APPENDIX 7

FLUVIAL GEOMORPHOLOGY ASSESSMENT REPORT

Technical Memorandum

To:	Mila Khatri, Junior Environmental Planner	**From:**	Michelle Robinson, Tatiana Hrytsak, & Robin McKillop
Company:	R.V. Anderson Associates Limited	**SLR Consulting (Canada) Ltd.**	
cc:		**Date:**	July 28, 2025
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		Revision	00

RE: Fluvial Geomorphology Crossing Assessment for Safari Road (Kirkwall Road to Valens Road)
Schedule B Municipal Class Environmental Assessment for Road and Drainage Improvements and Preliminary Design for the City of Hamilton

SLR is pleased to provide R.V. Anderson Associates Limited with our fluvial geomorphology crossing assessment for Safari Road between Kirkwall and Valens Road in Hamilton, Ontario (**Figure 1**). The City of Hamilton is undertaking a Schedule B Municipal Class Environmental Assessment for road and drainage improvements along Safari Road to address recurring flooding of the road surface. The crossing assessment is required to support potential crossing replacement or modifications to better convey flow beneath Safari Road and improve drainage of the road surface.

The study area is located in the headwaters of Fairchild Creek, within the jurisdiction of the Grand River Conservation Area (GRCA). Wetlands located on the north side of Safari Road contribute 1.876 km^2 of drainage area to a tributary south of Safari Road via an existing set of 3 corrugated steel pipe (CSP) culverts, 0.52 m diameter in size (OWIT, 2025). The tributary is mapped by GRCA as a regulated watercourse south of Safari Road.

The results of our assessment are intended to inform crossing siting, size and orientation, and provide recommendations for the crossing replacement. Our recommendations are based on field reconnaissance, characterization of channel morphology, and desktop analysis of historical aerial photos and recent imagery, completed in accordance with belt width delineation and crossing assessment procedures from Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation (CVC).

A background review (Section 1) is followed by a summary of methods (Section 2); a description of channel morphology and erosional processes (Section 3); establishment of meander belts, as applicable (Section 4); a fluvial perspective on crossing siting, sizing, and orientation for the watercourse crossings (Section 5); and a summary of key findings (Section 6).

1.0 Background Review

The study area focuses on an existing crossing of Safari Road approximately 250 m east of Kirkwall Road and is located within the Fairchild Creek subwatershed (**Figure 1**). The subwatershed exhibits low relief and is drained by a network of wetlands and small tributaries that ultimately become the main branch of Fairchild Creek, draining to the Grand River at Onondaga. The crossing at Safari Road has an upstream drainage area of approximately 1.876 km^2 (OWIT, 2025). The majority of the drainage is from the Beverly Swamp Wetland Complex, a provincially significant wetland. Agricultural and swamp landcover dominate the subwatershed. Limestone plains dominate the physiography (Ontario Geological Survey (OGS), 2014a). Surficial geology of the region is characterized by exposed or near-surface, Paleozoic shale and dolomite bedrock (OGS, 2010b).

2.0 Methods

The fluvial geomorphology of the creek in the vicinity of Safari Road was assessed through a combination of desktop and field investigations. SLR reviewed a number of important background information sources for the study area, including the GRCA policy document, *Technical Guidelines for Watercourse Crossings – Version 1* (Credit Valley Conservation (CVC, 2019), and OGS physiography and surficial geology mapping (OGS, 2014a and 2014b, respectively). SLR then completed a historical assessment of conditions, field reconnaissance, and delineated meander belt widths, as outlined below.

2.1 Historical Assessment and Channel Delineation

Historical aerial photography from 2002, 2006, 2010, 2015, and 2020, from the South Western Ontario Orthophotography Project (SWOOP, 2020) and City of Hamilton (Hamilton, 2002) were initially reviewed. The imagery provided a basis for characterizing historical land use and channel conditions. A comparative review was completed of channel characteristics in the historical aerial imagery and observed field data. The channel centreline downstream was delineated from Safari Road to Kirkwall Road to document the nature and degree of any channel adjustments. Due to the small size of the channel, delineation was limited where foliage obscured the watercourse and was not possible north of Safari Road.

2.2 Field Reconnaissance

SLR's Fluvial Processes Specialists completed field reconnaissance on October 18th, 2024. The day of field work was clear and 12°C with no precipitation in the previous 24 hours. Low flow conditions were observed at Safari Road. The purpose of the visit was to observe channel conditions, examine patterns and processes of local erosion, measure channel dimensions and ground truth aerial photograph-based interpretations of site conditions. Reconnaissance incorporated channel sections up to 20 m upstream and downstream of the crossing within the right-of-way where property access and safety allowed. The information gathered in the field was used to inform delineation of the meander belt, and to provide crossing recommendations.

2.3 Meander Belt

A meander belt delineation was completed for the Safari Road crossing, in accordance with TRCA's *Belt Width Delineation Procedures* (Parish Geomorphic Ltd., 2004) and CVC's (2019) crossing assessment guidelines. The existing meander belt was established by delineating and then buffering the meander belt axis until the boundary lines encompassed the current and historical planform alignments. Available LiDAR imagery was also reviewed to ensure that any remnant meander scars or oxbows lie within the delineation. Given that the wetland characteristics of site limit the application of this overlay assessment method, empirical models were also evaluated as a comparative check of the result. The final meander belt reflects the historical planform alignments plus a 20% factor of safety to accommodate future potential changes in the hydrological regime in relation to urbanization and climate change.

2.4 Crossing Assessment

Alternative crossing design considerations were evaluated based on site-specific observations and measurements and historical conditions (e.g., imagery interpretation). Factors including channel width, boundary conditions, indicators of instability (e.g., bank erosion), and meander belt width were incorporated into final crossing recommendations. Recommendations were considered for crossing siting, sizing, and orientation according to CVC's (2019) guidelines. Bankfull width was reported as the absolute minimum width for a culvert that could be considered, but it is often insufficiently conservative for active fluvial systems. One approach to accommodate lateral adjustment, which follows CVC's (2019) guidelines, was to ensure culverts were sized with widths/diameters of three times the bankfull width for channels up to 4 m wide. The final meander belt was also reported, as context, but would be cost-prohibitive and unnecessary to span.

3.0 Description of Channel Morphology

3.1 Channel at the Existing Crossing

The existing crossing on Safari Road is located 280 m east of Kirkwall Road and comprises three parallel CSP culverts perpendicular to Safari Road (**Figure 1**). The watercourse north of Safari Road is oriented northeast-southwest and drains an area of wetland associated with the Beverly Swamp. The downstream section of the channel is approximately 590 m long and flows southwestward, ultimately crossing beneath Kirkwall Road through a concrete box culvert.

The channel immediately upstream of the Safari Road culverts has a poorly defined irregular meandering planform, situated in a low-lying forested area (**Photo 1**). The primary flow path is aligned with the culvert; however, supplemental drainage channels associated with the wetland were observed in the forested area. The banks comprise loose alluvium that has been deposited around hard natural features, such as boulders or trees. The erodible banks and saturated ground readily allow planform changes during high flows, especially seasonally when the channel overtops the banks and Safari Road.

The channel has a low gradient with a mixture of silt, organic matter, and matted vegetation along its bed. Such characteristics are typical of a wetland channel. The bankfull depth is approximately 0.4 m. The average bankfull width is approximately 2 m north of the culverts and 4 m south of the culverts (**Table 1**). The wetted width is 1 m north of the culverts and 2 m south of the culverts. Herbaceous vegetation lines the channel banks and roadside ditch (perpendicular to the channel). Scour and erosion were neither observed upstream nor downstream of the culverts. It is anticipated that the upstream wetland has the capacity to attenuate high flows and reduce the erosive energy during flood events. The culverts are in stable condition, not blocked by sediment or vegetation, and currently pose no impediment to fish passage.

The channel becomes more well-defined downstream of the culverts (**Photo 2**). It has a similar irregularly meandering planform, and aerial imagery reveals multiple drainage paths in the vicinity of the channel associated with the wetland. Water in the channel and culverts had limited velocity at the time of the site visit.

Photo 1. Upstream view of the primary channel, north of Safari Road.

Photo 2. Downstream view of the channel, south of Safari Road.

Table 1. Culvert and channel characteristics

Site ID	Existing culvert(s) size (m)	Bankfull width (m)	Max. channel depth (m)
Safari Road – triple CSP culverts (upstream of crossing)	3 CSP Culverts 0.52 (wide) x 0.6 (high)	1	0.2
Safari Road – triple CSP culverts (downstream of crossing)		4	0.4

4.0 Meander Belt

Comparative overlay analysis using recent imagery reveals a generally stable planform downstream of the Safari Road crossing (**Figure 1)**. Given the limitations associated with delineating the meander belt along a treed channel in a wetland setting, an empirical approach was used as a check of the findings of the overlay assessment. The Williams – Hydraulic Depth (1986) empirical meander belt formula was used to determine an existing belt width (**Formula 1**). The resulting value was found to correlate reasonably well with the meander belt width estimated through the overlay assessment, although it was slightly less conservative. The existing and final meander belt width results at Safari Road are identified in **Table 2,** according to both the empirical and imagery overlay assessment methods. The final belt widths include a 20% factor of safety to account for potential future changes in the hydrological regime associated with potential upstream development and ongoing climate change.

Formula 1. Williams – Hydraulic Depth (1986)

$$Meander\ belt\ width\ (m) = 148D^{1.52}$$

Where D = the mean bankfull depth (m)

Table 2. Empirical meander belt widths

Method	Existing Belt Width (m)	Final Belt Width (m)
Empirical – Williams (1986) hydraulic depth	36.8	44.1
Historical imagery assessment*	48.0	57.6

*Based on TRCA's *Belt Width Delineation Procedures* (Parish Geomorphic Ltd., 2004)

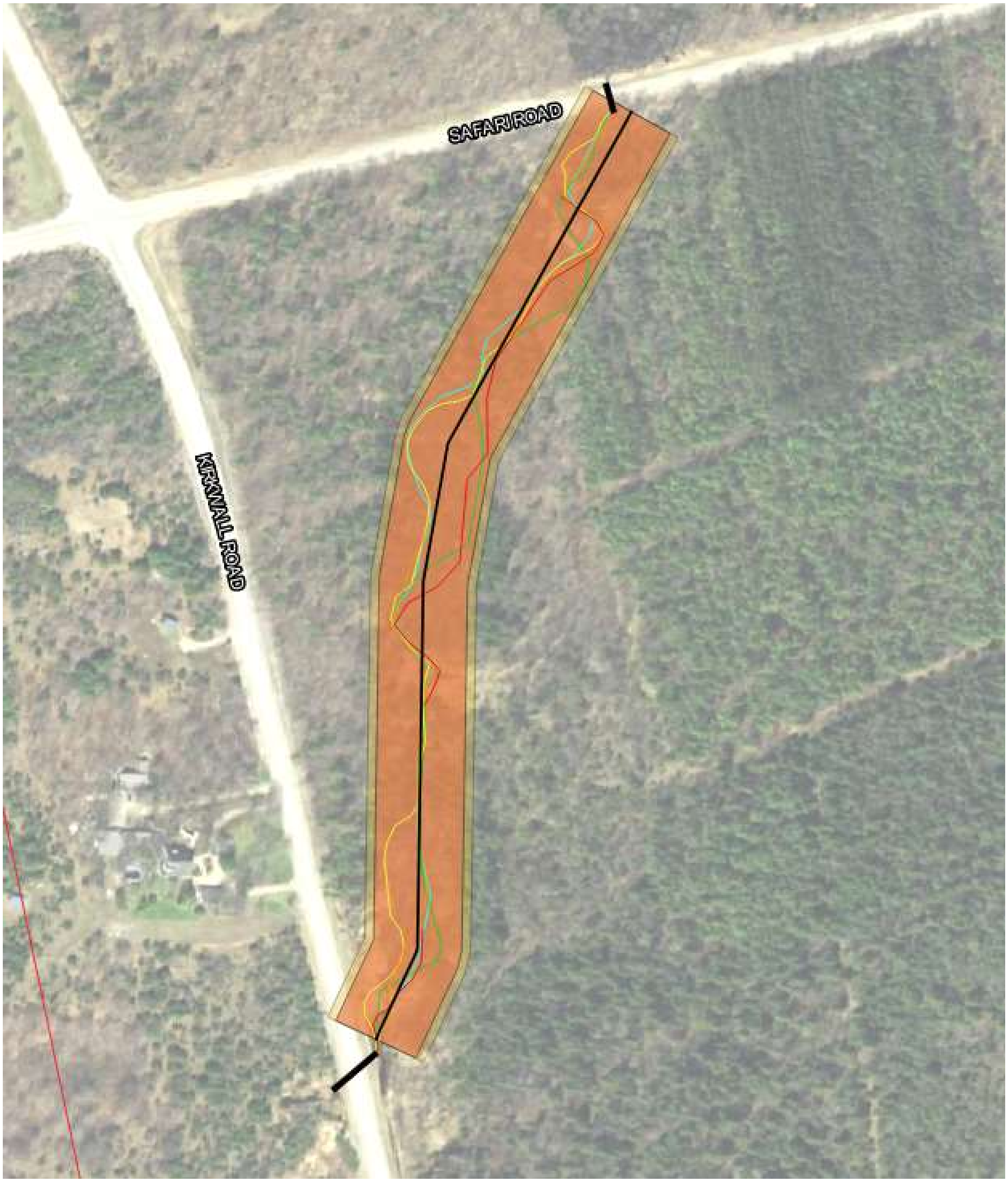

Figure 1. Safari Road crossing and downstream historical planform assessment

5.0 Safari Road Crossing Assessment

The watercourse at Safari Road is geomorphologically stable, and the existing crossing, comprising three CSP culverts, is currently in good condition. The findings of the Schedule B Municipal Class Environmental Assessment for road and drainage improvements of Safari Road may necessitate the need for replacement of the Safari Road Crossing.

Fluvial geomorphological considerations must be incorporated into the design of any proposed replacement watercourse crossing structures (CVC, 2019). This requirement is based on recognition that structures that are poorly sited, misaligned relative to the channel, or undersized hydraulically, geomorphologically or ecologically may compromise the natural form and function of the watercourse and the aquatic habitat it supports. Crossing structures that do not account for, and anticipate, fluvial processes may also become unnecessarily at risk from excessive erosion or sedimentation. Abutments can be outflanked, or undermined, closed-bottom structures can become perched at their outlets, and excessively wide structures can lose a significant portion of their hydraulic capacity through sediment build-up.

The following section outlines considerations and recommendations for the siting, sizing, and orientation of the crossing structure at Safari Road. Approximately 590 m downstream of the Safari Road crossing, the channel crosses Kirkwall Road through a concrete box culvert that has a span of approximately 3.5 m and is 1 m high. The channel conditions at this crossing are similar to the conditions at Safari Road. As such, the Kirkwall Road crossing is a suitable reference for the design considerations of Safari Road.

5.1 Crossing Siting

The first consideration to make when proposing a new or replacement crossing structure is the location of the structure relative to the existing planform and longitudinal geometry of the channel it must accommodate. As the objective of this assessment is to consider replacement of the existing culverts, no changes to the crossing location are anticipated.

5.2 Crossing Sizing

Several crossing width scenarios are presented for consideration (**Table 3**) according to CVC's (2019) recommended design approach and the observed reference crossing downstream at Kirkwall Road. The existing crossing at Safari Road consists of three, 0.52 m diameter CSPs with a combined crossing cross-sectional area of 0.64 m^2.

Comparative overlay analyses reveal minimal changes to the channel planform alignment over the past 20 years of record (2002 to 2020) (**Figure 1**) and the final meander belt is 57.6 m wide. The stability of the planform precludes establishment of site-specific 100-year erosion rates and justifies crossing spans being based on measures other than meander amplitudes or belt widths.

The hydrological regime of the channel is anticipated to be largely stable due to the upstream wetland and larger Beverly Swamp, both of which help attenuate flood flows and are protected from development. Limited lateral erosion is anticipated in the immediate vicinity of the existing culverts, over the long term, due to the relative lack of observable changes along the existing, small channel. Furthermore, site conditions are more driven by wetland processes than by fluvial processes. Minor erosion along one or both banks is possible, however, and should be accommodated according to the guidelines for culvert sizing.

Table 3. Alternative road crossing spans and fluvial implications

Crossing Span	Fluvial Considerations	Fluvial Implications
Single span of the bankfull width **4 m**	Can accommodate natural water/sediment conveyance, but no allowance for natural lateral adjustments (bank erosion).	The bankfull width would accommodate the existing channel conditions; however, there would still be a risk of outflanking the culvert during future channel adjustment.
Single span according to the reference crossing width at Kirkwall Road **3.5 m**	Does not accommodate bankfull width but is expected to accommodate natural water/sediment conveyance. Has no allowance for natural lateral adjustments (bank erosion).	A single span mirroring that at Kirkwall Road can be expected to function in a similar manner. Narrowing of the crossing below bankfull width introduces risk of culvert outflanking.
Three culverts spanning the bankfull width **4 m** (1.3 m * 3)	Increasing culvert size may improve natural water/sediment conveyance.	Three culverts can be expected to function similarly to the existing three culverts.
Single span sized to three times the bankfull width **12 m** (4 m * 3)	The additional width would better accommodate natural water/sediment conveyance and natural channel adjustments.	Sizing a single culvert to three times bankfull width may reduce the risk of scour and downstream erosion during high flow events and would accommodate some lateral adjustment. A larger footprint of disturbance would be required. The typical low velocity may lead to sediment deposits in an oversized crossing, unless a low-flow channel is incorporated.

5.3 Crossing Orientation

The existing culverts are aligned perpendicularly to Safari Road as opposed to along the natural trend, or axis, of the watercourse (**Figure 2**). The existing orientation effectively reduces the intended (designed) hydraulic capacity during flood conditions; therefore, SLR recommends consideration be given to reorienting the culverts along the natural axis of the channel corridor. Prioritizing alignment of the culverts with the watercourse as opposed to perpendicularly to the road would improve hydraulic performance during floods, allow for a more natural form and function of the channel in the immediate vicinity of the crossing, and reduce risks to road infrastructure and the need for excessive erosion protection. Practically, the channel itself would be shortened slightly, allowing the creek to enter the crossing structure along a more natural alignment. Given the low slope and discharge of this channel, a minor loss in channel length would pose no risk to the structure or downstream channel. Downstream, the crossing at Kirkwall Road has been aligned with skew to the northeast rather than perpendicularly crossing the road, which may serve as a reference for performance of the creek when aligned through the culvert.

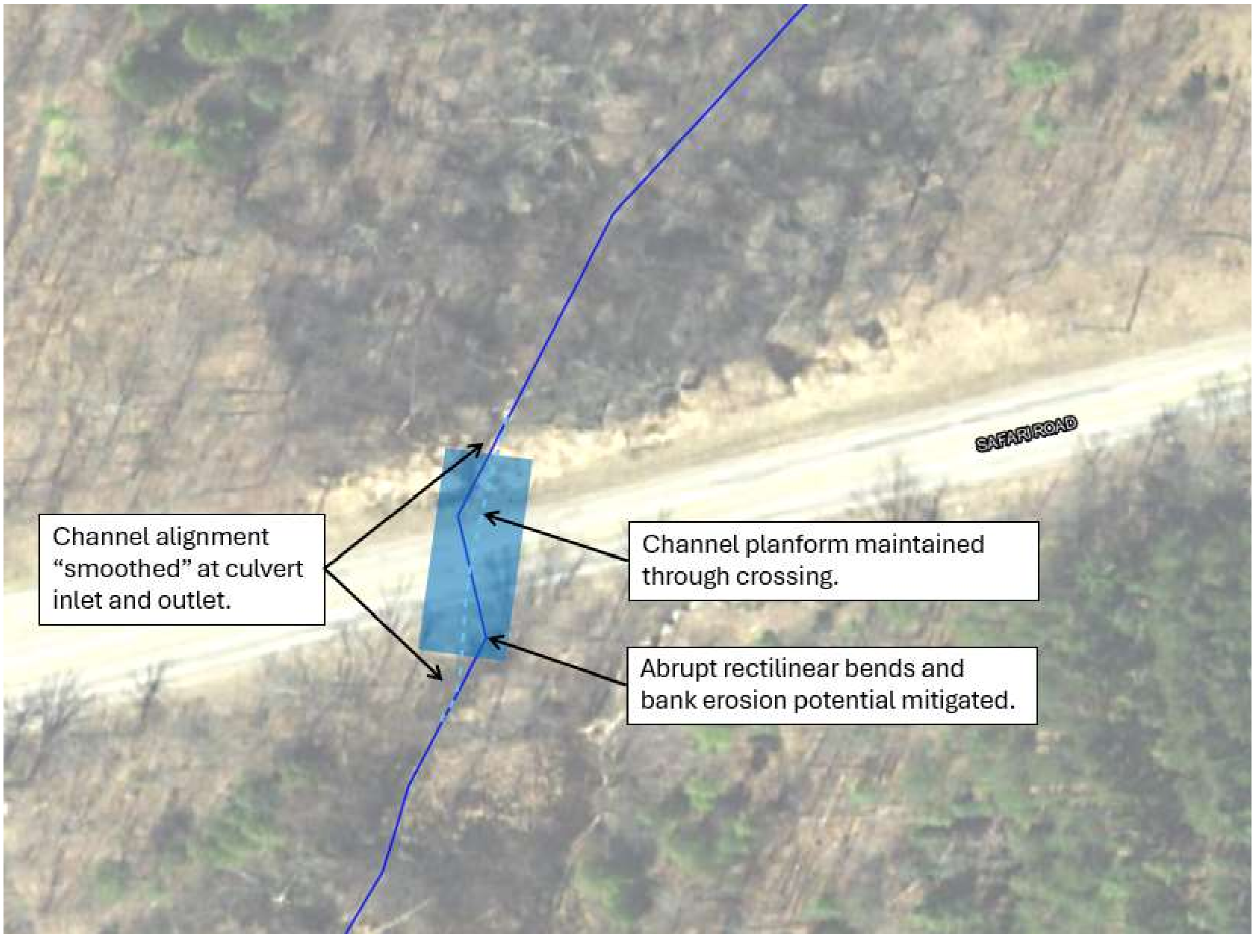

Figure 2. Recommended change in proposed culvert orientation to align with natural channel corridor at Safari Road

6.0 Summary

A fluvial geomorphic assessment was completed for the existing watercourse crossing of Safari Road, east of Kirkwall Road, to provide recommendations for crossing specifications that better accommodate natural fluvial processes (e.g., sediment transport, erosion).

A detailed crossing assessment for the triple-culverts at Safari Road was completed in accordance with CVC's (2019) crossing assessment guidelines, to inform the appropriate siting, sizing, and orientation of the replacement structure. The assessment included determination of the channel bankfull width, three times bankfull width, and final meander belt width to provide crossing alternatives. The alternatives for the crossing were evaluated from a fluvial geomorphological perspective, culminating in a guidance table to highlight corresponding risks for the proposed crossing replacement.

The CVC crossing assessment guideline (2019) recommends that replacement crossing structures span, at a minimum, the bankfull width. The watercourse has not undergone any appreciable lateral adjustment in the vicinity of the crossings in at least 20 years. As such, a minimum culvert width of 4 m is suitable to accommodate the geomorphic conditions of the channel. Limited bank erosion and related lateral adjustment is anticipated over a 100-year planning timeframe. The replaced culvert should be either a CSP Arch culvert, or an open-footed or embedded box culvert with a defined low-flow channel along its entire length to maintain geomorphological processes and facilitate fish passage.

7.0 Statement of Limitations

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8.0 Closure

We appreciate the opportunity to support R.V. Anderson Associates Limited in the fluvial geomorphic, meander belt and crossing assessments for the watercourse crossing at Safari Road. Should you have any questions, please do not hesitate to contact Tatiana Hrytsak or Robin McKillop.

Regards,

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