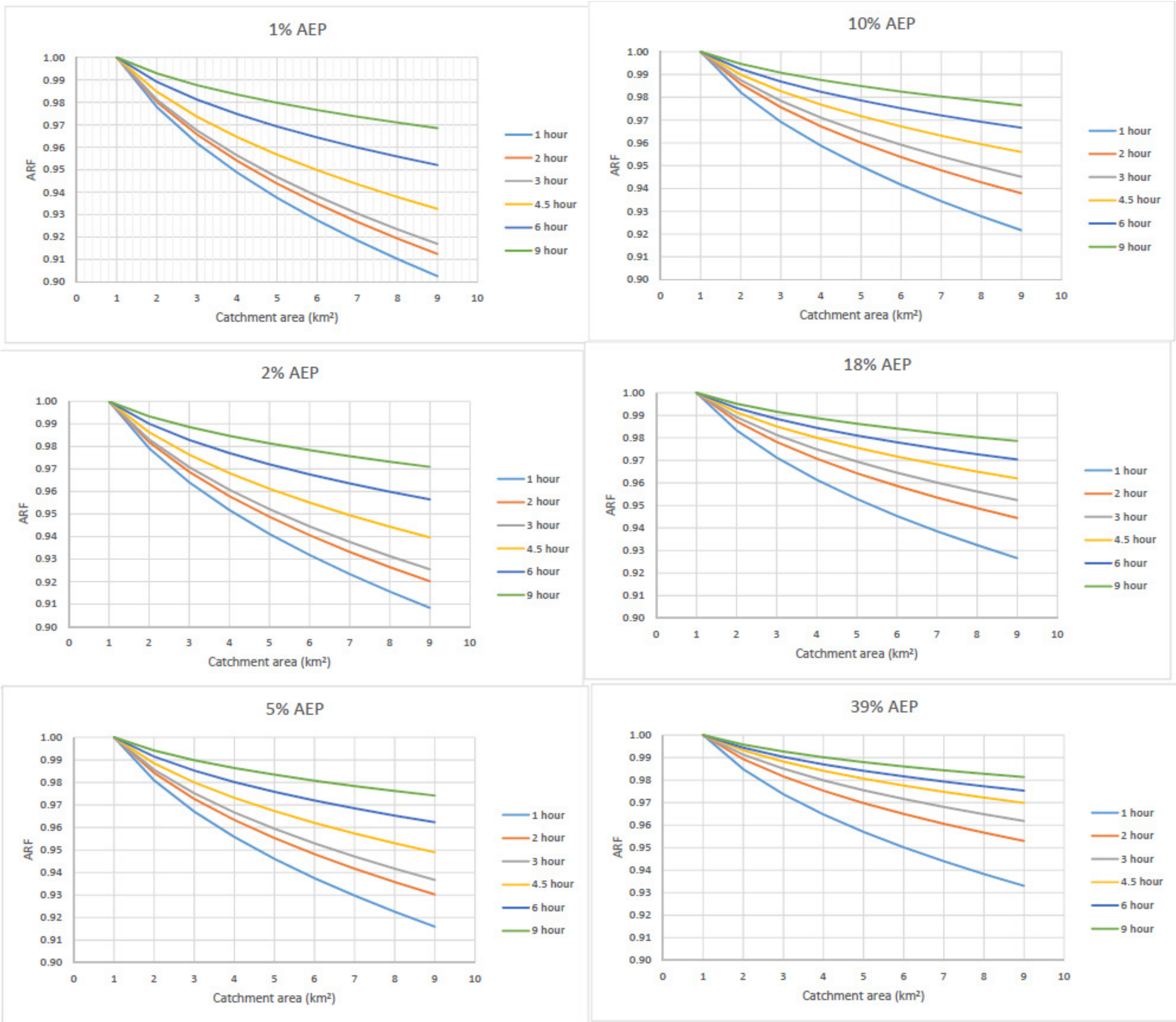

Figure 4.8 ARF range for RAFTS model sub-catchments <10 km²

- Catchments >10 km²: adopt a single ARF per AEP event, based on the maximum value from a subset range of 5 most likely critical durations, in accordance with the process outlined below:
  - estimate an ARF per AEP event
  - estimate the critical duration for the catchment based on the Probabilistic Rational Method time of concentration method factored by 2. This calculation is used to provide a reasonable estimate for the critical duration in advance of running the hydrological model and is similar to the assumptions on critical duration made in the ARR 2016 Revision Project 5 (ARR 2016 Project 5 Regional Flood Methods Stage 3 Report, 2015)
  - estimate the ARF for the estimated critical duration and for the nearest 4 storm event durations (2 longer and 2 shorter, for a total of 5)
  - assume the highest ARF from this sub-set for each AEP. This provides a slightly conservative ARF which is considered reasonable.

The approach resulted in the following range of ARFs which were applied in the RAFTS model:

- Catchments <10 km²: ARF = 1
- Catchments >10 km²: ARF = 0.91 (All AEP's fell within the range of 0.90–0.91).

The ARF was applied to the modelled sub-catchments as follows:

- when assessing local catchments within the Parkes SAP using a point temporal pattern, an ARF value was only applied to catchments north of the Parkes SAP boundary. This provides the local flow component of the assessment
- when assessing the catchment flows from the north using an areal temporal pattern, an ARF was applied to all catchments. This provides the upstream flow component of the catchment.

4.4.6 DESIGN EVENTS

The design events simulated in the RAFTS model are listed in Table 4.4 below.

Table 4.4 Design events simulated in RAFTS model

EVENT	PURPOSE
10% AEP	For validation against RFFE and required by brief
1% AEP	For validation against RFFE and required by brief
0.2% AEP	Required by brief
PMF	Required by brief

The design event modelling was undertaken using the ensemble event method of flow estimation, as detailed within ARR 2016 Book 4, Chapter 3 and shown in overview in Figure 4.9. Each flood event (AEP) was run for a range of standard durations and for an ensemble of 10 temporal patterns within each duration. The median flow of the ensemble is then selected as the design flow for each event.

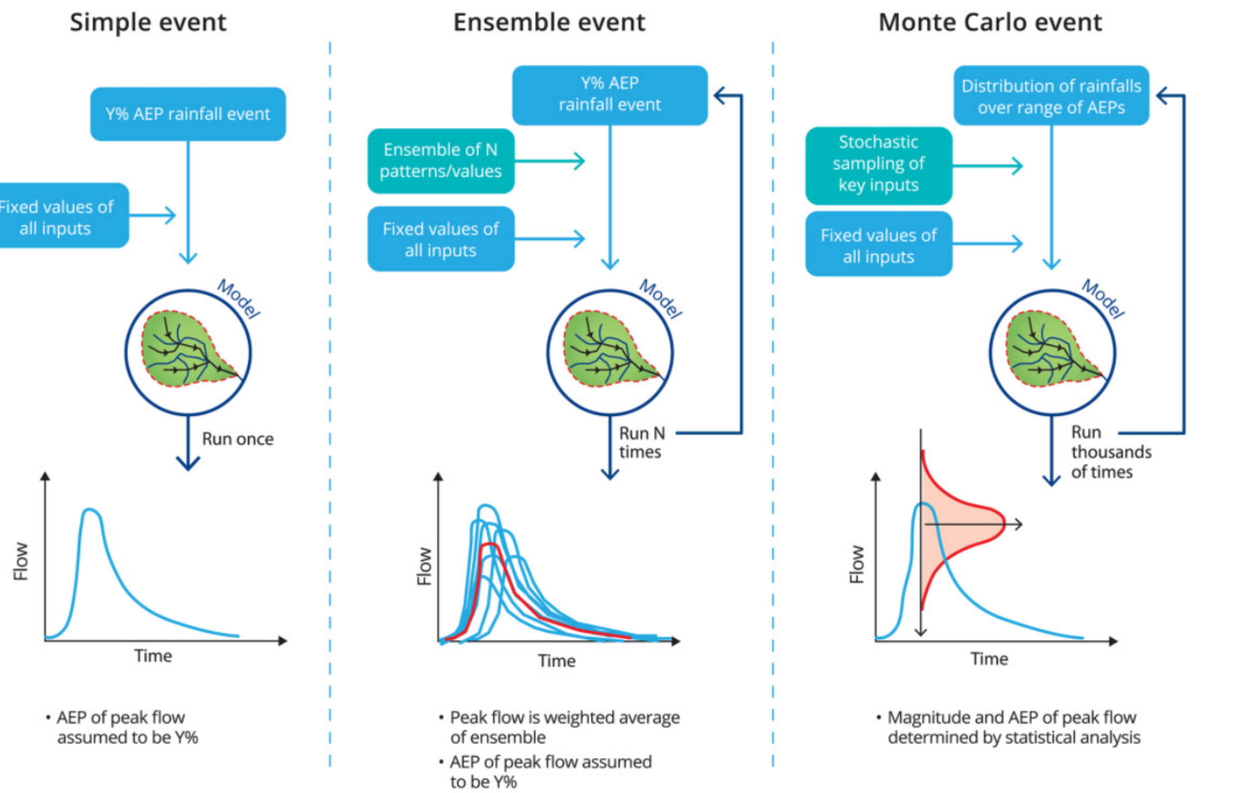

Figure 4.9 ARR 2016 approaches to estimation of peak flow (from ARR 2016 Book 4, Chapter 3)

For the Parkes SAP RAFTS model, the critical storm duration was found to vary between 1 and 12 hours, depending on sub-catchment size and AEP. The critical storm producing highest median flows to the downstream boundary of the SAP was the 12 hour storm.

4.4.7 VALIDATION OF DESIGN MODEL AGAINST RFFE

Table 4.5 presents a comparison of the RAFTS design model estimates of peak flow to those estimated by the RFFE method at the Gunningbland Creek streamflow gauge site for a range of events.

Table 4.5 Comparison of hydrological model peak flow estimates to RFFE for Gunningbland Creek at Milpose (gauge 412138)

EVENT (AEP)	PEAK FLOW ESTIMATES (m^3/s)		VARIANCE (RAFTS/RFFE)
	RAFTS design model	RFFE expected value	
10%	77	70	110%
5%	98	102	96%
2%	145	158	92%
1%	175	212	83%

The estimates were in reasonable agreement, although the variance for the 1% AEP event is significant. However, the streamflow gauges used for the RFFE in this region are located within catchments >100 km^2 which are significantly larger than the local sub-catchments in the Parkes SAP study area, which could account for the variance at the higher event. The comparison against RFFE did not suggest any further investigation of the RAFTS parameters was necessary and the RAFTS design model was considered to be validated by the RFFE comparison.

4.4.8 MASTER PLAN SCENARIO REPRESENTATION IN HYDROLOGICAL MODEL

4.4.8.1 MASTER PLAN SCENARIO

The Master Plan developed for the Parkes SAP is shown in Figure 4.10 and consists of the following land uses:

- freight terminals
- regional enterprise
- intensive livestock agriculture
- energy (Solar)
- resources and recycling
- mixed enterprise
- commercial gateways; and
- green infrastructure.

The change in land use was represented in the hydrological model by increasing the impervious area within each land use zone to reflect the future development and associated increase in hardstand area. This has the effect of a marked increase in the rate and volume of runoff from the developed sub-catchments.

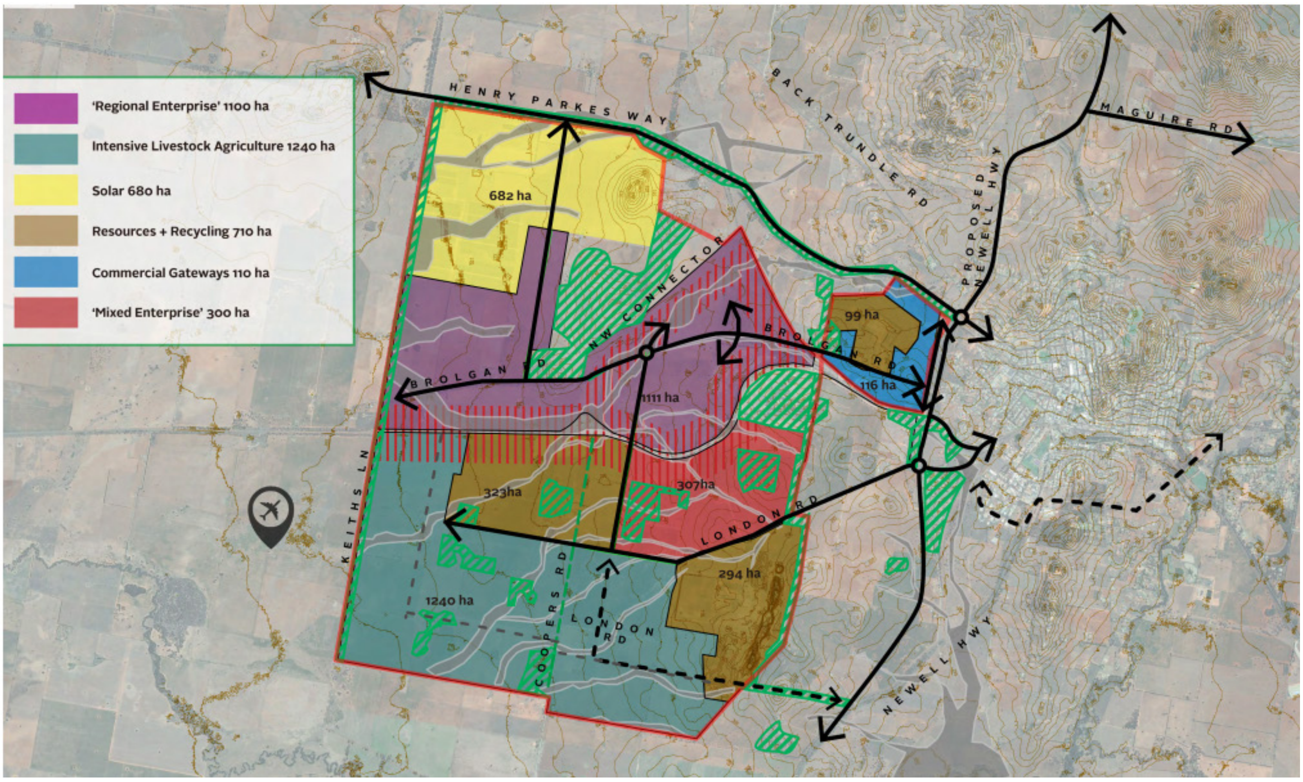

Figure 4.10 Parkes SAP Master Plan

4.4.8.2 HYDROLOGICAL DESIGN CRITERIA

For the Master Plan scenario, increases in runoff due to development need to be managed to meet the requirements of the Parkes Shire Council DCP (refer to Section 3.2.7.1). The flow management strategy for the Parkes SAP was agreed with Parkes Shire Council during the Enquiry by Design Workshop for the project undertaken in May 2019. The agreed strategy is as follows:

- ensure that runoff from the Parkes SAP is not increased above the pre-development rates in accordance with the DCP
- achieve this through the implementation of a two-tier flow detention scheme that involves detaining flood flows up to and including the 10% AEP at the individual lot level, and detaining flows up to and including the 1% AEP at the SAP level; and
- in practice, this would result in numerous 10% AEP detention devices (such as basins or other on-site detention systems) installed at each lot in combination with a series of 1% AEP detention basins installed at strategic locations around the SAP to protect sensitive assets and land uses and to maintain flows at or close to pre-development rates before discharging into the downstream receiving environment.

4.4.8.3 HYDROLOGICAL MODEL REPRESENTATION

Table 4.6 provides the impervious areas for the key Master Plan land uses that were specified in the RAFTS model sub-catchments for the Master Plan scenario.

Table 4.6 Impervious areas specified in the hydrological model for the key Master Plan land uses

LAND USE	IMPERVIOUS AREA
Commercial gateways	60%
Resources and recycling	50%
Intensive livestock agriculture	25%
Regional enterprise	70%
Mixed enterprise	70%
Freight terminals and rail infrastructure	70%
Energy (Solar)	50%

The flow detention strategy was simulated in the hydrological model by trialling and optimising a series of lot level 10% AEP detention systems (grouped by sub-catchment) in combination with the SAP level 1% AEP detention basins. This resulted in the following infrastructure requirements:

- 10% AEP lot level detention required within 14 sub-catchments, with the total number of detention devices to be determined during later stages of design when the number of individual lots is known
- 1% AEP SAP level detention basins required at 15 locations distributed throughout the SAP.

4.5 HYDRAULIC MODELLING METHODOLOGY

4.5.1 MODEL CONSTRUCTION

4.5.1.1 SOFTWARE

The hydraulic model was constructed in the TUFLOW HPC software program using a two-dimensional (2D) fixed grid for modelling the terrain and the one-dimensional (1D) solver used for flow control structures such as bridges and culverts under roads and rail lines.

4.5.1.2 EXTENT AND TOPOGRAPHIC DATA INPUTS

The extent of the TUFLOW model is shown below in Figure 4.11. A more detailed hydraulic model layout map is provided in Figure A3 in Appendix A.

The TUFLOW model extends to encompass all major flow paths in the vicinity of the Parkes SAP including the entirety of Ridleys Creek, and a significant portion of the Goobang Creek system to allow the influence of the regionally significant Goobang Creek system on the Parkes SAP to be assessed. In the extended parts of the model the topographic grid was defined from the model DEM (refer to Section 4.3).

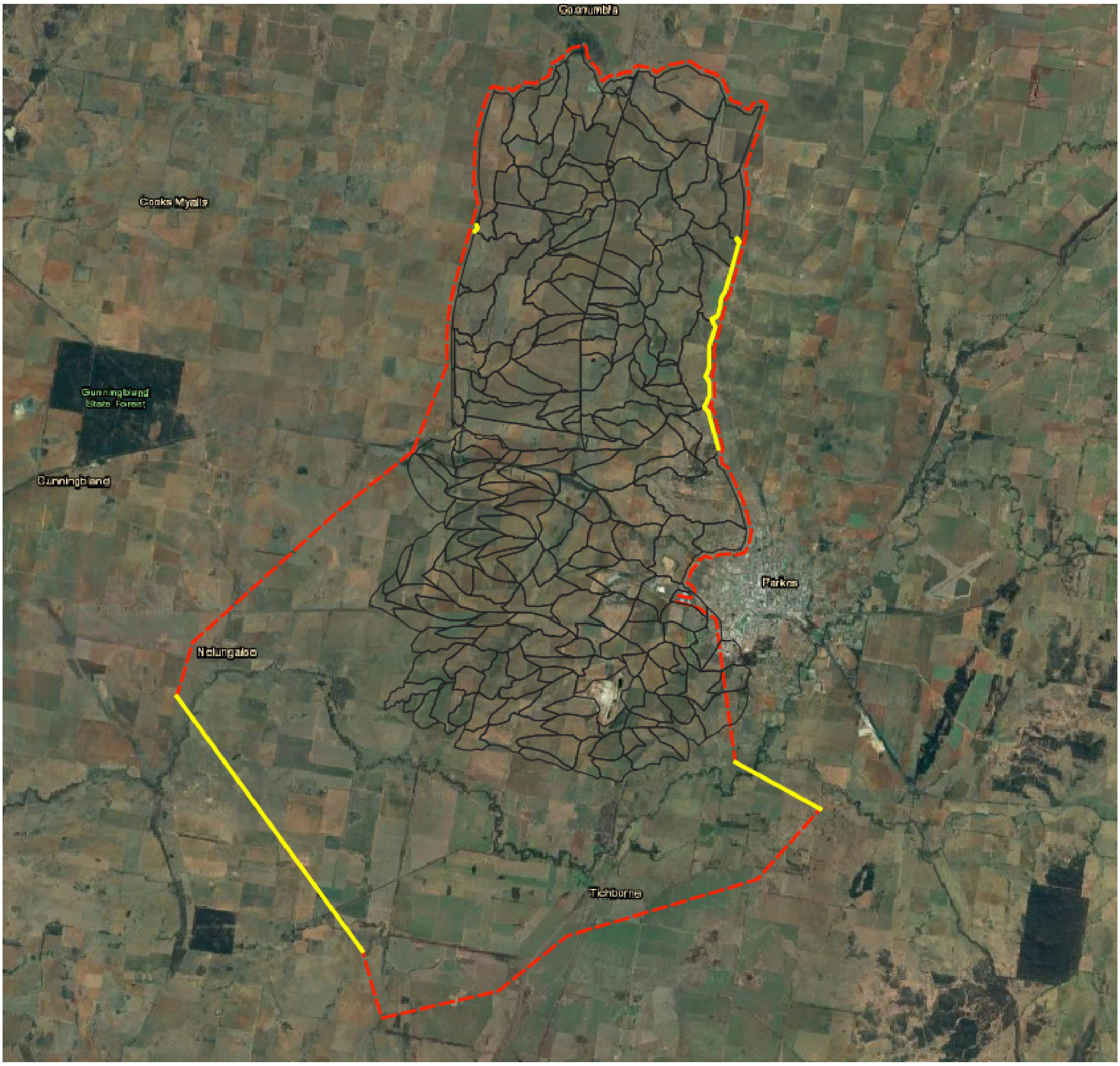

Figure 4.11 TUFLOW model extent

4.5.1.3 REPRESENTATION OF FLOW CONTROL STRUCTURES

Key structures that affect the conveyance or storage of flood flow within a floodplain system include raised embankments (e.g. levees, road/rail embankments), dams and bridges/culverts under embankments. The embankments and dams are represented in the 2D terrain model within TUFLOW and the flow behaviour through and around bridges and culverts is modelled using the 1D solver approach.

Within the modelled area, all rail bridges are small timber bridges that will shortly be replaced by reinforced concrete box culverts as part of the P2N Inland Rail construction works. No other bridges exist within the area of interest (i.e. within or adjacent to the SAP). Bridges over the Goobang Creek exist at the rail line and the Newell Highway south of Parkes but these structures are located well away from the SAP. Numerous culverts under roads and the rail line, including existing structures and those shortly to be constructed as part of the P2N works, are located within and adjacent to the SAP.

Culverts were represented in the TUFLOW model using a 1D network type '*1d_nwk*' input. This provides a 1D representation of a culvert structure conveying flows between two locations within the 2D model grid. 1D/2D connectivity was represented with a '*2d_bc*' layer, defining connection between the culvert network and the 2D grid mesh.

ARR 2016 Book 6, Chapter 6 recommends the specification of a degree of blockage of hydraulic structures to realistically assess the performance of structures as their capacity is decreased due to siltation and debris accumulation during flood events. A blockage assessment is required at each sub-catchment containing hydraulic structures that considers the following:

- debris type and dimensions: whether floating, non-floating, urban or sediment debris present in the source area and its size
- debris availability: the volume of debris available in the source area
- debris mobility: the ease with which available debris can be moved into the stream
- debris transportability: the ease with which the mobilised debris is transported once it enters the stream
- structure interaction: the resulting interaction between the transported debris and the bridge or culvert structure
- random chance: an additional risk factor accounting for unforeseen events.

The assessment procedure was undertaken for all sub-catchments containing culvert structures and resulted in blockage values ranging from 0 to 25%. Given the relatively narrow range of results, a single average blockage factor of 15% was specified at all culvert locations.

4.5.1.4 BOUNDARY CONDITIONS

Inflow hydrographs were imported to the TUFLOW model from the RAFTS model. The hydrographs were applied on a sub-catchment scale using a '*2d_sa*' TUFLOW boundary for local catchment flows and using a '*2d_bc*' flow versus time boundary for concentrated upstream overland flow in rivers and creeks.

The Parkes SAP watershed discharges downstream into the mainstream Goobang Creek catchment. During a peak flood event overtopping the creek banks, floodwater primarily flows south of the main creek channel and has no significant impact on the Parkes SAP. As the flows through Goobang Creek do not directly affect the SAP (but rather only the downstream water level boundary), a simplified constant flow versus time boundary was applied at the inflow point from Goobang Creek. The flow value was determined from based on an RFFE calculation for the 1% and 10% AEP flood flows, and of a simplified RAFTS single catchment for the 0.2% AEP and the PMF flood events at the upstream boundary. This was specified as a continuous inflow from Goobang Creek. This is a conservative approach that maximises main river flooding conditions in the Goobang Creek floodplain to determine any potential influence of Goobang Creek on flood behaviour within the SAP. The values adopted for the design flood events are given in Table 4.7 below.

Table 4.7 Goobang Creek peak flows applied at the boundary of the TUFLOW model

EVENT	GOOBANG CREEK PEAK FLOW (m^3/s)
10% AEP	360
1% AEP	1,100
0.2% AEP	2,631
PMF	13,897

A water level versus flow boundary condition with a slope matching the channel bed was specified at the downstream boundary of the TUFLOW model.

4.5.1.5 FLOODPLAIN ROUGHNESS

Floodplain roughness (specified as the Manning's 'n' value for different land use types) is a key hydraulic model parameter that affects the routing of overland flow as it is conveyed over land.

The Manning's 'n' values used in the TUFLOW model for floodplain areas are consistent with ARR 2016 guidance and were estimated from land use mapping and aerial photography. The values are identified below in Table 4.8.

Table 4.8 TUFLOW model roughness values adopted in floodplain areas

LAND USE	MANNING'S 'N' VALUE
Pasture	0.05
Roads/Rail	0.02
Buildings	3.00
Ponds and other water	0.03
Urbanised areas	0.10
Industrial areas	0.10
Low density urbanised areas	0.08
Heavily vegetated creek	0.08
Maintained grass	0.04

4.5.1.6 GRID SIZE AND TIMESTEP

A 10 m grid size was adopted for the TUFLOW model. The grid size was selected following initial testing of several model grid resolutions (5 m, 10 m and 20 m) to determine the optimum balance between accuracy of representation of floodplain and flow control features and model run time.

The TUFLOW HPC modelling solution uses an adaptive time step solution that allows the solution to vary the timestep and repeat timesteps as required to maintain stability of the numerical analysis.

4.5.2 MODEL CALIBRATION AND VALIDATION

No records of water level or flow exist within the TUFLOW model area that could be used to calibrate the model. However, as part of the P2N project, the original TUFLOW model was validated through the landowner consultation process, which involved each landowner reviewing the baseline flood extent and depth maps to verify that the model predictions matched their observations of flood behaviour during previous events.

As part of this process all of the landowners with land adjoining the rail corridor within the SAP and north of the SAP were consulted. All verified that the flood model predictions accurately represented the typical flood behaviour that has been observed in recent decades. This process is described in the Inland Rail Parkes to Narromine Hydrological Model Calibration Report (Inland Rail Design Joint Venture, 2018).

4.5.3 DESIGN EVENT MODELLING AND DESIGN FLOOD LEVEL SELECTION

The TUFLOW model was run for the design events required by the brief, i.e. the 10%, 1% and 0.2% AEP events and the PMF.

As discussed in Section 4.4, the RAFTS model has used the ensemble method of flow estimation from the ARR 2016 design guidelines. The selected median critical duration storm design flow for each AEP event for each individual sub-catchment was run in the TUFLOW model.

From TUFLOW, the flood level results have been taken as the combined maximum flood level from the selected range of flood events, which is an enveloping procedure that takes the maximum flood level from all of the median critical storm duration results. This method is slightly conservative in some areas but ensures that where flood levels are governed by hydraulic connectivity between sub-catchments (which typically happens in large events where sub-catchments spill from one to another), the peak flood level generated by the dominant sub-catchment is adopted. Further details of this process are documented in the Inland Rail Parkes to Narromine Flood Study Report (Inland Rail Design Joint Venture, 2018).

4.5.4 ASSESSMENT OF FLOOD HAZARD

The TUFLOW model is used to assess flood hazard for the SAP and surrounding area. Flood hazard is the product of flood depth and flood velocity and is used to define safe uses of land. Flood hazard has been assessed in accordance with the recommendations of ARR 2016 Book 6, Chapter 7. The hazard categories are shown below in Figure 4.12.

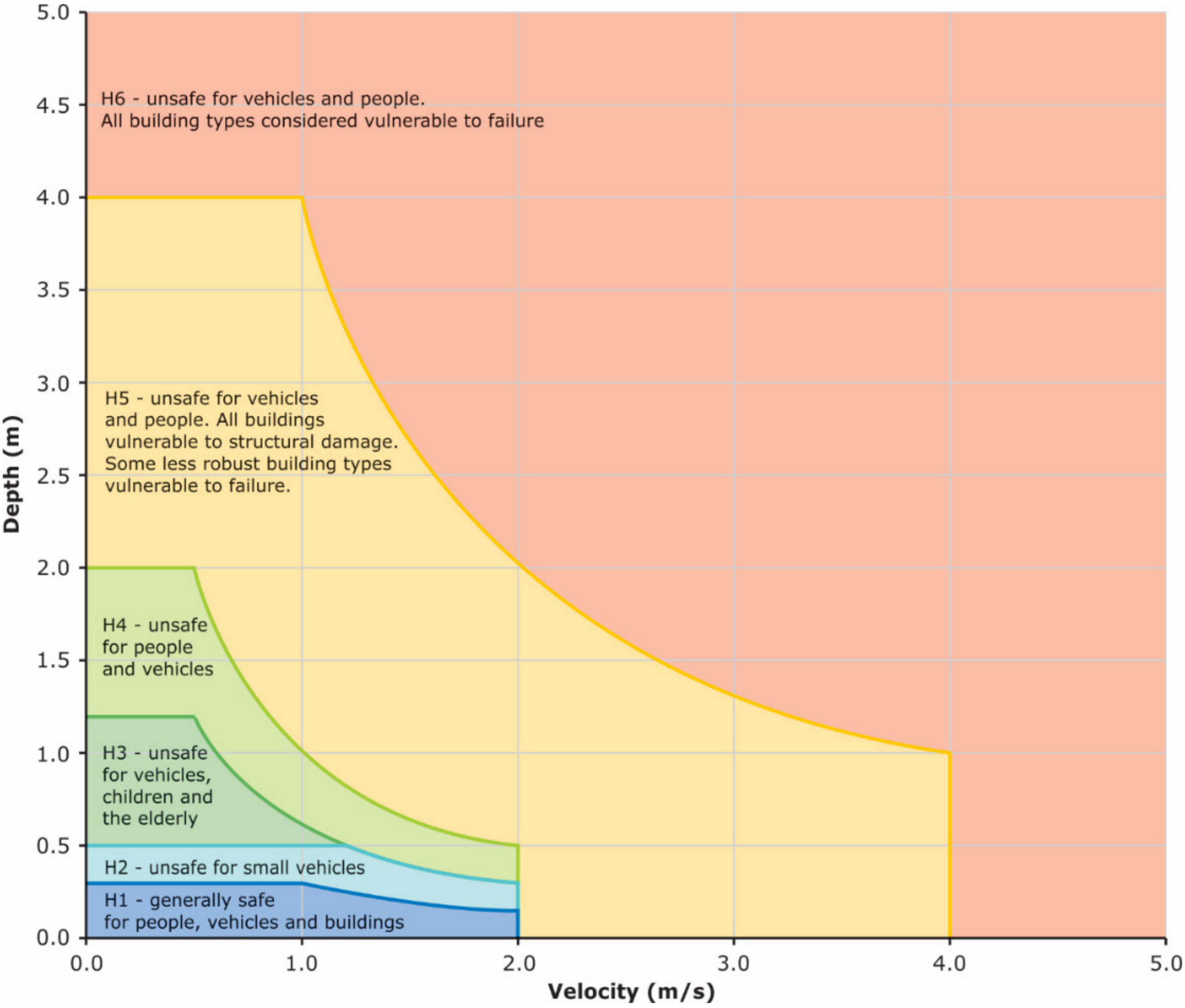

Figure 4.12 Combined flood hazard curves (from ARR 2016 Book 6, Chapter 7)

4.5.5 ASSESSMENT OF HYDRAULIC CATEGORISATION

There is no definitive method of deriving hydraulic categories (floodway, flood storage and flood fringe) for flood prone land as described in the Floodplain Development Manual (NSW 2005) and the Floodplain Risk Management Guideline: Floodway Definition (OEH 2007). Current industry practice provides a range of methods for calculation of floodway, however, the suitability of these methods needs to take into account the nature of flooding in the subject area.

A number of different methods were considered for the SAP. The methods described in Thomas et al (2010, 2012) were considered to be unsuitable for the SAP given the flood behaviour, which is dominated by local shallow overland flow. For this study, the floodway was defined using the following criteria set out in Howell et al (2003):

- Floodway is defined as flooded areas where:
  - depth x velocity product >0.25 m^2/s and velocity >0.25 m/s; or velocity >1 m/s
- The remainder of the flooded area is categorised as follows:
  - flood storage: flooded areas outside the floodway where depth >0.2 m; and
  - flood fringe: all other flooded areas outside the floodway and flood storage areas.

4.5.6 ASSESSMENT OF CLIMATE CHANGE EFFECTS

The 1% AEP flood event is typically used as the benchmark event for setting flood planning levels and assessing risks to development. Assessments of climate change effects typically involve application of increase factors to the 1% AEP rainfall or flow. The Floodplain Risk Management Guide (OEH 2019) allows the use of a more extreme event such as the 0.5% or 0.2% AEP as a proxy for the 1% AEP event under climate change conditions. For this study the 0.2% AEP event has been used as the proxy event for the 1% AEP under climate change conditions.

4.5.7 MASTER PLAN SCENARIO REPRESENTATION IN HYDRAULIC MODEL

4.5.7.1 MASTER PLAN SCENARIO

The Parkes SAP Master Plan is shown in Figure 4.10. The changes to the land use and associated changes in runoff characteristics are described in Section 4.4.8.1. For the hydraulic model, changes to hydraulic roughness and ground levels were also simulated to represent changes to ground cover and upgrade of the main road corridors.

4.5.7.2 HYDRAULIC DESIGN CRITERIA

The hydrological design criteria and strategy to manage increased flow from the SAP are described in Section 4.4.8.2. The following additional design criteria were also assumed when simulating the Master Plan scenario in the hydraulic model:

- flood conditions around sensitive assets within the SAP, such as road and rail embankments and existing development, should remain similar to those predicted under existing conditions, i.e. no worsening of flood risk to sensitive assets and land uses within the SAP; and
- flood conditions upstream and downstream of the SAP boundary should remain similar to those predicted under existing conditions, i.e. no worsening of flood risk to land adjacent to the SAP.

4.5.7.3 HYDRAULIC MODEL REPRESENTATION

The Master Plan scenario was represented in the hydraulic model by making the following adjustments to the existing conditions model:

- changes to hydraulic roughness of the floodplain and overland flow paths to represent the developed condition – see Table 4.9 below. Generally this entails a reduction in roughness to represent increased area of hardstand replacing the existing agricultural land
- changes to ground levels, specifically along the road corridors where elevated road embankments and bridges will be required to take the upgraded SAP road network over the rail corridors. The road corridor changes have been provided by the Parkes Special Activation Precinct Infrastructure and Transport Evaluation Report (Aurecon 2019)
- additional cross drainage provided under road embankments that will be elevated to facilitate the road corridor upgrades, such as at road over rail grade separations; and
- changes to runoff rates and durations within the SAP due to the provision of lot and SAP level detention systems (refer to Section 4.4.8.3 for details).

Table 4.9 TUFLOW model roughness values adopted in floodplain areas for the Master Plan scenario

LAND USE	MANNING'S 'N' VALUE
Maintained grass	0.04
Light vegetation/pasture	0.05
Medium vegetation	0.07
Roads	0.02
Ponds and other water	0.03
Heavily vegetated creek	0.07
Urbanised / industrial area	0.10
Large lot urbanised area	0.08
Commercial gateways	0.10
Resources and recycling	0.10
Intensive livestock agriculture	0.05
Regional enterprise	0.10
Mixed enterprise	0.10
Freight terminals and rail infrastructure	0.10
Energy (Solar)	0.08

4.6 RESULTS

4.6.1 EXISTING CONDITIONS

4.6.1.1 FLOOD EXTENT AND DEPTH

The following flood maps showing model predictions of flood extents and depths under existing conditions are provided in Appendix B:

Table 4.10 List of flood extent and depth maps for existing conditions

EVENT	APPENDIX B FIGURE REFERENCE
10% AEP	Figure B1.1
1% AEP	Figure B2.1
0.2% AEP	Figure B3.1
PMF	Figure B4.1

The results show that the flood behaviour within and immediately adjacent to the SAP up to the 1% AEP event is not affected by flooding in the larger Goobang Creek system to the south, and the flood behaviour within the SAP is therefore driven by local catchment rainfall runoff responses. In extreme events such as the 0.2% AEP and the PMF, the Goobang Creek system affects flood levels around the southern boundary of the SAP and within 200 m of the southern boundary by causing elevated tailwater conditions in the local watercourses within the SAP. However, the influence of Goobang Creek flooding does not extend more than approximately 200 m into the SAP even in very extreme events.

4.6.1.2 FLOOD VELOCITY

The following flood maps showing model predictions of flood velocity under existing conditions are provided in Appendix B:

Table 4.11 List of flood velocity maps for existing conditions

EVENT	APPENDIX B FIGURE REFERENCE
10% AEP	Figure B1.2
1% AEP	Figure B2.2
0.2% AEP	Figure B3.2
PMF	Figure B4.2

The maps show that flood velocities within the SAP are relatively low (<1.5 m/s) up to and including the 0.2% AEP event. This reflects the relatively flat topography of the overland flow paths within the SAP and indicates that the existing watercourses and flow paths are not subject to erosive flooding, with the exception of localised high velocities around structures such as road/rail embankment culverts.

4.6.1.3 FLOOD HAZARD

The following flood maps showing model predictions of flood hazard under existing conditions are provided in Appendix B:

Table 4.12 List of flood hazard maps for existing conditions

EVENT	APPENDIX B FIGURE REFERENCE
10% AEP	Figure B1.3
1% AEP	Figure B2.3
0.2% AEP	Figure B3.3
PMF	Figure B4.3

The maps show that, up to and including the 0.2% AEP event, there are no areas within the SAP where there is a risk to buildings (H5 and H6). The main flow paths running south west and west through the SAP contain some areas that are unsafe for people and vehicles (up to H4), but these areas are confined to the well defined watercourses and immediate overbank areas. Much of the flooded areas within the SAP are classified as H1, which is generally safe for people, vehicles and buildings.

4.6.1.4 HYDRAULIC CATEGORISATION

The following flood maps showing model predictions of hydraulic categorisation under existing conditions are provided in Appendix B:

Table 4.13 List of hydraulic categorisation maps for existing conditions

EVENT	APPENDIX B FIGURE REFERENCE
10% AEP	Figure B1.4
1% AEP	Figure B2.4
0.2% AEP	Figure B3.4
PMF	Figure B4.4

The maps show that, up to and including the 0.2% AEP event, the majority of the SAP is classified as flood fringe or flood storage, with the floodway classification applying within and close to the main watercourses and adjacent floodplains and overland flow paths. For the PMF event the majority of the flood prone area within the SAP becomes floodway.

4.6.1.5 CLIMATE CHANGE

The effects of climate change on flooding are demonstrated by comparing the results of the 1% AEP event to those of the 0.2% AEP event (i.e. comparing Figures B2.1 to B2.4 with Figures B3.1 to B3.4). The comparison demonstrates the following:

- Flood depths and extents are similar for both events (refer to Figures B2.1 and B3.1). Deeper and more extensive flooding for the 0.2% AEP event is most evident on the Ridgey Creek system west of the SAP boundary, while flood extents and depths are similar within the SAP.
- Flood velocities are similar for both events (refer to Figures B2.2 and B3.2), particularly within the areas of higher velocity (>0.8 m/s). At the lower end of the velocity range the 0.2% AEP event generates more extensive areas with velocities in the range 0.4 to 0.8 m/s.

- Flood hazard values are similar for both events (refer to Figures B2.3 and B3.3), particularly within the areas of higher hazard (>H4). The 0.2% AEP event generates more extensive areas with hazard classification of H2 to H4. The hazard classifications within the SAP are very similar for both events.
- Hydraulic categorisation is similar for both events (refer to Figures B2.4 and B3.4). The 0.2% AEP event generates more extensive areas of floodway within the Ridgey Creek system west of the SAP. The hydraulic categorisation within the SAP is very similar for both events.

The comparison demonstrates that climate change effects are not significant for flooding within the SAP boundary, but climate change would significantly increase flood risk within the Ridgey Creek system west of the SAP.

4.6.2 MASTER PLAN SCENARIO

4.6.2.1 FLOOD MANAGEMENT INFRASTRUCTURE

The primary flood management infrastructure requirements are the 1% AEP event detention basins provided at the SAP level. These are the main detention systems required to manage flooding within the SAP to protect sensitive land uses and infrastructure, and to protect the downstream catchment from adverse flood impacts. The 1% AEP event basins rely on lot level attenuation up to the 10% AEP event. Table 4.14 lists the sizes of the 1% AEP event basins. The locations of the basins are shown on Figure C0.1 in Appendix C.

Table 4.14 List of 1% AEP flood detention basins simulated in the Master Plan scenario

BASIN NAME	DETENTION STORAGE (m^3)	APPROXIMATE SURFACE AREA* (m^2)
A	10,000	24,000
B	60,000	144,000
C	45,000	108,000
D	37,000	88,800
E	57,000	136,800
F	40,000	96,000
G	85,000	204,000
H	17,500	42,000
I	17,500	42,000
J	25,000	60,000
K	50,000	120,000
L	8,000	19,200
M	20,000	48,000
N	38,000	91,200
O	50,000	120,000
Surface area calculated based on an average depth of detention storage of 0.5m and an additional 20% area to account for basin embankments and batters.		

Some of the basins listed above may be prescribed by the NSW Dam Safety Committee (DSC) if failure of the basin could result in loss of life, in accordance with the DSC Guidance Sheet 3E (DSC 2010). At the detailed design stage the likelihood and consequence of failure of the basins would need to be assessed against the DSC requirements to determine whether the basins are prescribed and are required to be designed, constructed, maintained and operated appropriately.

4.6.2.2 FLOOD EXTENT AND DEPTH

The following flood maps showing model predictions of flood extents and depths under the Master Plan scenario are provided in Appendix C:

Table 4.15 List of flood extent and depth maps for Master Plan scenario

EVENT	APPENDIX C FIGURE REFERENCE
10% AEP	Figure C1.1
1% AEP	Figure C2.1
0.2% AEP	Figure C3.1
PMF	Figure C4.1

To demonstrate the impacts of the SAP on flood depths and extents, Figures C1.1 to C4.1 can be compared to Figures B1.1 to B4.1 in Appendix B. The assessment found the following:

- the modelled detention basins effectively prevent any increase in flood depth and extent upstream and downstream of the SAP
- within the SAP the basins and enhanced cross drainage through elevated road embankments prevent any increase in flood risk to sensitive assets such as road and rail infrastructure and existing development.

4.6.2.3 FLOOD VELOCITY

The following flood maps showing model predictions of flood velocity under the Master Plan scenario are provided in Appendix C:

Table 4.16 List of flood velocity maps for Master Plan scenario

EVENT	APPENDIX C FIGURE REFERENCE
10% AEP	Figure C1.2
1% AEP	Figure C2.2
0.2% AEP	Figure C3.2
PMF	Figure C4.2

To demonstrate the impacts of the SAP on flood velocities, Figures C1.2 to C4.2 can be compared to Figures B1.2 to B4.2 in Appendix B. The assessment found the following:

- the modelled detention basins within the SAP retard flows to produce slightly lower velocities in the receiving creeks and floodplains downstream of the SAP
- within the SAP the basins achieve a significant reduction in flood velocities throughout the flood prone area, particularly within the main flow path running south west and west through the SAP.

4.6.2.4 FLOOD HAZARD

The following flood maps showing model predictions of flood hazard under the Master Plan scenario are provided in Appendix C:

Table 4.17 List of flood hazard maps for Master Plan scenario

EVENT	APPENDIX C FIGURE REFERENCE
10% AEP	Figure C1.3
1% AEP	Figure C2.3
0.2% AEP	Figure C3.3
PMF	Figure C4.3

To demonstrate the impacts of the SAP on flood hazard, Figures C1.3 to C4.3 can be compared to Figures B1.3 to B4.3 in Appendix B. The assessment found the following:

- similar to the effect on velocity, the modelled detention basins within the SAP retard flows to produce slightly lower hazard values in the receiving creeks and floodplains downstream of the SAP
- within the SAP the basins redistribute flow so that some areas receive less flooding (and reduced hazard) than under existing conditions, and other areas experience higher hazard values due to the direction and concentration of flow within the main flow paths leading to the basins.

4.6.2.5 HYDRAULIC CATEGORISATION

The following flood maps showing model predictions of hydraulic categorisation under the Master Plan scenario are provided in Appendix C:

Table 4.18 List of hydraulic categorisation maps for Master Plan scenario

EVENT	APPENDIX C FIGURE REFERENCE
10% AEP	Figure C1.4
1% AEP	Figure C2.4
0.2% AEP	Figure C3.4
PMF	Figure C4.4

To demonstrate the impacts of the SAP on hydraulic categorisation, Figures C1.4 to C4.4 can be compared to Figures B1.4 to B4.4 in Appendix B. The assessment found the following:

- similar to the effect on velocity and hazard, the modelled detention basins within the SAP retard flows to produce slightly lesser extent of floodway in the receiving creeks and floodplains downstream of the SAP
- within the SAP the basins also act to reduce the extent of floodway and reduce the hydraulic category generally to facilitate the future development.

4.6.2.6 CLIMATE CHANGE

The effects of climate change on the Master Plan scenario are demonstrated by comparing the results of the 1% AEP event to those of the 0.2% AEP event (i.e. comparing Figures C2.1 to C2.4 with Figures C3.1 to C3.4). The comparison demonstrates the following:

- Flood depths and extents are similar for both events (refer to Figures C2.1 and C3.1), however, deeper and more extensive flooding for the 0.2% AEP event occurs within the SAP and on the Ridgey Creek and Goobang Creek systems downstream of the SAP.
- Flood velocities are similar for both events (refer to Figures C2.2 and C3.2), particularly within the areas of higher velocity (>0.8 m/s). At the lower end of the velocity range the 0.2% AEP event generates more extensive areas with velocities in the range 0.4 to 0.8m/s.
- Flood hazard values are similar for both events (refer to Figures C2.3 and C3.3), particularly within the areas of higher hazard (>H4). The 0.2% AEP event generates more extensive areas with hazard classification of H2 to H4 in the Ridgey and Goobang Creek systems downstream of the SAP. The hazard classifications within the SAP are very similar for both events.
- Hydraulic categorisation is similar for both events (refer to Figures C2.4 and C3.4). The 0.2% AEP event generates more extensive areas of floodway within the Ridgey Creek and Goobang Creek systems downstream of the SAP. The hydraulic categorisation within the SAP is very similar for both events.

The comparison demonstrates that climate change effects would result in small increases in flood risk within the SAP. These are likely to be manageable through localised expansion and enhancement of the flood management infrastructure in the future should climate change effects occur. The flooding impacts to land adjacent to the SAP would not change significantly and, similar to impacts within the SAP, could be mitigated through future modification of the flood management infrastructure within the SAP.

5 WATER QUALITY ASSESSMENT

5.1 METHODOLOGY

5.1.1 OVERVIEW

The methodology for the water quality assessment was as follows:

- An existing conditions water quality model was developed for the SAP area and upstream sub-catchments draining to the SAP. The model was developed in the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software program and utilised the sub-catchment delineation determined by the flood modelling. The MUSIC model simulates rainfall, stormwater runoff and pollutant loads. It also simulates pollutant removal and flow reduction through stormwater management systems such as sediment ponds, wetlands, bio-retention systems and stormwater harvesting. The model set up was based on the recommendations of the NSW MUSIC Modelling Guidelines (BMT WBM, 2015.
- The existing conditions MUSIC model was used to predict the current annual flow and pollutant loads discharged from the SAP to the downstream receiving catchments.
- The existing conditions model was modified to represent the Master Plan scenario by adjusting the model representation of land uses, runoff and pollutant load characteristics to simulate the future development of the SAP.
- The Master Plan scenario model was first run with no stormwater quality mitigation measures to determine the impact on the downstream systems. Suitable mitigation measures were then identified and tested within the model to meet assumed water quality management criteria.
- The Master Plan scenario model was also used to determine the volumes of stormwater that can be harvested from within the SAP to contribute to meeting the future demand for non-potable water.

5.1.2 EXISTING CONDITIONS WATER QUALITY MODELLING

5.1.2.1 SUB-CATCHMENTS AND LAND USES

The existing conditions MUSIC model was set up using the sub-catchment delineations determined from the flood modelling and land uses determined from inspection of the aerial photography for the SAP and surrounding area. The MUSIC model sub-catchments and overview of land uses are shown in Figures 5.1 and 5.2.

Downstream receiving model nodes were determined from the major overland flow paths discharging across the SAP boundary as defined by the flood model. The receiving nodes are shown on Figure 5.1. Two junction catchment nodes were identified for Ridgey Creek (RC) and three junction catchment nodes for Goobang Creek (GC). Downstream nodes were included for Goobang Creek and Ridgey Creek and an ultimate downstream node for the whole SAP area.

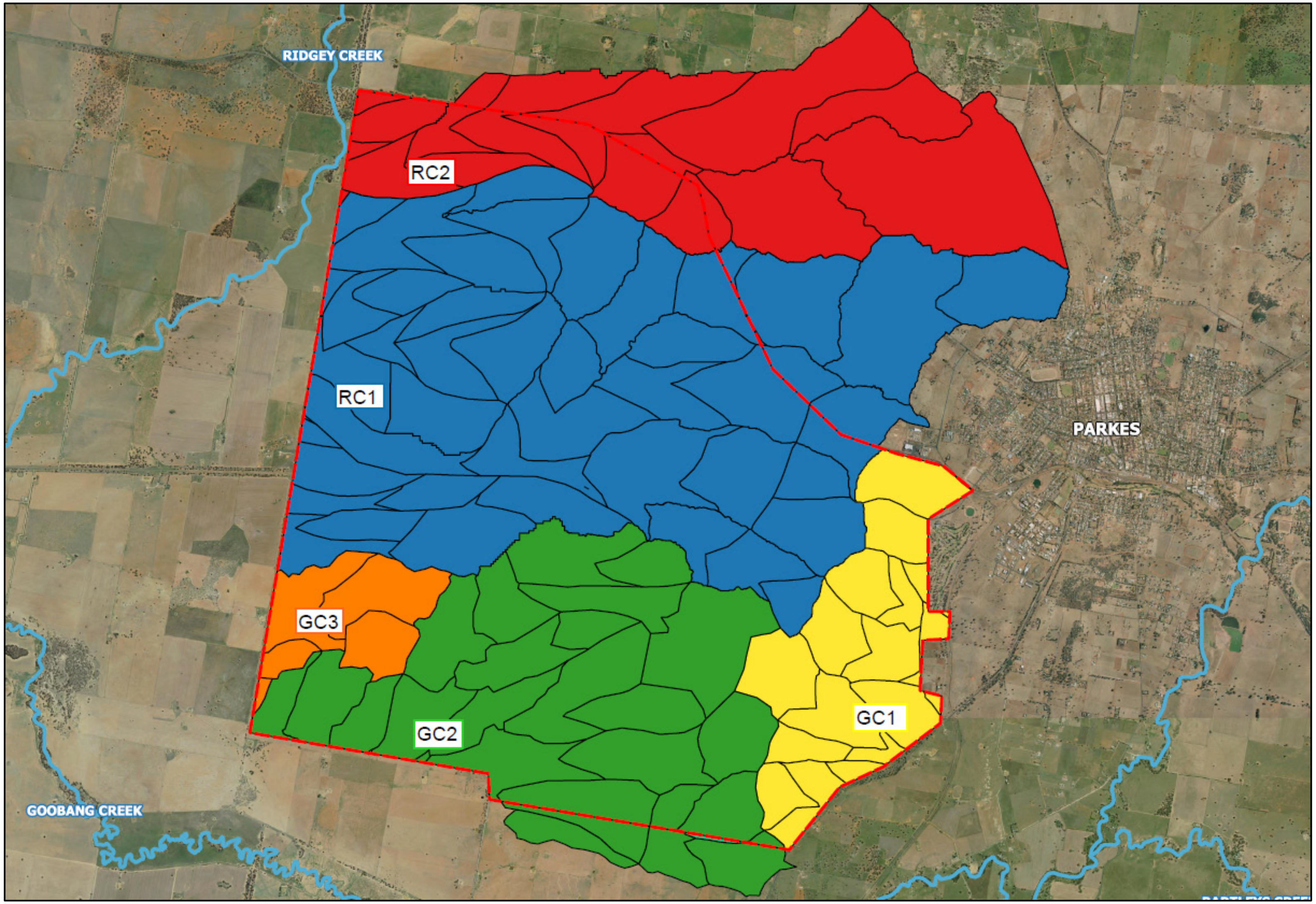

Figure 5.1 Existing conditions MUSIC model sub-catchments

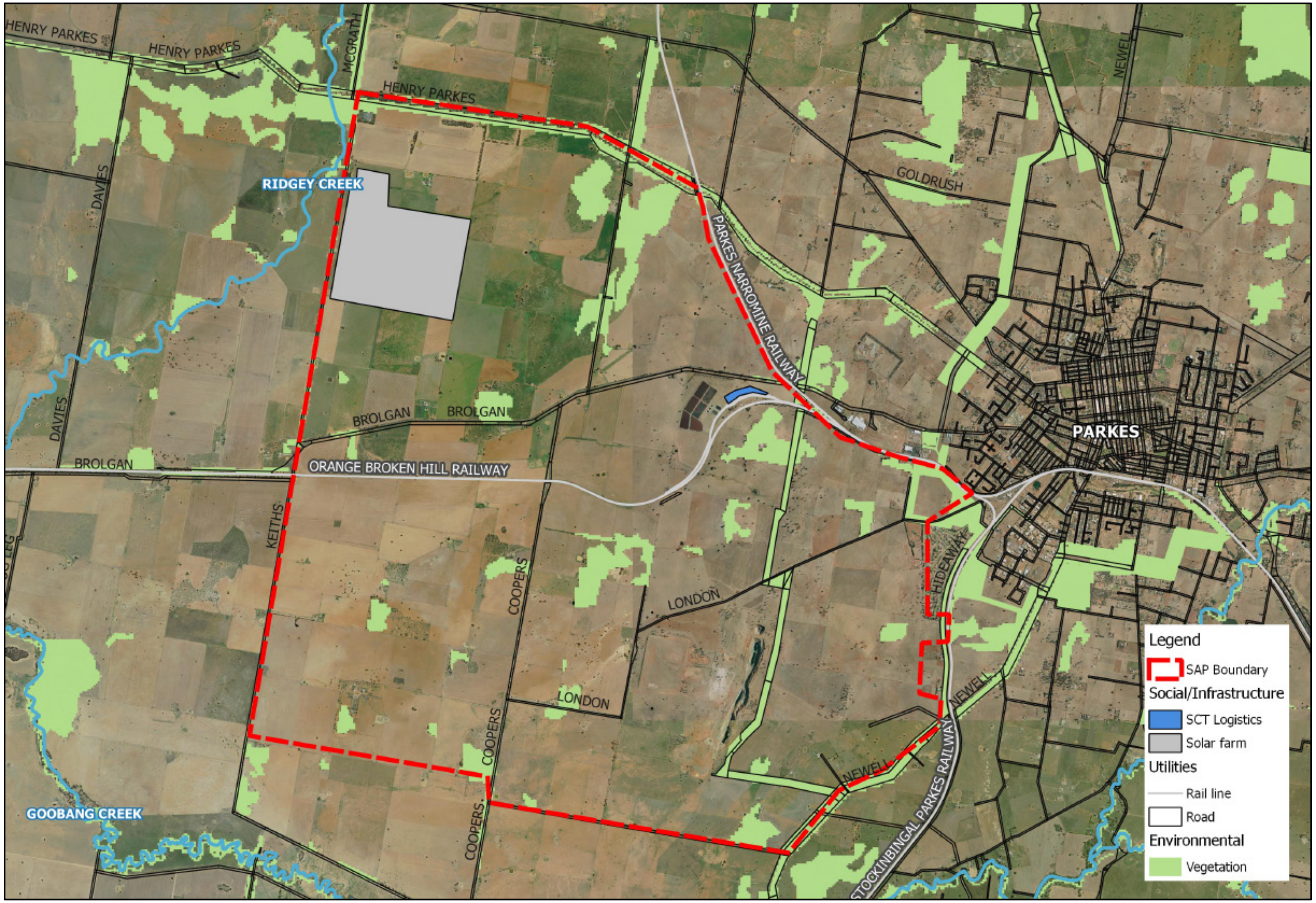

Figure 5.2 Existing land uses within and adjacent to the Parkes SAP

5.1.2.2 RAINFALL DATA

MUSIC does not contain a specific rainfall dataset for Parkes. It was therefore necessary to review rainfall data from the closest stations at Dubbo and Orange. Table 5.1 provides the MUSIC model rainfall parameters at these stations.

Table 5.1 MUSIC model rainfall parameters for Dubbo and Orange

RAINFALL STATION	MEAN ANNUAL RAINFALL (mm)	MODELLING PERIOD
65070 Dubbo	390	04/04/2000 – 31/03/2010
63254 Orange	709	04/04/2000 – 01/01/2009

Long-term annual average rainfall data from the Bureau of Meteorology for Parkes, Orange and Dubbo were reviewed to assess the most appropriate rainfall dataset for the Parkes SAP. Table 5.2 provides the long-term annual average rainfalls recorded at the three towns from the Bureau of Meteorology data.

Table 5.2 Long-term annual average rainfalls for Parkes, Dubbo and Orange

BUREAU OF METEOROLOGY WEATHER STATION	LONG TERM ANNUAL AVERAGE RAINFALL (mm)
Parkes	616.85
Dubbo	579.75
Orange	871.95

Table 5.2 shows that the long term average annual rainfall is similar at Parkes and Dubbo, with a significantly higher value for Orange. Since the MUSIC rainfall datasets for Dubbo and Orange cover a significant dry period (2000 to 2009/2010), the mean annual rainfall in MUSIC is significantly lower than the long term annual average rainfall for both locations. The Dubbo mean annual rainfall in MUSIC is particularly low, while the Orange mean annual rainfall is closer to the long term annual average rainfall for Parkes. Therefore, the Orange rainfall dataset was selected for the Parkes SAP MUSIC model in order to represent a period of typical rainfall consistent with the long term annual average rainfall rather than a dry period.

5.1.2.3 SOURCE NODES

The SAP area was divided into areas representing the various relevant MUSIC model source node types. The source nodes and extents within each modelled sub-catchment are given in Table 5.3. The existing rail corridors were included in the ‘unsealed road’ source node.

Table 5.3 Existing conditions MUSIC model source node types and areas

SOURCE NODE TYPE	EXTENT OF SOURCE NODE TYPE WITHIN EACH SUB-CATCHMENT (HECTARES)				
	GC1	GC2	GC3	RC1	RC2
Agricultural	566.46	1,577.64	254.95	2,748.20	1,505.75
Vegetation	40.87	107.50	8.94	84.59	–
Sealed road	9.09	3.23	3.82	5.71	–
Unsealed road	43.99	3.44	5.92	22.27	1.45
Industrial	205.93	14.58	–	–	–
Quarry	–	–	33.76	67.52	–

5.1.2.4 PERVIOUS AREA PARAMETERS

Soil reports from the NSW Soil and Land Information System identify the dominant top soil profile in the area as sandy clay loam (OEH, 1992). Table 5.4 shows the pervious area parameters provided by the NSW MUSIC Modelling Guidelines (BMT WBM 2015) for sandy clay loam. These parameters were adopted for all source nodes.

Table 5.4 MUSIC model pervious area parameters

PERVIOUS AREA PARAMETER	VALUE
Pervious Area Soil Storage Capacity (mm)	108
Pervious Area Soil Initial Storage (% of Capacity)	25
Field Capacity (mm)	73
Pervious Area Infiltration Capacity coefficient – a	250
Pervious Area Infiltration Capacity exponent – b	1.3
Groundwater Initial Depth (mm)	10
Groundwater Daily Recharge Rate (%)	60
Groundwater Daily Baseflow Rate (%)	45
Groundwater Daily Deep Seepage Rate (%)	0

5.1.2.5 IMPERVIOUS AREA PARAMETERS

The impervious area rainfall threshold was set at 1.5 mm for sealed and unsealed roads and 1 mm for all other land uses as per Table 5-4 in the NSW MUSIC Modelling Guidelines (BMT WBM 2015). The impervious area percentages for each node are given in Table 5.5 and were set based on the values in Table 5-3 of the NSW MUSIC Modelling Guidelines.

Table 5.5 Impervious and pervious areas for MUSIC model source nodes

NODE TYPE	% IMPERVIOUS	% PERVIOUS
Agricultural	0	100
Sealed road	100	0
Unsealed road	50	50
Industrial	90	10
Quarry	20	80

5.1.2.6 POLLUTANT CONCENTRATION PARAMETERS

Table 5.6 shows the baseflow and stormflow pollutant concentration parameters for the source nodes. These values were taken from Table 5-6 and 5-7 of the NSW MUSIC Modelling Guidelines (BMT WBM 2015). The guidelines note that phosphorus stormflow concentrations within MUSIC are correlated to suspended solids concentrations when the stochastic estimation method is selected. As such the "mean" estimation method was selected for generating nutrients for agricultural source nodes.

Table 5.6 MUSIC model source node pollutant concentrations

SOURCE NODE	FLOW	TOTAL SUSPENDED SOLIDS (mg/L)		TOTAL PHOSPHORUS (mg/L)		TOTAL NITROGEN (mg/L)	
		Mean log	SD log	Mean log	SD log	Mean log	SD log
Agricultural	Baseflow	1.30	0.13	-1.05	0.13	0.04	0.13
	Stormflow	2.15	0.31	-0.22	0.30	0.48	0.26
Sealed road	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	2.43	0.32	-0.30	0.25	0.34	0.19
Unsealed road	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	3.00	0.32	-0.30	0.25	0.34	0.19
Industrial	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	2.15	0.32	-0.60	0.25	0.3	0.19
Quarry	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	3.00	0.32	-0.30	0.25	0.34	0.19
Commercial (business)	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	2.15	0.32	-0.60	0.25	0.30	0.19
Vegetation (Forest)	Baseflow	0.78	0.13	-1.22	0.13	-0.52	0.13
	Stormflow	1.6	0.2	-1.10	0.22	-0.05	0.24

5.1.3 MASTER PLAN SCENARIO WATER QUALITY MODELLING

The existing conditions MUSIC model was modified to represent the Master Plan scenario. To align with the flood management strategy, the MUSIC model sub-catchments were refined for the Master Plan scenario based on the major overflow paths identified by the Master Plan scenario flood model. Each sub-catchment was separated into land use areas based on the Master Plan and then further separated into roof, hardstand and remaining pervious areas. Table 5.7 describes the MUSIC source nodes used to model the Master Plan land uses and the percentages of impervious area, roof area and hardstand area for each land use.

Table 5.7 Master Plan scenario MUSIC model land use source nodes

LAND USE	MUSIC SOURCE NODE	TOTAL IMPERVIOUS AREA (%)	ROOF AREA (%)	HARDSTAND AREA (%)
Commercial gateways	Commercial	60	30	30
Resources and recycling	Quarries	50	5	45
Biodiversity	Forest	0	0	0
Intensive livestock agriculture	Agriculture	25	10	15
Mixed enterprise	Industrial	70	30	40
Regional enterprise	Industrial	70	30	40
Energy (Solar)	Industrial	50	5	45

5.2 RESULTS

5.2.1 EXISTING CONDITIONS

Table 5.8 provides the existing flow and pollutant loads entering the downstream receiving catchments from the Parkes SAP.

Table 5.8 Existing conditions flow and pollutant loads to receiving catchments downstream of the SAP

PARAMETER	FROM SAP TO GOOBANG CREEK	FROM SAP TO RIDGEY CREEK	TOTAL FROM SAP TO DOWNSTREAM
Flow (ML/yr)	1,540	3,400	4,940
Total Suspended Solids (kg/yr)	319,183	470,817	790,000
Total Phosphorus (kg/yr)	341	752	1,093
Total Nitrogen (kg/yr)	2,514	6,086	8,600
Gross pollutants (kg/yr)	11,589	45,311	56,900

The results show that Ridgey Creek receives approximately 69% of the total flow from the SAP and receives a correspondingly higher pollutant load for all parameters.

5.2.2 MASTER PLAN SCENARIO

5.2.2.1 INITIAL RESULTS WITHOUT MITIGATION MEASURES

The Master Plan scenario was initially run in MUSIC with no mitigation measures to determine the increases in flow and pollutant loads from the SAP to the receiving catchments downstream. The results are given below in Table 5.9.

Table 5.9 Initial Master Plan scenario MUSIC model results without mitigation measures

PARAMETER	TOTAL FROM SAP TO DOWNSTREAM WITH NO MITIGATION MEASURES	INCREASE IN EXISTING LOADS
Flow (ML/yr)	16,800	340%
Total Suspended Solids (kg/yr)	4.250,000	538%
Total Phosphorus (kg/yr)	4,990	456%
Total Nitrogen (kg/yr)	34,900	406%
Gross pollutants (kg/yr)	275,000	483%

The results show the impact of the large increase in impervious area on the receiving catchments without mitigation measures. The Master Plan MUSIC model was next modified to incorporate suitable treatment systems to mitigate this impact.

5.2.2.2 STORMWATER QUALITY MANAGEMENT DESIGN CRITERIA

In NSW the consent authorities typically require stormwater quality management measures be designed to achieve pollutant load reductions from developed areas in the following typical ranges:

- Total Suspended Solids: 80 to 85% reduction
- Total Phosphorus: 30 to 60% reduction; and
- Total Nitrogen: 30 to 45%.

As noted in Section 3.2.4, Parkes Shire Council does not provide pollutant load reduction criteria, but instead requires appropriate objectives to be determined following investigation.

Given that no specific stormwater quality management criteria have been established for the Parkes SAP, and the opportunity to treat the runoff within the flood detention basins required to manage flood impacts, the following initial criteria have been assumed in the Master Plan scenario to assess the required mitigation measures:

- maintain flow volumes discharged to the receiving catchments at or close to existing volumes; and
- maintain loads of Total Suspended Solids, Total Phosphorus and Total Nitrogen discharged to the receiving catchments at or close to existing loads.

These criteria are conservative in that they would ensure little to no impact on the flow and water quality regimes within the receiving catchments. At later stages of assessment, site-specific flow and water quality objectives would need to be determined in consultation with the consent authorities to confirm stormwater treatment measures required to facilitate development of the SAP.

5.2.2.3 MITIGATION MEASURES

The following stormwater quality treatment measures were investigated for the Master Plan scenario:

- rainwater tanks for capture and re-use of stormwater from roof areas within the SAP
- stormwater capture and re-use from ponds collecting runoff from hardstand areas and other areas within the SAP
- bio-retention systems incorporated within the flood detention basins to treat runoff from the SAP prior to discharge downstream; and
- vegetated swales to provide additional treatment of runoff from the SAP.

Details of how these measures were assessed in the MUSIC model are provided in the following sections.

RAINWATER TANKS

Rainwater tanks are proposed at roofed areas to harvest and re-use stormwater. Tank volumes were sized based on provision of 30 kL/ha of roof area. A re-use rate of 0.96 mL/year per kL of storage was adopted. The rainwater tanks were modelled with the following parameters:

- Low flow bypass as 0 m^3/s
- High flow bypass as 100 m^3/s
- Depth above overflow as 0.2 m
- Initial volume as 10 kL.

PONDS

Stormwater harvesting and re-use from the hardstand and other land areas was also simulated in the Master Plan scenario MUSIC model. The model assumed that the harvesting system would consist of a series of ponds. The pond volumes were sized based on an assumed 30 m^3/ha capture. Re-use rates from the nodes were an assumed 0.48 ML/year per m^3 of storage. Table 5.10 provides the MUSIC model parameters used for pond nodes. Nominal values were used for extended detention depth and overflow weir width.

Table 5.10 Pond parameters modelled in MUSIC

PARAMETER	VALUE
Low flow bypass (m^3/s)	0
High flow bypass (m^3/s)	100
Surface Area (m^2)	Assumed square basins
Extended Detention Depth (m)	0.01
Permanent Pool Volume (m^3)	30 m^3/ha
Initial Volume (m^3)	10
Vegetation Cover (% of surface area)	10
Exfiltration Rate (mm/hr)	10
Evaporative Rate (mm/hr)	100
Overflow weir width	200

BIO-RETENTION BASINS

The flood detention basins provide an opportunity to treat stormwater via bio-retention systems provided within part of the detention basins. For this study it was assumed that the bio-retention component of the basins could extend to 40% of the detention basin surface area. Table 5.11 gives the other parameters adopted in the Master Plan scenario MUSIC model for the bio-retention basins.

Table 5.11 Bio-retention basin parameters modelled in MUSIC

PARAMETER	VALUE
Low flow bypass (m^3/s)	0
High flow bypass (m^3/s)	100
Extended Detention Depth (m)	0.5
Filter Area (m^2)	Same as surface area
Unlined Filter Media Perimeter (m)	Assumed square basins
Saturated Hydraulic Conductivity (mm/hr)	100
Filter Depth (m)	0.5
TN Content of Filter Media (mg/kg)	400
Orthophosphate Content of Filter Media (mg/kg)	40
Exfiltration Rate (mm/hr)	10

The resulting number of bio-retention basins to meet the requirements set out in Section 5.2.2.2 are shown on Figure C0.1 in Appendix C and scheduled below in Table 5.12:

Table 5.12 List of bio-retention basins simulated in the Master Plan scenario

BASIN NAME	TYPE	DETENTION STORAGE (m^3)	APPROXIMATE SURFACE AREA (m^2)	BIO-RETENTION FILTER COVERAGE
A	Combined flood detention and water quality basin	10,000	24,000	40%
B	Combined flood detention and water quality basin	60,000	144,000	40%
C	Combined flood detention and water quality basin	45,000	108,000	40%
D	Combined flood detention and water quality basin	37,000	88,800	40%
E	Combined flood detention and water quality basin	57,000	136,800	40%
F	Combined flood detention and water quality basin	40,000	96,000	40%
G	Combined flood detention and water quality basin	85,000	204,000	40%

BASIN NAME	TYPE	DETENTION STORAGE (m^3)	APPROXIMATE SURFACE AREA (m^2)	BIO-RETENTION FILTER COVERAGE
H	Combined flood detention and water quality basin	17,500	42,000	40%
I	Combined flood detention and water quality basin	17,500	42,000	40%
J	Combined flood detention and water quality basin	25,000	60,000	40%
K	Combined flood detention and water quality basin	50,000	120,000	40%
L	Combined flood detention and water quality basin	8,000	19,200	40%
M	Combined flood detention and water quality basin	20,000	48,000	40%
N	Combined flood detention and water quality basin	38,000	91,200	40%
O	Combined flood detention and water quality basin	50,000	120,000	40%
WQ1	Water quality basin	N/A	57,400	100%
WQ2	Water quality basin	N/A	16,850	100%

SWALES

It is proposed to maintain the existing main flow paths within the SAP. These provide an opportunity for further treatment of the runoff from the SAP by incorporating vegetated swales within the channels and main flow paths. Swales were therefore simulated in the Master Plan scenario MUSIC model with the following properties:

- 0 m^3/s low flow bypass
- 0.8% bed slope
- 0.25 m vegetation height; and
- 10 mm/hr exfiltration rate.

The locations of the swales are shown on Figure C0.1 in Appendix C.

5.2.2.4 FINAL RESULTS WITH MITIGATION MEASURES

The mitigation measures described above were simulated in the Master Plan scenario MUSIC model and the resulting flow and pollutant loads were compared to the results of the existing conditions model to determine the effectiveness of the measures. The results are provided below in Table 5.13.

Table 5.13 Master Plan scenario MUSIC model results with mitigation measures

PARAMETER	EXISTING	TOTAL FROM SAP TO DOWNSTREAM WITH MITIGATION MEASURES	CHANGE IN LOADS
Flow (ML/yr)	4,940	7,460	+51%
Total Suspended Solids (kg/yr)	790,000	200,000	-75%
Total Phosphorus (kg/yr)	1,093	782	-28%
Total Nitrogen (kg/yr)	8,600	7,770	-10%
Gross pollutants (kg/yr)	56,900	22,200	-61%

The results show that the simulated mitigation measures meet and exceed the initial criteria assumed in Section 5.2.2.2, with no reduction but rather a significant increase in total flow downstream and significant reductions in existing conditions pollutant loads.

It should be noted that these results are only intended to illustrate the effectiveness of best practice stormwater treatment measures in protecting the downstream environment from flow and water quality impacts of the SAP. The stormwater treatment strategy for the SAP is to be determined through further investigation and consultation with the consent authorities to establish flow and water quality objectives for the receiving systems downstream of the SAP.

5.2.2.5 STORMWATER HARVESTING AND RE-USE

The MUSIC modelling of the Master Plan scenario found that re-use rates of 27.5% were achieved from rainwater tank nodes and approximately 42% from pond nodes. A total of 791 ML/year was harvested and re-used from rainwater tanks and 1,154 ML/year from ponds, giving a total harvesting and re-use figure of 1,945 ML/year.

6 SUMMARY AND CONCLUSIONS

This report documents the findings of the Flood and Water Quality Management Study undertaken to support the development of the Parkes SAP Master Plan.

The study has established a detailed set of flood and water quality models that have defined the existing conditions relating to flood behaviour, surface water flow and surface water quality within the SAP and the receiving systems downstream. The models have also been used to simulate the effects of the SAP Master Plan on these regimes and determine the flooding and stormwater quality mitigation measures that will need to be delivered to maximise the developable land within the SAP and to protect the receiving environment from adverse flooding and water quality impacts.

The following key conclusions are drawn from the study:

- Flooding
  - Under existing conditions, the dominant flooding process within the SAP is local catchment runoff and overland flow, with no flood risk from the larger creek systems running south (Goobang Creek) and west (Ridgey Creek) of the SAP. Under very extreme events the Goobang Creek system has the potential to influence flood levels within approximately 200 m of the southern boundary of the SAP, however, the majority of the SAP is not influenced by flooding in the Goobang Creek system.
  - Under existing conditions flood depths, velocities and hazards remain relatively low across most of the SAP up to and including the 1% AEP event. The main hazardous area for flooding is located within and close to the main overland flow path running west through the SAP south of Brolgan Road.
  - The Master Plan will increase impervious areas throughout the SAP with a corresponding increase in runoff rates and volumes. To manage adverse flooding impacts within the SAP and downstream, a flood detention scheme is proposed that maintains flows at existing rates at the lot level up to and including the 10% AEP and at the SAP level up to and including the 1% AEP. This scheme requires a total of 15 SAP level detention basins and lot level detention provided within 15 sub-catchments of the SAP.
  - Some of the detention basins may be prescribed by the DSC if failure of the basin could result in loss of life. At the detailed design stage the likelihood and consequence of failure of the basins would need to be assessed against the DSC requirements to determine whether the basins are prescribed and are required to be designed, constructed, maintained and operated appropriately.
  - Simulation of the Master Plan scenario in the flood model shows that the SAP will not adversely affect the adjacent land due to the effectiveness of the detention scheme. The scheme is also effective at protecting sensitive assets within the SAP, such as existing development and transportation corridors.
  - Climate change effects have been assessed by using the 0.2% AEP event as a proxy for increases in 1% AEP event flooding due to climate change. The assessment found that the impacts of the SAP on adjacent land do not change appreciably when comparing the two events, and therefore the SAP is not sensitive to climate change and adaptation measures that may be required in the future should be possible through upgrades of the flood management infrastructure.

- Water quality
  - The surface water quality regime has been established through MUSIC modelling of the SAP and surrounding catchments. The model shows that Ridgey Creek is main receiver of flow and stormwater pollutant loads from the SAP.
  - The SAP will require stormwater treatment measures to protect the downstream environments within Ridgey Creek and Goobang Creek. A range of treatment measures have been assessed, and the flood detention scheme provides an opportunity to co-locate flooding and water quality management measures within the SAP.
  - A number of initial treatment measures have been tested and found to be effective in reducing downstream pollutant loads while maintaining or increasing flows downstream. Further investigation and consultation with consent authorities is required to confirm flow and water quality objectives for the SAP.
  - Stormwater harvesting within the SAP has the potential to yield almost 2 GL/year in some years which would make a significant contribution to meeting the demand for non-potable water for the SAP.

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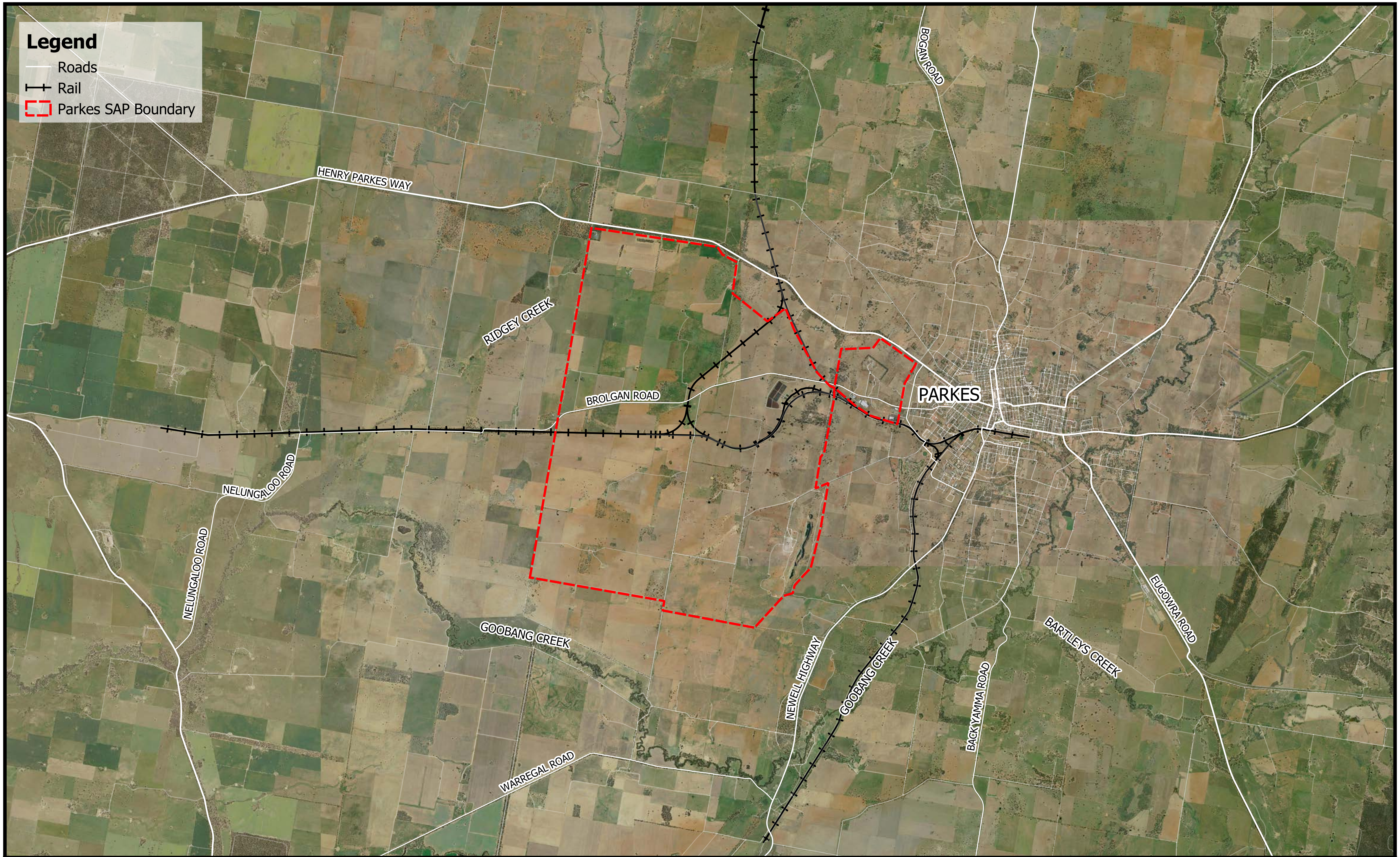
APPENDIX A

STUDY AREA AND MODEL LAYOUT MAPS

CONTENTS



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Aerial Source: NSW Six Map
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Figure A1
Study Area

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Aerial Source: NSW Six Map
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Rev: A

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Figure A2
Hydrological Model Layout

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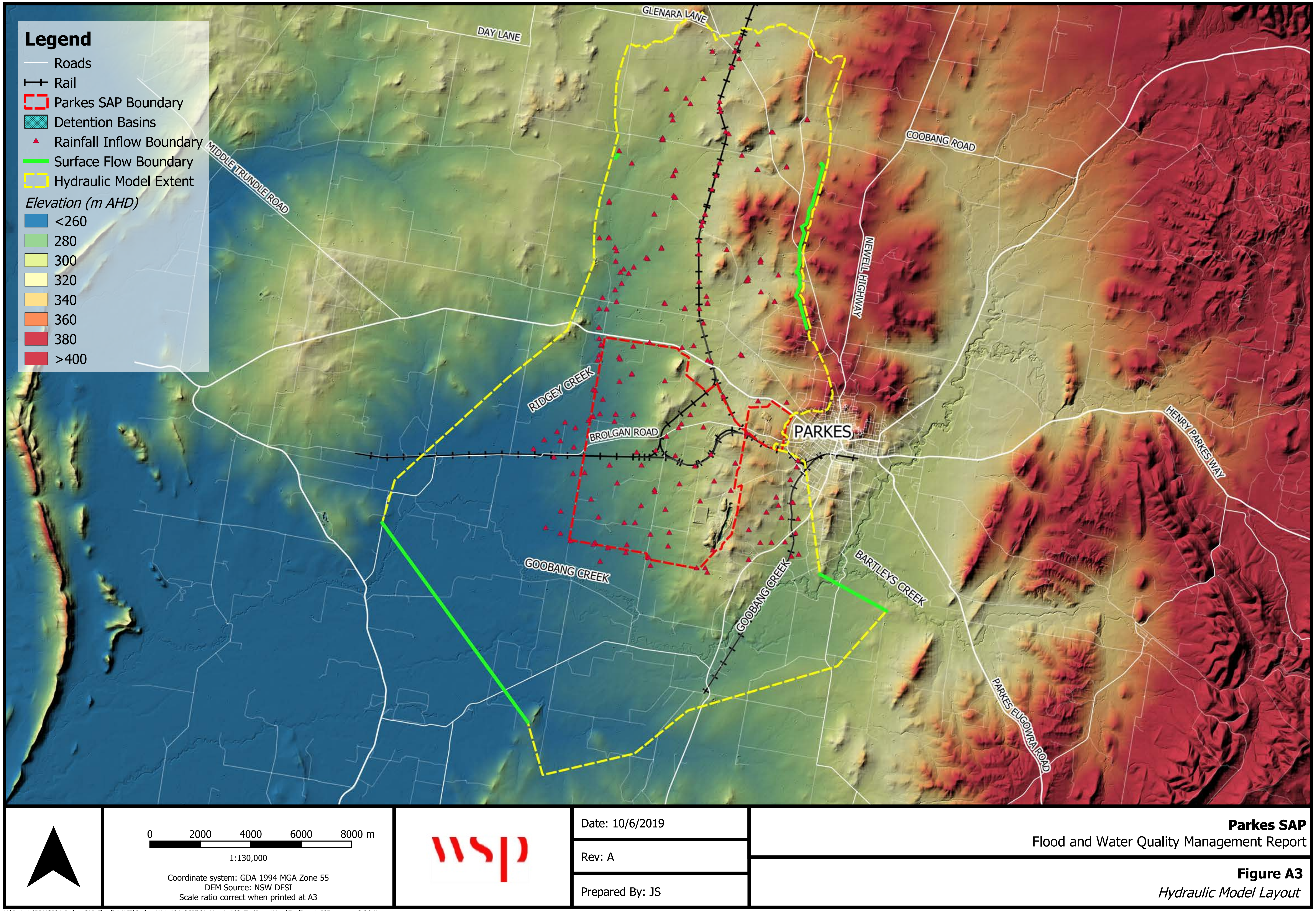

Date: 10/6/2019

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Figure A3
Hydraulic Model Layout

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APPENDIX B

EXISTING CONDITIONS FLOOD MAPS

CONTENTS

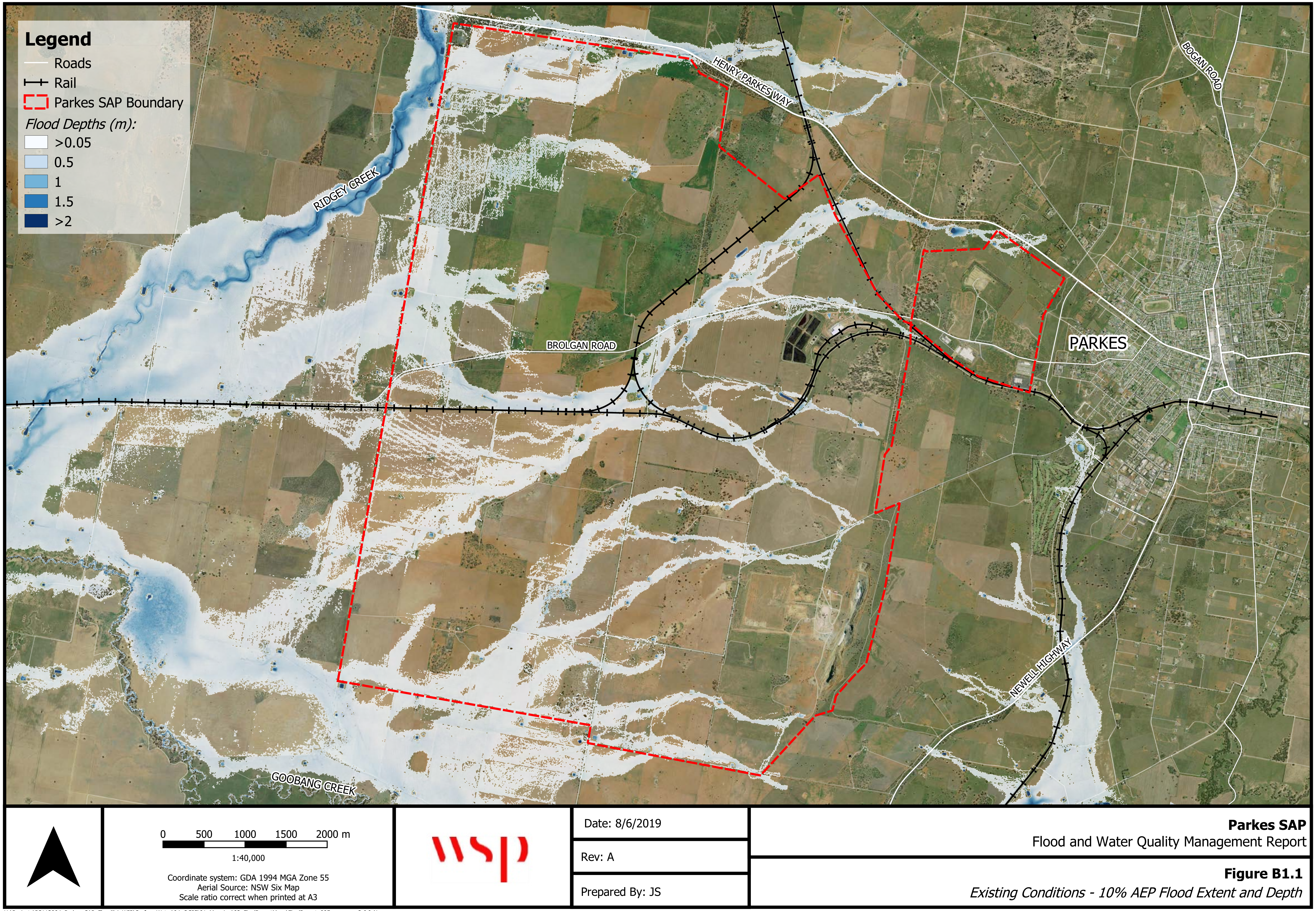

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Figure B1.1
Existing Conditions - 10% AEP Flood Extent and Depth

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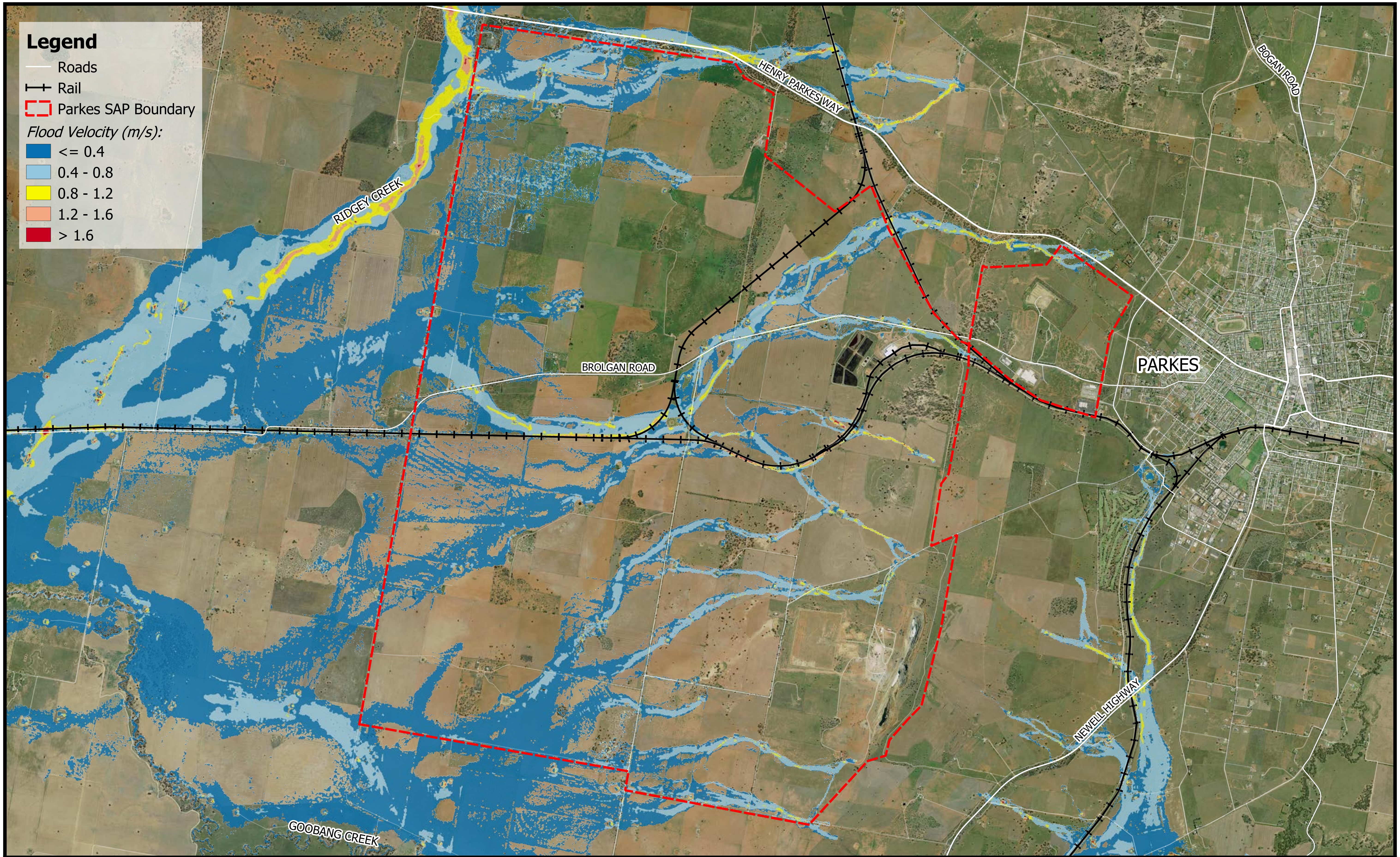

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Figure B1.2
Existing Conditions - 10% AEP Flood Velocity

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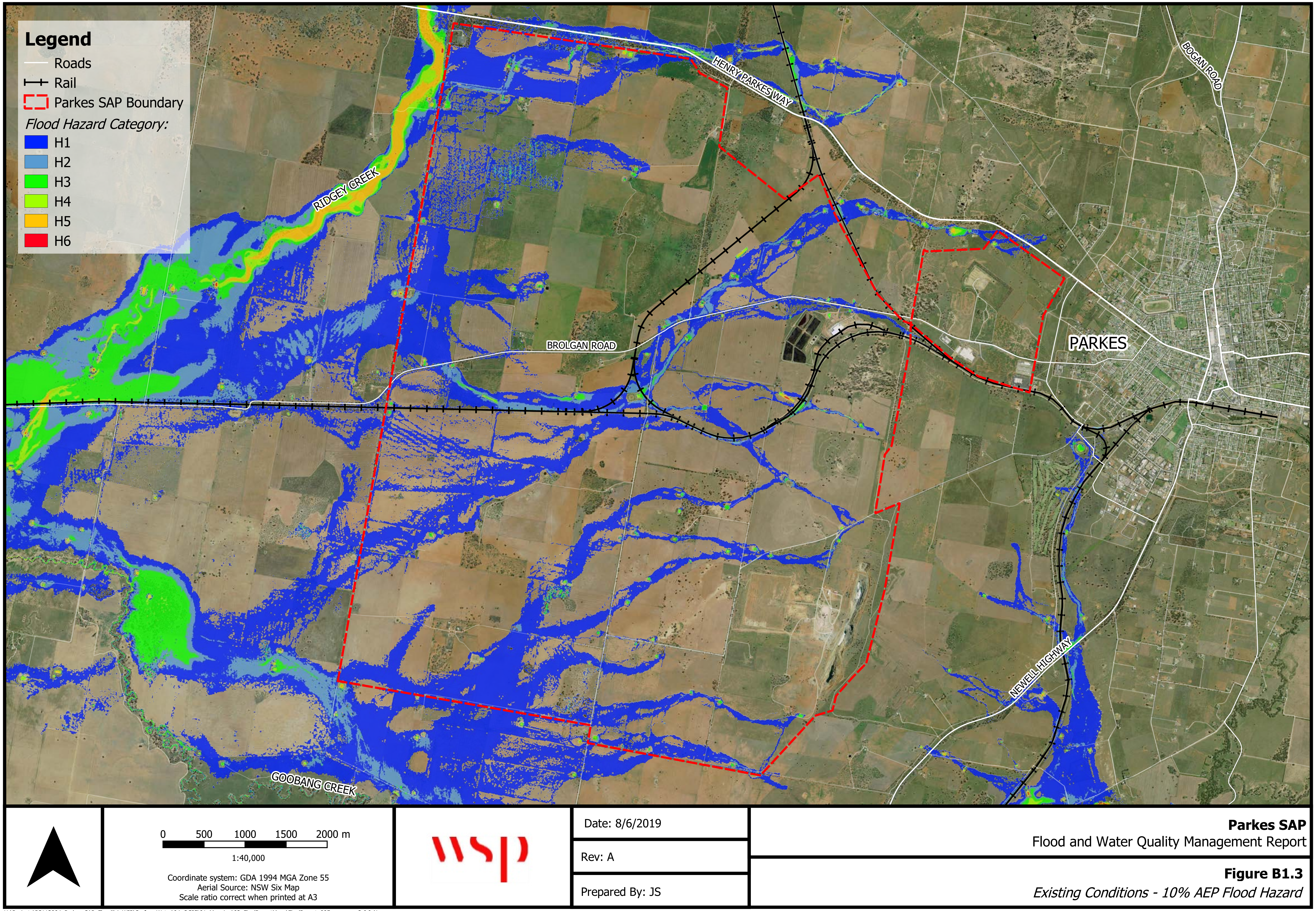

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Figure B1.3
Existing Conditions - 10% AEP Flood Hazard

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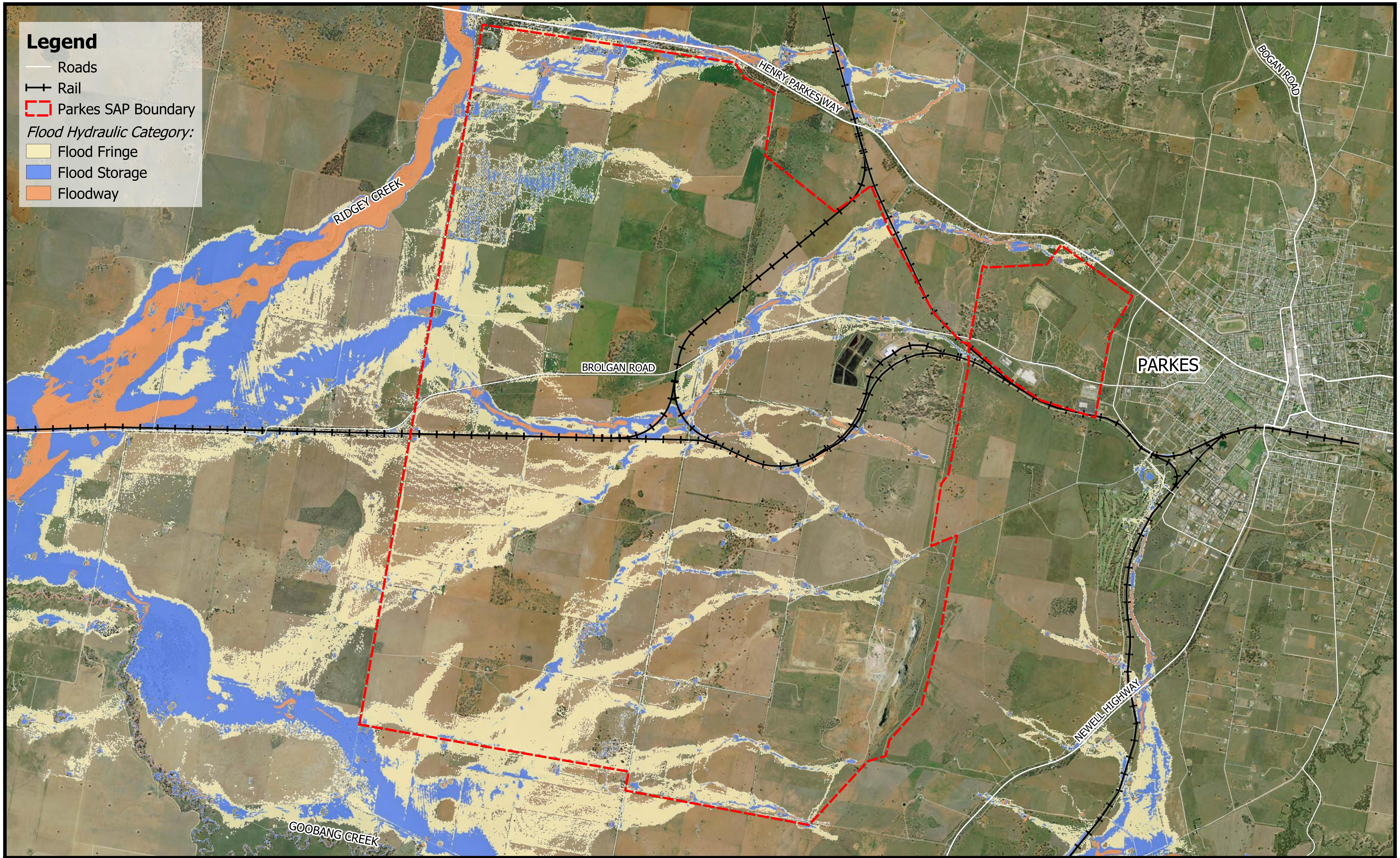

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Figure B1.4
Existing Conditions - 10% AEP Flood Hydraulic Categorisation

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Coordinate system: GDA 1994 MGA Zone 55
Aerial Source: NSW Six Map
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Figure B2.1
Existing Conditions - 1% AEP Flood Extent and Depth

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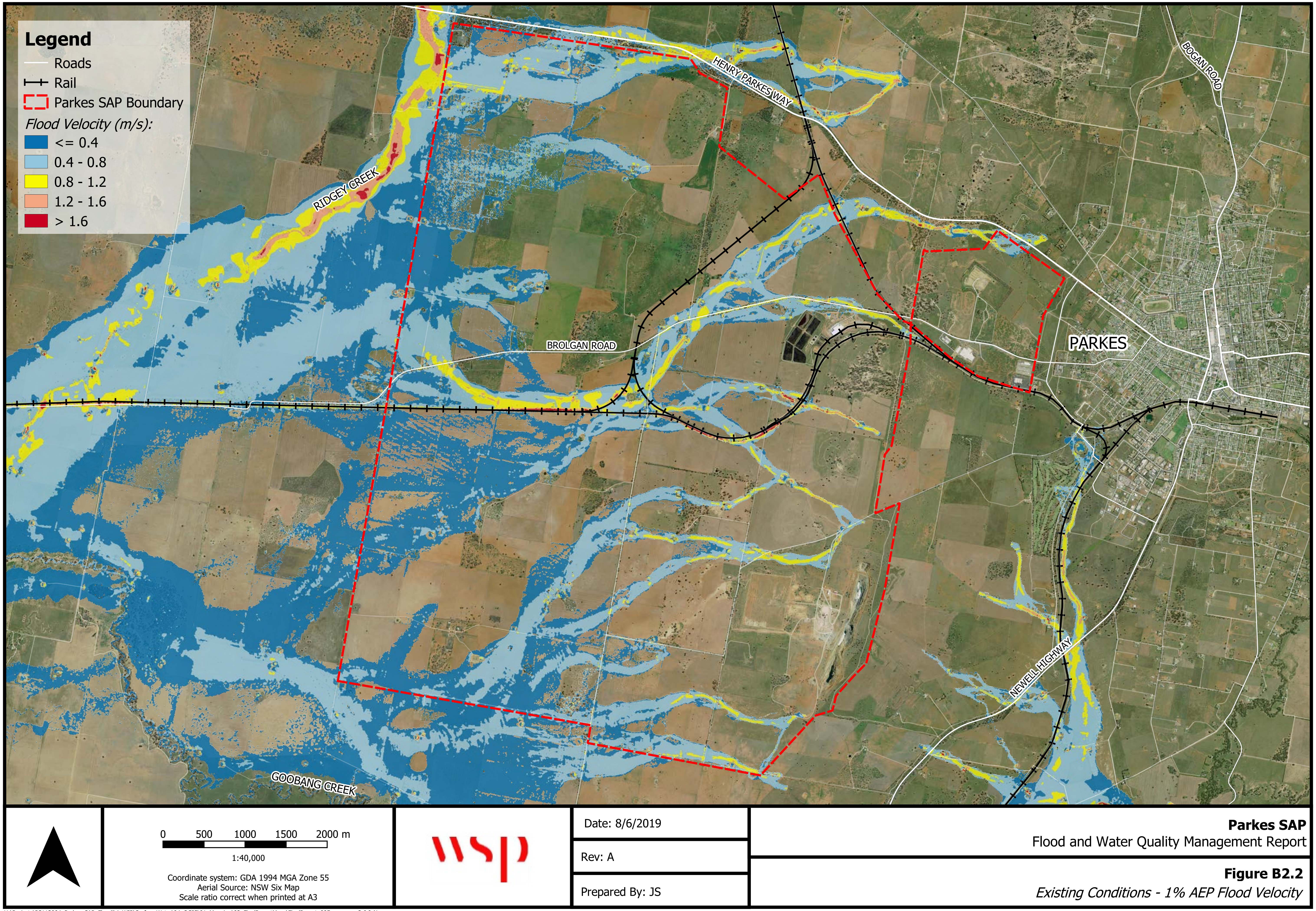

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Figure B2.2

Existing Conditions - 1% AEP Flood Velocity

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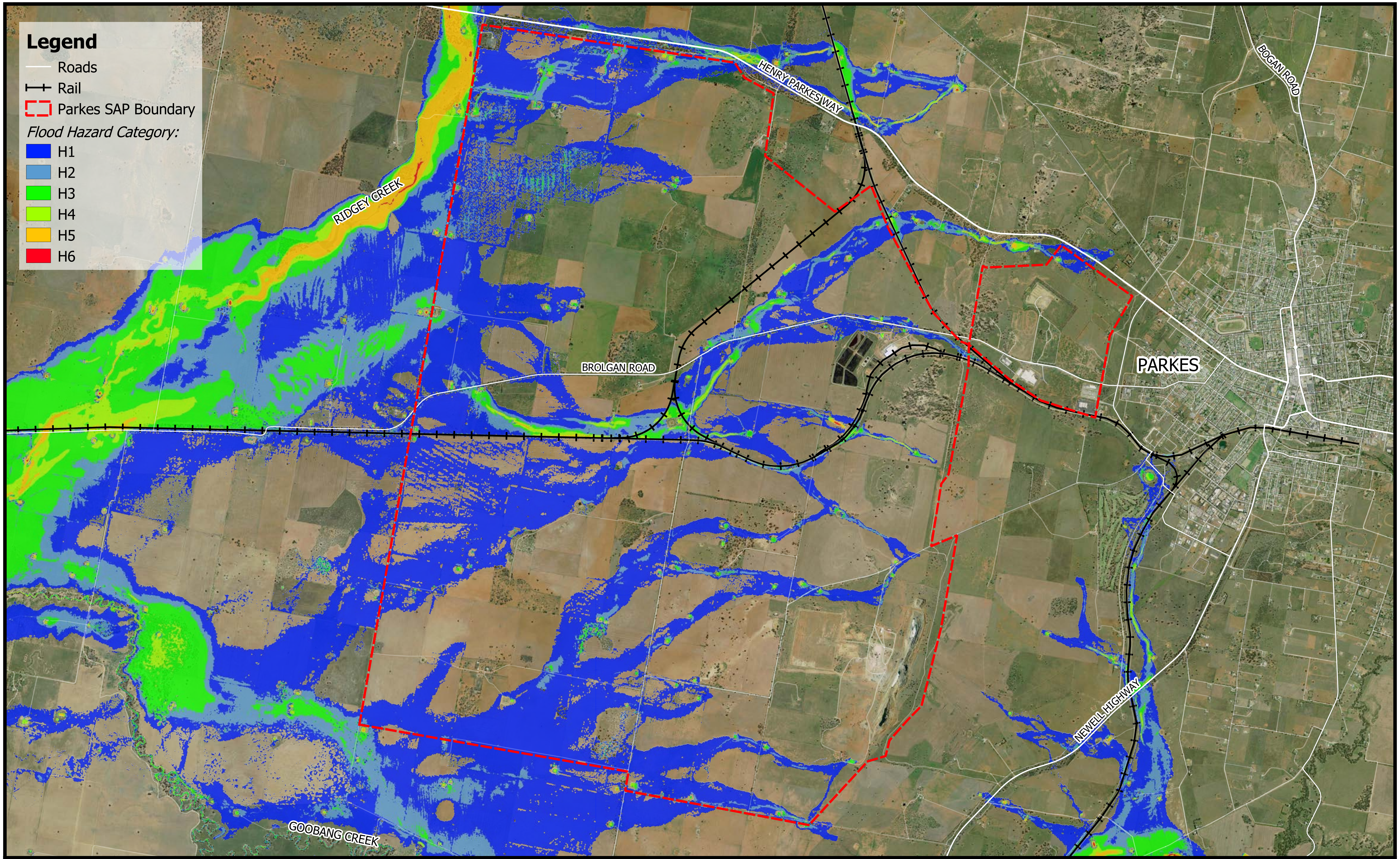

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Scale ratio correct when printed at A3

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Figure B2.3
Existing Conditions - 1% AEP Flood Hazard

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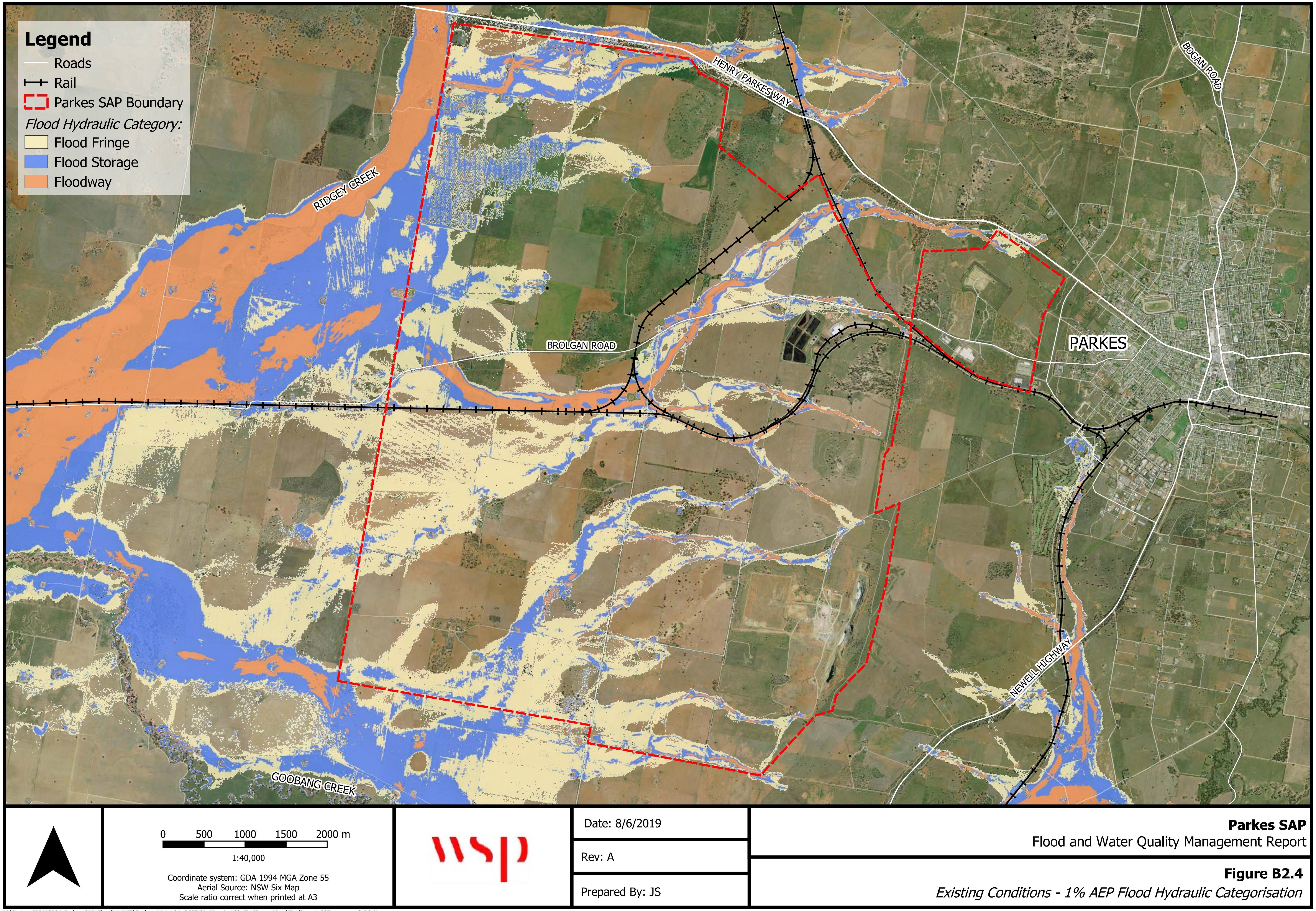

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Figure B2.4
Existing Conditions - 1% AEP Flood Hydraulic Categorisation

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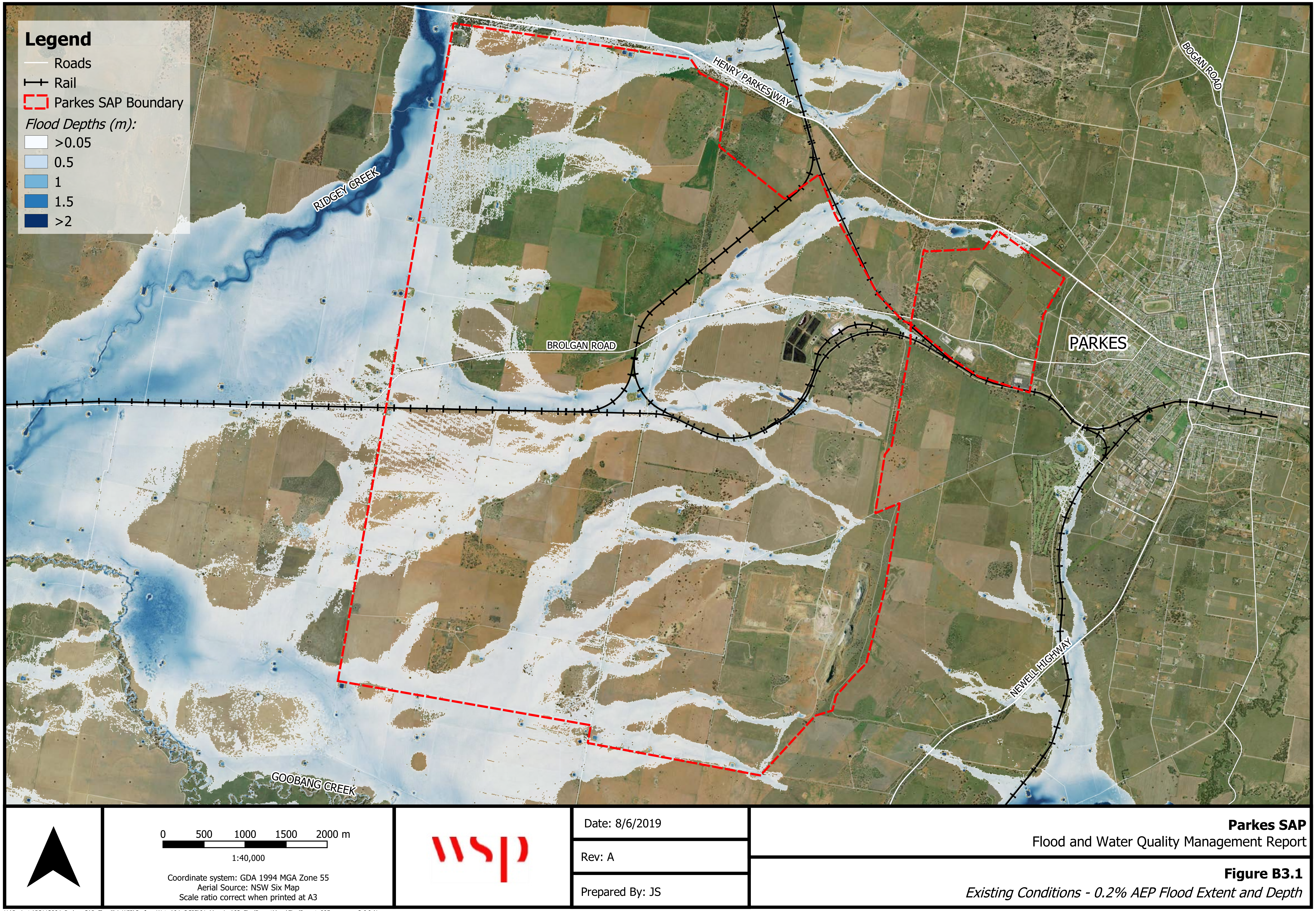

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Figure B3.1
Existing Conditions - 0.2% AEP Flood Extent and Depth

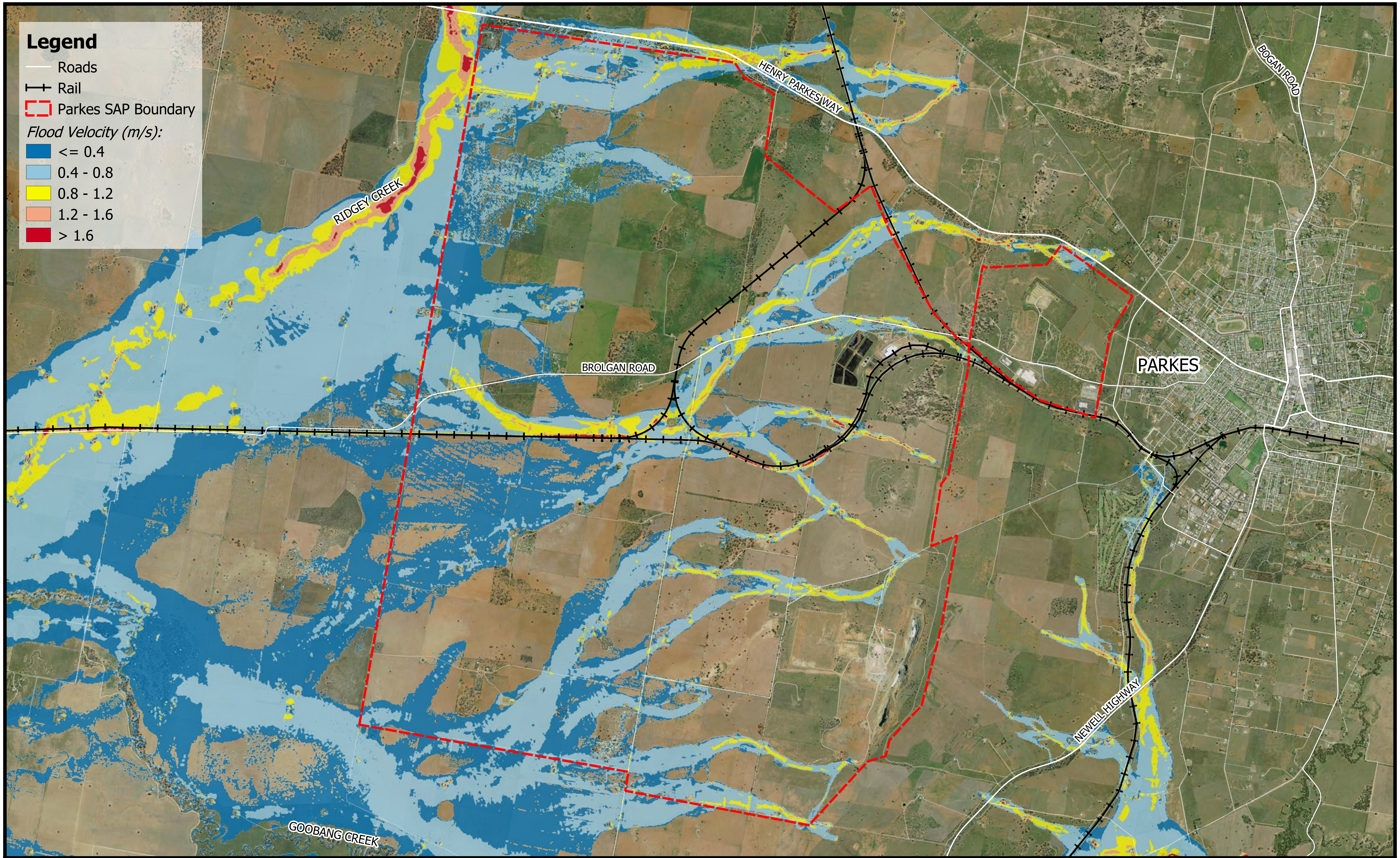

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Figure B3.2
Existing Conditions - 0.2% AEP Flood Velocity

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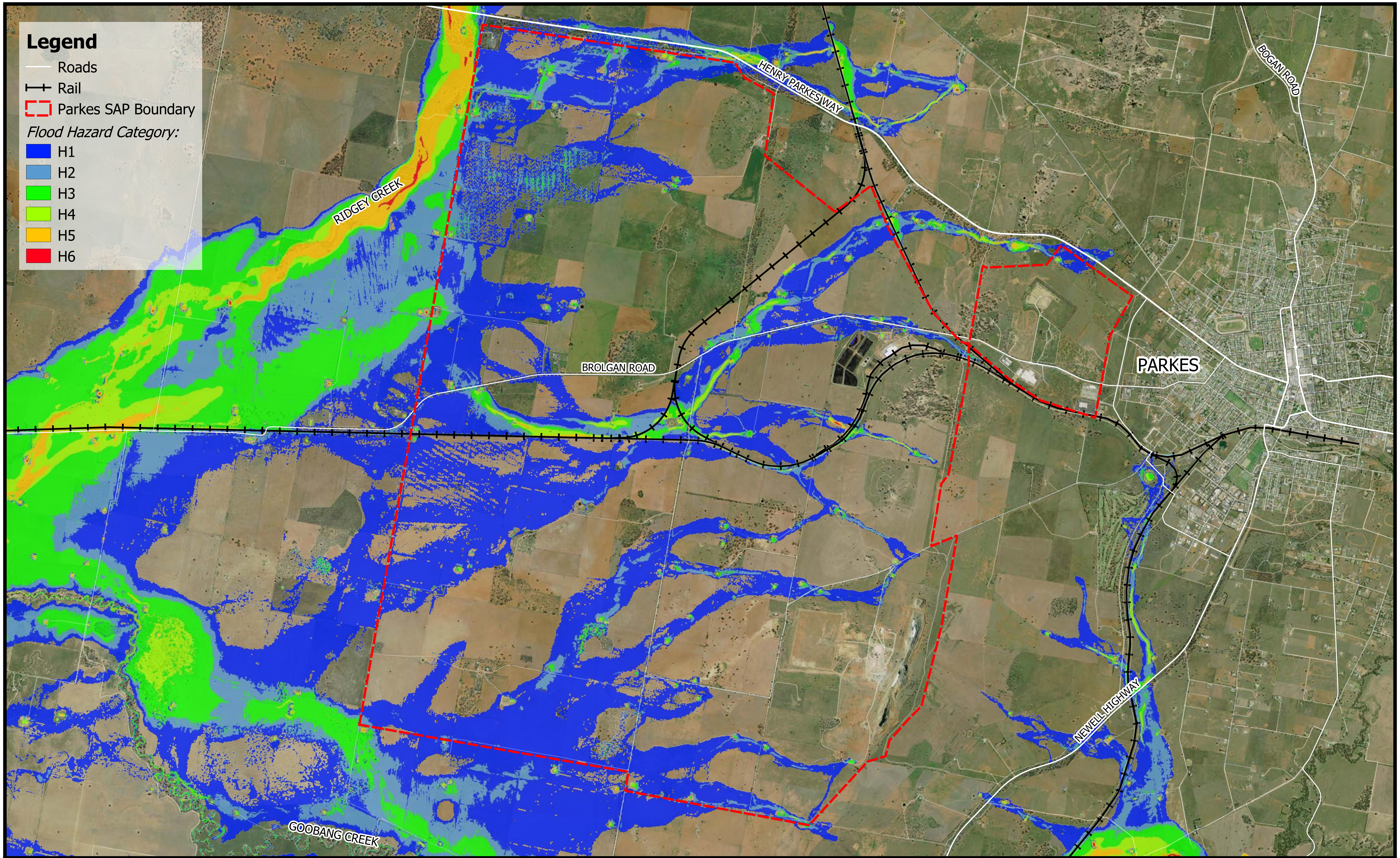

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Scale ratio correct when printed at A3

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Figure B3.3
Existing Conditions - 0.2% AEP Flood Hazard

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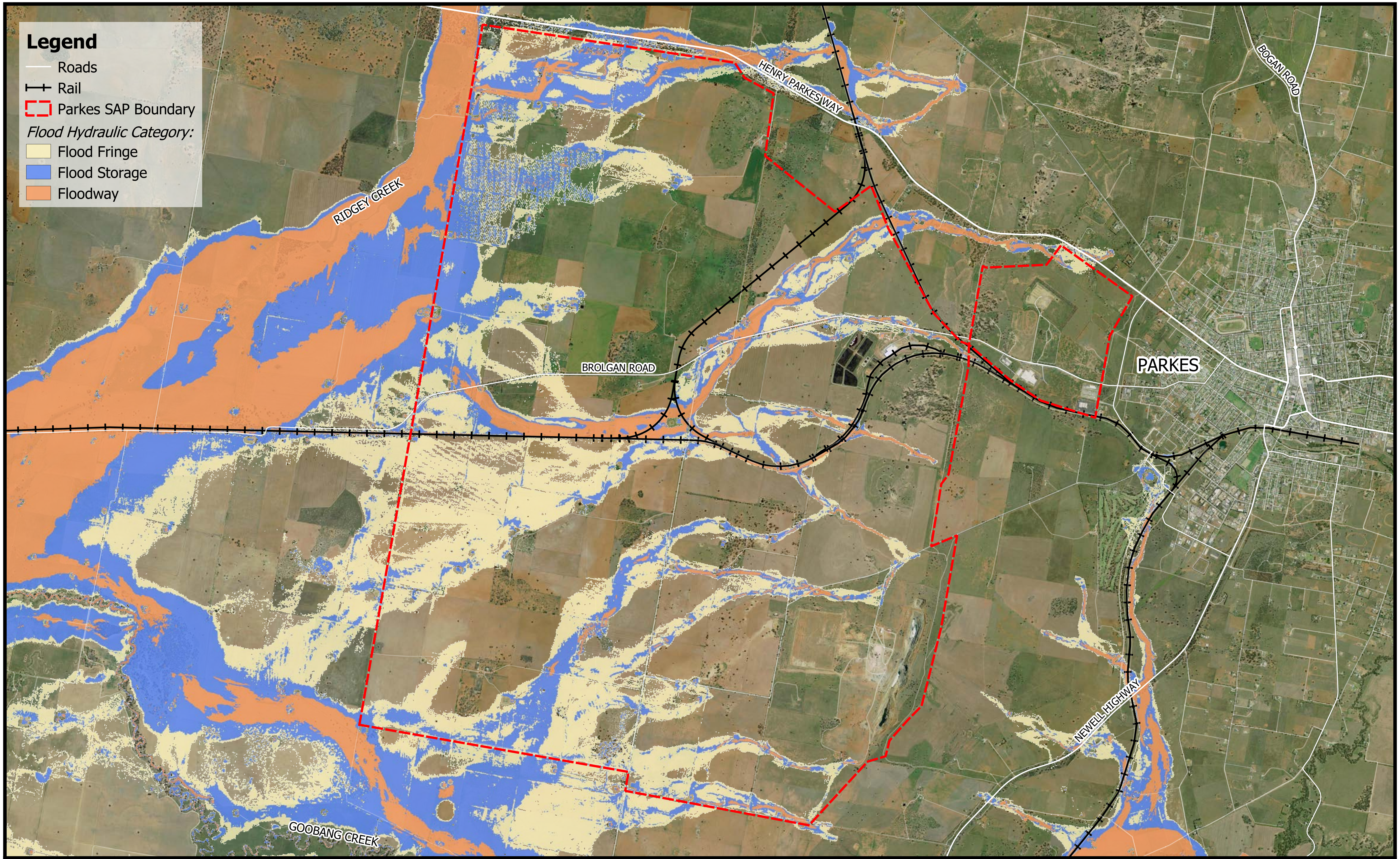

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Figure B3.4
Existing Conditions - 0.2% AEP Flood Hydraulic Categorisation

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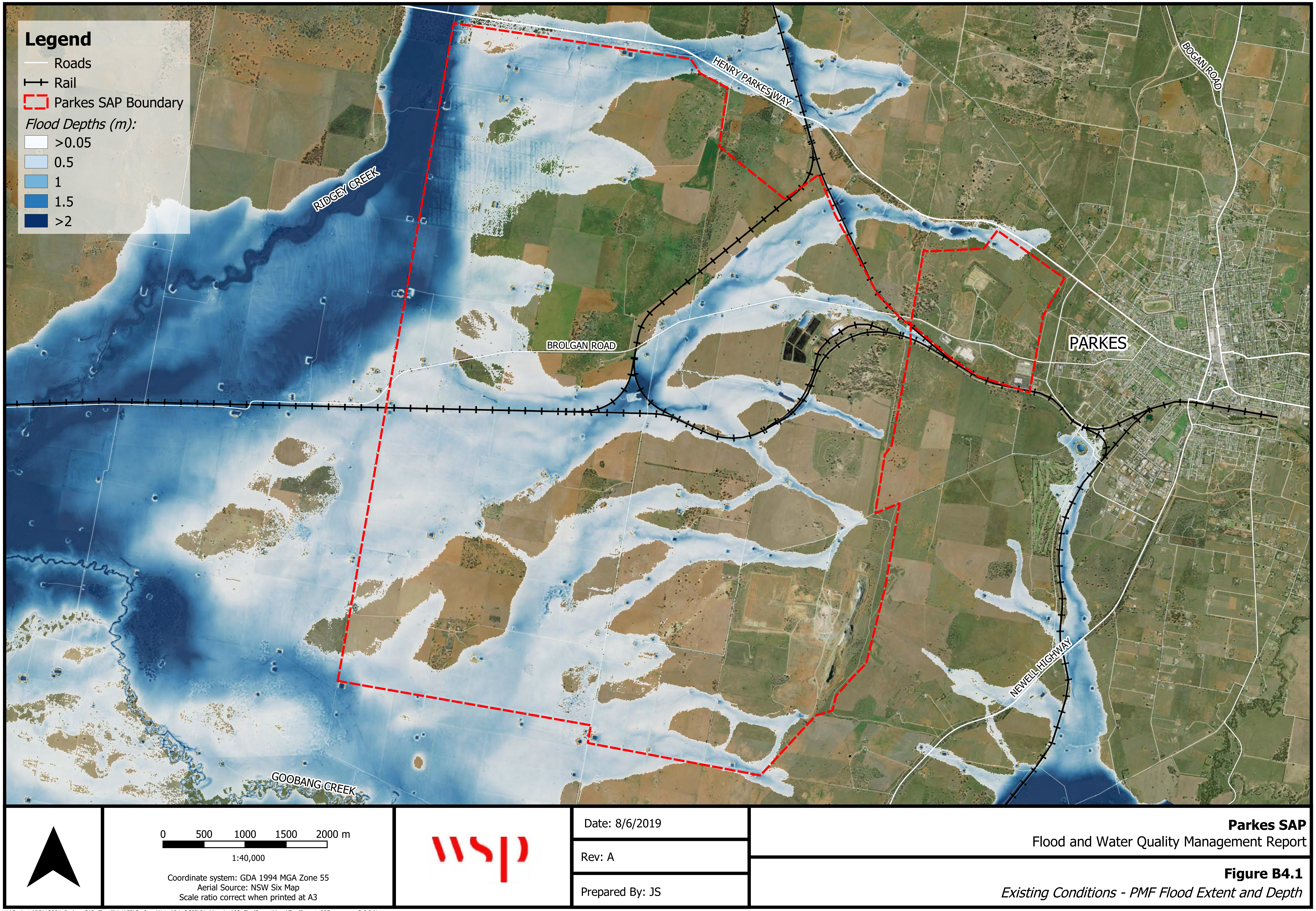

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Figure B4.1

Existing Conditions - PMF Flood Extent and Depth

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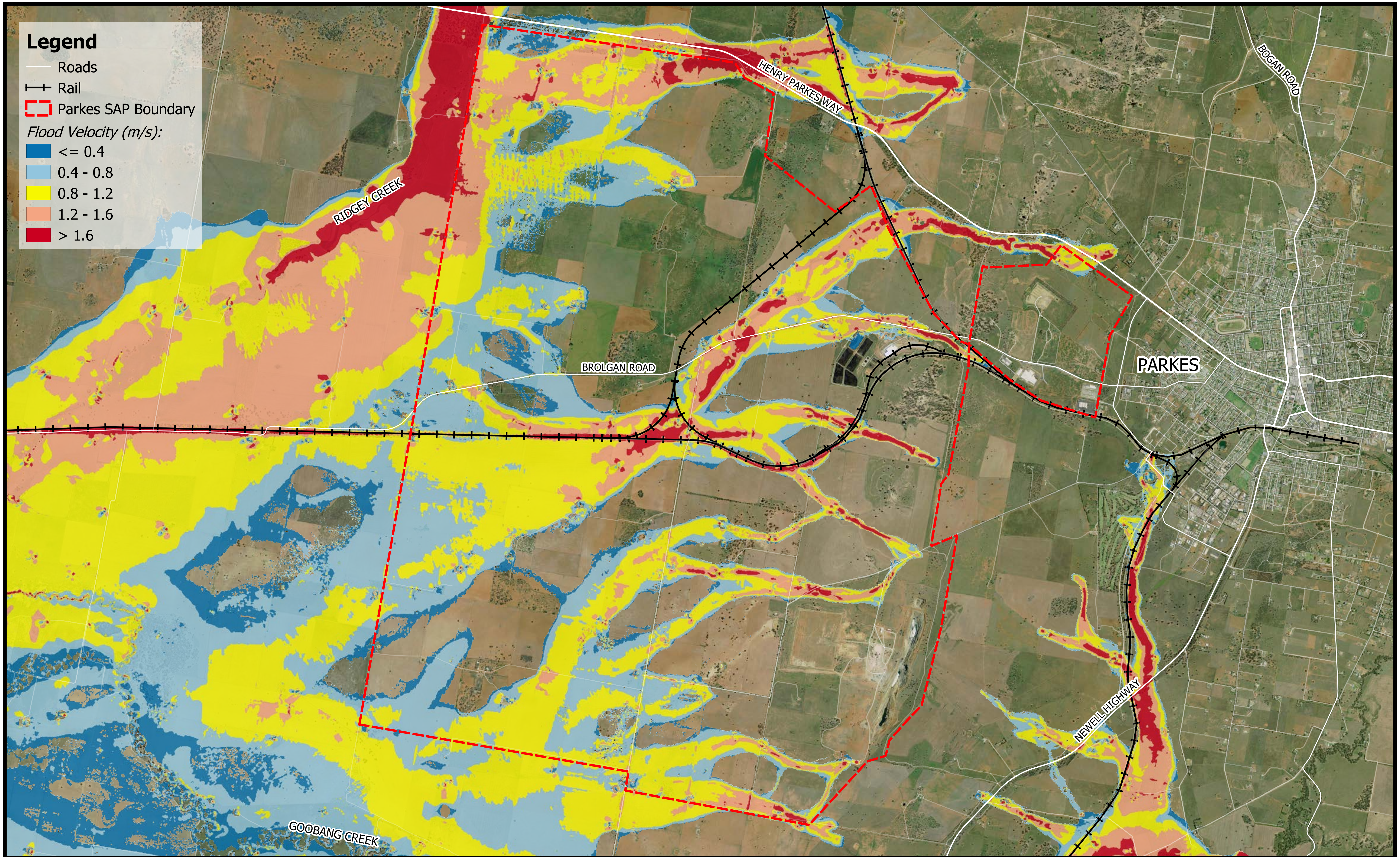

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Coordinate system: GDA 1994 MGA Zone 55
Aerial Source: NSW Six Map
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Figure B4.2
Existing Conditions - PMF Flood Velocity

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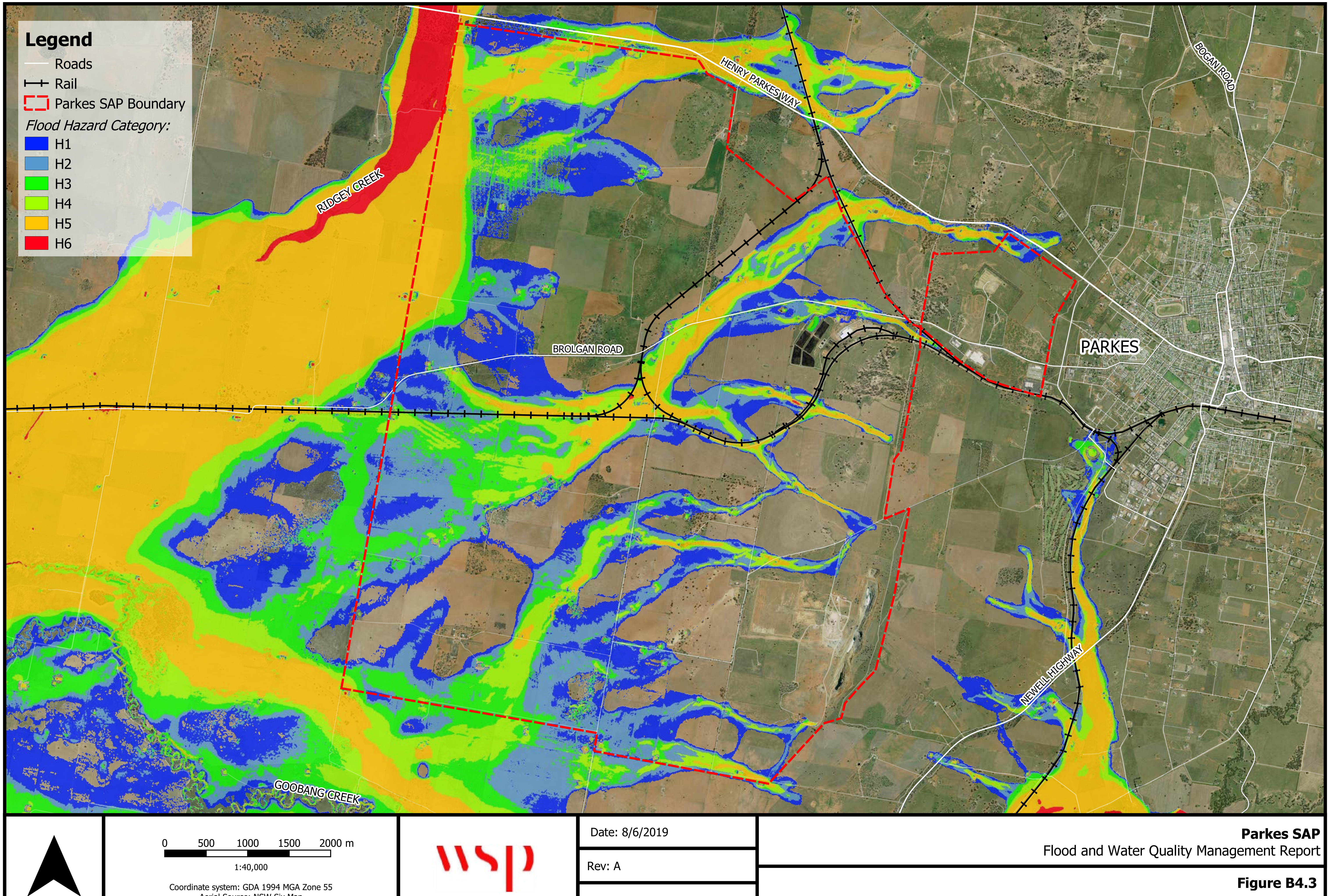

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Scale ratio correct when printed at A3

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Figure B4.3
Existing Conditions - PMF Flood Hazard

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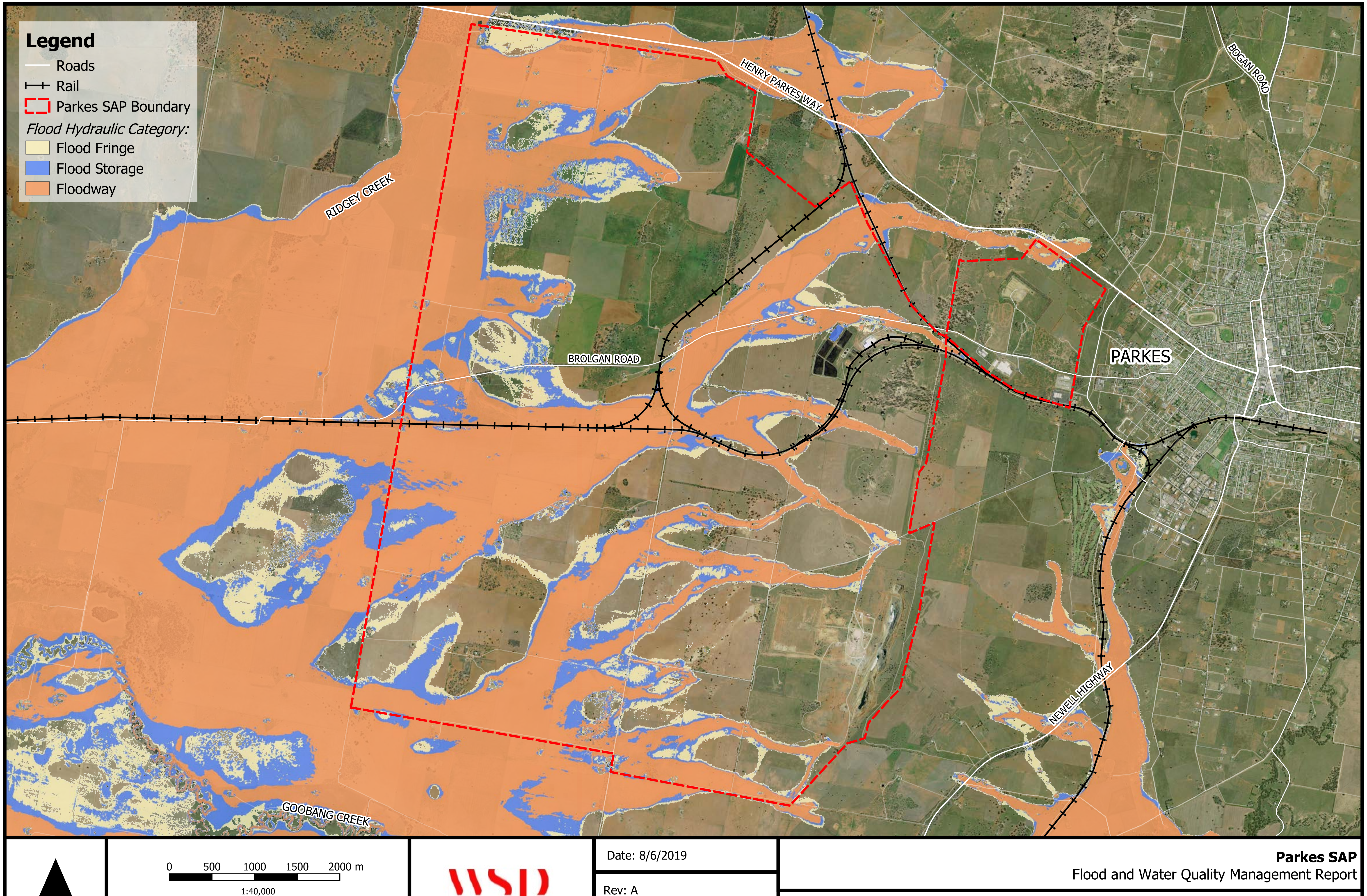

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Scale ratio correct when printed at A3

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Figure B4.4
Existing Conditions - PMF Flood Hydraulic Categorisation

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APPENDIX C

MASTER PLAN SCENARIO FLOOD MAPS

CONTENTS

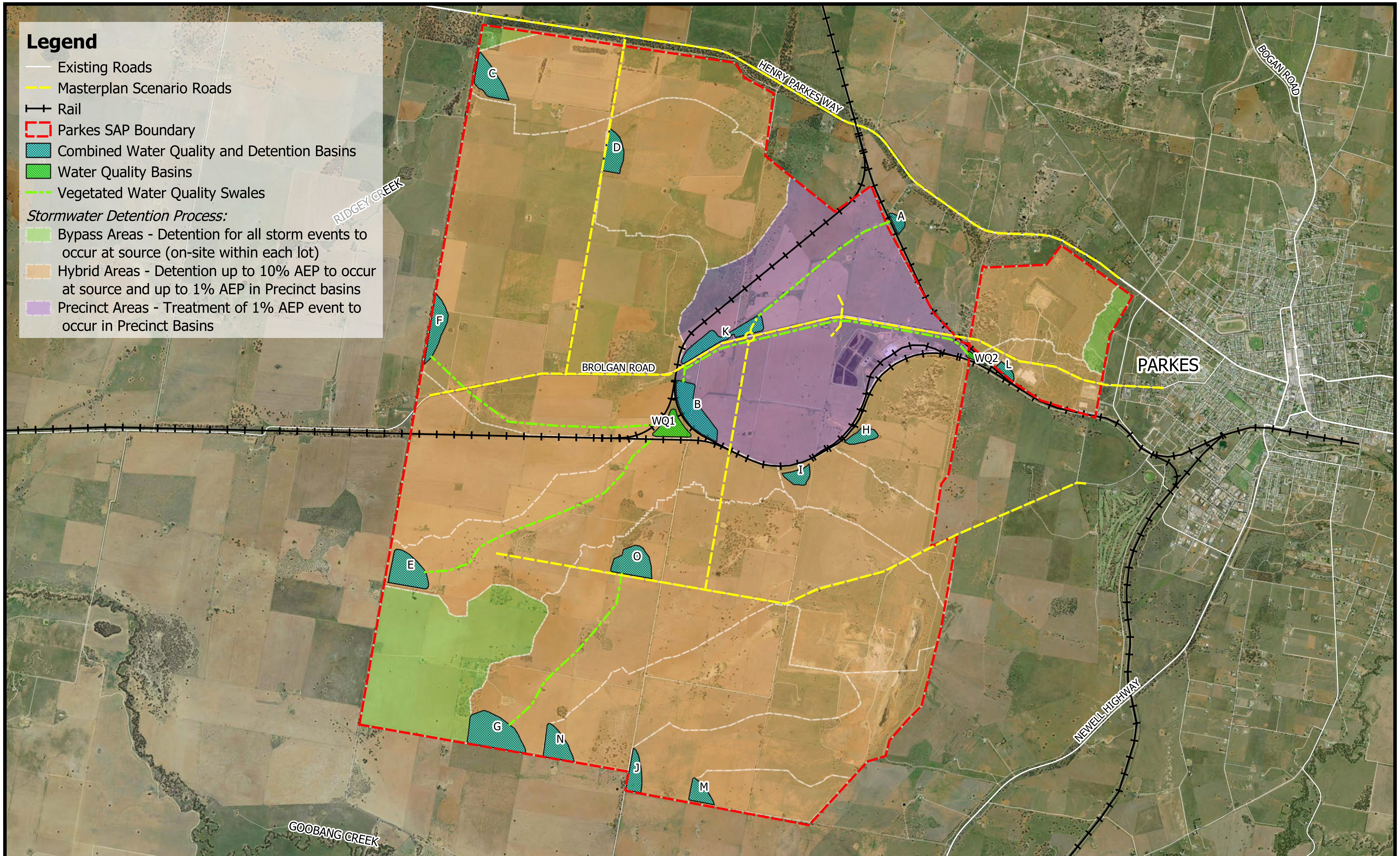

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Figure C0.1
Masterplan Scenario - Master Plan Water Management Infrastructure

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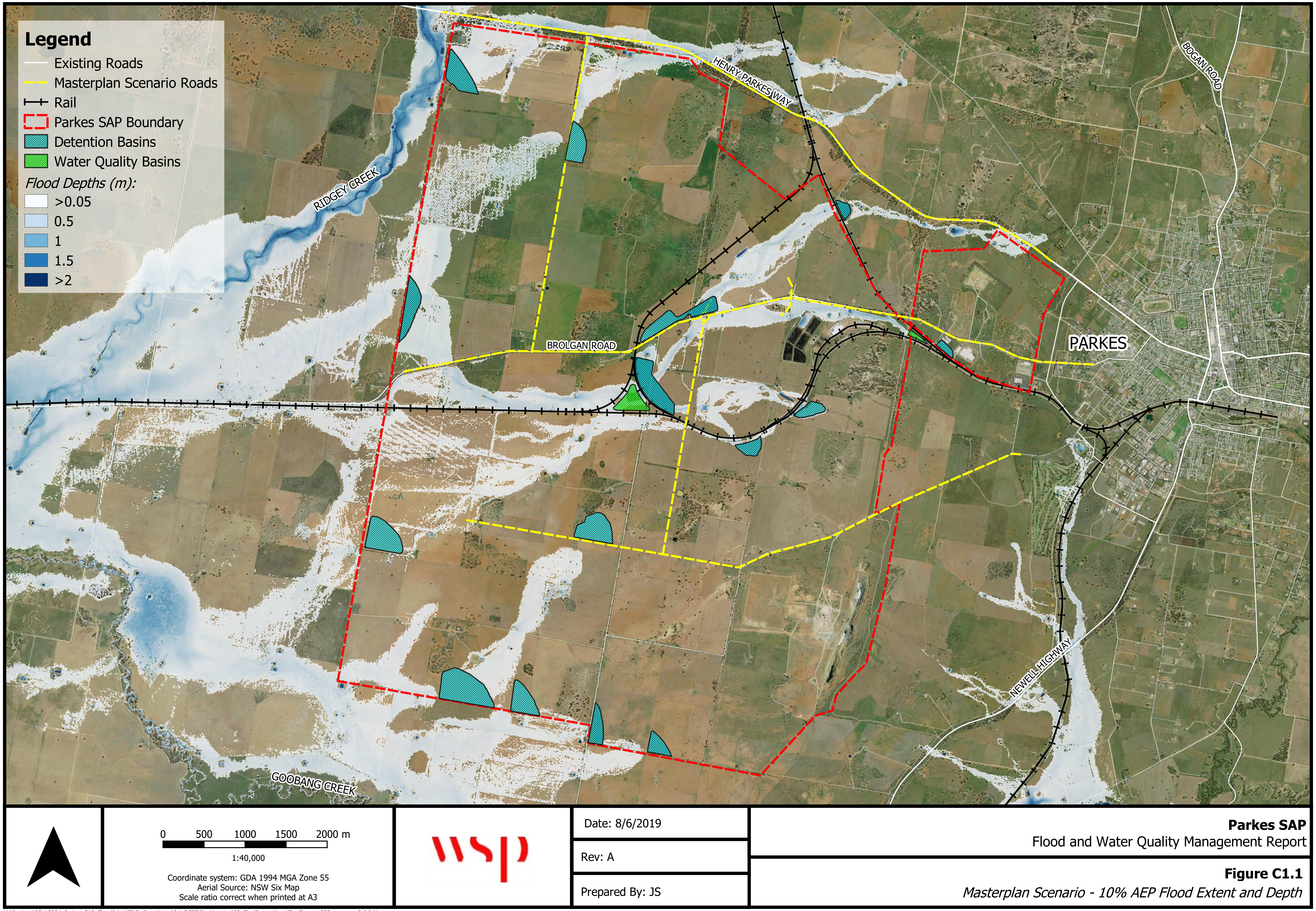

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Prepared By: JS

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Figure C1.1
Masterplan Scenario - 10% AEP Flood Extent and Depth

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Date: 8/6/2019

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Figure C1.2
Masterplan Scenario - 10% AEP Flood Velocity

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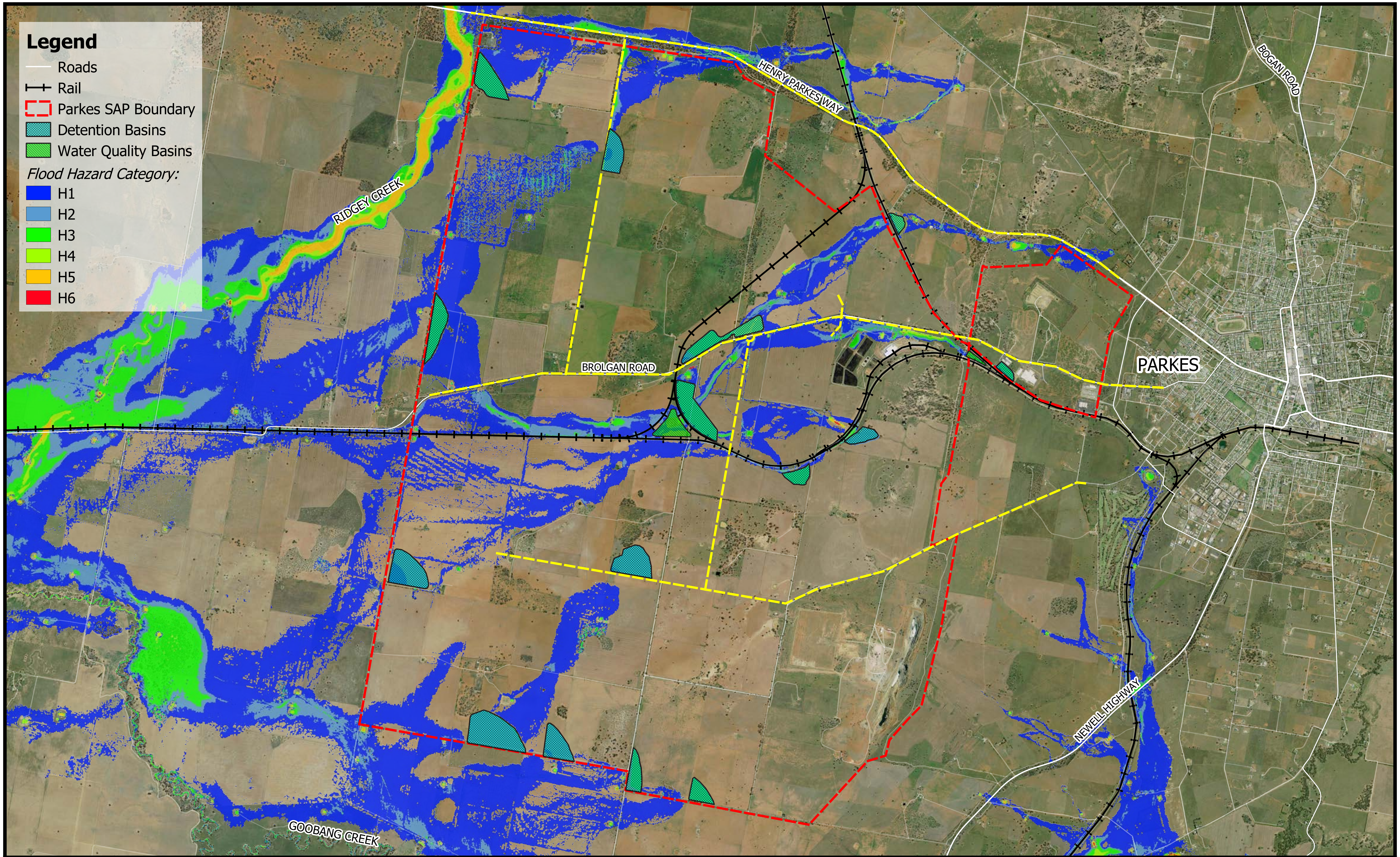

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Figure C1.3
Masterplan Scenario - 10% AEP Flood Hazard

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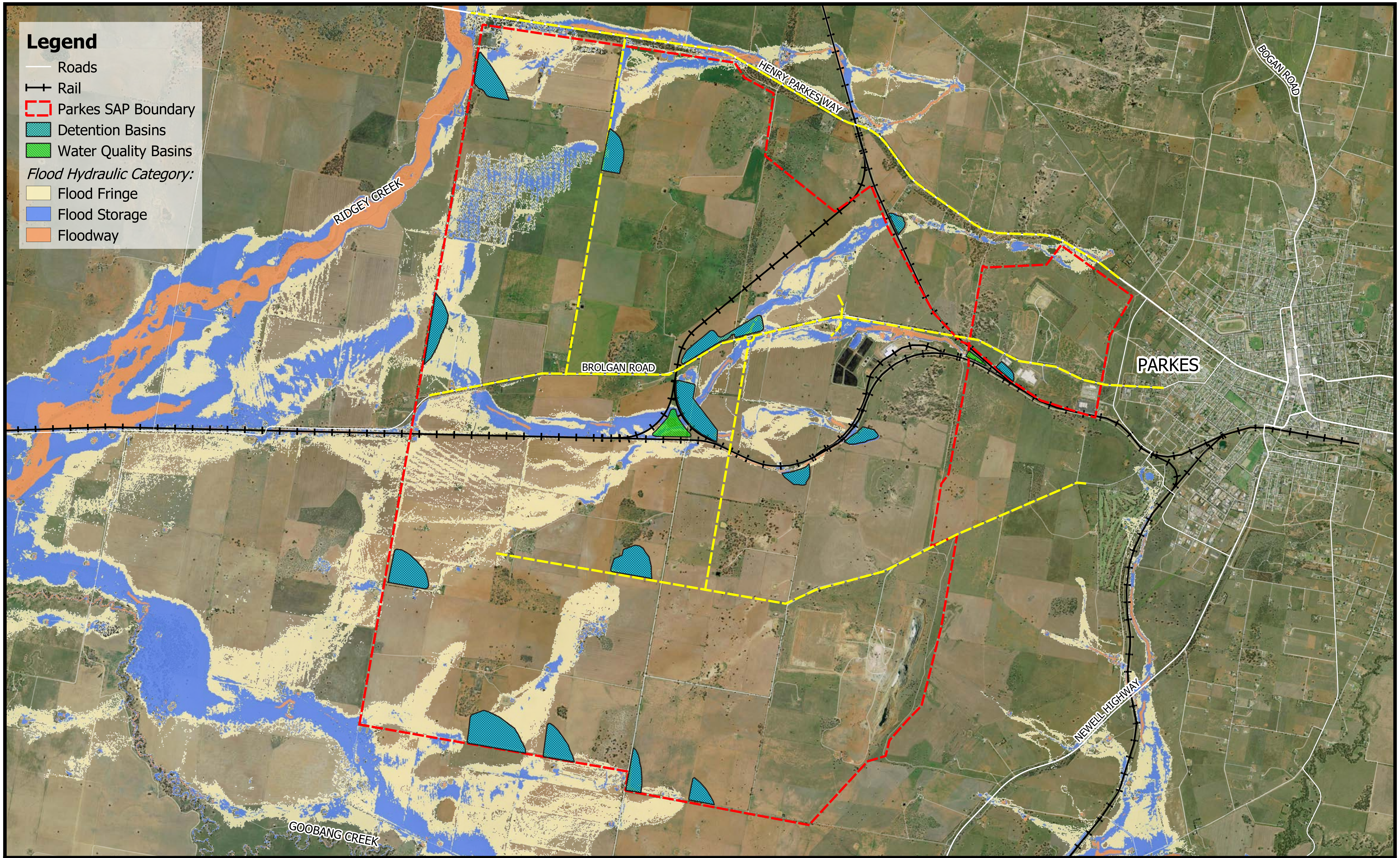

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Flood and Water Quality Management Report

Figure C1.4
Masterplan Scenario - 10% AEP Flood Hydraulic Categorisation

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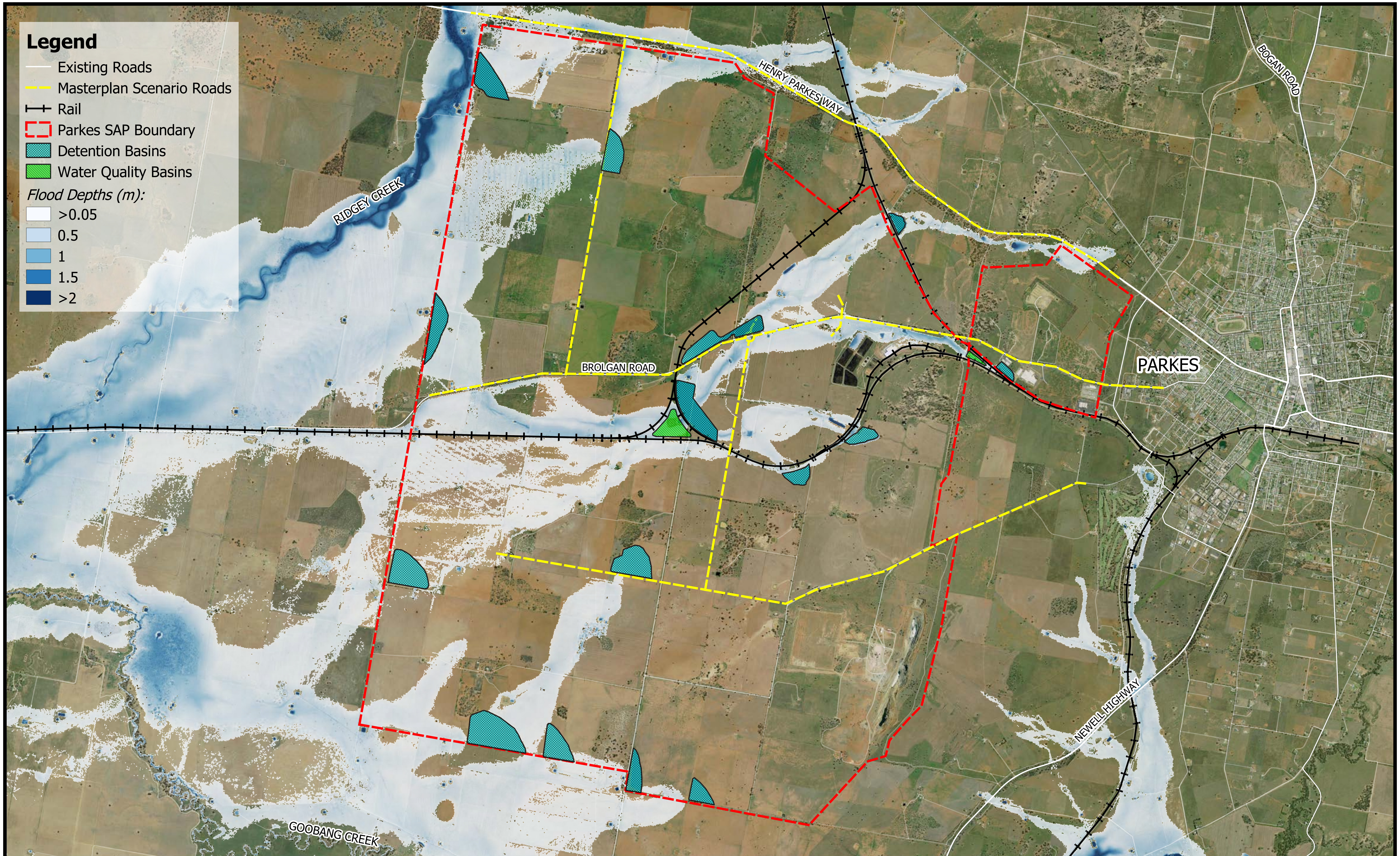

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Figure C2.1
Masterplan Scenario - 1% AEP Flood Extent and Depth

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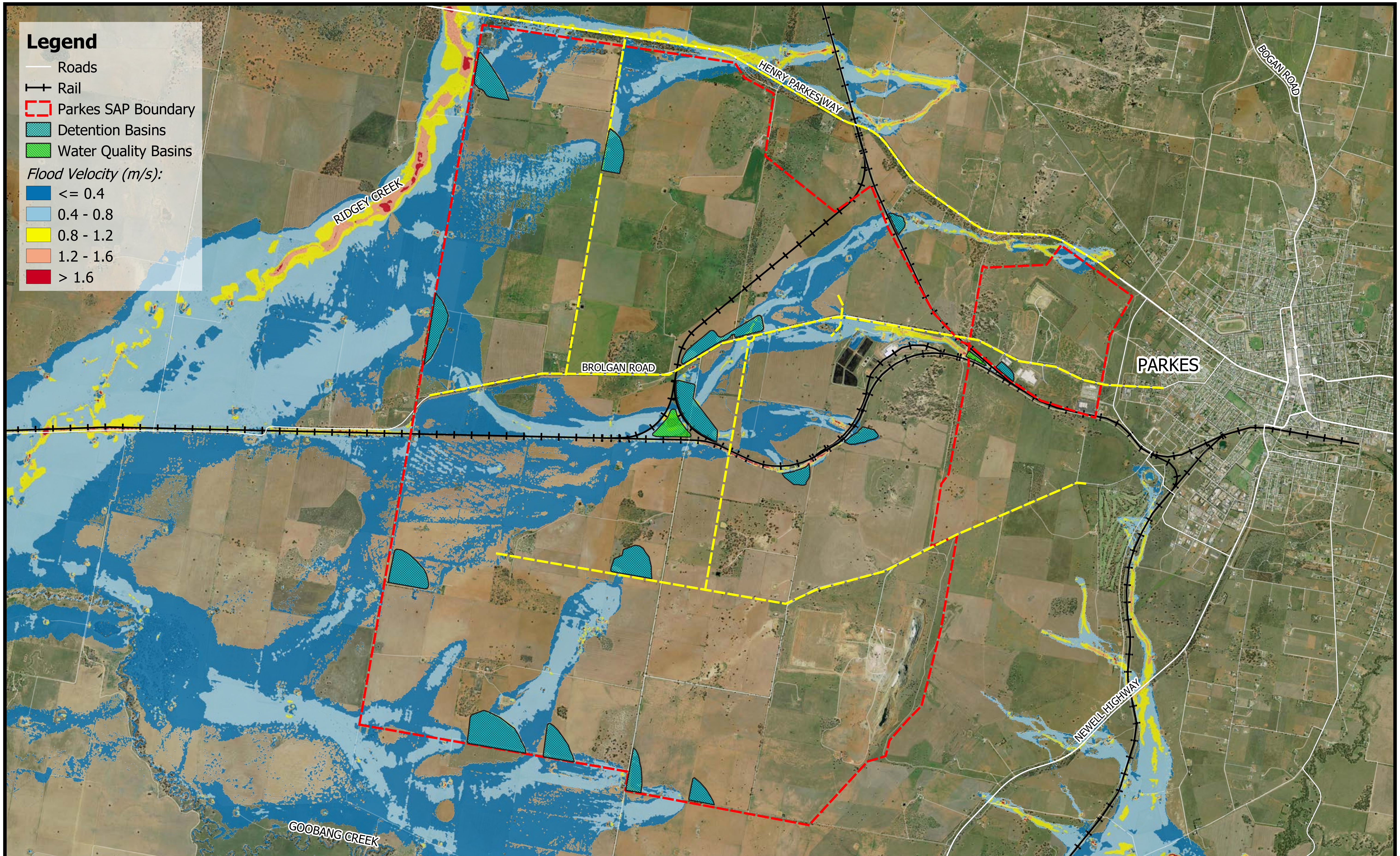

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Scale ratio correct when printed at A3

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Prepared By: JS

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Figure C2.2
Masterplan Scenario - 1% AEP Flood Velocity

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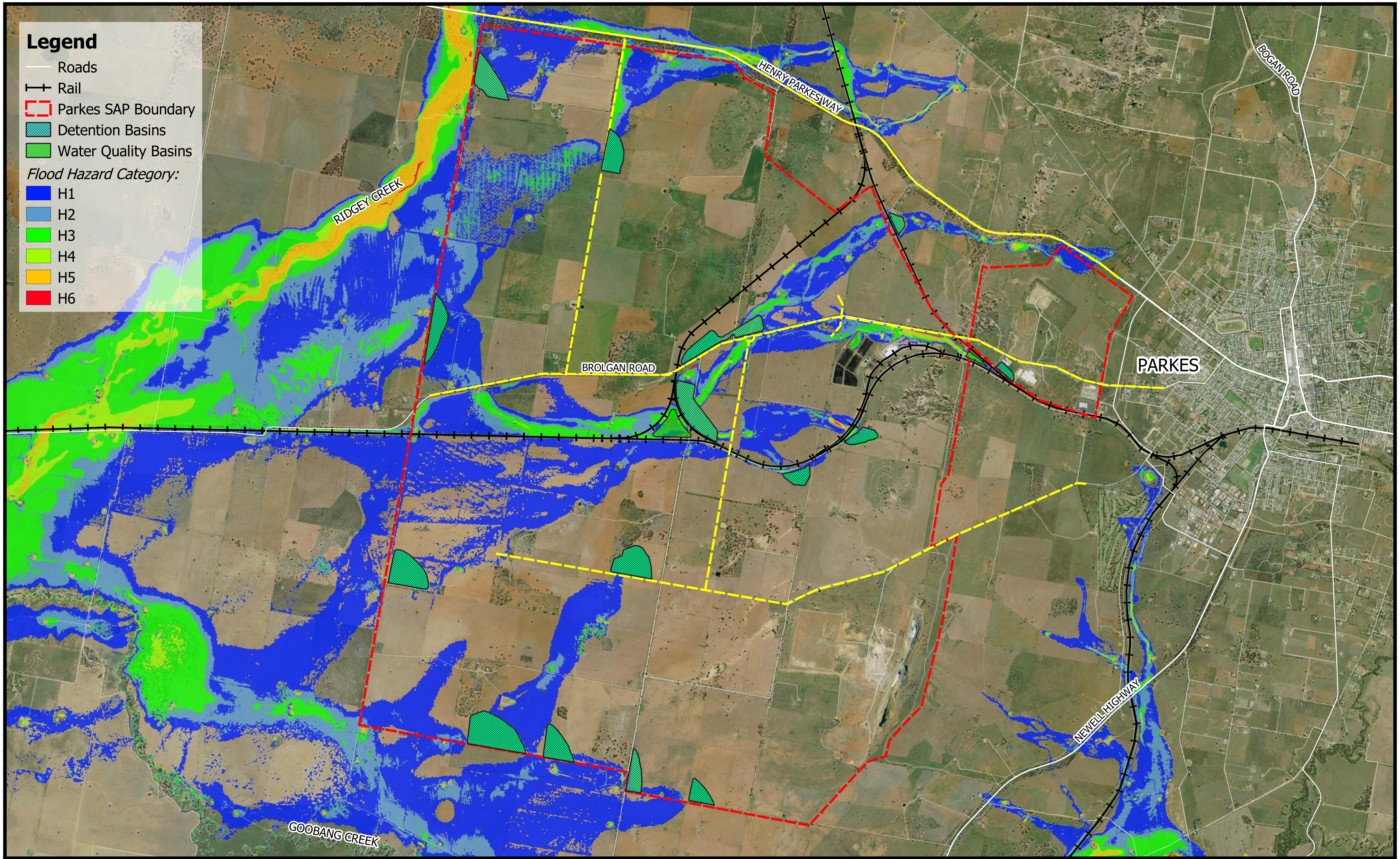

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Flood and Water Quality Management Report

Figure C2.3
Masterplan Scenario - 1% AEP Flood Hazard

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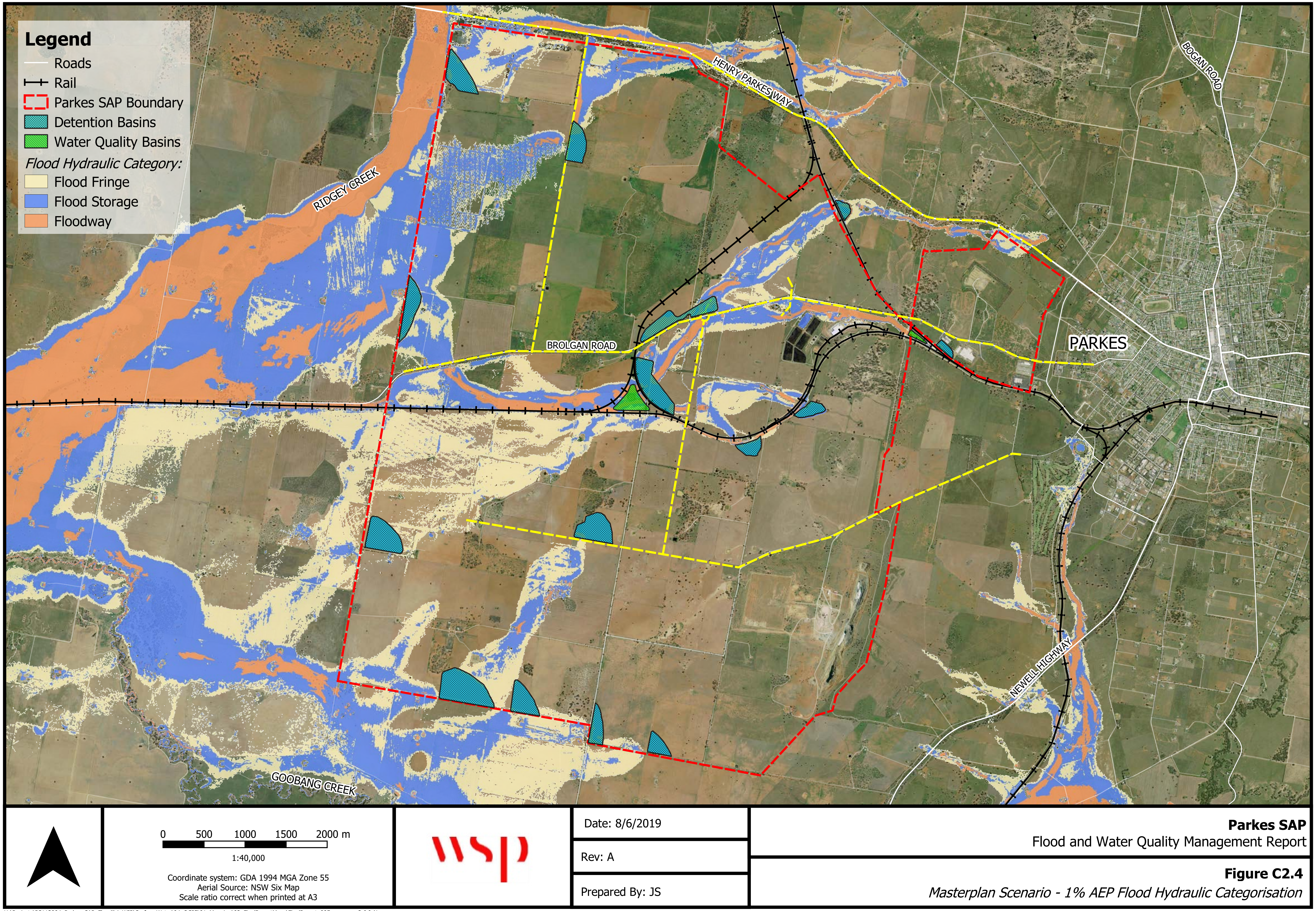

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Flood and Water Quality Management Report

Figure C2.4

Masterplan Scenario - 1% AEP Flood Hydraulic Categorisation

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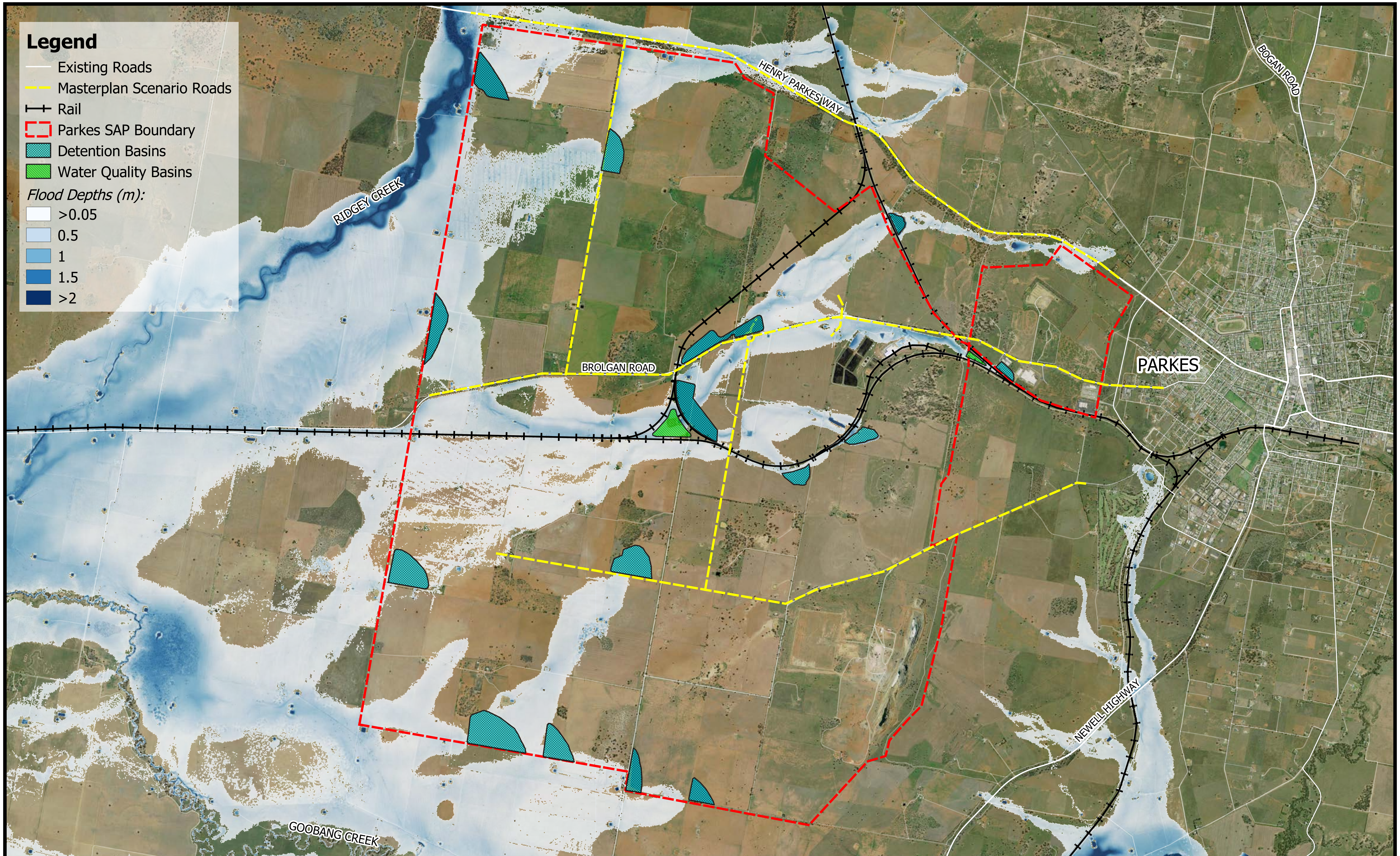

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Aerial Source: NSW Six Map
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Prepared By: JS

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Flood and Water Quality Management Report

Figure C3.1
Masterplan Scenario - 0.2% AEP Flood Extent and Depth

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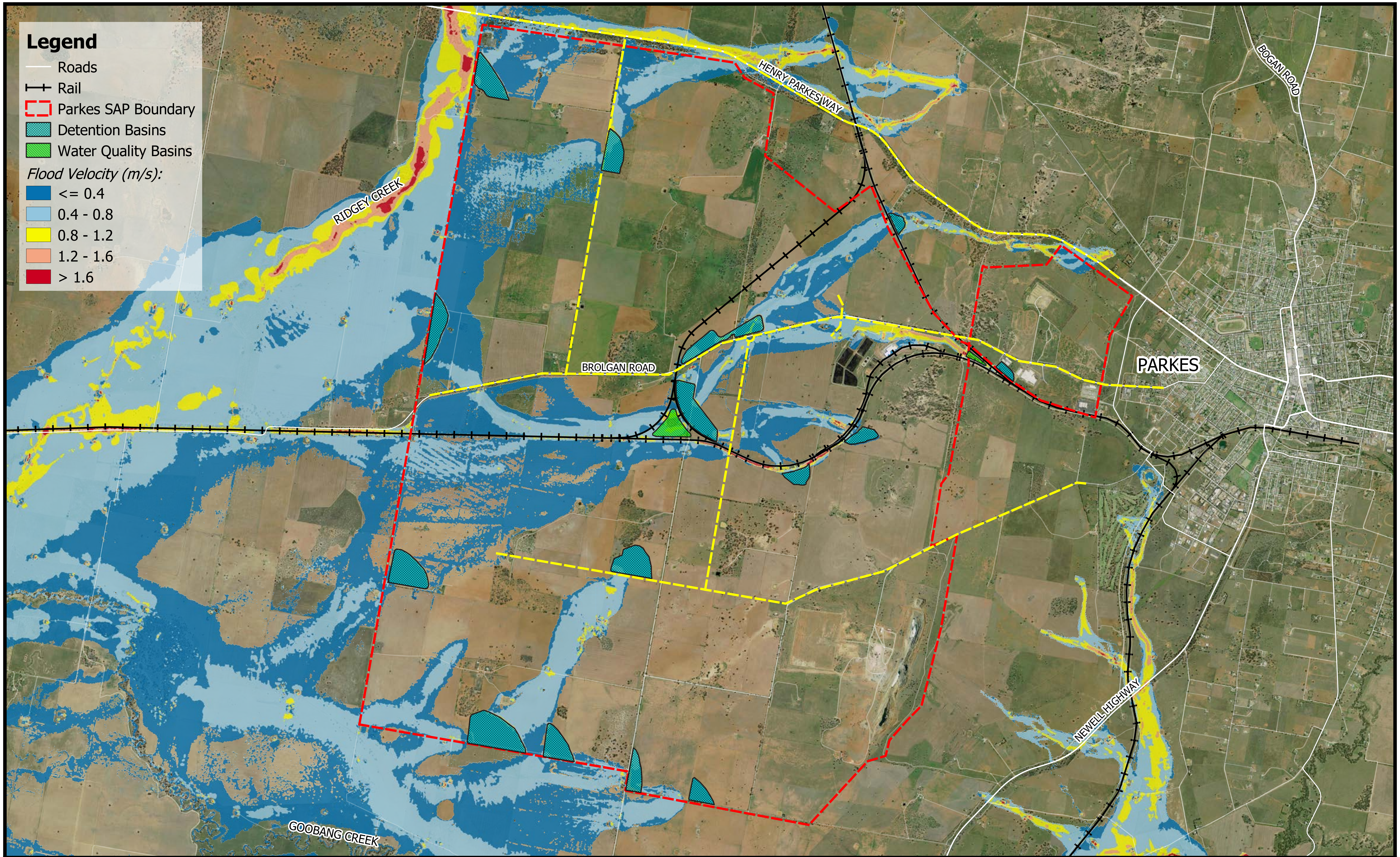

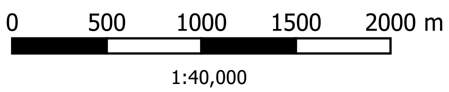

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Prepared By: JS

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Flood and Water Quality Management Report

Figure C3.2
Masterplan Scenario - 0.2% AEP Flood Velocity

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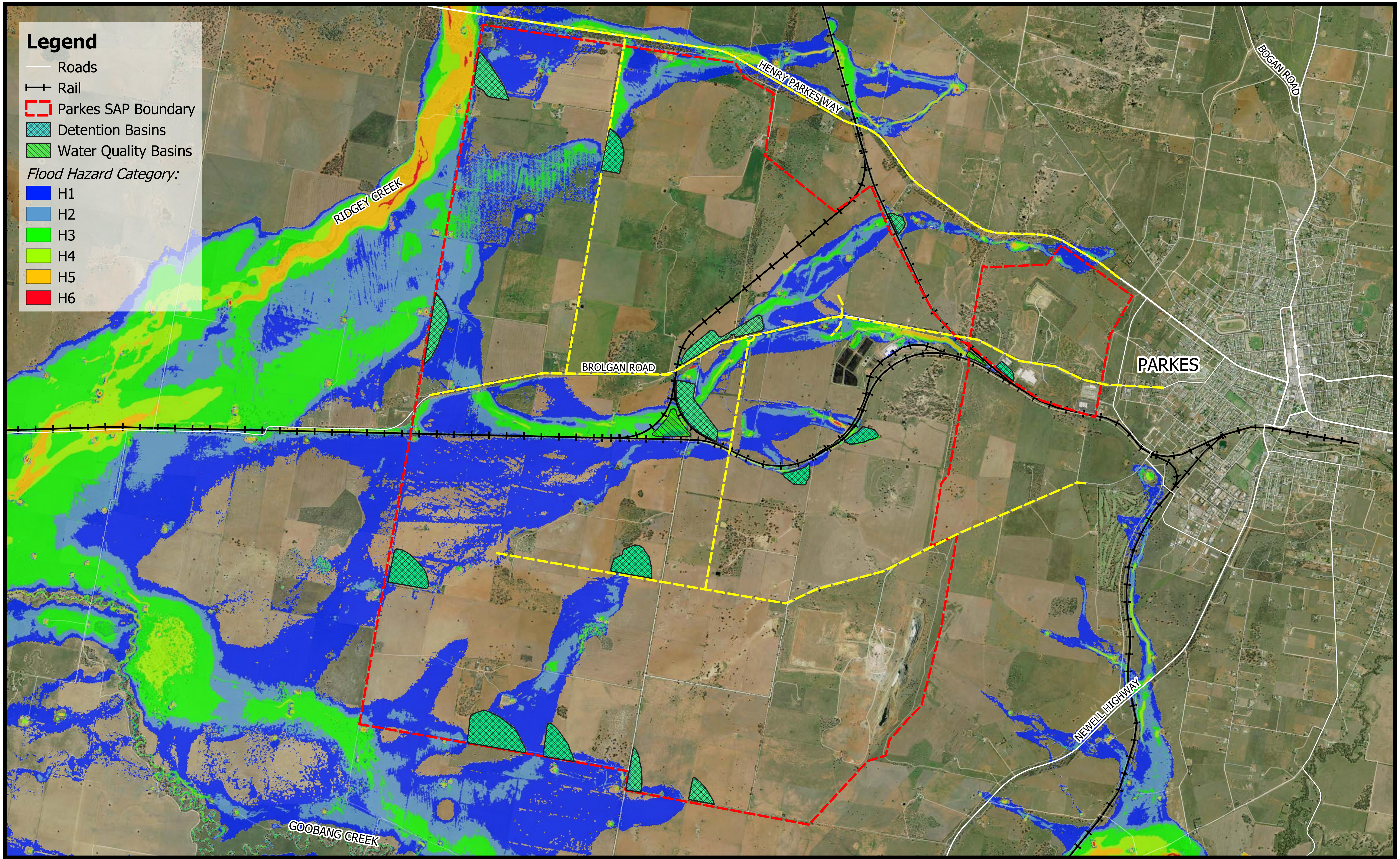

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Figure C3.3
Masterplan Scenario - 0.2% AEP Flood Hazard

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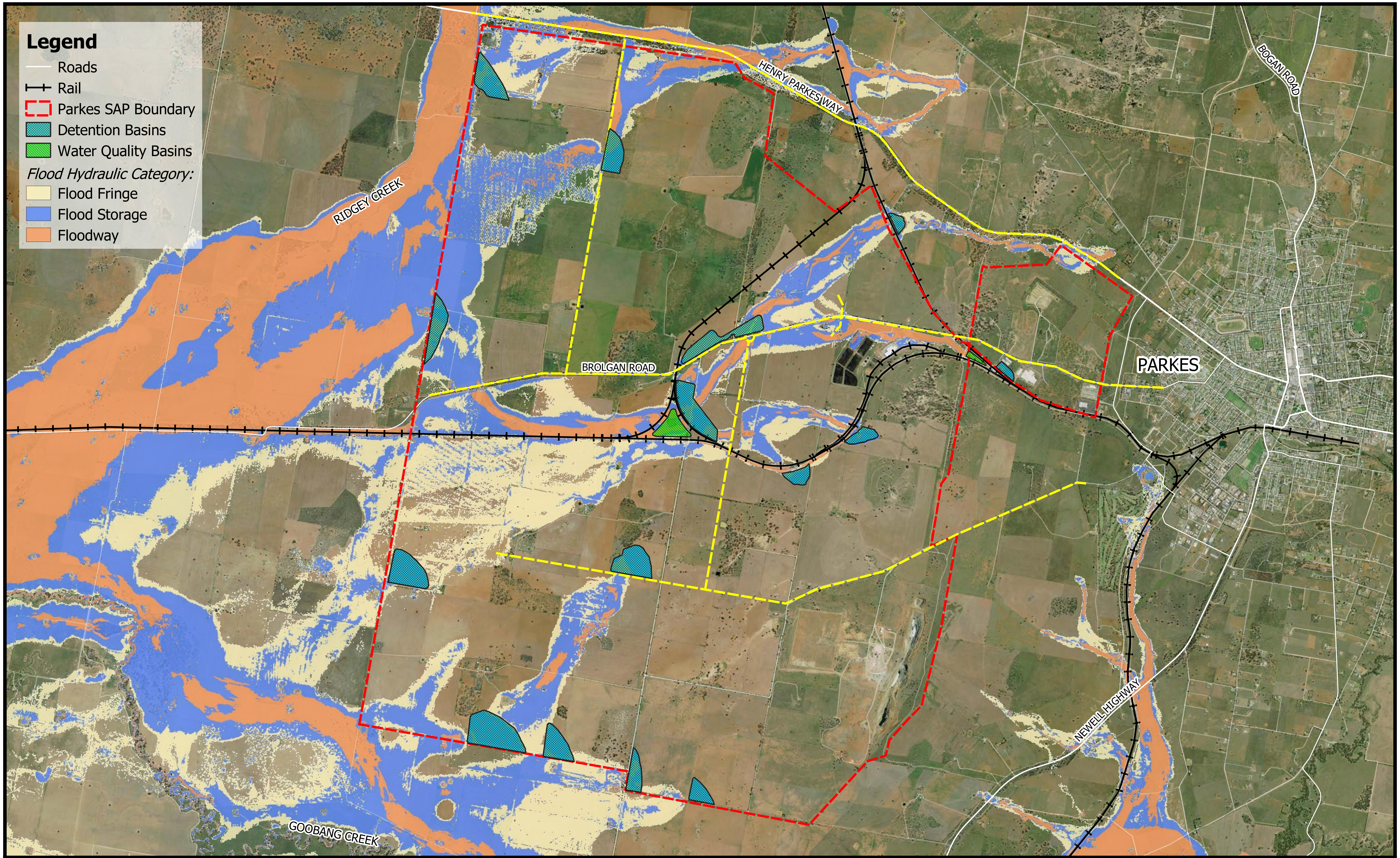

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Figure C3.4

Masterplan Scenario - 0.2% AEP Flood Hydraulic Categorisation

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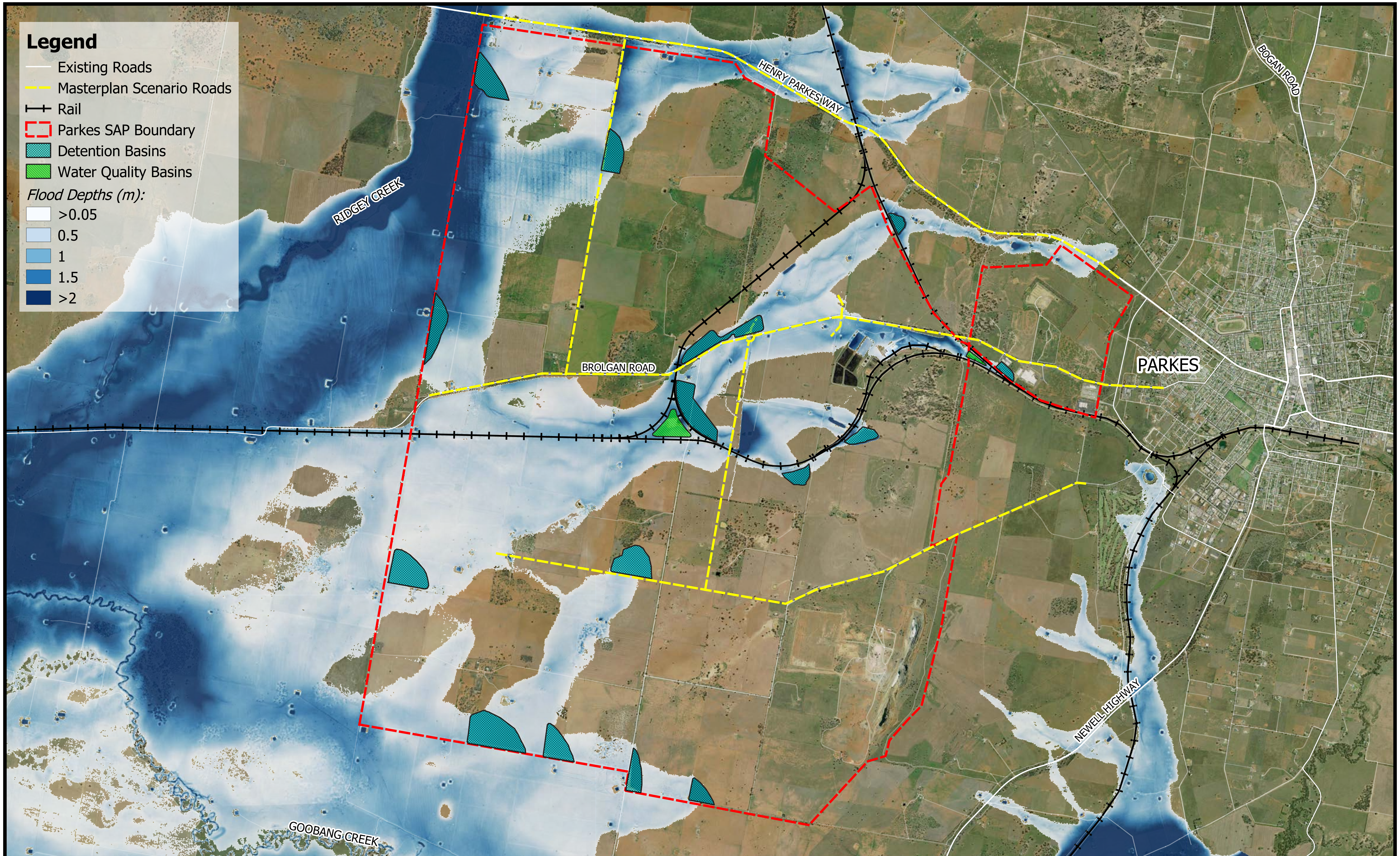

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Coordinate system: GDA 1994 MGA Zone 55
Aerial Source: NSW Six Map
Scale ratio correct when printed at A3

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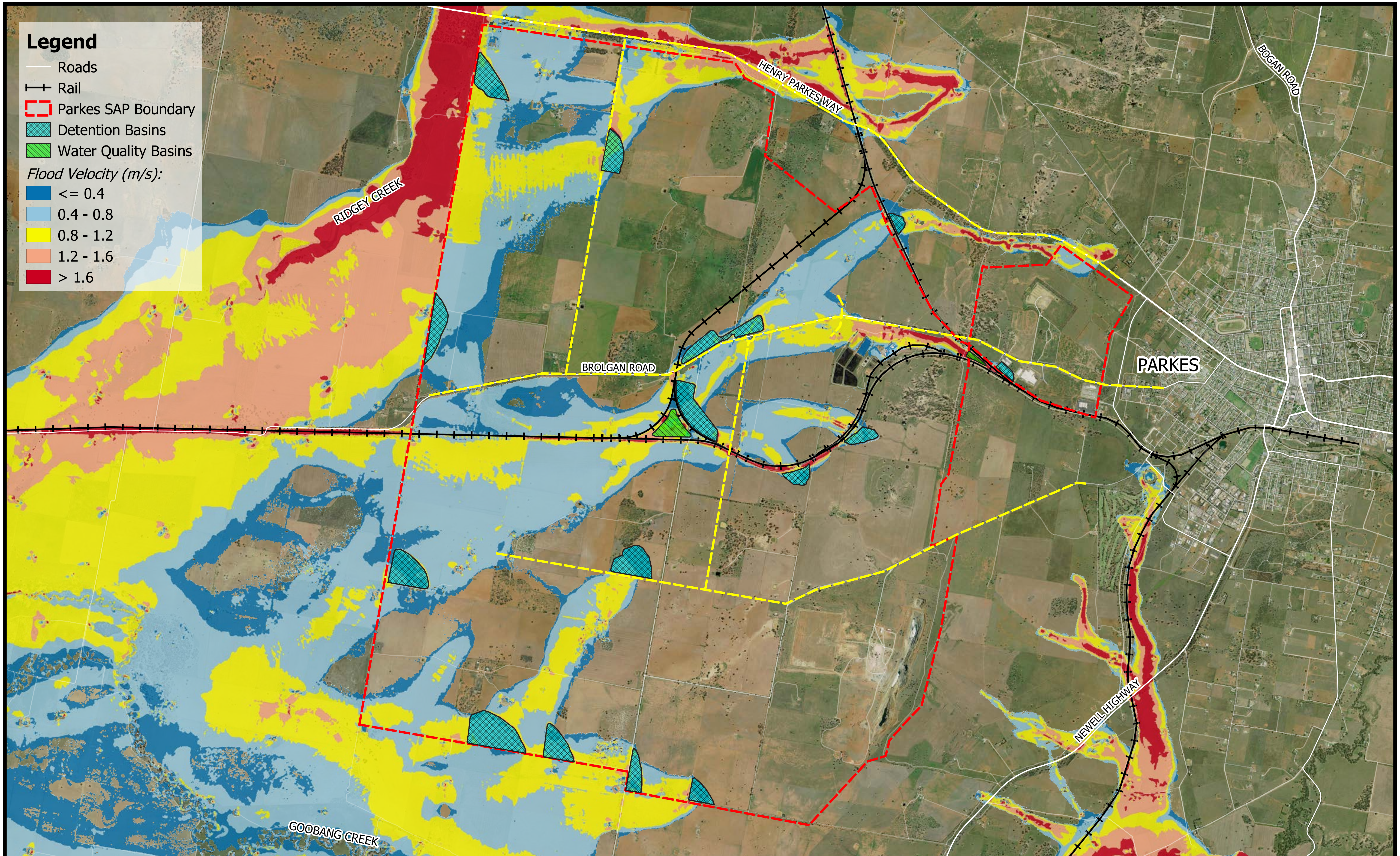
Figure C4.1
Masterplan Scenario - PMF Flood Extent and Depth

U:\Projects\PS113004_Parkes_SAP_Flood\4_WIP\Surface Water\04_QGIS\01_Mapping\02_FinalReportMaps\FinalReport_005.qgs.qgz - 3.6.0-Noosa



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Coordinate system: GDA 1994 MGA Zone 55
Aerial Source: NSW Six Map
Scale ratio correct when printed at A3

Date: 8/6/2019

Rev: A

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Figure C4.2
Masterplan Scenario - PMF Flood Velocity

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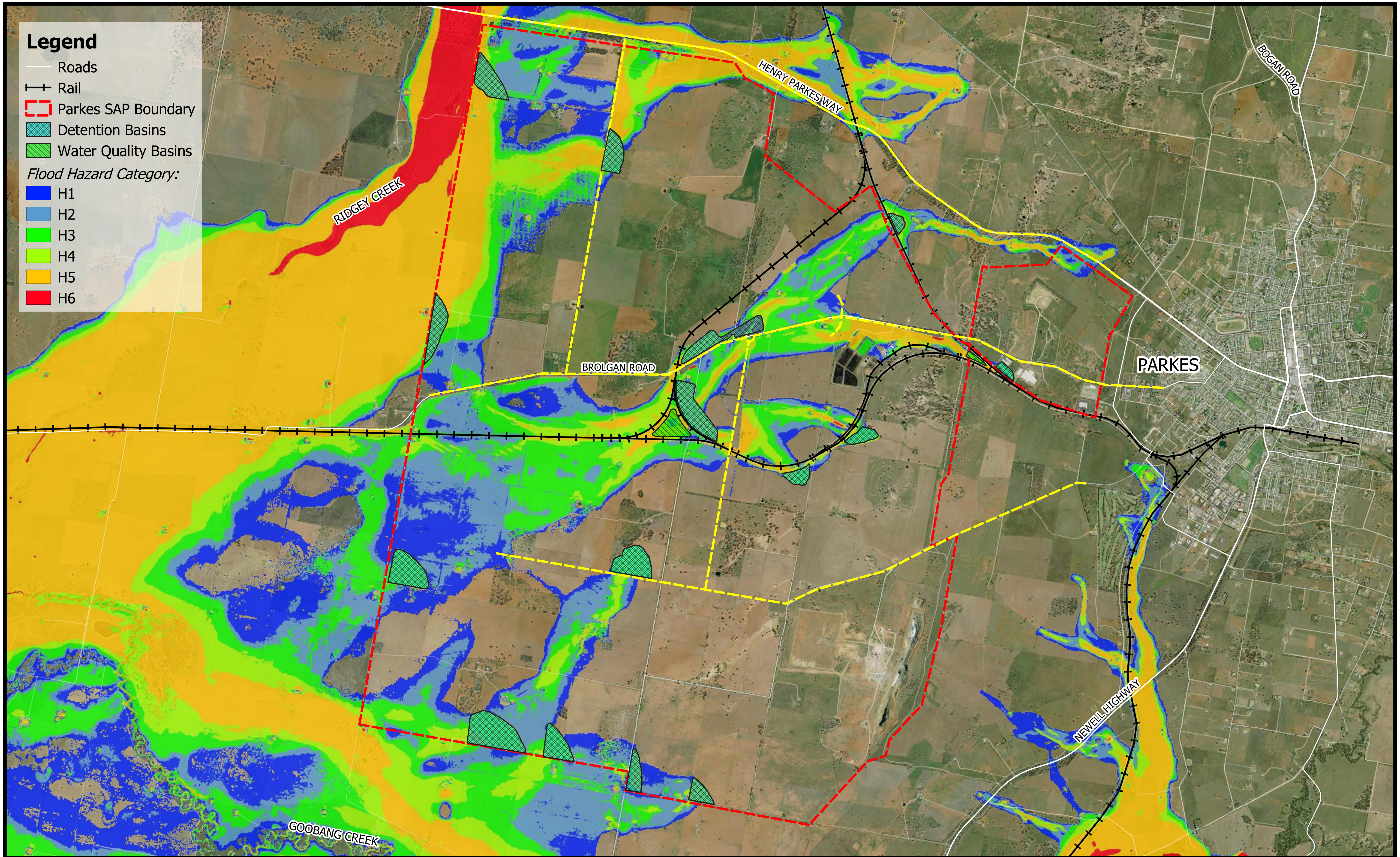

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Figure C4.3
Masterplan Scenario - PMF Flood Hazard

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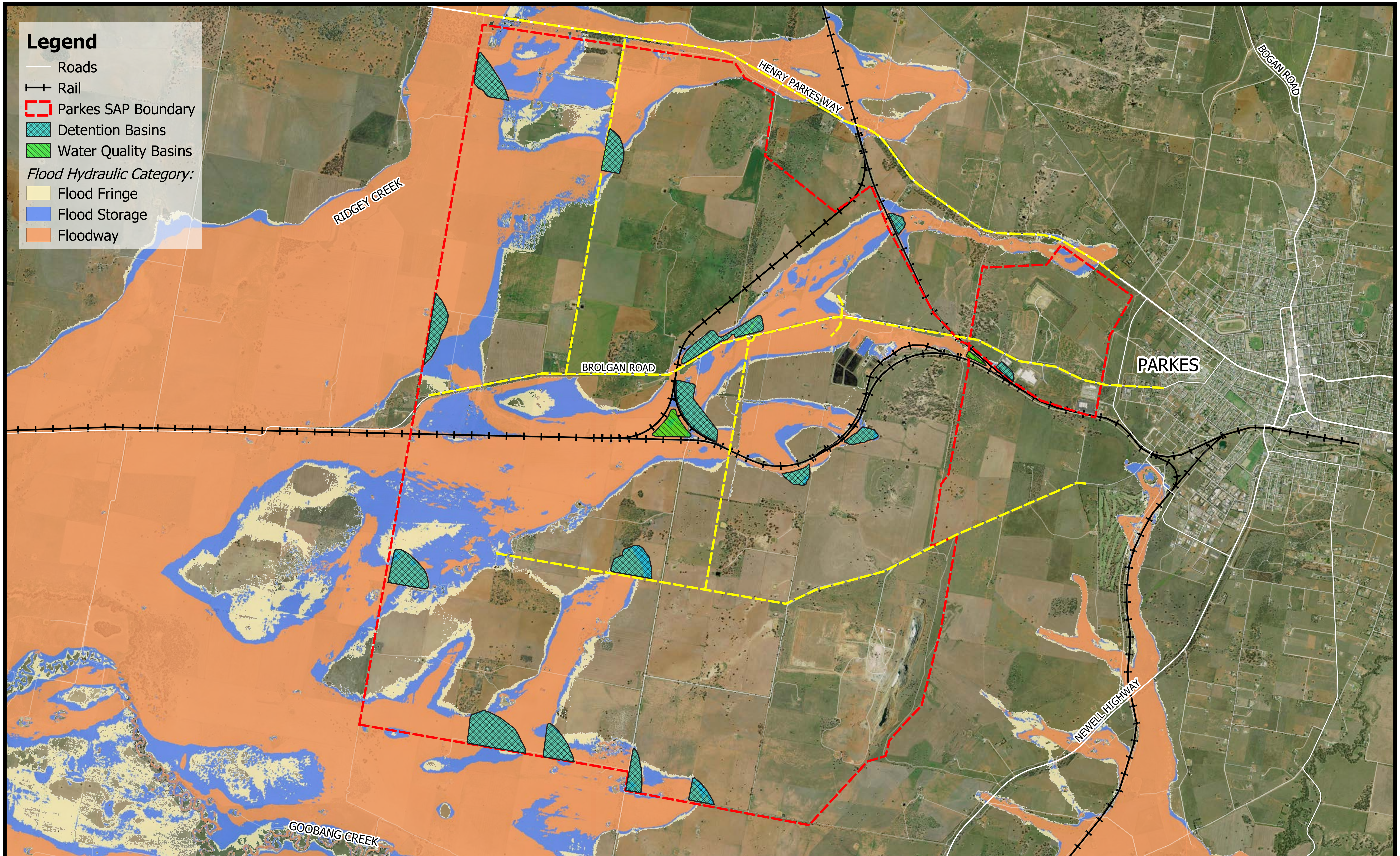

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Coordinate system: GDA 1994 MGA Zone 55
Aerial Source: NSW Six Map
Scale ratio correct when printed at A3

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Figure C4.4
Masterplan Scenario - PMF Flood Hydraulic Categorisation

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