Adani Mining Pty Ltd

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Carmichael Coal Mine and Rail Project

Carmichael River Flood Inundation Assessment

29 January 2014

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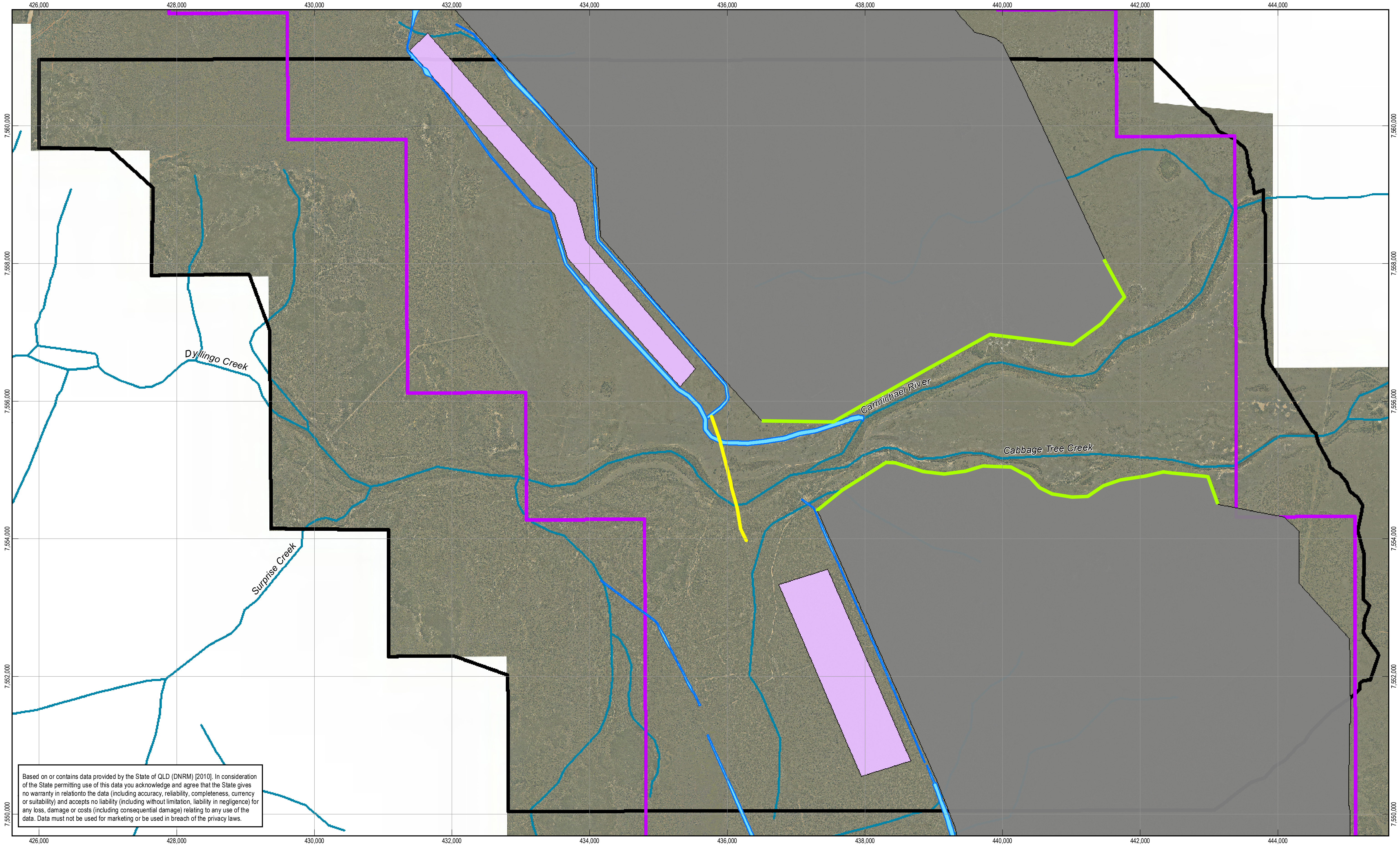
1. Introduction

1.1 Project description

Adani Mining Pty Ltd (Adani) is proposing to develop a 60 million tonne (product) per annum (Mtpa) thermal coal Mine in the north Galilee Basin approximately 160 kilometres (km) northwest of the town of Clermont, Central Queensland. All coal will be railed via a privately owned rail line connecting to the existing Goonyella rail system south of Moranbah, and shipped through coal terminal facilities at the Port of Abbot Point and/or the Port of Hay Point. The Carmichael Coal Mine and Rail Project will have an operating life of approximately 60 years. Key components of the Project include:

- The Project (Mine): a greenfield coal Mine over EPC 1690 and the eastern portion of EPC 1080, which includes both open cut and underground mining, on Mine infrastructure and associated Mine processing facilities (the Mine), and the Mine (offsite) infrastructure including a workers accommodation village and associated facilities, an airport, an industrial area and water supply infrastructure.
- The Project (Rail): a greenfield rail line connecting the Mine to the existing Goonyella and Newlands rail systems to provide for the export of coal via the Port of Hay Point (Dudgeon Point expansion) and the Port of Abbot Point, respectively including:
  - Rail (west): a 120 km dual gauge portion running west from the Mine site east to Diamond Creek
  - Rail (east): a 69 km narrow gauge portion running east from Diamond Creek connecting to the Goonyella rail system south of Moranbah
  - Quarries: The use of five local quarries to extract quarry materials for construction and operational purposes.

The study area including the proposed north and south levees, diversion drains and bridge crossing are shown in Figure 1.



Paper Size A3

0 250 500 1,000 1,500 2,000

Metres

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Legend

- 2D Hydraulic Model Boundary
- Mine Lease Boundary
- Modelled Open Cut Mine Bund
- Modelled Carmichael River Levee
- Modelled Haul Road Alignment
- Modelled Diversion Drain Alignments
- Modelled Top Soil Spoil Piles
- Watercourses

GHD adani

Adani Mining Pty Ltd
Carmichael River Hydraulic Modelling (TUFLOW)

Job Number	41-26330
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Date	29 Jan 2014

Study Area

Figure 1

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180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: Geoimage:Aerial (2012); GA: Watercourse (2007); DNRM: Roads (2010); GHD: Hydraulic Model Layers\WSL Hydrograph Locations (2013). Created by:mstanley

1.2 Purpose

The purpose of this report is to provide an assessment of potential impacts to ecological values associated with the Carmichael River which may result from alteration of the flood inundation periods associated with changes in the floodplain due to the Project (Mine).

1.3 Scope

This report is limited to describing changes on the periods of flood inundation of the Carmichael River where it interests the Project (Mine) and presenting findings of an assessment of ecological impacts associated with identified changes in inundation. The ecological assessment is limited to State Significant Biodiversity Values and Matters of National Environmental Significance located within the Carmichael River corridor within the Project Area.

1.4 Assumptions and Limitations

- The assessment was undertaken with the existing top soil locations submitted as part of 'Appendix K4 – Flood Mitigation and Creek Diversion Design'.
- The assessment was undertaken with the levee location adjacent to the Carmichael River located as per 'Appendix K4 – Flood Mitigation and Creek Diversion Design'. The final levee location will be refined to ensure a minimum 500 m buffer from the main Carmichael River channel.
- The Central MAW Dam North is not included in the Hydraulic Tuflow model
- The mine pit shells have not been included within the Tuflow Model. Change of Inundation duration, shown on the figures in Appendix A, within or immediately downstream of the mine pit areas should be disregarded.

2. Hydraulic modelling

2.1 Tuflow modelling

Hydraulic modelling of the Carmichael River was undertaken using the existing TUFLOW model for the Q10, Q50, Q100, and Q1000 ARI design events for both the ultimate developed case and the existing scenario.

TUFLOW can track the time areas are inundated above a given depth threshold, which can then be post-processed and presented spatially. The time of inundation above 250 mm was agreed as a suitable depth to allow for review of the ecological effects of flood duration change between the two modelled scenarios.

The following events were run through the models:

- 1000 year 36 hour storm
- 100 year 18 hour storm
- 50 year 18 hour storm; and
- 10 year 30 hour storm.

2.2 Flood duration mapping

The maps provided in Appendix A present the differences in duration of inundation above 250 mm for the ultimate developed case compared to the existing case. This inundation depth is deemed to be an appropriate indicator of where impacts may occur.

The difference in inundation duration within the Carmichael River is mapped using a colour code key. Red colours represent areas of increased flood inundation duration for the developed case when compared to the existing case, and blue colours represent areas that experience decreased duration of inundation for the developed case compared to the existing case.

2.3 Description of the Pre and Post Development Characteristics of Carmichael River

2.3.1 Existing Drainage

Under existing conditions, most regions of the Project Area drain into a series of ephemeral creeks at the east of the mine area including Pear Gully and Eight Mile Creek. There are also a number of ill-defined watercourses across the northern and southern parts of the study area that drain generally in the easterly direction towards the Belyando River. The balance of the site drains overland into the Carmichael River.

The Carmichael River catchment upstream of the mine area is approximately 2,000 km^2 and lies within the Burdekin Basin. Tributaries within the Carmichael River catchment include Cattle Creek, Dylingo Creek and Surprise Creek which converge into the Carmichael River just upstream of the mine area. Under normal conditions, the Carmichael River maintains a modest baseflow in the dry season. Once storm events reach the river, it rapidly fills and overflows the channel onto the relatively flat floodplain and contributes effluent flow south east to Cabbage

Tree Creek. Downstream of the Project Area the Carmichael River catchment drains into the Belyando River.

2.3.2 General Observations of the Mine Development related to the Carmichael River

With the establishment of the mine site and accompanying flood mitigation infrastructure, the Carmichael River is now confined to the corridor between the flood levees with no runoff being received from the area internal to the mine area, excepting the new contribution from the diversion channels. The contraction of the floodplain causes an insignificant increase in flood extent upstream of the mine area for any of the simulated flood events. This outcome reflects the relative distance of the contraction from the western mine area boundary.

The proposed levees successfully prevent flooding of either the underground mining area or the open cut pit areas. The haul road crossing bridge is immune to the 10 year, 50 year ARI, and 100 year events, but is overtopped by the 1,000 year ARI event

2.3.3 Description of the Pre and Post development effects on the Carmichael River

10 Year ARI

The redistribution of flows due to the diversion drains and bunds, together with the restriction of the haul road on the Carmichael River floodplain has generally resulted in minimal inundation duration changes. A few notable exceptions to this are:

- The area immediately upstream of the haul road – which experiences an increased inundation duration (with the higher duration south of the bridge and along the local drainage path at the second set of culverts north of the bridge)
- A localised area midway along the southern levee in Cabbage Tree Creek which experiences up to 12 to 24 hours of increased inundation duration
- A local drainage path adjacent to the northern levee– which also experiences increased inundation duration.

50 Year ARI

The overall pattern of inundation duration changes in the 50 year ARI event is similar to that in the 10 year ARI, with the majority of the duration change being confined to the immediate floodplain of the Carmichael River and proposed diversion drains. The magnitude and extent of the inundation has however increased as follows:

- The pond upstream of the haul road has expanded to cover the bridge and three culvert crossings to the north (with the higher duration being either side of the bridge)
- The entire length of the Cabbage Tree Creek effluent path adjacent to the southern Carmichael River levee experiences increased duration of inundation (a likely result of the levee redirecting some water that would have otherwise left the creek as overland flow to the south)
- The full first half of the area confined by the Carmichael River levees experiences increased duration.

The results also show a reduction in inundation duration immediately downstream of the bridge, due to the restriction of flow along the floodplain. Similarly to the 10 year ARI event, the duration change was shown to be negligible at the western mine area boundary and relatively insignificant at the eastern mine area boundary.

100 Year ARI

As expected, the impacts expected for the 50-year ARI event are marginally worsened in the 100-year ARI event. The key changes in this event are:

- The pond upstream of the haul road has expanded to connect in with the downstream end of proposed diversion drain 5 and now experiences an increase in inundation duration.
- The area midway along the northern levee experiencing increased duration and has grown in the upstream direction
- The area of reduced inundation duration downstream of the haul road has reduced due to flows overtopping the terrain between diversion drain 5 and the Carmichael River downstream of the haul road.

These changed conditions did not significantly change the inundation duration at the mine area boundary compared to the 50 year ARI event, with the western boundary and eastern boundary near the Carmichael River experiencing only minor inundation changes.

1,000 Year ARI

Due to the haul road being overtopped in the 1,000 year ARI event the inundation duration change shown in the study areas is more extensive and significant than the other events throughout. The key properties of the 1,000 year ARI results are:

- Minimal inundation change from approximately 3 km upstream of the haul road
- Increased inundation change from immediately upstream of the haul road to approximately 3 km upstream.

These changed conditions increase the inundation change at the mine area boundary compared to the 100 year ARI event.

2.4 Description of Hydrographs

Pre- and post- mine development water surface level (WSL) hydrographs for eight points of interest along either the Carmichael River and Cabbage Tree Creek are provided in Appendix B. These results show the following general trends:

- Upstream of the mine lease area (location 1) – the proposed development works do not seem to have changed the existing WSL hydrographs.
- Immediately upstream of modelled haul road (location 2) – the proposed development works have not changed the rise and fall of the WSL hydrographs, but have caused an increase in the peak levels. The hydrographs at this location also show that the change in WSL increases with ARI.
- Underneath the haul road bridge and downstream along the Carmichael River (location 3, 4, 5, 6 & 7) - the proposed development works have not significantly altered the existing

WSL hydrographs in the 10, 50 or 100 year ARI (perhaps a minor decrease in peak levels), but have increased the peak level in the 1000 year ARI.

- Overflow to Cabbage Tree Creek (location 8) - the proposed development works have not significantly altered the existing WSL hydrograph in the 10 year ARI, but have increased the peak levels in the 50, 100 and 1000 year ARI.

The increase in levels observed are likely to be the result of the proposed haul road, Carmichael River levees and/or mine bunds that have restricted flow paths and/or reduced storage on the floodplain.

3. Ecological assessment

3.1 Overview

This ecological assessment has been undertaken using findings from inundation flood modelling completed for the 10, 50, 100 and 1,000 year ARI return period event. The change in duration of inundation above 250 mm from the modelled ARI flood events at key locations is presented in Table 1. The sites are presented in Appendix A.

Table 1 Change in duration of inundation above 250 mm

ARI	Carmichael River channel (hours)	Carmichael River downstream of diversion drains (hours)	Upstream of proposed road bridge (hours)	Downstream proposed road bridge (hours)	Cabbage Tree Creek channel (hours)	Cabbage Tree Creek floodplain (hours)
Site	1	2	3	4	5	6
10 year	0.08	1.32	49.86	-5.03	-14.47	11.22
50 year	0.55	1.01	52.42	-1.4	-3.86	3.8
100 year	0.37	0.18	49.44	-1.31	-3.46	2.81
1000 year	0.4	0.25	29.45	-1.12	-3.03	2.6

3.2 Legislation

3.2.1 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Commonwealth's principal piece of environmental protection legislation. It provides a national framework for the protection of the Australian environment and its unique biodiversity. The EPBC Act also provides a systematic framework for assessment and approval of actions potentially impacting matters of NES. The Project was referred to the DSEWPaC on 18 November 2010 (EPBC 2010/5736). It was declared a 'controlled action' requiring assessment and approval under the EPBC Act on 6 January 2011. The controlling provisions for the Project that are relevant to the change in inundation include:

- Listed threatened species and ecological communities

Waxy cabbage palms are considered matters of NES and are listed as vulnerable under the EPBC Act.

3.2.2 Environmental Protection Act 1994

The aim of the *Environmental Protection Act 1994* (EP Act) is to protect Queensland's environment while allowing for development that improves the quality of life as well as maintaining the ecological processes on which it depends.

The EP Act also imposes a general environmental duty on all persons (including corporations) such that they must not conduct any activity that causes, or is likely to cause, environmental harm, unless they take all reasonable and practicable measures to prevent or minimise the harm.

3.2.3 Environmental Protection (Water) Policy 2009

The *Environmental Protection (Water) Policy 2008* (EPP Water) (part 2, Section 6) provides a framework for:

- Identifying environmental values (EVs) for Queensland waters
- Deciding and stating water quality guidelines and objectives to enhance or protect the EVs
- Making consistent and equitable decisions about Queensland waters that promote the efficient use of resources and best practice environmental management
- Involving the community through consultation and education, and promoting community responsibility.

The EVs considered applicable to the Project (Mine) to be particularly enhanced or protected under the EPP (Water) are the following:

- Biological integrity of an aquatic ecosystem
- Suitability for agricultural use
- The cultural and spiritual values of the water.

3.2.4 Water Act 2000

The *Water Act 2000* provides a framework for management and allocation of water resources and licences, based on development of catchment-based Water Resource Plans (WRPs). The WRPs are then activated through related Resource Operations Plans (ROPs) which provide detail on how the water resources will be managed to implement the strategies and objectives as set out in the WRP.

The *Water Act 2000* defines a watercourse as a:

- river, creek or stream in which water flows permanently or intermittently in a natural channel, whether artificially improved or not
- or in an artificial channel that has changed the course of the watercourse.

The Carmichael River has been determined as a watercourse as defined in the Water Act. A conclusive watercourse determination for Cabbage Tree Creek was unable to be made during a desktop assessment. It has been included as a watercourse in this assessment.

3.2.5 Queensland Nature Conservation Act 1992

The *Nature Conservation Act 1992* (NC Act) provides for the conservation of nature through protection of all native plants and animals in Queensland. Protection is provided under the NC Act through conservation of land as protected areas and wildlife protection outside of protected areas. Actions impacting on protected native flora and fauna are regulated under the NC Act. Permits for disturbance to native flora and fauna can be administered under the NC Act. The Queensland *Nature Conservation (Wildlife) Regulation 2006* lists flora and fauna species considered to be extinct in the wild, endangered, vulnerable, near threatened and least concern in Queensland.

3.2.6 Queensland Vegetation Management Act 1999

The *Vegetation Management Act 1999* (VM Act) provides a framework for the regulation of woody, terrestrial native vegetation located outside of protected areas. The stated purpose of the Act is to regulate the clearing of native vegetation in a way that:

- Conserves remnant vegetation that is an endangered, of concern or least concern RE
- Conserves vegetation in declared areas
- Ensures clearing does not cause land degradation
- Prevents biodiversity loss
- Maintains ecological processes
- Manages the environmental effects of the clearing to ensure the above purposes are obtained
- Reduce greenhouse gas emissions

The VM Act provides for the establishment and mapping of REs that encompass vegetation community descriptions within a geological and bioregional context, and for the creation and use of clearing codes (among other things). In addition, it provides a process for applying to change RE mapping and for the investigation and prosecution of clearing offences. Details on what clearing activities require assessment against the various regional clearing codes authorised under the VM Act are provided by the *Sustainable Planning Act 2009* (SP Act).

Matters of NES and State Significant Biodiversity Values that have been identified within the Project (Mine) Area are:

- Aquatic ecosystem and riparian vegetation of Carmichael River and Cabbage Tree Creek
- Waxy cabbage palms.

3.3 Carmichael River and Cabbage Tree Creek

The Carmichael River is the major surface water resource which runs through the Project (Mine) Area. The flow regime of the Carmichael River is subject to seasonal variability as wet season overland flow drains from the catchment. Late in the dry season the Carmichael River is reduced to a low flow environment, interspersed with deeper pools. The Carmichael River is characterised by a well-established riparian zone that provides extensive shading of the water.

The riparian vegetation the Carmichael River and Cabbage Tree Creek is dominated by river red gum (*E. camaldulensis* var. *obtusa*), weeping paperbark (*M. leucadendra*) and narrow-leaved paperbark (*M. fluviatilis*). Waxy cabbage palms (*Livistona lanuginosa*) are also present along the Carmichael River.

The riparian community species composition is consistent over the entire length of the Carmichael River within the Project (Mine) Area, with the exception of the dense cluster of waxy cabbage palms in the vicinity of the western Project (Mine) Area boundary. Waxy cabbage palms are present along the Carmichael River and become progressively less common from west to east.

Field surveys in 2012 of the Project (Mine) Area found the greatest diversity of aquatic habitats for aquatic fauna in Carmichael River and Cabbage Tree Creek. Diversity of habitats in Cabbage Tree Creek was also reflected in the results of fish and crustacean sampling in this waterbody (GHD, 2012).

3.4 Waxy cabbage palms

Waxy cabbage palms are considered matters of NES and are listed as vulnerable under the EPBC Act. Waxy cabbage palms grows to approximately 20 m tall. Its leaves are broadly circular, and leaf stems have protruding sharp thorns. The species is distinctive for the long woolly hairs on the stems of the leaves and the flower stalks.

The waxy cabbage palm is dependent on a seasonal recharging of soil water, which includes pockets and lenses that store water and which palms in arid watercourses often rely on (Paul Forster, Queensland Herbarium, pers. comm., 21.09.2012). All known populations of waxy cabbage palm are growing on sandy, ephemeral watercourses or their floodplains. Unlike the other characteristic riparian species (river red gums and paperbarks), these palms have a root ball which does not extend more than several metres in diameter.

Waxy cabbage palm were confirmed present within the Project (Mine) Area during investigations for the EIS at the Carmichael River in 2012 (GHD, 2012). Additional targeted field surveys in 2013 found waxy cabbage palms growing primarily in sandy alluvial soil on channel benches, channel bars, and in the bed of the Carmichael River (GHD, 2013c). The majority of individuals were situated in two areas of high population density (of 479 palms and 155 palms, respectively). Adult palms accounted for only 11 percent of this population.

It is considered that the Carmichael River supports an ‘important population’ of the waxy cabbage palm, noting that an important population of an (EPBC Act) vulnerable species is defined as a population that is necessary for a species’ long-term survival and recovery, including populations identified as such in recovery plans, and/or that are:

- Key source populations either for breeding or dispersal
- Populations that are necessary for maintaining genetic diversity
- Populations that are near the limit of the species range (DEWHA, 2009a).

Furthermore, habitat for this species within the Carmichael River is considered ‘habitat critical to the survival of the species’, as defined in the Significant Impact Guidelines (DEWHA, 2009a).

4. Potential ecological impacts

4.1 Overview

The change in inundation duration of flood waters as a result of the Project (Mine) is predicted to have the following potential impacts on ecology:

- Increase inundation duration of flooding upstream and decrease inundation duration downstream of the proposed road bridge across the Carmichael River. This has potential to impact on riparian vegetation and waxy cabbage palms.
- Reduction in Cabbage Tree Creek channel flood duration which may impact on riparian vegetation.
- Increase in flood inundation duration on the floodplain north of Cabbage Tree Creek may cause a change in vegetation species composition to species with greater tolerance to inundation.

Generally, the riparian community of rivers are specifically adapted to the flow conditions that have prevailed for thousands of years (Blom and Voesenek 1996; Jackson and Colmer 2005). Within the Carmichael River catchment, there are a number of riparian flora species (including the waxy cabbage palm (*Livistona lanuginosa*)) that have adapted to the specific flow patterns of the river (Blom and Voesenek 1996; Pettit and Dowe 2003). Changes to these flow patterns may result in environmental conditions that are outside of the range of tolerance for the existing riparian community (Jackson and Colmer 2005). The existing riparian vegetation, including waxy cabbage palms, along the Carmichael River and Cabbage Tree Creek has developed under existing flow patterns. Changes to the inundation duration may therefore, impact the aquatic habitats and riparian vegetation in the Study Area. The waxy cabbage palm populations may be placed under pressure in areas that will experience higher and more frequent flooding, as seedlings are less likely to persist to maturation in these areas (due to scouring) (Pettit and Dowe 2003).

4.1 Carmichael River channel

The change in flood inundation duration within the Carmichael River channel is predicted to be less than 1 hour, except upstream of bridge crossing (Table 1).

In general, bridge structures promote natural, unimpeded stream flow, allowing the free movement of fish underneath the structure during a wide range of hydrological conditions. However, bridges that are built too low, or whose piers and footings constrict the channel, can affect hydraulic flows and aquatic habitat conditions (Fairfull and Witheridge, 2003). Possible impacts of bridge structures include:

- Large scale turbulence resulting from bridge piers
- Increased flood flow velocities
- Changes to in-stream and bank vegetation affecting water shading, habitat values and water velocities
- Limited light penetration under the bridge deck creating a nonphysical barrier for some fish species that may avoid dark areas during daylight hours

- Restrictions to dispersal and/or migration leading to the loss or decline of populations upstream and/or downstream, and the loss of gene flow and genetic diversity contained within those populations

The bridge crossing will involve fill being placed on the floodplain of the Carmichael River (between sites 3 and 4 presented in Appendix A). The placement of fill will change the inundation duration upstream and downstream of the bridge crossing. The bridge crossing the Carmichael River will impact the inundation duration upstream and downstream of the bridge. A change in the duration of inundation of the floodplain directly upstream of the Carmichael River channel during operation is predicted to take approximately 48 to 60 hours longer for the water to be back at pre operation flood levels during a 1:10, 1:50 and 1:100 year ARI event (Table 1).

A change in the duration of inundation of the floodplain directly downstream of the Carmichael River channel during operation is predicted to be reduced by 5 hours for the water to be back at pre flood levels during a 1:10 year ARI event. The decrease in duration of inundation downstream of the road bridge is not predicted to be a significant impact on the ecology of the Carmichael River.

The increase in duration of inundation upstream of the road bridge is predicted to impact the riparian vegetation and waxy cabbage palms in the immediate area. The increase in inundation duration of flood waters is likely to stress riparian vegetation and waxy cabbage palms in the vicinity of the bridge crossing. The stress may lead to a reduction in the health and mortality in riparian vegetation.

In summary, significant impacts to waxy cabbage palm in the Carmichael River may occur upstream of the bridge crossing, including:

- A decrease in the size of an important population of a species
- Reduce the area of occupancy of an important population
- Adversely affect habitat critical to the survival of a species.

To address the impacts on riparian vegetation, the design of the bridge crossing should follow appropriate guidelines including Culvert Fishway Planning and Design Guidelines (Kapitzke 2010), Waterway barrier works development approvals (Peterken et al. 2009), Fisheries Guidelines for Fish-Friendly Structures (Derbyshire 2006), Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge 2003) and Fisheries guidelines for design of stream crossings (Cotterell 1998).

4.2 Cabbage Tree Creek channel and riparian vegetation

The predicted change in inundation duration of flood waters within the Cabbage Tree Creek channel as a result of the Project (Mine) is a reduction of 12 to 24 hours for the water to be back at pre flood levels during a 1:10 year ARI event (Table 1). This reduction in inundation duration may result in:

- delayed onset of breeding cues and opportunities with subsequent loss of biodiversity
- loss of trigger flows may favour reproductive success of exotic species
- loss of bank habitat and species.

The reduction in inundation duration of flood waters within the Cabbage Tree Creek channel may also impact the riparian vegetation. Hydrological changes can affect the character of riparian habitats and have implications for the diversity and dynamics of riparian vegetation.

The Carmichael River riparian community is dominated by river red gums and paperbarks, with waxy cabbage palms sub-dominant in places (GHD, 2013a and b). The riparian vegetation along Cabbage Tree Creek is similar to that present along the Carmichael River (GHD, 2012). However, during 2013 surveys, no waxy cabbage palms were observed growing in or beside Cabbage Tree Creek for at least the southern 2 km. The habitat (a clay loam plain) is not considered likely to support waxy cabbage palm is unlikely to be present along Cabbage Tree Creek (GHD 2013c).

Stands of river red gum are intimately associated with the surface-flooding regime of the watercourses and related ground water flow. Dieback in river red gums has been attributed to altered hydrologic regime, including the reduced frequency and depth of inundation (Centre for Australian National Biodiversity Research and Australian National Herbarium, 2004). While the dominant riparian vegetation in Cabbage Tree Creek is tolerant of extended zero/low flow events, a predicted reduction in inundation duration of flood waters may stress riparian vegetation, including river red gums.

The duration of flood events can also be influential in determining germination responses from riparian soil seed banks (Casanova and Brock 2000). A change in germination responses can influence the riparian vegetation community composition.

The potential impacts of a reduction in the duration of flood water can include a:

- reduction in health, leading to stress and mortality of the dominant riparian species (river red gums and paperbarks). Impacts may commence with less deeply rooted paperbarks and smaller trees, and continue to more persistent species such as river red-gums (this latter stage may take decades).
- change in riparian vegetation community composition and an increase in weeds.

If dieback of some or all of the trees in the canopy occurs, other potential impacts may result, including:

- Loss of the large trees growing in banks and channel bars which may result in increased instability of those banks and channel bars. High flow events in future has the potential to increase bank and channel erosion, and bank slumping.
- Altered environmental conditions (humidity, dappled shade/sun, temperature gradients in pools, etc.) that are important for instream aquatic macrophytes and invertebrates.
- A general loss of breeding, roosting and foraging riparian habitat for fauna utilising the riparian community.
- An increase in the amount of light, which may favour weeds and shrubs. In particular, rubber vine (*C. grandiflora* – a class two declared weed) infestations currently in the Carmichael River within the Mine Area may increase in height, area and density, with the capability to render the watercourse inaccessible to humans and large animals. Other weeds such as parkinsonia (*Parkinsonia aculeata* - another class two declared weed) and noogoora burr may also flourish.
- An increase in weeds may also increase the quantity of seed moved downstream to other sections of the Carmichael and Belyando Rivers.

4.3 Cabbage Tree Creek floodplain

Many tree species can survive months of flood inundation as long as their canopies remain above the water. Mature, well-established trees are more tolerant of flood inundation than over-mature trees or seedlings of the same species. Short periods of flooding can be tolerated by most trees, but if flooding is recurrent or uninterrupted and keeps soils saturated, serious damage to trees may occur. Roots of trees and shrubs in saturated soils often die of oxygen deficiency.

Vegetation communities that are fully submerged under standing water (such as native grasslands) will start to dieback within a number of days as they are unable to photosynthesise and saturated soils will be depleted of oxygen within 48 hours of inundation (Mommer and Visser 2005, Sinclair and Lyon, 1987; Iowa State University, 2008).

Inundation duration of less than 48 hours is predicted to have a low impact on vegetation and areas inundated for more than 48 hours as having a high impact on vegetation.

The flood footprint of the Cabbage Tree Creek is predicted to change as a consequence of the Project (Mine) operation, and may encompass areas that do not normally experience inundation. An area of floodplain north of Cabbage Tree Creek is predicted to take approximately 6 to 12 hours longer for the water to be back at pre flood levels during a 1:10 year ARI event (Table 1) and up to 20 hours during a 1:1000 year ARI event.

The terrestrial vegetation in such areas may not be able to tolerant increased flood inundation conditions, and inundation-related mortality may occur (Kramer 1951; Mommer and Visser 2005). In general, it can be predicted that the altered flow and flood patterns may impact existing riparian flora communities and any inundated terrestrial flora communities. These impacted communities may experience mortality if inundation duration is greater than 48 hours. If flood events are frequent enough the flora community of such areas will transform towards one that is more adapted to flood events. It is predicted that the impacted areas will only support a reduced range of species that are tolerant of the changed conditions (Nilsson *et al.* 1991).

The new floodplain area may replace the function of the floodplain area lost as a result of the southern Carmichael River levee. However, this new floodplain area, is smaller and has a shorter inundation duration than that of the floodplain lost as a result of the Carmichael River levees.

5. Conclusion

Changes in inundation duration of flooding has the potential to impact riparian vegetation and waxy cabbage palms along the Carmichael River and Cabbage Tree Creek. The impact to riparian vegetation may lead to a reduction in the health and mortality in riparian vegetation.

The primary cause of potential impact to flood inundation duration is due by the conceptual bridge crossing in the model. The final design of the bridge crossing needs to minimise the increase inundation duration upstream of the bridge and any disturbance to waxy cabbage palms. The Proponent has already committed to ensure that the bridge will span the main channel of the Carmichael River, with no pylons or supports within the low flow channel. The final design of the bridge crossing should follow appropriate guidelines.

In addition potential impacts of changes in flood inundation duration will be mitigated and monitored by the measures outlined in the Groundwater Dependent Ecosystem Management Plan – Carmichael River and Waxy Cabbage Palm subplans (GHD, 2014).

The Proponent has also committed to ensure a corridor, at a minimum of 500 m will be retained either side of the centre line of the Carmichael River to protect it and the riparian zone from mining operations.

Further modelling prior to construction should include the final levee location and the final bridge design to demonstrate that the impact due to increased flood inundation duration is minimised to protect riparian vegetation and waxy cabbage palms.

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Appendices

Appendix A Carmichael River Model Results – Change in Inundation Duration – Developed Case versus Existing Conditions

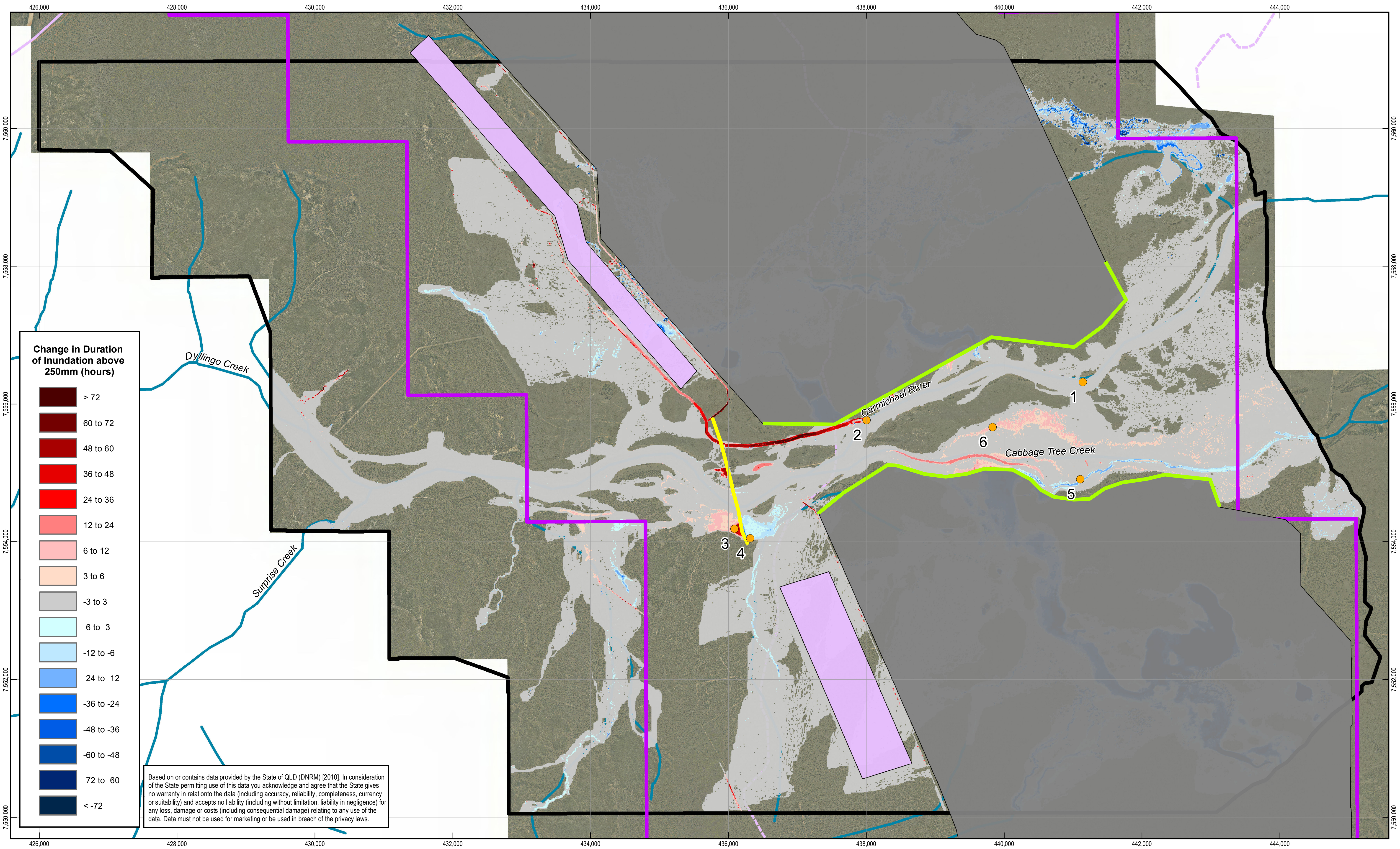
Figure 1: 10 Year ARI Design Flood Map, Change in Inundation Duration, Developed Case versus Existing Conditions

Figure 2: 50 Year ARI Design Flood Map, Change in Inundation Duration, Developed Case versus Existing Conditions

Figure 3: 100 Year ARI Design Flood Map, Change in Inundation Duration, Developed Case versus Existing Conditions

Figure 4: 1,000 Year ARI Design Flood Map, Change in Inundation Duration, Developed Case versus Existing Conditions

Table 1 Existing and developed scenario and change in duration of inundation above 250 mm at key locations



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Metres

Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 55

N

Legend

- 2D Hydraulic Model Boundary
- Mine Lease Boundary
- Modelled Open Cut Mine Bund
- Modelled Top Soil Spoil Piles
- Modelled Carmichael River Levee
- Modelled Haul Road Alignment
- Key Locations (Ecology)
- Watercourses
- Minor Road
- Track

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Adani Mining Pty Ltd
Carmichael River Hydraulic Modelling (TUFLOW)

10 Year ARI Design Flood (30 h)
Change in Inundation Duration (DEV - EXIST)

Job Number	41-26330
Revision	0
Date	29 Jan 2014

Figure 1

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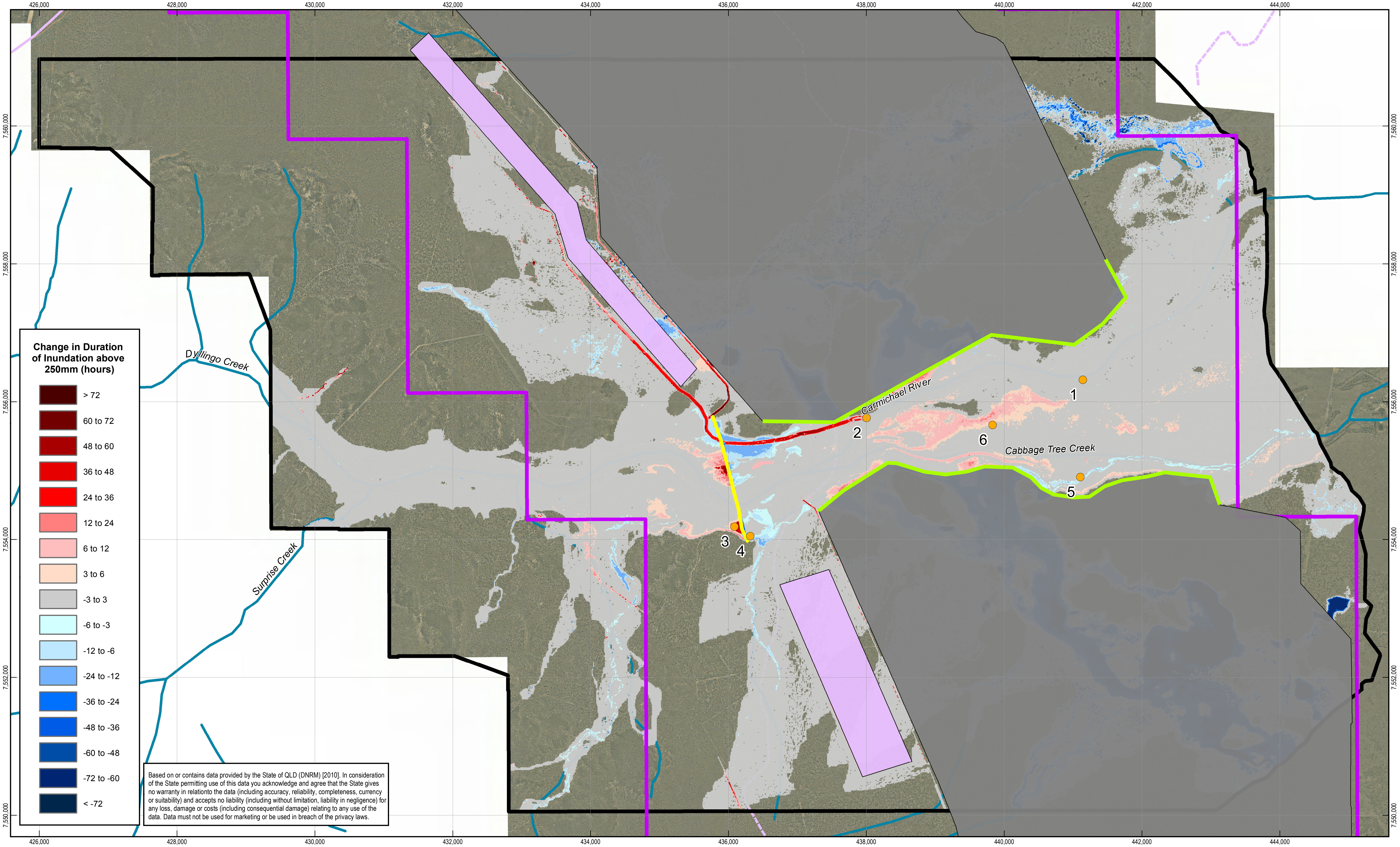
Data source: Geoimage:Aerial (2012); GA: Watercourse (2007); DNRM: Roads (2010); GHD: Hydraulic Model Layers\Key Locations (2013). Created by:pwoodman



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Legend

- 2D Hydraulic Model Boundary
- Mine Lease Boundary
- Modelled Open Cut Mine Bund
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- Modelled Carmichael River Levee
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- Key Locations (Ecology)
- Watercourses
- Minor Road
- Track

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50 Year ARI Design Flood (18 h)
Change in Inundation Duration (DEV - EXIST)

Job Number	41-26330
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Date	29 Jan 2014

Figure 2

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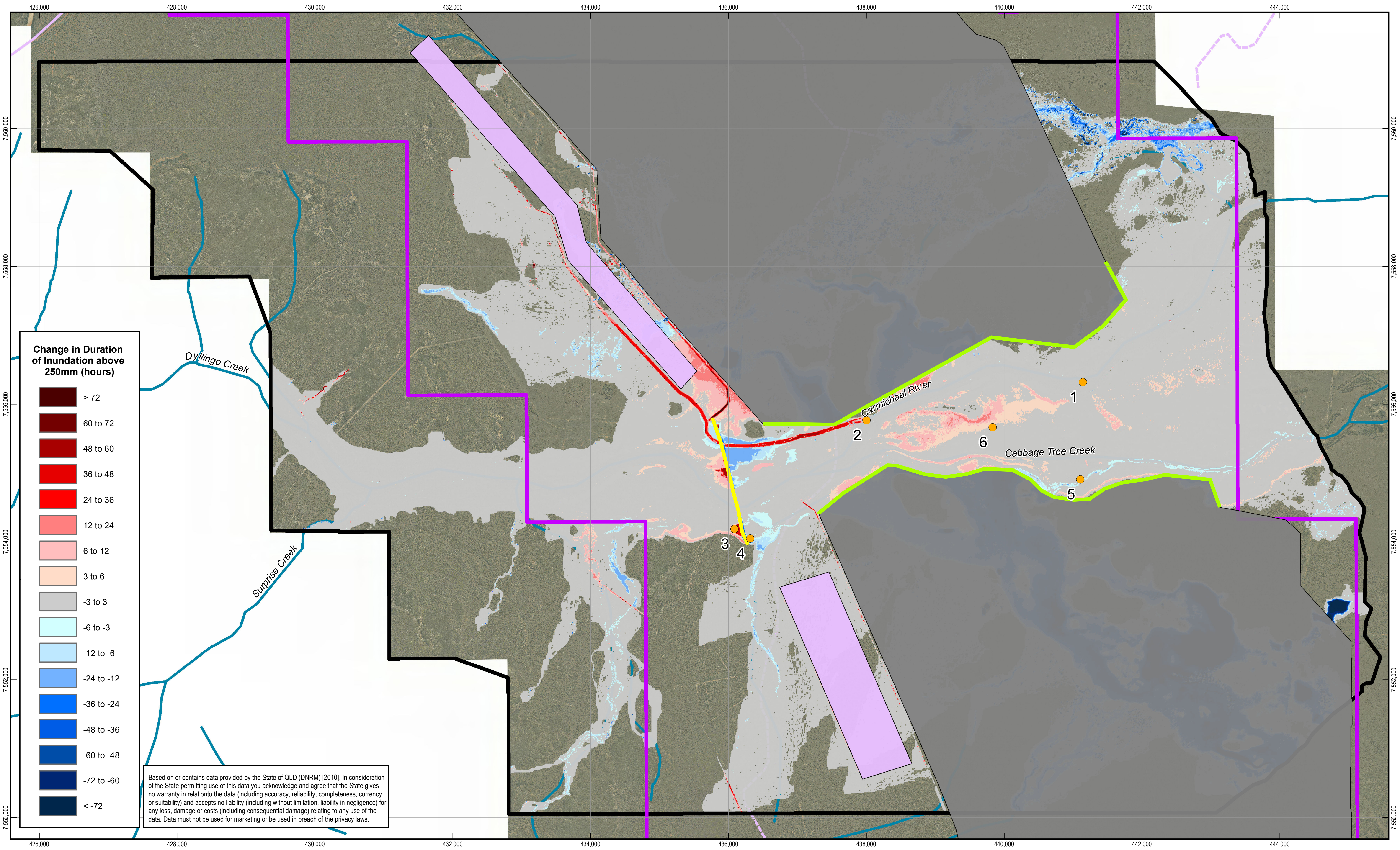
Data source: Geoimage:Aerial (2012); GA: Watercourse (2007); DNRM: Roads (2010): GHD: Hydraulic Model Layers\Key Locations (2013). Created by:pwoodman



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

- 2D Hydraulic Model Boundary
- Mine Lease Boundary
- Modelled Open Cut Mine Bund
- Modelled Top Soil Spoil Piles
- Modelled Carmichael River Levee
- Modelled Haul Road Alignment
- Key Locations (Ecology)
- Watercourses
- Minor Road
- Track

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Carmichael River Hydraulic Modelling (TUFLOW)

100 Year ARI Design Flood (18 h)
Change in Inundation Duration (DEV - EXIST)

Job Number	41-26330
Revision	0
Date	29 Jan 2014

Figure 3

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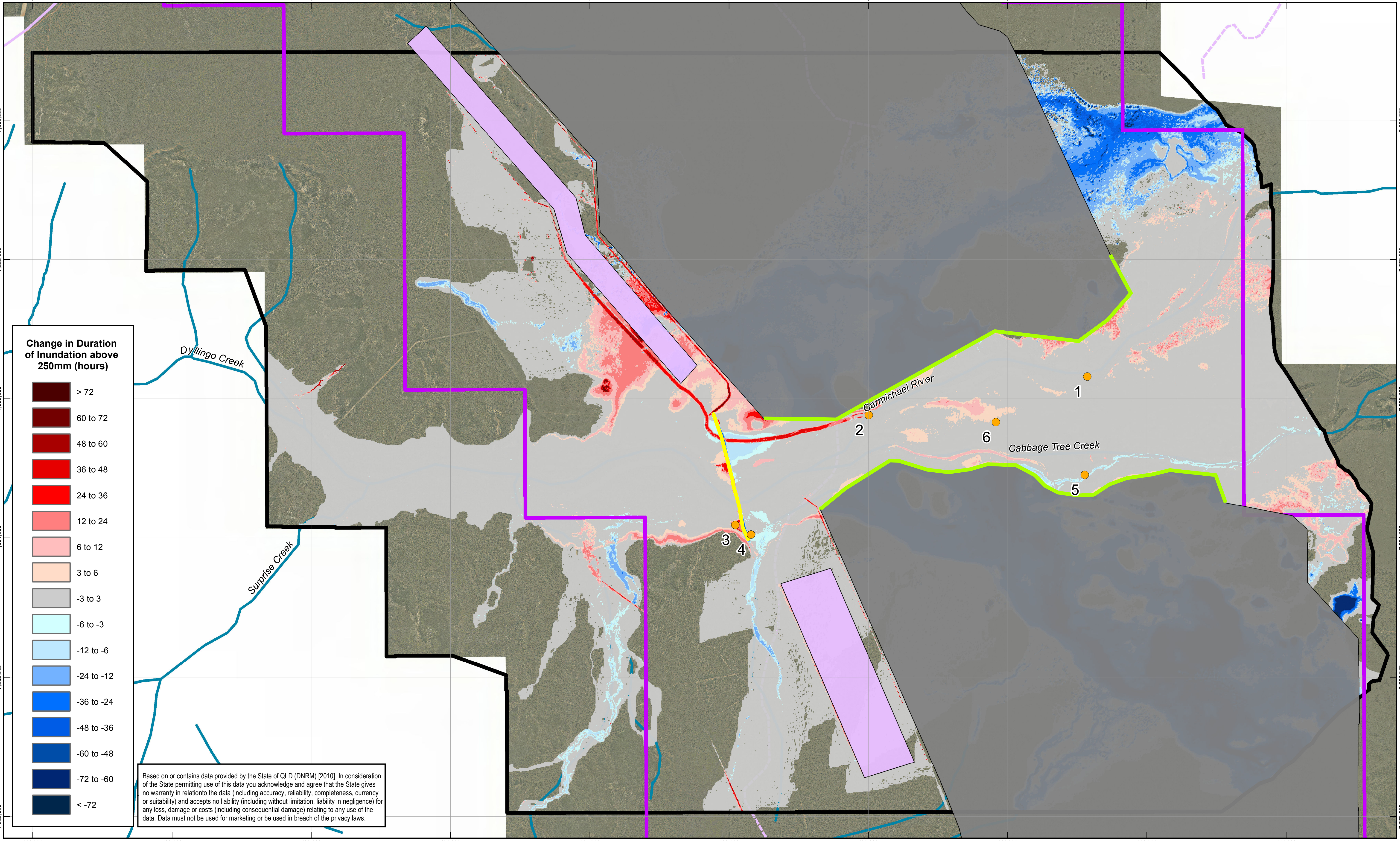

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

- 2D Hydraulic Model Boundary
- Mine Lease Boundary
- Modelled Open Cut Mine Bund
- Modelled Top Soil Spoil Piles
- Modelled Carmichael River Levee
- Modelled Haul Road Alignment
- Key Locations (Ecology)
- Watercourses
- Minor Road
- Track

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Carmichael River Hydraulic Modelling (TUFLOW)

1000 Year ARI Design Flood (36 h)
Change in Inundation Duration (DEV - EXIST)

Job Number	41-26330
Revision	0
Date	29 Jan 2014

Figure 4

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Data source: Geoimage:Aerial (2012); GA: Watercourse (2007); DNRM: Roads (2010); GHD: Hydraulic Model Layers\Key Locations (2013). Created by:pwoodman

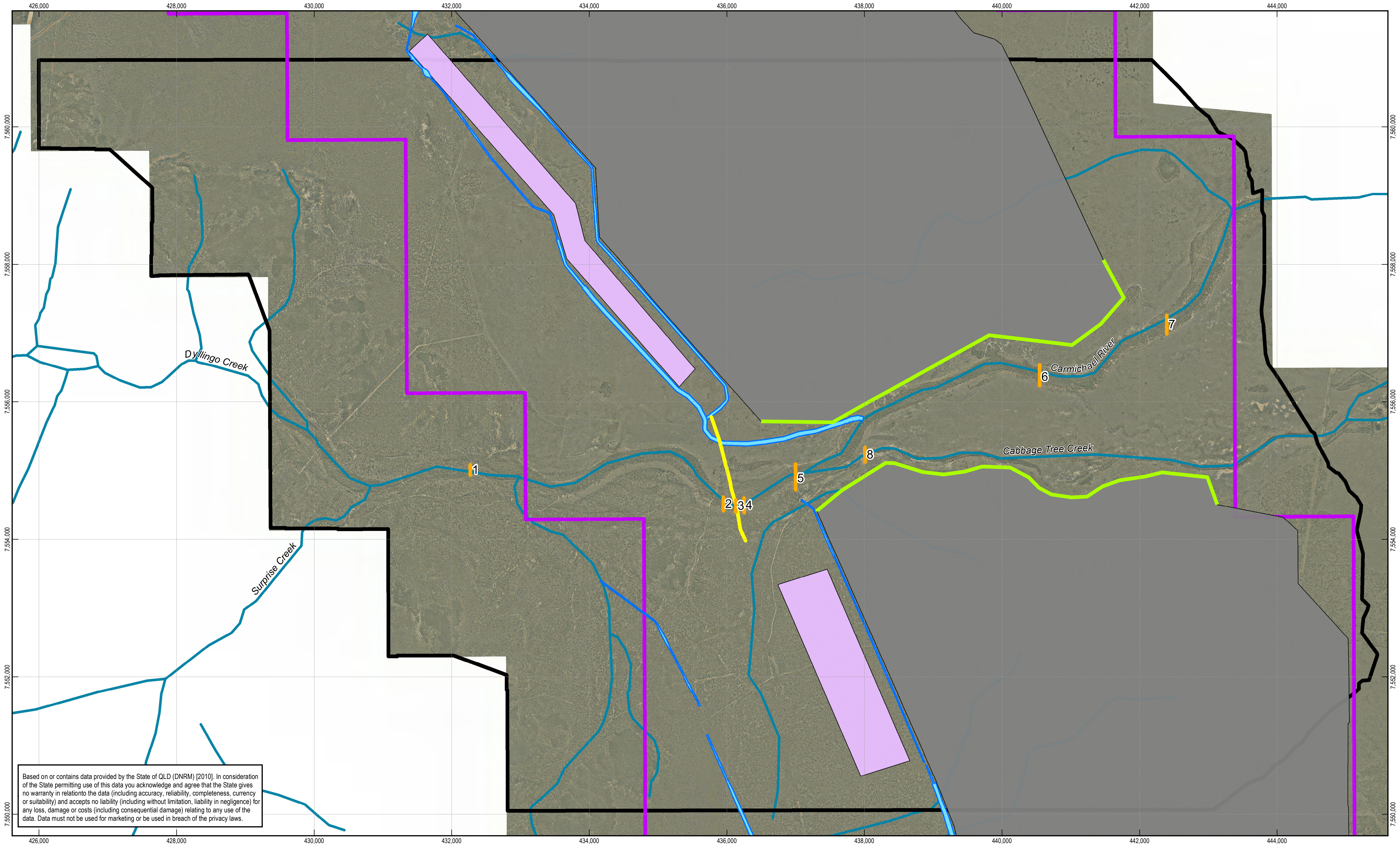
Table 1 Existing and developed scenario and change in duration of inundation above 250 mm at key locations

ID	Description	1000 year ARI \ 36 hour Duration - Inundation Duration (hours)			100 year ARI \ 18 hour Duration - Inundation Duration (hours)			50 year ARI \ 18 hour Duration - Inundation Duration (hours)			10 year ARI \ 30 hour Duration - Inundation Duration (hours)		
		Existing Scenario [A]	Developed Scenario [B]	Difference [B] - [A]	Existing Scenario [A]	Developed Scenario [B]	Difference [B] - [A]	Existing Scenario [A]	Developed Scenario [B]	Difference [B] - [A]	Existing Scenario [A]	Developed Scenario [B]	Difference [B] - [A]
1	Carmichael River channel	71.80	72.20	0.40	58.23	58.60	0.37	55.92	56.47	0.55	50.34	50.41	0.08
2	Carmichael River downstream of diversion drains	87.79	88.03	0.25	84.28	84.46	0.18	82.39	83.39	1.01	82.37	83.68	1.32
3	Upstream of proposed road bridge	47.28	76.73	29.45	33.88	83.32	49.44	29.30	81.72	52.42	11.95	61.81	49.86
4	Downstream proposed road bridge	59.75	58.63	-1.12	45.26	43.96	-1.31	42.99	41.58	-1.40	22.58	17.56	-5.03
5	Cabbage Tree Creek channel	86.50	83.48	-3.03	91.63	88.17	-3.46	90.91	87.05	-3.86	87.76	73.28	-14.47
6	Cabbage Tree Creek floodplain	43.35	45.94	2.60	29.13	31.94	2.81	24.49	28.29	3.80	0.22	11.44	11.22

Appendix B Hydrographs

Figure 5 Location of Water Surface Level (WSL) Hydrograph Extraction

Water Surface Level Hydrographs (8 Locations)



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Grid: GDA 1994 MGA Zone 55

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Legend

- 2D Hydraulic Model Boundary
- Mine Lease Boundary
- Modelled Open Cut Mine Bund
- Modelled Carmichael River Levee
- Modelled Haul Road Alignment
- Modelled Diversion Drain Alignments
- Modelled Top Soil Spoil Piles
- WSL Hydrograph Locations
- Watercourses

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Carmichael River Hydraulic Modelling (TUFLOW)

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Location of Water Surface level (WSL) Hydrograph Extraction

Figure 5

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Data source: Geoimage:Aerial (2012); GA: Watercourse (2007); DNRM: Roads (2010); GHD: Hydraulic Model Layers\WSL Hydrograph Locations (2013). Created by:pwoodman

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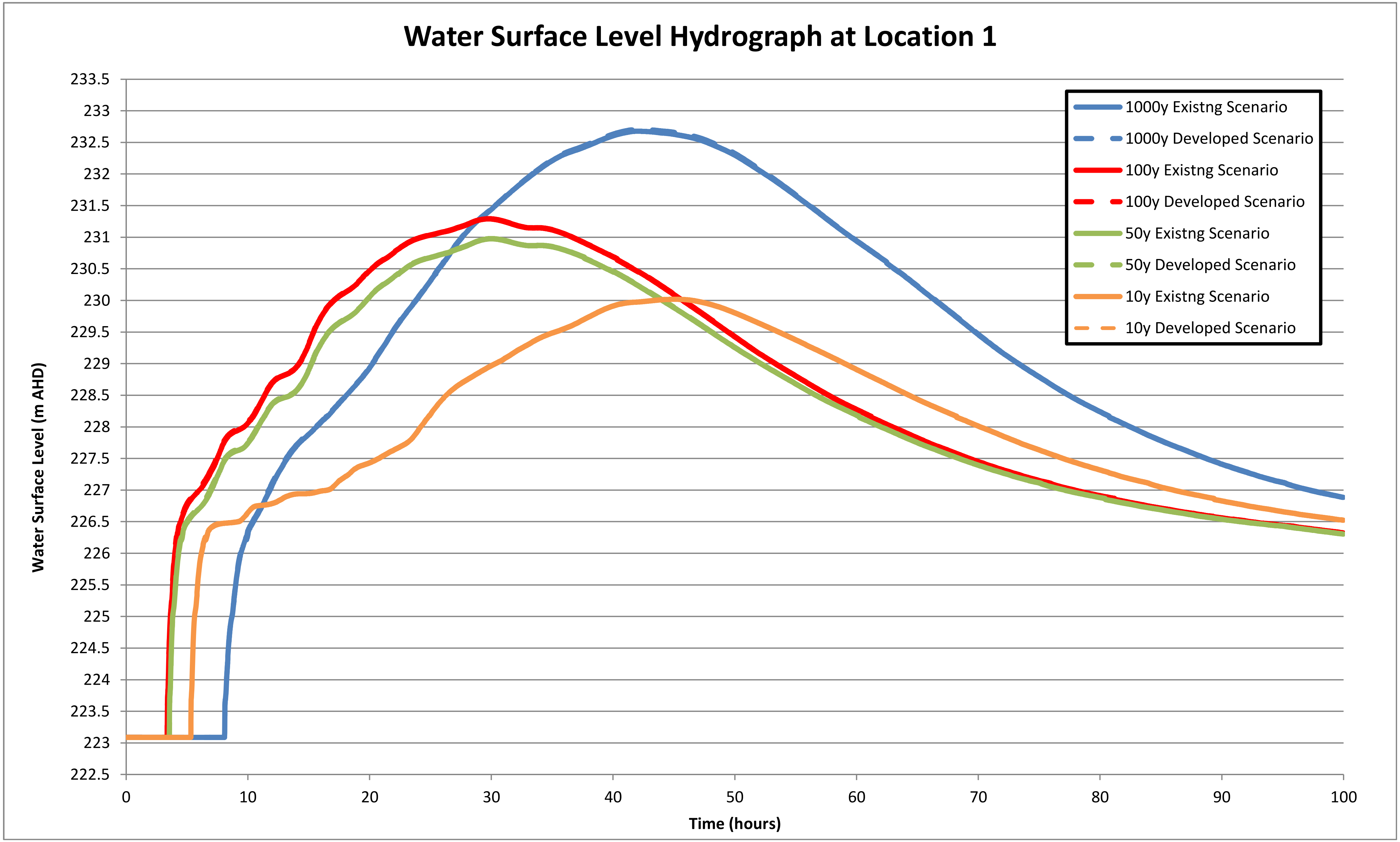

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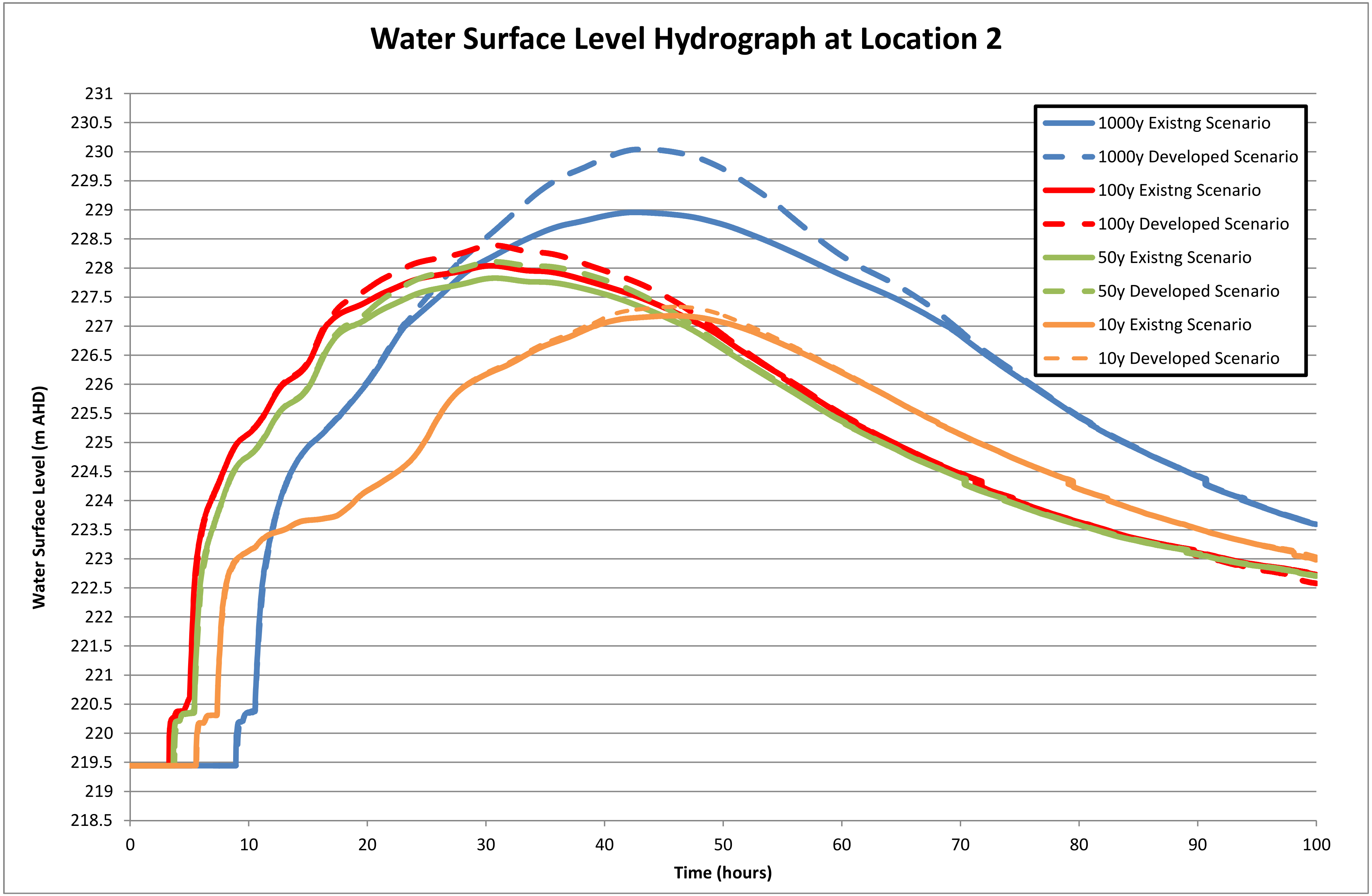

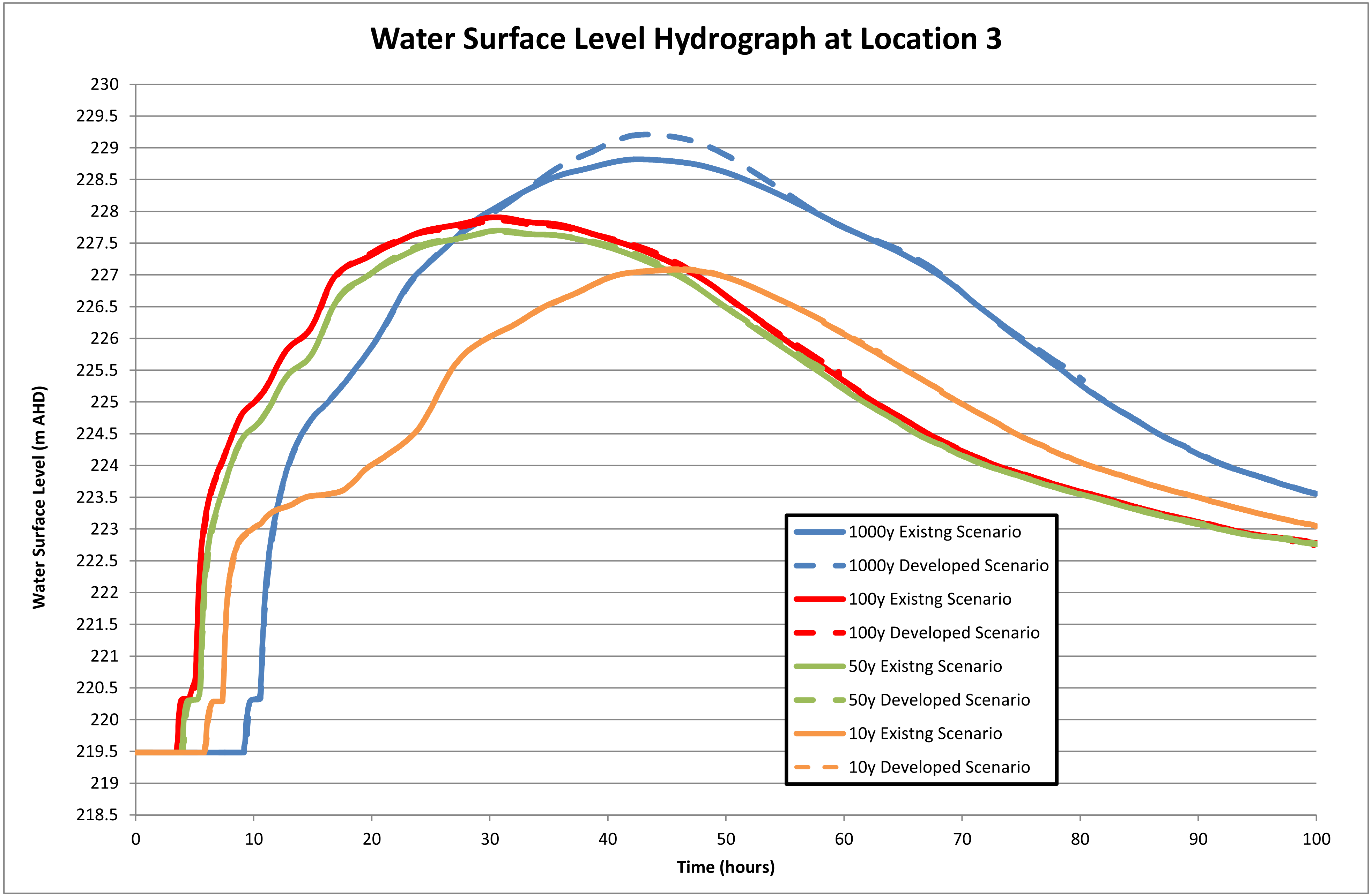
Water Surface Level Hydrograph at Location 3
Water Surface Level (m AHD)
230
229.5
229
228.5
228
227.5
227
226.5
226
225.5
225
224.5
224
223.5
223
222.5
222
221.5
221
220.5
220
219.5
219
218.5
0
10
20
30
40
50
60
70
80
90
100
Time (hours)
1000y Existng Scenario
1000y Developed Scenario
100y Existng Scenario
100y Developed Scenario
50y Existng Scenario
50y Developed Scenario
10y Existng Scenario
10y Developed Scenario

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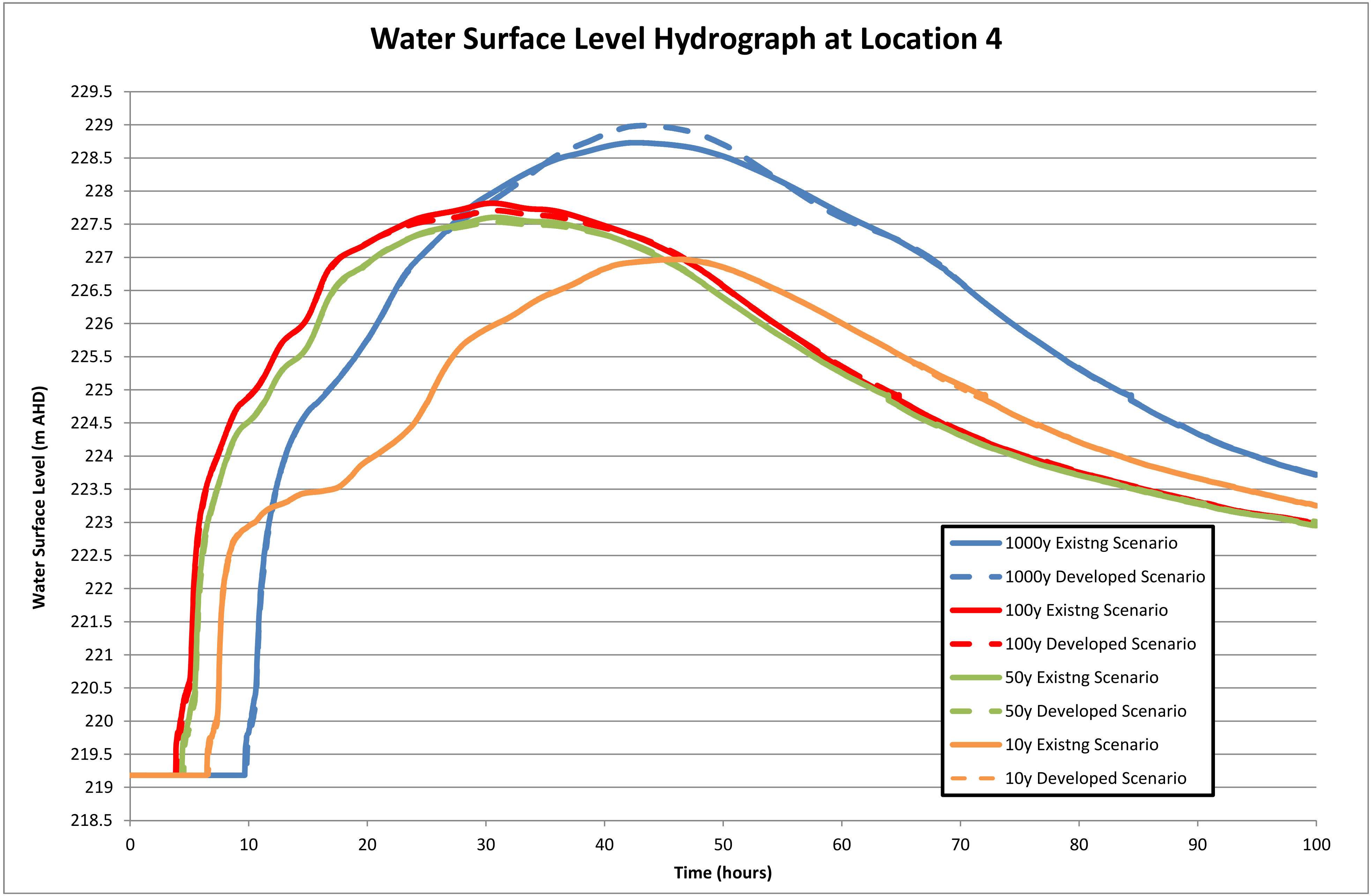

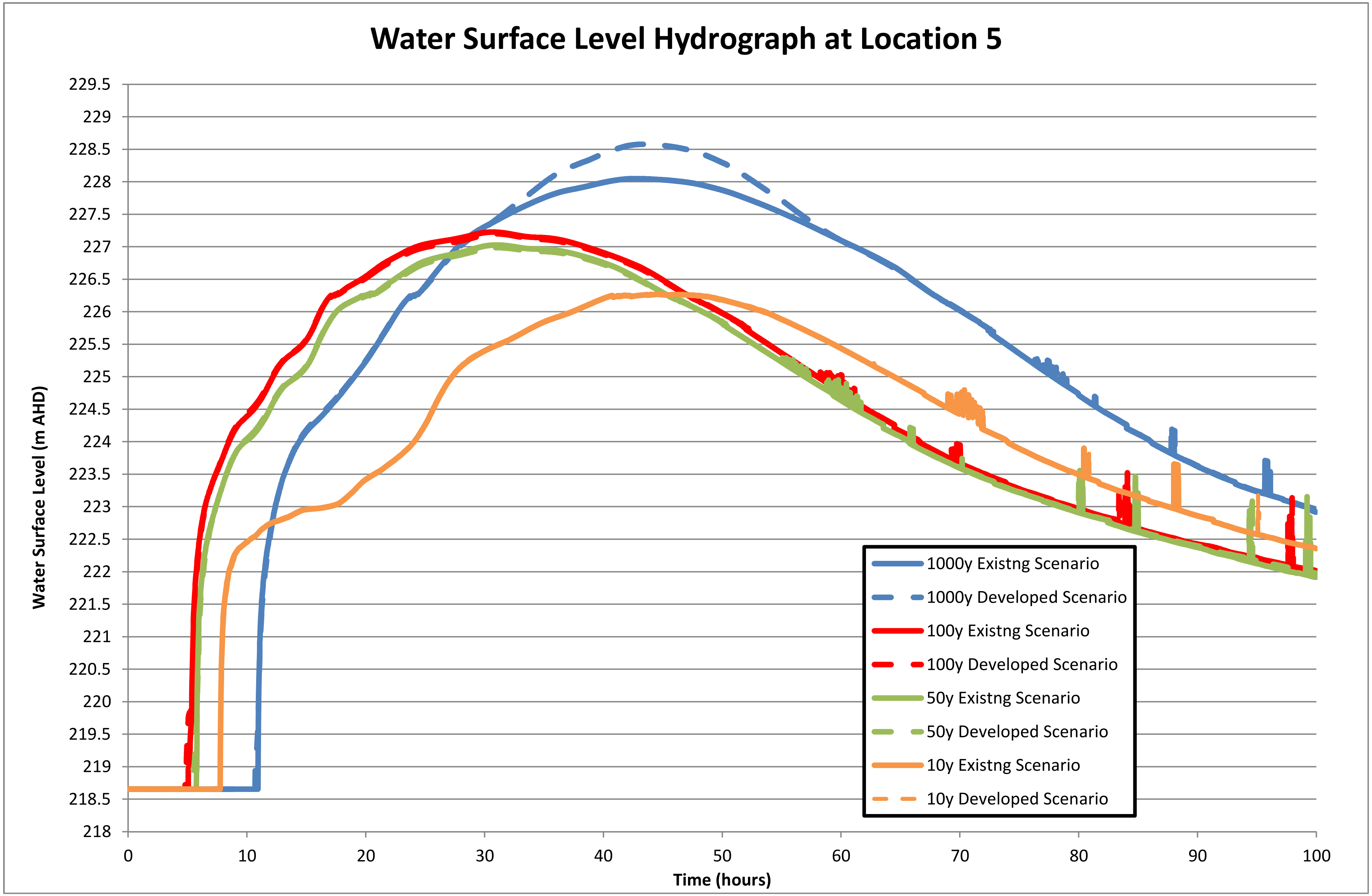
Water Surface Level Hydrograph at Location 5
Water Surface Level (m AHD)
229.5
229
228.5
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227.5
227
226.5
226
225.5
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224.5
224
223.5
223
222.5
222
221.5
221
220.5
220
219.5
219
218.5
218
0
10
20
30
40
50
60
70
80
90
100
Time (hours)
1000y Existng Scenario
1000y Developed Scenario
100y Existng Scenario
100y Developed Scenario
50y Existng Scenario
50y Developed Scenario
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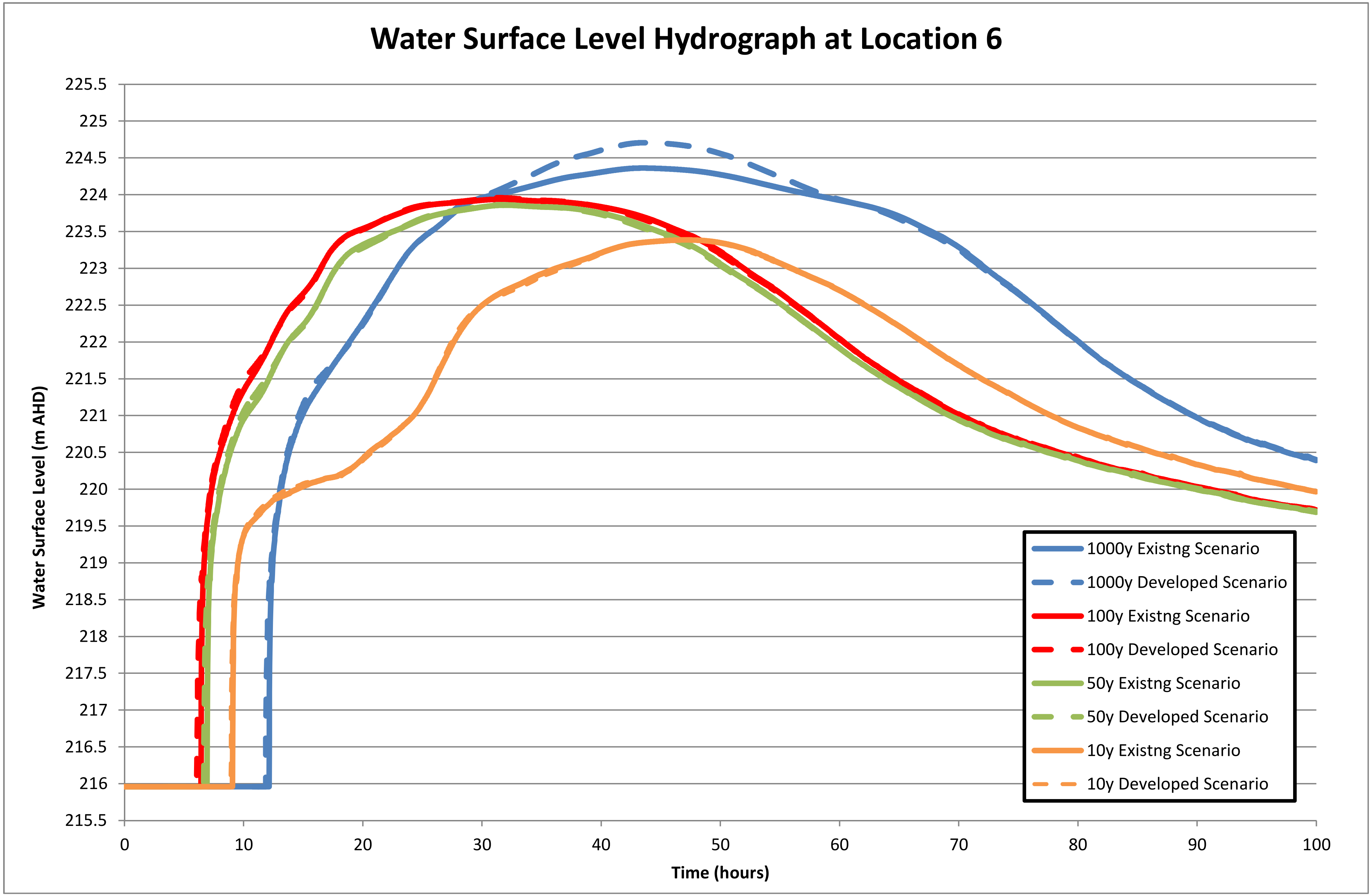

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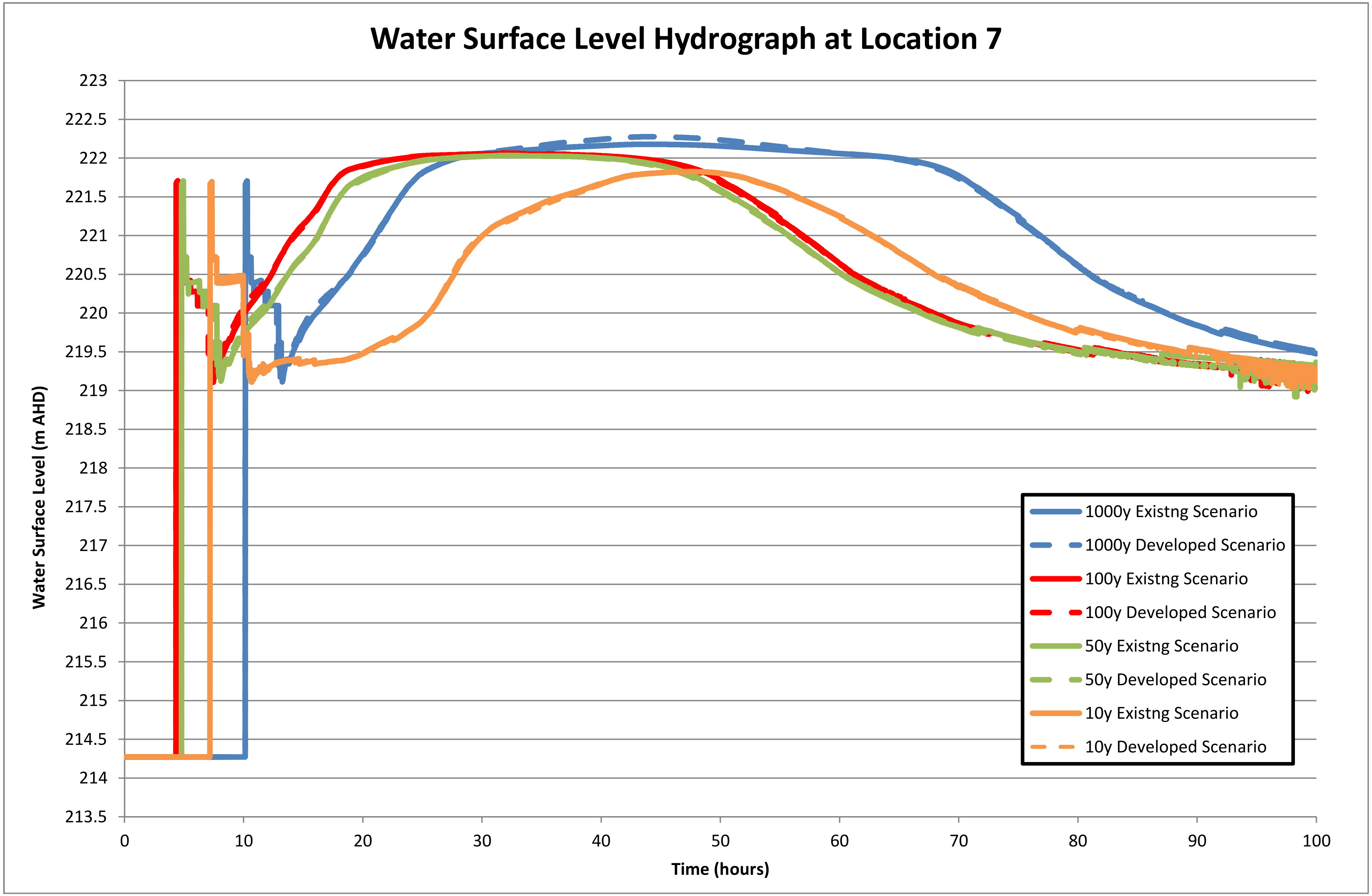

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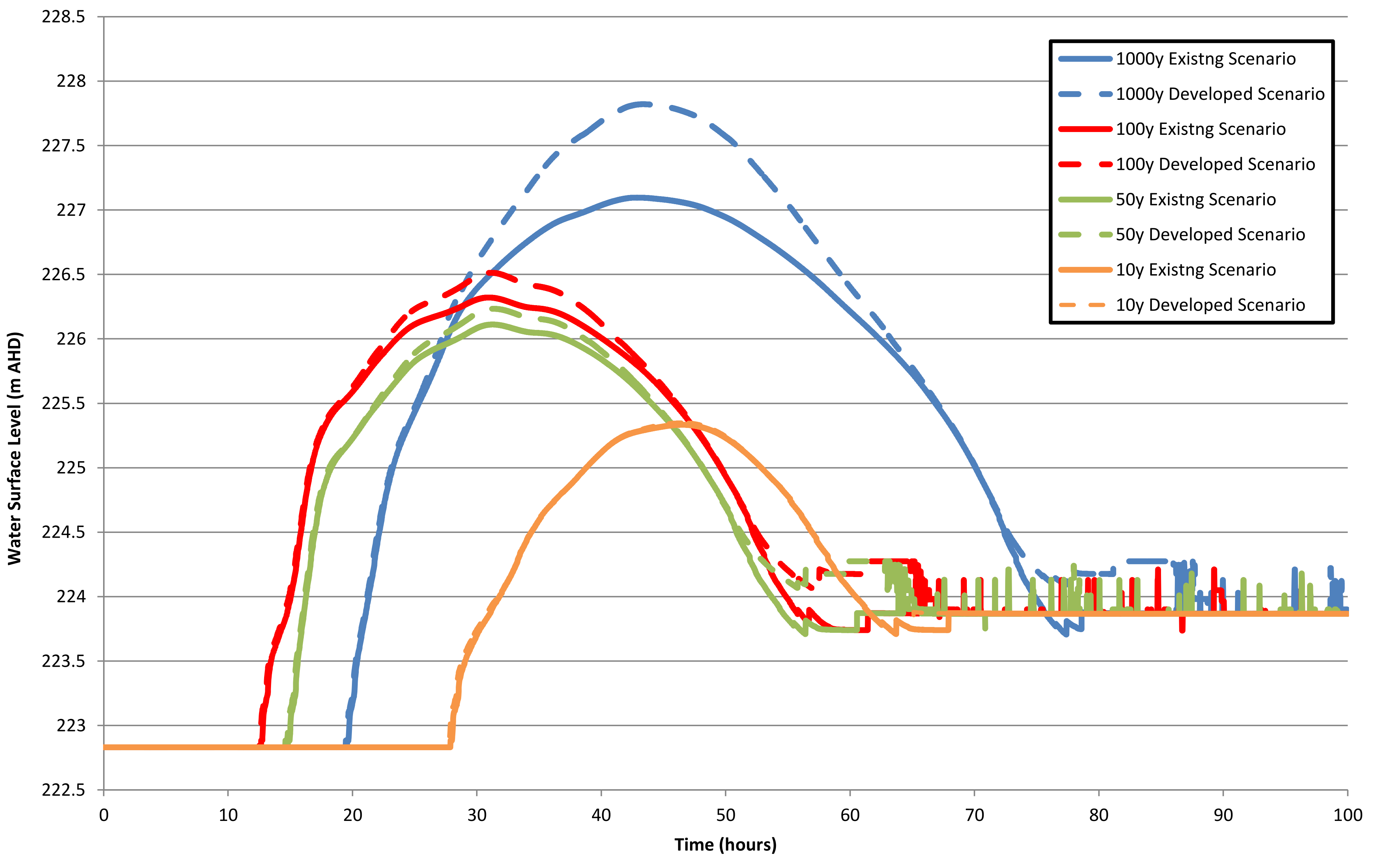
Water Surface Level Hydrograph at Location 8



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GPO Box 668 Brisbane QLD 4001
T: (07) 3316 3000   F: (07) 3316 3333   E: bnemail@ghd.com

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Rev No.	Author	Reviewer		Approved for Issue		
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A	Chris Howell/ Peter Woodman/ Sonia Claus	Chris Howell	DRAFT	Philip Bradley	DRAFT	22/01/13
0	Chris Howell/ Peter Woodman/ Sonia Claus	Chris Howell		Philip Bradley		29/01/13

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