FINAL REPORT:

BRIODY DRIVE - DEEP CREEK GEOMORPHIC ASSESSMENT

December 2023

streamology
waterway science and management

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EXECUTIVE SUMMARY

Streamology have been engaged by Summerset Torquay to undertake a geomorphic assessment of a reach of Deep Creek, Torquay. The aim of the project is to develop an understanding of the current geomorphic condition of the study reach and its potential sensitivity to changes in the flow regime associated with stormwater flows from the proposed development.

The development site is along Briody Drive, Torquay which lies approximately 60 km south of the Geelong. Stormwater will be discharged to Deep Creek, and the study reach for this project spans approximately 1.6 km of Deep Creek between Messmate Road and the Surf Coast Highway in Torquay and it is bordered at present by mostly low-density development, except for the 500 m section immediately upstream of the highway where higher density development has occurred along the southern side of the creek corridor.

The Briody Drive West Development Plan area is split into east and west catchments, and each will have its own stand-alone drainage infrastructure which separately deliver stormwater flows to Deep Creek, to the north of the site.

There is an existing Development Plan for the area that has been approved by the Surf Coast Shire. This review is undertaken on the amended Development Plan which seeks changes to the stormwater management strategy for the east catchment that will change the flow conditions at the east catchment drainage outfall to Deep Creek and moving to a ‘no detention’ strategy for the west catchment.

Based on the Storm Water Management Strategy (Colliers, 2023), it is understood that detention is not required as the developed flows do not increase the peak flows in Deep Creek as demonstrated by the Water Technology report from 2019.

The geomorphic assessment considered the length of Deep Creek from upstream of the west outlet to downstream of the Surf Coast Highway, and identified two distinct reaches of the waterway, with differing geomorphic conditions, as summarised In Section 3 of this review.

In general, it was found that between the existing culvert and approximately Yellow Gum Drive, Deep Creek is geomorphically sensitive and unstable in several locations, as indicated by the existing dumped rock structures. Upstream of the culvert to the existing dam structure is also geomorphically sensitive and unstable, with active incision and widening processes occurring, although the rate of change is unknown. These processes appear to be associated with the construction and operation of the dam.

However, the change in flows because of the development, from both the east and west catchments has a **Low** risk of triggering additional erosion above that which is already occurring in the waterway, because the timing of flood event flows reducing the peak flow in the creek and the low magnitude of the more regular catchment outflows.

To further mitigate against potential erosion risks, it is recommended that all stormwater outlet designs ensure peak flow velocities measured at the downstream of the outlet are less than 0.5 m/s. This would limit the

potential for flows from the outlets contributing to the existing incision and widening processes in the channel. Other general recommendations for the outlet design include:

- The outlets should direct flows in a downstream direction at a maximum 45-degree angle.
- An example outlet design is shown in the Melbourne Water standard drawing 7251/08/103 (Appendix 1).
- Rockwork protection is required for the bed and banks from the end of the outlet to the base of the channel (see standard drawing 7251/08/103 as an example).
- Revegetation of any areas disturbed by works using indigenous species.

Given the presence of Bellarine yellow-gum and other large trees, it is also recommended that:

- The outlets are positioned to ensure the construction footprint avoids the removal of native vegetation including any tree protection zones of Bellarine yellow-gum and other large trees.
- Boring to install each outlet could be considered to avoid and minimise the removal of native vegetation during the construction of an outlet.

To address the existing erosion and geomorphic instabilities in Deep Creek which are likely the result of previous changes to the flow regime from construction of the dam and installation of culverts, Council could consider monitoring the rate of development of the instabilities followed by erosion treatments such as grade control structures; however, any design would need to be cognisant of constraints around access and vegetation removal.

Contents

1 Introduction

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1.1 Location

The development site is along Briody Drive, Torquay which lies approximately 60 km south of the Geelong. Stormwater will be discharged to Deep Creek, and the study reach for this project spans approximately 1.6 km of Deep Creek between Messmate Road and the Surf Coast Highway in Torquay and it is bordered at present by mostly low-density development, except for the 500m section immediately upstream of the highway where higher density development has occurred along the southern side of the creek corridor.

1.2 Stormwater Management Strategy

The location of the proposed development on Briody Drive is shown in Figure 1. The stormwater management strategy for the previously endorsed development plan includes two points of discharge to Deep Creek:

1. Runoff from the West Catchment is conveyed into a treatment wetland and retarding basin and flows are discharged to Deep Creek at pre-developed flow rates.
2. Drainage from the East Catchment is conveyed directly to Deep Creek without detention.
3. Within the sub-division the 10-year ARI runoff volumes are conveyed using the pipe network, with flows above this becoming overland flows.

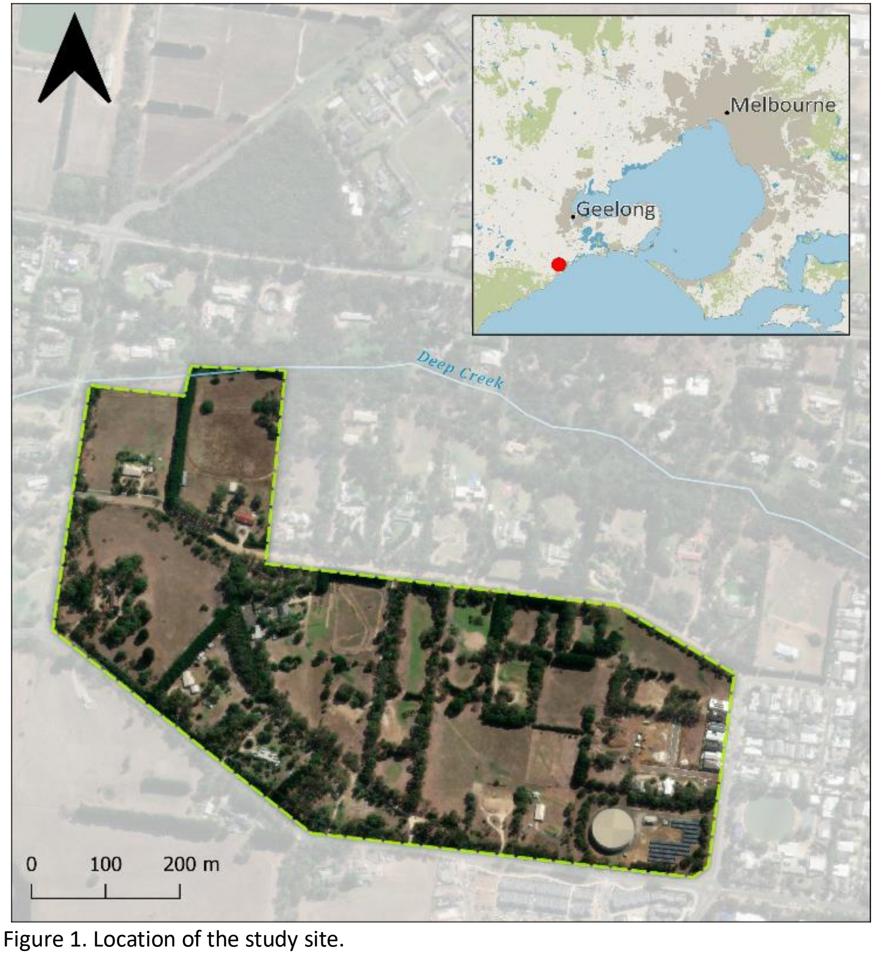


Figure 1. Location of the study site.

A revised stormwater management plan has been developed by Spiire (2020) and recently revised (Colliers, 2023).

Key features of the revised plan include:

- No flood attenuation.
- The piped network conveys flows up to the 1% AEP scenario by sizing pipe capacity for the typical 20% AEP scenario in the south of the catchment (upstream), then increasing up to the 1% AEP scenario in the northern (downstream) sections.
- Flows greater than the 20% AEP and up to and including the 1% AEP design event are to be conveyed through the Site utilising the road network as urbanised floodways.
- Stormwater quality is managed through a sediment pond and wetland for the west catchment.
- The east catchment utilises more distributed methods of stormwater treatment, inclusive of bioretention, proprietary products and stormwater harvesting.
- Stormwater harvesting using rainwater tanks (conservatively modelled as 50% uptake) within the eastern catchment only.

2 Background

2.1 Geology

The surface geology type within the study site is Torquay Group (Nt) (Figure 2). This geologic unit comprises generally marlstone, limestone, mudstone, sandstone and minor lignite. To the north-west of the study site the surface geology is Black Rock Sandstone (Nbb). This consist of sand, sandstone, conglomerate, minor sandy limestone, and local ironstone.

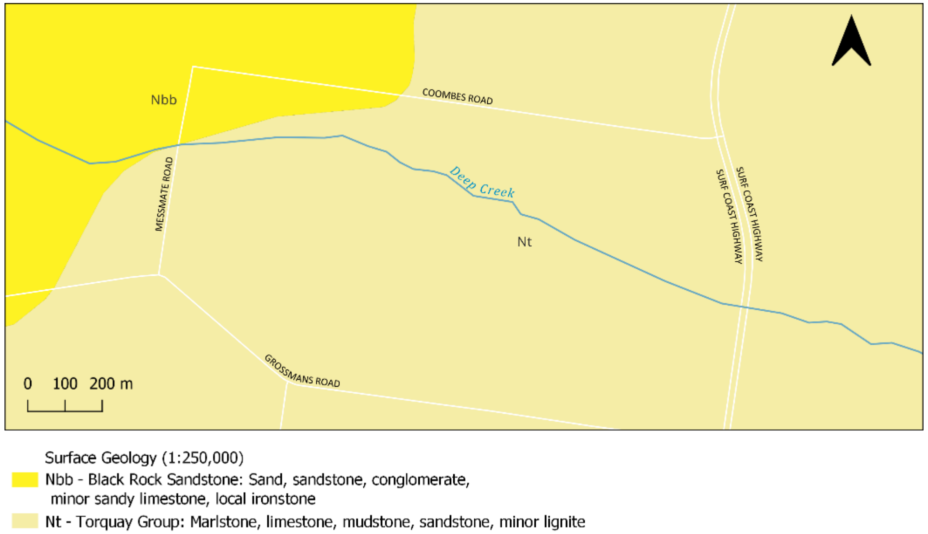


Figure 2. Surface geology types surrounding the study site.

2.2 Soil

The soil type mapped within the study area is Chromosols (CH). Chromosols have a strong texture contrast between the upper A horizons and the lower B horizons, which are not strongly acid (CSIRO, 2016).

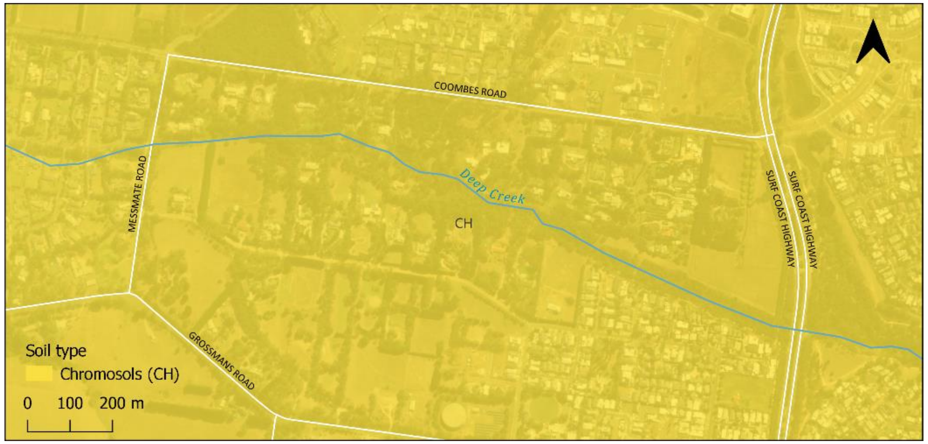


Figure 3. Soil types covering study site.

2.3 Geomorphology

The Victorian Geomorphological Framework (VRO, 2007) places the study site within the geomorphological management unit 6.2.4.

6.2.4 Western Plains; Sedimentary plains (Plains on unconsolidated (sedimentary) deposits; Plains and plains with low rises (Duck Hole Plain, Irrewillipe, Hanson Plain)

Western Plains are made up of low-lying undulating plains formed on both volcanic and sedimentary lithologies. This geomorphological management unit is characterised by undissected sand plains that occupy an area south of the volcanic plains and north of the Heytesbury (Hanson Plain, Ross Plain, Duck Hole Plain, Saddlecloth Plain). It is characterised by flat landscapes and gently low rises. further north, around Leslie Manor, sand plains are present through the basalt plains. to the east, a remnant of the sedimentary plains forms a gently dissected plains north of Anglesea. This geomorphic unit include sodic and non-sodic mottled texture contrast soils. (VRO, 2007).

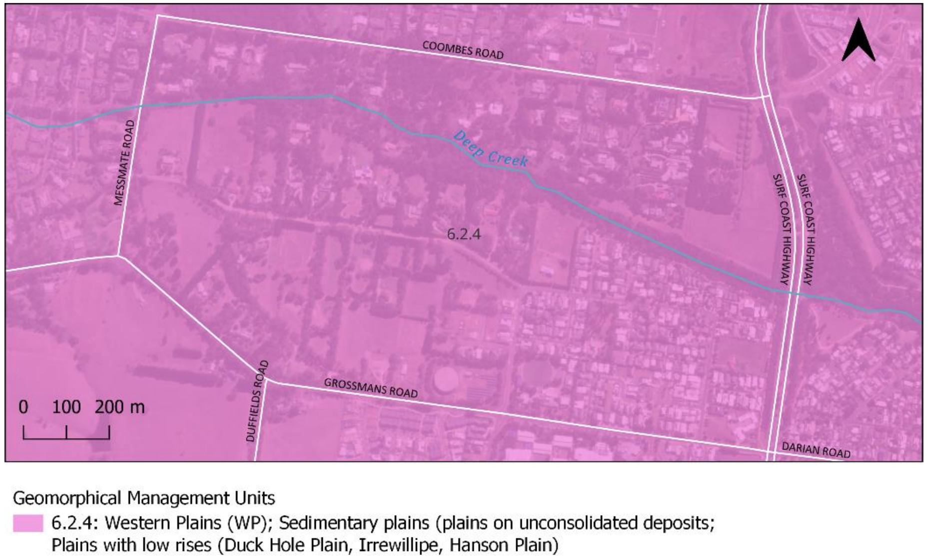


Figure 4. Geomorphological Management Unit 7.2.2 covers entirety of the study site.

2.4 Vegetation

To support this geomorphic assessment, a vegetation assessment of the Deep Creek riparian corridor was completed by Ökologie Consulting in November 2023 (Appendix 1). The assessment found that the waterway corridor was characterised by a modified cover of Grassy Woodland, interspersed with exotic dominated grassland. One state listed threatened flora species, Bellarine Yellow-gum *Eucalyptus leucoxylon* subsp. *Bellarinensis*, was recorded in the assessment area (Figure 5). No listed threatened fauna species or associated habitats were recorded in the field assessment, and none are considered likely to occur due to the absence of suitable habitat.

In addition, four listed protected species (Golden Wattle, Prickly Moses, Tree Everlasting and Black Wattle) were also recorded in the assessment area.

Figure 5 Ecological Features of Deep Creek, Torquay

2.5 Flow Conditions

Deep Creek is ungauged and therefore no long-term flow information is available. However, previous investigations as part of the stormwater management plan for the development included flood modelling by Water Technology (Spiire, 2022). The modelling included both frequent events (2-year ARI) and less frequent events (10- and 100- year ARI events).

From a geomorphic perspective, the more frequent events are often more critical if the waterway is sensitive to erosion, as the threshold for erosion of bed and bank materials tends to be around the 1- to 2- year ARI event magnitude.

Flood events

The peak flow in Deep Creek upstream of the development is estimated to be 1.0 m^3/s and 3.58 m^3/s for the 2-year and 10-year ARI events respectively. Corresponding flows from the west catchment were 0.28 m^3/s and 0.07 m^3/s for these events, and 0.46 m^3/s and 0.11 m^3/s for the east catchment respectively.

Figure 6 and Figure 7 show the modelled flow velocity results for the 2-year ARI flood event, highlighting where velocities are greater than 0.5 m/s which is an indicative erosion threshold for medium to coarse sand.

Maps of the modelled flood depths and velocities for both existing and developed conditions are presented in the Figure 8 to Figure 15. As noted in the recently updated Stormwater Management Plan (Colliers, 2023) "no meaningful changes in flooding were identified in during the modelled storm events" and confirmed that although there are changes to the proposed Stormwater Management Plan since the modelling was undertake, the changes do not impact the results.

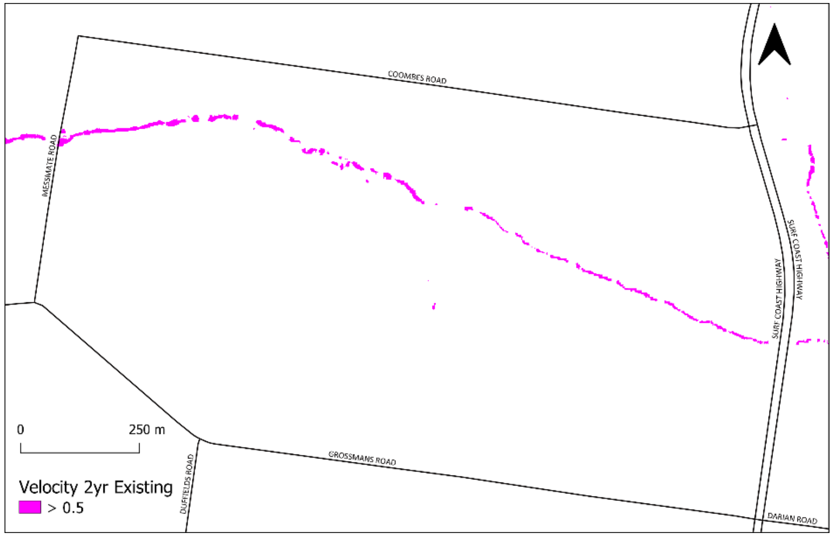


Figure 6. Velocity above a threshold of 0.5 m/s for a 2-year ARI flood event for existing conditions

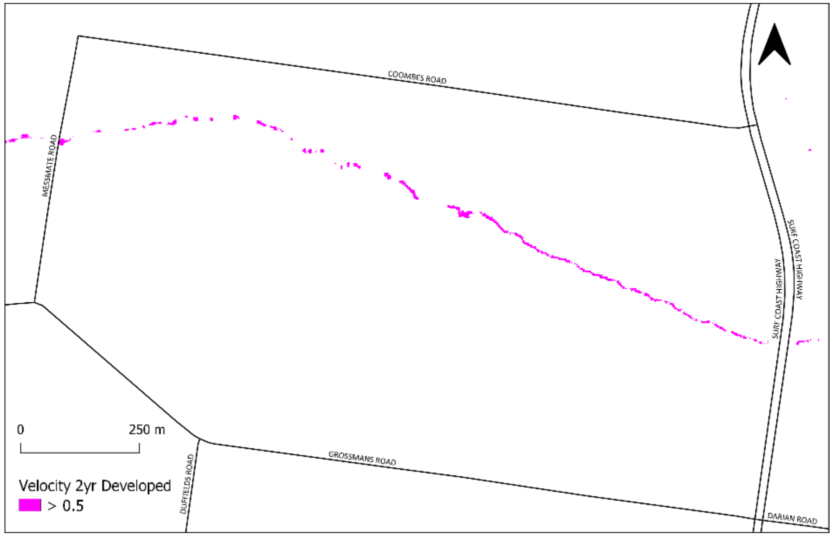


Figure 7. Velocity above a threshold of 0.5 m/s for a 2-year ARI event for developed conditions

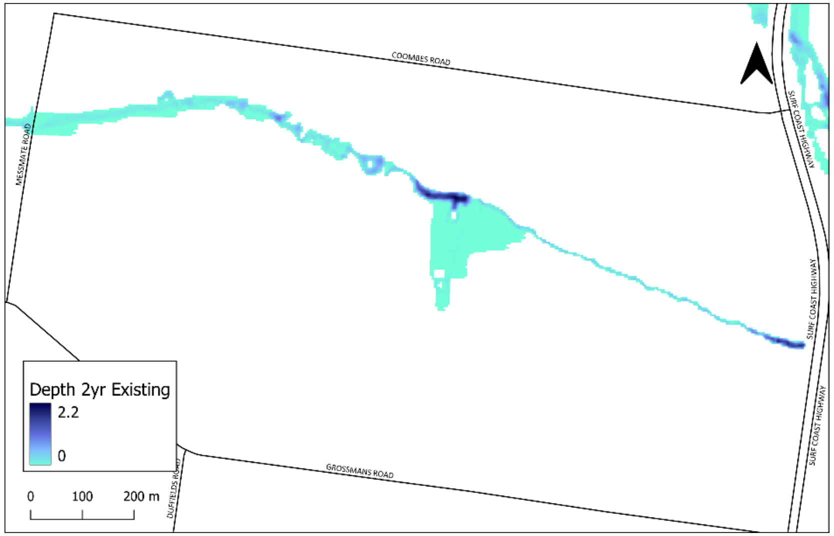


Figure 8. Flood depth for 2-year ARI event for existing conditions.

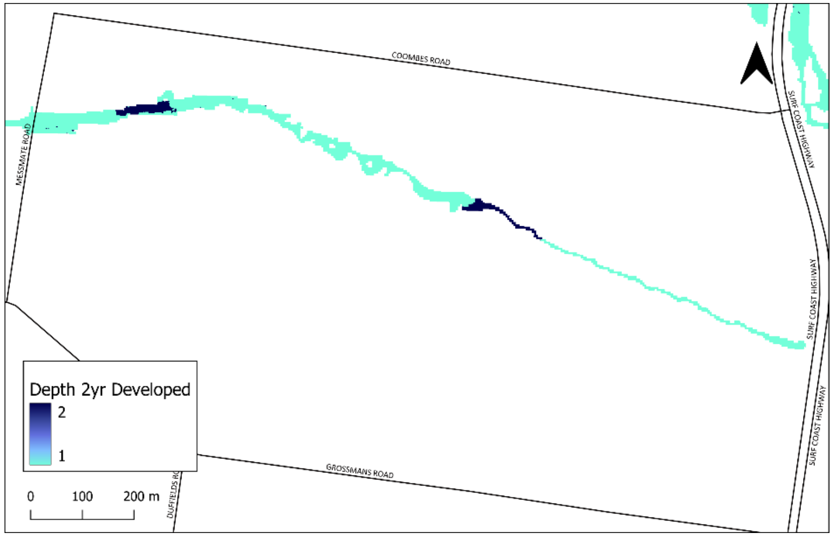


Figure 10. Flood depth for 2-year ARI event for developed conditions.

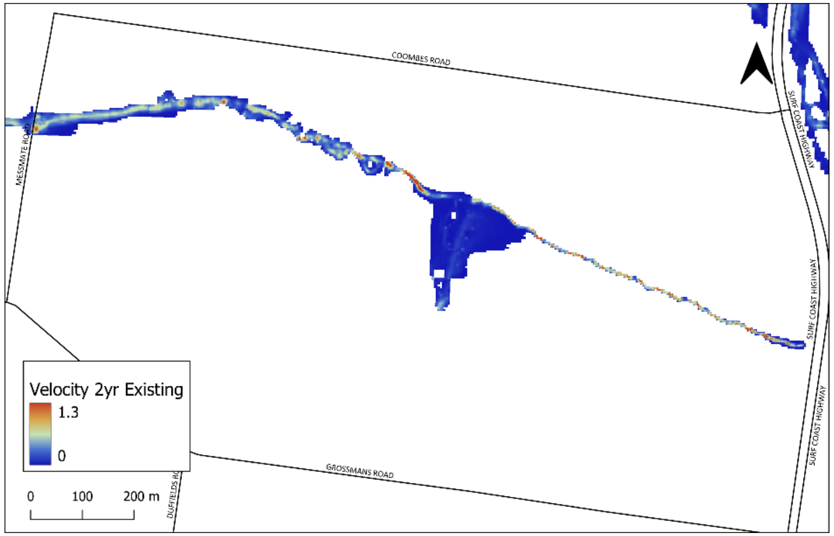


Figure 9. Flood velocity for 2-year ARI event for existing conditions.

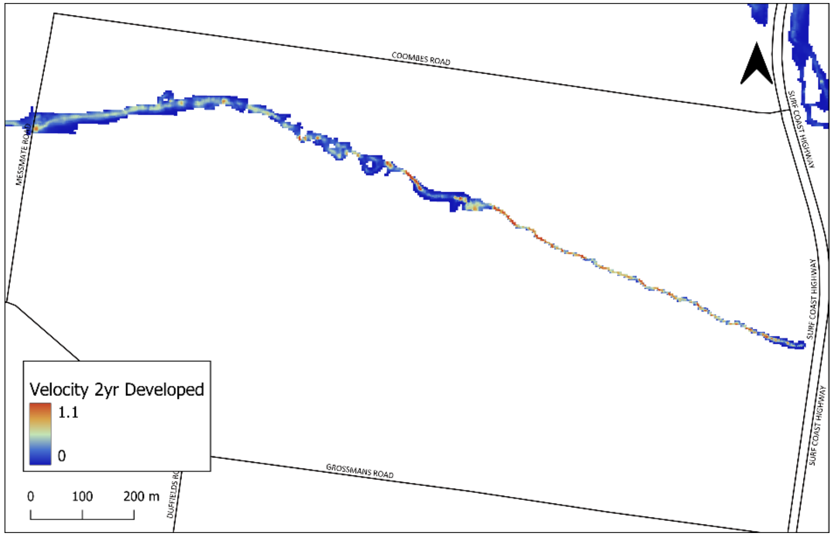


Figure 11. Flood velocity for 2-year ARI event for developed conditions.

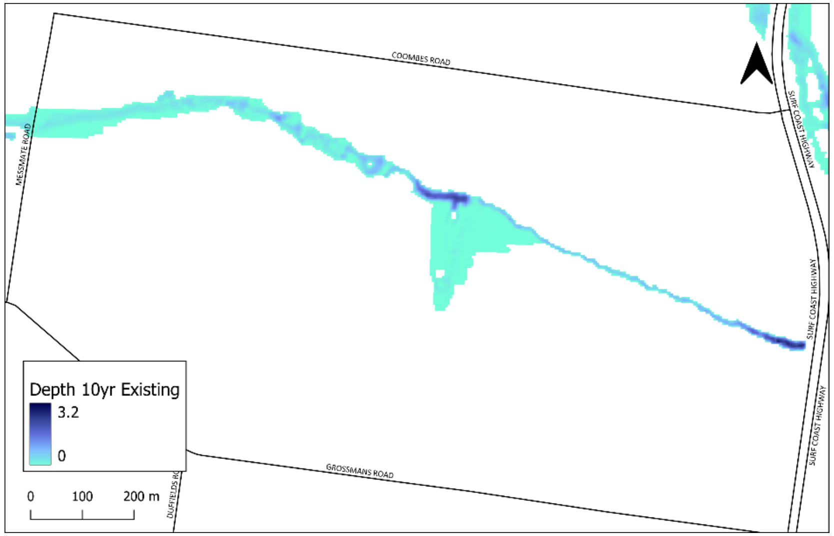


Figure 12. Flood depth for 10-year ARI event for existing conditions.

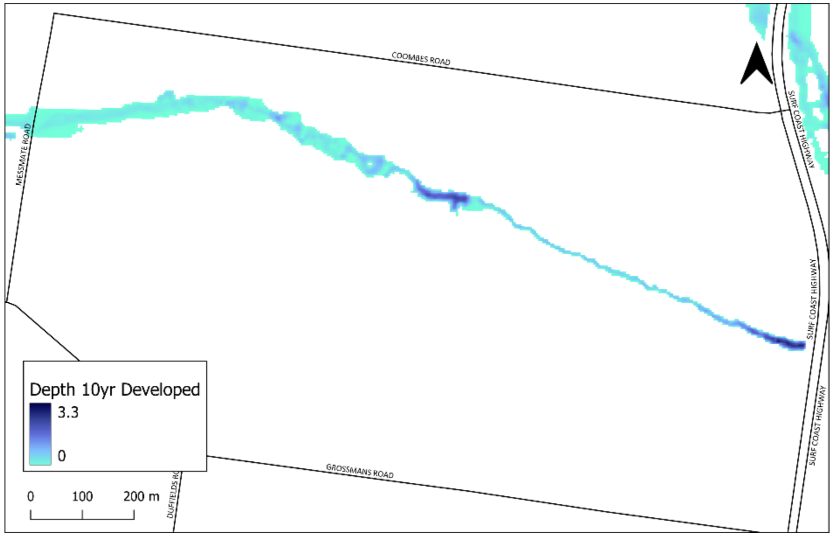


Figure 14. Flood depth for 10-year ARI event for developed conditions.

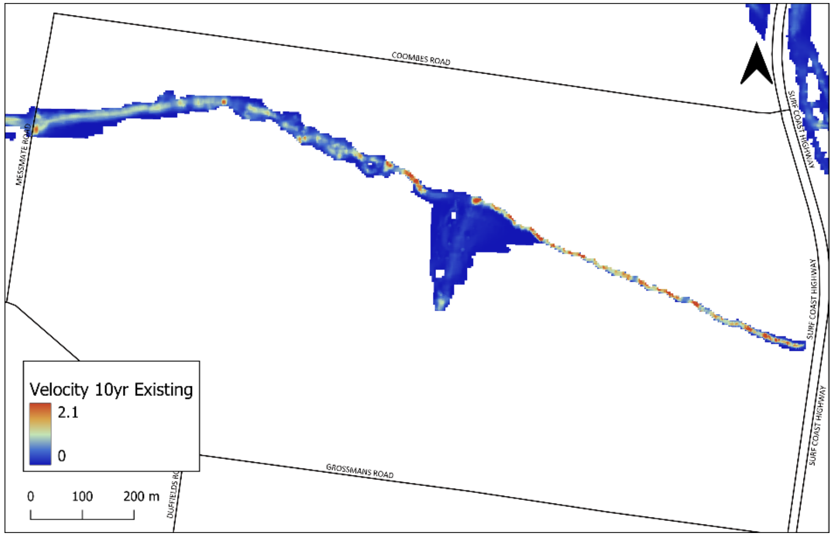


Figure 13. Flood velocity for 10-year ARI event for existing conditions.

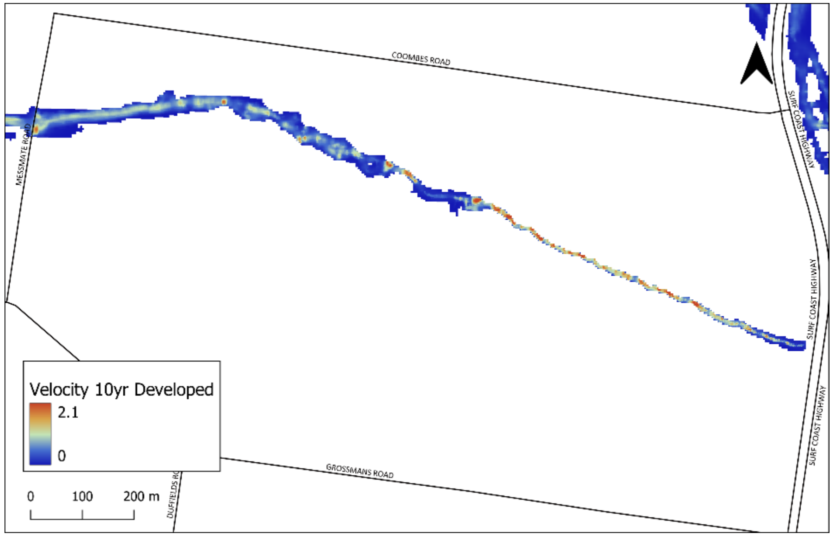


Figure 15. Flood velocity for 10-year ARI event for developed conditions.

Flow regime

To characterise the range in outflows from the proposed development into Deep Creek at the east outlet, the time series of outflows from the MUSIC model provided by Colliers for this assessment are presented as an annual flow duration curve in Figure 16 and seasonal curves in Figure 17.

The flows regime can also be described through hydrologic metrics, and a selected of relevant metrics for the outflows are presented in Table 1.

Unfortunately, there is no gauged flow data for Deep Creek for comparison, however this analysis shows that the mean daily flow from the development for the combined east and west catchments is only 0.04 ML/d, and more than 80% of the time the flow is less than 0.2 ML/d (0.0023 m^3/s).

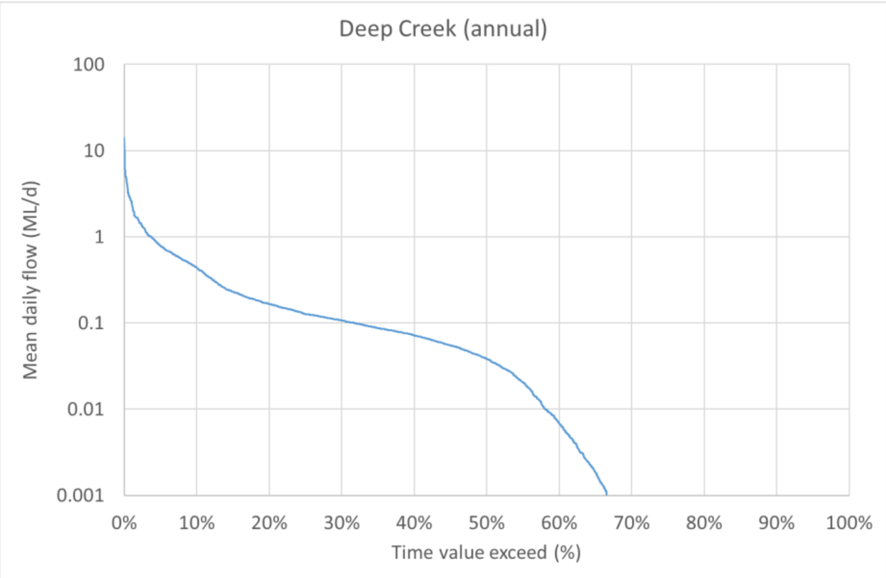


Figure 16. Annual flow duration curve for outflows from the site for developed conditions

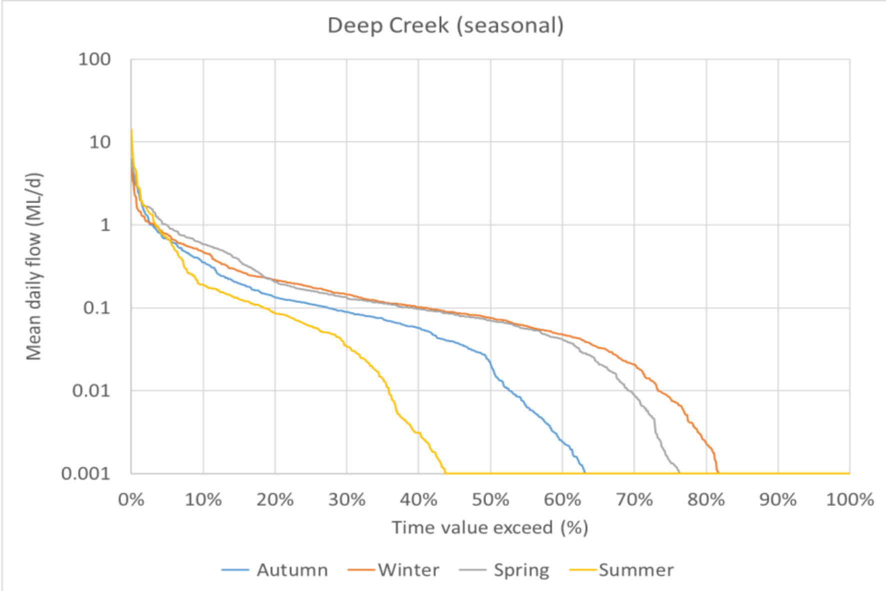


Figure 17. Seasonal flow duration curves for outflows from the site for developed conditions.

Table 1 Flow components and metrics for the outflows from the site for developed conditions

Flow Component	Flow Metric	Developed
Flow dynamics	Maximum (ML/d)	14.1
	Minimum (ML/d)	0.001
	Mean (ML/d)	0.2
	Mean Annual Flow Volume (ML)	65.2
	Median (ML/d)	0.038
Zero Flow	Average 0 flow duration (days)	6.8
	% of time with zero flow	33.4
Freshes	# fresh events (> 3 x median)/yr	33.2
	% of time over fresh event	28.1
Baseflow	Baseflow index	0.2
	Mean daily baseflow (ML/d)	0.03

3 Field observations & existing condition assessment

3.1 Field observations

A field assessment was undertaken on the 20th of October 2023 by Greg Peters from Streamology. The aim of the visit was to:

- Assess the current physical form condition of Deep Creek & geomorphic sensitivity to change.
- Identify any existing flow related impacts along Deep Creek.

The field assessment reach of Deep Creek was from Piper Lane (upstream) to The Esplanade (downstream) as shown in Figure 18. The proposed stormwater outlet for the east catchment is located at approximately pin 3 in the figure.

An overview of the field observations is provided in the remainder of this section.

Figure 18 Assessment locations and reaches along Deep Creek

Reach 1 – upstream of Yellow Gum Place (locations 1-6)

Physical form

- Streambed. This segment appears to be actively incising and is currently in the deepening phase (the initial stage of incision). No obvious knickpoints were observed in the streambed during the assessment, however the channel was not flowing making such observations difficult. The dominant bed material throughout this reach was sand.
- Streambanks. Within the incised low-flow channel, the banks are vertical with some signs of undercutting downstream. Overtime it is likely that the incision channel will widen.

Vegetation

- Instream. Minimal instream vegetation was observed in the upper sections of this segment.
- Riparian. The riparian vegetation throughout this segment is largely intact with minimal weed cover. Vegetation along the right bank (looking downstream) becomes more in the lower sections enabling the encroachment of exotic grasses.

Photo 1 – Tributary input to Deep Creek (looking upstream). Gully is developing and deepening in response to lower bed level in Deep Creek.

Photo 2 – Deep Creek (looking downstream). The waterway has incised with a 1.5 x 1.5m box channel cut into the creek bed. Subsequent widening as the next phase following incision has not occurred. Streambed is sandy. Riparian vegetation is relatively intact.

Photo 3 – Upstream end of culvert at Deep Creek crossing. Pipe diameter is approx. 1.5m.

Photo 4 – Below informal timber crossing of Deep Creek (looking downstream). Waterway is incised with evidence of bank undercutting. Right bank vegetation becomes more cleared allowing introduced grasses to enter the riparian zone.

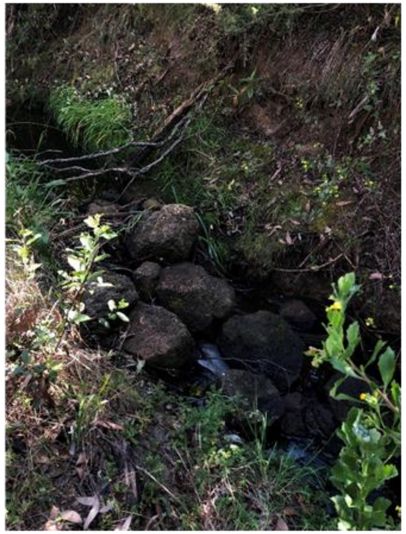


Photo 5 – Informal rock structure in Deep Creek. Rocks have been placed to reduce bed deepening with noticeable effect on water levels upstream and downstream.

Photo 6 – Deep Creek looking downstream from informal rock structure. Evidence of undercutting occurring along left bank.

Reach 2 –Yellow Gum Place (locations 7-13)

Physical form

- Streambed. This segment appears to be relatively stable with some aggradation in the upper sections (noted by the dominance of cumbungi in the section upstream of the crossing adjacent Saltbush Place). The dominant bed material changes in this segment from sandy to gravelly (with the source of the gravel being road base from the south which enter the stream from the stormwater network).
- Streambanks. No erosion was observed, and the deeply incised segment of Deep Creek appears to have reached a new stable equilibrium.

Vegetation

- Instream. The streambed is relatively devoid of instream vegetation other than the dense stand of cumbungi upstream of the crossing adjacent Saltbush Place.
- Riparian. The riparian vegetation throughout this segment is largely intact with only isolated weed species observed

Photo 7 – Beginning of emergent aquatic vegetation (cumbungi) in the streambed of Deep Creek.

Photo 8 –Upstream end of culvert at Deep Creek crossing. Pipe diameter is approx. 1.5m.

Photo 9 – Dense cumbungi stand (looking upstream from Deep Creek crossing).

Photo 10 – Typical channel profile of Deep Creek (looking downstream). Streambed has changed from sandy to gravels overlaying sands. The gravels are coming from the adjacent road networks to the south and entering the channel via stormwater (particularly overflow structures).

Photo 11 – Stormwater infrastructure adjacent to the walking track at the bottom of Tea Tree Rise.

Photo 12 – Stormwater overflow structure entering Deep Creek at the bottom of Tea Tree Rise.

Reach 3 –Surf Coast Highway to The Esplanade (locations 14-17)

Physical form

- Streambed. This segment appears to be relatively stable.
- Streambanks. No erosion was observed, and the deeply incised segment of Deep Creek has reached a new stable equilibrium

Vegetation

- Instream. Minimal surface flows occur through this segment, enabling vegetation to colonise the streambed, particularly in the lower sections.
- Riparian. The riparian vegetation throughout this segment is a mix of native and introduced vegetation


Photo 14 – Typical channel profile of Deep Creek (looking upstream from Fisher Street culvert).


Photo 15 – Downtream end of stormwater inlet to to Deep Creek (upstream of Fisher Street). Pipe diameter is approx. 1.0m.

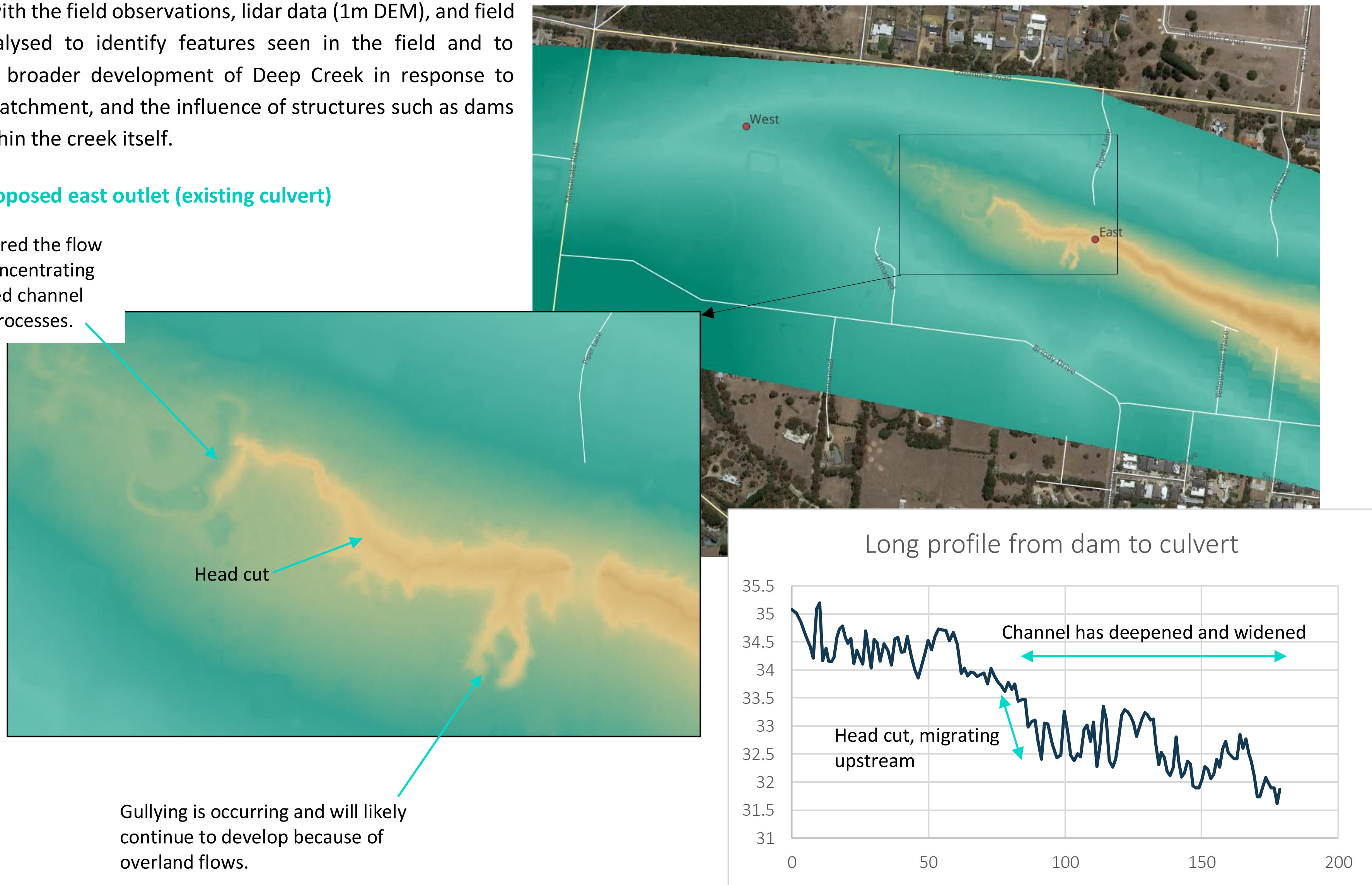

Photo 16 – Upstream end of culvert along Deep Creek at Fisher Street crossing. Pipe diameter is approx. 2.0m.


Photo 17 – Typical channel profile of Deep Creek (looking downstream from walk-bridge towards The Esplanade).

3.2 Current geomorphic condition

In conjunction with the field observations, lidar data (1m DEM), and field survey was analysed to identify features seen in the field and to understand the broader development of Deep Creek in response to changes in the catchment, and the influence of structures such as dams and culverts within the creek itself.

Upstream of proposed east outlet (existing culvert)

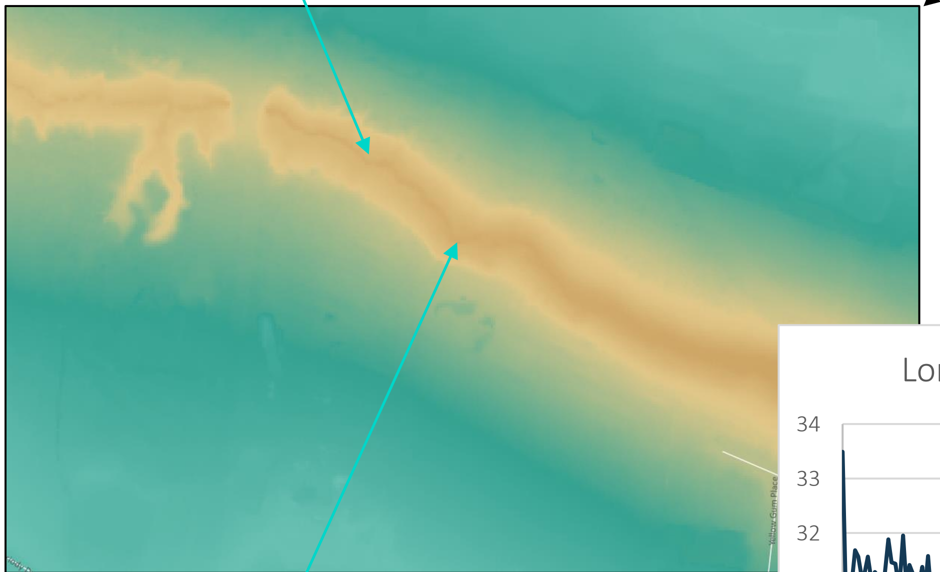


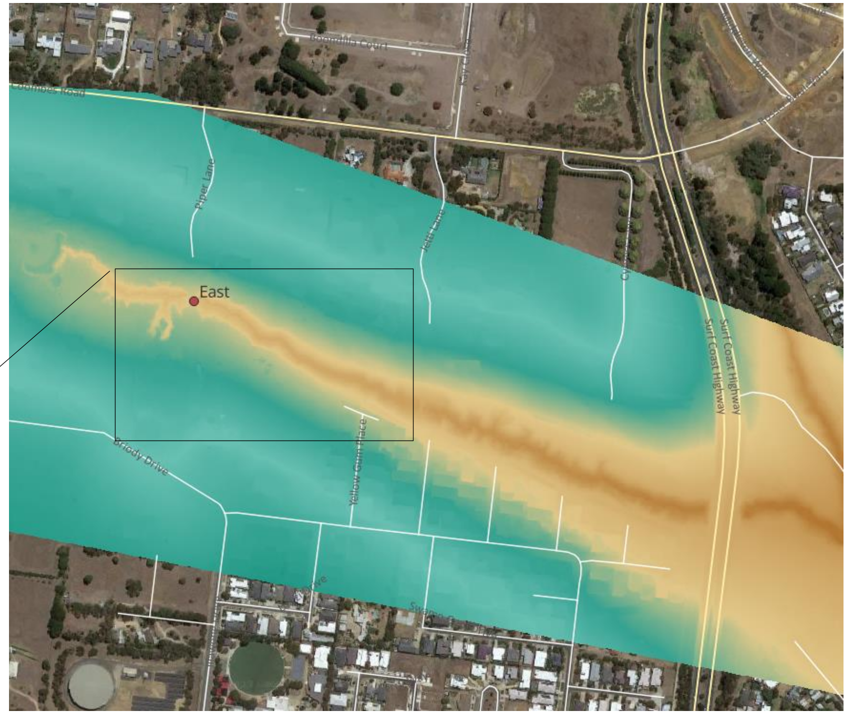
Downstream of proposed east outlet (existing culvert)

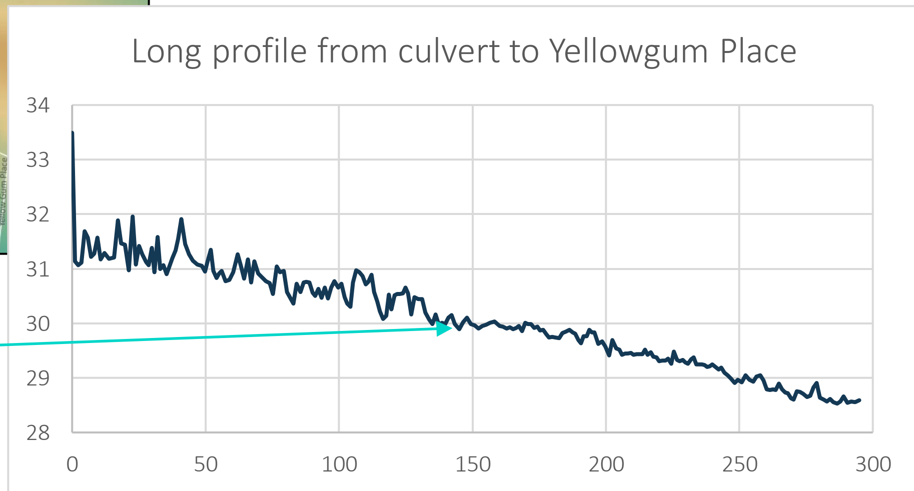
Downstream of the existing culvert the channel is wider, with a deepening low flow channel. There is a step change in the bed level at the culvert, with the invert of the bed upstream at 31.8 m AHD, and 31.1 m AHD downstream of the culvert.

Approximately 150m downstream of the culvert the channel appears to have stabilised where a sediment depositional zone has formed.

Defined low flow channel.







Depositional zone, increased stability downstream to the Surf Coast Highway.

There are several steeper sections of channel downstream of the culvert some of which appear to be associated with previous in-channel bed stabilisation works (i.e., grade control works). For example, approximately 70 m downstream of the culvert, dumped rock was observed in the channel (approximately cross-section H from the field survey, Figure 19).

Photo 8. - (Cross section H)

Figure 19 Photo from the field survey at cross-section H showing previous in-channel rock works, likely installed to address incision and erosion processes

4 Geomorphic risk assessment

4.1 Current geomorphic condition and sensitivity

The physical form of a channel can be related to condition through the Channel Evolution Model (CEM). We know that channels undergoing change due to increased catchment stressors are likely to undergo channel incision. This means they deepen, then widen, and this may continue through various stages Figure 20). The first stage of the CEM sees waterway channels that are typically stable (Type I). The second stage (Type II) is the incision stage where the channel bed lowers, followed by channel widening (Type III) where failure of banks occurs as they become over-steepened. A recovery stage (Type IV) occurs when the channel widens to a point where it can accommodate incoming flow energy without further erosion and receives sediment from upstream to rebuild in-channel features. If recovery occurs, then a low-flow channel is re-established (Type V) within the new broader stable channel.

Deep Creek downstream of Messmate Road has experienced change under the current hydrologic regime, with these changes triggering erosional processes, as evidenced by the dam and culvert structures, along with incision and widening processes observed on site and in the lidar.

Current geomorphic conditions can be summarised as follows:

- Upstream of the dam structure, the channel retains is original form (Type 1).
- From the dam to the culvert structure, the channel is in the process of deepening and widening (Type II to III) with instability along the channel itself in the form of head cuts, and gully formation.
- From the culvert to approximately Yellow Gum Drive, it appears that the incision process is slowing and widening Is becoming more dominant.
- The reach from Yellow Gum Drive to the Surf Coast Highway has already deepened and widened, and then aggraded, putting it in a Type IV to V category.

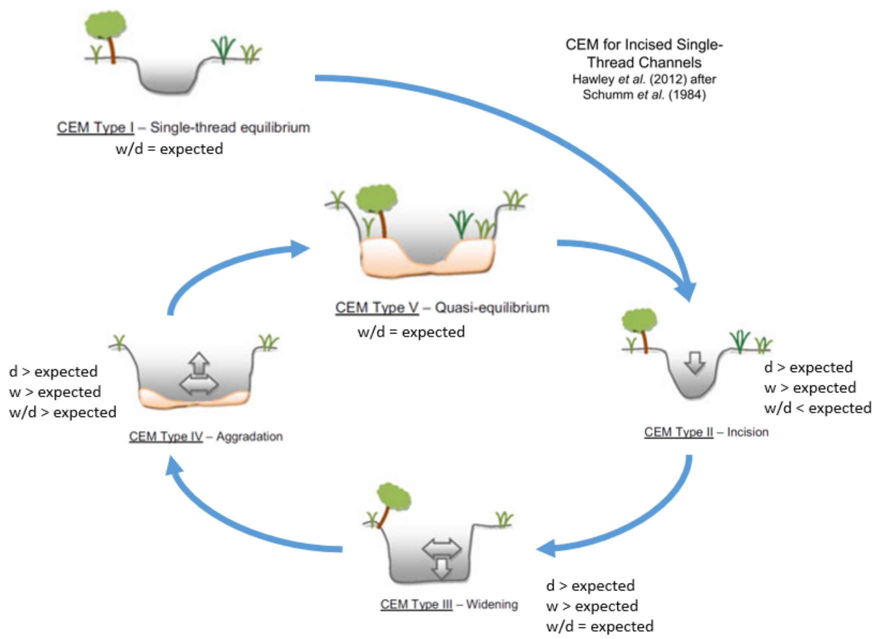


Figure 20 Channel evolution model (Hawley et al. 2012 after Schumm et al. 1984)

Based on the current geomorphic condition of Deep Creek, the section of waterway between the existing dam structure and culvert is likely to be the most sensitive to changes in the hydrologic regime, followed by the reach downstream of the culvert to around Yellow Gum Drive.

4.2 Flow changes and geomorphic impacts

Flow changes

Flows changes because of increased stormwater inputs are variable in terms of their impacts on Deep Creek.

- Flow depths are marginally (up to 0.01m) higher under the modelled developed conditions upstream of the culvert for large flood events (e.g., 100-year ARI). For the modelled 2-year ARI event the change in depth is more variable because of changes to the overland flows paths towards Deep Creek from the east catchment.
- In general, upstream of the culvert, velocities are lower as the channel is less incised and the flood extent is wider for both existing and developed conditions. Similar to the depth results, changes in velocity are variable due to changes in flow distribution.
- Upstream of the culvert under a 2-year ARI event, locations where the erosion threshold of 0.5 m/s is exceeded are reduced for developed conditions compared to current conditions whereas downstream of the culvert there is a slight increase in length of channel affected by flows above this threshold (Figure 6 and Figure 7). The length of channel impacted aligns with the section between the culvert and Yellow Gum Drive. This occurs because of the reduction in the overland flow path extent from the east catchment for developed conditions.
- For more regular flow conditions (e.g. < 1-year ARI), flows from the both the west and east catchments are low, with combined outflows from the catchments less than 0.2 ML/d (0.0023 m^3/s) more than 80% of the time. These flows do not exceed the erosion threshold and would not be sufficient to increase the flows in the creek above the erosion threshold.

Geomorphic impacts

East Outlet

Overall, the flows from the proposed east outlet for developed conditions are low and unlikely to exceed erosion thresholds under most flow conditions by themselves. As the stormwater management plan allows for unretarded flows from the development, the outflows enter Deep Creek before upstream flows and therefore do not increase the peak flows in the waterway. Regular flows from the east catchment are also low and unlikely to exceed the erosion threshold. Therefore, the risk of additional erosion along Deep Creek due to the east catchment development flows under flood events and regular flow conditions is **Low**.

However, due to the geomorphic sensitivity of the waterway between the culvert and Yellow Gum Drive, it is recommended that the stormwater outlet design ensures peak flow velocities are less than 0.5 m/s. This would further limit potential for flows from the east outlet contributing to the existing incision and widening processes in the channel.

Given the low risk of additional erosion being triggered by the proposed outlet, not additional erosion control works are necessary beyond the outlet. However, to stabilise the existing incision and widening processes downstream of the culvert and the new outlet structure, formalising the existing dumped rock structure approximately 70m downstream of the culvert using a grade control structure such as a rock chute is recommended. The change in grade at this location is around 0.5 m, and assuming a 1 in 15 grade, the rock chute would need to be approximately 7.5 m long plus an additional 1 m upstream and downstream to merge into the existing channel bed. Alternatively, a simpler rock weir structure to replace the existing rock structure may suffice, given constraints on access and vegetation removal.

West Outlet

A 'no retention' stormwater management strategy is proposed for the west catchment, which means that flows from the west catchment enter Deep Creek before the upstream flows. The result is that the peak flows in the creek are reduced compared to existing conditions. As for the east outlet, regular flows from the west catchment are low and unlikely to exceed the erosion threshold. Therefore, the risk of additional erosion along Deep Creek due to the west catchment development flows under flood events and regular flow conditions is **Low**.

However, the Deep Creek channel between the existing dam and the culvert is unstable, likely because of changes to the flow regime following the construction of the dam and its outlet. It is unknown when the dam was built. A 2010 aerial image (Google Earth, imagery date 1/7/2010) shows the dam is present at the time the culvert downstream was being constructed.

The concentration of flows through the existing dam outlet structure appears to have contributed to the current incision and widening processes as well as gully erosion along Deep Creek. The erosion processes, particularly the head cut, will continue to progress upstream without any changes to the west catchment inflows. However, the current rate of development and migration of the head cut is unknown, and it is recommended that monitoring be undertaken to determine the current rate of erosion. This information would then inform any decision on when to stabilise the head cut.

To stabilise the existing channel, a grade control structure like a rock chute would need to be installed within the channel. Given the change in bed level at the head cut of around 1 m, and assuming a grade of 1 in 15, an approximately 15 m grade control structure would be required to stabilise the channel.

No additional erosion control measures are required because of the proposed changes to the west catchment stormwater management strategy and flows from the west catchment do not increase the existing erosion issues downstream of the dam. Nonetheless, it is recommended that Council consider monitoring the rate of development of the instabilities followed by erosion treatments such as grade control structures; however, any design would need to be cognisant of constraints around access and vegetation removal.

4.3 Vegetation Considerations

Any outlet or in-channel works must consider vegetation constraints, such as the presence of Bellarine Yellow-gum, as shown in Figure 5.

5 Recommendations

Deep Creek, between the existing culvert and approximately Yellow Gum Drive is geomorphically sensitive and unstable in several locations, as indicated by the existing dumped rock structures. Upstream of the culvert to the existing dam structure is also geomorphically sensitive and unstable, with active incision and widening processes occurring, although the rate of change is unknown.

The change in flows because of the development, from both the east and west catchments has a **Low** risk of triggering additional erosion above that which is already occurring due to a reduction in peak flows in the creek and the low magnitude of the more regular outflows.

It is recommended that the east catchment stormwater outlet design ensures peak flow velocities measured at the downstream of the outlet are less than 0.5 m/s. This would limit the potential for flows from the east outlet contributing to the existing incision and widening processes in the channel. Other general recommendations for the outlet design include:

- The outlet should direct flows in a downstream direction at a maximum 45-degree angle.
- An example outlet design is shown in the Melbourne Water standard drawing 7251/08/103 (Appendix 1).
- Rockwork protection is required for the bed and banks from the end of the outlet to the base of the channel (see standard drawing 7251/08/103 as an example).
- Revegetation of any areas disturbed by works using indigenous species.

Given the presence of Bellarine yellow-gum and other large trees, it is also recommended that:

- The outlet is positioned to ensure the construction footprint avoids the removal of native vegetation including any tree protection zones of Bellarine yellow-gum and other large trees.
- Boring to install the outlet could be considered to avoid and minimise the removal of native vegetation during the construction of an outlet.

These outlet design recommendations also apply to the west outlet.

The risk of increasing the rate of current erosion processes in Deep Creek through the additional of flows from the development through the west and east outlets is low.

However, monitoring and potentially treating the existing channel instabilities such as the head cuts, would reduce the geomorphic risks to infrastructure such as the dam outlet. Typical treatments include grade control structures; however, any design would need to be cognisant of constraints around access and vegetation removal. It is recommended that Council consider monitoring the rate of development of the instabilities followed by erosion treatments such as grade control structures; however, any design would need to be cognisant of constraints around access and vegetation removal.

6 References

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Appendix 1 – Vegetation Assessment

Appendix 2 – Standard drawing 7251/08/103