VOLUME 4

Appendix L1
Surface water hydrology and geomorphology

Department of Infrastructure and Regional Development

Western Sydney Airport EIS

Surface Water Hydrology and Geomorphology

August 2016

Limitations

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Executive summary

This report presents an assessment of the impacts of the proposed Western Sydney Airport (proposed airport) on surface hydrology and geomorphology during construction, operation of the Stage 1 Development, and operation of the long term development for the proposed airport. The assessment includes definition of the existing environment both on and off the airport site with respect to watercourse type, quantities of estimated surface water and potential flooding. The assessment was carried out through desktop analysis, site inspections and hydrologic and hydraulic modelling of the airport site and related catchments. An assessment was also made of the sensitivity of the watercourses downstream of the airport site to changes in flow hydraulics. Nearby flood-affected residences were also identified in the review of flood impacts.

The indicative Stage 1 and long term airport layouts and specifications were reviewed and an assessment was made of the potential for impacts on surface water sources. The impact analysis includes consideration of the sensitivity of the existing creeks and surrounding environment to change, together with the results of predictive modelling of surface water hydrology and hydraulics for Stage 1 and for the long term airport.

Specific indicators of impact include changes in discharge from the airport site, changes in watercourse bed shear stress and changes in downstream water level. Consideration was also given to biodiversity that could be affected by changes to surface water flows, based on the findings of the biodiversity assessment carried out for this environmental impact statement (EIS). Potential groundwater changes are also considered for their impact on surface water sources.

The study finds that construction of the proposed airport would result in a major modification of the airport site in terms of land use characteristics and surface water runoff generated. It would also result in removal of a large number of watercourses and farm dams on the airport site. The effects of these changes were mitigated by the inclusion in the design of a number of detention basins. Several of the basins would be operational during Stage 1, with a number of additional basins to be constructed in the long term to cater for the later development. The basins would mitigate increases in runoff peaks, though the strategy does not eliminate impacts altogether.

During construction, a detailed surface water management plan would be developed that would need to consider the impacts of flooding on-site over the course of the construction period.

The assessment found that the detention basin strategy would be effective at limiting the downstream impact, such that any increases in flood level would not worsen flooding to surrounding roads and dwellings. The risk to changes in creek geomorphology would be low, other than for short reaches of Badgerys Creek in the long term. Some localised increases and decreases in water level were predicted downstream of the airport site.

The assessment considers the potential for the cumulative impacts of climate change to exacerbate the environmental impacts of the proposed airport and also to increase susceptibility of the airport infrastructure to flooding. Aspects of climate change science, particularly as they relate to flooding, are still developing and the effect of climate change on the proposed airport cannot be determined with certainty. It is concluded that current and emerging advice should be considered as the airport design is finalised. The cumulative impact of potential future development surrounding the airport was also considered.

The assessment finds that the basin strategy is generally able to limit peak flow discharges but that there is a need to further develop the strategy during upcoming stages of design development for the proposed airport, such that the basins would be effective at mimicking natural flows as closely as possible across a range of storm durations and magnitudes, including low and high flows. Consideration would need to be given to providing a basin or other form of water quantity detention on a tributary of Duncans Creek prior to discharge from the airport site.

Another mitigation requirement would be to ensure that any future development in the vicinity of Badgerys Creek where it passes through the airport site would be appropriate for a third order creek. This would involve protecting and preserving the habitat and riparian corridor and ensuring no worsening of flooding downstream.

During construction, demands on potable water would be high and there would be a need to develop a strategy for water supply to the airport site to meet the construction requirements as well as the ongoing operational water requirements. During operation, use of potable water on site would be supplemented with recycled water to reduce demand on potable water.

The effects of the proposed airport on surface water quality and groundwater are discussed in the *Western Sydney Airport Surface Water Quality Assessment* (GHD, 2016) report and in the *Western Sydney Airport EIS Ground Water Assessment* (GHD, 2015) report, which are respectively Appendix L2 and Appendix L3 in the EIS.

Glossary and abbreviations

Term	Definition
Annual exceedance probability (AEP)	The annual exceedance probability is a measure of the frequency of a rainfall event. It is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. A one per cent event is a rainfall event with a one per cent chance of being exceeded in magnitude in any year. The current Australian Rainfall and Runoff recommendations (Institute of Engineers, Australia, 1987) are for use of AEP terminology rather than Average Recurrence Interval (ARI) terminology (refer below). However, for consistency with the hydrological modelling undertaken, Average Recurrence Interval terminology is used in this report.
Afflux	With reference to flooding, afflux refers to the predicted change, usually in flood levels, between two scenarios. It is frequently used as a measure of the change in flood levels between an existing scenario and a proposed scenario.
Airport site	The site for Sydney West Airport as defined in the *Airports Act 1996*.
Airport features	Specific features of the proposed airport, such as runways, taxiways, terminal buildings or hangars.
Alluvium	Unconsolidated deposit of gravel, sand or mud formed by water flowing in identifiable channels. Commonly well sorted and stratified.
Australian Height Datum (AHD)	A common reference level used in Australia which is approximately equivalent to the height above sea level.

Term	Definition
Average recurrence interval (ARI)	The average recurrence interval, like the annual exceedance probability, is a measure of the frequency of a rainfall event. The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. For example, a 100-year average recurrence interval event occurs or is exceeded on average once every 100 years. It is important to note that the ARI is an average period and it is implicit in the definition of the ARI that the periods between exceedances are generally random. Average recurrence intervals of greater than ten years are closely approximate to the reciprocal of the annual exceedance probability. A 100-year average recurrence interval is therefore approximately equivalent to a 1 per cent annual exceedance probability event. See also annual exceedance probability.
Badgerys Creek	Badgerys Creek is a suburb in Western Sydney and the general locality of the proposed airport, which is about 50 kilometres west of the Sydney central business district. Badgerys Creek is also the name of a watercourse which is referred to in this report.
Catchment	The area drained by a stream or body of water or the area of land from which water is collected.
Consent	Approval to undertake a development received from the consent authority.
Construction impact zone	The area that would be directly impacted by construction of the Stage 1 development – indicatively shown in the revised draft Airport Plan.
Datum	A level surface used as a reference in measuring elevations.
DEM	Digital elevation model
the Department	Australian Government Department of Infrastructure and Regional Development
Discharge	Quantity of water per unit of time flowing in a stream, for example cubic meters per second or megalitres per day.

Term	Definition
DRAINS modelling	DRAINS is a multi-purpose software program for designing and analysing urban stormwater drainage systems and catchments.
Ephemeral	A stream that is usually dry, but may contain water for rare or irregular periods, usually after significant rainfall.
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
Flood	For the purposes of this report, a flood is defined as the inundation of normally dry land by water which escapes from, is released from, is unable to enter, or overflows from the normal confines of a natural body of water or watercourse such as rivers, creeks or lakes, or any altered or modified body of water, including dams, canals, reservoirs and stormwater channels.
Flood liable land	Land which is within the extent of the probable maximum flood and therefore prone to flooding.
Floodplain	The area of land subject to inundation by floods up to and including the probable maximum flood.
Floodway	The area of the floodplain where a significant portion of flow is conveyed during floods. Usually aligned with naturally defined channels.
Formation	A fundamental unit used in the classification of rock or soil sequences, generally comprising a body with distinctive physical and chemical features.
Geomorphology	Scientific study of landforms, their evolution and the processes that shape them. In this report, geomorphology relates to the form and structure of watercourses.
Groundwater	Subsurface water stored in pores of soil or rocks.
Hazard	The potential or capacity of a known or potential risk to cause adverse effects.
Headward erosion	The upstream lengthening and/or cutting of a valley or gully at its head, as the stream erodes away the rock and soil at its headwaters in the opposite direction to the stream flow.

Term	Definition
Hydraulic conductivity	The rate at which water at the prevailing kinematic viscosity will move under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow, usually expressed in metres per day (this assumes a medium in which the pores are completely filled with water).
Hydraulics	The physics of channel and floodplain flow relating to depth, velocity and turbulence.
Hydrograph	A graph which shows how a water level at any particular location changes with time.
Hydrology	The study of rainfall and surface water runoff processes.
Impervious	In the context of this report, impervious surfaces are surfaces non-permeable to water. These include hardstanding areas such as paved surfaces.
Infiltration	The downward movement of water into soil and rock, which is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.
Landform	A specific feature of the landscape or the general shape of the land.
Light Detection and Ranging (LiDAR)	LiDAR is a remote sensing method used to examine the surface of the Earth. LiDAR has been used in this study to define the topography of the airport site and surroundings.
Long term development	The long term development of the airport, including parallel runways and facilities for up to 82 million passengers annually (nominally occurring in 2063).The EIS provides a strategic level assessment of potential impacts from the long term development. Development of the airport beyond the scope of Stage 1 would be subject to separate planning and environmental processes.
LPI	NSW Land and Property Information
Meteorology	The science concerned with the processes and phenomena of the atmosphere, especially as a means of forecasting the weather.

Term	Definition
MIKE21 modelling	MIKE21 is a two dimensional hydraulic modelling software program used to simulate surface flow and estimate flood levels and flow velocities.
ML	Megalitres (equivalent to one million litres)
Monitoring well/bore	A hole sunk into the ground and completed for the abstraction or injection of water or for water observation purposes. Generally synonymous with bore.
MUSIC modelling	MUSIC is a software program used to estimate the performance of stormwater quality management systems.
Newtons per square metre (N/m^2)	A measure of force per unit area, in this case, per square metre. In this report it is used to measure stream bed shear stress i.e. the force of water acting parallel to the stream bed. The level of shear stress is used as a parameter for prediction of the movement of stream bed sediments.
Overbank	The portion of the flow that extends over the top of watercourse banks.
Overland flow path	The path that water can follow if it leaves the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Water travelling along overland flow paths, often referred to as 'overland flows', may either re-enter the main channel or may be diverted to another watercourse.
Permeability	The capacity of a porous medium to transmit water.
Pluviograph	A rain gauge with the capability to record data in real time to observe rainfall over a short period of time.
Probable maximum flood (PMF)	The probable maximum flood is the maximum flood which can theoretically occur based on the worst combination of the probable maximum precipitation and flood-producing catchment conditions that are reasonably possible at a given location.
Probable maximum precipitation (PMP)	The probable maximum precipitation is the greatest amount of rainfall which can theoretically occur over a given duration (period of time) for a particular geographical location.

Term	Definition
Proposed airport	See 'Western Sydney Airport'.
RAFTS modelling	XP-RAFTS is a hydrology modelling software program used to simulate urban and rural runoff and routing through a watershed based on catchment characteristics and rainfall events.
Reach	Defined section of a stream with uniform character and behaviour.
Recharge	Addition of water to the zone of saturation; also the amount of water added. An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.
Revised Draft Airport Plan	Draft plan developed in accordance with the requirements of the Airports Act 1996, setting out the Australian Government's requirements for the initial development of the proposed airport.
Riparian	Pertaining to, or situated on, the bank of a river or other water body.
Risk	The chance of something happening that will have an impact measured in terms of likelihood and consequence.
Risk assessment	Systematic process of evaluating potential risks of harmful effects on the environment from exposure to hazards associated with a particular product or activity.
River Styles® framework	A geomorphic approach for examining river character, behaviour, condition and recovery potential which provides a template for river management.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Salinity	The total soluble mineral content of water or soil (dissolved solids); concentrations of total salts are expressed as milligrams per litre (equivalent to parts per million).

Term	Definition
Sediment	Material of varying sizes that has been or is being moved from its site of origin by the action of wind, water or gravity.
Sinuosity	Extent of curvature or meandering of a stream. Highly sinuous streams meander over a low gradient and short distance. Low sinuosity streams are straighter and have a steeper gradient.
Stream order	Stream classification system, where order 1 is for headwater (new) streams at the top of a catchment. Order number increases downstream using a defined methodology relating to the branching of streams.
Stage 1 development	The initial stage in the development of the proposed airport, including a single runway and facilities for 10 million annual passengers. The EIS assumes the airport could be operating at this level approximately 5 years after operations commence which for assessment purposes has been assumed to be 2030.
Study area	The subject site and any additional areas which are likely to be affected by the proposal, either directly or indirectly. The study area extends as far as is necessary to take all potential impacts into account.
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Topography	Representation of the features and configuration of land surfaces.
Watercourse	Generic term used to refer to rivers, streams and creeks.
Water quality	Chemical, physical and biological characteristics of water. Also the degree (or lack) of contamination.
Water sharing plan	A legal document prepared under the *Water Management Act 2000* (NSW) that establishes rules for sharing water between the environmental needs of the river or aquifer and water users and also different types of water use.
Water table	The surface of saturation in an unconfined aquifer, or the level at which pressure of the water is equal to atmospheric pressure.

Term	Definition
Western Sydney Airport	The proposed airport which would be located on the Commonwealth owned land at Badgerys Creek and has been assessed in the Western Sydney Airport environment impact statement.

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1. Introduction

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946, with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the Joint Study on Aviation Capacity in the Sydney Region (Department of Infrastructure and Transport, 2012) and A Study of Wilton and RAAF Base Richmond for civil aviation operations (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,780 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Airport operations are expected to commence in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport (referred to as the Stage 1 development) would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of approximately 10 million passengers per year as well as freight operations. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site subject to relevant approvals.

While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A joint scoping study is being undertaken with the NSW Government to determine rail needs for Western Sydney and the airport. A potential final rail alignment will be determined through the joint scoping study with the New South Wales Government, with any significant enabling work required during Stage 1 expected to be subject to a separate approval and environmental assessment process.

As demand increases, additional aviation infrastructure and aviation support precincts are expected to be developed until the first runway reaches capacity at around 37 million passenger movements. At this time, expected to be around 2050, a second parallel runway is expected to be required. In the long term, approximately 40 years after operations commence, the airport development is expected to fully occupy the airport site, with additional passenger and transport facilities for around 82 million passenger movements per year.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015.

Approval for the construction and operation of the proposed airport will be controlled by the Airports Act 1996 (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan, which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. A draft Airport Plan was exhibited for public comment with the draft EIS late in 2015.

Following receipt of public comments, a revised draft Airport Plan has been developed. The revised draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The revised draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, as well as a long-term vision of the airport's development over a number of stages. This enables preliminary consideration of the implications of long term airport operations. Any airport development beyond Stage 1, including the construction of additional terminal areas or supporting infrastructure to expand the capacity of the airport using the first runway or construction of a second runway, would be managed in accordance with the existing process in the Airports Act. This includes a requirement that, for major airport developments (defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Scope of the assessment

The study assesses the impacts of the proposed airport on:

- surface water hydrology and flooding; and
- geomorphology.

Impacts on groundwater, aquatic ecology and surface water quality are discussed in the following reports: *Western Sydney Airport Surface Water Quality Assessment* (GHD, 2016, refer to EIS Appendix L2), *Western Sydney Airport EIS Ground Water Assessment* (GHD, 2015, refer to EIS Appendix L3) and *Western Sydney Airport EIS Biodiversity Assessment* (GHD, 2016, refer to EIS Appendix K1). The key findings relevant to the scope of this report are included.

The key aspects of this study are to:

- describe the existing environment with respect to surface water hydrology, flooding and geomorphology;
- assess the likely impact of the airport on these features in the context of Commonwealth legislation, EIS guidelines and national, regional and local industry practice and guidelines; and
- identify measures to mitigate or manage the expected impacts.

1.3 Study area

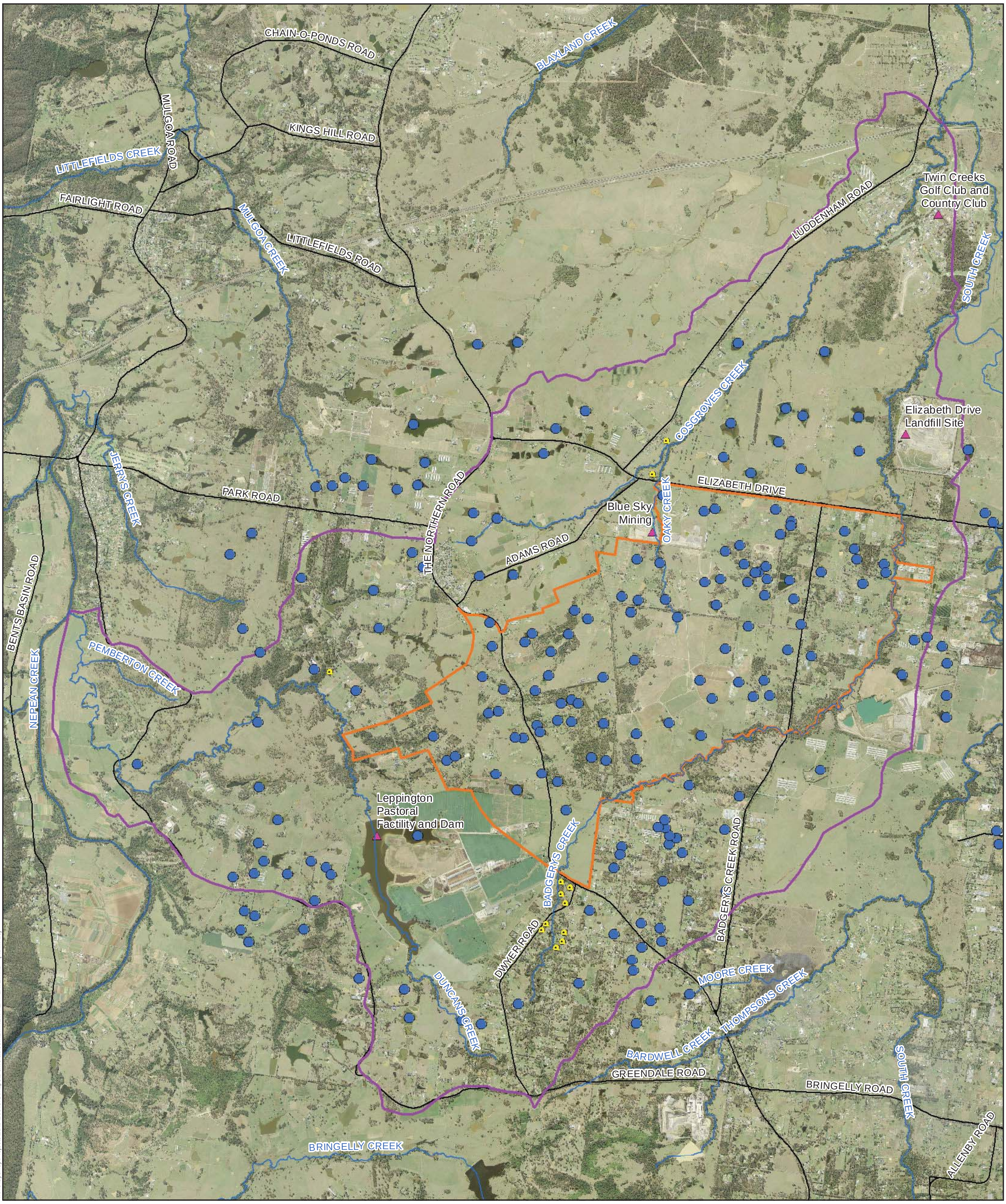
The study area for both the Stage 1 and potential long term development consists of the airport site as well as the hydrological catchments of Duncans Creek to its confluence with the Nepean River, and Oaky Creek, Cosgroves Creek and Badgerys Creek to their confluences with South Creek.

The airport site and the study area are shown in Figure 1-1, together with a number of points of interest referred to in this report.

1.4 Structure of this report

The remainder of this report is structured as follows.

- **Section 2**: Provides the legislative context for the assessment including relevant policies and guidelines.
- **Section 3**: Describes in detail the methodology used in the surface water assessment, including details of the surface water modelling methodology.
- **Section 4**: Describes the existing environment, based on the findings of the desktop assessment, site visits and modelling analyses.
- **Section 5**: Describes the potential impact of the proposed airport on surface water features during construction.
- **Section 6**: Describes the potential impact of the proposed airport on surface water features during operation.
- **Section 7**: Assesses the likely cumulative impact of the proposed airport together with other factors such as climate change and surrounding development.
- **Section 8**: Outlines management and mitigation measures to address the impacts.
- **Section 9**: Provides a summary and conclusion for this report.



Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND
- Airport site
- Watercourses
- Farm dam
- Surface water study area
- Surface water key features
- Dwellings located within or near to 1 in 100-year ARI flood extent
- Dams / ponds

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Figure 1-1 - Airport site and surface water study area

2. Legislation and guidelines

The legislative requirements and guidelines relevant to this assessment are described in this section. The methodology outlined in the following sections has been developed to address the legislative and regulatory requirements.

2.1 Environment Protection and Biodiversity Conservation Act 1999 and Airports Act 1999

The EIS for the proposed airport has been prepared in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) but authorisation for the project would be made under the *Airports Act 1996* (Cth) (Airports Act) (see Chapter 3 of the EIS for more information on the regulatory framework).

The objects of the EPBC Act include to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance (MNES) and to promote the conservation of biodiversity.

MNES are relevant to surface water where either:

- surface water features form part of the natural environment associated with a MNES; or
- a MNES is dependent on surface water features.

Surface water features are natural resources and are an integral part of the environment. They are relevant in the context of the EPBC Act wherever there is potential for impact upon them.

2.1.1 Environmental Impact Statement Guidelines

The Guidelines for the Content of a Draft Environmental Impact Statement, Western Sydney Airport (the EIS guidelines) (Australian Government, 2015), identify that impacts to the environment including hydrological changes must be assessed. In particular, Section 5 of the Guidelines (EPBC 2014/7391) require that:

(g) Impacts to the environment should include but not be limited to the following:

- *changes to siltation*
- *hydrological changes.*

This report has been prepared in accordance with the EIS guidelines.

2.2 NSW Water Management Act

The *Water Management Act 2000* (NSW) (WM Act) is administered by the NSW Department of Primary Industries (DPI) (formerly NSW Office of Water) and is intended to ensure that water resources are conserved and properly managed for sustainable use benefitting both present and future generations. The WM Act is also intended to provide a formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses as well as to provide for protection of catchment conditions. The intent and objectives of the WM Act have been considered as part of this assessment. The WM Act is relevant to any potential transfer of water between water sharing areas that could arise from the proposed airport.

NSW Water Sharing Plans

Water sharing plans are implemented under the WM Act and specify the rules for the sharing of water between the environment and water users and between water users themselves. Water sharing plans also specify rules for the trade and management of water access licences.

The Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources (the water sharing plan), which commenced in 2011, covers 87 management zones that are grouped into six water sources. The airport is situated in the Hawkesbury and Lower Nepean Rivers catchment or source.

The Hawkesbury and Lower Nepean Rivers catchment is separated into management areas, which includes amongst others the Upper and Lower South Creek Management Zones and the Mid Nepean River Catchment Management Zone. Badgerys Creek, Oaky Creek and Cosgroves Creek are interpreted to be within the Upper South Creek Management Zone, and Duncans Creek is interpreted to be within the Wallacia Weir Management Zone (one of the Mid Nepean River Catchment Management Zones). Extraction from these zones currently occurs for irrigation, town and industrial water supply.

The water sharing rules listed in the water sharing plan for the Upper South Creek and Wallacia Weir Management Zones are summarised below.

Upper South Creek Management Zone

- Access rules stipulate at what flow rates users must cease to pump from the creek, based on A and B flow classes.
- Trading is permitted within the management zone (subject to assessment) but is not permitted into the management zone.

Wallacia Weir Management Zone

- Environmental flow protection rules apply when inflows to the dams are greater than the 80th percentile, depending on the ability of the weir to pass flows released upstream.
- Trading is permitted within the management zone and is permitted into the management zone from upstream management zones (but not from other management zones).
- Limited access to very low flows is allowed during water shortages depending on conditions that trigger a water shortage.
- Lagoon rules prevent water trading onto a lagoon and applications for new works on a lagoon.

Water Sharing Plans in relation to groundwater resources and groundwater recharge are discussed in the groundwater assessment report (refer to EIS Appendix L3).

2.3 Other policies and guidelines

2.3.1 New South Wales Floodplain Development Manual

The New South Wales Floodplain Development Manual (former Department of Infrastructure, Planning and Natural Resources, 2005) concerns the management of flood-prone land within NSW. It provides guidelines in relation to the management of flood liable lands, including any development that has the potential to influence flooding, particularly in relation to increasing the flood risk to people and infrastructure.

2.3.2 Hawkesbury Nepean Catchment Action Plan

The Hawkesbury-Nepean and Sydney Metropolitan Catchment Management Authority (CMA) regions were amalgamated in late 2012. Following this, a Catchment Action Plan (CAP) for the Hawkesbury-Nepean catchment was developed and later superseded by a *Greater Sydney Local Land Service Transition Catchment Action Plan* (NSW Government, 2014).

Catchment Action Plans (CAPs) are ten year plans to guide the management of water, land and vegetation by state government and local communities.

The catchments of Badgerys Creek, Oaky Creek, Cosgroves Creek and Duncans Creek fall within the *Greater Sydney Local Land Service Transition Catchment Action Plan*. The action plan is relevant with respect to any influence the proposed airport may have on the downstream catchments in relation to surface water and aquatic ecology.

Relevant strategies within the action plan include development of a more water sensitive catchment, promoting resilience through climate change adaptation and a number of strategies relating to protecting aquatic ecosystems.

2.3.3 Managing Urban Stormwater: Soils and Construction (Blue Book)

The NSW Government publishes the following documents about the management of erosion and sediment control during construction and other land disturbance activities.

Managing Urban Stormwater: Soils and Construction – Volume 1 (Blue Book)

The document provides guidance for local councils and practitioners on the design, construction and implementation of measures to improve stormwater management, primarily erosion and sediment control, during the construction phase of urban development.

Managing Urban Stormwater: Main road construction – Volume 2D

This document provides guidelines, principles and recommended minimum design standards for managing erosion and sediment control during the construction of main roads. The construction of main roads and highways commonly involves extensive earthworks, with significant potential for erosion and subsequent sedimentation of watercourses and the landscape, and the document therefore has been considered in the preparation of this report.

3. Methodology

3.1 Overview

The approach adopted to surface water assessment in this report includes the following steps:

- data collection and review;
- existing environment modelling and analysis;
- Stage 1 and long term development modelling and analysis;
- impact assessment; and
- development of mitigation and management measures.

Each stage is explained in more detail below.

3.2 Data collection and review

3.2.1 Key project documents and data

Key data relevant to the project and surface water studies was collected and reviewed. Key reference documents and data are listed in Table 3-1.

Table 3-1 Key reference documents and data

Document / dataset	Data source	Description	Date
Aerial imagery	AusImage	Aerial imagery of study area.	2014
Revised draft Airport Plan – Concept Plan – Stage 1 Development	The Department of Infrastructure and Regional Development	Concept drawing of the proposed Stage 1 airport layout.	2016
Revised draft Airport Plan – Concept Plan – Longer Term Development	The Department of Infrastructure and Regional Development	Concept drawing of the indicative long term airport layout.	2016
Revised draft Airport Plan – Concept Plan – Stage 1 Land Use Zoning Plan	The Department of Infrastructure and Regional Development	Drawing of proposed land use zoning for Stage 1.	2016
Revised draft Airport Plan – Concept Plan – Longer Term Land Use Zoning Plan	The Department of Infrastructure and Regional Development	Drawing of indicative land use zoning for a long term development.	2016

Document / dataset	Data source	Description	Date
Stage 1 Surface Water Concept Drawings	The Department of Infrastructure and Regional Development	Drawing of proposed surface water management strategy for Stage 1.	January 2016
Longer term Surface Water Concept Drawings	The Department of Infrastructure and Regional Development	Drawing of indicative surface water management strategy for a long term development.	2015
Revised draft Airport Plan – Western Sydney Airport	The Department of Infrastructure and Regional Development	Revised draft Airport Plan outlining the proposed Western Sydney Airport Stage 1 development.	2016
Environmental Field Survey of Commonwealth Land at Badgerys Creek	The Department of Infrastructure and Regional Development	Documentation of water quality sampling data collected by SMEC.	2014
Hydrology models	The Department of Infrastructure and Regional Development	RAFTS model of the existing airport site and long term development.	2016
Hydraulic models	The Department of Infrastructure and Regional Development	MIKE 21 models of the existing airport site and long term development. DRAINS models of the existing airport site and long term development.	2016
LiDAR	NSW LPI	Topographical LiDAR outputs at 1 metre and 5 metre intervals.	2014
Hydrolines layer	NSW LPI	Map layer defining watercourse centre lines.	2012
Updated South Creek Flood Study	Worley Parsons	Flood study of South Creek and its contributing catchments.	2015

Document / dataset	Data source	Description	Date
Western Sydney Airport – Bulk Earthworks Concept Design Report	The Department of Infrastructure and Regional Development	Design report for proposed earthworks for Stage 1.	February 2016
Western Sydney Airport Climatological Review	Bureau of Meteorology	Report containing analysis of climatic data from Badgerys Creek gauge.	April 2015
Western Sydney Airport Usability Report	Bureau of Meteorology	Report documenting the meteorological parameters affecting the usability of the airport site.	April 2015

A detailed list of references is provided in Section 10.

3.2.2 Review of related studies

A number of past studies investigated hydrology and flooding characteristics of the catchments of South Creek and the Nepean River. These are summarised below and relevant findings in relation to the existing environment are discussed in Section 4.

1997 – 1999 Environmental Impact Assessment

An Environmental Impact Statement for a second Sydney airport at Badgerys Creek was prepared in 1997 and updated following public consultation and review in 1999. The impacts for surface water hydrology and geomorphology documented in the *Draft Environmental Impact Statement – Second Sydney Airport Proposal* included removal of stream habitat and associated ecological impact. The focus of the water study was on surface water quality impacts.

An updated technical study associated with the 1999 EIS identified the following key impacts including associated ecological impacts:

- removal of wetland habitat;
- increases in downstream runoff; and
- changes in streamflow characteristics.

Updated South Creek Flood Study

This study was completed in January 2015 and is the most recent available flood study for the catchment of South Creek (Worley Parsons 2015). The study was prepared for Penrith, Liverpool City, Fairfield City and Blacktown City Councils and will be used to inform floodplain management within the South Creek catchment. The study documents flooding under existing conditions and is relevant as a benchmark for definition of flood extents within the catchment.

A RAFTS hydrological model was developed for the study. The extent of the RAFTS model includes the airport site. The focus of the study was on South Creek and the available subcatchment mapping suggests that it is not of sufficient detail at the airport site for the purposes of this study.

Flood extents, levels and depths were generated using a hydraulic model. The model results cover a portion of Badgerys Creek at the airport site. However, for Cosgroves Creek the model does not extend as far upstream as the airport site.

Based on correspondence with the modellers who prepared the study, detailed information regarding hydraulic structures in the vicinity of the airport was not available during preparation of their study.

The study was validated against the findings of earlier studies of the South Creek catchment, including the *South Creek Flood Study* (NSW Department of Water Resources 1990) and the *South Creek Floodplain Risk Management Study and Plan* (Willing and Partners 1991).

The Updated South Creek Flood Study document was used in this assessment for the validation of findings where appropriate. The associated hydraulic models, hydrology models and input data used in the Updated South Creek Flood Study were not used in the current study. Consultation was undertaken with various parties to obtain the information from this study but it was not available. Models specific to the airport site were prepared for the purposes of the assessment (refer section 3.2.2 for details).

3.2.3 Field investigations

Field investigations at the airport site and surrounding areas were conducted on 6 and 7 May 2015.

The field visits focused on the following:

- collection of details regarding key hydraulic structures (road bridge and culvert crossings);
- review of land use characteristics;
- visual inspection of watercourse condition at several locations; and
- inspection of debris marks from recent flooding, believed to be from the event which occurred between 21 April and 22 April 2015.

There were limitations on accessibility to tenanted and private properties. This meant that conducting a walkover of the entire length of watercourses on the airport site and downstream was not possible. The available data was used in characterising existing watercourse types and condition as discussed in Section 4.

Geomorphological findings of the field investigations are described in Section 4. The field observations relating to hydrology were used mainly in the development and validation of the flood model.

Photographs of some of the key hydraulic structures used in the hydraulic modelling are provided in Appendix A. The Twin Creeks Golf and Country Club Estate Manager provided rainfall records from a daily rainfall gauge held on site which was used in the validation of the hydraulic model (refer Appendix A).

3.3 Existing environment modelling and analysis

Hydrologic and hydraulic modelling was undertaken to establish baseline conditions and assess the potential impact of the proposed airport. The methodology adopted for the modelling analysis is described in this section. Definition of the existing environment based on the results of the modelling is discussed in Section 4. Additional model development detail not contained in this section is included in Appendix A.

3.3.1 Hydrology

Watercourse stream ordering

Stream ordering of watercourses was established using the Strahler stream classification system where watercourses are given an 'order' according to the number of additional tributaries associated with each watercourse (Strahler, 1952). This system provides a measure of system complexity and is used as an input into assessing hydrological significance and environmental attributes such as potential for fish habitat. Watercourse locations were determined from the NSW LPI hydrolines layer. The stream ordering was used as an input to various EIS studies.

Hydrological modelling

A RAFTS hydrology model prepared by the Department of Infrastructure and Regional Development was available and was refined and updated for the purposes of the EIS. The RAFTS model was used to define the existing hydrology for the airport site and surrounds.

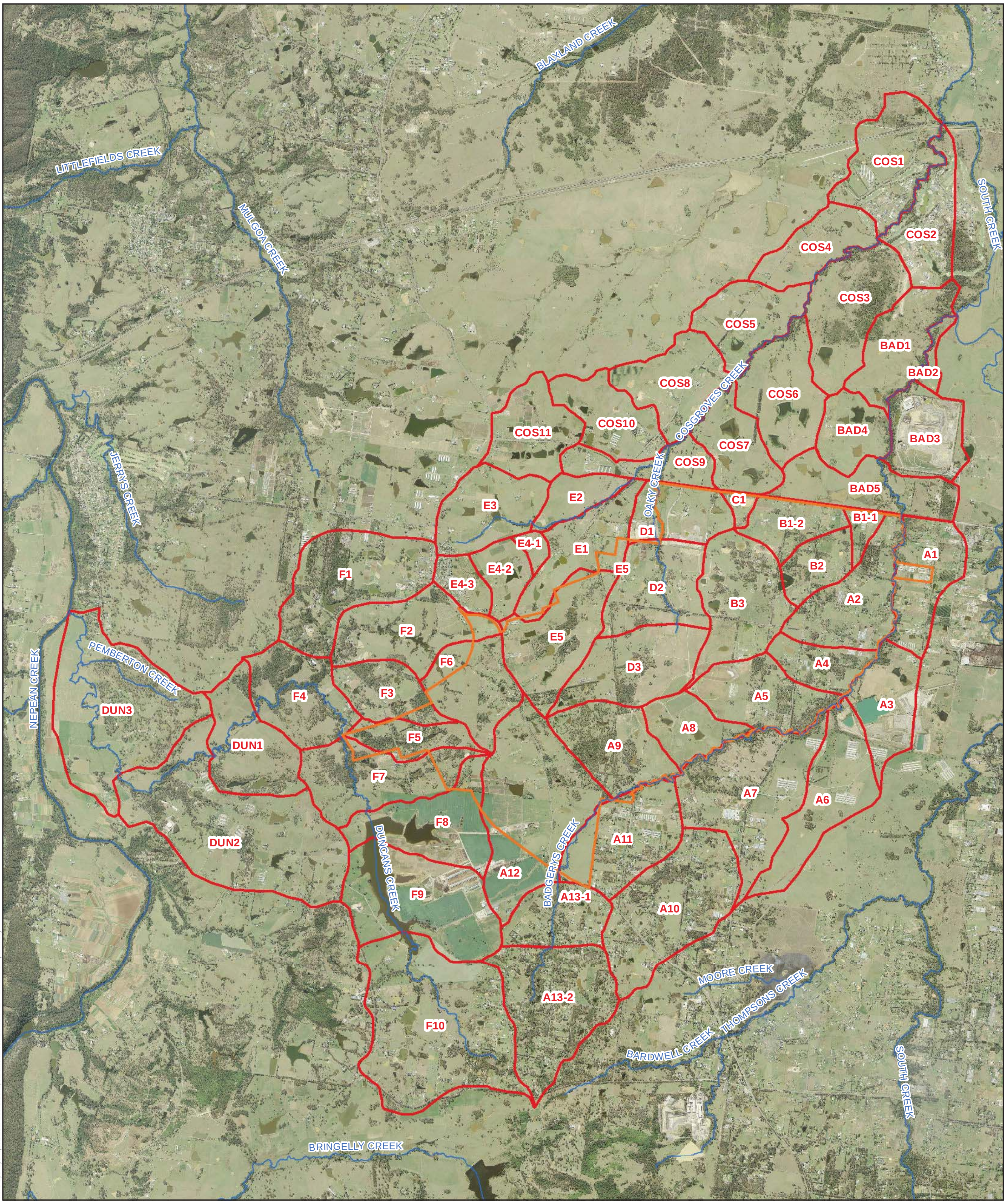
Hydrological subcatchments and land use

Subcatchments were delineated using available elevation data and regional hydroline mapping. Aerial imagery was used to determine the existing landuse types within each catchment. Subcatchment boundaries are shown in Figure 3-1.

Impervious areas were calculated by adopting rates of imperviousness for typical landuse types within the modelled area. This is the approach adopted in Liverpool City Council's Handbook for Drainage Design Criteria (2003). Landuse types used in the hydrology modelling of the existing study area and the adopted percentage impervious for each are shown in Table 3-2. The dominant landuse in the study area is farmland (pasture), listed here as primary production. The pervious and impervious areas for each catchment were input into the RAFTS model as subcatchments.

Table 3-2 Landuse types and adopted impervious percentages

Landuse type	% impervious
Low density residential	45%
Large lot residential	20%
Primary production	10%
Primary production (small lot)	15%
Dams	100%
Infrastructure	10%
Commonwealth land	10%



LEGEND

- Airport site
- Watercourses
- EIS Subcatchment Boundaries

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

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Kilometres

Figure 3-1 - Hydrology assessment existing subcatchment boundaries

A summary of the Badgerys Creek, Cosgroves Creek and Duncans Creek catchments within the airport site and their impervious percentage is provided in Table 3-3.

Table 3-3 Summary of existing catchment areas and impervious percentages

Catchment	Catchment area (ha)	% of catchment within airport site	% impervious in existing catchment
Badgerys Creek to South Creek	2,799	38	12
Cosgroves Creek to South Creek	2,165	23	14
Duncans Creek to Nepean River	2,379	9	14

Design storms

Design storms were generated in RAFTS using design rainfall intensity-frequency-duration (IFD) data for the airport site from Australian Rainfall and Runoff (Institute of Engineers Australia 1987). Design storms of various durations (1 to 24 hours) and average recurrence intervals (100, 20, 5, 2 and 1 year) were simulated in the RAFTS model to assess the existing hydrology of the study area.

Probable maximum flood (PMF) simulations were conducted in RAFTS using probable maximum precipitation estimates calculated using the generalised short duration method as described by the Bureau of Meteorology (BOM 2003). Further details of the model development and validation are provided in Appendix A.

3.3.2 Hydraulics and flooding

A flood model prepared using MIKE 21 software was developed for the Department of Infrastructure and Regional Development. The model was refined and extended for the purposes of the EIS and used to define existing flooding downstream of the airport site and adjacent to it. No hydraulic models were available for the tributaries of Duncans Creek on the airport site or for Duncans Creek itself.

In the early stages of assessment, hydrological changes to Duncans Creek were limited and the downstream catchment areas were largely primary industry with few dwellings identified close to the Creek. During design development however, although the net catchment area draining to Duncans Creek decreased, there were localised subcatchment increases introduced into the design with the potential for downstream impact. A MIKE 21 flood model was therefore developed for Duncans Creek for the purposes of the EIS.

Model terrain

The hydraulic model terrain was developed from Light Detection and Ranging data (LiDAR). The LiDAR data from which the model terrain was sourced was provided on a one metre by one metre square grid. It was adjusted to a five metre square grid size for use in the model.

Hydraulic roughness

Hydraulic roughness parameters were selected based on aerial imagery and on-site observations. The values adopted are included in Table 3-4.

Table 3-4 Hydraulic model adopted roughness values

Land use	Hydraulic roughness
Water	0.02
Roads	0.02
Floodplain – grass with light vegetation	0.08
Channel – trees	0.12
Channel – grass	0.05

The downstream boundary of the model was chosen to ensure that flood behaviour at the study area boundary could be identified. A normal depth open channel flow was selected at the extreme downstream section of the model.

Representation of key hydraulic structures

Bridges and other flow controlling structures were represented in the model as a MIKE 21 feature. Dimensions were based on observations made during the site visit. Adjustments to the MIKE 21 grid were made to represent the road level across the structure.

The hydraulic model extents and key structures are shown in Figure 3-2.

3.3.3 Watercourse geomorphology

The assessment of the physical form and geomorphic condition of watercourses was broadly based on the methods and principles of the River Styles® framework (Brierley and Fryirs 2005). Determination of watercourse geomorphic types is largely based on the following parameters:

- degree of valley confinement and bedrock influences;
- presence and continuity of a channel;
- channel planform (number of channels, sinuosity);
- channel and floodplain geomorphic features; and
- nature of channel and floodplain sediments.

The assessment of the geomorphic type and condition of watercourses in the study area was primarily based on a desktop review of aerial imagery and topographic data. This was supported by visual inspections of watercourses at several locations undertaken over the period 6–7 May 2015.

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Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

- Airport site
- Watercourses
- Hydraulic model key structures
- Hydraulic model extent - Badgerys Creek
- Hydraulic model extent - Cosgoves Creek
- Hydraulic model extent - Duncans Creek

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Kilometres

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Figure 3-2 - Hydraulic model extent and key hydraulic structures

3.4 Stage 1 and long term modelling and analysis

3.4.1 Description of proposals for surface water

Construction of the Stage 1 development would involve significant earthworks to level the central and northern portions of the airport site, known as the construction impact zone, for the runway and related Stage 1 infrastructure. Developments outside the scope of Stage 1, including activities associated with a long term development, would be subject to further planning and environmental processes.

The Stage 1 development will require removal of existing surface water features within the Stage 1 construction impact zone. The Stage 1 development area would be drained via a number of pipes and swales in order to maintain the serviceability of the airport site from a stormwater perspective and to the required design standards.

The design of the proposed airport incorporates a number of stormwater detention and treatment basins for the management of the quantity and quality of expected stormwater runoff. Basins are comprised of a detention component and an offline bio-retention component for the water quality treatment of flows up to a 3-month ARI event.

In the long term, development of the proposed airport could include construction of an additional runway in the south of the airport site, as well as development of ancillary facilities. The long term development would require the removal of remaining surface water features on the airport site.

The following paragraphs outline the proposed design of stormwater management infrastructure during the Stage 1 and the long term development. The Stage 1 design incorporates considerations of long term requirements and, where practical and appropriate, installation of stormwater infrastructure with capacity for the long term during Stage 1.

Stage 1

During Stage 1 the following stormwater management infrastructure would be developed:

- Construction of trunk drainage in the northern half of the airport site that will be sized to be able to convey expected flows during both the Stage 1 and the long term.
- Construction of detention basins and their associated bio-retention basins labelled Basins 1, 2, 3, 6, 7 and 8 and bio-retention basin 9 that are designed to maintain pre-existing outflows during the 100 ARI storm event.
- Construction of temporary trunk drainage infrastructure in the southern half the airport site that is sized to convey flows during Stage 1.

Key stormwater features of the proposed Stage 1 development are shown in Figure 3-3.

Long term

During the long term the following stormwater management infrastructure may be developed, subject to separate environmental and planning approval processes:

- Addition of Basin 4 and Basin 5 in order to retain the increase in flows during the long term and maintain pre-existing outflows during the 100 ARI storm event.
- Minor adjustments to basin outlets as required.
- The trunk drainage on the northern side of the airport site will be extended.
- The trunk drainage on the southern side of the airport site will be modified to convey flows during the long term of the airport development.
- The existing basins will maintain the same retention capacities as they had during Stage 1.

Figure 3-4 shows the key stormwater features of the long term development.

The bio-retention filter medium areas will potentially be enlarged in the long term, dependent on their performance over time to deliver water quality targets. These targets are expected to be determined by local standards set under the Airport (Environment Protection) Regulations 1997 (Cth), following a period of water quality monitoring (this is addressed separately in the water quality report (refer to EIS Appendix L2) .

3.4.2 Adopted Design Standards

The adopted design criteria for the stormwater management infrastructure on the airport site are outlined in Table 3-5. The design criteria were developed with consideration of a number of standards and guidelines including but not limited to:

- Former Commonwealth Government Department of Construction Roads and Aerodromes Branch, *Stormwater Drainage Design Manual,* 1978
- Engineers Australia, *Australia Rainfall and Runoff Revision Projects – Project 11 – Blockage of Hydraulic Structures*
- Serviceability requirements for the airport site as set out in the revised draft Airport Plan.

Table 3-5 Adopted Annual Recurrence Intervals for the Airport Concept Design

Aerodrome Area	Criterion	Storm Frequency (ARI)
Conveyance		
All areas	Convey all surface runoff and maintain freeboard	100 years
All areas	Convey all surface runoff, without freeboard, under design blockage conditions: ▪ 25% culverts ▪ 50% grated pits	100 years
All areas	Minimising property damage, airport operations interruption and providing safe evacuation	PMF
All areas	Convey all surface runoff without overflow considering climate change impact	100 years + 30% increase in rainfall intensities
Infrastructure		
Airport access road	Remain trafficable	PMF
Trunk Drainage		
Pipes and culverts	Self-cleaning (velocity ≥ 0.6m/s) or provide sediment clean-out system	0.5 years
Detention		
Downstream of airport	No increase, if feasible, in the peak flow rate downstream or at adjacent waterways from pre-existing flows	100 years
Downstream of airport	No expected damage to property or impact on land use caused by increases in flood levels	100 years
Detention basins	Maximum detention time of 48 hours or provision of fauna-repelling features	10 years
Bio-retention basin	Bio-retention system design reliability to appropriate ARI and ability to resist damage up to an including appropriate ARI	10 years
	Bio-retention treatment design (low flow conveyance only)	3 months
Spillways	Free overflow over embankments	100 years

Additional design standards for the stormwater management infrastructure on the airport site include:

Conveyance

- Pits should be provided with access manholes for inspection and maintenance.
- Design life in excess of 100 years.
- Stilling/energy dissipation basins are provided at the exit points of below ground pipes and culverts, to destroy energy where these flow into open swales.
- Open swales are generally grassed, however certain areas may require erosion protection, particularly in steeper sections.

Detention

- As far as is reasonable and feasible, maintain the discharge locations of low flow to downstream environments.

Capture and reuse of stormwater runoff from the proposed airport (for example roof water recycling) has been identified as a possibility but has not been incorporated into the design at this stage. Reuse of stormwater on the airport site could reduce the volume of runoff discharged from the airport site. This would tend to counteract the increases in runoff resulting from the increase in impervious areas on the airport site. The current design and sizing of stormwater capture systems and detention basins does not include reuse of stormwater. Future designs may also include infrastructure for the reuse of treated wastewater for typical recycled water applications.

LEGEND

Airport site

Watercourses

Detention Basin

Bioretention Basin

Stage 1 development area

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

Figure 3-3 - Stage 1 - key development features

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Kilometres

LEGEND

Airport site

Watercourses

Detention Basin

Bioretention Basin

Long term development area

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

Figure 3-4 - Long term - key development features

0 0.25 0.5 1
Kilometres

3.4.3 Hydrology and hydraulics

An analysis of the Stage 1 surface water system, utilising hydrology and hydraulic models, was carried out to inform the impact assessment.

The hydrology model was provided by the Department and takes into account the Concept Design and Land Use Plan contained within the revised draft Airport Plan as well as the Stage 1 Surface Water Concept Drawings. The hydrology model for Stage 1 was updated for the purposes of the EIS in 2016 to take into account refinements to the Concept Design in the revised draft Airport Plan.

Hydraulic models were developed for the proposed airport based on the Concept Designs and Land Use Plans. Hydraulic models were developed for the long term development as this was considered critical for the sizing of water detention basins to avoid the need to expand existing basins in the future. For the purpose of assessing the impacts of the Stage 1 development, additional hydraulic models were developed for the EIS, principally to model catchments draining to Basins 6, 7 and 8 in the Stage 1 Concept Design.

Subcatchment boundaries were delineated based on the available information and are shown in Figure 3-5 for Stage 1 and in Figure 3-6

Figure 3-6 for the long term development. Outlet configurations for the basins have been modelled in accordance with the Concept Design in the revised draft Airport Plan. The assessment included more detailed assessment of basin outlet hydraulics and management of lower ARI events, as well as larger events such as the 100 year ARI event.

A Stage 1 hydraulic model was created by:

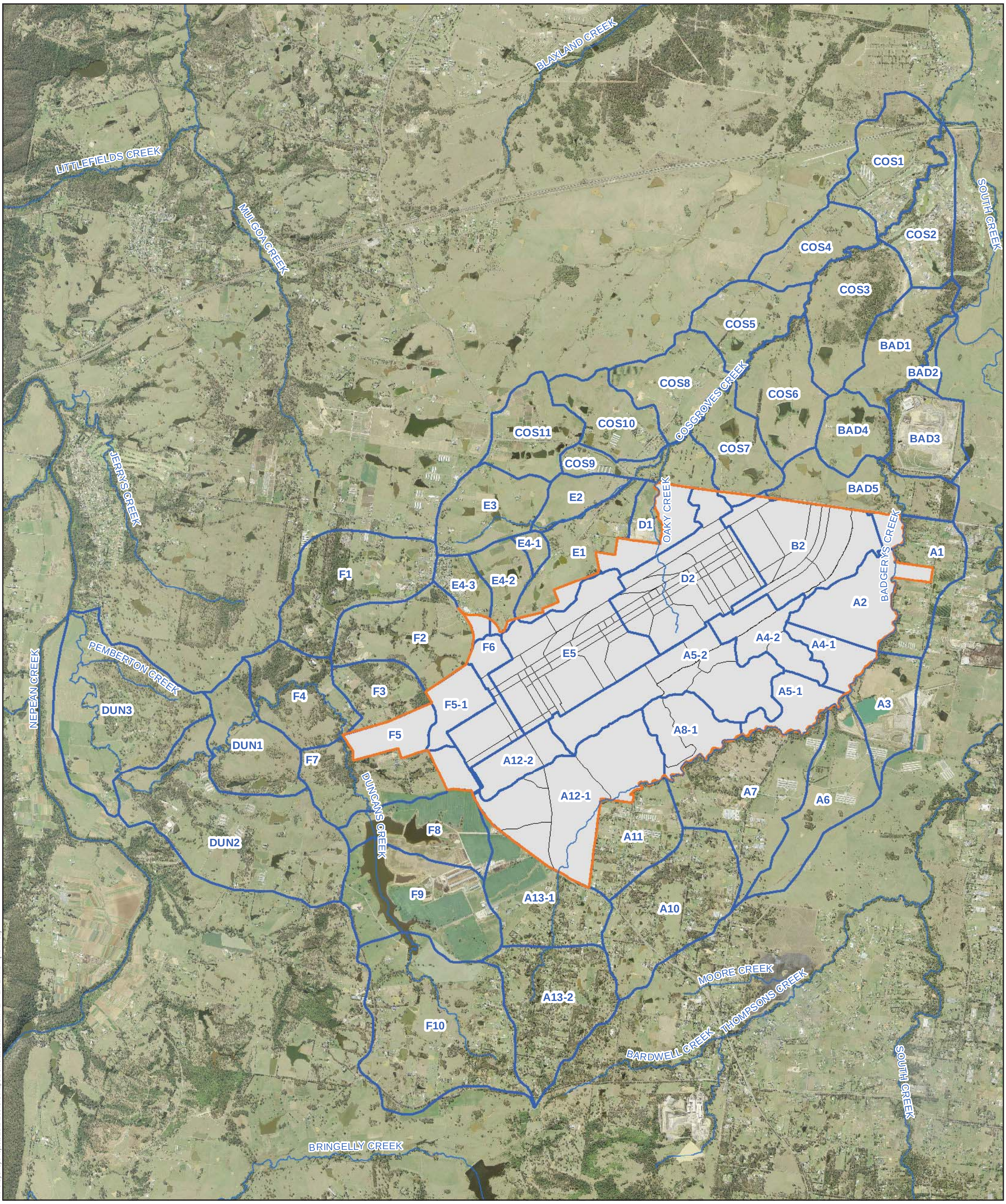
- incorporating the available design landform within the model topography; and
- incorporating the Stage 1 surface water runoff estimated by the hydrology assessment.

In order to refine hydraulic estimates, hydraulic structures were incorporated into both the Stage 1 and the long term models, and their description was based on site observations.

DRAINS software was used to model the hydraulics and hydrology within the airport site for both the Stage 1 and long term scenarios.

RAFTS was used to simulate runoff hydrographs at defined points throughout the watersheds affected by the airport footprint based on a set of catchment characteristics and specific rainfall events for both the Stage 1 and long term scenarios. Only the catchment areas outside the airport footprint were modelled within RAFTS and these took into consideration changes in the catchment boundaries caused by the airport development.

The hydrographs generated by DRAINS and RAFTS were then input into the MIKE hydraulic model to simulate expected downstream flood levels. Comparing the simulated flood levels to existing flood levels can provide an assessment of the potential downstream impacts caused by the airport development.



LEGEND

- Airport site
- Watercourses
- Stage 1 subcatchment boundaries
- Stage 1 - DRAINS subcatchment boundaries

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

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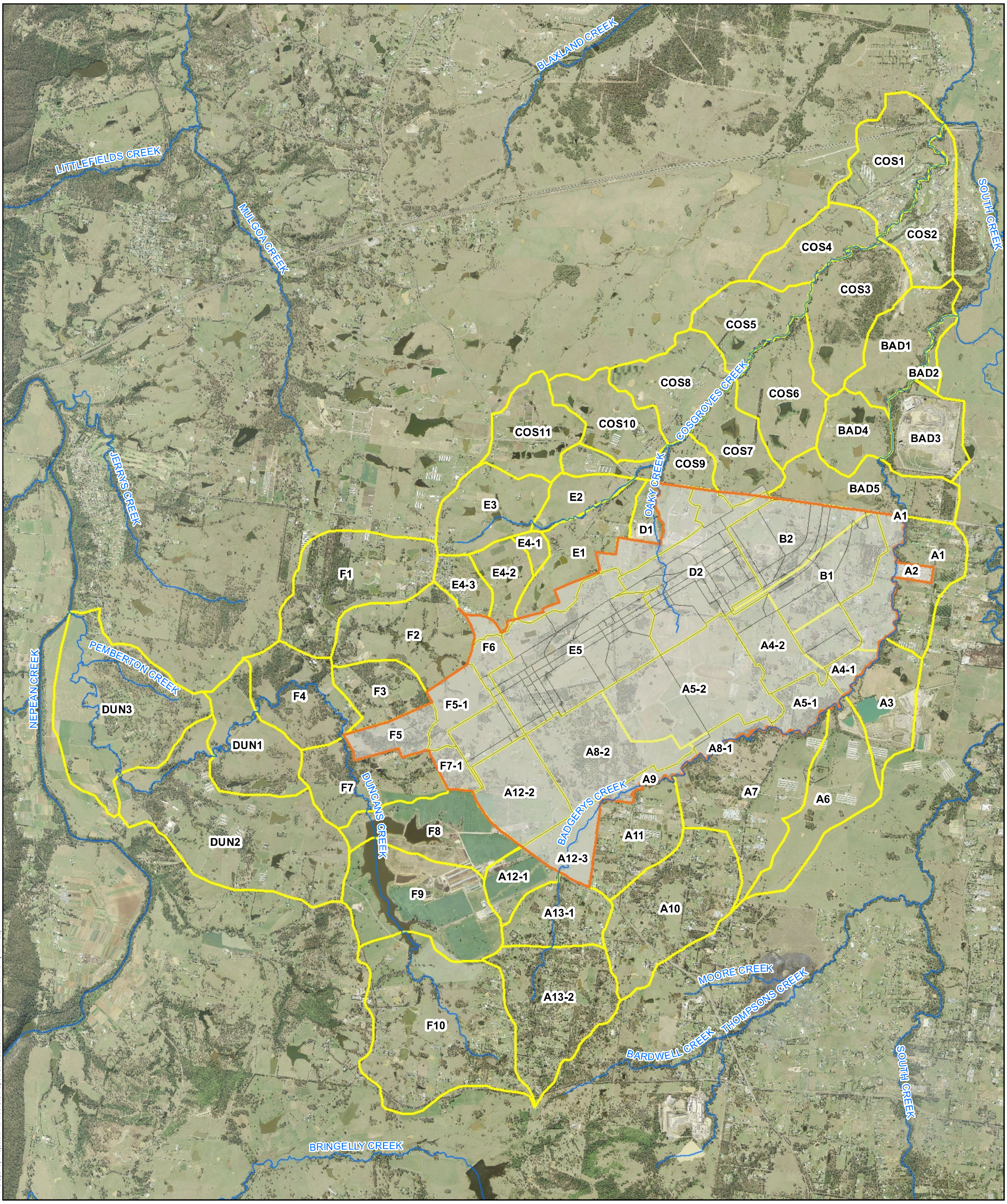
Kilometres

Figure 3-5 - Stage 1 - hydrology assessment subcatchment boundaries



LEGEND

Airport site

Watercourses

Long term subcatchment boundaries

Long term DRAINS subcatchment boundaries

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

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Figure 3-6 - Long term - hydrology assessment subcatchment boundaries

3.4.4 Hydrological sub-catchments and land use

DRAINS

The catchment areas in DRAINS are defined based on the Concept Design outlined in the revised draft Airport Plan. Land use in the DRAINS models was based on delineation of roofed, grassed and paved/hardstand areas. Percentage impervious fractions were then assigned to each node based on the surface types identified.

Table 3-6 Land use types and adopted impervious percentages within the airport site

Landuse type	% impervious – Stage 1 Scenario	% impervious – Long term Scenario
Roofed areas	2	10
Grassed areas	83	46
Paved/hardstand areas	15	44

3.4.5 Representation of key hydraulic structures

In the DRAINS model, on-site hydraulic structures have been represented as model features during both Stage 1 and the long term development. These include culverts, channels, pits, pipes, basins and overflow routes that make up the proposed trunk drainage concept design.

3.5 Impact assessment

The assessment considered the impacts of the development on:

- surface flows, including the effectiveness of the proposed basins in mitigating changes to hydrology;
- watercourse geomorphology;
- flooding and flood risk to surrounding developments and people; and
- cumulative aspects.

3.5.1 Hydrology and hydraulics

Findings are reported in Section 6.1.1.

Outputs from the hydrology model were used:

- to inform the impact assessment of changes to flows as a result of the airport; and
- to confirm the effectiveness of the proposed basins in mitigating changes to hydrology.

The results of the hydraulic modelling were used to determine:

- the impact of the proposed airport on watercourse geomorphology; and
- the impact of the proposed airport on flooding and the flood risk to surrounding developments and people.

Changes in catchment area and land use were identified for their potential to change the flows discharging from the airport site during both Stage 1 and the long term development.

The significance of the magnitude of change to flow discharge between the existing and the Stage 1 or long term scenarios depends on factors, including:

- watercourse stability (see Section 3.5.2 below);
- the sensitivity of biodiversity to changes in surface water parameters; and
- the sensitivity of surrounding infrastructure and residences to flooding.

These factors were considered when assessing changes to surface water between the existing condition and the Stage 1 and long term development.

As part of the flood analysis, differences in predicted flood depth of greater than or less than 100 mm were reviewed for the potential to influence flooding of surrounding residences and other infrastructure.

3.5.2 Geomorphology

The length and stream order of mapped watercourses within the development footprints of the Stage 1 and long term developments were reviewed. Changes in baseline hydraulics at discharge points from the airport site were considered together with watercourse type to determine the likelihood of such changes affecting watercourse stability.

Where levels of shear stress were expected to be low (less than 100 Newtons per square metre (N/m^2)), changes in shear stress of less than 10 N/m^2 were considered to be minor in influencing watercourse stability.

3.5.3 Cumulative impacts

The impacts of climate change and future development of the surrounding catchment were considered in the assessment of cumulative impacts of the Stage 1 and long term development.

3.5.4 Accounting for the future effects of climate change

Background to adopted climate change methodology

The NSW Office of Environment and Heritage (OEH) publishes information regarding the expected effects of future climate change on rainfall and sea levels. The document *Metropolitan Sydney Climate Change Snapshot* (OEH November 2014), which incorporates the airport site, is the most recent relevant New South Wales publication. The report identifies predicted short term (from 2020 – 2039) and long term (from 2060 – 2079) changes to rainfall seasonality and average rainfall.

In the Sydney region, the majority of the climate change models show that autumn rainfall will increase in the near and far future. The majority of models show that spring rainfall will decrease in the near future, though far future predictions are less clear. It is important to note that there is a significant degree of uncertainty in the findings of the climate change modelling, and that the NSW Government is conducting ongoing research into climate change.

The publication does not provide details regarding changes to flood-producing rainfall events other than to confirm that changes to rainfall intensity are expected.

The *Practical Consideration of Climate Change* (NSW Department of Environment and Climate Change 2007) publication references climate change modelling carried out by the CSIRO in 2007 for the NSW Government to assess the impacts of climate change on rainfall intensities. The results showed a trend of increased rainfall intensities for the 40 year ARI one-day rainfall event across New South Wales. The projected changes in rainfall totals in the Sydney Metropolitan Area are indicated in Table 3-7.

Table 3-7 CSIRO indicative change in rainfall one-day totals (CSIRO, 2007)

Location	40 Year 1 day rainfall total projected change by 2030	40 Year 1 day rainfall total projected change by 2070
Sydney Metropolitan Area	-3% to +12%	-7% to +10%
New South Wales average	-2% to +15%	-1% to +15%

The values in the table are considered indicative. OEH is currently working with the University of New South Wales to analyse the effects of climate change on flooding. It is expected that the values above will change as new information becomes available.

For catchments in NSW, the Practical Consideration of Climate Change publication suggests considering a 10 per cent, 20 per cent and 30 per cent increase in peak rainfall and volume to account for the future effects of climate change when considering flood events.

Adopted climate change methodology

Climate change predictions are not incorporated into the hydrology of the impact assessment but are considered as a future cumulative impact. Consideration was given to the potential for both increases and decreases in rainfall as outlined in the Metropolitan Sydney Climate Change Snapshot.

For the flood assessment, the cumulative impact of the Stage 1 and long term development together with the predicted impacts of climate change were assessed for the following modelling scenarios based on the upper and lower range recommendations of the Practical Consideration of Climate Change publication:

- Stage 1 development and 100 year ARI flood event with 30 per cent increase in rainfall intensity; and
- Long term development and 100 year flood ARI event with 30 per cent increase in rainfall intensity.

The Stage 1 Concept Design makes some provision for climate change as outlined in Section 3.4.2.

Accounting for the effects of future development

The analysis also considered the cumulative impacts of future development surrounding the airport site. This is discussed further in Section 0.

4. Existing environment

4.1 Topography

The airport site is located in the south-west portion of the Cumberland Plain (PPK, 1997) and includes rolling hills dissected by a number of drainage lines. A ridge system trends northwest to southeast in the vicinity of The Northern Road and reaches elevations of just over 120m AHD. There are some other isolated ridge lines in and around the Luddenham Dyke and The Northern Road with approximate elevations of slightly more than 100m AHD. The topography generally slopes away from these ridgelines to the south and east into Oaky Creek, Cosgrove Creek and Badgerys Creek as part of the South Creek catchment and to the northwest into Duncans Creek as part of the Nepean River Catchment. The lowest points of the airport site are where Badgerys Creek exits the north eastern extent of the airport site (approximately 44m AHD).

4.2 Land use

The airport site is predominantly rural, with a mixture of vacant lots, large agricultural lots and smaller scale residential and rural use. A large number of small farm dams are present across the airport site. Paved areas on the airport site are associated mainly with buildings and the arterial and local roads located on the airport site or passing through it.

4.3 Rainfall

An Automatic Weather Station (AWS) operated by the Bureau of Meteorology is located on the airport site. The data from the station has been analysed by the Bureau of Meteorology in the *Western Sydney Airport Climatological Review* (Bureau of Meteorology 2015). Results from the analysis of the gauge are summarised in Table 4-1.

Monthly statistics, taken from Table 4-1 of the *Western Sydney Airport Usability Report, Meteorological Impacts* (Bureau of Meteorology 2015) are provided in Table 4-2.

Table 4-1 Badgerys Creek AWS rainfall gauge data

Gauge name	Badgerys Creek AWS
Gauge Number	067108
Location	33.90 S, 150.73 E
Period of data	Dec 1998 – Present
Data Set Completeness	93.9%
Data resolution	1 minute
Mean Annual Rainfall (mm)	676.4

Table 4-2 Monthly rainfall statistics at Badgerys Creek AWS

Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly (mm)	77.4	108.0	77.3	43.2	40.1	52.1	23.0	35.9	33.9	52.7	74.5	63.6
Highest Monthly (mm)	192.2	342.4	198.0	129.4	155.6	220.0	71.6	231.0	82.2	182.2	173.2	131.2
Lowest Monthly (mm)	13.6	13.4	21.4	1.8	1.8	2.0	2.8	1.0	6.4	0.4	8.4	14.2
Highest Daily (mm)	138.0	106.8	67.8	82.4	54.0	63.8	28.4	70.0	50.8	63.0	63.0	65.0

The findings of the Bureau of Meteorology studies also indicate that heavy rainfall events of probability 1 Exceedance Year (EY) and rarer are more likely to occur between November and March, based on the available record. The likely timing of heavy rainfall events would be relevant for consideration during the scheduling of the airport construction (refer also to Section 0).

4.4 Surface water sources

4.4.1 Regional

The airport site is situated in the Hawkesbury-Nepean basin. The Hawkesbury-Nepean catchment is one of the largest coastal basins in NSW with an area of 21,400 square kilometres (NSW Office of Water). The airport site is located downstream of Warragamba Dam in a part of the catchment termed the lower Hawkesbury-Nepean. The airport site drains partially to both the Nepean and South Creek catchments and through to the Hawkesbury River, downstream of Warragamba Dam, via a system of tributaries.

South Creek drains a catchment of approximately 414 square kilometres and flows generally from south to north along its length (Worley Parsons 2015). It has its headwaters near Narellan and flows for a length of around 70 kilometres to its discharge point into the Hawkesbury River near Windsor. South Creek could be sensitive to impacts from the proposed airport if they spread downstream via the tributaries. The South Creek catchment is shale-based and is characterised by meandering streams. The catchment is highly disturbed due to increasing urbanisation and associated land clearing.

Based on available flood maps for the Hawkesbury-Nepean River, as well as Penrith and Liverpool Council Local Environmental Plan Flood Maps, the airport site is not affected by flooding from the Hawkesbury-Nepean system. In particular, it is not within the available modelled flood extents of the PMF resulting from the overtopping of Warragamba Dam.

4.4.2 Local

The airport site is located in the upper reaches of the catchments of Badgerys Creek, Cosgroves Creek, Oaky Creek (a tributary of Cosgroves Creek) and Duncans Creek. Badgerys Creek and Cosgroves Creek are tributaries of South Creek which is itself a tributary of the Hawkesbury River. Duncans Creek is a tributary of the Nepean River.

The catchments of Cosgroves and Oaky Creeks, Badgerys Creek and Duncans Creek are shown in Figure 4-1. The creeks and their associated ecosystems are environmental receptors for potential impacts from the airport development. Further details of the hydrological and geomorphological features of key catchments are described in greater detail later in this section.

Badgerys Creek

Badgerys Creek has its headwaters in the vicinity of Findley Road, Bringelly, approximately two kilometres upstream of the airport site. It flows generally in a north to north-east direction. It passes through the airport site starting at the aiport site’s southern extent and continues for a distance of approximately 1.2 kilometres before its course returns to the airport site boundary. The creek then forms the south-eastern boundary of the airport site as far as Elizabeth Drive. Downstream of the airport site, Badgerys Creek continues for a further four kilometres until its confluence with South Creek. Between the airport site and the confluence, the creek passes the Elizabeth Drive landfill site operated by SUEZ Environnement (previously operating as SITA).

Badgerys Creek has a catchment area of approximately 2,800 hectares (28.0 square kilometres) in total and an area of 2,360 hectares (23.6 square kilometres) at the downstream extent of the airport site at Elizabeth Drive. In addition to being used for agricultural and landfill purposes, the catchment of Badgerys Creek contains a number of residential properties downstream of the airport site and adjacent to the airport site which would be sensitive to changes in flood behaviour.

Oaky and Cosgroves Creeks

The headwaters of Oaky Creek are located on the airport site. The watercourse flows in a north-westerly direction for around two kilometres before it reaches the western boundary of the airport site. From this point, it meanders away from the airport site boundary, through the Blue Sky Mining site for several hundred metres, before rejoining the airport site boundary and continuing along it for 400 metres as far as the north-west corner of the airport site. Downstream of the airport site, the watercourse continues for a further half a kilometre before its confluence with Cosgroves Creek. Downstream of the confluence, the watercourse continues as Cosgroves Creek.

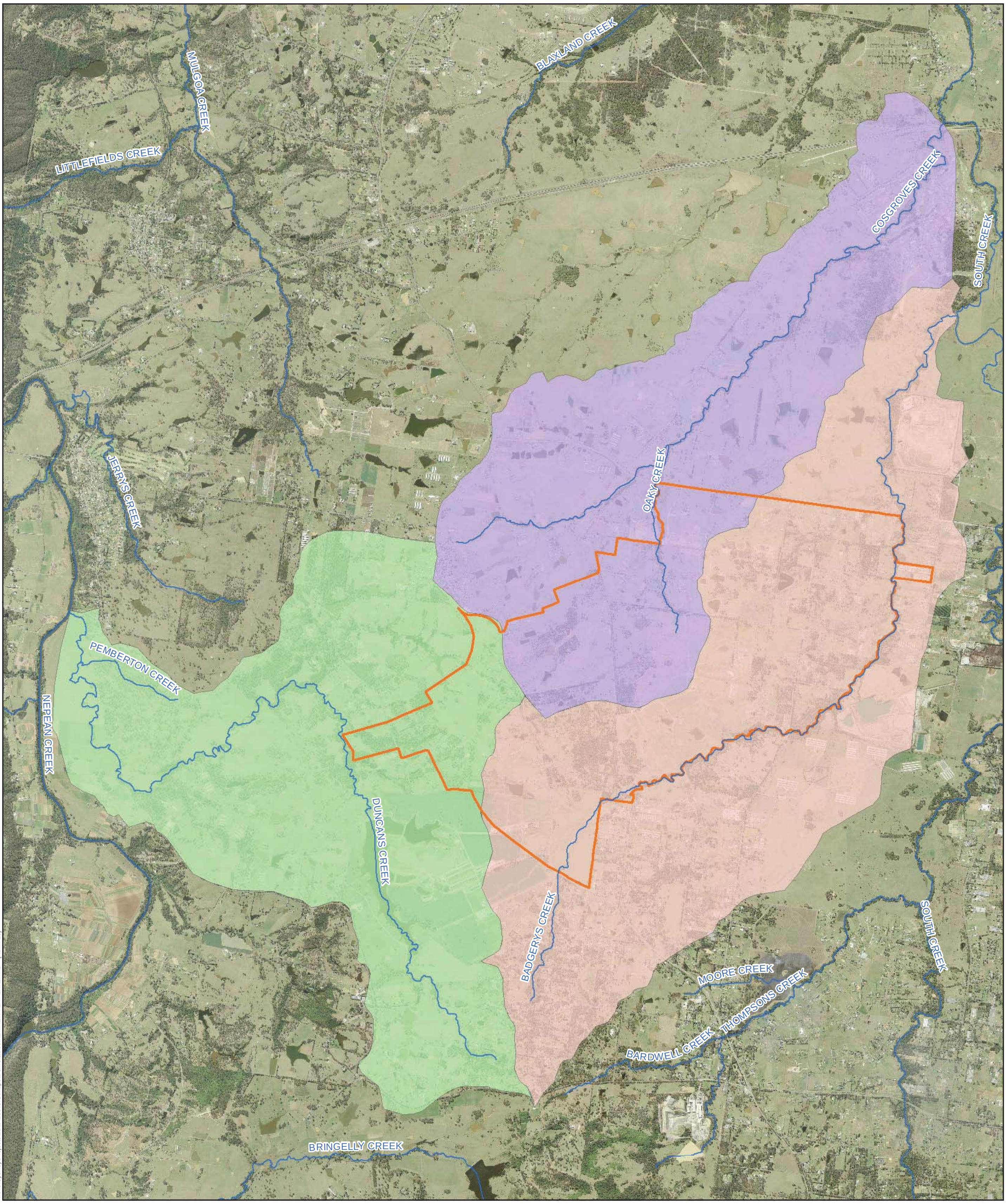
Downstream of the confluence with Oaky Creek, Cosgroves Creek continues for approximately seven kilometres before joining with South Creek. In the reach between Oaky Creek and South Creek, Cosgroves Creek passes through rural lots, the Twin Creeks Golf and Country Club and beneath an above-ground Sydney Water Corporation water pipeline.

Oaky Creek has a catchment area of 382 hectares (3.82 square kilometres) in total, and 361 hectares (3.61 square kilometres) at the downstream extent of the airport site. The total catchment area of Cosgroves Creek at the confluence with South Creek is approximately 2163 hectares (21.63 square kilometres). The catchments are largely rural and without residential development downstream of the airport site, with the exception of the Twin Creeks Golf and Country Club residential estate towards Cosgroves Creek's confluence with South Creek.

Duncans Creek

Duncans Creek has its headwaters in Bringelly and flows initially in a north-westerly direction. A number of unnamed tributaries of Duncans Creek are located on the airport site. A large water storage dam is located on the creek at the Leppington Pastoral Company site. Information regarding the dam was requested from the owners but available data was limited to the total dam size of 5,000 ML. Downstream of the dam the creek continues, passing close to the southern tip of the airport site before turning sharply towards the south west and later meandering north again before discharging into the Nepean River around nine kilometres downstream of the southern extent of the airport site.

The Duncans Creek catchment downstream of the airport site is rural and zoned for primary production (plant or animal cultivation) according to the Liverpool City Council Local Environmental Plan. A small portion of the airport site north west of The Northern Road drains to Duncans Creek via several tributaries.



LEGEND

Airport site

Watercourses

Catchment

Badgerys creek

Duncans creek

Oaky and Cosgroves creeks

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

0 0.4 0.8 1.6

Kilometres

Figure 4-1 - Local hydrological catchments

4.5 Hydrology and flooding

4.5.1 Hydrological modelling findings

The RAFTS hydrology model was used to understand characteristics of flood flows on, and downstream of, the airport site. The critical storm for each catchment is the storm producing the highest flood peak at a given location for a given ARI. The critical duration is influenced by factors such as overall catchment size as well as the properties of contributing sub-catchments.

Critical durations vary by subcatchment but are generally around nine hours for Badgerys Creek, six hours for Oaky Creek and Cosgroves Creeks and six hours for Duncans Creek. The results indicate that peak flows are typically generated by longer duration storms for smaller ARI events which are reflective of the greater influence of initial storm losses on peak flows for the smaller shorter duration events.

Peak flows at selected locations are shown in Table 4-3 below. Locations correspond to the hydrology assessment reporting locations depicted on Figure 4-2. An increase in peak flow would generally correspond to an increase in flood level and shear stress and is therefore an indicator of potential impact on flooding or geomorphology. The potential impacts were investigated further through hydraulic modelling (Section 4.5.2).

Table 4-3 Peak flows at selected locations, existing conditions

Location	Description	Peak flow (m^3/s), 100 year ARI event	Peak flow (m^3/s), 1 year ARI event
A	Badgerys Creek downstream of Elizabeth Drive	136.6	27.1
B	Badgerys Creek downstream of Basin 2	120.7	25.7
C	Cosgroves Creek at confluence with Oaky Creek	114.5	21.7
D	Oaky Creek downstream of quarry	34.3	7.4
F2	Duncans Creek tributary at catchment F2	24.2	5.8
F3	Duncans Creek tributary at catchment F3	12.5	2.6
F4	Duncans Creek tributary at catchment F4	14.5	2.9
F5	Duncans Creek tributary at catchment F5	9.7	2.1
F7	Duncans Creek tributary at catchment F7	19.8	3.8
Node2	Duncans Creek tributary downstream of Basin 8	14.3	2.9
Dun3	Duncans Creek at catchment Dun3	43.0	8.8

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

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LEGEND

- Airport site
- Watercourses
- Hydrology assessment reporting locations
- Detention Basin
- Bioretention Basin
- Long term development area

Figure 4-2 - Hydrology assessment reporting locations

0 0.4 0.8 1.6
Kilometres

4.5.2 Hydraulic modelling

Figure 4-3, Figure 4-4 and Figure 4-5 show peak flood flows (extracted from the flood model for the 100 year ARI event) for the critical storm durations for each catchment (refer to Section 4.5.1) for Badgerys Creek and Cosgroves Creek at Elizabeth Drive as well as for Duncans Creek downstream of catchment F4. The extent of flooding under existing conditions and predicted flood depths are shown in Figure 4-6 to Figure 4-13 for Badgerys, Cosgroves, Oaky and Duncans Creeks.

In the 1 year ARI event, flooding is mostly confined to main watercourse channels and dams. In the 5 year ARI event, overbank flooding is expected at depths of up to around 0.6 metres on Oaky Creek and Cosgrove Creek. Deeper flood depths are expected on Badgerys Creek, particularly upstream of Elizabeth Drive. Flood depths of up to around 0.5 metres in overbank areas are predicted on Duncans Creek.

In a 100 year ARI event, significant overbank flooding is also expected. On Badgerys Creek near the downstream area, the floodplain is more extensive on the airport side (western bank) than on the eastern bank due to the wider and flatter floodplain in this location. Considerable overbank flooding is expected on Duncans Creek in a 100 year ARI event. Flooding of Duncans Creek in the area immediately adjacent to the airport site is however limited by the flow attenuation provided by the Leppington Pastoral site dam located immediately upstream in the catchment. A number of the flood-affected rural residential lots outside the airport site are located in Bringelly in the area bounded by the airport site, The Northern Road and Badgerys Creek Road. Based on the available imagery, though a number of lots would experience some inundation in a 100 year ARI event, most existing dwellings in this area remain outside the flood extent. There are a number of existing dwellings located within the flood extent or in close proximity to the flood extent clustered on Badgerys Creek upstream of the airport site (Figure 1-1).

Two dwellings in close proximity to the flood extent were also identified downstream of the airport site on Cosgroves Creek. On the eastern bank of Badgerys Creek are a number of flood affected lots, though the existing dwellings are located beyond the 100 year flood extent. This includes dwellings on the parcel of land located on the eastern side of Badgerys Creek that may in future become part of the airport site which are not within the 100 year flood extent and are therefore not marked on the map.

On Duncans Creek, flood affected dwellings are largely outside the 100 year flood extent. A single structure has been identified as a possible dwelling within the 100 year flood extent, though it is unclear from aerial imagery whether this is a residential home or farm outbuildings.

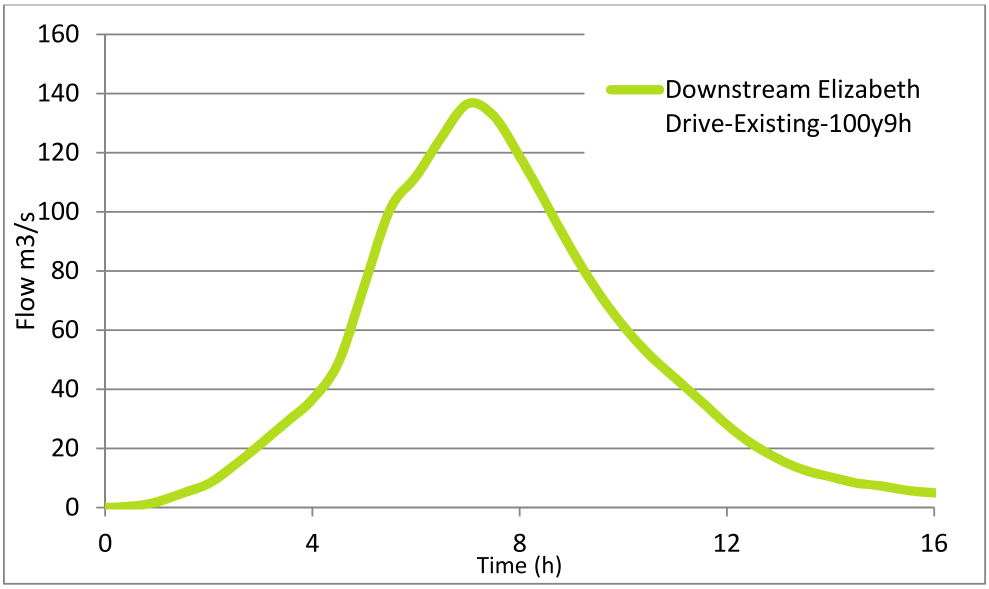


Figure 4-3 Hydrograph at Elizabeth Drive, 100 year ARI 9 hour storm duration, Badgerys Creek

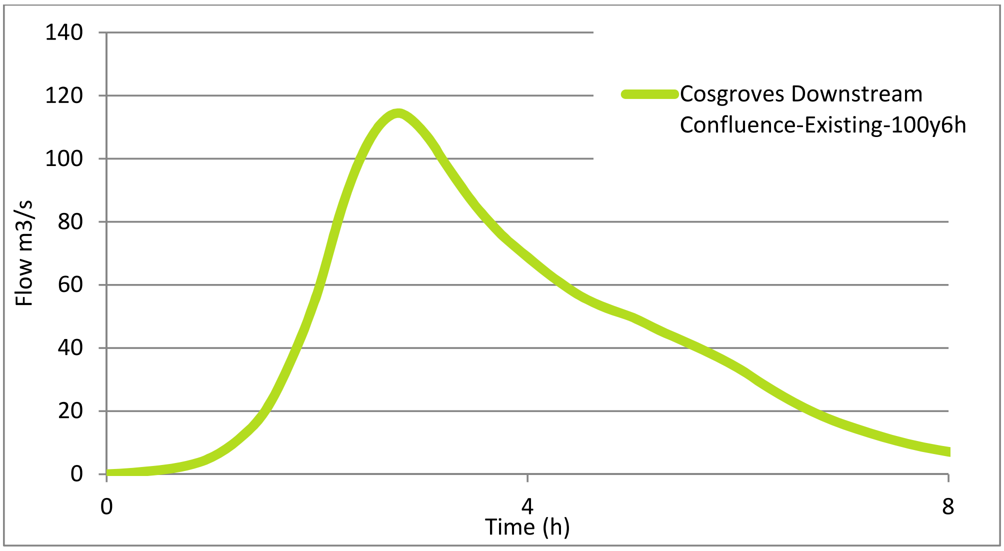


Figure 4-4 Hydrograph at confluence with Elizabeth Drive, 100 year ARI 6 hour storm duration, Cosgroves Creek

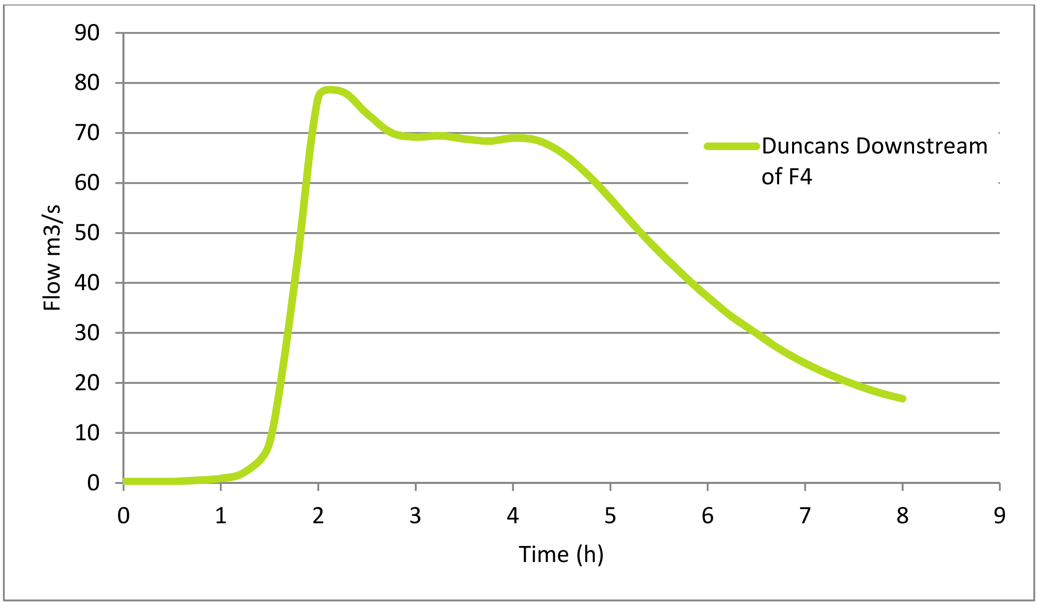


Figure 4-5 Hydrograph downstream of catchment F4 inflow, 100 year ARI 4.5 hour storm duration, Duncans Creek

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

- Airport site

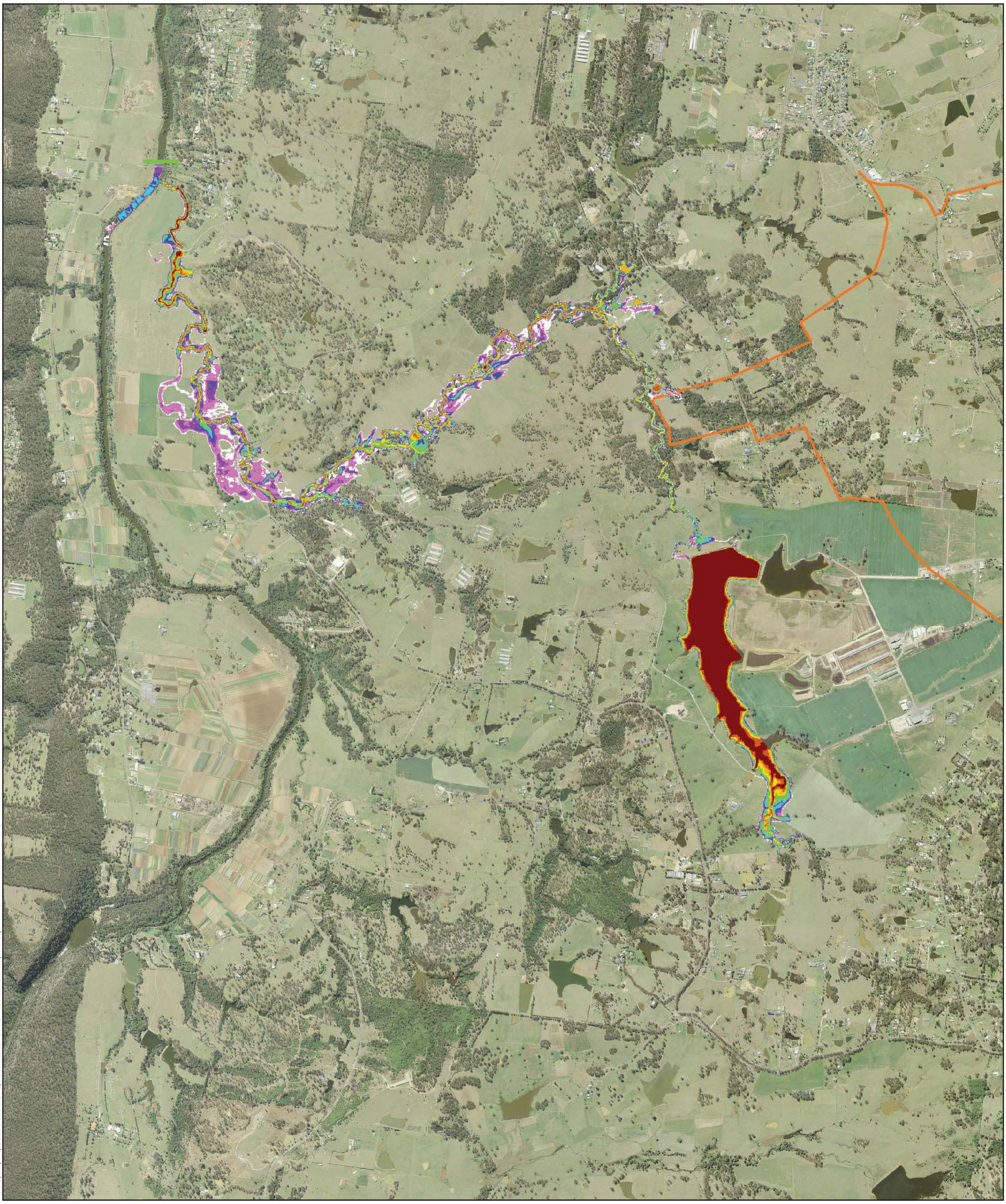
Flood depth (m)

- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- >4

Figure 4-6 - Existing flood depths - 1 year ARI, Badgerys and Cosgroves Creeks

0 0.25 0.5 1
Kilometres

N



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LEGEND

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

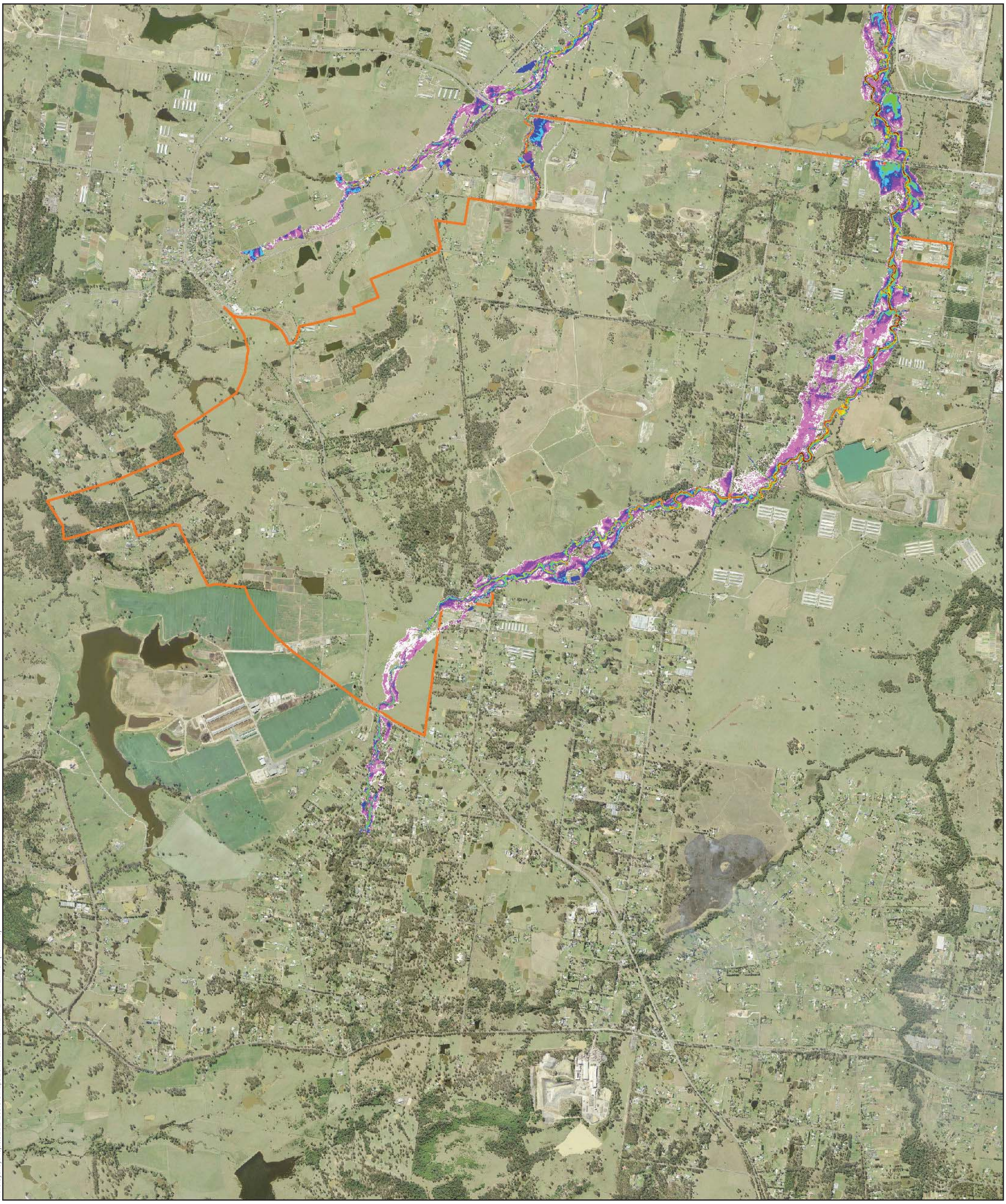
Airport site

Flood depth (m)
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- >4

0 0.225 0.45 0.9
Kilometres

N

Figure 4-7 - Existing flood depths - 1 year ARI, Duncans Creek



LEGEND

Airport site

Flood depth (m)

- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- >4

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

0 0.25 0.5 1

Kilometres

N

Figure 4-8 - Existing flood depths - 5 year ARI, Badgerys and Cogroves Creeks

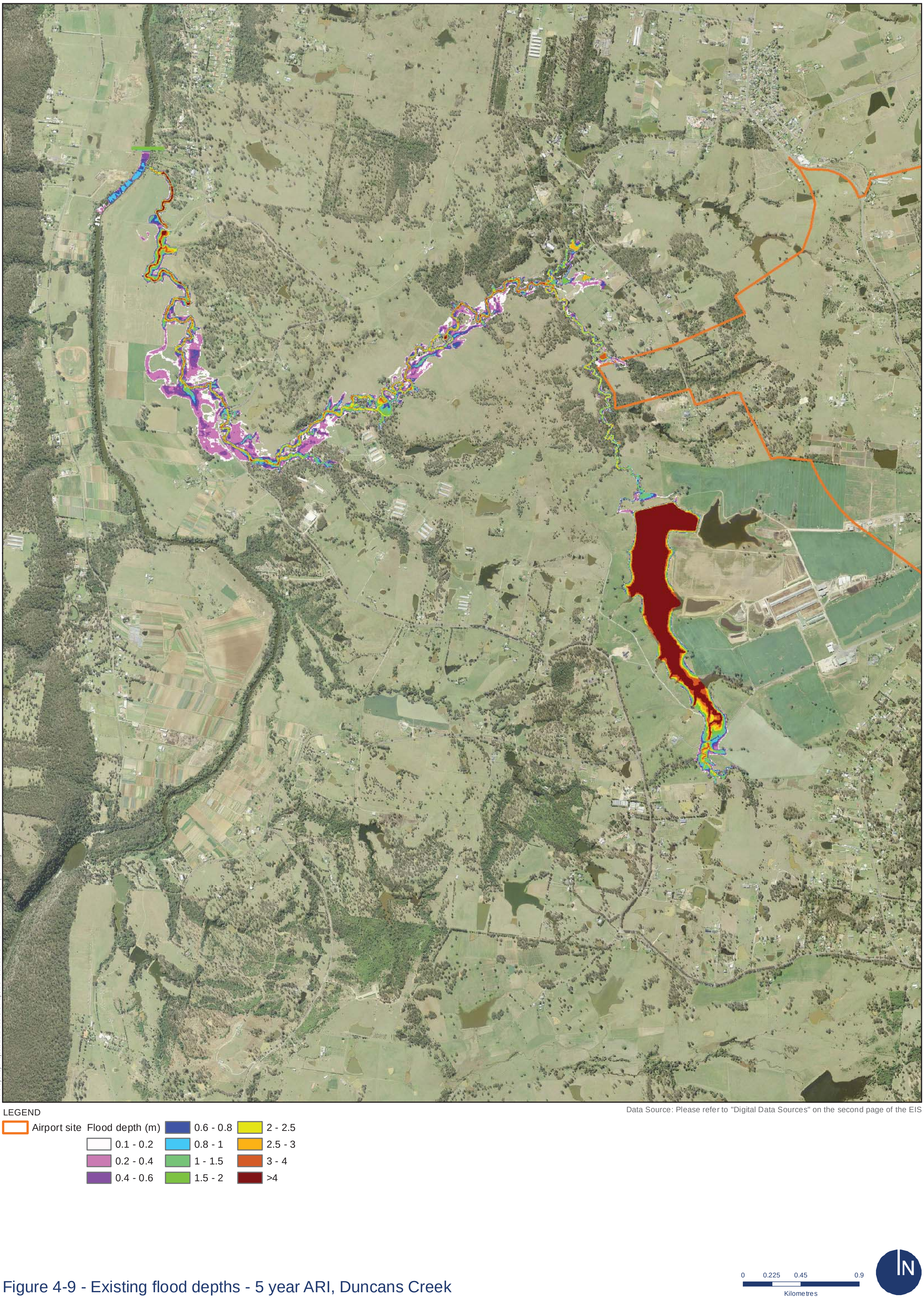
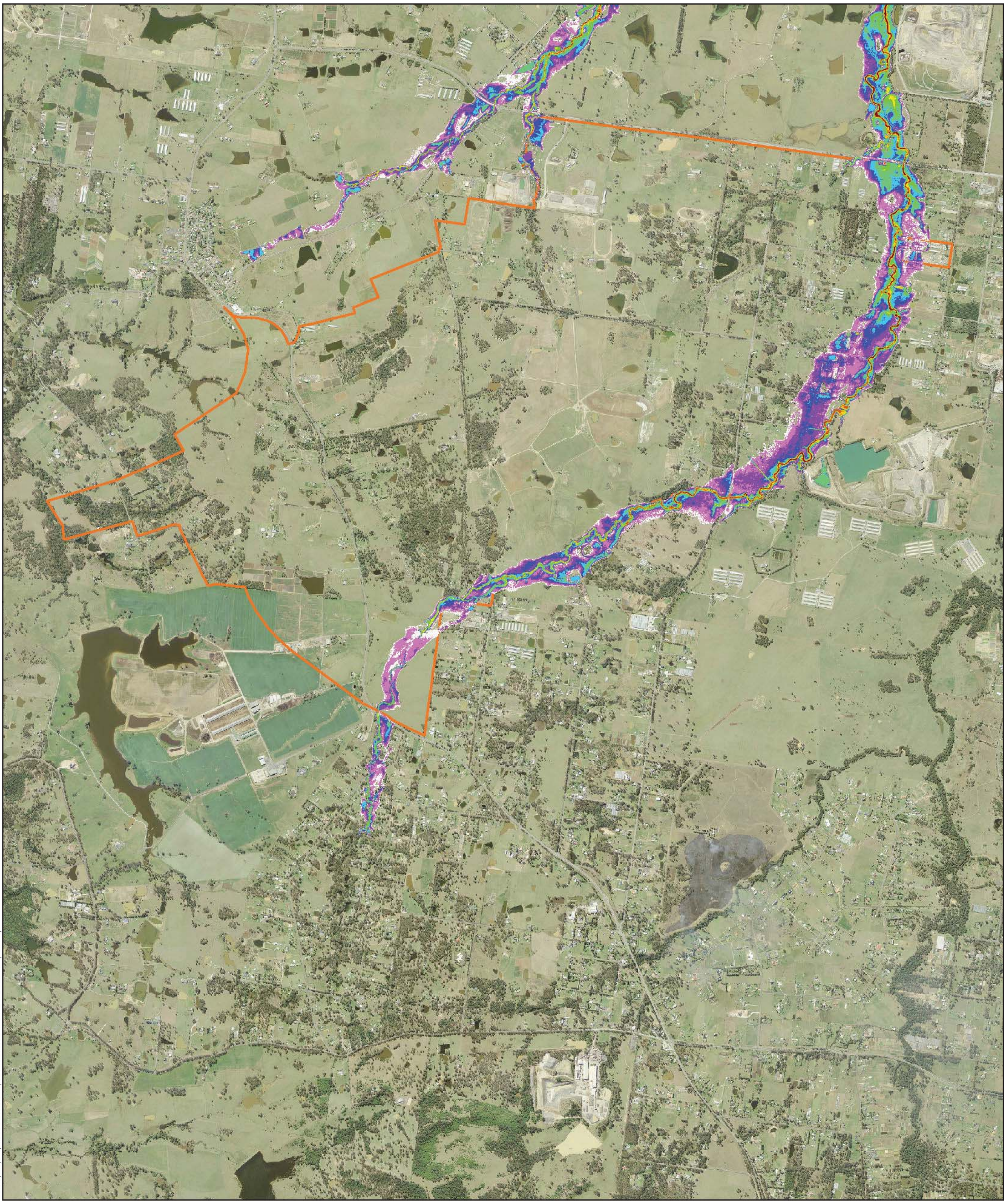


Figure 4-9 - Existing flood depths - 5 year ARI, Duncans Creek



Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site

Flood depth (m)

- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- >4

Figure 4-10 - Existing flood depths - 100 year ARI, Badgerys and Cosgroves Creeks

0 0.25 0.5 1

Kilometres

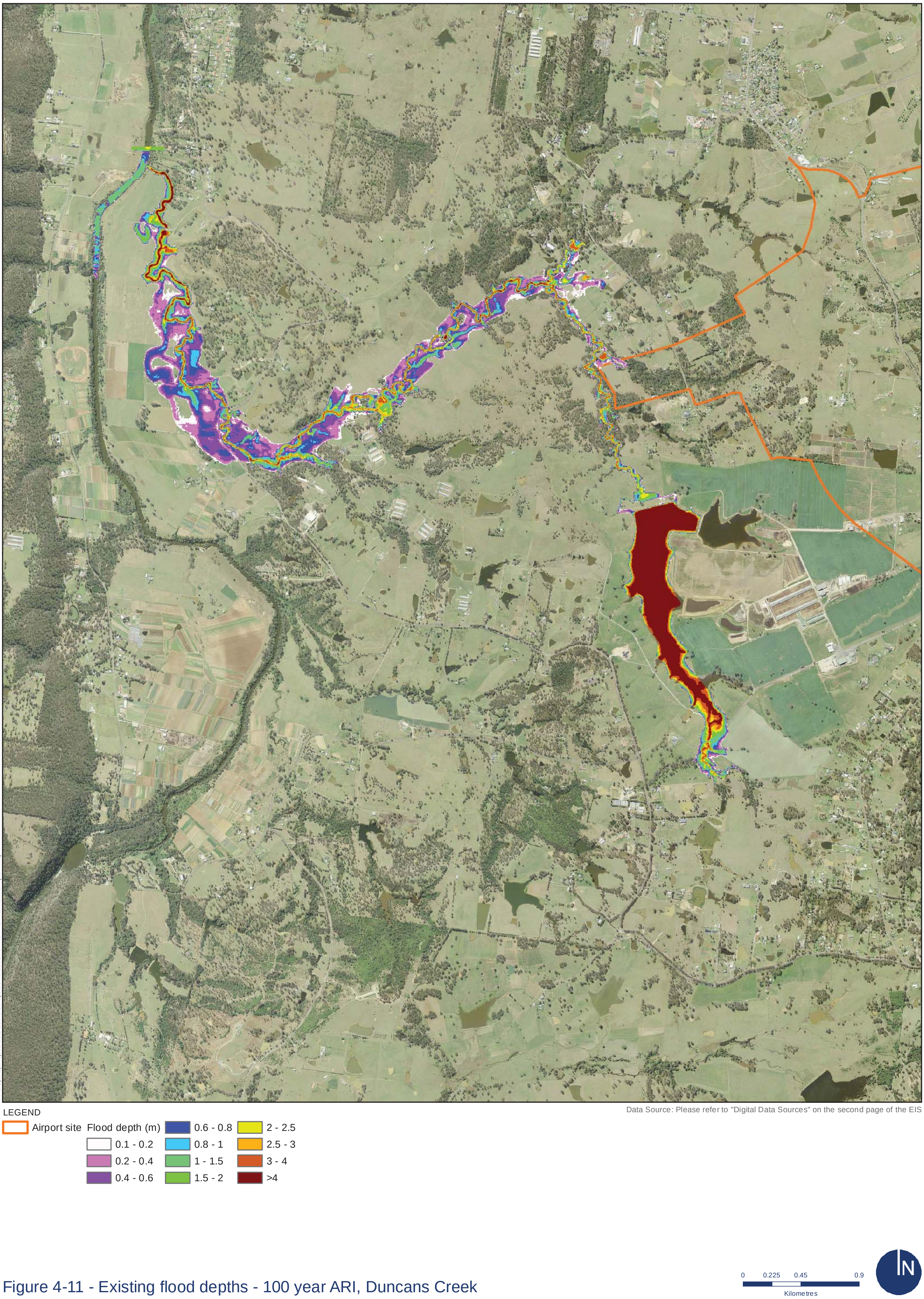
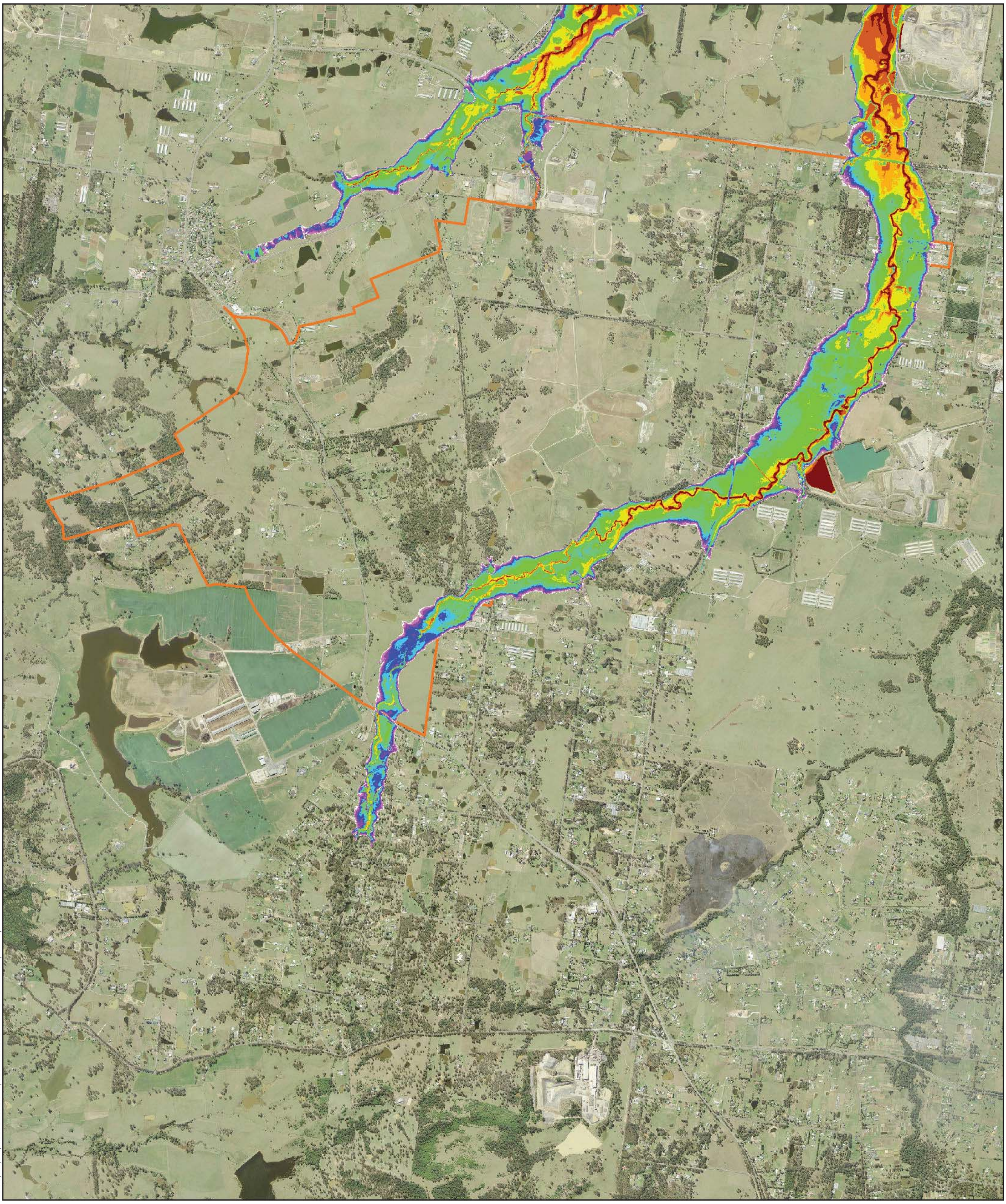


Figure 4-11 - Existing flood depths - 100 year ARI, Duncans Creek



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Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

Airport site

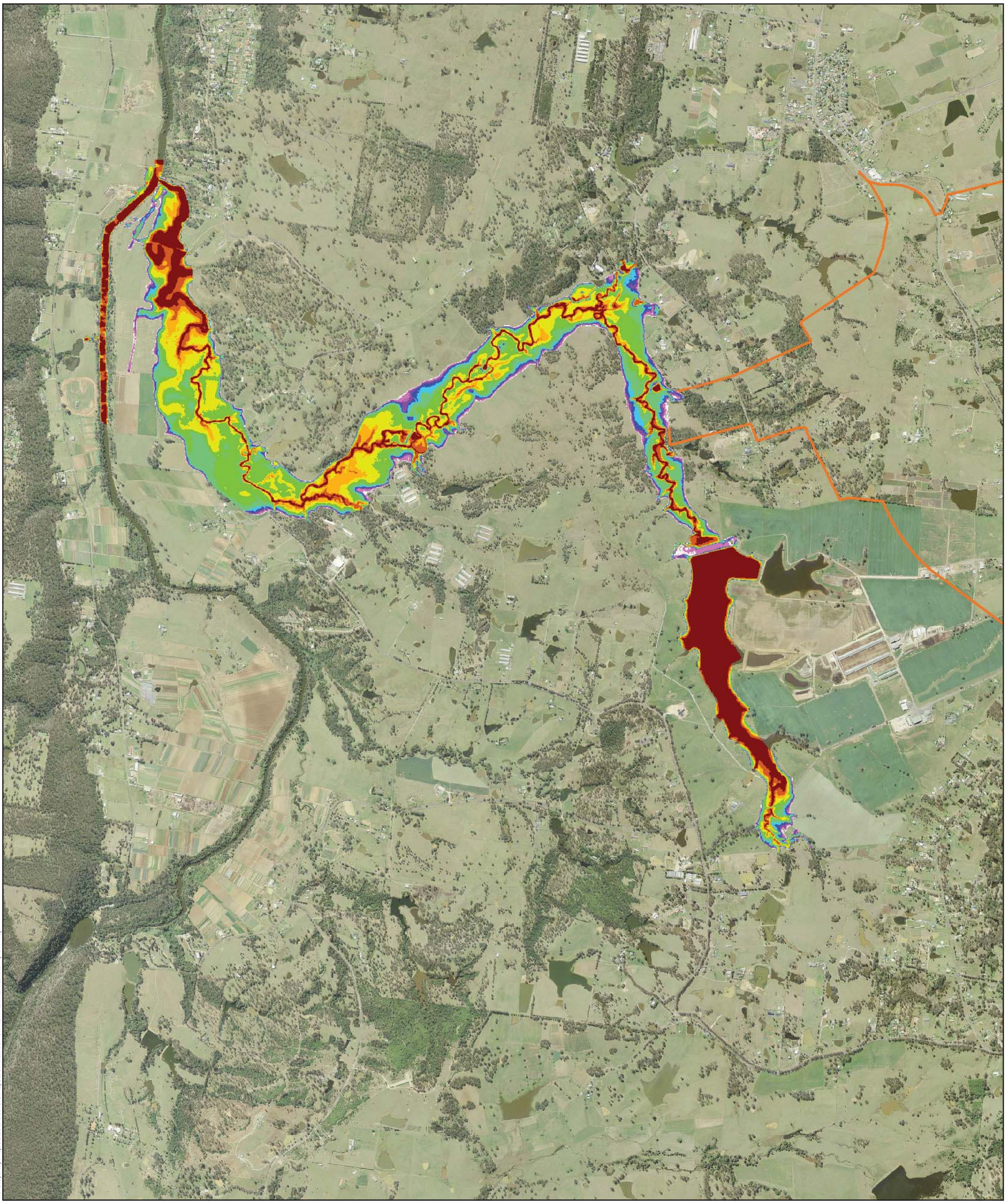
Flood depth (m)

- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- >4

Figure 4-12 - Existing flood depths - PMF, Badgerys and Cosgroves Creeks

0 0.25 0.5 1
Kilometres

N



LEGEND

Airport site	Flood depth (m)	0.6 - 0.8	2 - 2.5
	0.1 - 0.2	0.8 - 1	2.5 - 3
	0.2 - 0.4	1 - 1.5	3 - 4
	0.4 - 0.6	1.5 - 2	>4

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

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0 0.225 0.45 0.9
Kilometres

Figure 4-13 - Existing flood depths - PMF, Duncans

4.6 Watercourse geomorphology

The general topography of the airport site is undulating, with rolling, broad crested hills developed on the geology of the Wianamatta Group shales. These shales are generally composed of claystones, siltstones and carbonaceous shales with sparse sandstone lenses. As a result, the primary weathering products derived from the airport site will consist of fine grained sediments (clay and silt). Existing drainage from the airport site predominantly flows either easterly to the northerly flowing Badgerys Creek or northerly to Cosgroves Creek. Watercourses in the south–western section of the airport site drain to the westerly flowing Duncans Creek.

4.6.1 Stream orders

The Strahler stream order of mapped watercourses on the airport site is displayed in Figure 4-14. The majority of watercourses are first and second order, accounting for approximately 70 per cent of the total length of the mapped watercourses on the airport site. Badgerys Creek attains the highest stream order on the airport site, being fourth order for most of its length along the eastern boundary of the airport site.

4.6.2 Watercourse types

A total of five watercourse geomorphic types were identified during the desktop and field assessment of the watercourses across the airport site. These are as follows:

- poorly defined drainage lines;
- steep confined watercourses;
- valley fill systems;
- channelised fill systems; and
- partly confined to unconfined, fine grained watercourses.

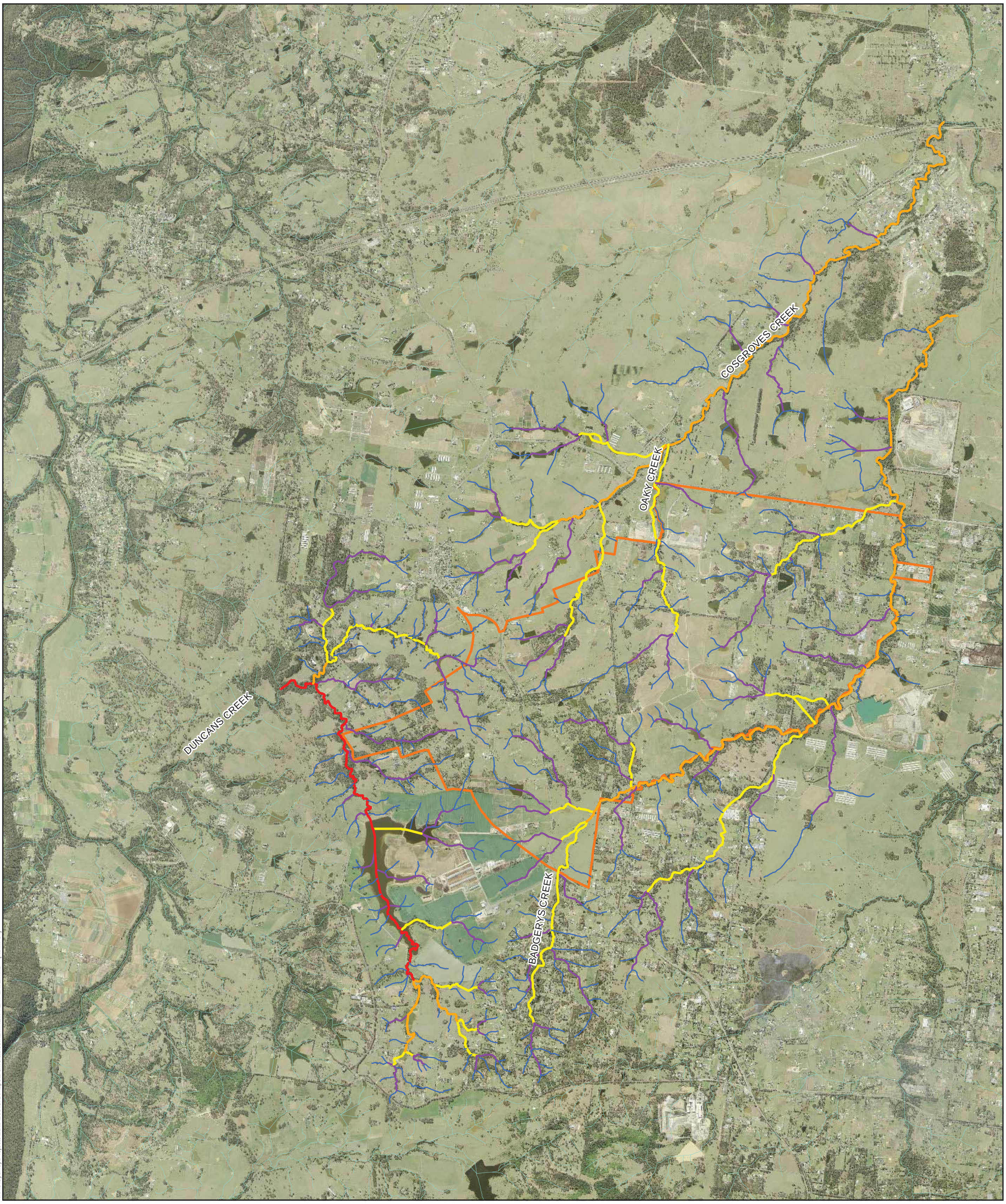
There are also numerous farm dams constructed along watercourses, accounting for 16 per cent of the mapped watercourse length on the airport site. The mapped distribution of watercourse types and farm dams located on defined watercourses is shown in Figure 4-15 and their characteristics are described below.

Poorly defined drainage lines

Poorly defined drainage lines are primarily located along first order watercourses within the airport site. These systems consist of a narrow depression set within a gently concave valley. There are no defined channels and as a result, flow occurs via sheet flow during rainfall events. Typically, these watercourses are geomorphologically stable with no visible signs of erosion or instability. Poorly defined drainage lines are predominantly first order watercourses and account for 31 per cent of the mapped watercourse length on the airport site.

Steep confined watercourses

This watercourse type is characterised by a steep gradient channel occupying a narrow v-shaped valley. The channel is laterally and vertically stable, although it may slowly erode the valley wall if it consists of weathered bedrock or colluvium. Floodplains are absent such that sediment storage is limited to small bars and benches. This watercourse type is only located in the south-western section of the airport site and accounts for three per cent of the mapped watercourse length on the airport site.



LEGEND

Airport site
Strahler Stream Order
Not classified
1
2
3
4
5

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

0 0.4 0.8 1.6
Kilometres

N

Figure 4-14 - Strahler stream order

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

- Airport site
- Watercourses
- Watercourse type
  - Drainage lines
  - Steep confined watercourses
  - Valley fill
  - Channelised fill
  - Fine grained systems
  - Dam

0 0.25 0.5 1
Kilometres

Figure 4-15 - Watercourse type

Valley fill systems

Valley fill systems consist of flat valley floors with no defined channel such that the whole valley floor acts as a channel with valley margins as the banks. During high intensity rain events, water flows across the surface as sheet flow. As such, the flow energy is dissipated across the valley floor, resulting in the deposition of fine-grained suspended sediments. Low energies associated with flow dissipation lead to long term accumulation of sediments derived from upstream. If the valley floor is disturbed, a headcut may be initiated (refer also to Channelised fill, below). This will form a continuous channel that will incise, enlarge and progress up stream with each subsequent flow event. Valley fill systems are located throughout the study area along first to third order streamlines and account for 32 per cent of the mapped watercourse length on the airport site.

Channelised fill systems

Channelised fill systems exhibit a continuous channel that has incised, probably since European settlement, into valley fill through headcut retreat and channel expansion. The floodplains represent former valley fill surfaces and are generally flat and featureless. Channelised fill systems generally have an intermittent flow regime and do not usually retain surface water between flow events. Moderate stream energies generated during higher flow events can re-activate erosional processes. Headcuts will progress upstream and unprotected banks will erode. As most channels have incised to a point where all flows are contained within the channel, the former fill surfaces are rarely inundated. Consequently, flow energy concentrates within the channel resulting in increased rates and occurrences of channel erosion. Channelised fill systems have a scattered distribution along first to fourth order streamlines and account for three per cent of the mapped watercourse length on the airport site.

Partly confined to unconfined, fine grained systems

This waterway type exhibits a single channel set within floodplain deposits of alluvial silt and sand. The channel is partly constrained by resistant bedrock but is largely bordered by alluvial floodplains. The channel generally holds water in isolated pools between flows. The channel itself is of low gradient and low energy such that sediment transported is predominantly limited to fine grained silts and clays in suspension. The low capacity channel allows overbank flows to be readily dissipated across the floodplain surfaces, activating flood channels and depositing fine grained sediments on the floodplain. Partly confined to unconfined, fine grained systems are located along third and fourth order watercourses and account for 15 per cent of the mapped watercourse length on the airport site.

4.6.3 Watercourse geomorphic condition

Both through and downstream of the airport site, Badgerys Creek, Cosgrove Creek and Duncans Creek display evidence of past and ongoing bed degradation. This is evidenced through the presence of active headcuts and over-steepened eroding banks. Despite having a generally well-vegetated riparian zone, these watercourses are considered to be in moderate geomorphic condition. As a result of past clearing, the construction of dams along the watercourses and ongoing agricultural activities, tributaries of Badgerys Creek and Cosgroves Creek across the airport site are also considered to be in largely moderate geomorphic condition.

4.7 Related features

4.7.1 Ecology and groundwater

Based on available mapping discussed in the biodiversity assessment (refer to EIS Appendix K1), none of the watercourses on the airport site or immediately downstream are considered to be groundwater dependent ecosystems (GDEs). South Creek to the east and the Nepean River to the west, both of which are further downstream of the airport site beyond the study extents are mapped as GDEs that are reliant on the surface expression of groundwater.

Many farm dams and ponds on the airport site are considered to be artificial freshwater wetlands, some of which are in good condition and feature predominantly native plant species. They are associated with artificial dams and flooded depressions that have been formed by the construction of barriers across small drainage lines. Because they are not natural geomorphic features, they do not comprise a local occurrence of the Threatened Ecological Community (TEC) 'Freshwater wetlands on coastal floodplains'. Nonetheless, they are considered to have ecological value.

Other receptors in the catchment downstream of the proposed airport include riparian vegetation which would be reliant on occasional flooding.

The biodiversity assessment found that the Australian Painted Snipe (*Rostratula australis*) bird may occur at wetlands and nearby flooded grassland within the airport site. Even though there are no local records of this species, and none were recorded during surveys, the species is cryptic. Wetlands at the airport site provide potential foraging and breeding habitat for this species.An aquatic ecology assessment found the macroinvertebrate communities downstream of the airport site to be in generally poor health, though the sampling undertaken occurred in a limited season. Fish communities identified were found to be "indicative of a disturbed habitat". Fish habitat downstream of the airport site was found to be mostly minimal, with some reaches of moderate habitat present.

5. Construction impacts

5.1 Flooding and waterlogging

Stage 1 of the proposed airport would be constructed over a period of approximately ten years. During this timeframe, the likelihood of a large rainfall event occurring is high. The historical record indicates that the likelihood for large rainfall events is skewed towards summer occurrence (refer also to Section 4.3). It is possible that impacts could occur both on the airport site, with general disruption to construction activities, and off the airport site, with impacts to surrounding properties and watercourses.

As the area of impervious surfaces is increased throughout construction, the volume of runoff from the airport site would increase due to a reduction in ground surface infiltration. Without mitigation, this would result in increased peak flows from the airport site and the potential for associated flooding and geomorphological impacts downstream. However, detention basins have been incorporated into the design of the proposed airport to mitigate the increase in runoff, reducing off-site impacts of potentially increased peak flows. The detention basins would be utilised during the construction phase and to manage stormwater throughout the operation of the proposed airport.

The airport site will include substantial and large-scale earthworks, which will modify drainage direction and overland flow paths, changing the nature of flooding on the airport site. Without progressive introduction of formal drainage designed to cater to the new site conditions, there is potential for disruption to construction activities due to flooding and waterlogged soils, as well as the potential for downstream flooding.

5.2 Mobilisation of soils

Impacts of increased sedimentation are discussed in detail in the surface water quality assessment (refer to EIS Appendix L2) but are mentioned here for their potential to change surface water flows. There is potential for large quantities of sediment to be directed into the network of temporary drainage as it is progressively constructed. If not appropriately managed, this would cause blockage of the on-site stormwater management network, reducing its effectiveness and increasing the likelihood of flow breakouts and overland flow paths with the effect of causing on-site flooding or flooding downstream.

5.3 Watercourse geomorphology

The primary impact on watercourse geomorphology during the Stage 1 construction will be the loss of natural drainage lines and watercourses within the construction impact zone (Figure 5-1). The total length of mapped watercourses within the Stage 1 construction impact zone is approximately 36.5 km, predominantly consisting of first and second order watercourses (Table 5-1). Approximately 4.4 km of watercourses within the Stage 1 construction impact zone are third order.

Table 5-1 Length of watercourses by stream order within the Stage 1 construction impact zone

Stream Order	Length (km)
1	22.2
2	9.9
3	4.4

The construction impact zone for a potential long term development is not yet well defined. However, further expansion of the airport facilities is expected to occur in the areas between the Stage 1 construction impact zone and Badgerys Creek. This expansion will subsume additional watercourses, primarily first and second order tributaries of Badgerys Creek.

Without appropriate erosion and sediment controls, the disturbance as a result of construction may result in higher rates of off-site sediment generation, leading to sedimentation within pools along watercourses adjoining and downstream of the airport site. However, it is expected that construction practices would be in accordance with current erosion and sediment control standards and the off-site movement of sediment would be expected to be minimal. Hence, the risk of significant pool sedimentation is considered low.

5.4 Groundwater seepage

Groundwater seepage is expected during construction and will be required to be collected and managed, either by discharge back to the environment and/or removal off-site and disposal at an appropriately licensed treatment facility. Further details of the activities expected to generate seepage are provided in the groundwater assessment prepared for this EIS (refer to EIS Appendix L3).

Treated water discharged to the environment may have a range of potential water quality impacts and these are discussed separately in the surface water quality assessment (refer to EIS Appendix L2). Changes to the volume of discharge may alter the natural flow regime and cause downstream impacts to flows and associated ecology (refer to EIS Appendix K1 for the biodiversity assessment). While the groundwater seepage disposal strategy is still to be determined, the groundwater assessment determined that seepage volumes are expected to be low and unlikely to significantly influence downstream hydrology.

5.5 Construction water use

It has been estimated (refer to the project description) that construction would require, on average, 1.3ML of water per day during bulk earthworks. Additional high water demand activities are expected for activities associated with the asphalt and concrete batching plants.

It is envisaged that within the construction impact zone, temporary basins would be constructed, and existing on-site dams would be repurposed, to catch any runoff for reuse in the bulk earthworks. However, these measures would be insufficient to meet the estimated 1.3 ML/day of water required for the bulk earthworks. Potable water would be used to supplement construction water requirements. To avoid constraints in potable water supply capacity, potable water would be extracted from the network in off peak times and used to fill the temporary basins for later use. The use of basins for storage of potable water would limit their capacity for capture of surface water runoff. The basins would be provided with their long term capacity for Stage 1 (refer to section 6.1.1) so in some instances there would be excess storage volume available in the basins for construction water use. The construction staging would need to incorporate these considerations, augmenting basin capacity or providing additional basins if necessary to cater to both the needs of construction water use and the need to provide for appropriate flood storage during construction (refer Section 8.1).

There are two existing potable water supply pipes located adjacent to the airport site. The first is located along Elizabeth Drive, the second on The Northern Road. Connection points would be determined in consultation with Sydney Water Corporation. The construction contractor for the Stage 1 development may also investigate alternative water sources, and seek appropriate approvals for their use.

Figure 5-1 - Stage 1 earthworks with watercourse stream order

6. Operational impacts

6.1 Stage 1 development

6.1.1 Impacts on hydrology and flooding

Identified changes and potential implications

The establishment of the Stage 1 development would result in major modification to existing flow paths and catchment boundaries with resultant potential impacts on surface water flows and the receiving watercourses. Redistribution of catchment areas would occur across much of the airport site. For example, a portion of the catchment on the northwest part of the airport site currently draining to Cosgroves Creek near Elizabeth Drive would be redirected into Badgerys Creek. In the location of the proposed car rental area and other ancillary support infrastructure, a portion of catchment currently draining to Badgerys Creek would be redirected towards Cosgroves Creek via Oaky Creek. In the south and west of the airport site, areas currently draining to Badgerys Creek and Cosgroves Creek would be redirected to tributaries of Duncans Creek. Redistribution of catchment boundaries in Stage 1 from the existing case can be seen by comparing Figure 3-1 and Figure 3-5.

Under the existing case, a tributary of Badgerys Creek crosses Elizabeth Drive around 350 metres west of the main crossing and joins with Badgerys Creek downstream of Elizabeth Drive. Under Stage 1, the tributary catchment at Elizabeth Drive would be diverted into Basin 1. Low flows would pass through the bioretention portion of the basin and then to the tributary via a culvert outlet in a manner similar to existing conditions. High flows would bypass the tributary outlet and would be diverted for detention and eventual discharge via a secondary outlet directly to Badgerys Creek. A summary of changes to catchment areas is provided in Table 6-1 based on Geographical Information System (GIS) area calculations.

Table 6-1 Catchment area comparison between existing and Stage 1

Location	Catchment area (existing) (ha)	Catchment area (Stage 1) (ha)	% impervious (existing)	% impervious (Stage 1)
Badgerys Creek at Elizabeth Drive	2,361	2,351	12	16
Oaky Creek at Elizabeth Drive	361	286	10	43
Cosgroves Creek at Elizabeth Drive	550	635	14	20
Badgerys Creek at South Creek	2,799	2,792	12	14
Cosgroves Creek at South Creek	2,165	2,183	14	20
Duncans Creek at Nepean River	2,379	2,357	14	15

The table shows that the Stage 1 development would result in:

- a net minor decrease in catchment area draining to Badgerys Creek at Elizabeth Drive and a minor net increase in percentage imperviousness of the resulting catchment area;
- a net decrease in catchment area draining to Oaky Creek due to diversions to Badgerys Creek and Cosgroves Creek and a substantial net increase in catchment percentage imperviousness;
- a net increase in catchment area draining to Cosgroves Creek at Elizabeth Drive and a moderate net increase in catchment imperviousness;
- a negligible change in catchment for Badgerys Creek at South Creek;
- a net increase in catchment area draining to Cosgroves Creek at South Creek and a moderate net increase in catchment imperviousness; and
- a minor decrease in catchment area draining to Duncans Creek and negligible increase in catchment percentage imperviousness.

During Stage 1, bulk earthworks including extensive cutting and filling across the airport site to level it would result in changes to storage characteristics, as would the removal of existing farm dams. The model results account for these changes with respect to the representation of changes to catchment slope, boundary and rainfall losses.

The airport would change surface run-off conditions in the catchments it intersects, which may also create minor incidental losses associated with evaporative changes. A decrease in catchment area, dependent on impervious fraction, would tend to decrease flows downstream and conversely, in the case of an increase in catchment area, would tend to increase flows downstream. An increase in catchment imperviousness has the potential to increase peak flows and cause flows to peak earlier. The effect of the change in each catchment area, whether major or minor, is dependent on the changes in flows and hydraulics that result from the changes. The changes in flow are discussed later in this report.

Design control measures

Detention basins are proposed at most site discharge points for the dual purpose of treating water quality and mitigating potential increases in peak flows (refer to Figure 3-3). Where no basin is proposed, this is because it was not deemed necessary during design development. In general, detention basins used for construction of Stage 1 would be reused in the long term. It is proposed that basins to be constructed in Stage 1 incorporate their full long term capacity (refer also to section 5.5 and section 6.2.1). The proposed storage basin volumes are presented in Table 6-2.

Table 6-2 Detention basin attenuation volume

Basin Number	Basin Volume (m^3) *
1	125,000
2	39,000
3	100,000
4	*Not included in Stage 1 and 82,000 in long term*
5	*Not included in Stage 1 and 65,000 in long term*
6	101,000
7	117,000
8	59,000

** Note that the concept design report indicates that a number of these basin volumes may be in excess of requirements and considered for reduction in size at the detailed design stage*

Predicted impacts

Comparison of flows under existing and Stage 1 conditions for 1 year ARI and 100 year ARI events are provided in Figure 6-1 to Figure 6-11. The figures show, at the various locations indicated in Figure 4-2, the existing flows and the Stage 1 flows incorporating the effects of the detention basins (where present). The plots show flows for the critical duration at each location and encompass the findings of other storm durations as well.

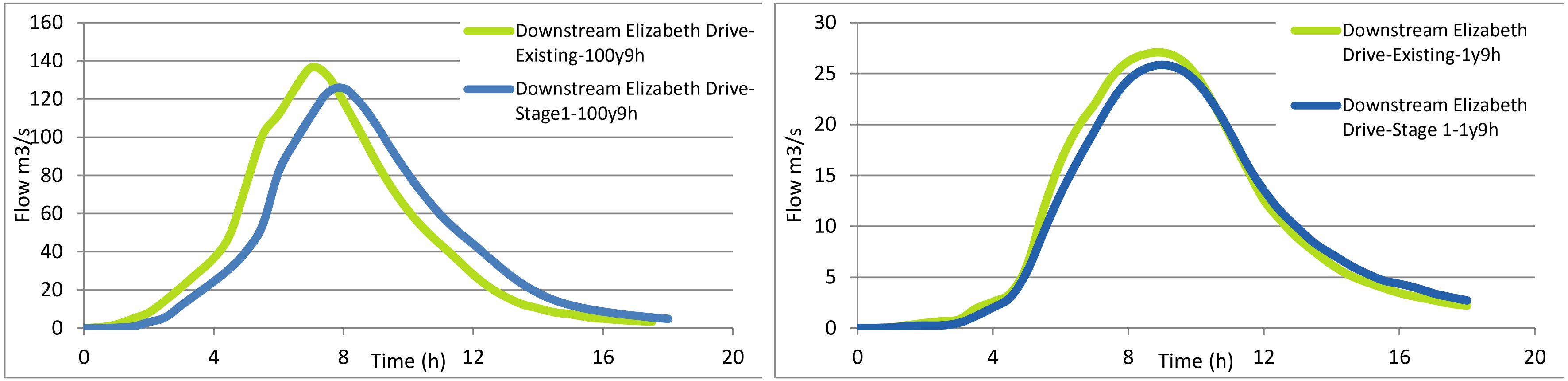


Figure 6-1 Location A, comparison of existing and Stage 1 flows, Badgerys Creek

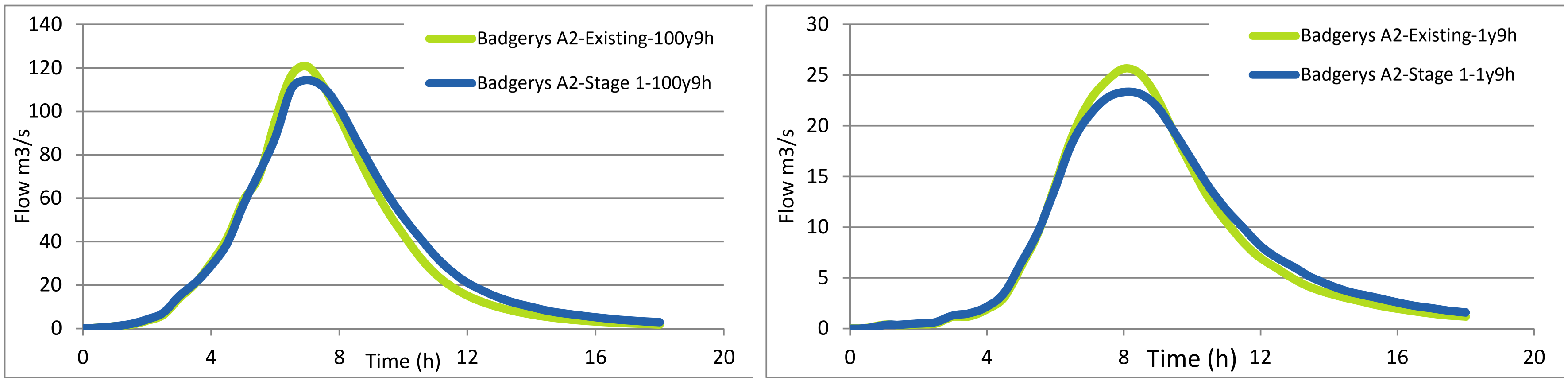


Figure 6-2 Location B, comparison of existing and Stage 1 flows, Badgerys Creek

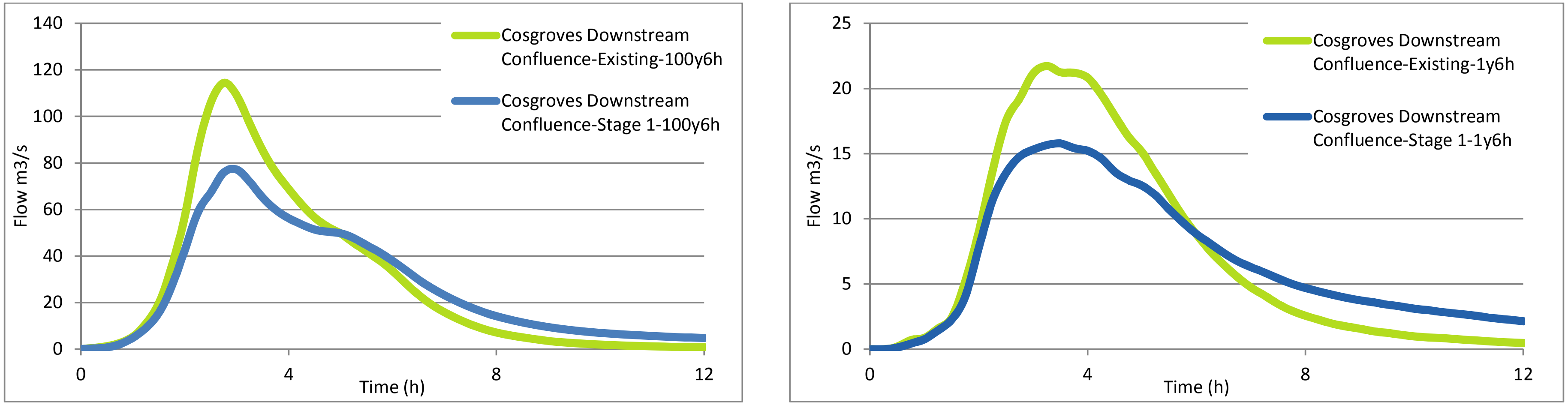


Figure 6-3 Location C, comparison of existing and Stage 1 flows, Cosgroves Creek

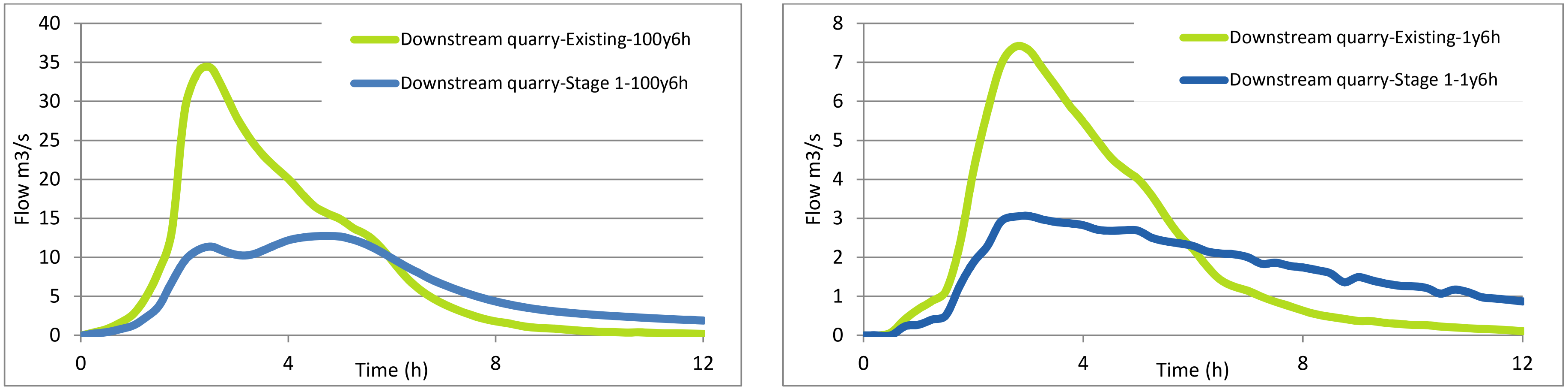


Figure 6-4 Location D, comparison of existing and Stage 1 flows, Oaky Creek

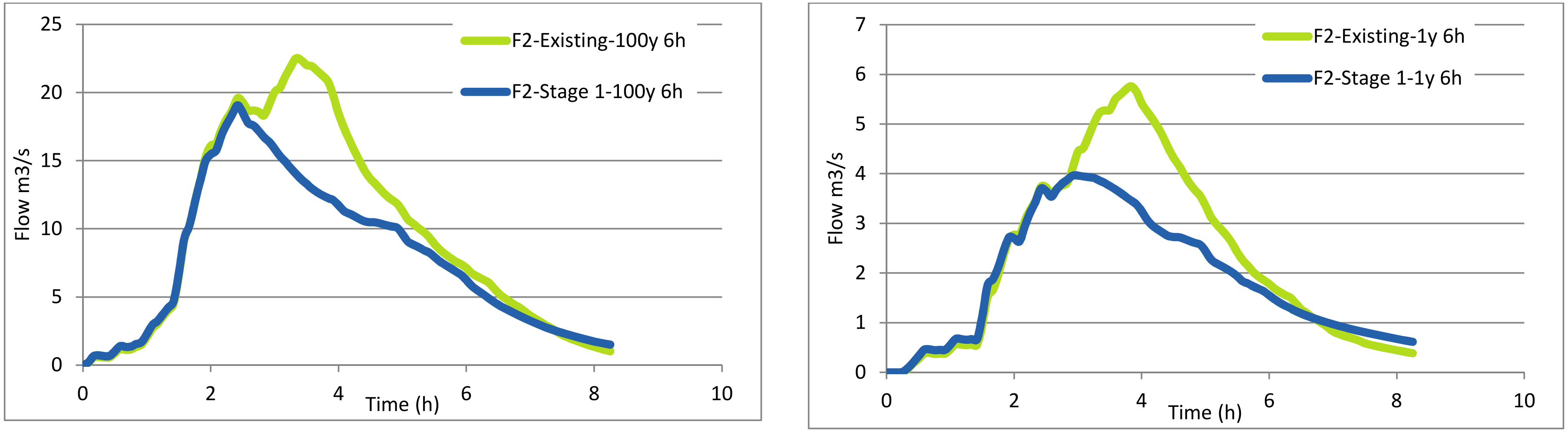


Figure 6-5 Location F2, comparison of existing and Stage 1 flows, Duncans Creek tributary

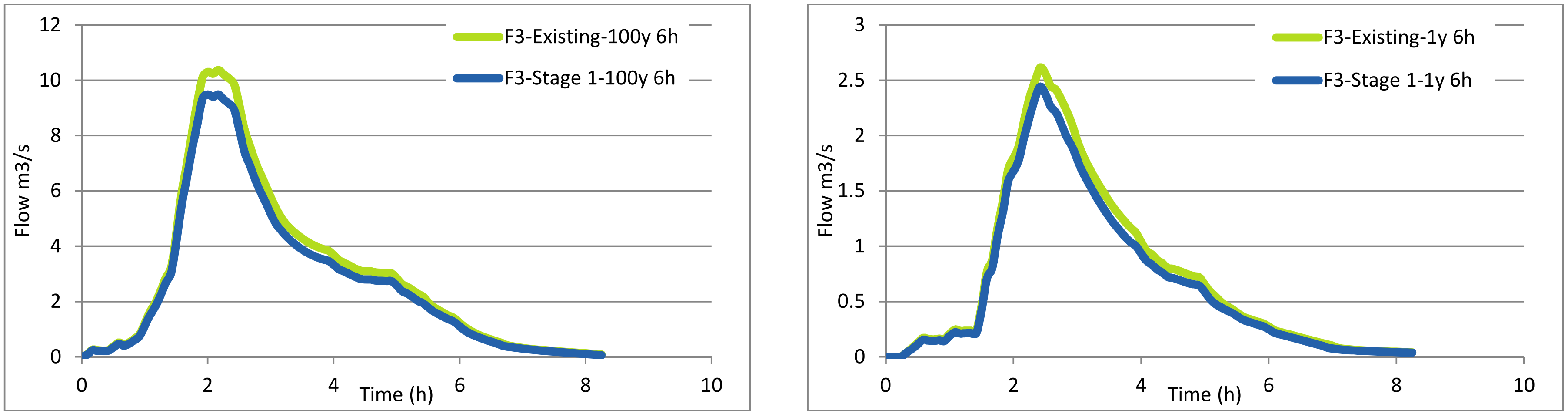


Figure 6-6 Location F3, comparison of existing and Stage 1 flows, Duncans Creek tributary

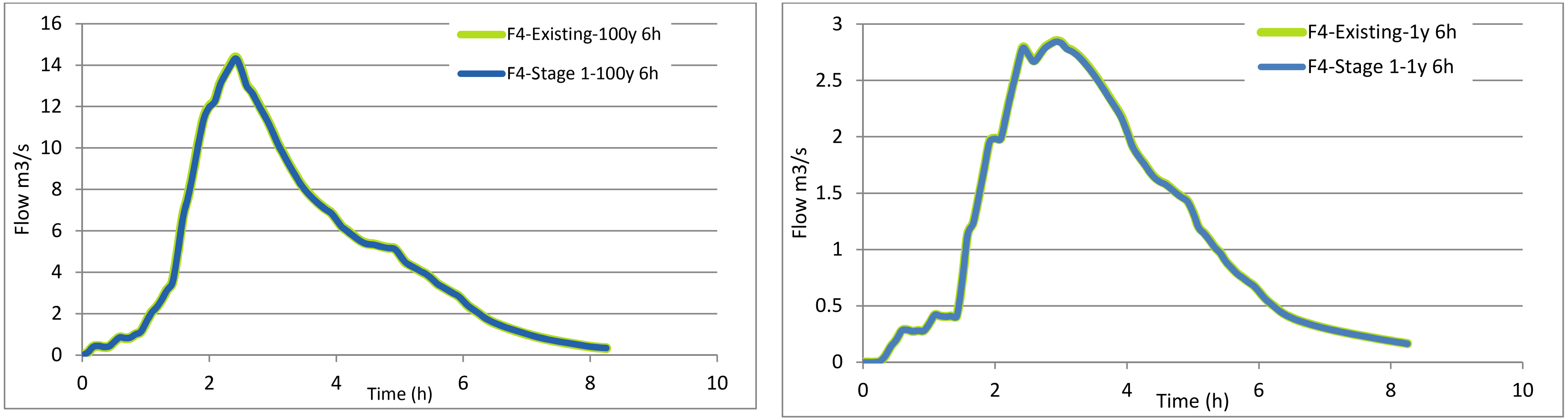


Figure 6-7 Location F4, comparison of existing and Stage 1 flows, Duncans Creek tributary

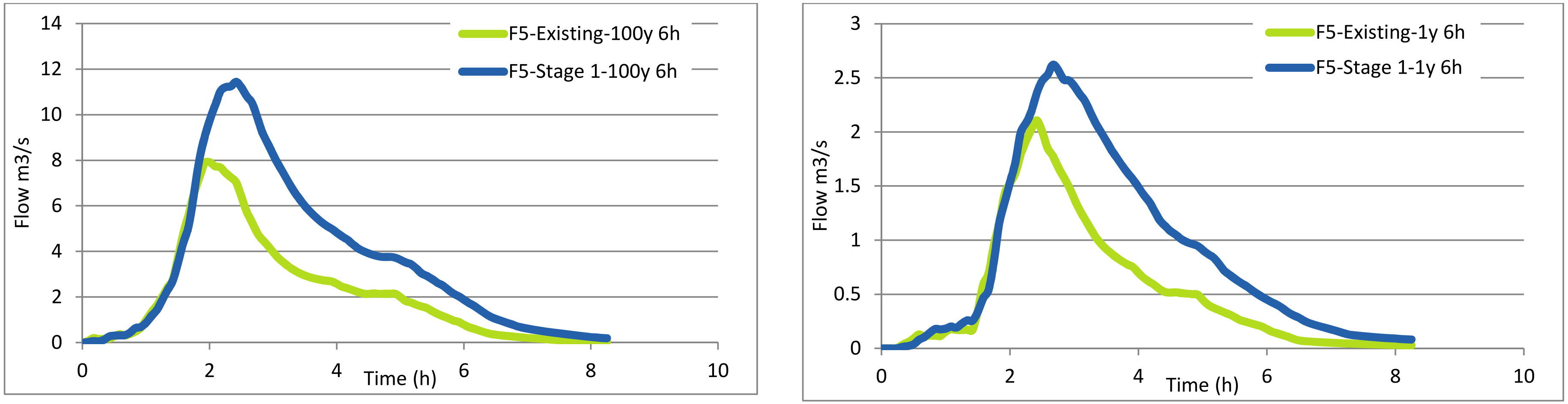


Figure 6-8 Location F5, comparison of existing and Stage 1 flows, Duncans Creek tributary

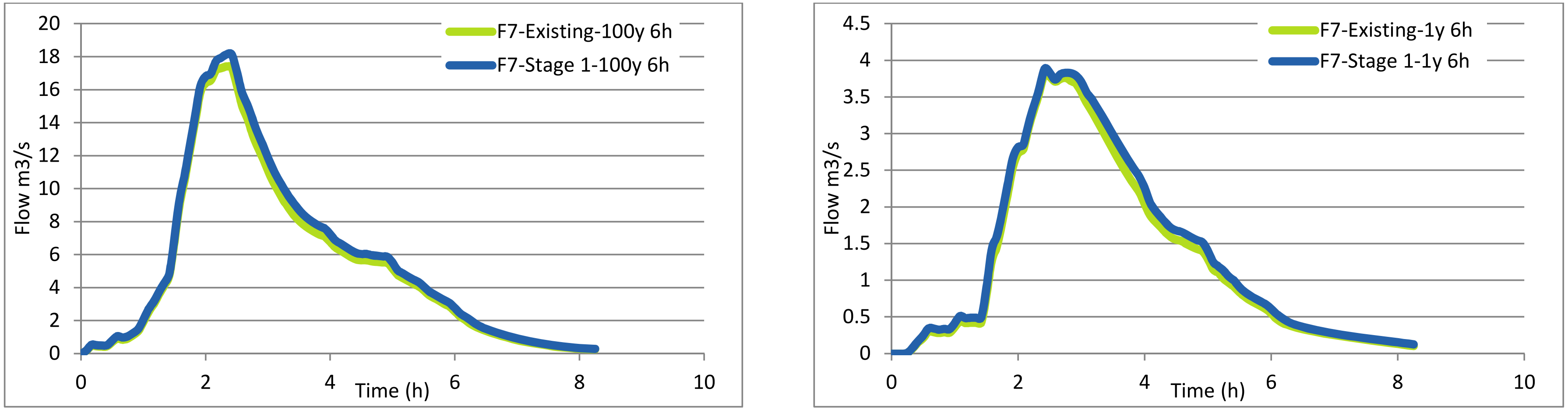


Figure 6-9 Location F7, comparison of existing and Stage 1 flows, Duncans Creek

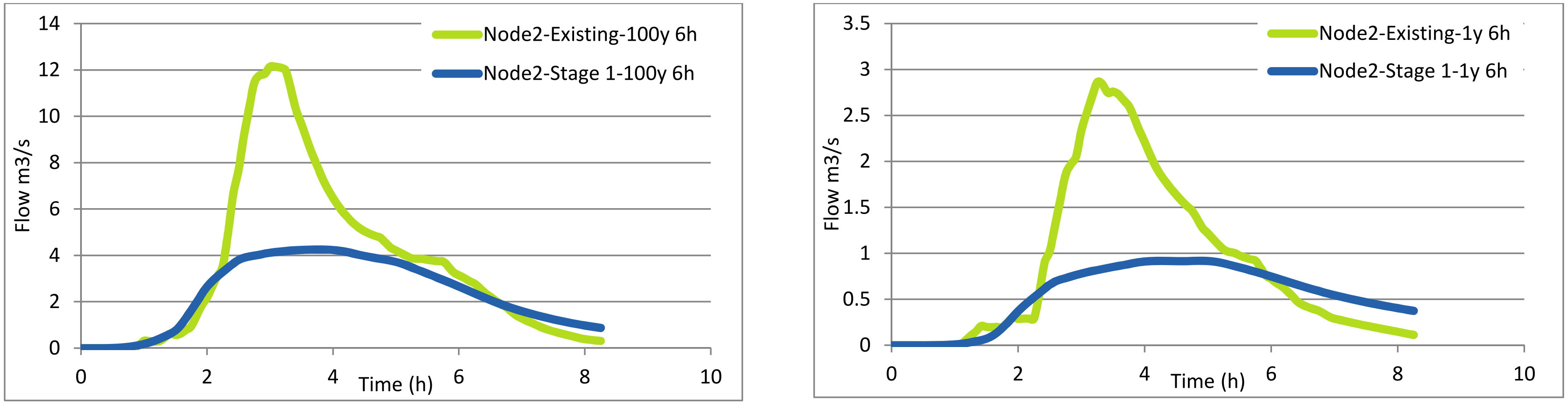
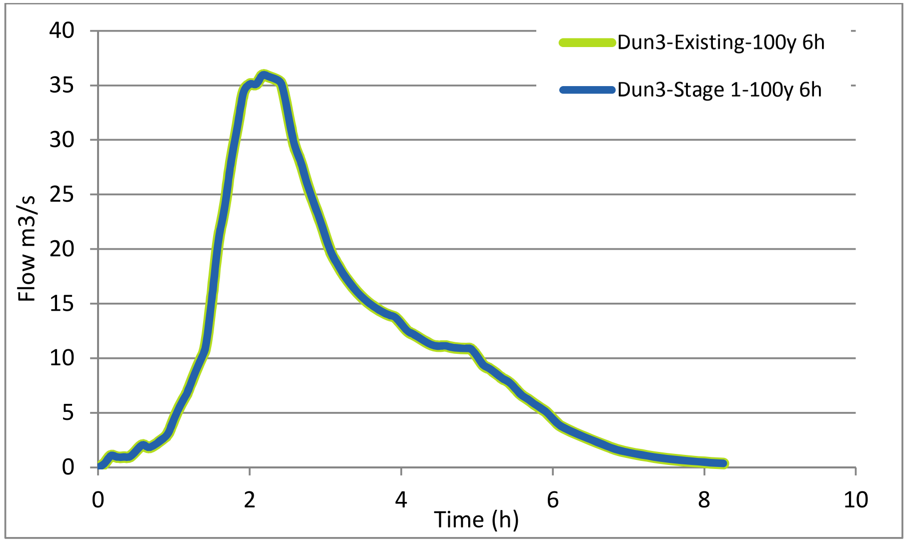


Figure 6-10 Location Node2, comparison of existing and Stage 1 flows, Duncans Creek tributary



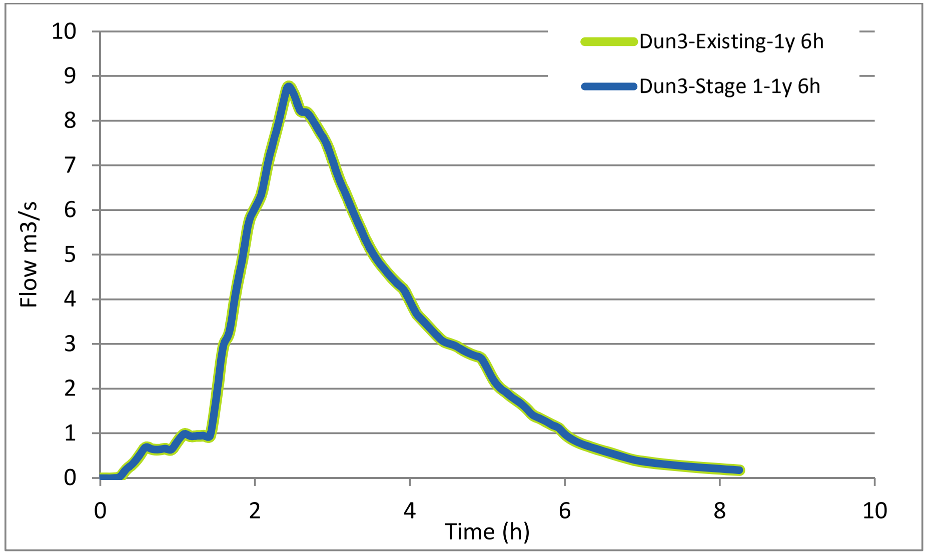


Figure 6-11 Location Dun3, comparison of existing and Stage 1 flows, Duncans Creek

The results show slight decreases in peak flow to Badgerys Creek and substantial decreases to Oaky Creek and Cosgroves Creek as a result of the detention basins. Figure 6-5 to Figure 6-11 compare the flows for the various tributaries of Duncans Creek. Marginal decreases are expected for the critical duration storm events. There is no expected increase in flows between the existing scenario and the Stage 1 development in catchments F2, F3, F4 and Dun 3 (Refer to Figure 4-2 for reporting locations). There is a significant decrease in flows anticipated at Node 2 and catchment F2, because they are downstream of Basin 8 which has been designed to mitigate against any increases in stormwater runoff during Stage 1.

In Catchment F5 the flow is expected to increase from around 8 m^3/s to 11.5 m^3/s for the 100 year ARI, 6 hour rainfall event. The increase is due to part of the catchment that drains to Cosgroves Creek under existing conditions being redirected to pass through bio-retention Basin 9 and then to the tributary of Duncans Creek (although the net total catchment area draining to Duncans Creek decreases under Stage 1). There is also a small increase in flow at Catchment F7 as a result of amendments to subcatchment boundaries and a slight increase in the total hardstanding area in this catchment.

It is possible that localised scour and erosion at the points of discharge may occur and mitigation measures to address these are discussed in Section 8 of this report. The influence of the current Stage 1 design on downstream hydraulics is assessed below and in Section 6.1.2.

Impacts on low flows and watercourse flooding

The impacts of the proposed Stage 1 development on flood depths are shown in Figure 6-12 to Figure 6-16. In the figures, a positive value indicates an increase in flooding in Stage 1 over the existing case, and a negative value indicates a decrease. Extents of flooding in Stage 1 are included in Appendix C.

Oaky and Cosgroves Creeks

In a 1 year ARI event, flood impacts downstream of Elizabeth Drive include decreases in flow depth of up to around 100 mm on Cosgroves Creek and 300 mm on Oaky Creek. Within the channels, increases in level are within 100 mm of existing flow depth, except for a 200 metre reach of Oaky Creek immediately downstream of Elizabeth Drive and upstream of its confluence with Cosgroves Creek where increases in flow depth of up to 250 mm are predicted. Increases in depth on Cosgroves Creek upstream of the airport site are up to around 25 mm and are considered relatively minor.

For a 5 year ARI flood event, a decrease in flood level is predicted downstream of the airport, as with the 1 year ARI event. Results for the 100 year ARI event are similar. The dwellings identified as being located in, or within close proximity of, the 100 year ARI flood event would not experience an increase in flood levels based on the findings of this assessment.

Badgerys Creek

Flow depths downstream of Elizabeth Drive are predicted to decrease, generally by less than 120 mm in most events, with the exception of the tributary that joins Badgerys Creek approximately 300 metres downstream of Elizabeth Drive under existing conditions.

During design development, low flow bio-retention outlets have been incorporated into the design, and would allow flows to continue to discharge via a proposed set of culverts underneath Elizabeth Drive and into this tributary for events up to the 3-month ARI. Whilst diversion of flows would occur in larger events, low flows to the tributary would be maintained. Decreases in water levels along Badgerys Creek of up to around 150 mm would be expected in the critical duration event, generally due to the influence of the basins.

In all events, the modelling shows some increases in flood level in Badgerys Creek in the upstream reaches of the airport site. These increases result from potential future changes to the alignment of the Northern Road, rather than the proposed airport. The realignment of the Northern Road has potential to divert flows into Badgerys Creek further upstream than under existing conditions, resulting in localised increases in flood level. Increases in flood level of up to 90 mm in a 100-year event have the potential to affect two residential dwellings identified on the aerial imagery. These effects would need to be considered as part of any future road design.

Duncans Creek

The hydraulic model results on Duncans Creek indicate that flood levels are within 50 mm of existing levels with some small areas of up to 65 mm. Despite the predicted changes to flows in the vicinity of catchment F5, the net effect along Duncans Creek and in the vicinity of the residential dwelling is a marginal change in flood levels.

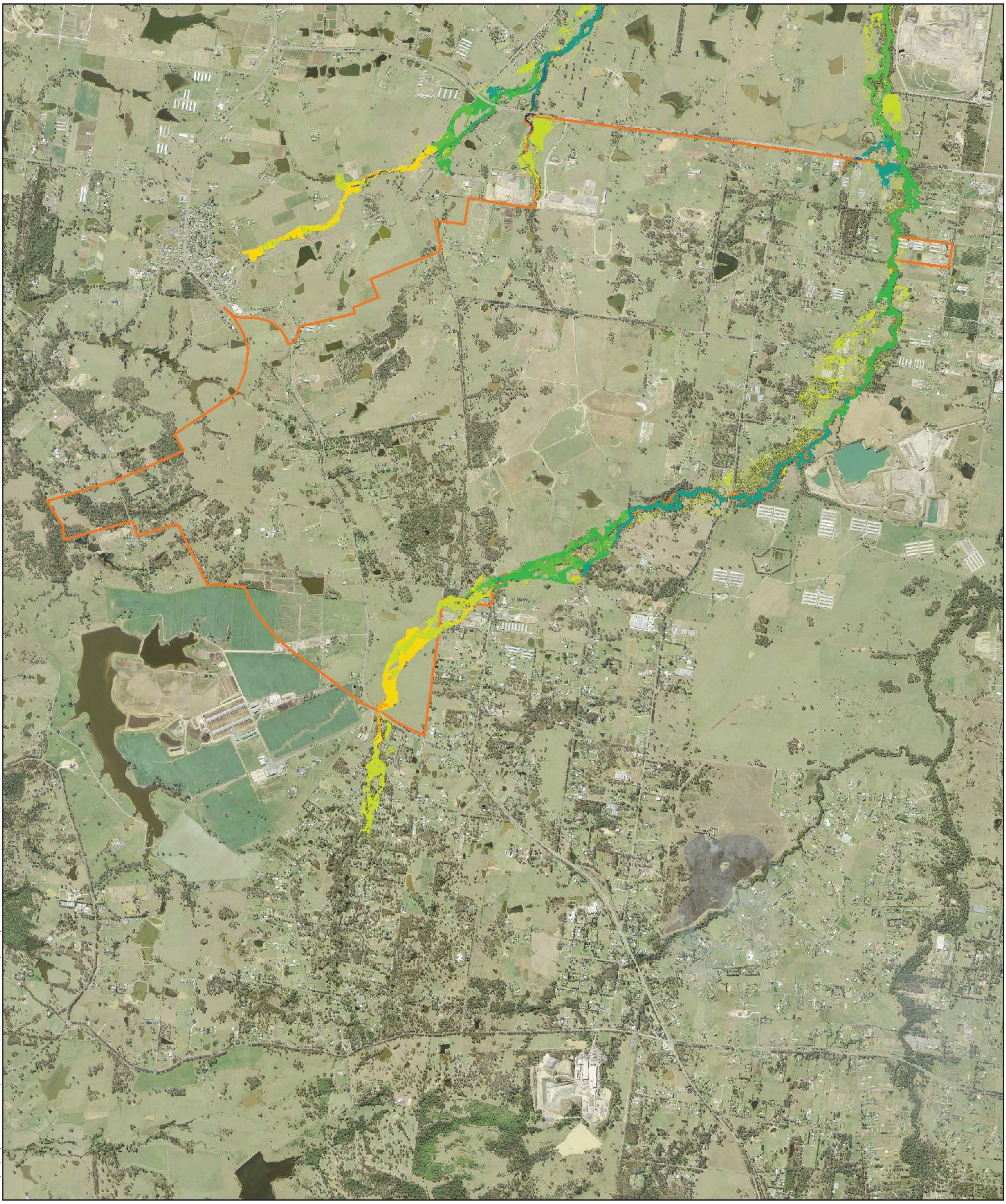
Effectiveness of the basins

The current basin designs may result in a reduction of flows to the downstream creeks, with associated potential impacts on stream stability and ecology. This is in the case where basins are sized in excess of the Stage 1 requirements and may require design refinement during the next stage of design. Alternatively, an increase in peak flows may occur where basin sizing or basin outlet configurations are not optimal with associated potential flood and watercourse stability impacts. The continued development of the basins during the next stage of design would need to address these potential outcomes.

It is understood from the biodiversity assessment (refer to EIS Appendix K1), that there is some native vegetation in the riparian corridors beyond the airport site that would be considered reliant on occasional flooding, for example along the tributary of Badgerys Creek downstream of Elizabeth Drive (refer discussion earlier in this section). It is anticipated that minor changes in flows would be unlikely to have an adverse impact on the vegetation, provided that the vegetation still experiences occasional flood flows. Basin 1 still supplies flows to this tributary up to the three month event. Larger flows would be diverted to the detention storage portion of the basin for eventual discharge directly into Badgerys Creek.

The macroinvertebrate surveys found that the numbers of macroinvertebrates sensitive to changes in flow downstream of the airport site would generally be low and the influence of minor fluctuations in flow on macroinvertebrates is expected to be limited (refer to biodiversity assessment in Appendix K1).

An increase in flood level may potentially affect the two existing flood-prone residential dwellings. The finished floor levels of the residences are unknown and the relative impact on flood affectedness at the properties due to the increases in flood level is unknown.



LEGEND

Airport site

Increase in Flood Level (m)

- < -0.50
- -0.50 - -0.25
- -0.25 - -0.10
- -0.010 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.20
- 0.20 - 0.30
- > 0.30

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

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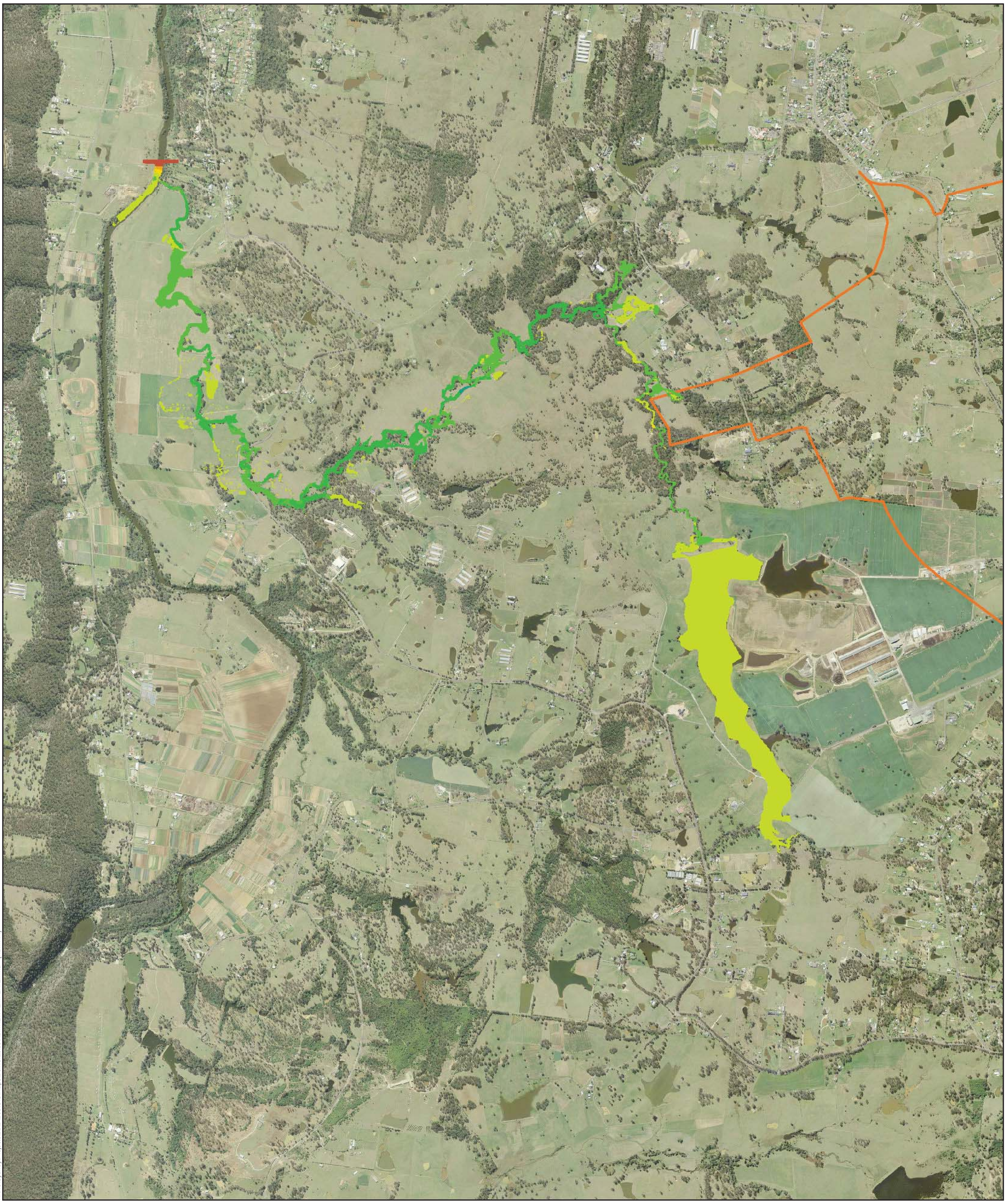
Figure 6-12 - Stage 1 - flood depth impact, 1 year ARI, Badgerys and Cosgroves Creeks

0 0.25 0.5 1
Kilometres



LEGEND

Airport site

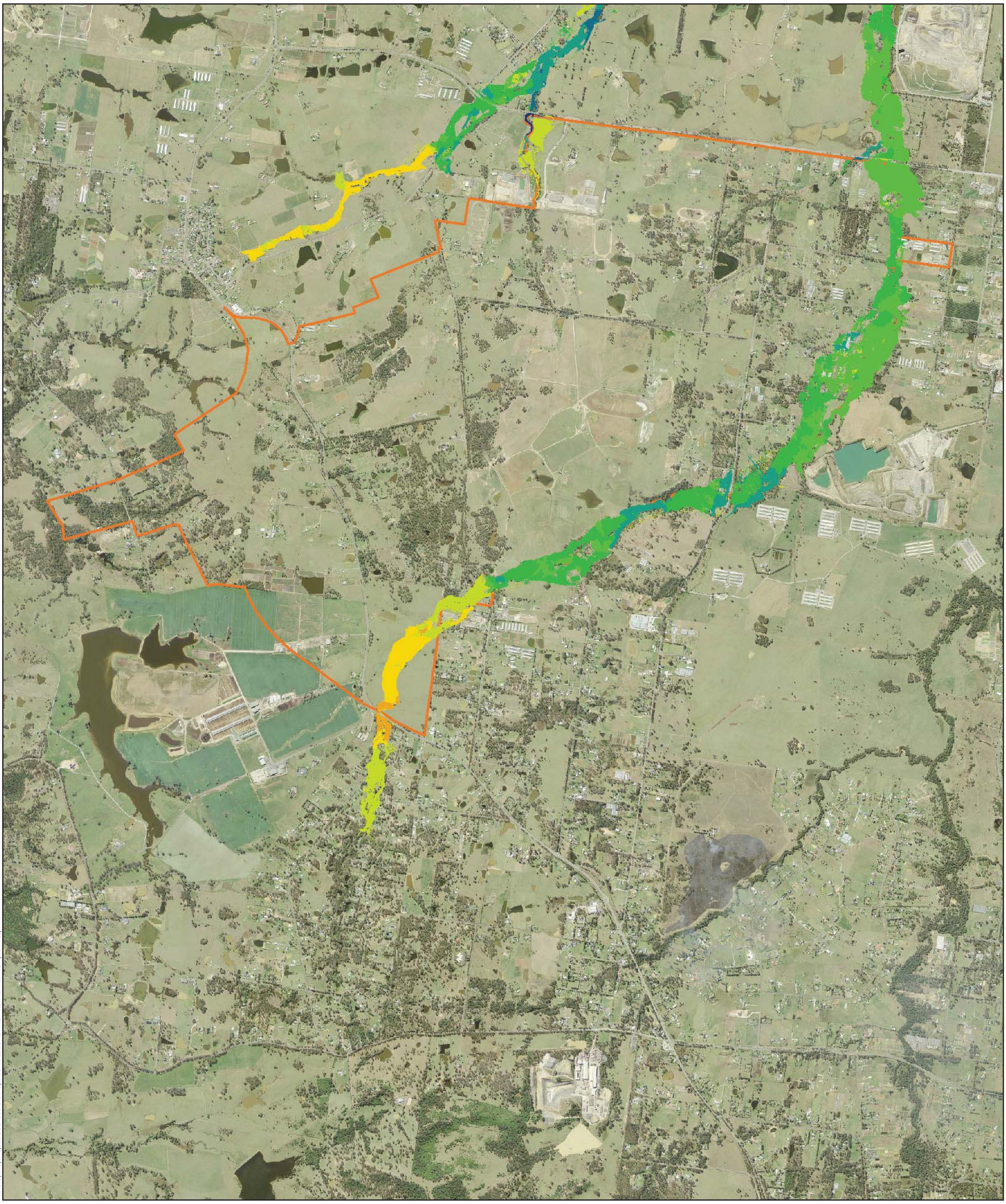
Increase in Flood Level (m)

- < -0.50
- -0.50 - -0.25
- -0.25 - -0.10
- -0.010 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.20
- 0.20 - 0.30
- > 0.30

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

0 0.225 0.45 0.9
Kilometres

Figure 6-13 - Stage 1 - flood depth impact, 1 year ARI, Duncans Creek



Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site

Increase in Flood Level (m)

- < -0.50
- -0.50 - -0.25
- -0.25 - -0.10
- -0.010 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.20
- 0.20 - 0.30
- > 0.30

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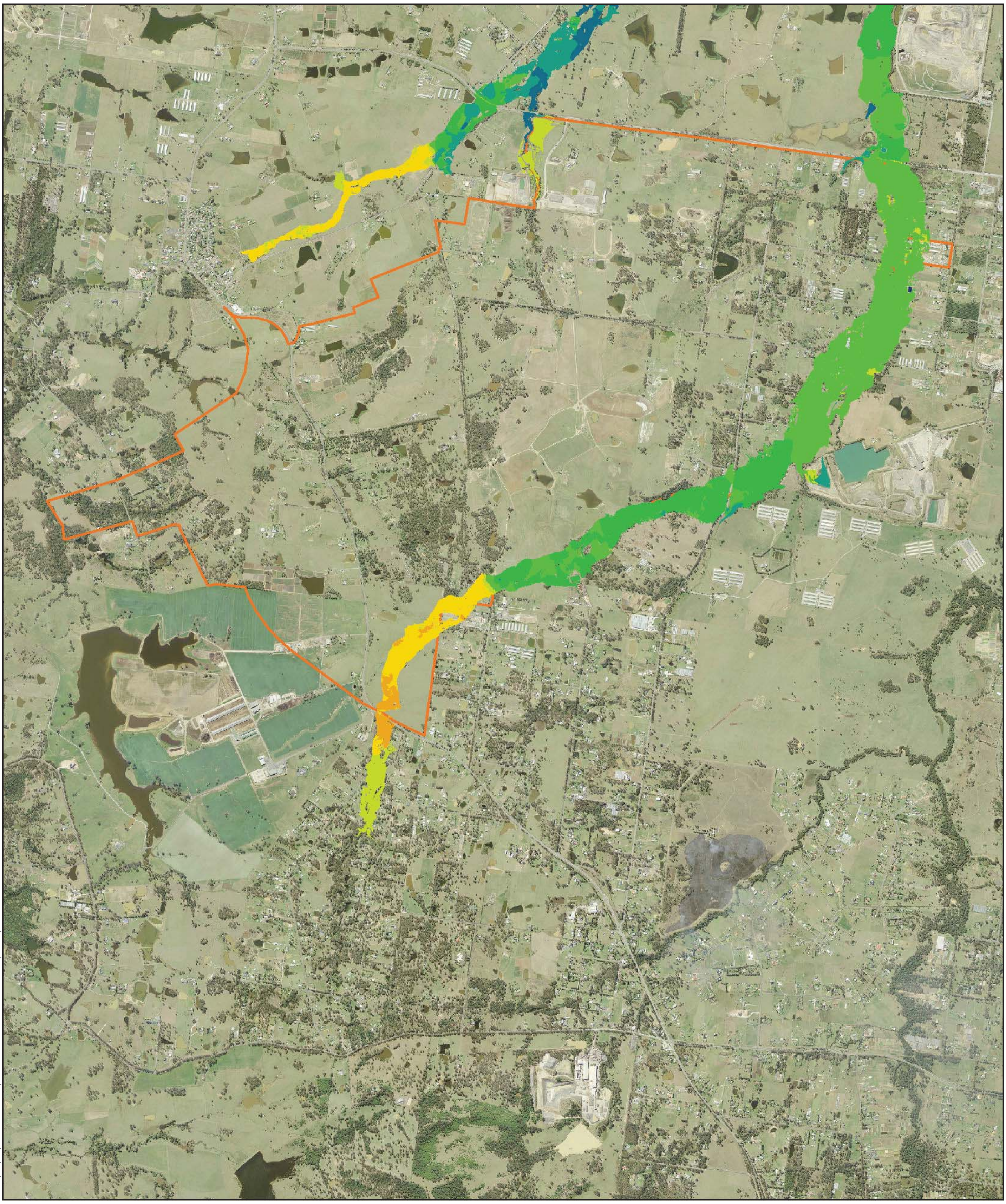
Figure 6-14 - Stage 1 - flood depth impact, 5 year ARI, Badgerys and Cosgroves Creeks

0 0.25 0.5 1
Kilometres

Figure 6-15 - Stage 1 - flood depth impact, 5 year ARI, Duncans Creek



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LEGEND

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

Airport site

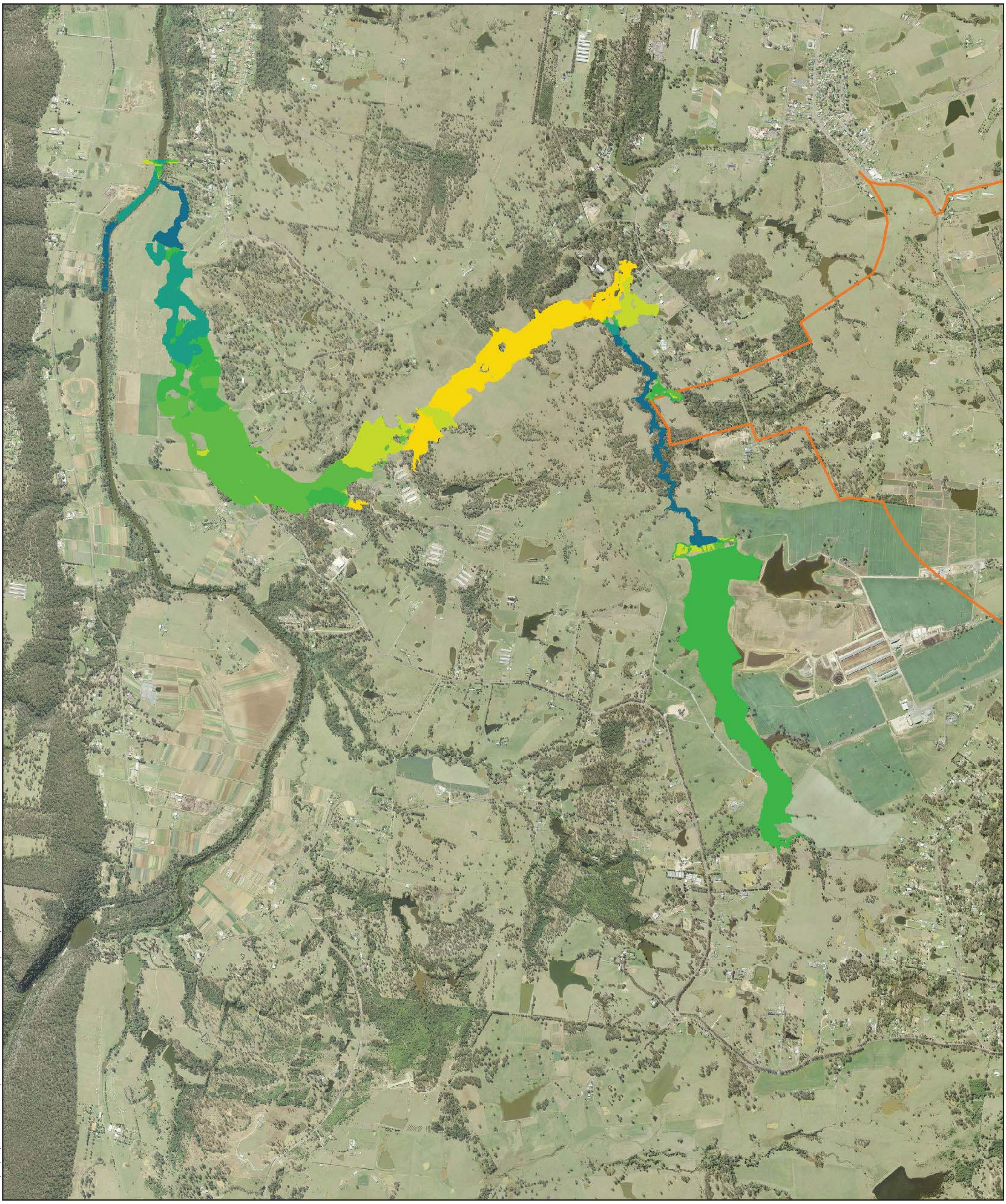
Increase in Flood Level (m)

- < -0.50
- -0.50 - -0.25
- -0.25 - -0.10
- -0.010 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.20
- 0.20 - 0.30
- > 0.30

Figure 6-16 - Stage 1 - flood depth impact, 100 year ARI, Badgerys and Cosgroves Creeks

0 0.25 0.5 1

Kilometres



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Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site

Increase in Flood Level (m)

- < -0.50
- -0.50 - -0.25
- -0.25 - -0.10
- -0.010 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.20
- 0.20 - 0.30
- > 0.30

0 0.225 0.45 0.9

Kilometres

N

Figure 6-17 - Stage 1 - flood depth impact, 100 year ARI, Duncans Creek

In summary, the basins are effective at reducing the impacts of the airport development. The results indicate that the basins may be oversized and could benefit from a review of outlet configurations during the next stage of design, particularly for Basin 6. Refinement of the basin strategy during the next stage of design development would be required to reduce impacts to negligible levels and address the specific and more substantial impacts on the tributary of Duncans Creek encompassed by subcatchment F5 and in the upper reaches of Badgerys Creek.

Surplus recycled water

During the Stage 1 development wastewater from the proposed airport would be treated on-site. Sludge would be transported off-site, and the treated water re-used for restrooms, washing of vehicles and aircrafts, cooling towers and landscaping. It is expected that availability of recycled water would exceed demand, in which case alternative uses for the surplus recycled water would need to be developed, such as the use of the water for on-site subsurface irrigation. An irrigation scheme would need to be developed to ensure there would be no significant downstream flow impacts, particularly where runoff of additional irrigation water could alter the natural stream flow patterns.

Groundwater discharge

Groundwater seepage into cuts and subsurface basement areas would be treated and discharged back to the environment and/or removed off-site to an appropriately licensed treatment facility. However, significant volumes of groundwater seepage is not considered likely and discharge of high volumes into the surface water system would not be required.

6.1.2 Impacts on watercourse geomorphology

Changes to catchments and impervious areas may indirectly impact the channel morphology of watercourses downstream of the airport site. In particular, catchment changes that result in increasing downstream flow durations and/or increased hydraulic shear stress can exacerbate erosion of the bed and banks of watercourse channels downstream of the airport site.

In reference to the discharge hydrographs displayed in Figure 6-1, Figure 6-3 and Figure 6-11, the changes in flow durations downstream of the airport site are summarised below.

- Along Badgerys Creeks downstream of Elizabeth Drive, the flow event durations for the Stage 1 conditions are similar to those of existing conditions with a minor decrease in peak discharge.
- Along Cosgroves Creek downstream of the Oaky Creek confluence, the flow event durations for the Stage 1 conditions are also similar to those of existing conditions with a modest decrease in peak discharge.
- Along Duncans Creek there is no significant difference between the flow event durations or peak discharges for the Stage 1 conditions and those of existing conditions.

As flow durations for the modelled events under Stage 1 conditions remain similar to the existing conditions and peak discharges typically reduce, the potential for significant impacts to the morphology of watercourses downstream of the airport site is considered low.

To further explore the spatial distribution of potential morphological impacts to watercourses adjoining and downstream of the airport site, the modelled shear stress distributions for the Stage 1 development and the existing conditions were compared.

Figure B-8 to B-10 (Appendix B) display maximum modelled shear stress differentials between the Stage 1 development and the existing conditions for the 1, 5 and 100 Year ARI events. These indicate that changes in shear stress values as a result of the Stage 1 development largely remain within the range of – 10 to +10 N/m² to those of the modelled existing results along all three creeks. Typically, modelled changes in shear stress outside of this range are reductions, with only small localised areas experiencing increases greater than 10 N/m².

To provide further context, Figure B-1 to Figure B-3 (Appendix B) also display the modelled maximum shear stress distributions for existing conditions. These indicate that maximum shear stress values under existing conditions along Cosgroves Creek , Badgerys Creek and Duncans Creek are typically less than 100 N/m², with very localised higher values in the range of 100 to 200 N/m² during the 100 Year ARI event.

Based on a synthesis from various studies by Blackham (2006), shear stress thresholds for the disturbance of vegetation and subsequent surface erosion lie in the range of 100 to 200 N/m², varying largely by vegetation type. Given the modelled shear stress changes under the Stage 1 development are typically less than 5 to 10 per cent of this threshold range and generally reduce, the Stage 1 development is unlikely to result in widespread or significant further exceedances of thresholds for the disturbance of vegetation and surface erosion along watercourses adjoining and downstream of the airport site. This further supports the conclusion that the Stage 1 development will have a low impact on the stability of watercourses adjoining and downstream of the airport site.

6.1.3 Impacts on water quantity from wastewater

An estimated 2.5 ML of wastewater per day would be generated during operation of the Stage 1 development. Wastewater would be reticulated to a treatment facility before being recycled or irrigated at the airport site. Recycled water could be utilised for a range of potential uses. These include the use of reclaimed water in maintenance of plant and infrastructure, industrial cooling processes or landscaping and also in irrigation. Irrigation of treated wastewater has the potential to affect the quantity of flow into receiving waterways depending on the means of application and irrigation technology.

Any irrigation of reclaimed water would likely occur on land previously disturbed by the construction of the Stage 1 development (the construction impact zone). The irrigation area would be designed and operated in accordance with the risk framework and management principles contained in the National Guidelines on Water Recycling (Environment Protection and Heritage Council 2006) and the Environmental guidelines: Use of effluent by irrigation (NSW DEC 2004). The following would apply with respect to water quantity (effects on soils are discussed in other chapters of this EIS, refer Appendix L2):

- the irrigation area would be delineated based on the expected rate of irrigation and the drainage characteristics of the receiving soil;
- the irrigation area would be designed to include capacity to store treated water for the duration of typical wet weather events;
- the rate of irrigation would be optimised to avoid the ponding of reclaimed water or creation of excess surface water runoff; and
- soil and groundwater conditions would be monitored to identify and correct trends in soil salinity, sodicity or other potential effects of irrigation.

It is considered that this approach would avoid impacts to the patterns of flow in the downstream environment.

6.2 Long term development

The long term catchment areas and changes in impervious areas incorporate changes which would occur in Stage 1 as well as the subsequent long term effects. Note that the long term assessment has been based on more preliminary design information than the Stage 1 assessment as it would be subject to separate environmental and planning processes in the future.

6.2.1 Impacts on hydrology and flooding

Identified changes and potential implications

As with Stage 1, there would be a change in the on-site catchment area in the long term as a result of the proposed airport. A summary of these changes to catchment areas is provided in Table 6-3.

Table 6-3 Catchment area comparison between the existing environment and the long term development

Location	Catchment area (existing) (ha)	Catchment area (long term) (ha)	% impervious (existing)	% impervious (long term)
Badgerys Creek at Elizabeth Drive	2,361	2,332	12	30
Oaky Creek at Elizabeth Drive	361	270	10	47
Cosgroves Creek at Elizabeth Drive	550	647	14	39
Badgerys Creek at South Creek	2,799	2,775	12	28
Cosgroves Creek at South Creek	2,165	2,179	14	25
Duncans Creek at Nepean River	2,379	2,380	14	15

The table shows that there would be substantial increases in impervious areas for all catchments. Changes in catchment area are relatively small, though the overall impact of these in terms of the flow patterns that result is examined further in this section.

The increase in catchment area (where applicable) and catchment imperviousness would, without intervention, tend to increase the peak flows and have the potential to influence timing of peak flows. Flows may generally peak earlier, but later peaks could also occur. A decrease in catchment area, dependent on the impervious fraction, would tend to decrease flows downstream. The increase in imperviousness for the long term development is, in some catchments, a further increase from that proposed in Stage 1.

Design control measures

Proposed detention basin volumes are as in Stage 1, with the addition of two new basins, 4 and 5. The proposed storage basin volumes in the long term are presented in Table 6-4.

Table 6-4 Long term detention basin attenuation volume

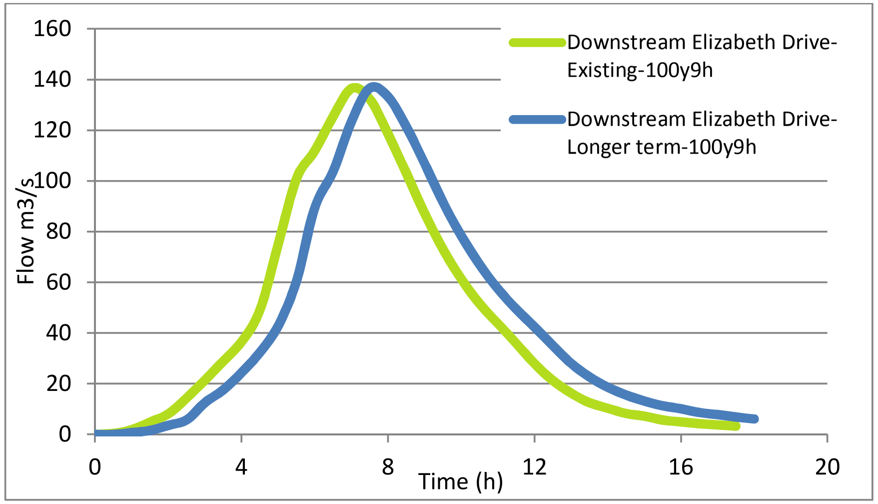
Basin Number	Basin volume (m^3)
1	125,000
2	39,000
3	100,000
4	82,000
5	65,000
6	101,000
7	117,000
8	59,000

Predicted impacts with design control measures in place

Comparisons of flows under existing and long term conditions for a 1 year ARI and 100 year ARI events are provided in Figure 6-18 to Figure 6-24. The figures show, at the various site discharge points indicated in Figure 4-2, the existing flow and the long term flows incorporating the effects of the detention basins.

The results show potentially minor increases in peak flow to Badgerys Creek under small and large flood events. Flows to Cosgroves and Oaky Creeks are reduced over the existing case, as with the Stage 1 development. The increases in flow to Duncans Creek noted in Stage 1 for Catchment A5 are still present. Additionally, increases in flow at Catchment A7 are also predicted as a result of the future commercial area at the airport site's west.

The flows from Catchment A7 have the potential to be impacted by this future commercial development area. There is no site layout plan and no surface water management plan for the commercial area at this stage and it is not part of the essential airport infrastructure. It has conservatively been assumed to be 100 per cent impervious without mitigation for the purposes of this assessment. It has been assumed that future site grading in this area will drain entirely to a tributary of Duncans Creek via a single point of discharge.



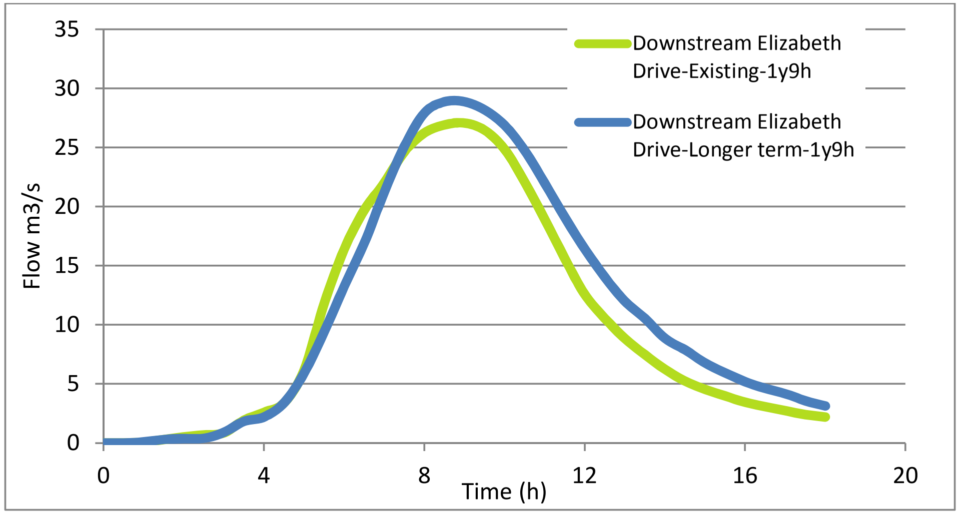
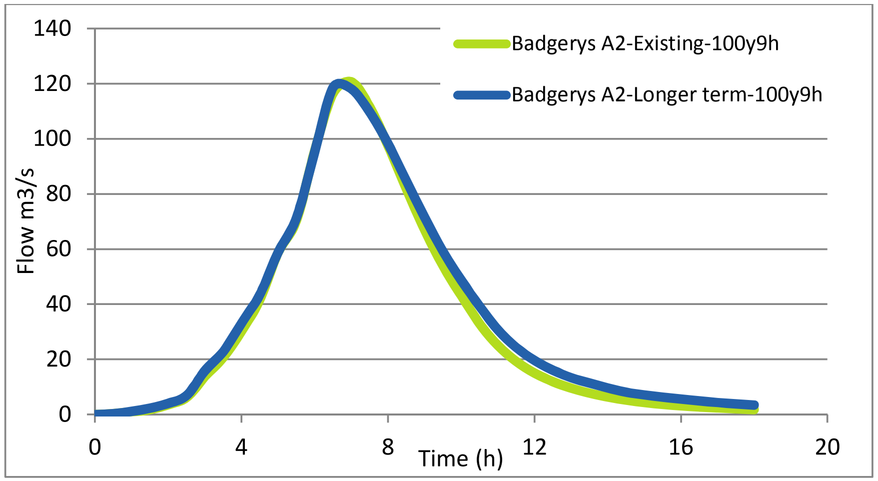


Figure 6-18 Location A, comparison of existing and long term flows, Badgerys Creek



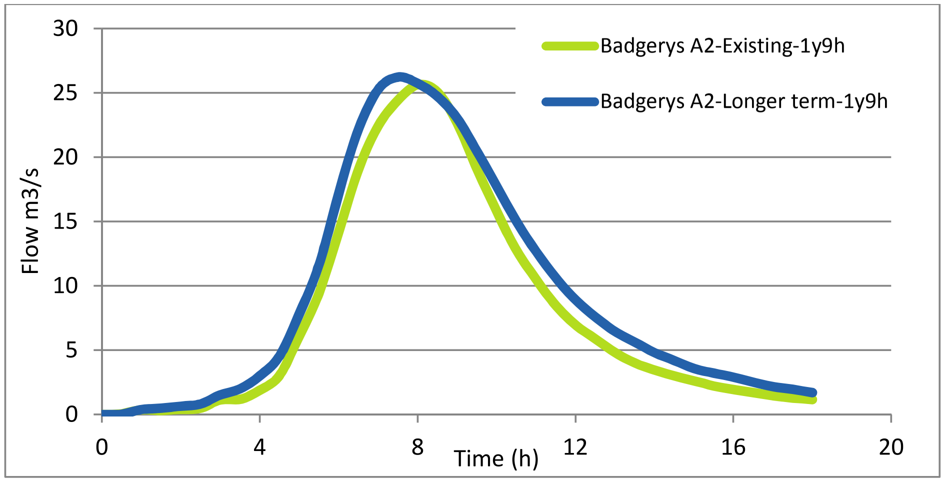


Figure 6-19 Location B, comparison of existing and long term flows, Badgerys Creek

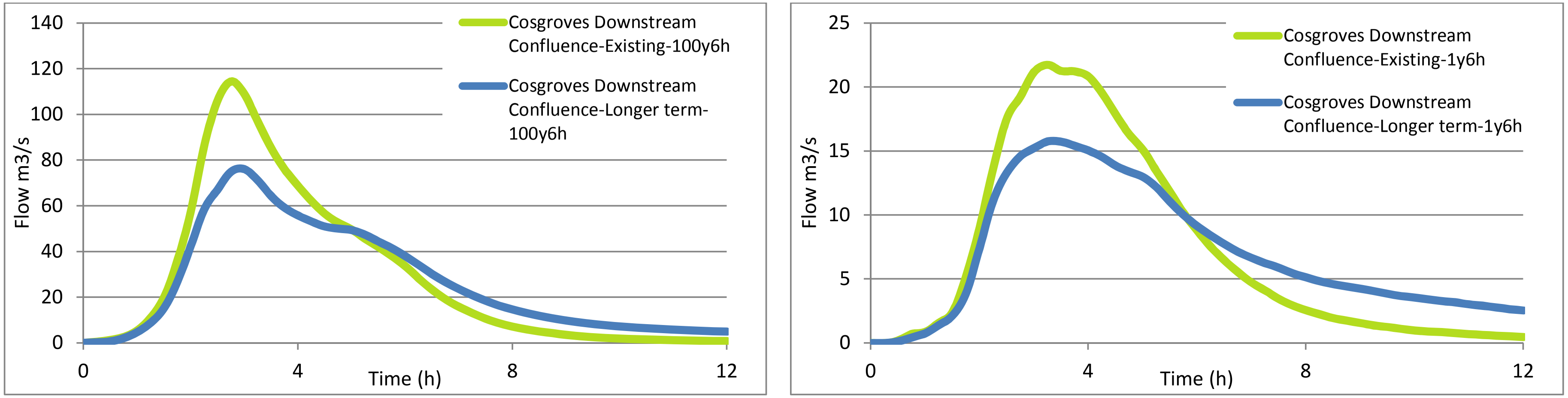


Figure 6-20 Location C, comparison of existing and long term flows, Cosgroves Creek

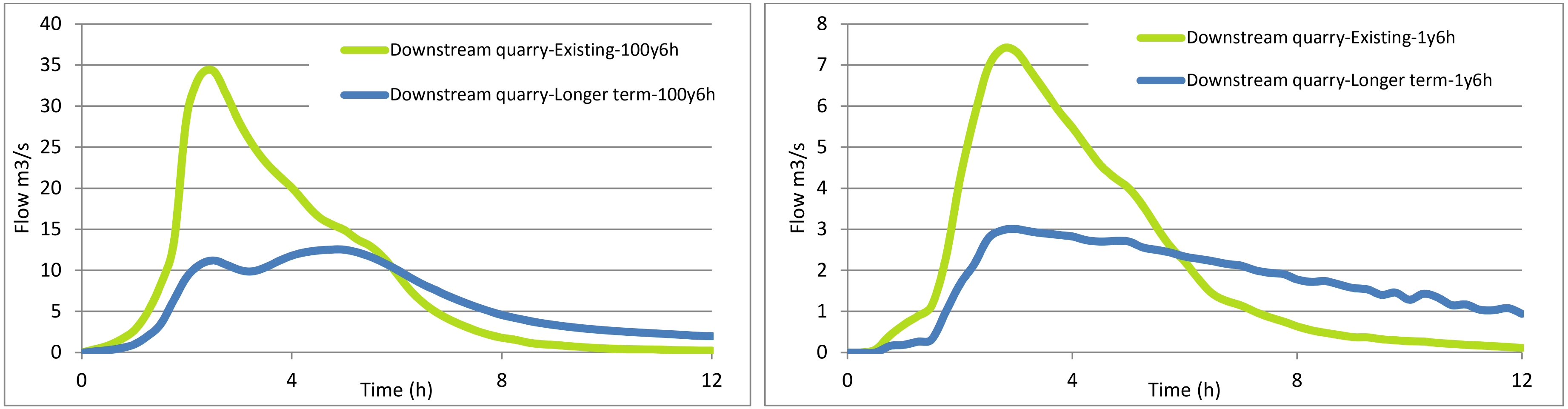


Figure 6-21 Location D, comparison of existing and long term flows, Oaky Creek

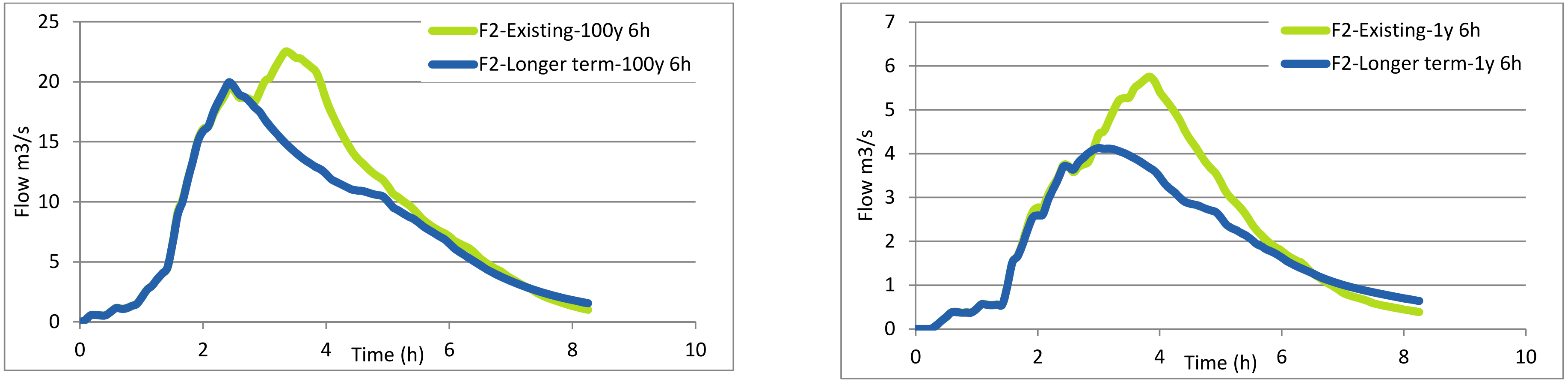


Figure 6-22 Location F2, comparison of existing and long term flows, Duncans Creek tributary

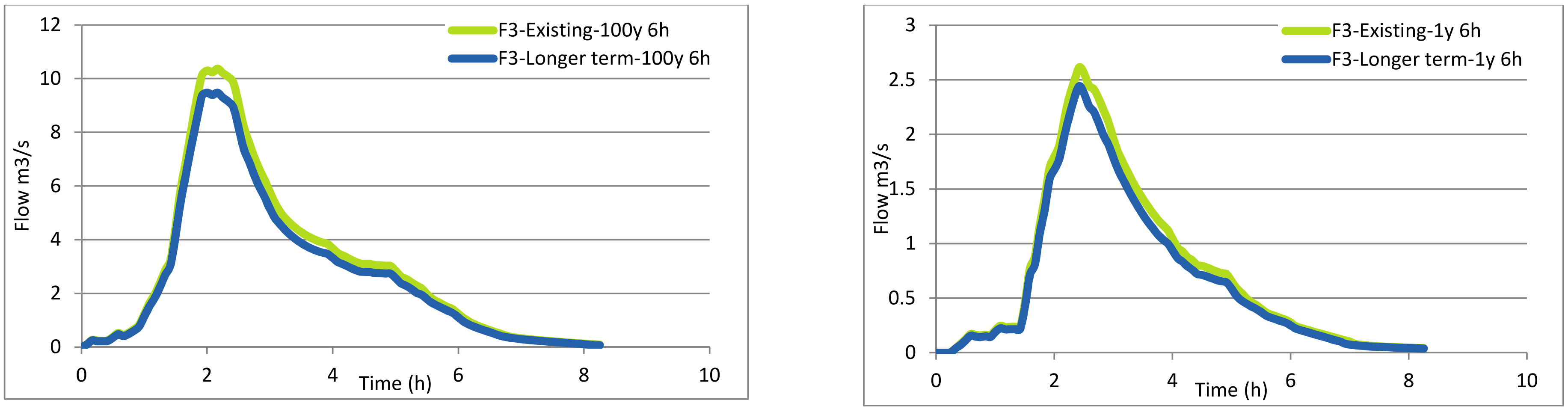
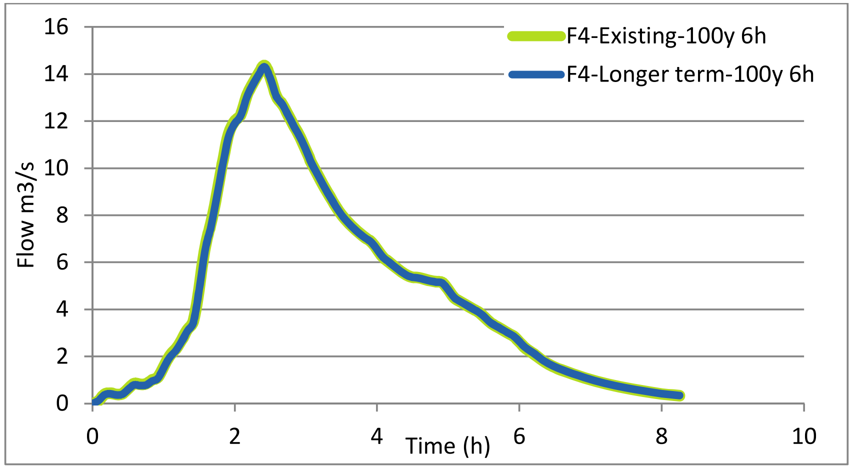


Figure 6-23 Location F3, comparison of existing and long term flows, Duncans Creek tributary



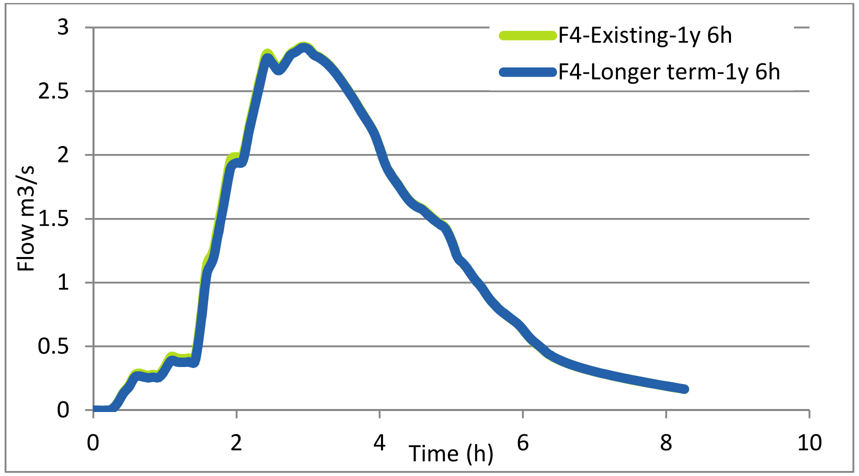
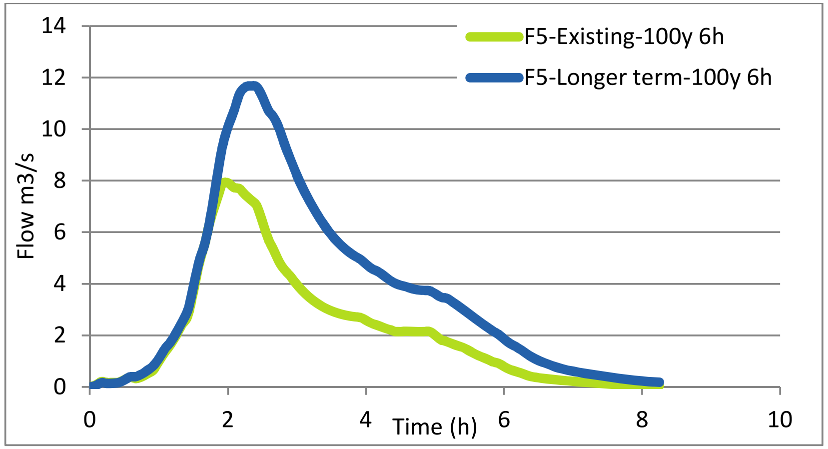


Figure 6-24 Location F4, comparison of existing and long term flows, Duncans Creek tributary



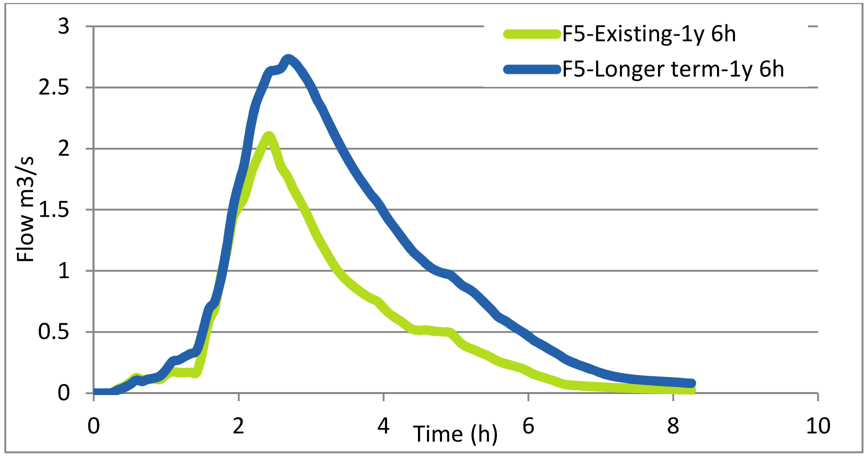
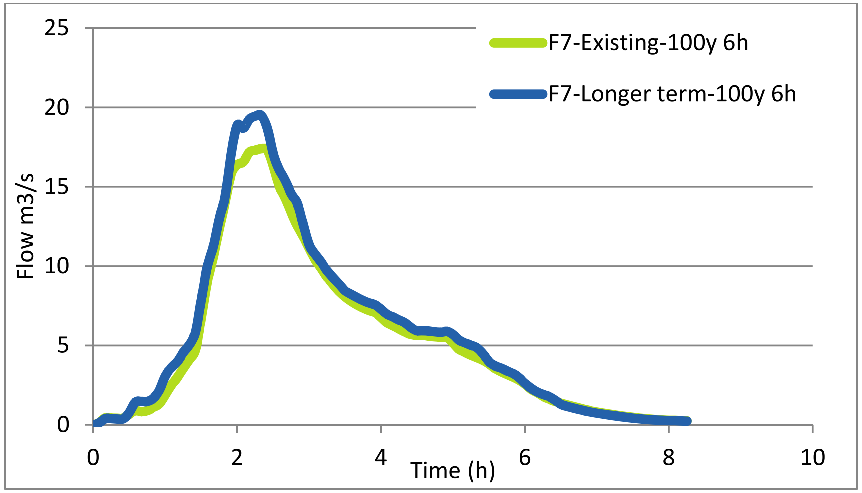


Figure 6-25 Location F5, comparison of existing and long term flows, Duncans Creek tributary



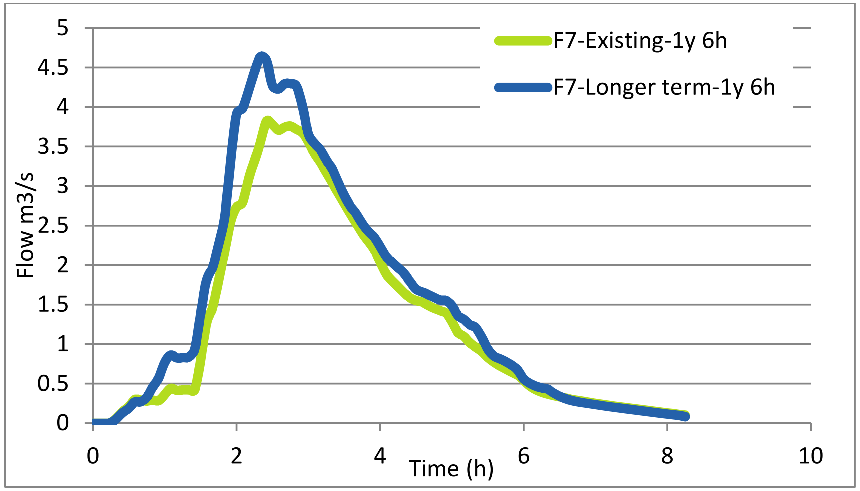
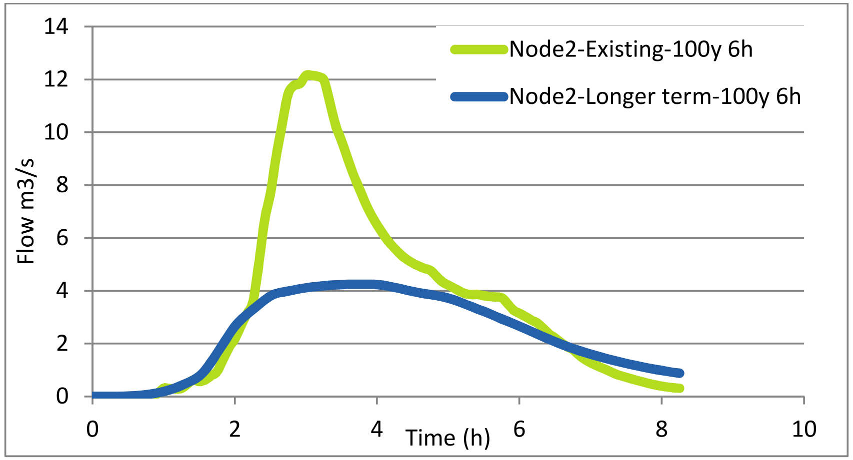


Figure 6-26 Location F7, comparison of existing and long term flows, Duncans Creek



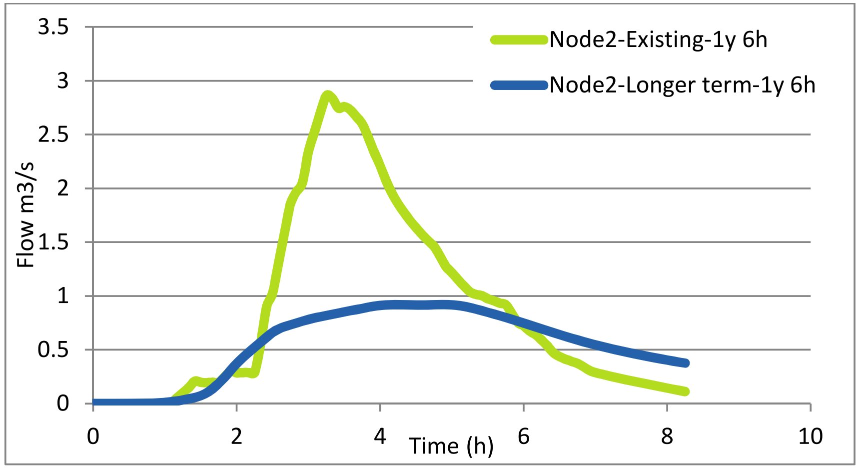
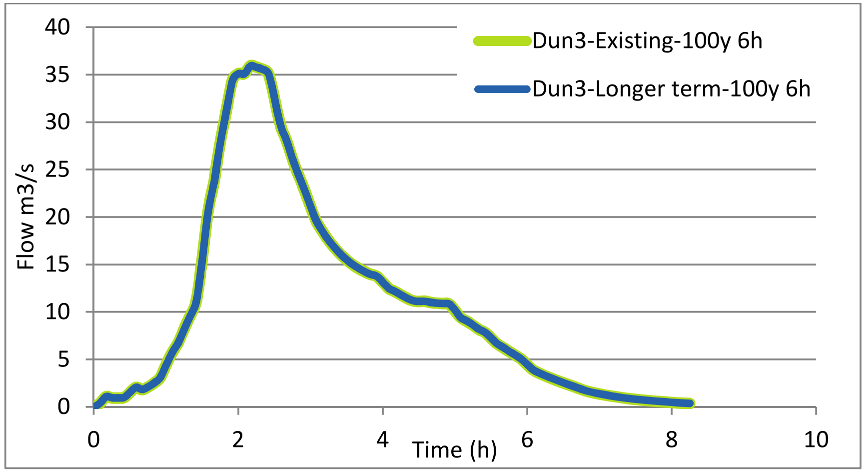


Figure 6-27 Location Node2, comparison of existing and long term flows, Duncans Creek tributary



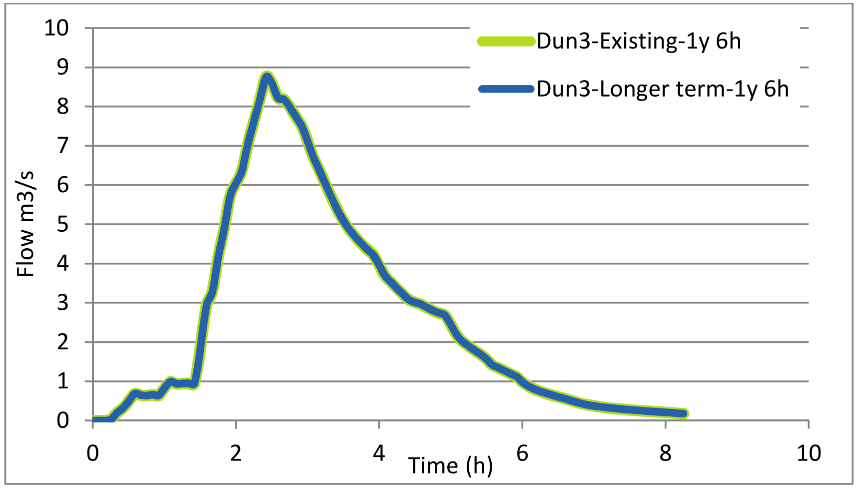


Figure 6-28 Location Dun3, comparison of existing and long term flows, Duncans Creek

The predicted impacts of the long term development on flood depths for the 1 year ARI, 5 year ARI and 100 year ARI events are shown in Figure 6-29 to Figure 6-31.

Oaky and Cosgroves Creeks

In a 1 year, 5 year and 100 year ARI events, flood level increases are predicted to be a maximum of 10 mm in excess of existing levels and are therefore considered negligible. Flood level decreases in isolated locations downstream of Elizabeth Drive of up to around 350 mm are predicted on Oaky Creek.

Badgerys Creek

In a 1 year ARI event, flow depths downstream of Elizabeth Drive are predicted to increase, but generally by less than 50 mm. In the 5-year and 100-year events, where overbank flooding is more prevalent and has the potential to affect residential dwellings, flood levels are predicted to decrease. Surrounding dwellings and infrastructure are not expected to be impacted by worsened flood levels based on the proposed design. Localised flood level increases are predicted to occur in the area downstream of Basin 2 and upstream of Basin 1. Long term earthworks may alter the landform in this area, causing the increased flood levels. However, the earthworks design for the long term can only be considered indicative at this stage.

Impacts experienced upstream of the airport site due to the realignment of the Northern Road (predicted to occur in Stage 1) are not expected during the long term development of the proposed airport, due to further modification to on-site grading and subcatchments.

A portion of Badgerys Creek passes through the proposed long term development area, in the south of the airport site. This area is proposed for environmental conservation and business use in the long term. There is potential for a range of impacts to Badgerys Creek if the surrounding development is not appropriately managed, including increased flooding and changes to creek geomorphology. Proposals for treatment of the creek where it passes through the airport site would be developed in subsequent design stages.

Duncans Creek

The long term impacts on Duncans Creek have not been modelled hydraulically due to uncertainty regarding the future plans for the commercial development area that may be developed at a future point in the south west of the airport site. It is not considered at this stage that impacts as a result of this area can accurately be estimated on downstream waterways. The future commercial area would be subject to development of a site specific water management plan to manage and mitigate surface water runoff from the airport site. The flow results suggest that some impact could be affected in the form of increases in flow, and these would need to be appropriately managed and mitigated.

6.2.2 Impacts on watercourse geomorphology

Further changes to catchment areas and impervious areas as a result of the long term development may also indirectly impact the channel morphology of watercourses downstream of the airport site. In particular, further catchment changes that result in increasing downstream flow durations and/or increased hydraulic shear stress can result in exacerbated erosion of the bed and banks of watercourse channels downstream of the airport site.

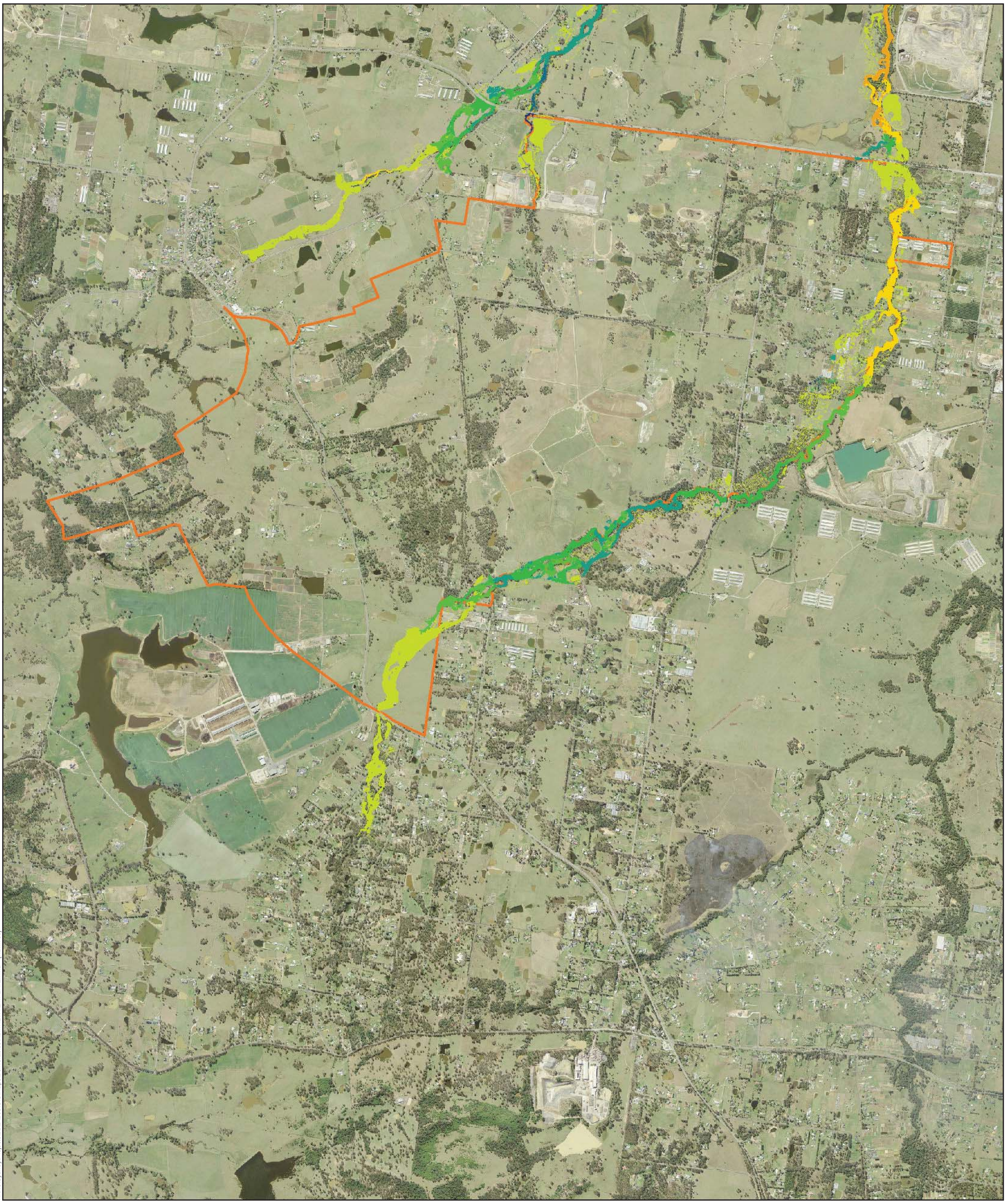
The hydrographs (Figure 6-18 to Figure 6-28) show that flow durations for the modelled events under the long term development conditions remain similar to existing conditions with peak discharges typically reducing. This indicates that the potential for significant impacts to the morphology of watercourses downstream is likely to be minor.

To further explore the spatial distribution of potential morphological impacts to watercourses adjoining and downstream of the airport site, the modelled shear stress distributions for the long term and existing conditions were also compared. Figures B15 to B17 (Appendix C) display maximum modelled shear stress differentials between the long term development and the existing conditions for the 1, 5 and 100 year ARI events. These differences are similar to the differences between the existing conditions and the conditions during the Stage 1 Development, with shear stress changes largely remaining within – 10 to +10 N/m^2 to those of the modelled existing results along all three creeks. This therefore indicates that the long term development will generally have a low impact on the stability of watercourses adjoining and downstream of the airport site.

However, in two small areas along Badgerys Creek, increases are predicted under the 100 Year ARI. These increases are generally in the range of 10 to 30 N/m^2 but locally up to 70 N/m^2 from existing values of around 20 N/m^2 and are directly associated with the encroachment of Basin 4 into the existing flood zone. The increases therefore may result in additional localised erosion and/or put the basin at risk of failure as a result of wall erosion by flood flows. Reducing the extent of encroachment during future design phases will alleviate this localised potential impact.

6.2.3 Impacts on water quantity from wastewater

The principles applying in Stage 1 to the use of recycled water for water quality would also be expected to apply in the long term (refer to Section 6.1.3). In this case, impacts to surface water would be minimal.



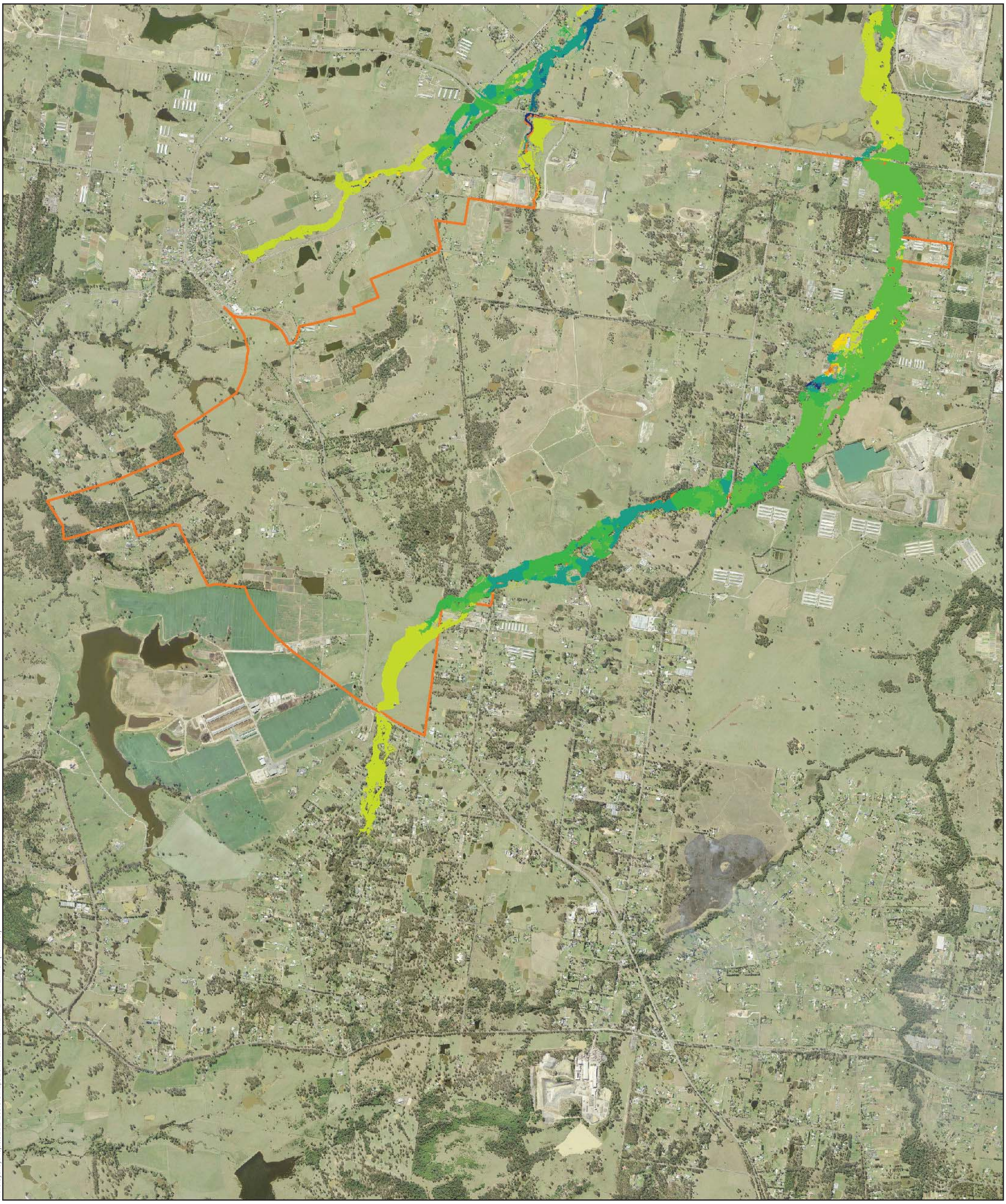
Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site	**Increase in Flood Level (m)**	-0.01 - 0.01
	< -0.50	0.01 - 0.05
	-0.50 - -0.25	0.05 - 0.20
	-0.25 - -0.10	0.20 - 0.30
	-0.010 - -0.05	> 0.30
	-0.05 - -0.01	

Figure 6-29 - Long term - flood depth impact, 1 year ARI, Badgerys and Cosgroves Creeks

0 0.25 0.5 1
Kilometres



Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site

Increase in Flood Level (m)

- < -0.50
- -0.50 - -0.25
- -0.25 - -0.10
- -0.010 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.20
- 0.20 - 0.30
- > 0.30

0 0.25 0.5 1
Kilometres

N

Figure 6-30 - Long term - flood depth impact, 5 year ARI, Badgerys and Cosgroves Creeks

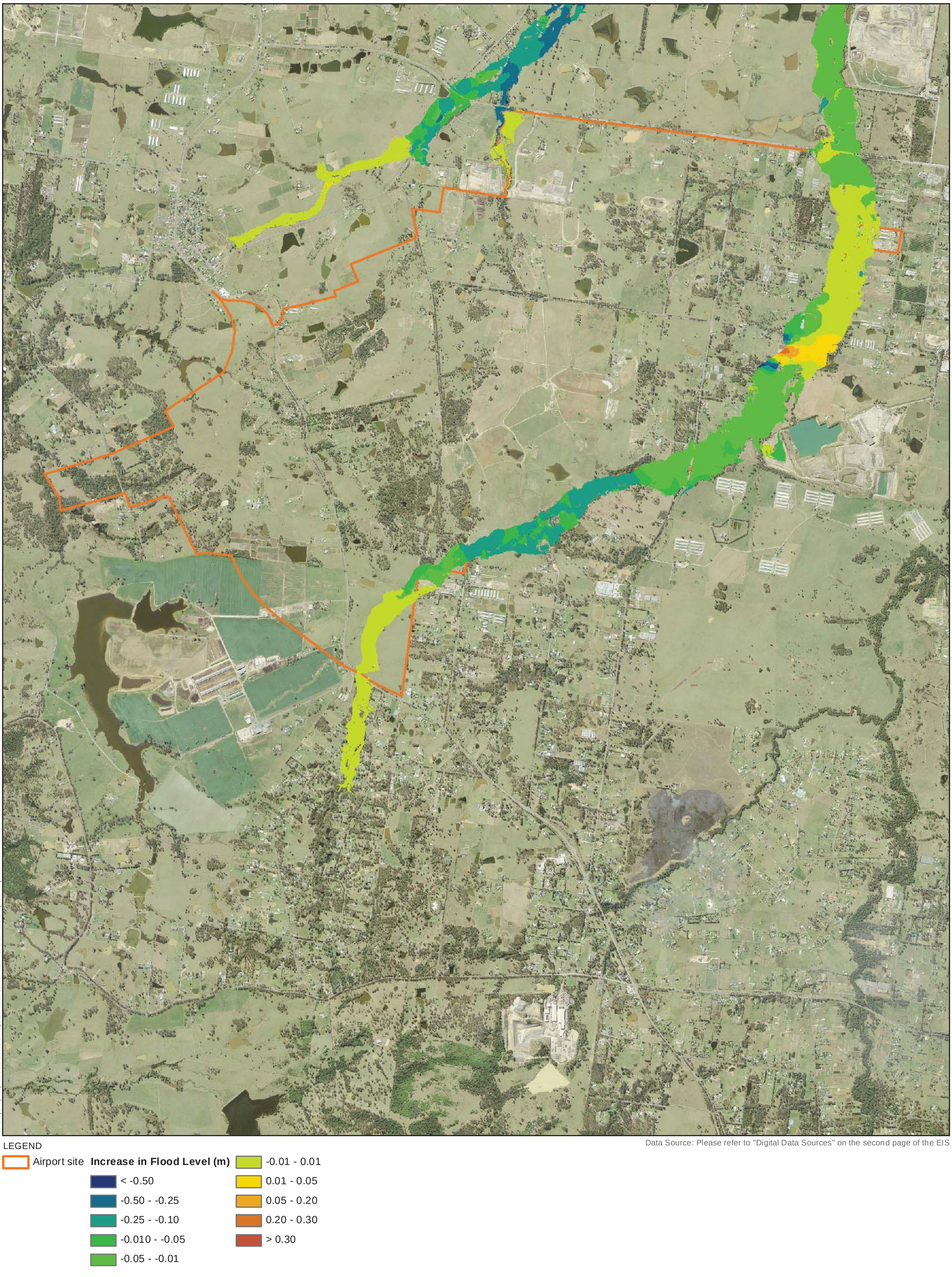


Figure 6-31 - Long term - flood depth impact, 100 year ARI, Badgerys and Cosgroves Creeks

7. Cumulative impacts

7.1 Influence of climate change

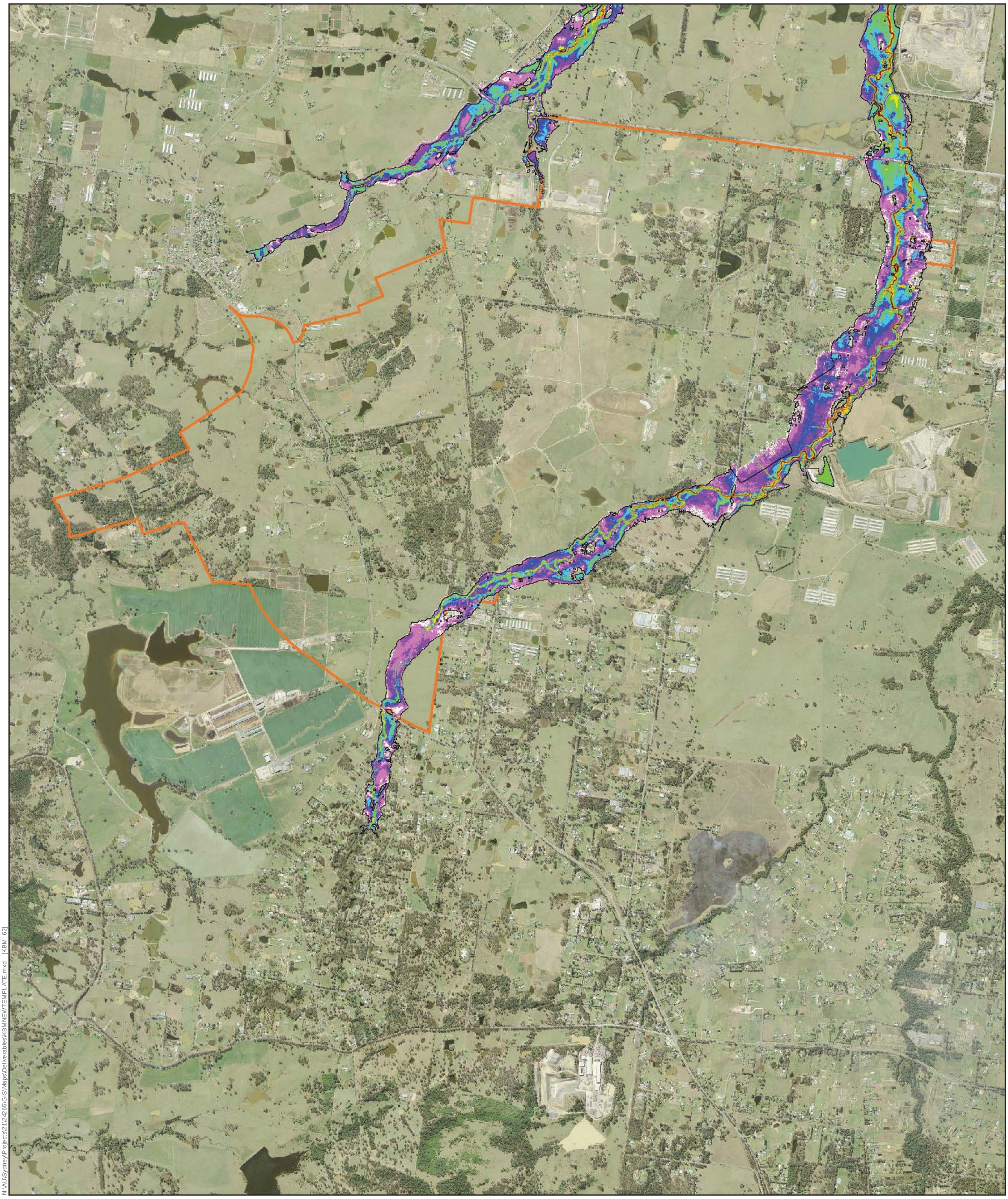
It is possible that impacts of the development on hydrology and geomorphology could be exacerbated through the impacts of climate change. In particular, due to predicted changes to rainfall seasonality and intensity.

Under current available climate change predictions for the region, a decrease in rainfall is predicted during spring, at least in the near future (refer to Section 3.5.3). A decrease in rainfall has the potential for a range of impacts on the surface water environment, including drying of creeks and associated impacts on stream health and ecology. The basins have been designed for existing climatic conditions and have the effect of creating a minor decrease in flows to the downstream creeks (refer to Section 6.1.1 and 6.2.1). If rainfall, and resulting runoff, to the basins decreases in the future, together with a general decrease in rainfall in the wider catchment, the airport site impacts on surface water runoff could be exacerbated. This may also compound the impacts of changes in rainfall seasonality and intensity locally.

It is predicted that summer rainfall will increase in the future and it is possible that the intensity of flood-producing rainfall events will likewise increase in the future. At present, the design of the basins result in no increase in flooding downstream (though localised increases in flow are possible at discharge locations). The future impact of changes to summer rainfall in the area is not predicted to be any worse as a result of the proposed airport. The exception is the reach on Oaky Creek downstream of the airport site where the proposed airport tends to increase flood levels.

Figure 7-1 to Figure 7-3 show the extent of increase in flooding due to climate change and indicates that the effects on flood extent would be minimal. The potential increased localised flows at discharge points do have the potential to cause erosion and scour at basin outlets which can be managed with mitigation measures.

On the airport site, the flood immunity of any runways and associated infrastructure could be reduced in the future as a result of increases in the magnitude of flood events. The design makes provision for this through the sizing of stormwater infrastructure on the airport site for no overflow considering the present day 100 year event flow plus an increase of 30 per cent in intensity to account for the possible future effects of climate change. Impacts are therefore expected to be minimal on downstream environments in the case of an increase in rainfall intensity.



Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site	Flood depth (m)	1 - 1.5
Flood extent for Stage 1 without climate change	0.1 - 0.2	1.5 - 2
	0.2 - 0.4	2 - 2.5
	0.4 - 0.6	2.5 - 3
	0.6 - 0.8	3 - 4
	0.8 - 1	>4

Figure 7-1 - Stage 1 - climate change flooding, 100 year ARI, Badgerys and Cosgroves Creeks

0 0.25 0.5 1
Kilometres

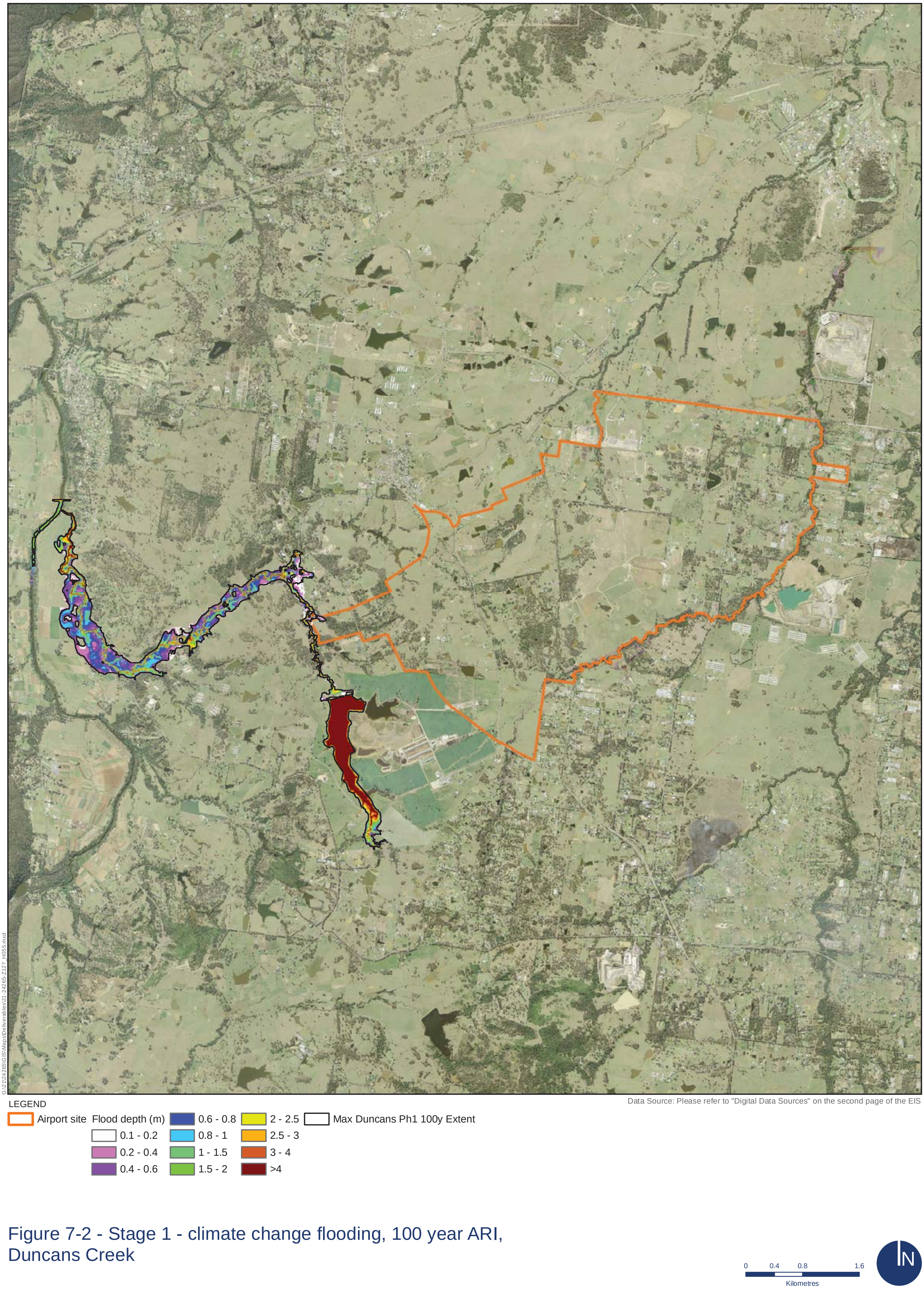
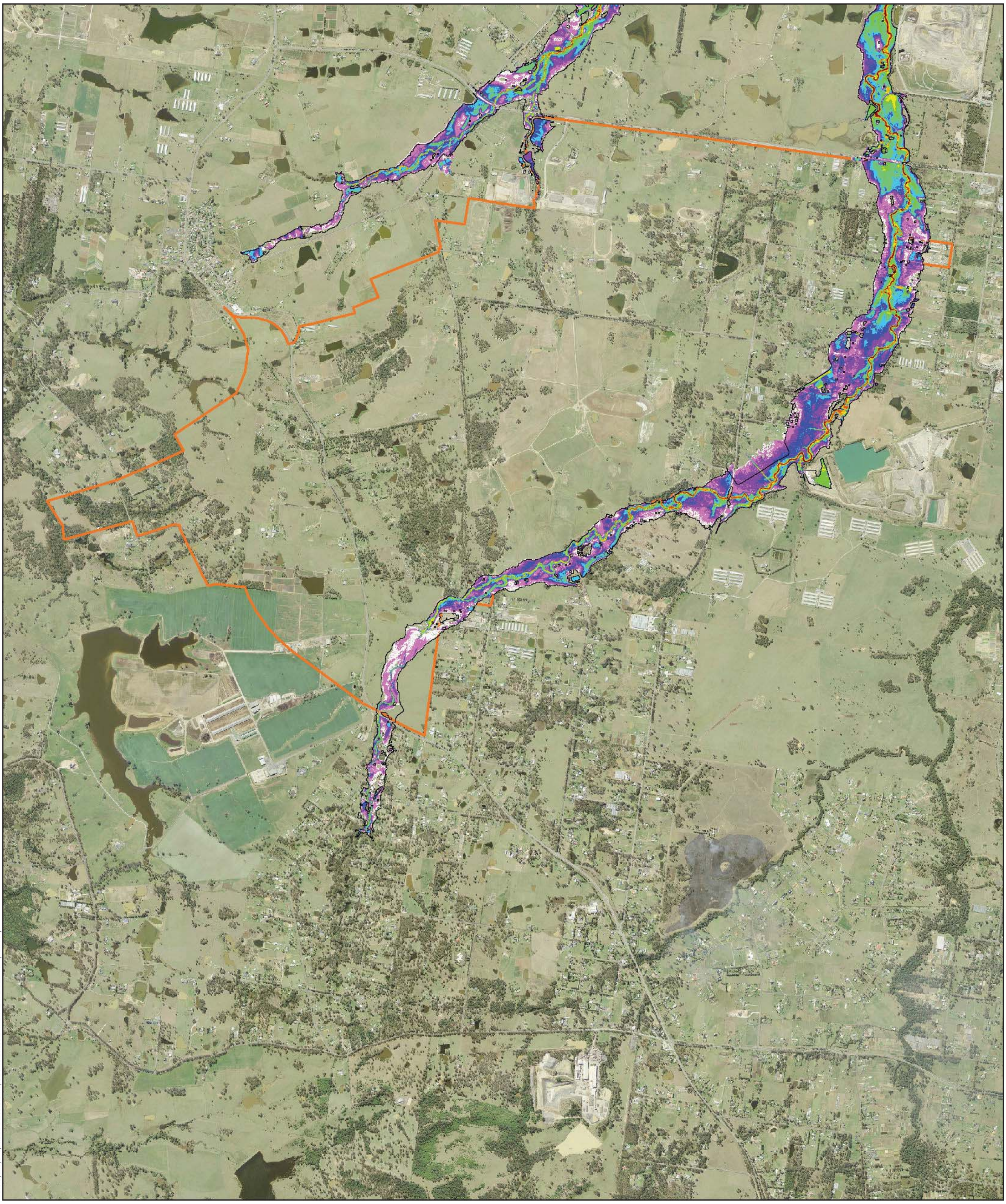


Figure 7-2 - Stage 1 - climate change flooding, 100 year ARI, Duncans Creek



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Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site

Flood extent for Longer term without climate change

Flood depth (m)

0.1 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 4
>4

Figure 7-3 -Long term - climate change flooding, 100 year ARI, Badgerys and Cosgroves Creeks

0 0.25 0.5 1
Kilometres

7.2 Influence of future urban development in the catchment

Planned and potential development within the vicinity of the proposed airport includes:

- Development of the Western Sydney Employment Area and Western Sydney Priority Growth Area
- Implementation of the South West Priority Growth Area
- The likely realignment of the Northern Road around the airport site (discussed separately in Section 6.1)
- Implementation of the Western Sydney Infrastructure Plan which incorporates additional Northern Road upgrades, development of the new M12 motorway between the M7 and the Northern Road
- Potential extension of the South West Rail Link and the possible development of a rail link to the proposed airport
- Potential development of the Outer Sydney Orbital corridor
- Proposals for development of residential and commercial areas to the south and west of the airport site which fall outside of existing priority growth areas.

Though currently zoned primarily for agricultural and primary industry uses, the areas downstream of the airport site to the north form part of the Western Sydney Employment Area and the Western Sydney Priority Growth Area. The Western Sydney Priority Growth Area includes large amounts of land situated within the catchment of South Creek upstream of its confluence with Badgerys Creek and also incorporates land to the east of the airport site, incorporating portions of the area upstream of Badgerys Creek on its eastern bank adjacent to the airport site.The land will be developed for a mix of employment and housing use.

The future route of the M12 motorway is likely to cross Badgerys Creek and Cosgroves Creek downstream of the airport site, with flows discharged from the proposed airport needing to be effectively conveyed beneath the new road alignment without exacerbating flooding or causing flooding to the airport upstream.

The development of the Outer Sydney Orbital corridor as well as the extension of the South West Rail Link and a possible rail link into the airport site may need to cross watercourses in the area and could have impacts on flood levels and flood storage.

In general, the future urban development has the potential to cause impacts on flooding and watercourse geomorphology and to exacerbate impacts arising from the proposed airport. . Without mitigation, these could include:

- Increases in peak runoff rates due to increased impervious areas
- Changes to the natural flow regime with resultant impacts on creek stability and flooding
- Flood impacts to the proposed airport (for example, from construction of the M12 motorway or development as part of the Western Sydney Priority Growth Area).
- Impacts from development to the south east of the airport could include changes to flooding or low flow regime to Badgerys Creek

Any new development would be subject to requirements to review and mitigate impacts downstream through measures such as on-site detention.

The implications of potential future development in relation to mitigation measures are considered in Section 8 of this report.

8. Mitigation and management measures

8.1 Construction

The range of potential impacts identified during construction, and potential mitigation and management measures to address those impacts, are summarised in Table 8-1. The increased impervious surface area associated with the proposed airport would have the potential for adverse impacts on the hydrological regime in terms of increased runoff volumes and peak flows as the airport site is progressively constructed. Stormwater management features including drains, swales and basins would be constructed progressively to manage potential flow increases. Where necessary, temporary stormwater drainage would need to be installed to manage on-site surface water, including consideration of potential flooding given the extended timeframe over which the airport will be developed.

There is potential for large quantities of sediments to be directed into the stormwater management network resulting in blockage. This impact is discussed in detail in the water quality report (refer to EIS Appendix L2). Mitigation measures would include the development of appropriate erosion and sediment control measures for the construction stage. Infrastructure to manage surface water on site would also incorporate allowance for the separation of “clean” and “dirty” water. A detailed construction surface water management strategy would be incorporated into a Soil and Water Management Plan (SWMP), which should also consider seasonal variability of rainfall when planning construction stage activities.

Water use during construction is expected to be high and a construction water supply strategy needs to be developed to cater to the needs of the proposed airport development in order to meet the water needs of the construction program without compromising supply to existing users. Consultation with Sydney Water Corporation is required to investigate the capacity of existing potable sources to provide the likely demand for the proposed airport. The possibility of alternative water sources would also be considered during detailed design development. The construction water supply strategy would need to be developed with a consideration of construction stormwater management and flood potential. This would include the need to make provision for storage of rainfall runoff during wet periods through provision of basin capacity in addition to that required for construction water use. Progressive requirements for water use and flood mitigation during construction would need to be developed as part of the construction water supply strategy and surface water management strategy.

8.2 Operation

The range of potential impacts identified during operation, and potential mitigation and management measures to address those impacts, are summarised in Table 8-1. The impacts stem from the following key factors discussed in Section 0. In particular:

- changes to the catchments in terms of catchment area, configuration and degree of imperviousness;
- resulting changes in the peaks, volumes and timing of flows discharging from the airport site leading to influence on downstream flow depths and velocities; and
- removal or diversion of watercourses on the airport site.

The surface water management systems at the airport site will be designed to avoid substantial alteration to surface water drainage patterns and the volume of downstream flow to minimise the potential for adverse impacts to the downstream environment.

The primary design control measure already proposed to minimise these impacts is the use of detention basins to mitigate increases in peak flow and changes to timing of flows as well as manage discharge velocities. The assessment undertaken indicates that the current basin strategy does influence flow peaks, though it does not entirely mitigate impacts across all magnitudes and durations of storm events. There is also potential for some of the impacts to be exacerbated due to the cumulative impact of upstream or downstream development and the possible future effects of climate change.

To mitigate potential downstream impacts, the basin configuration, including high and low flow outlet structures and volume characteristics, would need to be developed further as part of the upcoming stages of detailed design of the proposed airport. This design should aim to mimic natural flows as closely as reasonably practical. Design development may incorporate reviewing the shape of basins and the level and size of low and high flow outlets. The analysis would need to consider a range of eventualities, such as low flows, flood flows and storm durations and also management of localised scour and erosion at basin outlets. In addition, the cumulative impacts of climate change and surrounding development should be considered.

The design of the airport drainage does consider and incorporate the possible future effects of climate change. As the design develops, the latest recommendations and guidelines regarding climate change effects should be considered, as these may change from currently available information. In particular, the Australian Rainfall and Runoff Revision Project 19 will provide updated guidance on climate change in relation to hydrology and rainfall. As governments and other institutions continue researching the effects of climate change, new information may emerge prior to finalisation of the airport design.

The net effects on flood levels and creek stability on Duncans Creek are assessed to be minor based on the current design. In the event that detail design results in downstream impacts, then it may be possible to expand Basin 9 (bio-retention basin) to incorporate a detention component. A preliminary assessment carried out for this EIS indicates that provision of a storage volume in the order of 20,000 m^3, together with appropriate low level culvert outlets would be required to reduce flows to existing levels. This would need to be refined through detailed design. If a basin is not included, then outlet protection works to limit scour and erosion will be required.

Mitigation of groundwater seepage is discussed in detail in the groundwater assessment (refer Appendix L3 of the EIS). A monitoring program is proposed that would monitor both groundwater and surface water quality. This would provide warning of excessive groundwater seepage that may have downstream hydrological impacts and would allow remedial action to be taken.

During operation, options for the expansion of potable water supply lines would be investigated in consultation with Sydney Water and in consideration of their existing plans for expansion of the network to supply developments associated with the Western Sydney Priority Growth Area and the South West Priority Growth Area.

Table 8-1 Impact and mitigation summary

Section reference	Activity	Description of consequences	Control measures incorporated in design / management plans	Project phases	Mitigation / management measures
5.1	Volume of runoff expected from the airport site will increase due to reduction in infiltration into the ground as site is constructed	Downstream flooding	Detention basins	Construction	Basin design to be refined during detailed design to address flooding across the full range of flood events and appropriate construction phasing
5.1	Flooding and waterlogged soils on site	Disruption to construction activities, damage to equipment	-	Construction	Develop construction surface water management strategy as part of Soil and Water Management Plan
5.1	Water use during construction and operation	Impact on regional and/or local water resources	Use of farm dams on site where practical during construction, use of recycled water during operation to supplement potable water supply	Construction and operation	Strategy for water supply to be developed during detailed design and in consultation with Sydney Water Corporation
5.2	Progressive development of site resulting in progressive removal of existing water bodies	Permanent removal of watercourses and artificial wetland area including associated habitat destruction	-	Operation (Stage 1 and long term)	The significance of the habitat removal is assessed in the biodiversity report (refer to Appendix K1 of the EIS) together with the need for offset measures
6.1.1 and 6.2.1	Diversion of tributary into Badgerys Creek upstream of Elizabeth Drive	Increased likelihood of flooding to Elizabeth Drive	Detention basins to manage peak flows, low flow outlets underneath Elizabeth Drive to maintain existing low flows	Operation (Stage 1 and long term)	Detailed design of detention basins
6.1.1 and 6.2.1	Diversion of tributary into Badgerys Creek upstream of Elizabeth Drive	Potential drying of 200 m of third order tributary downstream of Elizabeth Drive	Low flow outlets underneath Elizabeth Drive to maintain existing low flows	Operation (Stage 1 and long term)	Refine through detailed design

Section reference	Activity	Description of consequences	Control measures incorporated in design / management plans	Project phases	Mitigation / management measures
6.1.1 and 6.2.1	Decrease in catchment area draining to Oaky and Cosgroves Creeks	Removal of flow from creek resulting in potential downstream habitat and creek degradation, noting that change in flows is minor	-	Operation (Stage 1 and long term)	Review design of detention basins during detailed design to achieve appropriate flow at the outlet
6.1.1 and 6.2.1	Increase in site discharge due to increase in site impervious area	Flood impact to residents downstream	Detention basins	Operation (Stage 1 and long term)	Limited based on current design. Basin design to be refined during airport design development to address flooding across the full range of flood events
6.1.1 and 6.2.1	Increase in discharge on Badgerys Creek due to future diversion of The Northern Road	Flood impacts to residents upstream of The Northern Road	-	Operation (Stage 1 and long term)	Consultation with the NSW Government to ensure diverted The Northern Road design makes appropriate provision for future cross drainage to prevent inappropriate diversion of subcatchments flows on Badgerys Creek
6.2.1	Potentional development of commercial area in south of airport site where Badgerys Creek passes through	Range of potential impacts to creek on the airport site and downstream	-	Operation (long term)	Developments outside the Stage 1 construction impact zone would be subject to separate approvals processes. Plans for development of commercial area to incorporate strategy appropriate to a third order stream at this location
6.2.2	Increases in shear stress due to encroachment of Basin 4 along Badgerys Creek	Increase in scour and erosion along this reach of Badgerys Creek and risk of basin failure.	Detention basins	Operation (long term)	Review design of detention basin 4 during detailed design to reduce encroachment.
6.1.1 and 6.2.1	Increase in flows at point of discharge on tributary of Duncans Creek	Localised erosion, scour and flooding, increased flood risk to properties in the immediate vicinity	-	Operation (Stage 1 and long term)	Review need for expansion of bio-retention Basin 9 to incorporate detention component.

9. Summary and conclusion

A surface water hydrology and geomorphology assessment was carried out to determine the impact of the proposed airport on flooding and watercourse geomorphology during both construction and operation of the proposed Stage 1 development and an indicative long term development. It also explored mitigation and management measures to address impacts during construction and operation.

The study considered key indicators of changes including:

- changes in discharge from the airport site;
- changes in watercourse bed shear stress; and
- changes in downstream water level.

The study found that construction of the proposed airport would result in a major modification of the airport site in terms of land use characteristics and surface water runoff generated. It would also result in removal of a large number of watercourses and farm dams from the airport site. The ecology aspects of removal of surface water habitat and associated flora and fauna species are assessed separately in the biodiversity report which forms Appendix K1 of the EIS.

A detailed Surface Water Management Plan would be developed and would need to consider impacts of flooding on-site over the course of the construction period. During construction of the proposed airport, demands on potable water would be high and there is a need to develop a strategy for water supply to the airport site to meet the construction requirements, and also the ongoing operational requirements.

During operation of the proposed airport, use of potable water on site would be supplemented by recycled water to reduce demand on potable water. The assessment found that the detention basin strategy would be effective at limiting the downstream impacts such that any increases in flood level would not worsen flooding to surrounding roads and dwellings, and the risk to changes in creek geomorphology would be low.

Some localised changes in water level were predicted downstream of the airport site. These were found to be minor. Increases in flow for catchment F5 (that drains via bioretention basin 9) were found not to have a substantial impact on Duncans Creek. This would need to be confirmed through detail design and, if required, expansion of bioretention Basin 9 to incorporate a detention component to provide mitigation if required.

The assessment found that there would be a need to further develop the basin strategy during upcoming stages of design development for the proposed airport such that the basins would be effective at mimicking natural flows as closely as possible across a range of storm durations and magnitudes including low and high flows.

Further, though not impacts arising from the airport infrastructure, the assessment highlighted the potential for impacts to arise from diversion of The Northern Road and, in the long term, from potential commercial development in the south of the airport site. Substantial planned growth and development in the areas surrounding the airport site has the potential for impacts to surface water features including Oaky, Cosgroves, Badgerys and Duncans Creek and also has the potential to impact flooding of the airport site. These would need to be considered through separate studies.

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Appendices

Appendix A – Additional model development details

DRAINS model

Parameters

Pit/Nodes

Pits, like other forms of node, act as entry points for water into the pipe system. They can represent a street gully pit, a manhole, a junction, a flow diversion or other components. On-grade pits are located on slopes, while sag pits are in hollows or depressions.

Catchment slope

Catchment slopes were estimated along the major flowpath for each catchment from the catchment boundary to the outlet based on the airport site grading during Stage 1 and the long term.

Surface roughness (n)

Surface roughness coefficient values were adopted for pervious and impervious catchments and were applied across the model based on industry standard values.

Table A-1 Surface Roughness Coefficients adopted in DRAINS modelling

Surface Roughness Coefficient	Current Study
Paved area	0.015
Grassed area	0.025
Supplementary area	0.015
Pipe	0.013
Channel	0.03

RAFTS model

Parameters

Links

Links are used in RAFTS to connect catchments and route runoff downstream. Lagging links were used in the RAFTS models developed for this study. Lagging links are used to delay, or translate, the flow (hydrograph) from an upstream location to a downstream location, to account for the travel time between two points.

Lag times were estimated by calculating travel distances along major flowpaths in mapping software, and converting distance to time by assuming an average flow velocity of 1 m/s. Review of hydraulic model results supported the use of this velocity, and this assumption was tested in the sensitivity analysis of the RAFTS model.

Catchment slope

Catchment slopes were estimated along the major flowpath for each catchment from the catchment boundary to the outlet. The equal area slope method was used. Catchment slopes ranged from 0.5 % – 7.3% and the average slope was 2.0 %.

Losses

An initial/continuing loss model was adopted in RAFTS to estimate runoff from design rainfall. Losses were adopted for pervious and impervious catchments and applied across the model. Pervious catchment losses were selected based on Australian Rainfall and Runoff (1987) recommendations for design loss rates for New South Wales.

Surface roughness (n)

Surface roughness coefficient values were adopted for pervious and impervious catchments and were applied across the model based on industry standard values.

Storage coefficient multiplication factor (BX)

The current study adopted the RAFTS default value for BX of 1 for consistency with the modelling and design work carried out by the Department of Infrastructure and Regional Development. Previous studies have used BX to calibrate model results to historical flood data.

Table A-2 Comparison of RAFTS parameters for flood studies

Parameter	Current study	1990 South Creek flood study	SMEC study 1991 report for second Sydney airport	Updated South Creek flood study (Worley Parsons 2015)
BX	1.0	1.3	1.3	1.3
Surface roughness	Pervious catchments 0.025 Impervious catchments 0.015	No information available	No information available	0.025
Losses Initial loss/continuing loss (IL/CL)	Pervious catchments IL 10 mm CL 2.5 mm/hr Impervious catchments (100% impervious) IL 1 mm CL 0 mm/hr	IL 35 mm (40 hour storms), or IL 10 mm (9 hour storms), based on critical durations of 9 and 40 hours for most of the catchment CL 1 mm/hr	IL 5 mm CL 0.5 mm/hr	Pervious catchments IL varies 5-37.1 mm CL 0.94 mm/hr Impervious catchments (75-100% impervious) IL 1 mm CL 0 mm/hr

Probable maximum flood derivation

Results of probable maximum flood simulations in RAFTS are provided in Table A-2, with the peak flow and critical duration storm event shown for a range of key locations. Critical durations ranged from two to four hours depending on location.

Hydrographs from the simulation of the two hour probable maximum flood event are shown in Figure A-1 together with the rainfall hyetograph for the event. The hydrographs shown are at the Elizabeth Drive crossing of Badgerys, Oaky and Cosgroves Creek.

Table A-3 Probable maximum flood peak flows

Location	Design PMP event peak flow (m^3/s) (critical duration)
Badgerys Creek at Elizabeth Drive	880 (2.5 hr)
Oaky Creek at Elizabeth Drive	200 (2 hr)
Cosgroves Creek at Elizabeth Drive	370 (2 hr)
Badgerys Creek at South Creek	1050 (4 hr)
Cosgroves Creek at South Creek	950 (2.5 hr)
Duncans Creek at Nepean River	950 (4 hr)

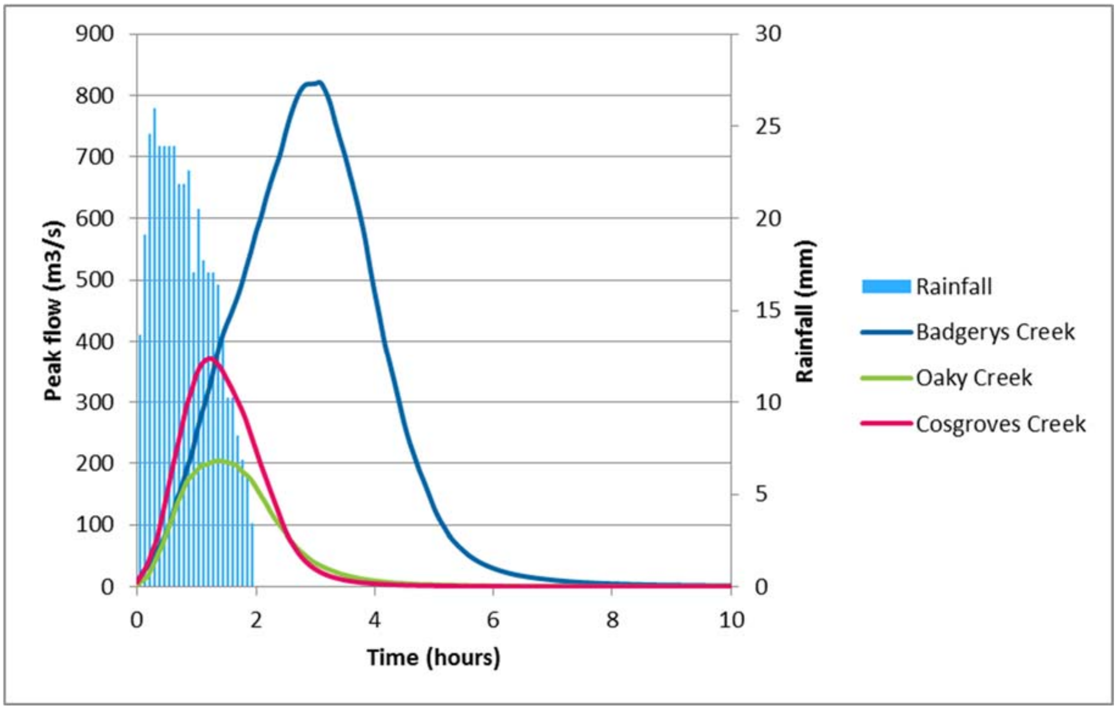

Figure A-1 Probable Maximum Flood simulation results at Elizabeth Drive, 2 hour storm duration

It is noted that on-site stormwater infrastructure would be overwhelmed in the PMF. It is therefore difficult to accurately determine PMF subcatchments areas and flow paths without an on-site two-dimensional flood model. PMF flood depths and extents are subject to this additional degree of uncertainty and are based on the available information.

Hydrology modelling verification

Comparisons against previous studies

Results of the RAFTS model were compared to design storm flow estimates from other sources, including previous flood studies and the probabilistic Rational Method for eastern New South Wales as described in Australian Rainfall and Runoff (Institute of Engineers Australia 1987).

Peak flows for the 100 year average recurrence interval (ARI) storm event are compared in Table A-4, and the critical duration storm that resulted in the reported flow is provided in brackets where known. For the probabilistic Rational Method results, the time of concentration for Badgerys Creek, Cosgroves Creek and Duncans Creek were all approximately 2.5 hours.

The current study produced higher flow estimates than reported peak flows at the same locations in the Updated South Creek Flood Study. This was expected because the Updated South Creek Flood Study flows were for long duration storm events that were critical for the South Creek catchment as a whole, but the critical duration for the catchments in the current study were shorter. This may also be the case for the earlier South Creek flood study and floodplain management study, where South Creek was the watercourse of interest and the storm duration reported on was the one producing the largest flows in South Creek. A 100-year ARI storm was simulated in the RAFTS model for comparison with the Updated South Creek Flood Study and the results are also indicated in the table at key locations.

The flows calculated in RAFTS in the current study compared well with rational method estimates for the 100 year ARI event, particularly for Badgerys Creek. Duncans Creek had the highest peak flow according to the RAFTS results, reflecting the higher impervious fraction for its catchment associated with large dams. The rational method calculation only considers differences in total area for catchments in the same region, and so Badgerys Creek, with the largest catchment area, was estimated to have the highest peak flow.

The RAFTS results correspond well with the 1991 Concept Design study, with peak flows from the two studies within 5 per cent of one another.

For the purposes of comparison with the Updated South Creek Flood Study, a 100 year 36-hour storm went through simulation in the hydrology model. The results are shown in Table A-4.

Table A-4 Comparison of 100 year ARI design storm flow estimates

Location	100 year ARI peak flow (m^3/s) (critical duration)					
	RAFTS (current study)	Rational method (current study)	1990 South Creek Flood Study (1)	1991 South Creek Floodplain Mgmt. Study (1)	1991 Concept Design for Second Sydney Airport	2015 Updated South Creek Flood Study
Badgerys Creek at Elizabeth Drive	150.6 (6 hr) 125 (36 hr)	-	112	126	153 (2-6 hrs)	126 (36 hr (2))
Oaky Creek at Elizabeth Drive	37.6 (2 hr)	-	-	-	39 (2-6 hrs)	-
Badgerys Creek at South Creek	179.5 (6 hr) 136 (36 hr)	172	151	151	-	138 (36 hr (2))
Cosgroves Creek at South Creek	179.2 (6 hr) 136 (36 hr)	135	129	129	-	123 (36 hr (2))
Duncans Creek at Nepean River	181.8 (6 hr)	147	-	-	-	-

Table notes:
(1) This data was reported in the 2015 Updated South Creek Flood Study (Worley Parsons)
(2) This duration is not critical at these locations – but is for South Creek as a whole.

Sensitivity analysis of RAFTS model parameters

Sensitivity analysis was conducted by testing the impact of variations to the values of key model parameters, as follows.

- Initial loss: a higher initial loss of 35 mm was tested for pervious catchments, this being the upper limit in the range of recommended losses for this region provided in *Australian Rainfall and Runoff* (Institute of Engineers Australia 1987).

- Continuing loss: a higher continuing loss of 4.1 mm/hr for pervious catchments was tested in combination with both low and high initial losses (10 and 35 mm).
- Roughness: a higher roughness value of 0.05 was tested for pervious catchments.
- Lag times: the lag times assigned to lagging links between nodes in the model were adjusted to test a high velocity (2 m/s) and low velocity (0.5 m/s) scenario.
- BX: the storage coefficient multiplication factor was tested at 1.3, which was the value used in several previous flood studies (see Table A-4).

The sensitivity of the model results on the values of the input parameters has been assessed by comparing the hydrographs and peak flows for the 10 and 100 year ARI events at the downstream boundaries of the model. The peak flows at the end of Badgerys, Cosgroves and Duncans Creeks are compared for the base case (adopted parameterisation) and sensitivity analysis scenarios in Table A-5.

Table A-5 Sensitivity analysis results

	10 year ARI peak flow (m^3/s)			100 year ARI peak flow (m^3/s)		
Storm duration	*9 hr*	*6 hr*	*6 hr*	*6 hr*	*6 hr*	*6 hr*
	Badgerys Creek at South Creek	Cosgroves Creek at South Creek	Duncans Creek at Nepean River	Badgerys Creek at South Creek	Cosgroves Creek at South Creek	Duncans Creek at Nepean River
Base case	109	113	114	177	180	183
High initial loss	91	69	70	142	143	143
High continuing loss	97	106	106	167	172	175
High initial loss, high continuing loss	81	63	64	133	136	137
High pervious catchment roughness	91	92	91	148	155	154
Slow lagging links	77	76	74	119	124	120
Fast lagging links	138	135	136	218	214	221
Bx 1.3	101	104	103	164	170	171

The results were most sensitive to link lagging velocity, with a doubling in link lagging velocity corresponding to an approximate 20 per cent increase in peak flow, and a halving of link lagging velocity leading to an approximate 30 per cent decrease in peak flow. The timing of the peak was also impacted, as shown by the comparison of hydrographs for Badgerys Creek below.

A limitation of the model in terms of storage was that data was not available for the Leppington Pastoral site storage structure sufficient to appropriately estimate hydrology for this catchment. Results on Duncans Creek downstream of the airport site are considered indicative only.

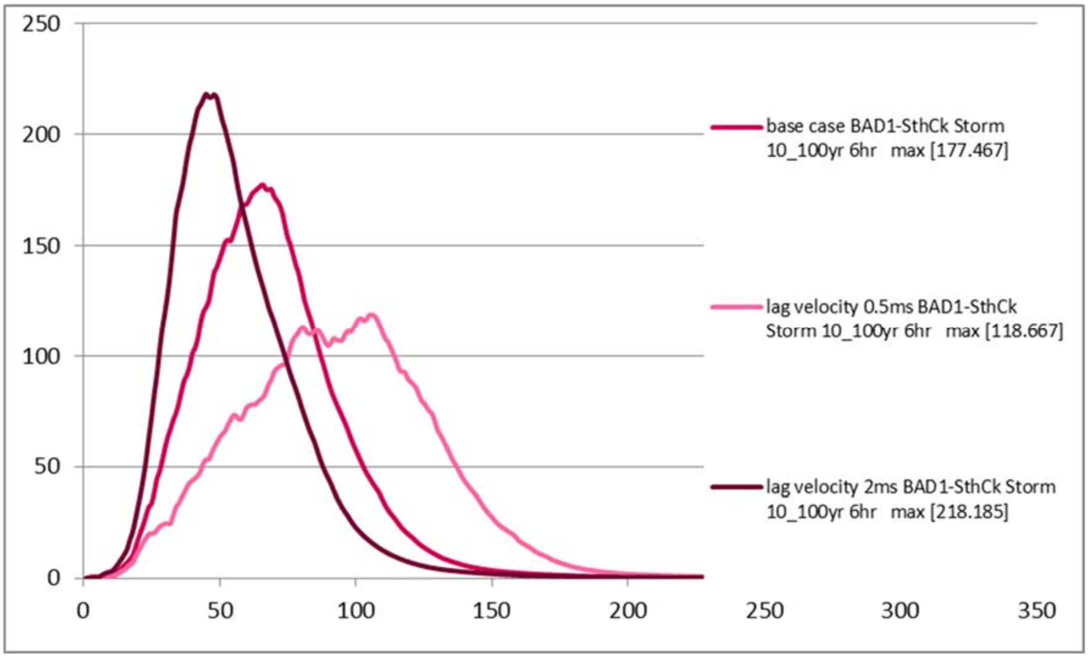

Figure A-2 Badgerys Creek at South Creek, sensitivity of lag velocity

The influence of the lagging assumption on impact assessment findings is expected to be limited. This is because flows for each subcatchment were explicitly routed in the MIKE 21 model rather than in the RAFTS model, meaning that the RAFTS lagging assumptions were not used within the extent of the hydraulic models.

Comparison of 1987 design rainfall IFD data with 2013 rainfall IFD data

Australian Rainfall and Runoff is currently undergoing revision and rainfall Intensity-Frequency-Duration (IFD) data has recently been revised from the 1987 published data to 2013 data. The 2013 data cannot currently be used for detailed studies as the associated temporal patterns and other information used to define the design storm events are still undergoing revision.

However, the 1987 data (used in this study) was compared with the 2013 data to understand the scale of expected change to rainfall because it is expected that, in the future, the airport site would need to be assessed against the revised data.

A comparison of the IFD curves is provided in Figure A-3.

It is important to note that the new data uses Annual Exceedance Probabilities (AEPs) as the probability measure rather than Average Recurrance Intervals (ARIs). ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP.

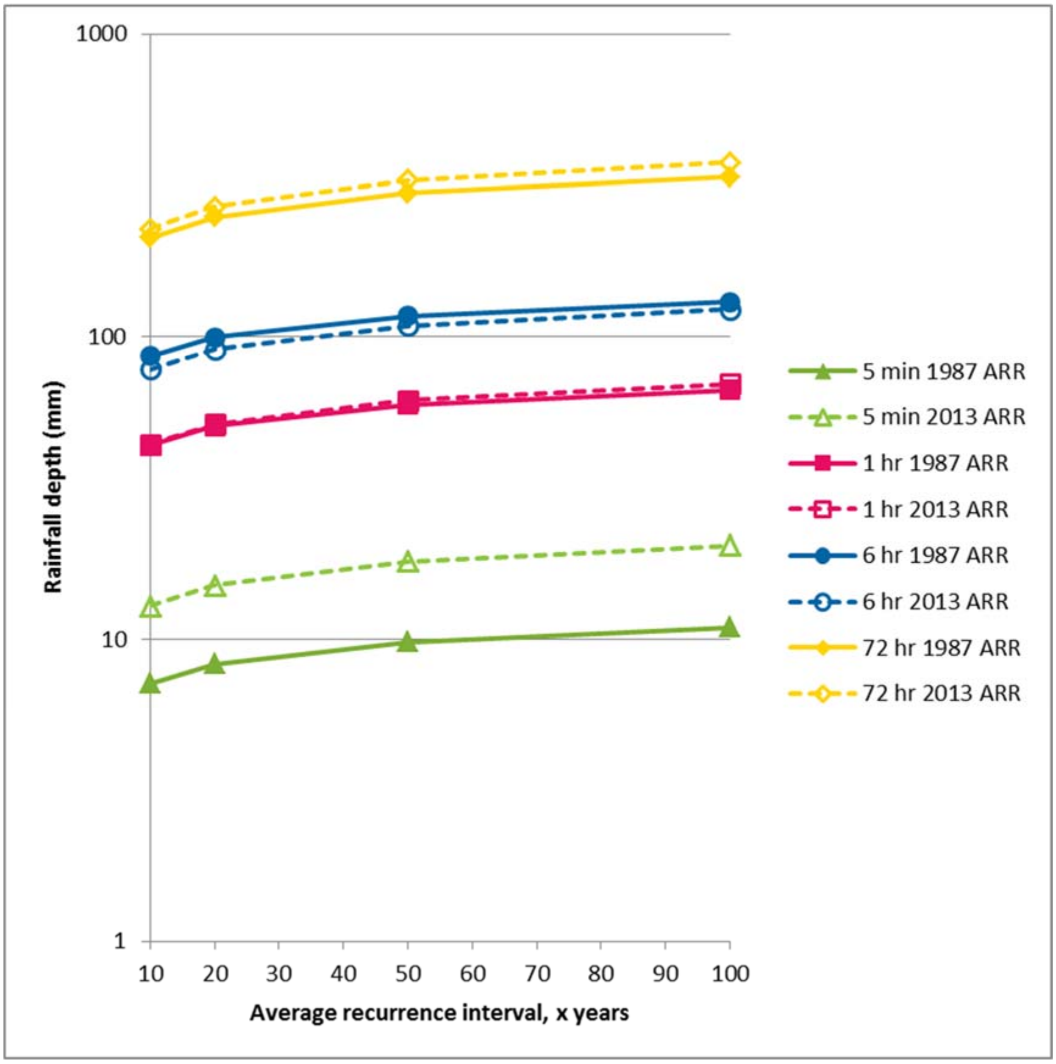

Figure A-3 Comparison of design IFD data for various durations

For very short duration storms, the 2013 IFD is much higher than the 1987 data. For longer duration storms, the rainfall is more closely aligned. On the basis of the available information it is not expected that the findings of the EIS would be materially altered due to the revised IFD data.

Hydraulic model

Photographs of key hydraulic structures from site inspection

Several key hydraulic structures are indicated in the following photographs. The photographs, together with on-site measurements, were used to define hydraulic structures in the MIKE 21 model.

Oaky Creek crossing at Elizabeth Drive

Badgerys Creek crossing at Elizabeth Drive

Badgerys Creek crossing at Badgerys Creek Road

Badgerys Creek crossing at The Northern Road

Hydraulic model verification

The accuracy of hydrologic and hydraulic modelling is influenced by a number of key factors, including:

- inherent uncertainty in the procedures documented in Australian Rainfall and Runoff (Engineers Australia, 1987) which are used to estimate peak flood flows, particularly for large flood events;
- the accuracy and resolution of the underlying data used to represent the model topography; and
- the uncertainty in hydraulic modelling methodology, in particular in estimating factors such as Manning's n which requires a significant amount of engineering judgement.

There was no detailed data available within the study area that could be used directly to calibrate the models, however model checks and validation was carried out on the basis of available information.

Comparison of results was made against those documented in the Updated South Creek Flood Study (WP, 2015). Levels were compared upstream of Elizabeth Drive and are shown in the following table.

Table A-6 Validation of model

Flood event	GHD existing case model, flood level (m AHD)	Updated South Creek Flood Study, flood level (m AHD)
100 year ARI event	47.0	46.6

The modelled water level was higher for the current study, which was expected as the value quoted for the Updated South Creek Flood Study was for a 36-hour duration flood event, which is not critical for the Badgerys Creek catchment. The value quoted for the current study is for a 6-hour storm duration event, which is critical for the catchment.

Other important points to note include:

- the representation of bridges and culverts in the Updated South Creek Flood Study is understood to be based on review of LiDAR rather than detailed information;
- the model validation undertaken for the Updated South Creek Flood Study was to the South Creek Flood Study (1991) which was calibrated to data on South Creek; and
- the focus of the Updated South Creek Flood Study was not Badgerys Creek, Cosgroves Creek or the airport site and it included only limited reaches of these creeks and the airport site within the study.

Whilst general agreement with the findings of the Updated South Creek Flood Study was considered appropriate, for the above reasons it was not considered appropriate to calibrate or otherwise amend the parameters used in this study to match exactly the findings of the Updated South Creek Flood Study.

Predicted water levels for a number of model cross-sections of the streamline in a 1 year ARI event were checked against visual inspections on site of bank full levels and were considered generally reasonable.

Rainfall data from the Twin Creeks Golf Course and Country Club was provided for the rainfall event of the 21 April 2015 and 22 April 2015 (see Section 3.2.3) and was compared to the data from the BOM AWS Badgerys Creek gauge. The gauge recordings are included in Table A-7.

Table A-7 Rainfall totals for 21 and 22 April 2015

Gauge	Rainfall total (mm) in 24-hour period	Rainfall total (mm) in 48-hour period
Twin Creeks Golf Course and Country Club rainfall gauge	77	134
Badgerys Creek AWS	84	135

Compared to the BOM IFD for the airport site, these totals equate to around a 5 year ARI event or slightly larger.

Locations of debris marks observed on Badgerys Creek, believed to be from the recent flood events, were compared to modelled 5 year ARI flood events and the agreement was found to be reasonable.

Appendix B – Hydraulic model results

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site NM²

- 20 - 100
- 100 - 150
- 150 - 200
- >200

0 0.4 0.8 1.6
Kilometres

Figure B-1 - Existing watercourse shear stress maps, 1-year ARI

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site NM²

20 - 100

100 - 150

150 - 200

>200

0 0.4 0.8 1.6
Kilometres

N

Figure B-2 - Existing watercourse shear stress maps, 5-year ARI

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Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site

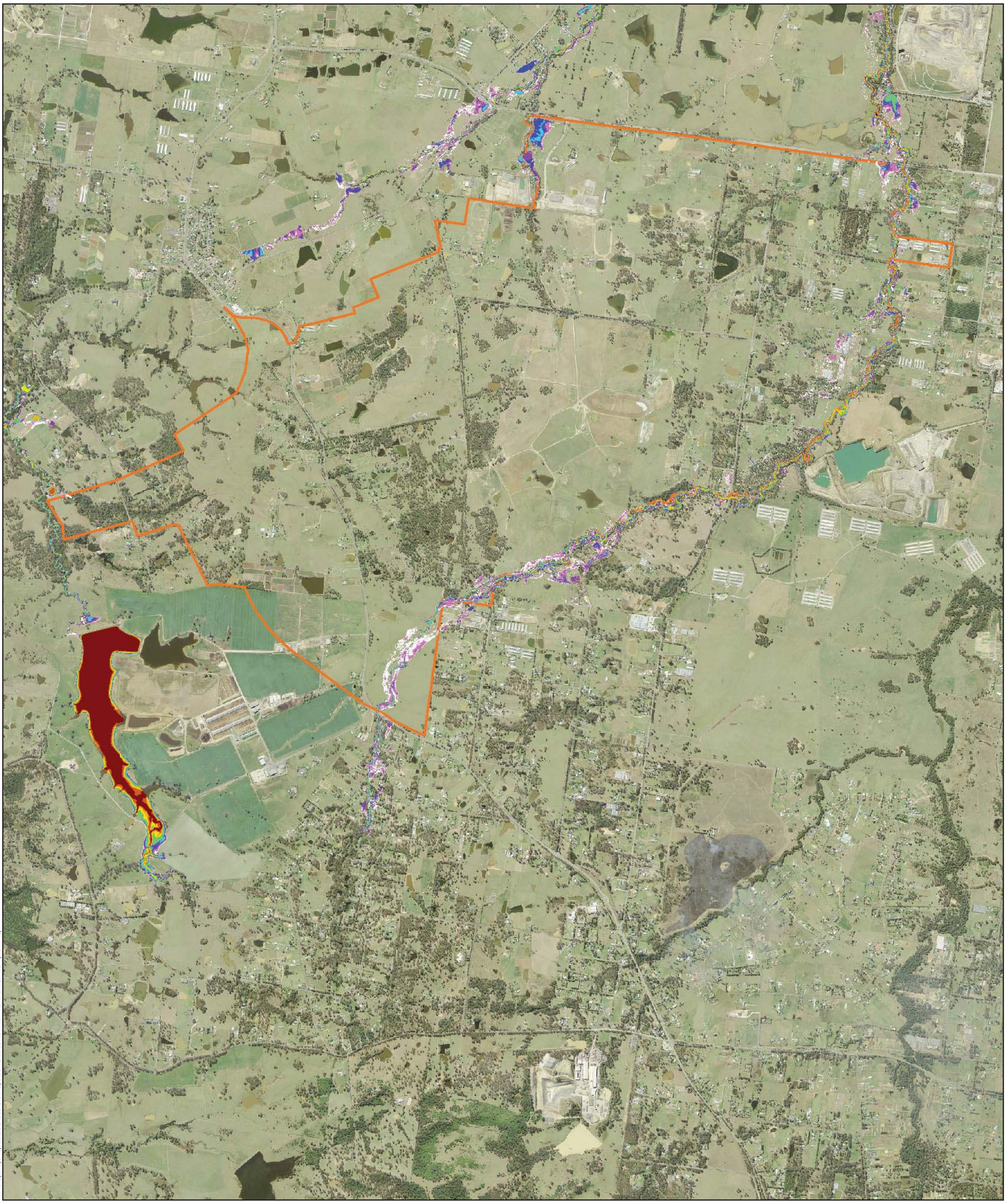
NM²

- 20 - 100
- 100 - 150
- 150 - 200
- >200

0 0.4 0.8 1.6
Kilometres

N

Figure B-3 - Existing watercourse shear stress maps, 100-year ARI



LEGEND

Airport site

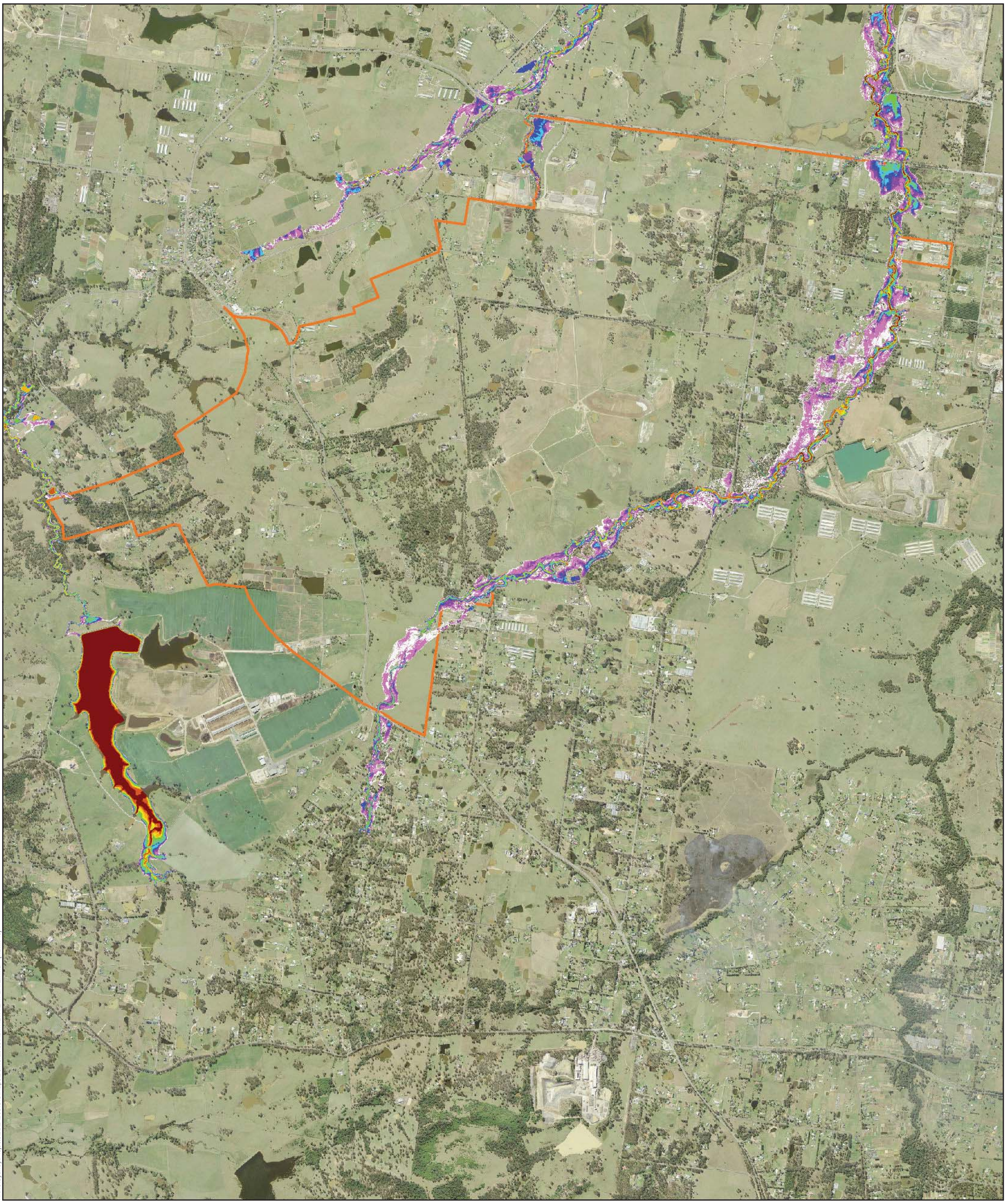
Flood depth (m)

- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- >4

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

0 0.25 0.5 1
Kilometres

Figure B-4 - Stage 1 - flood depths, 1-year ARI event



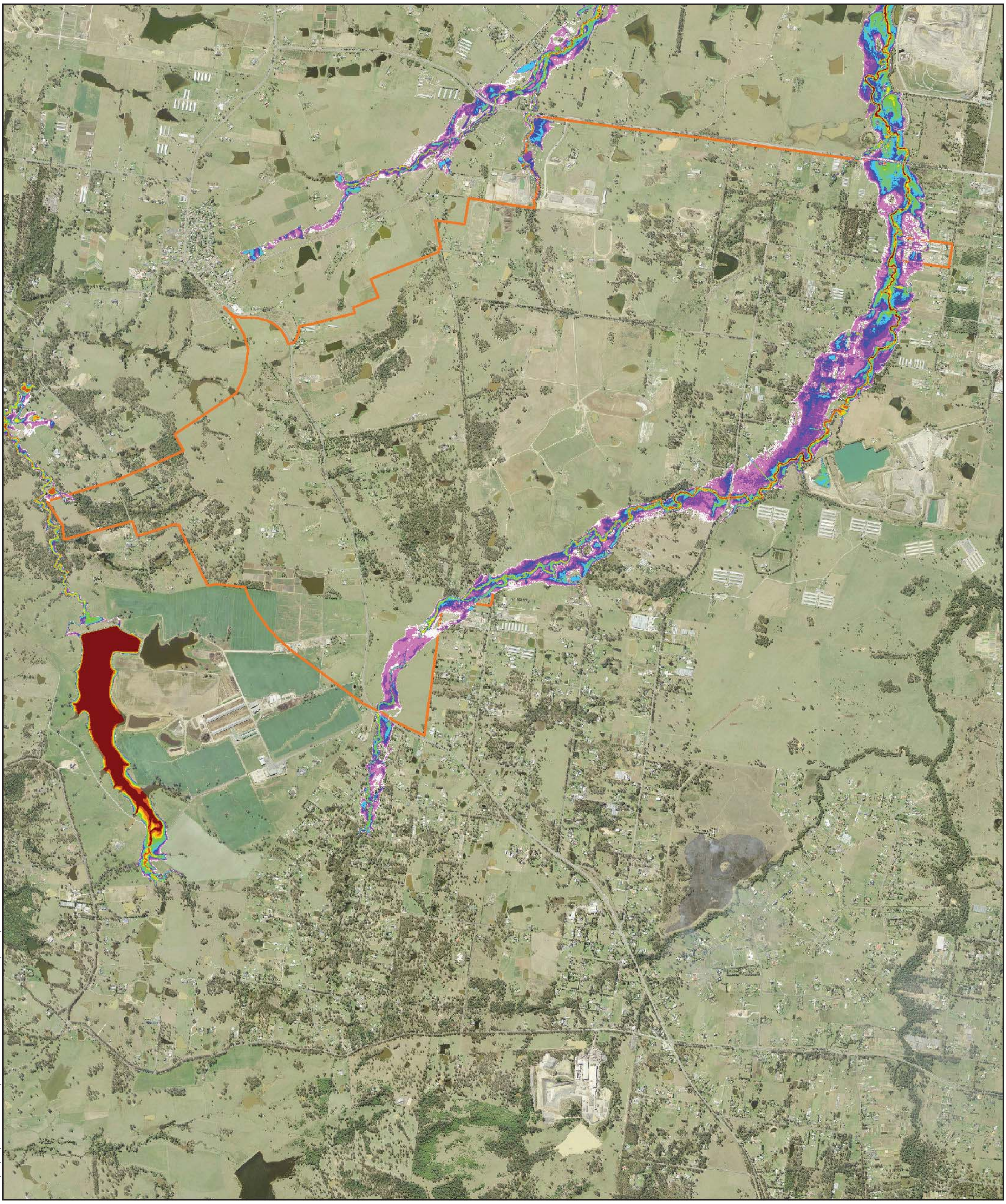
Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site	
Flood depth (m)	
0.1 - 0.2	1 - 1.5
0.2 - 0.4	1.5 - 2
0.4 - 0.6	2 - 2.5
0.6 - 0.8	2.5 - 3
0.8 - 1	3 - 4
	>4

Figure B-5 - Stage 1 - flood depths, 5-year ARI event

0 0.25 0.5 1
Kilometres



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Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

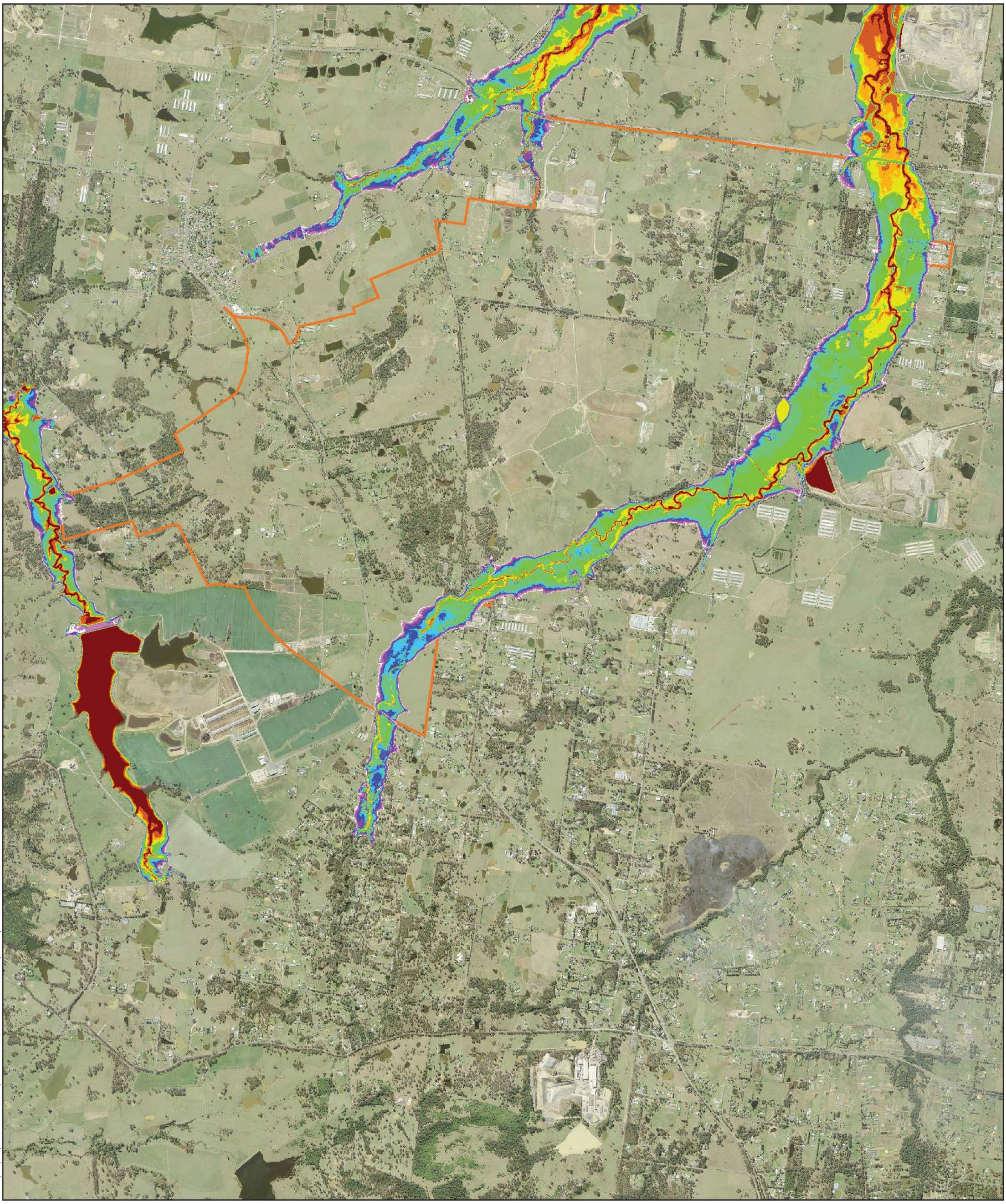
Airport site

Flood depth (m)

- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- >4

Figure B-6 - Stage 1 - flood depths, 100-year ARI event

0 0.25 0.5 1
Kilometres



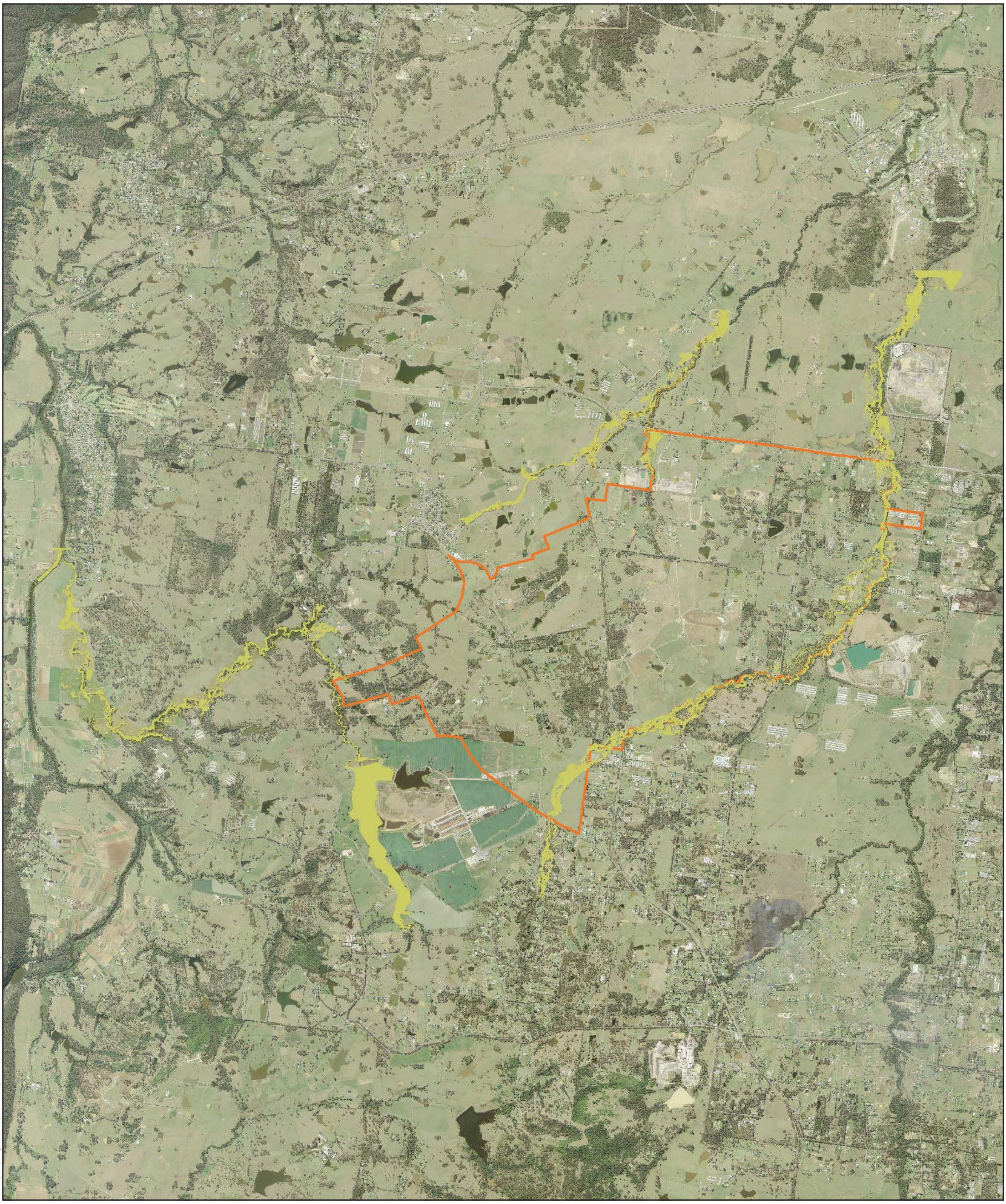
Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site	
Flood depth (m)	
0.1 - 0.2	1 - 1.5
0.2 - 0.4	1.5 - 2
0.4 - 0.6	2 - 2.5
0.6 - 0.8	2.5 - 3
0.8 - 1	3 - 4
	>4

Figure B-7 - Stage 1 - flood depths, PMF

0 0.25 0.5 1
Kilometres



LEGEND

Airport site NM²

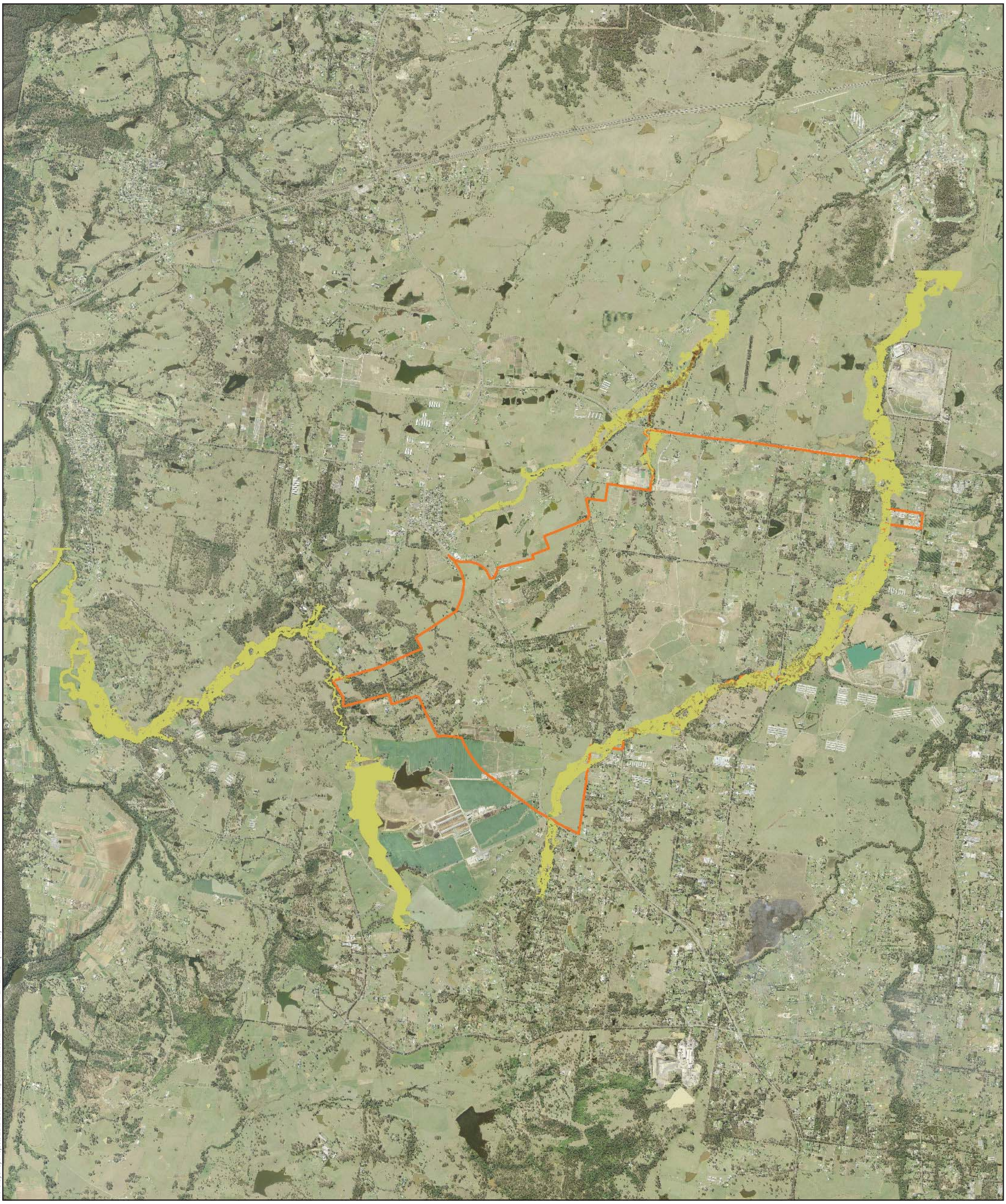
- < -20
- -20 to -10
- -10 to -5
- -5 to 5
- 5 to 10
- 10 to 20
- >20

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

0 0.4 0.8 1.6 Kilometres

N

Figure B-8 - Stage 1 - change in shear stress, 1 year ARI



LEGEND

Airport site NM²

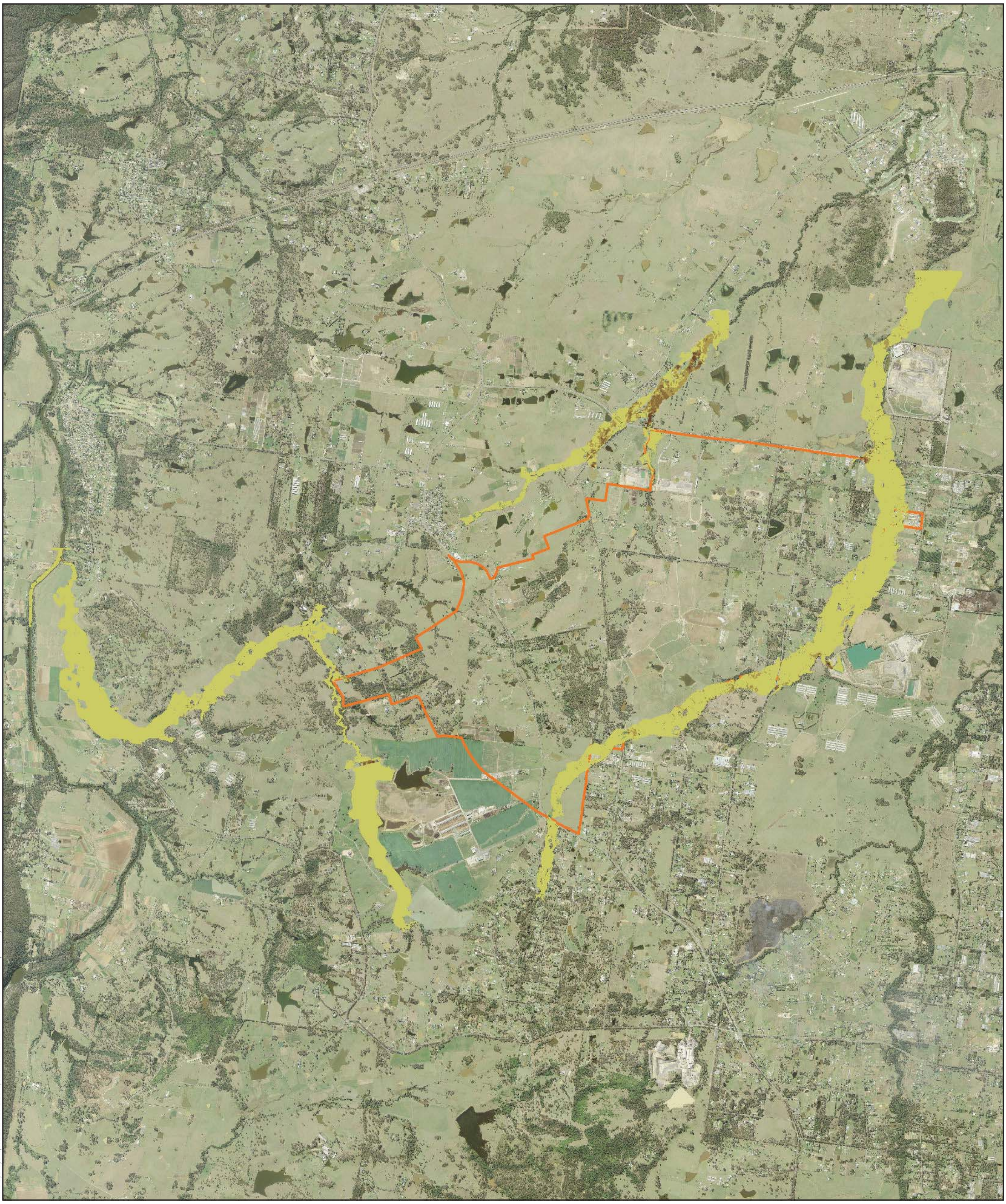
- < -20
- -20 to -10
- -10 to -5
- -5 to 5
- 5 to 10
- 10 to 20
- >20

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

0 0.4 0.8 1.6
Kilometres

N

Figure B-9 - Stage 1 - change in shear stress, 5 year ARI



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Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

- Airport site
- NM^2
  - < -20
  - -20 to -10
  - -10 to -5
  - -5 to 5
  - 5 to 10
  - 10 to 20
  - >20

0 0.4 0.8 1.6

Kilometres

N

Figure B-10 - Stage 1 - change in shear stress, 100 year ARI

LEGEND

Airport site

Flood depth (m)

- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- >4

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

0 0.25 0.5 1

Kilometres

Figure B-11 - Long term - flood results 1-year ARI event

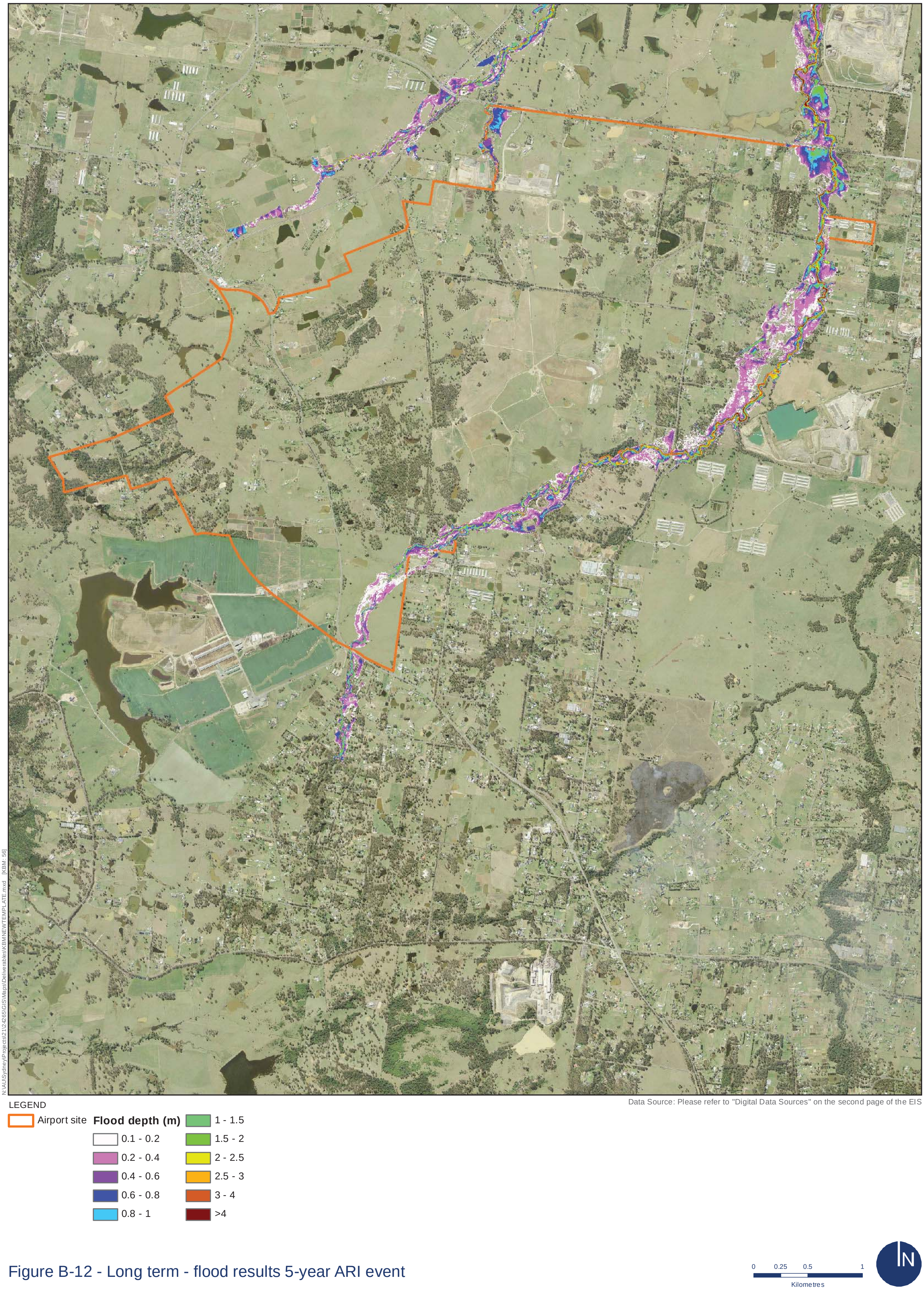
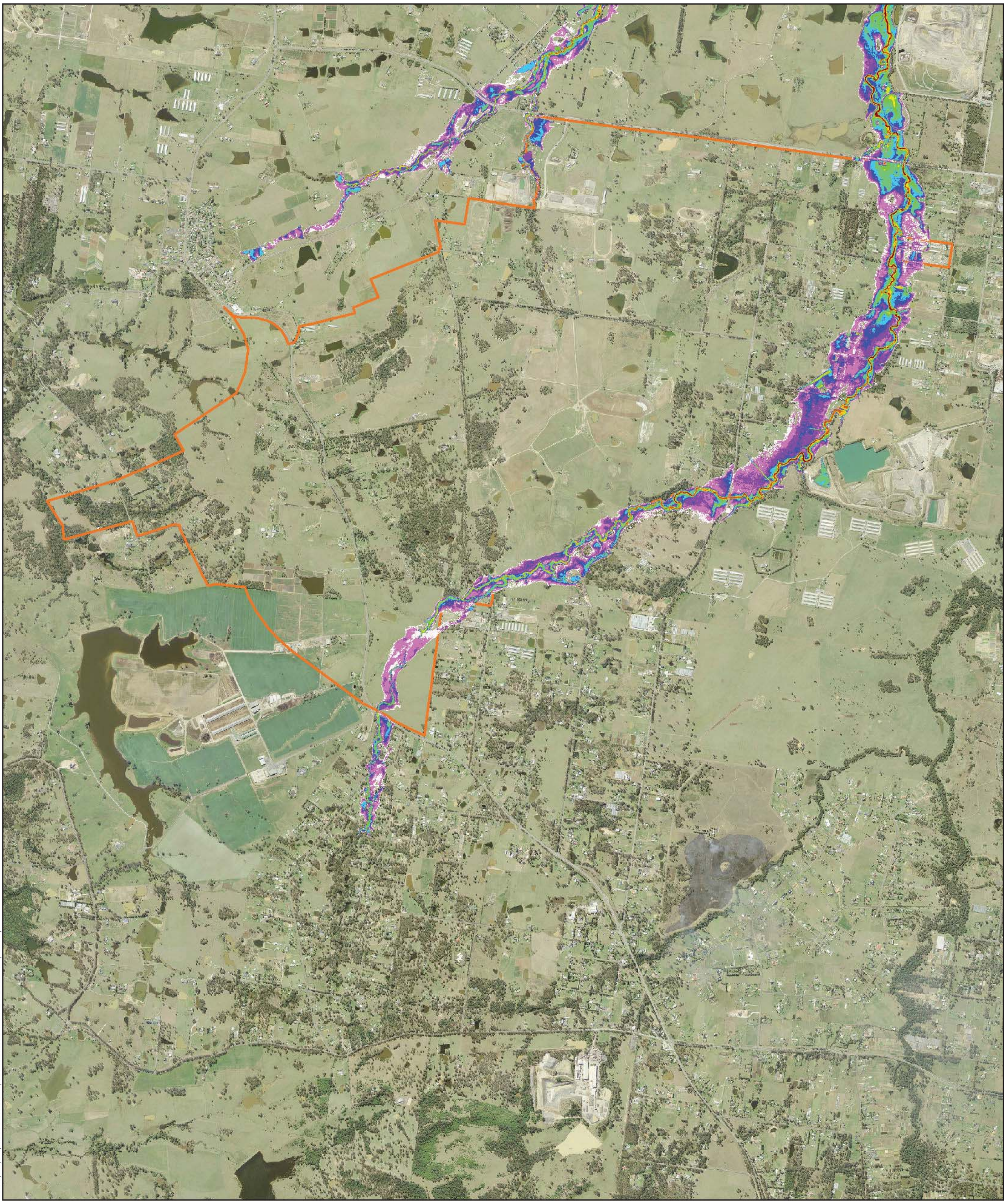


Figure B-12 - Long term - flood results 5-year ARI event



Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

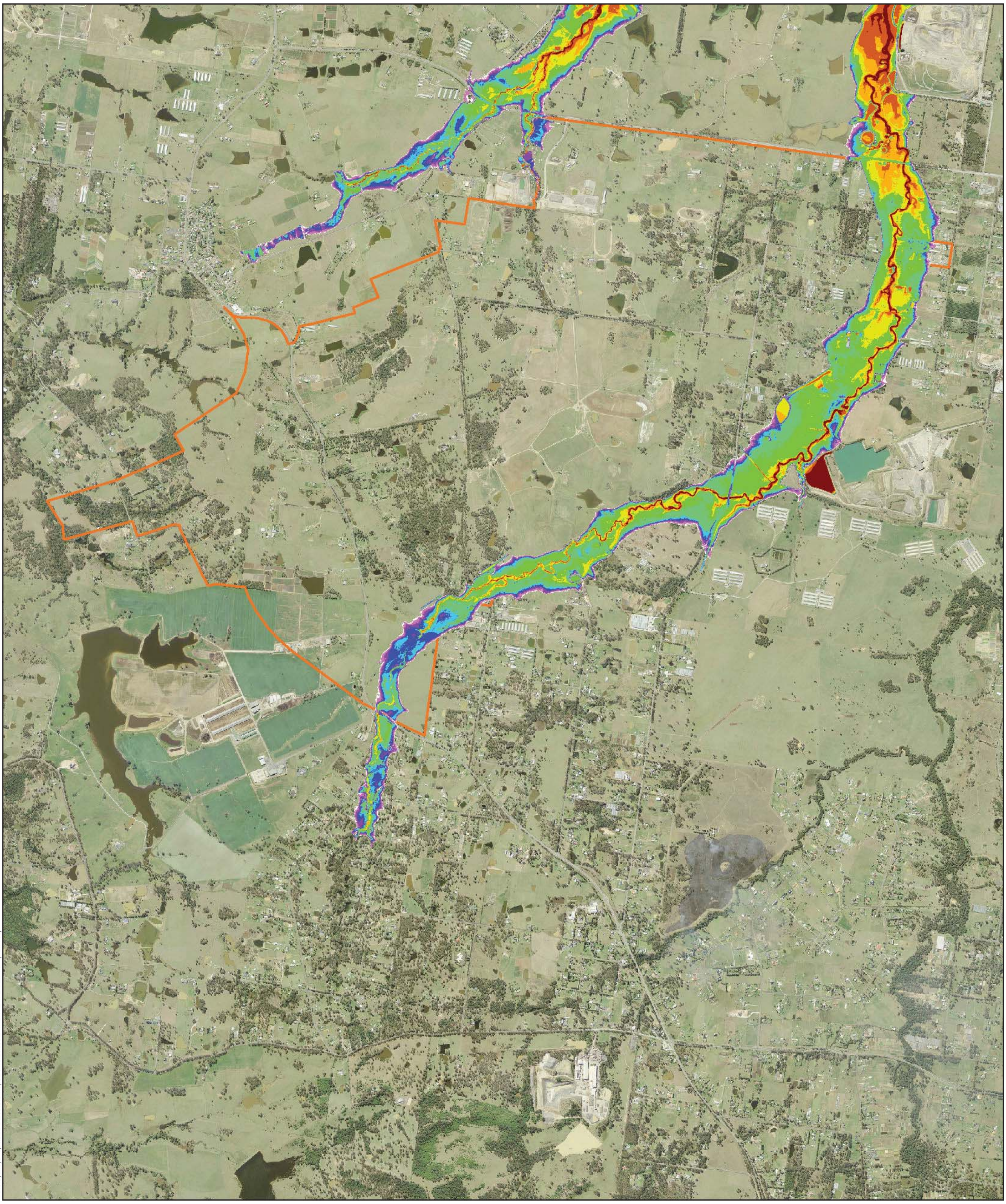
LEGEND

Airport site	**Flood depth (m)**		1 - 1.5
	0.1 - 0.2		1.5 - 2
	0.2 - 0.4		2 - 2.5
	0.4 - 0.6		2.5 - 3
	0.6 - 0.8		3 - 4
	0.8 - 1		>4

Figure B-13 - Long term - flood results 100-year ARI event

0 0.25 0.5 1
Kilometres

N



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Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site

Flood depth (m)

- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- >4

0 0.25 0.5 1
Kilometres

N

Figure B-14 - Long term - flood results PMF

Figure B-15 - Long term - change in shear stress, 1 year ARI

Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site	NM2		-5 to 5
	< -20		5 to 10
	-20 to -10		10 to 20
	-10 to -5		>20

0 0.25 0.5 1
Kilometres

Figure B-16 - Long term - change in shear stress, 5 year ARI

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Data Source: Please refer to "Digital Data Sources" on the second page of the EIS

LEGEND

Airport site NM²

< -20

-20 to -10

-10 to -5

-5 to 5

5 to 10

10 to 20

>20

Figure B-17 - Long term - change in shear stress, 100 year ARI

0 0.25 0.5 1

Kilometres

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