Report

Investigation Area 2 – Model of Flood Behaviour

Greater Shepparton City Council

28 November 2022

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Project Details

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Cover Photo: Seven Creeks Upstream of Rafferty Road

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EXECUTIVE SUMMARY

Water Technology was commissioned by Greater Shepparton City Council (GSCC) to investigate and better understand the flood impact that differing development density levels may have on “Investigation Area No. 2” and the broader floodplain area between the Goulburn River and Seven Creeks with the inclusion of climate change.

An earlier investigation assessed the current flooding conditions (based on existing hydrology). Updated hydrology and changes to planning requirements now require an assessment to incorporate climate change conditions. The study provided an update to the mapping provided in the Shepparton Investigation Area No.2 Flood Modelling[1] project, undertaken in 2020 and supersedes the flood modelling undertaken for the 1% AEP flood event and incorporates climate change modelling.

The study provided an update to the mapping provided in the earlier 2020 Memo by adopting a revised flood model form Shepparton Mooroopna Flood Mapping and Intelligence Study[1] undertaken in 2019 and incorporated climate change modelling. Initial modelling of the proposed layout (based on earlier work) was undertaken with the updated climate change flows; however, it showed increases in flood levels outside the site in a 1% AEP event. This does not meet acceptable limits from the floodplain referral authority as part of a greenfield development.

These initial results were submitted to GSCC, following their submission, further information from GSCC, Goulburn Broken Catchment Management Authority (GBCMA) and Goulburn Murry Water (GM-Water) was provided and several iterations were undertaken until a result was achieved that meet appropriate afflux. Flood modelling has been undertaken providing mapping outputs and an area marked for development from a purely floodplain management perspective. Update to the climate change modelling suggests significantly more of the site is inundated when using climate change as the design scenario.

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1 INTRODUCTION

Water Technology was commissioned by Greater Shepparton City Council (GSCC) to investigate and better understand the flood impact that differing development density levels may have on "Investigation Area No. 2" and the broader floodplain area between the Goulburn River and Seven Creeks. Investigation Area No. 2 is bounded by the Goulburn Valley Highway and Seven Creeks to the east, Bennetts Road to the south, the Arcadia Downs residential area to the west and a flood contained "pinch point" between Seven Creeks and Goulburn River to the north. This area is shown in Figure 1-1. A previous investigation undertaken in March 2020 involved a review of the relevant and available information and re-running the existing TUFLOW model with updated topographic LiDAR[1] data. From this assessment, areas suitable for residential development (based on the 1% AEP flood event) were identified and then modelled to ensure the development had minimal impact on flood behaviour and there were no flood level increases on neighbouring properties. Since the completion of the initial study, climate change modelling has been undertaken for Shepparton, Mooroopna and Kialla and is planned to form the basis of flood related planning controls in the future. Due to the recent availability of the climate change modelling information, a review of the assessment for Investigation Area 2 using the latest available information was required. This involved:

1. Review of the hydraulic model and climate change modelling results for existing conditions.
    - Map existing conditions flood behaviour (climate change event).
    - Review the existing climate change modelling results and identify developable areas within the growth corridor.
    - Provide Calculation for loss of floodplain storage and estimated bulk earthworks to achieve outcome.
2. Review of the previously determined final development layout flood risk.
    - Rerun previously determined final development layout in the hydraulic model with climate change inflows.
    - Compare the revised development scenario results with the revised existing condition results (first task above) to identify if there is further developable area and an impact on surrounding properties.

[1] Light Distance and Ranging

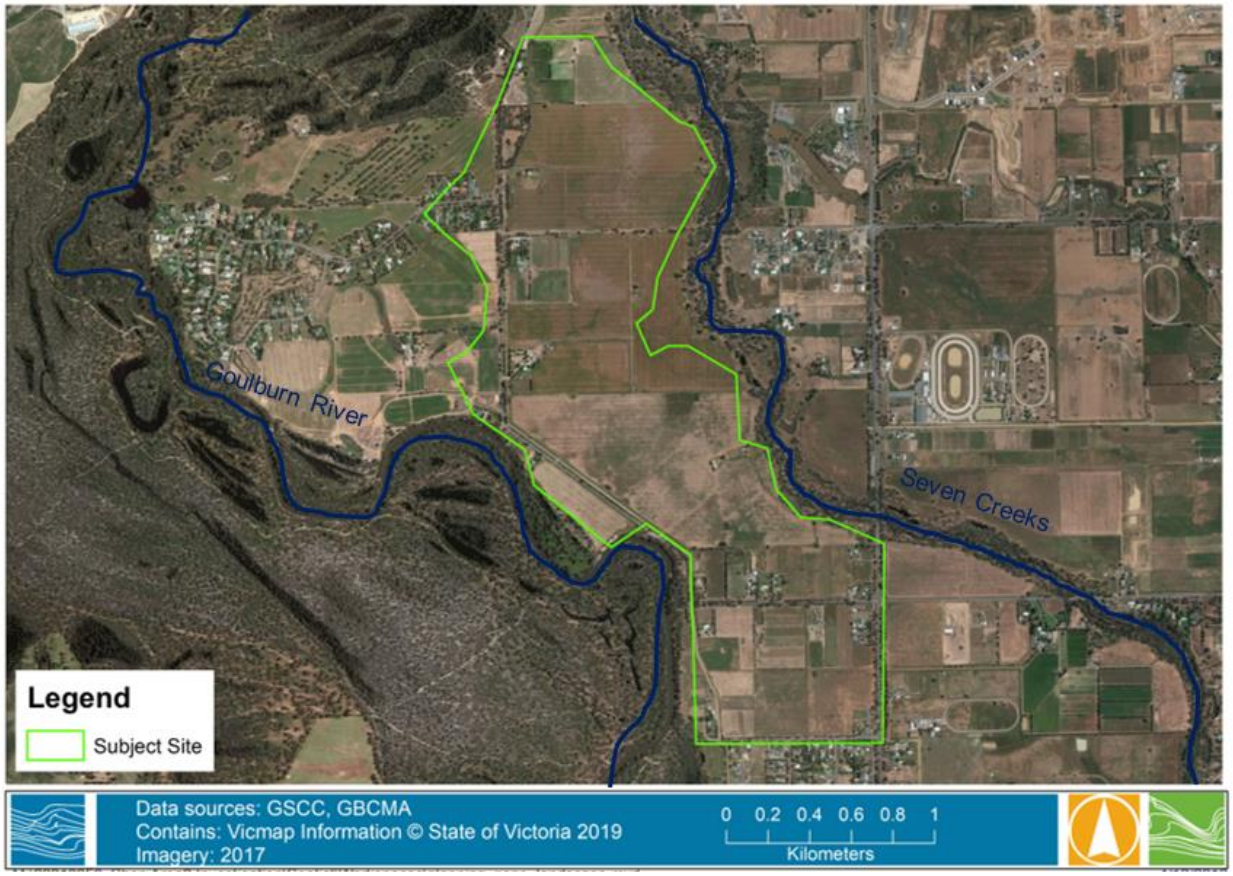

Figure 1-1 Investigation Area No. 2

This report details development opportunities and constraints including estimated earthworks volumes and an assessment of floodplain volumes under development conditions. The initial assessment was provided to GSCC and amended with multiple iterations based upon feedback from GSCC and GBCMA, with more detail provided on proposed development areas and to meet afflux requirements, ensuring no flood level increases outside of the site boundary.

2 LAND USE IDENTIFICATION

An initial development layout was produced based on flood modelling results developed as part of the Shepparton-Mooroopna Flood Mapping and Intelligence Study, along with an initial meeting with GSCC and the GBCMA. The initial delineation of the developable area to be filled was based on the existing conditions flood depths and was used as the initial developed scenario with the specific areas filled based on the categorisation shown in Figure 2-1 and summarised in Table 2-2. As a starting point, a 200-metre buffer was applied from the Seven Creeks top of bank to reduce the likelihood of impacting on environmental and culturally sensitive areas. This buffer was used as an exclusion zone prior to assessing the existing conditions flood depths.

Areas categorised for General Residential development were based on ensuring no development where the existing 1% AEP flood depths exceeded 300 mm. These areas would require fill up to the existing 1% AEP flood level to allow for the finished floor level of any new houses to be constructed at least 300 mm above the fill level. This aims to prevent new parcels being inundated in events up to the 1% AEP flood event. Further design work (including lot and road layouts) would be required to provide a more detailed earthworks estimate; however, roadways within the area would be likely to be filled to 250-300 mm below the 1% AEP flood level to ensure access and egress requirements are met. An indication of the current 1% AEP levels in existing conditions is shown in Figure 2-2.

To compensate for the floodplain storage lost as a result of floodplain fill in areas within the development, compensation storage is likely to be required to balance floodplain cut and fill. Previous flood modelling for other investigation areas in the Shepparton area has required that the storage lost be at least met with a 1:1 ratio (i.e. neutral cut/fill).

Other constraints as to where the compensation storage can be provided include environmental, cultural heritage, traffic management, as well as general planning and infrastructure requirements. These are likely to restrict areas for development. From a purely hydraulic floodplain assessment, ensuring the compensation storage is located close to areas with the highest conveyance across the floodplain is generally the most suitable approach. To achieve this, and to provide the greatest area for development, the compensation storage should be in areas where existing flood depths are greatest.

Table 2-1 Site categories based on existing flood depths.

Existing Flood Depth	Area (ha)	% of Site	Land Use Development	Floodplain Storage (m^3)
Not Flooded	160	48	No earthworks considered for this assessment	N/A
Up to 30cm	108	32	Raised to existing flood level (up to 30cm) for General Residential	101,050
Above 30cm	40	12	No development can occur	180,000
200m buffer from Seven Creeks top of bank	25	8	No development can occur	190,000

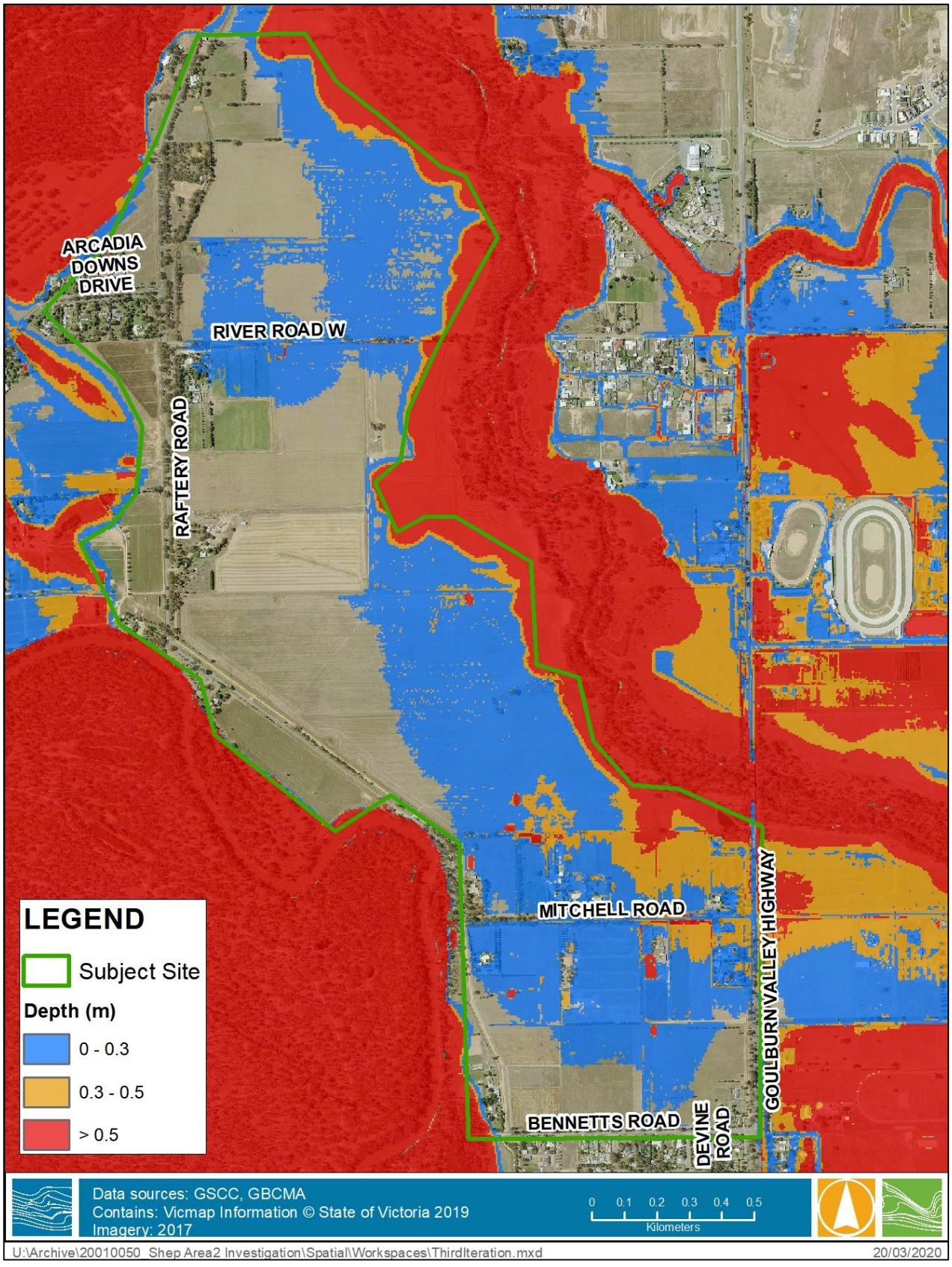

Figure 2-1 Flood Depth Plot – 1% AEP Existing Conditions

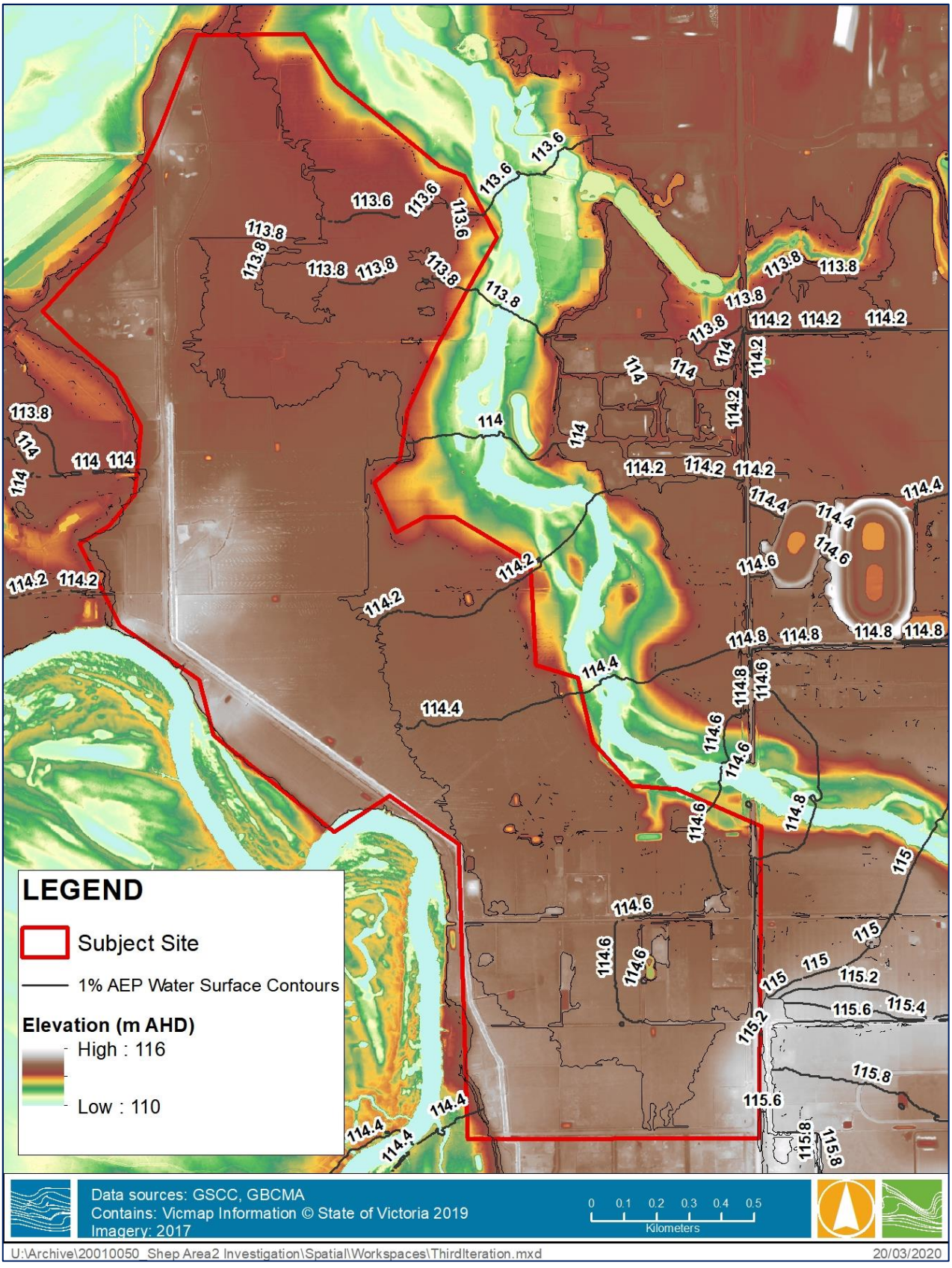

Figure 2-2 1% AEP Water Surface Elevation Contours and LiDAR

Table 2-2 Proposed development layout categories based on existing flood depths.

Existing Flood Depth	Area (ha)	% Site	Land Use Development	Floodplain Storage Reduced (m^3)	Estimated Earthworks Required (m^3)
Not Flooded	160	47.5	No earthworks considered for this assessment	N/A	N/A
Up to 30cm	112	33.2	Raised to existing flood level (up to 30cm) for General Residential	101,050	350,000
			Roadways	7,500	7,500
Above 30cm	40	12	No development can occur	N/A	N/A
200m buffer from Seven Creeks top of bank	25.5	7.3	No development can occur	N/A	N/A

2.1 Climate Change Results

A climate change scenario was modelled as part of the supplementary Shepparton Flood Modelling Project undertaken in 2021. This utilised the 0.5% AEP hydrology based on a comparison with the HARC Broken River and Goulburn River Climate change Study (2020). The results shown in Figure 2-3 highlight the study area is significantly more impacted than under the current 1% AEP conditions. Table 2-3 summarises the percentage of each area inundated under climate change conditions. The developable area has significantly reduced and there is considerably more floodplain storage that requires balancing.

Table 2-3 Climate change Existing Conditions Summary

Existing Flood Depth	Area (ha)	% Site	Land Use Development	Floodplain Storage Reduced (m^3)	Estimated Earthworks Required (m^3)
Not Flooded	90	26.8	No earthworks considered for this assessment	N/A	N/A
Up to 30cm	130	38.7	Raised to existing flood level (up to 30cm) for General Residential	256,600	350,000
			Roadways	9,700	9,700
Above 30cm	91	27.2	No development can occur	N/A	N/A
200m buffer from Seven Creeks top of bank	25.5	7.3	No development can occur	N/A	N/A

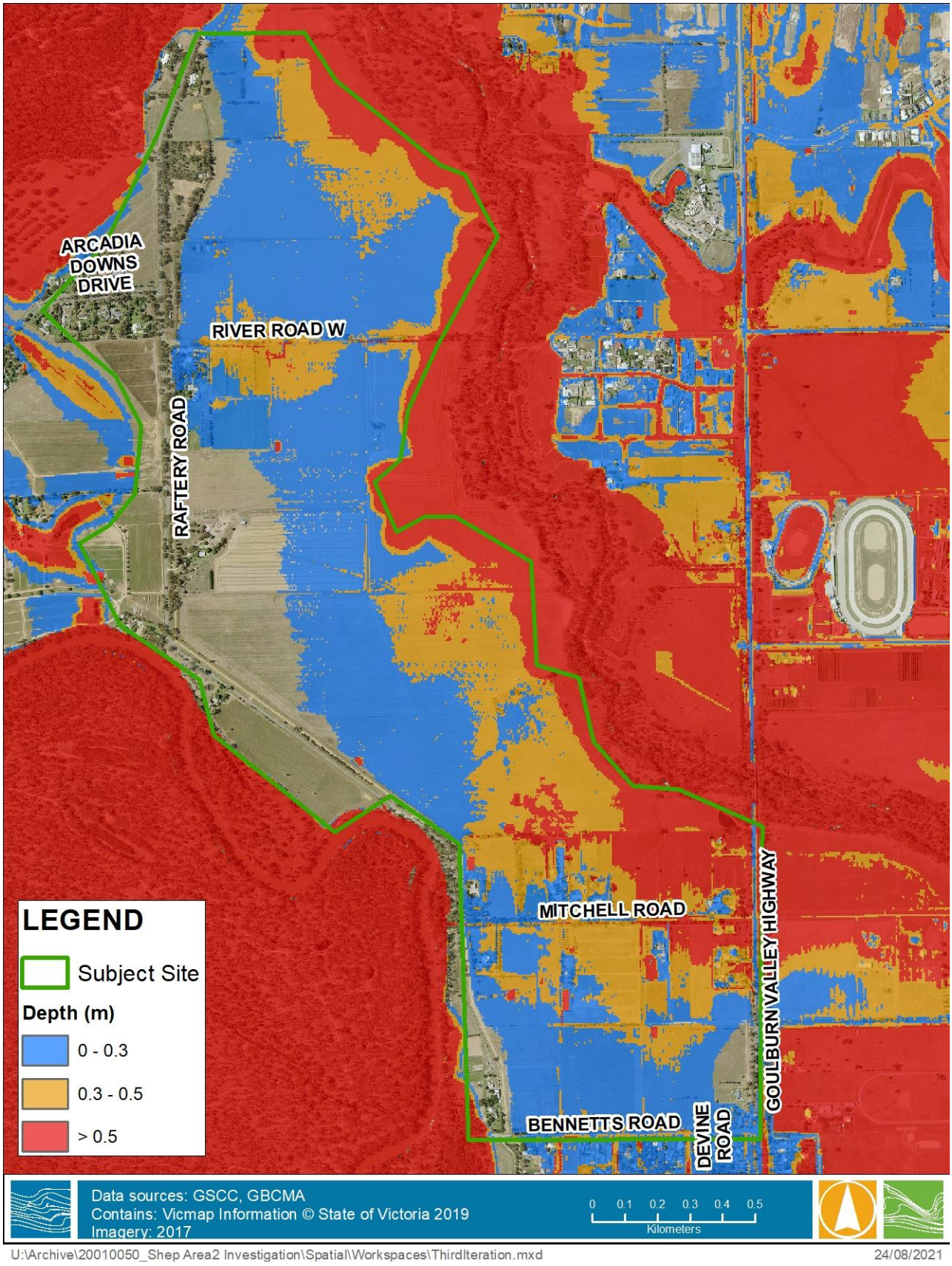

Figure 2-3 Climate change Flood Depth

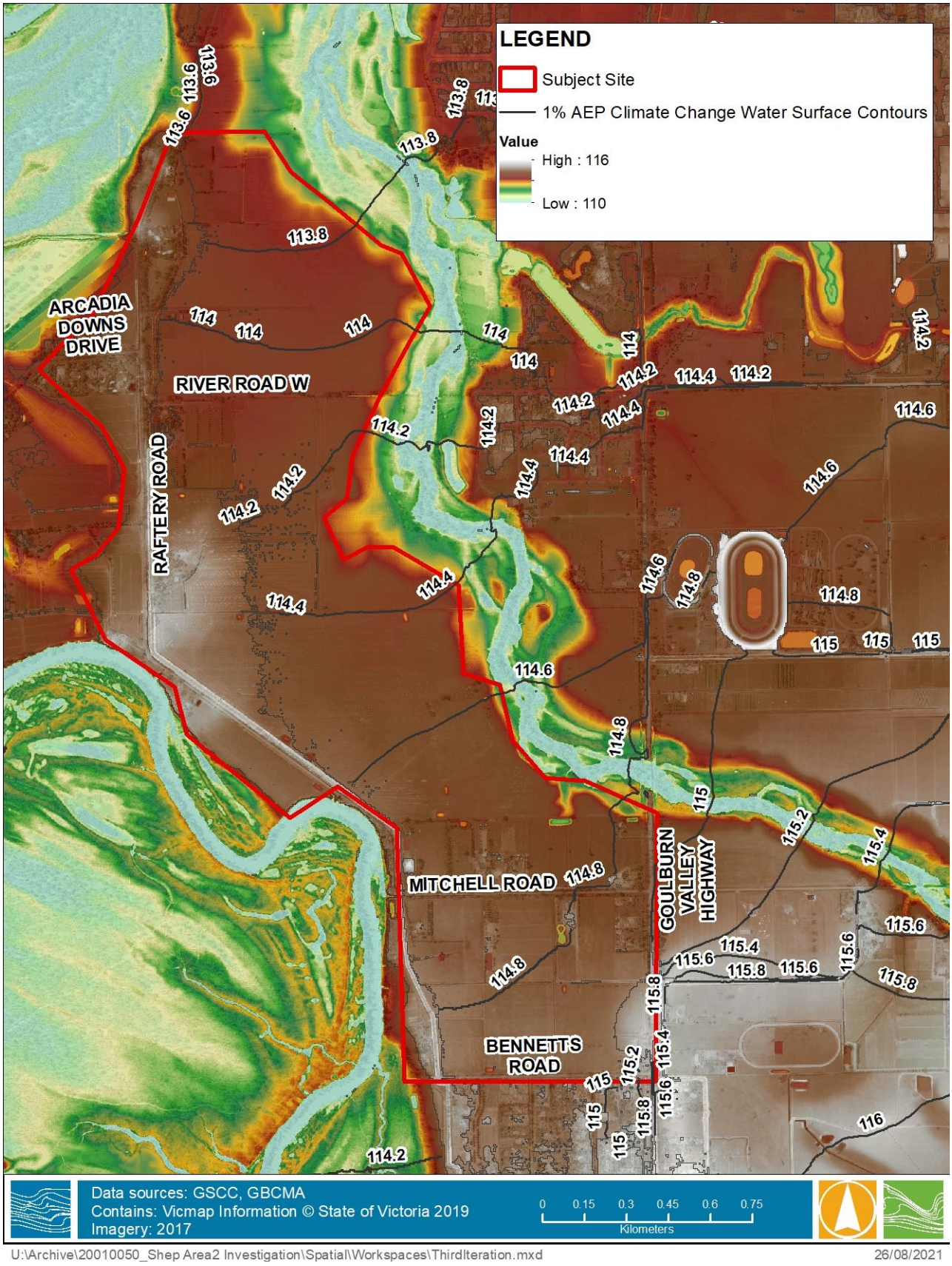

Figure 2-4 1% AEP Climate change Water Surface Elevation Contours and LiDAR

3 DEVELOPMENT FLOOD RISK

The flood model was updated to include the proposed fill areas. Updated modelling for the 1% AEP event was compared to that of existing conditions. To understand the impact development would have on water levels, depths and extents; a direct comparison was drawn between the flood levels for existing and proposed filled conditions.

The revised flood depths are shown in Figure 3-1, and the impact of the development on climate change 1% AEP flood levels shown in Figure 3-2. The result comparison shows a widespread increase in flood levels east and south of the investigation area across Mitchell Road and Goulburn Valley Highway. These increases range from 10-30 mm, upstream of the Goulburn Valley Highway most increases are between 5-20mm. South of Mitchell Road shows increases in flood levels of up to 300mm as floodwaters become trapped. These increases are not likely to be considered acceptable by the GBCMA, as they impact neighbouring landholders. To address this, the development footprint required a reduction along the eastern edge of the subject site allowing for an increase in conveyance, taking into account that no fill in areas where flooding exceeds 300mm depth in existing conditions.

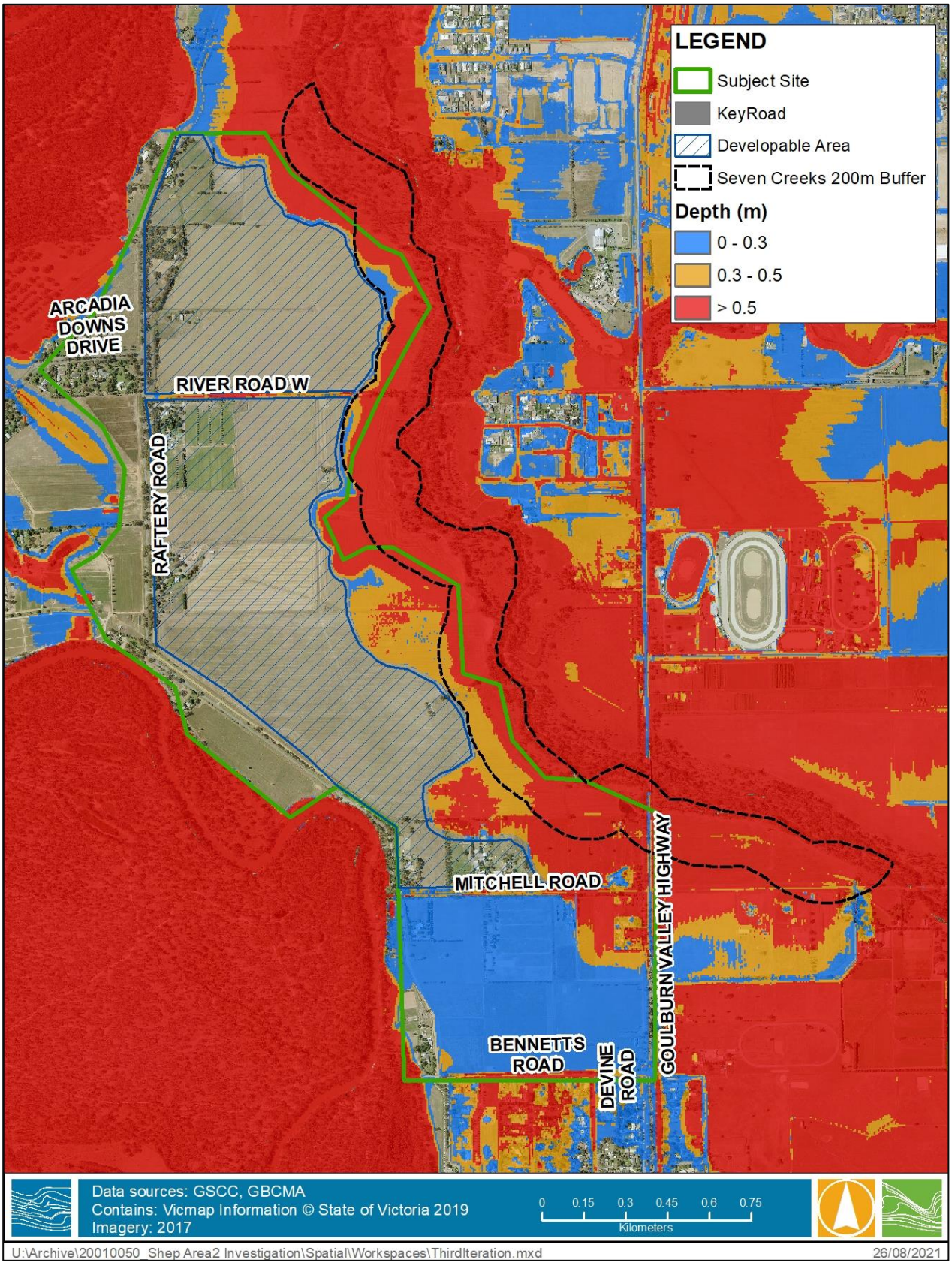

Figure 3-1 Flood depth plot – Revised Development 1% AEP

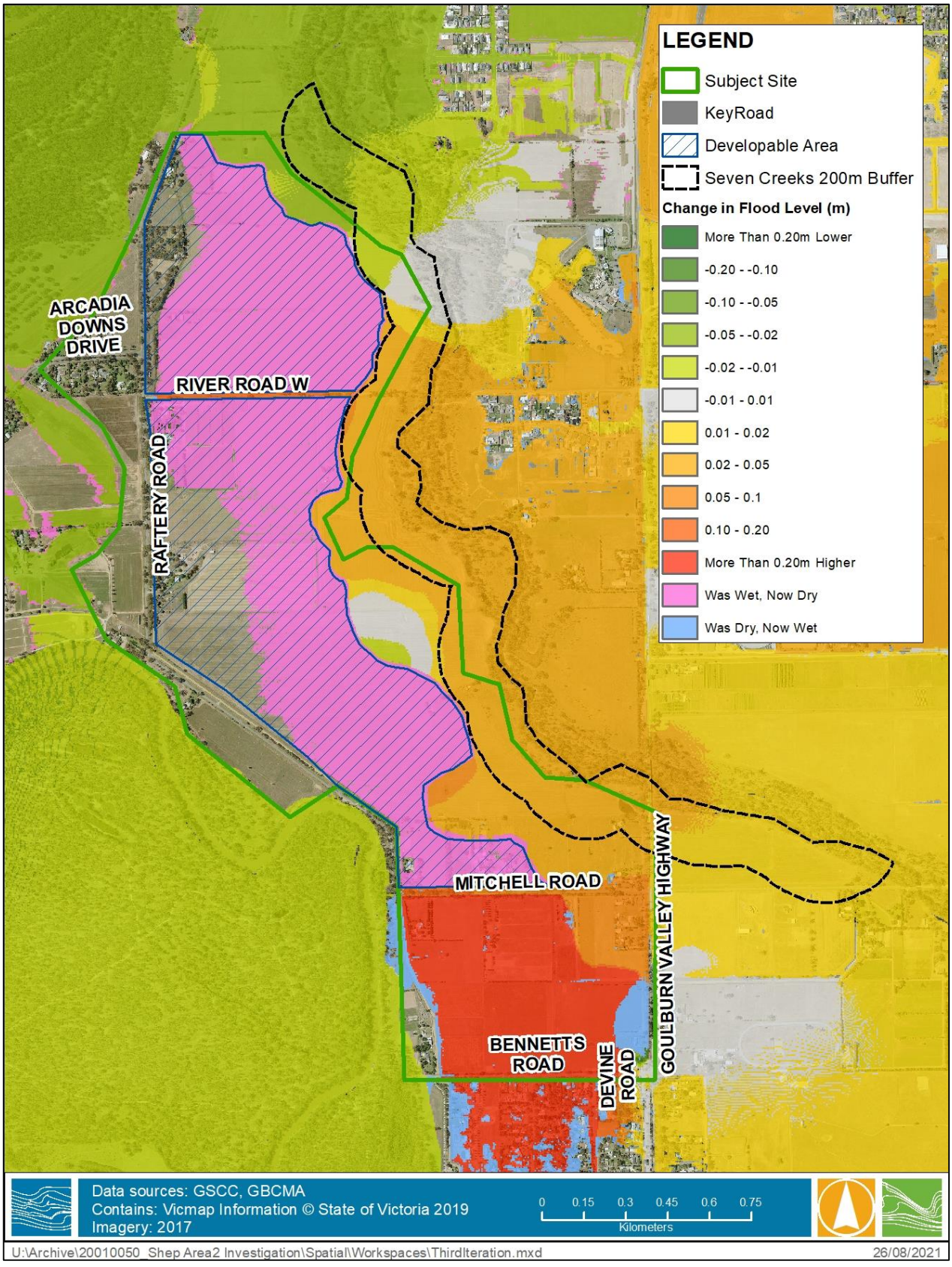

Figure 3-2 Flood depth difference plot – Development Minus climate change 1% AEP

3.1 Revised Development Footprint

Based on the flood level difference plot shown in Figure 3-2, afflux outside of the site area is significant and not likely to be accepted by the GBCMA. Several revised development footprints were assessed as part of the investigation. These generally resulted in reductions in developable area to minimise afflux outside of the site. Options to develop the area in the south of the study area between Mitchell Road and Bennetts Road were trialled; however, any attempts to raise the area above flood level resulted in an increased flood extent and flood levels to the south and southeast.

Other options assessed included piping flows through the GM-W irrigation channel located at the western end of Mitchell Road; however, this was found to not provide significant reduction in flood levels.

The initial results and various design iterations were presented and discussed with officers from GSCC and GBCMA.

3.2 Final Development Footprint

From the above iterations, a final development scenario (Figure 3-3) was modelled. Flood depth results for the 1% AEP with climate change are provided in Figure 3-4. This scenario was shown to meet the afflux requirements (Figure 3-5) and included:

- Three precincts for development (152 ha) east of Rafferty Road to be filled above the 1% AEP (climate change) flood level.
- A boulevard type road running along the eastern edge of the development connecting Mitchel Road and Rafferty Road at the northern end of the study area.
- A minimum 200m buffer from Sevens Creek western bank.
- Re-sculpting of the southern portion of the study area (north of Mitchell Road) to help maintain flow conveyance and floodplain storage.
- A 80m wide floodway south of Mitchell Road that runs from the Goulburn Valley Highway to the Goulburn River floodplain. This will require the piping of the GM-W channel in this area.

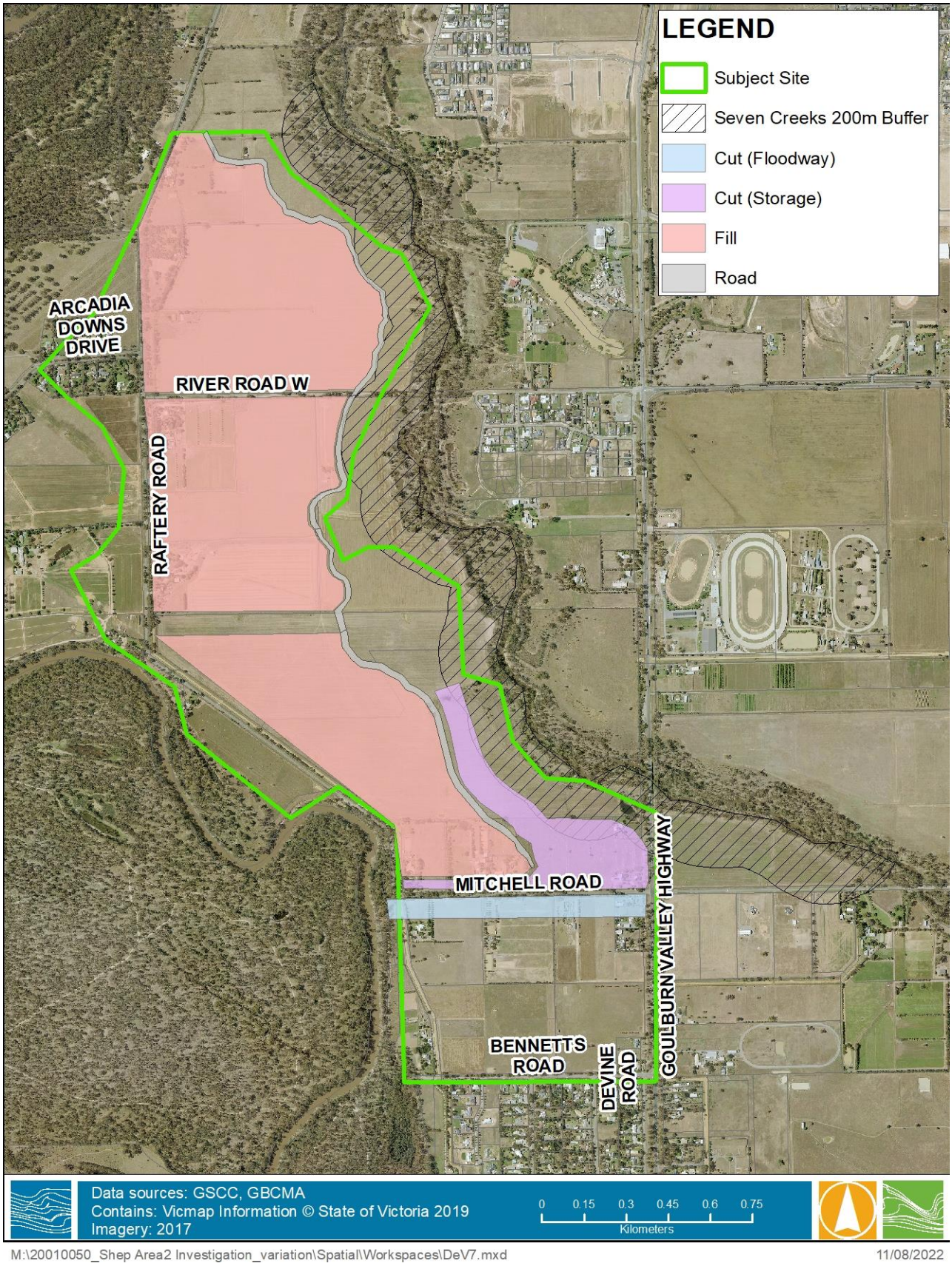

Figure 3-3 Final Development Layout

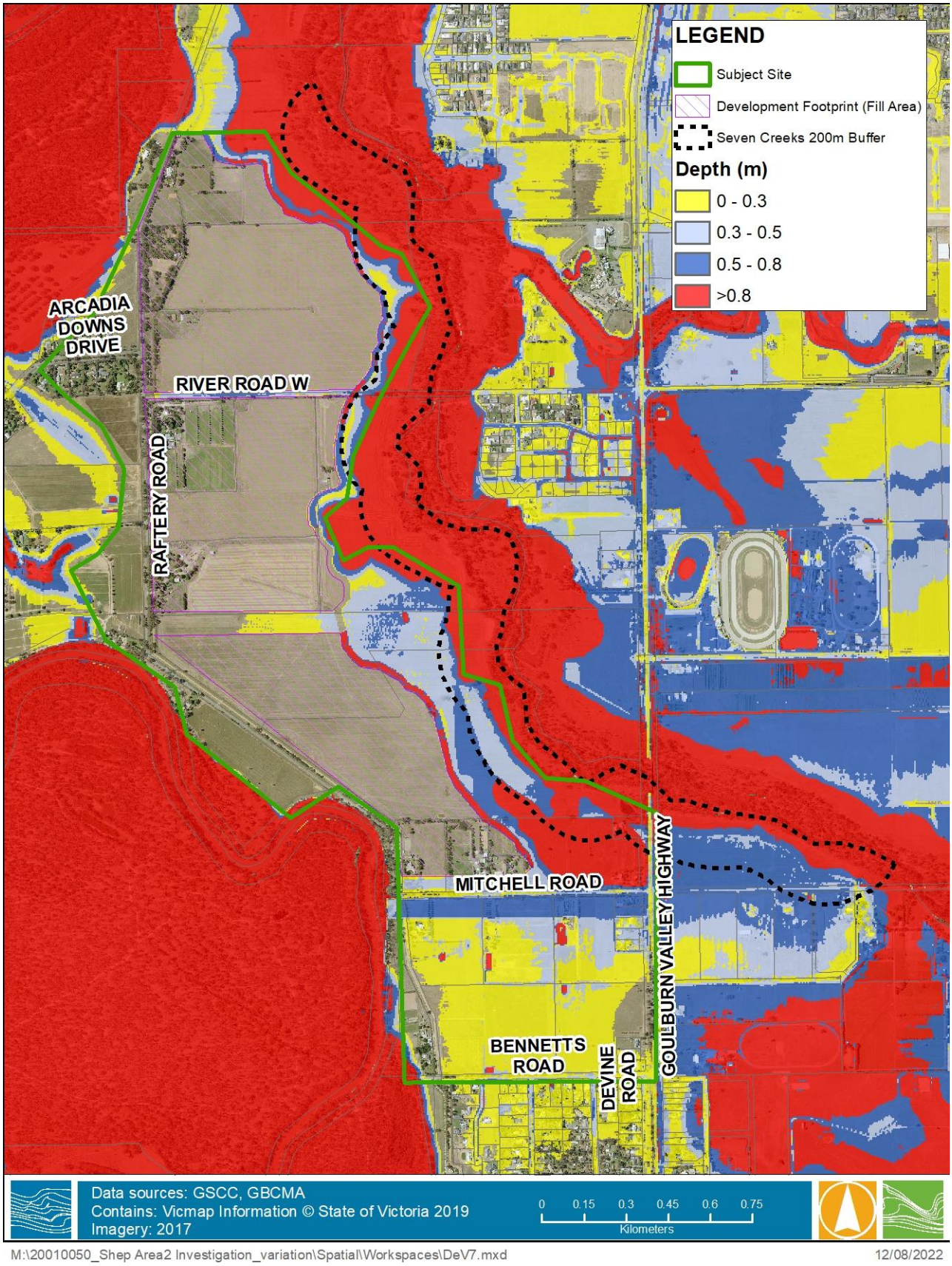

Figure 3-4 Final Development Layout – 1% AEP Depth

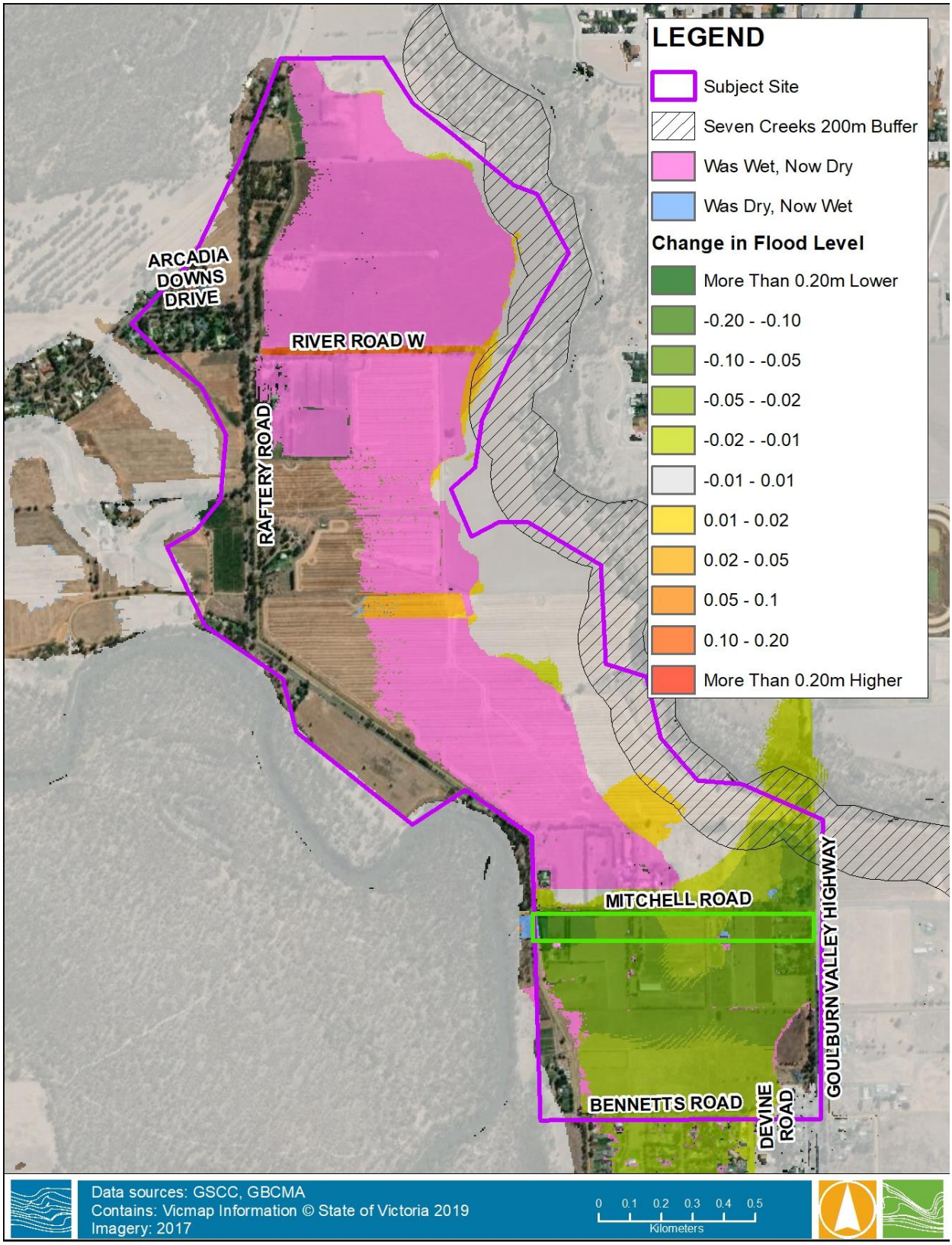

Figure 3-5 Flood Level Afflux - Final Development Layout

4 EARTHWORKS AND FLOODPLAIN STORAGE

4.1 Earthworks

The proposed development scenario relies on filling the site above the 1% AEP (with climate change) flood level in locations where existing flood depths are less than 0.3 m. This requires significant volumes of fill to be imported into the development precinct, which can be somewhat offset by 'cut' taken from within the site.

The finished levels used for the flooding modelling are not final design levels and are based on a grid resolution of 5m x 5m. These volumes are an estimate and are to only be used as an estimate of total earthworks required. The cut and fill volumes quoted are likely to change slightly at a further detailed design stage; the addition of road levels into the design will see further changes to the quoted volumes.

The total cut and fill calculated from the development layout is shown in Table 4-1 below and shows that a total of approximately 238,500 m^3 of fill will need to be imported (based on the assumptions adopted in the model). These calculations do not incorporate changes to floodplain storage, which are discussed further below.

Table 4-1 Cut/Fill Earthworks Summary

	Fill Required (m^3)	Cut Required (m^3)	Net Balance (m^3)
Investigation Area 2	460,500	220,000	238,500

4.2 Floodplain Storage

Typically, the GBCMA would require than any loss of floodplain storage be compensated in a 1:1.3 ratio for a single private development. Given the size of the development been undertaken, it is understood the GBCMA will assess floodplain storage requirements on a 1:1 ratio given flood modelling has been carried out to assess the impact. It is also assumed that provided flood mapping shows no significant afflux outside of the subject site. A summary of the loss of floodplain storage (based on a 1:1 ratio) is shown in **Table 4-2**. This shows that the proposed fill extents will result in a floodplain storage loss of approximately 140,000 m^3, which equates to around 15% of the total volume stored within the subject site under existing conditions.

Table 4-2 Floodplain Storage Summary

Storm Event	Floodplain Storage		Net Balance
	Existing Conditions (m^3)	Developed Conditions (m^3)	
1% AEP + Climate change	943,500	802,870	-143,000

5 FLOOOD HAZARD

5.1 Potential Flood Risk with Development

Modelling of flood behaviour developed by Water Technology has shown that areas within the Investigation Area may be suitable for residential development from a floodplain management perspective; however, there is still a need to assess the broader flood hazard risk. The updated design has not considered drainage requirements from stormwater generated within the site. Mapping of the 1% AEP (with climate change) velocity and water surface elevation are provided in Figure 5-2 and Figure 5-3 respectively.

The combined impact of depth and velocity is often provided as a representation of flood hazard. The ARR2019 recommendations provide a further assessment of flood hazard through the Flood Hazard categories as outlined by Australian Emergency Management Institute (2014). The categories in Table 5-1 provide recommendations for suitable design criteria based on a value from 1 to 6. TUFLOW provides ZAEM1 output values are 0 (zero) for no hazard and 1 to 6 for H1 to H6 respectively. The results of the developed flood hazard conditions are shown in Figure 5-4. The plot shows the residential areas filled above the flood level and the remaining areas mostly classified as H1 and H2 with a small area of H3 category located in the drainage reserve and floodway.

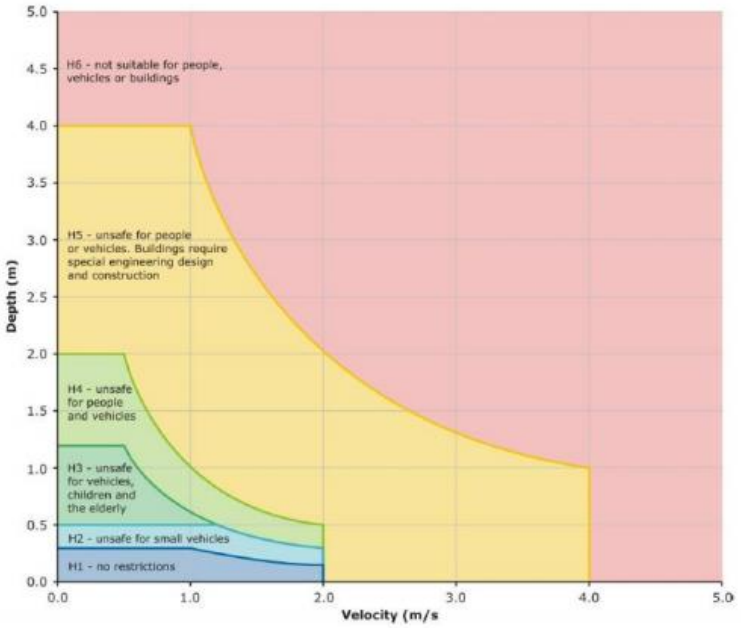

Figure 5-1 Flood Hazard Classification (ARR2019)

Table 5-1 Flood Hazard Classification Summary

Hazard Classification	Description
H1	Relatively benign flow conditions. No vulnerability constraints.
H2	Unsafe for small vehicles.
H3	Unsafe for all vehicles, children and the elderly
H4	Unsafe for all people and all vehicles
H5	Unsafe for all people and vehicles. Buildings require special engineering design and construction.
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure.

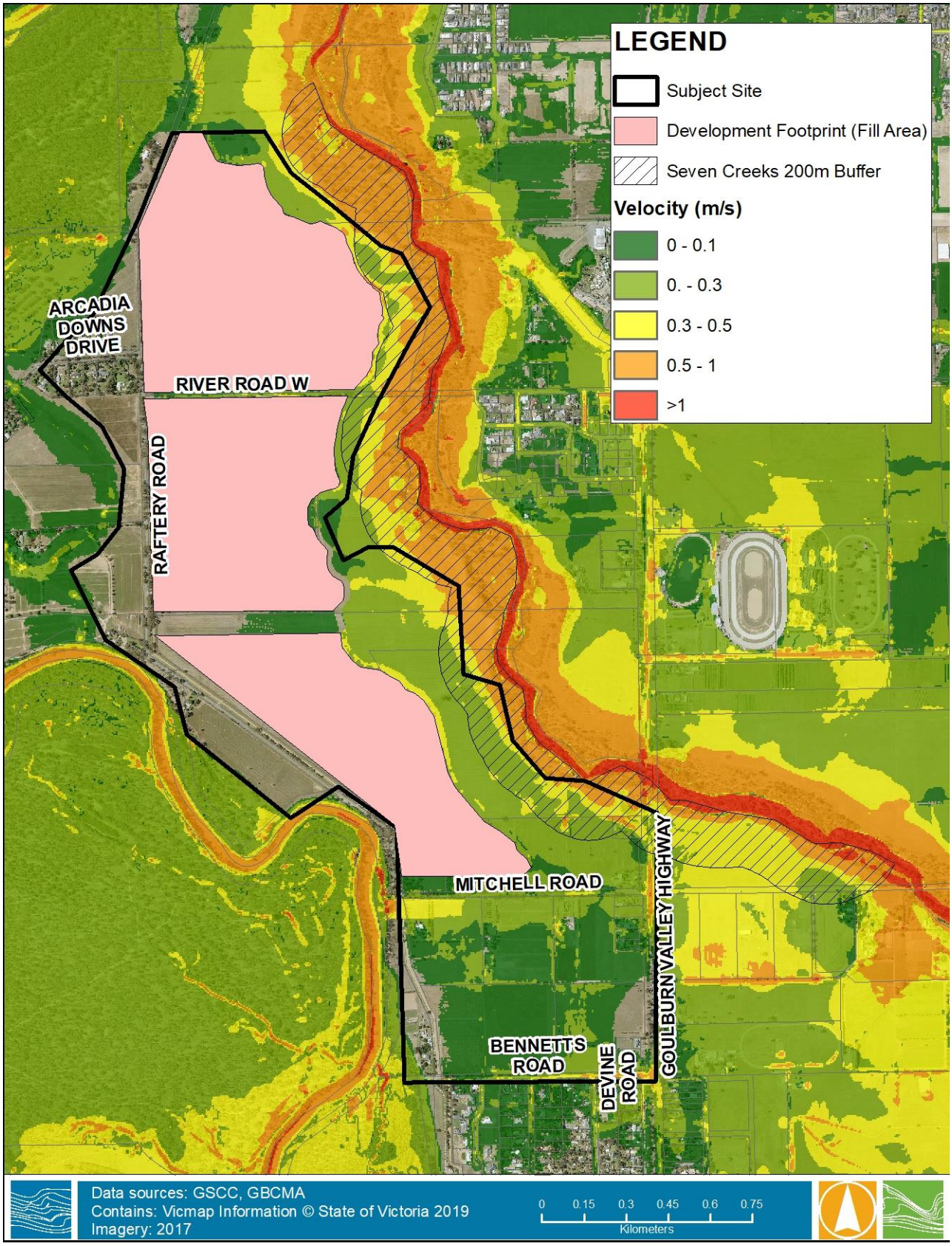

Figure 5-2 Development Scenario – 1% AEP Velocity Plot

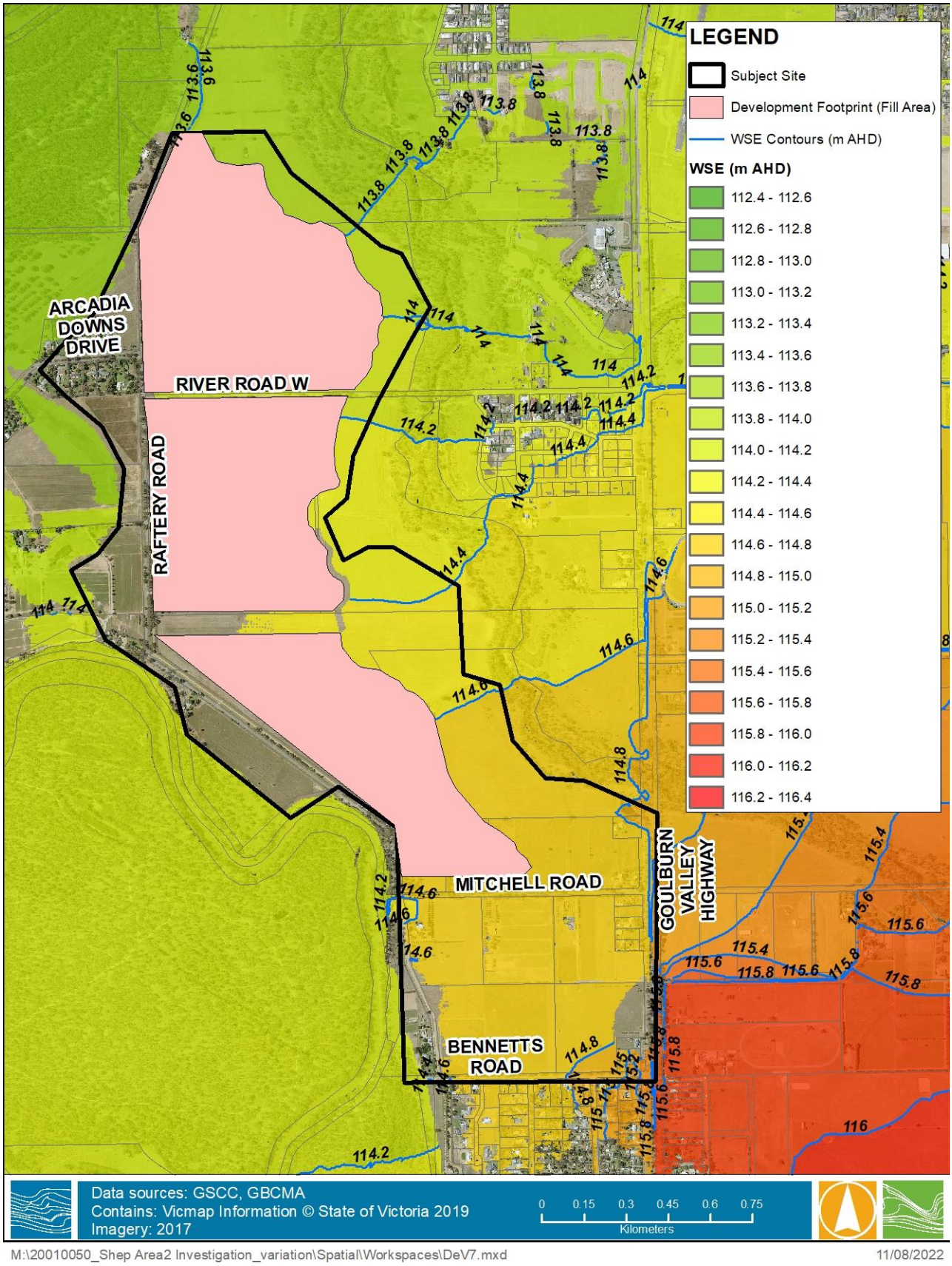

Figure 5-3 Development Scenario – 1% AEP Water Surface Elevation Plot

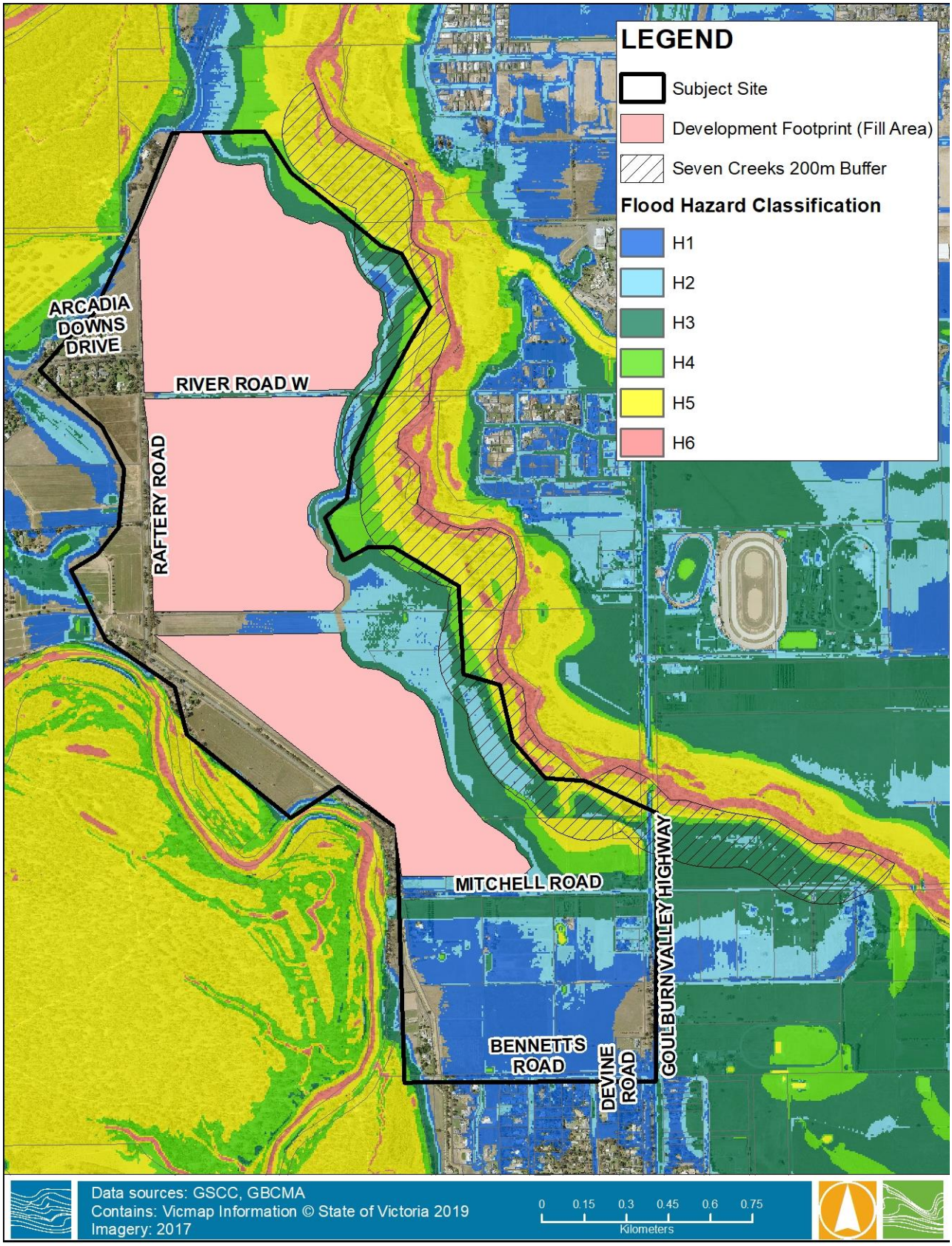

Figure 5-4 Development Scenario – 1% AEP Flood Hazard Plot

5.1.1 Flood Warning Time

The site has considerable flood warning time from a Seven Creeks flood. There are currently streamflow gauges on Seven Creeks at Kialla West, Euroa, and further upstream at Polly McQuinn Weir. These gauges provide a good indication of expected peak flooding as well as estimated flood levels at Kialla West. The Seven Creeks at Kialla West gauge (located just upstream of site) is part of the of Bureau of Meteorology Flood Warning Network and predicted flood levels are provided for this gauge.

Flood peak travel times from the gauge upstream of Euroa to Kialla West is estimated at 24-48 hours based on historical floods including 1993, 1995 and 2010.

5.1.2 Site Egress

Any vehicular and/or pedestrian access must be designed and constructed to comply with the following safety criteria as indicated by the Goulburn Broken CMA:

- Depth of flow does not exceed 0.50m; and
- Velocity of flow does not exceed 3.0m/s; and
- The Flood Hazard classification does not exceed H2.

Assessment of the developed conditions flood results along Mitchell Road and the Goulburn Valley Highway indicate that safe access can be maintained to each of the respective lots during a 1% AEP flood event (current conditions). Climate change egress was also considered as a comparison between and 'existing' and 'developed' conditions scenario.

In the 1% AEP current (2020) conditions, flood depths along the egress routes from Mitchell Road to the Goulburn Valley Highway are shown to generally be below 0.3 metres in depth with the exception of around 10m where the road profile lowers slightly. Flow velocities are less than 0.5 m/s up until reaching the shallow water overtopping the Goulburn Valley Highway where velocities increase to 0.9 m/s. The Flood Hazard classification is also shown to be at H2 or lower along this egress route.

Under the 1% AEP climate change existing development conditions, flood depths are around 150mm higher than under the current (2020) conditions. Depths in the 1% AEP climate change developed conditions event exceed 0.5 m at around 100m where the road profile lowers slightly.

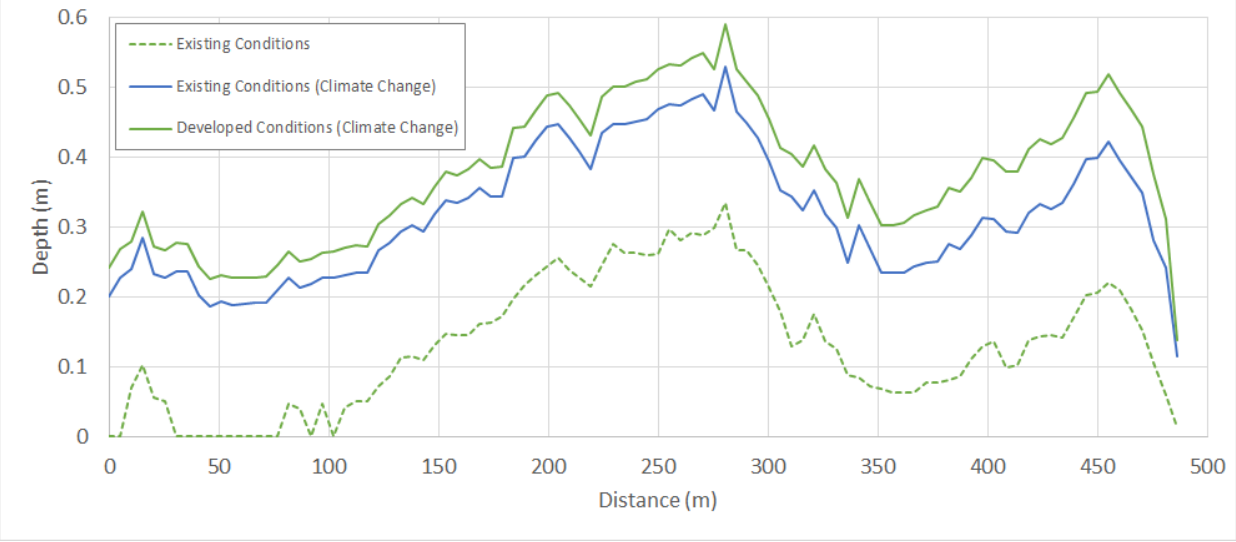

Figure 5-5 Flood Depths along egress route (Mitchell Road to GVH)

6 SUMMARY

The initial proposed development plan provided in 2020 was modified based on feedback provided by GSCC and the GBCMA due to the 1% AEP flood level increases caused by floodplain fill. To mitigate the impact on flood levels, the design layout was modified to reduce the proposed fill areas.

Flood modelling was undertaken to provide mapping outputs and highlight an area marked for development from a purely floodplain management perspective. Update to the climate change modelling suggests there is significantly more of the site inundated when using climate change modelling as the design scenario. The revised modelling shows there is a significant increase in flood levels using the development footprint from the 2020 assessment. Refinement to the development footprint has resulted in an outcome which appears to meet suitable afflux requirements.

Earthworks estimates indicate significant volumes of fill are required to be imported and there is a net loss of floodplain storage within the precinct. Further refinement and detailed flood modelling are expected to be completed at later stages of the design process, that includes incorporation of stormwater drainage assets, an internal road network (which can be inundated to depths up to 300mm) and a detailed design surface.

7 ADDENDUM

During 2022, a concept plan for the site was developed by Mesh Consulting. The plan contained a higher level of detail compared with the earlier assessment. Water Technology was engaged to incorporate the alternative design plan into the model of flood behaviour and assess the floodplain impacts.

7.1 Alternative Development Footprint

From the previous iterations, an alternative development plan (**Error! Reference source not found.**) was provided by Mesh Consulting, in conjunction with Water Modelling Solutions, for hydraulic modelling. Flood depth results for the 1% AEP with climate change are provided in Figure 7-1 below. This scenario was shown to meet several of the GBCMA's criterion, but also indicated minor afflux south of the site during the 1% AEP (climate change) event). The alternative development is understood to have been based on the following:

- The extent of fill from development is primarily confined to existing flood depths less than 0.5 metres for the 1% AEP (climate change) event. However, there are some lot and road parcels positioned within depths greater than 0.5 metres.
- The proposed lots are filled above the 1% AEP (climate change) flood level and most of the road network is subject to inundation of depths less than 0.3 metres.

Key points from the flood modelling include:

- Afflux mapping of the alternative development plan (shown in Figure 7-2) shows that, although some lot and road networks are located within exclusions zones greater than 0.5 metres, most of the development does not negatively impact neighbouring properties or the Seven Creeks water corridor. However, depths south of Mitchell Road have increases in the range of 2 to 5cm.
- Depths along Mitchell Road reach 0.62 metres approximately 270 metres west of the Goulburn Valley Highway. The resulting hazard classification is H3. It is noted this is for the 1% AEP climate change assessment.

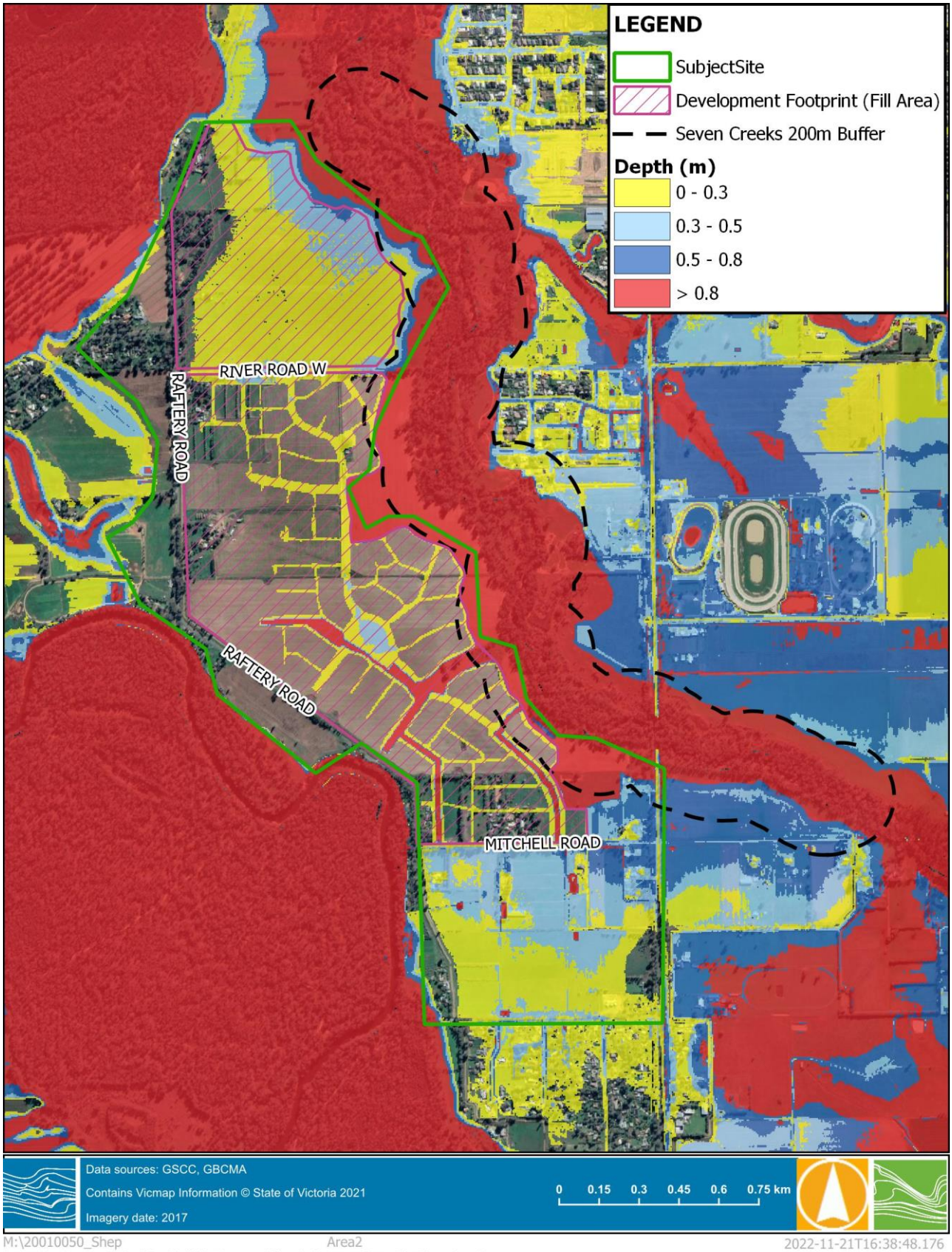

Figure 7-1 Alternative Design Plan – 1% AEP Depth

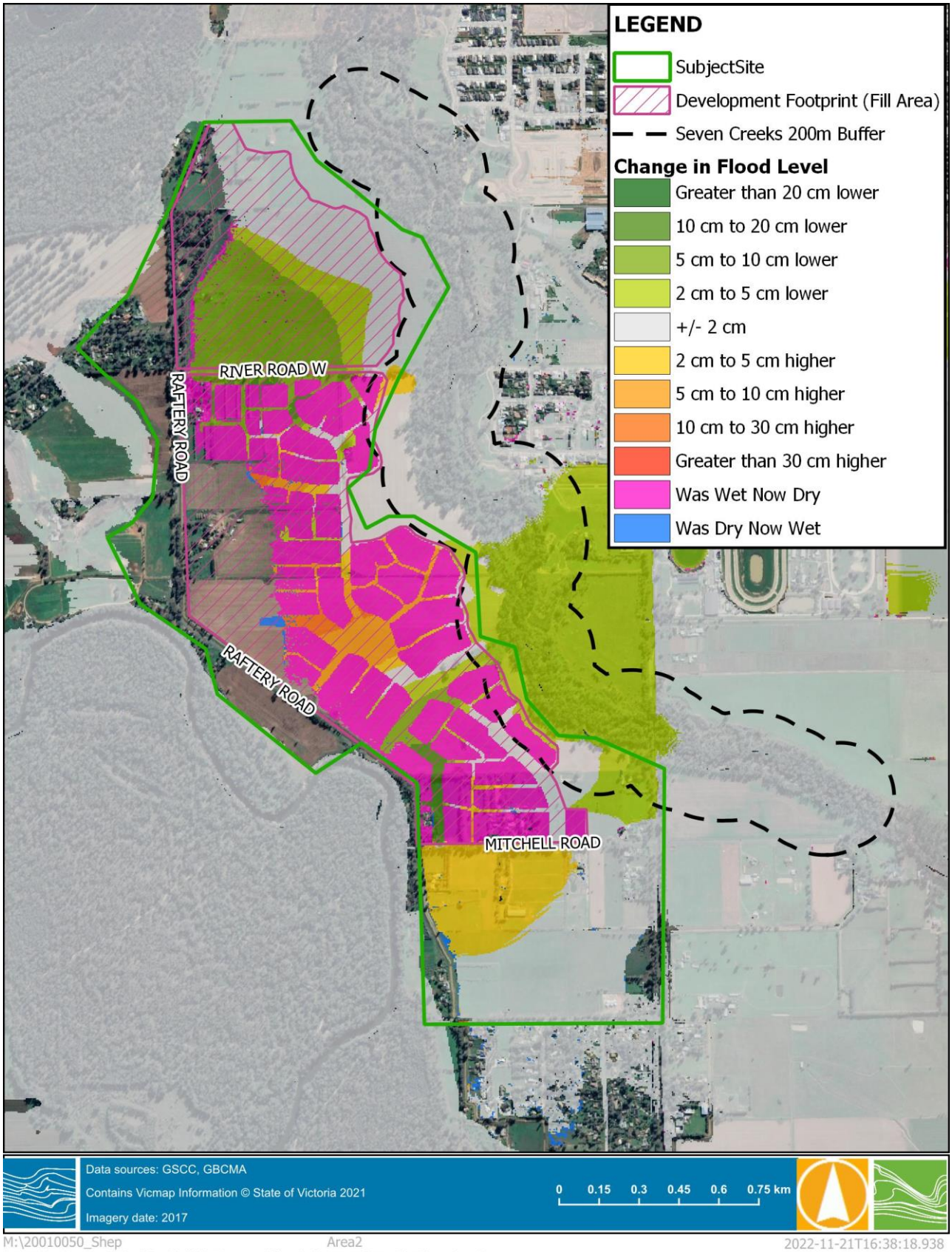

Figure 7-2 Alternative Design Plan – Flood Level Afflux

7.2 Earthworks and Floodplain Storage

The total cut and fill calculated from the alternative development plan is shown in Table 7-1 below and shows that a total of approximately 90,490 m^3 of material will need to be removed from the site (based on the assumptions adopted in the model). These calculations do not incorporate changes to floodplain storage, which are discussed further below.

Table 7-1 Cut/Fill Earthworks Summary

	Fill Required (m^3)	Cut Required (m^3)	Net Balance (m^3)
Investigation Area 2	183,340	273,830	-90,490

7.3 Floodplain Storage

Typically, the GBCMA would require than any loss of floodplain storage be compensated in a 1:1.3 ratio for a single private development. Given the size of the development been undertaken, it is understood the GBCMA will assess floodplain storage requirements on a 1:1 ratio given flood modelling has been carried out to assess the impact. It is also assumed that provided flood mapping shows no significant afflux outside of the subject site. A summary of the loss of floodplain storage (based on a 1:1 ratio) is shown in Table 7-2. This shows that the proposed development extents will result in a floodplain storage loss of approximately 231,235 m^3, which equates to around 25% of the total volume stored within the subject site under existing conditions.

Table 7-2 Floodplain Storage Summary

Storm Event	Floodplain Storage		Net Balance
	Existing Conditions (m^3)	Developed Conditions (m^3)	
1% AEP + Climate change	943,500	712,265	-231,235

7.4 Flood Hazard

Results from the modelled alternative development plan show that the residential areas and road networks within the site are classified as H1 and below. Inundation along Mitchell Road, a critical access route, is classified as H3 and regarded as unsafe for all vehicles, children and the elderly. A plot of the alternative development plan flood hazard conditions is shown in Figure 7-3 below.

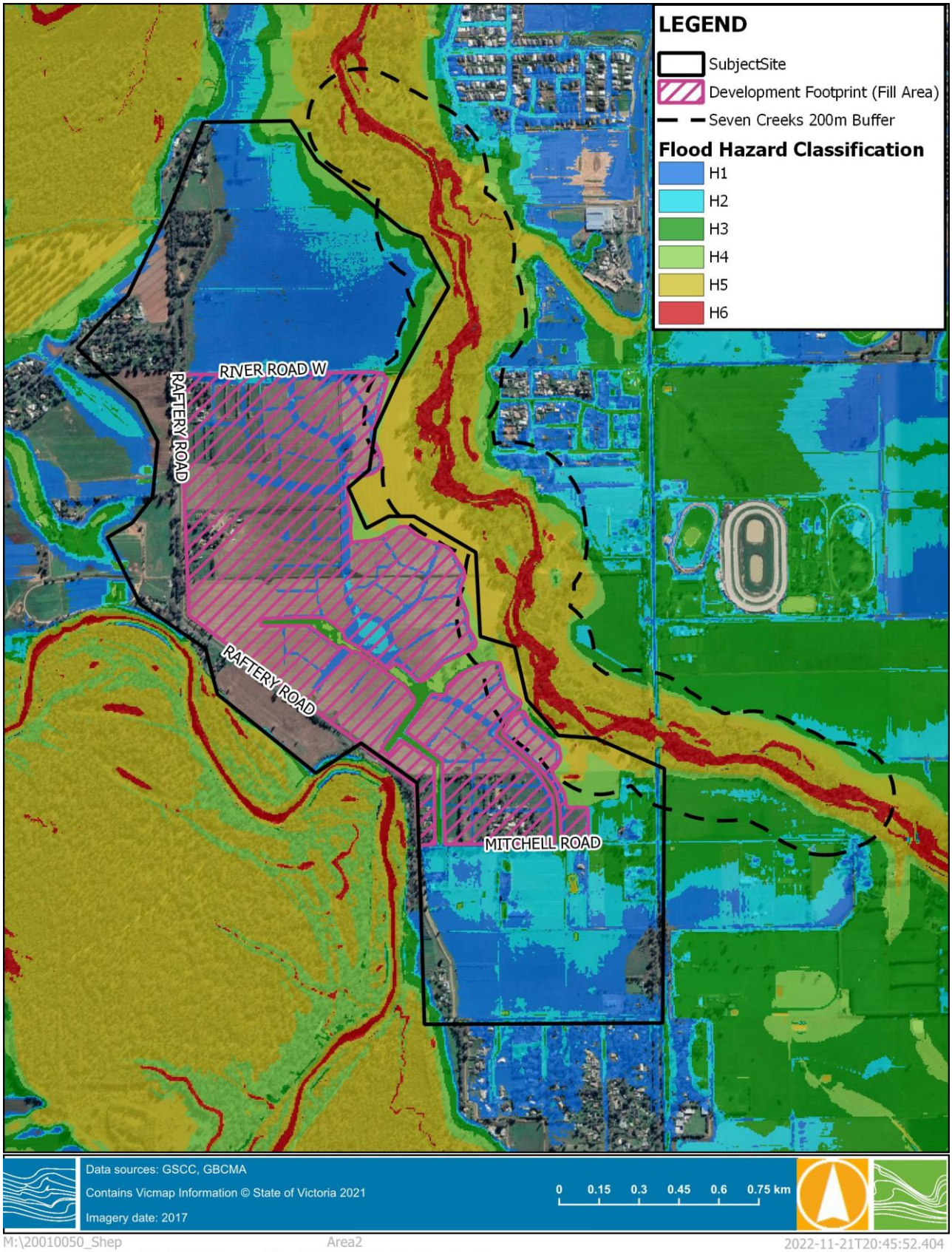

Figure 7-3 Alternative Development Plan – 1% AEP Flood Hazard Plot

1.1.1 Site Egress

Under the 1% AEP climate change Alternative Development Plan conditions, flood depths are around 4 cm higher on the west end of Mitchel Road when compared to the existing 1% AEP climate change conditions. Depths in the 1% AEP climate change Alternative Development Plan conditions reach 0.62 metres at around 250 metres (270 metres west of Goulburn Valley Highway) where the road profile lowers.

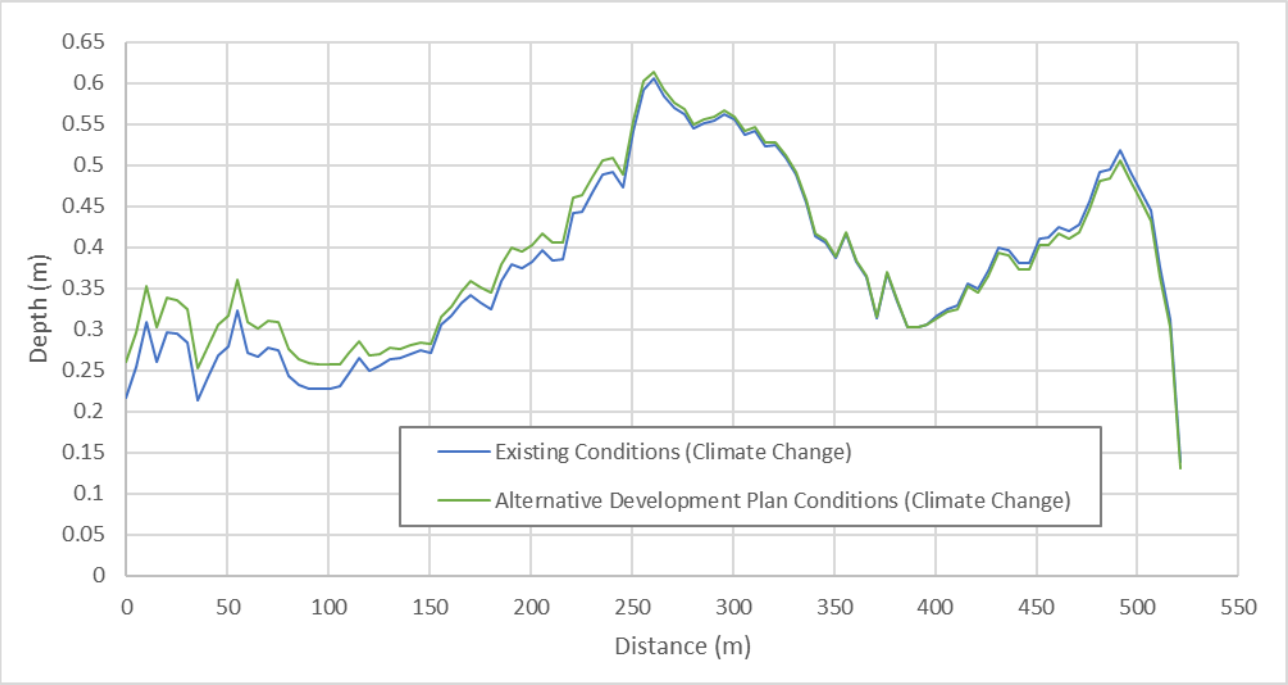

Figure 7-4 Flood Depths along egress route (Mitchell Road to GVH) – Alternative Development Plan

7.5 Summary

An alternative development plan developed by Mesh consulting in conjunction with Water Modelling Solutions was modelled to assess the impact on flood behaviour along the Seven Creeks system. The modelling has shown that there is minimal impact on flood levels outside of the investigation area. There are however some concerns regarding increased levels south of Mitchell Road. Further investigations to include a floodway south of the road or further setback of the filling of lots to the north of Mitchell Road is recommended to maintain existing flood levels (or reduce them).

A cumulative impact assessment utilising a development plan to the east of Seven Creeks may be required to ensure that the combination of development on both sides of the waterway does not negatively impact on floodplain behaviour.

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