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Dear John,

Waiau Braidplain Delineation

Upon your request, we have assessed the NIWA report on the use of LiDAR (Light Imaging and Ranging) technology for the delineation of braidplain width (Hoyle & Bind 2018). To demonstrate the methodology, NIWA uses an example of a foothills-source braided river (i.e., the Ashley River), and an alpine-source river (i.e., The Waiau River).

The NIWA report takes a braidplain to mean the area which the various braids/channels can move and adjust within the bed, and provides the explanatory graphic below (Fig. 1).

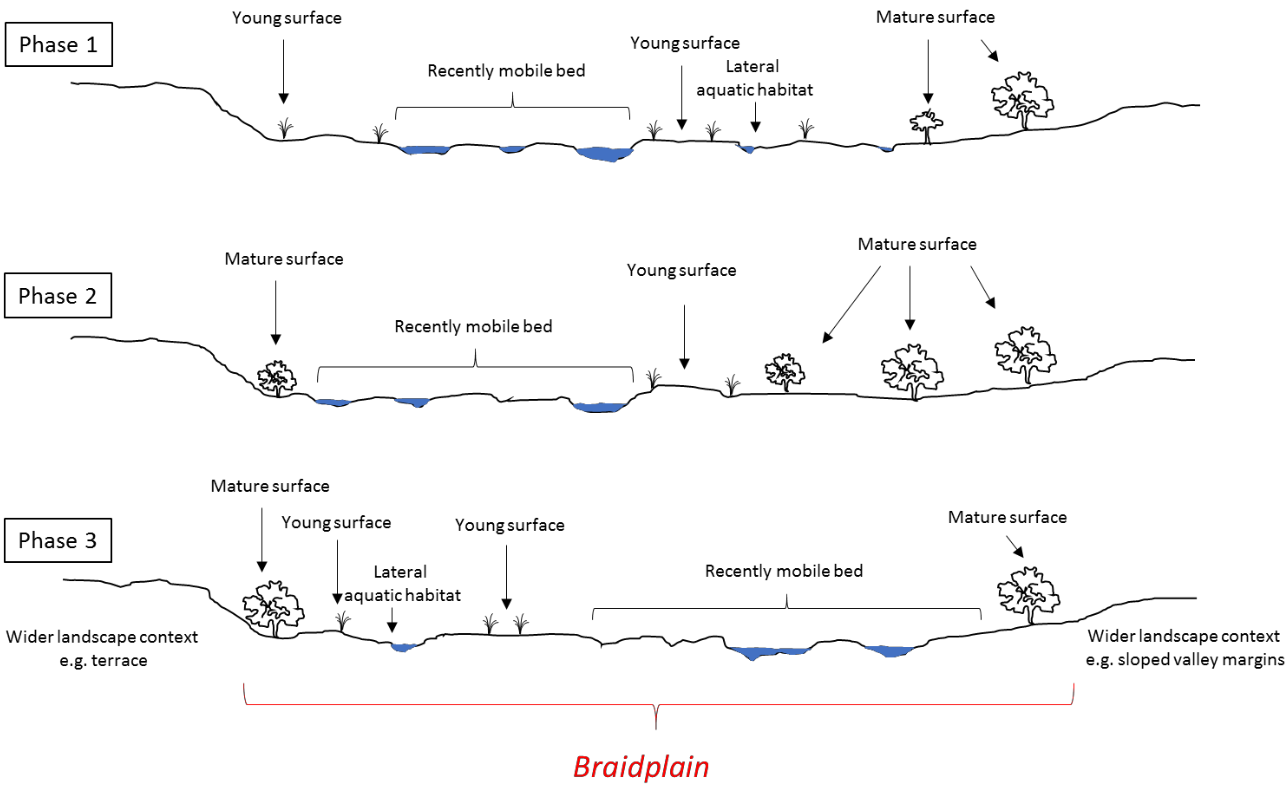

Figure 1. Schematic diagram showing the adjustment of active channels over time within the braidplain (Hoyle & Bind 2018).

In the 2018 NIWA report demonstrating the LiDAR technique (Hoyle & Bind 2018), NIWA used two approaches to delineate the braidplain. Firstly a 'historical' braidplain based on historical imagery and maps and secondly a 'contemporary' braidplain based on digital high-resolution elevation contours from LiDAR, but underpinned with topographic information. NIWA considered the contemporary braidplain to represent the truer braidplain, largely because temporal gaps in the photographic record, may mean the full extent of the braidplain may be missed.

Introduction

The morphology of braided rivers is highly dynamic. The location of the main river flow within the braid plain is constantly shifting due to many processes including erosion, geomorphology, and seismic events. Frequently, flood flows can have significant effects on overall river morphology and braiding patterns. Often, adjacent wetlands and stable braids at the edges of the braid plain have superior biodiversity than the deeper faster channels that are more centrally placed. On the other hand, the deeper channels, while often being more ecological barren serve an important role in fish passage. The alluvium across the active braid plain form an important breeding and rearing habitat for native birds. Defining the limits of a braid plain is therefore important for the ecological integrity of a waterway.

The Resource Management Act (1991) does not define the braid plain of a braided river, however it defines the bed of a river as "the space of land which the waters of the river cover at its fullest flow without overtopping its banks". This definition does not align well with the nature of braided rivers when the bank form may not be obvious. Due to the dynamic morphology of a braided river, the Canterbury Regional Council, Environment Canterbury, have defined braid plains in more specificity. Their definition of a braidplain is as follows:

"*The area of land covered currently and historically by the active river surfaces within the current hydrological and geomorphic context in the absence of flood defences or invasive weeds"* (Gray 2018).

According to Gray (2018), this definition is distinctly separate from the area that may be inundated by flood events, also known as a floodplain, and notes a braidplain incorporates land across which the river may migrate to in the next 10s to 100s of years. The braidplain can incorporate a variety of terrestrial and aquatic habitats, included forested areas. Gray (2018) does not include the magnitude of the flood which would assist in delineating between a braidplain and a floodplain, and it may vary with location and hydrological context.

Proposal

The consent application (CRC231732 and CRC231733) pertains to the installation of two lengths of anchored tree protection (ATP) on the true left (north) bank of the Waiau River, downstream of Leslie Hills Road. The purpose of this ATP is to prevent further erosion of the true left bank into the neighbouring farmland. The farmland in this instance is used for grazing stock.

Historic Braid Plain determination

The 'historic' braidplain of the Waiau River were delineated by NIWA using a combination of historic and recent survey and topographic maps, combined with satellite imagery, a data set spanning 136 years from 1879 to 2015 (Hoyle & Bind 2018). A consequent GIS delineation layer was created, indicating the historical maximum extent of the braid plain, and depicted as the green area in App. I, Fig. i. NIWA considered it possible that the river extended laterally beyond that depicted in the old imagery, especially in the late 1800s and early 1900's, when mapping was infrequent.

DEM-determined braidplain Delineation methods

Due partly to information gaps in the historic dataset, a so-called 'contemporary braidplain' was also delineated, using terraces identified from the LiDAR's digital elevation models (DEM) provided by Environment Canterbury (yellow line in App. I, Fig. i). The DEM's generated were based on the captured water surface level at "low flow", with elevation steps of 0.5 m from 1 m – 6 m above the LiDAR determined low flow level. In this case, the DEMs from 1 m to 4.5 m above the observed low flow are provided in App. I, Figs. ii-ix. The geomorphology identified by LiDAR can be considered as covering both contemporary and geologically recent potentially discriminating old braids as far back as possibly thousands of years. The age of the terraces identified in the DEM have not been determined, so over this undefined time scale, the proposed ATP locations are within the contemporary braidplain definition. However, the unidentified timeframe used for the DEM underpinning the braidplain delineation may be outside the braidplain definition provided in Gray (2018), which defines the braidplain area over a timescale of current and historical hydrology and geomorphology :

"The braidplain is the area of land covered potentially, currently and historically by the active river surfaces within the current hydrological and geomorphic context in the absence of flood defences or invasive weeds. "

Based on the LiDAR-measured elevations, the water level in the Waiau River would have to exceed a stage height elevation of 2.0 m (above the low-flow water surface level) before surface water could encroach beyond the historic maximum extent (App. I, Fig. iv). Even then, encroachment is limited to a small area between the proposed ATP locations, with no flowing braid formation around the back of the proposed ATP structures. At stage height elevations at and above 2.0 m above low-flow water surface, surface water will exceed the boundary of the contemporary braidplain on the true right (south) bank, flooding SH7 to the base of the low terrace just to the south side of the road, which is at 240 m asl.

The braids remain blind at an elevation of 2.5 m above low flow (App. I, Fig. v), and at 3.0 m above low-flow water surface, while the lower area between the ATP locations is flooded to Leslie Hills Road (App. I, Fig. vi). This would suggest, at the 3m level and lower, the habitat could not be considered a braidplain, as there is unlikely to be flow around the ATP location to form braids. In summary, the short, proposed ATP structures do not stop river water flooding the pastured plain and the lower areas between them, which, based on the DEM model represent more of a floodplain not a braidplain. At this point Leslie Hills Road may be inundated, as would the pylon and high-voltage line which traverses the pasture proposed to be protected by the ATP.

At river levels equal to and greater than 3.5 m above low flow, the water level would probably obscure the pasture and infrastructure of the upstream location (App. I, Figs. vii-ix).

It is worth noting that the above interpretation of LiDAR data does not consider potential erosion of the true left bank, which is occurring in places along the reach at lower flows as the bank is undercut from below. A process called 'winnowing' draws fines from armoured steep banks of alluvium, where the shear stress (i.e., in this instance provided by fast water velocity near the bank) causes the bank to collapse further. While erosive processes are a natural process, the process is accelerated by the lack of deep-rooted trees along the bank edge, which would naturally occur if the riparian edge was left to naturally vegetate over a long timeframe. The process of ATP placement provides an artificial means of providing limited localised bank support that natural vegetation would otherwise provide in a natural setting. The presence of tall vegetation on the mature surfaces of the braid plain is depicted in Fig. 1. On lowland braidplains in Canterbury, for example on the lower Waiau River, willow trees provide bank support and stability at the edge of the active channel, and historically, native beech trees and sub-canopy smaller species would have provided the role. In this respect, the proposed ATP is replacing a limited and localised consolidation role that natural mature vegetation would otherwise provide at the margin of an active braid plain. The role of vegetation, both native and introduced, on the morphology of braided rivers is described in Caruso *et al.* (2013), who demonstrates that the invasion of vegetation can control and constrain rivers, but large floods can also strip a significant proportion of the vegetation from the braid plain.

Moreover, the historic maximum extent indicates the Waiau River has probably been contained within the extents of the proposed ATP for at least 136 years. Even if some historic incursions over the plains took place over a century ago, it is improbable that incursion has frequently occurred since then as mapping has become more frequent. It is also important to note that both the existing RMA 1991 definition of a riverbed and Environment Canterbury Regional Policy Statement 2013 (with amendments to October 2020) does not use the term braidplain, despite the 2018 work on braidplain by NIWA.

NIWA also noted that both the historical maximum extents and LiDAR surveys were desktop studies only, and the GIS files may not perfectly match the physical boundaries. Verification of the boundaries through site visits was recommended for any locations where braidplain boundaries were of particular interest. In this context, our field observations are relevant.

Field survey

The physical geomorphology of the ATP locations, as observed during a site visit on 23/08/2022, is consistent with the braidplain definitions and historical maximum extent mentioned above. The water level during this survey was deemed higher than normal baseflow conditions, but was not considered a flood flow. While signs of bank erosion were present, especially in the downstream ATP reach, no signs of previous water egress over the bank toe were observed at either location (App. II, Figs. i - iv). There have been no recent flood flow conditions in which the waterway exceeded the historical maximum extent on the true left bank. While the land appeared flat, there was a low terrace present on the upstream ATP reach (Fig. 2), which is detectable on the aerial imagery, but the DEM indicates that the high water does not connect to the channel directly upstream of the proposed ATP placement, but floods back to the high terrace on the north side of Leslie Hills Road.

It is worthy to note that infrastructure (high-voltage lines, pylon, Leslie Hill) is situated in the area behind the proposed upstream ATP (Fig. 2). So, not only would the ATP provide locale defence against water for pasture, it would also protect critical power supply infrastructure and road incursion.

In the location of the downstream DEM (App. II, Fig. ii), old channels are discernible across a flat plain, which is consistent with the DEM in that these backfill with water at levels in excess of 4.0 m above the low flow level (App. I, Fig. viii-ix), and may accommodate braids connected to the main flow at levels of 4.5 m and above. However, inspection of DEM models indicate that old braids do not connect to the main flow within the ATP areas until the greater river width is flooded back to old terraces, and water levels this high are likely to cause infrastructure damage.

However, similar to the upstream proposed ATP location, localised erosion may occur at lower flow/stage levels by a process called winnowing which weakens armoured banks and beds. This localised small-scale erosion protection provided by the two small ATPs are insufficient to prevent natural geomorphic processes induced by high river-shaping flows.

This point is elaborated in the opinion expressed by hydrologist Rob Hall "I can confirm that with my knowledge of the sites where you propose to install ATP works and the style and scope of the works you are proposing, these works are highly unlikely to materially affect the overall lateral migration of the true left bank of the Waiau River in this reach nor will they adversely affect the rivers true right bank in this reach. I reach this conclusion on the basis that the works themselves are localised and of what might best be described as modest scale and not likely to survive without damage a flow in the order of half to bank full flow. I note with reference to GNS 1:250 000 Map No. 13 that the true left terrace that ECan are relying on to define the river's braid plain limit on the river in this reach is described variously as Q2a river gravel, sand with some silt and fan deposits (Age 12 000 – 20 000) lower terrace abutting an older terrace, Q4a similarly described (Age 60 000 to 70 000 years). On that basis it is opined that it is speculative to assume that these surfaces were formed under current or recent hydrological and / or morphological conditions. Further to that it is highly probable that he influence of processes such as seismic, aseismic and immediate post glacial climate were responsible for the formation of the terrace ECan are relying on to define their braid plain."

Figure 2. Drone footage of the flat flood-plain behind the location of the proposed localised ATP and the eroding bank in the foreground. A low terrace and pylons can be seen within the proposed ATP area.

Conclusion

Since historic records began, from 1837, there are no aerial photos or historic maps which indicate that braids have traversed the plain which is proposed to be partially protected by the two ATP structures.

We conclude that LiDAR analysis indicate that the braid plain contours extend into the pastoralised plain between the two proposed ATP locations., but not through the ATP locations until the river elevation exceeds 3.5 m elevation above the low flow level. Geological maps indicate that the river terrace gravels date back to the last glaciation (12000-20000 years), rather than more recent geomorphic processes.

Our interpretation is that the pastoralised area, with silty soils, resembles more of a flood plain than a braid plain, and that the two short ATP structures will not inhibit braid plain formation should the river shift to the north. Overall, the lack of riparian vegetation bordering and within the pastoralised region is likely to increase the chance of braid plain formation during a massive flood event. However, the function of the ATP structures is to inhibit benign erosive forces over a two limited bank reaches at relatively low flows, much as a short reach of trees would do in a natural setting, and would replicate natural localised edge protection already present elsewhere along the north bank. The ATP structures would be essentially washed away well before flood flows were of a magnitude to restore the area to active braid plain and habitat.

Yours sincerely,

Riley Payne, Mark Taylor

References

Caruso, B. S.; Edmondson, L.; Pithie, C. 2013: Braided River Flow and Invasive Vegetation Dynamics in the Southern Alps, New Zealand. *Environmental Management 52*: 1-18.

Gray, D. 2018. Natural character assessment guidelines for braided rivers. Environment Canterbury, Christchurch. *R18/35*. 21 p.

Hoyle, J.; Bind, J. 2018. Braidplain delineation methodology. National Institute of Water and Atmospheric Research, Christchurch. *NIWA Client Report* 35 p.

Resource Management Act 1991. Resource Management Act, pp. 801 (*Issue*): 801.

Appendix I. GIS layers from Hoyle and Bind (2018)

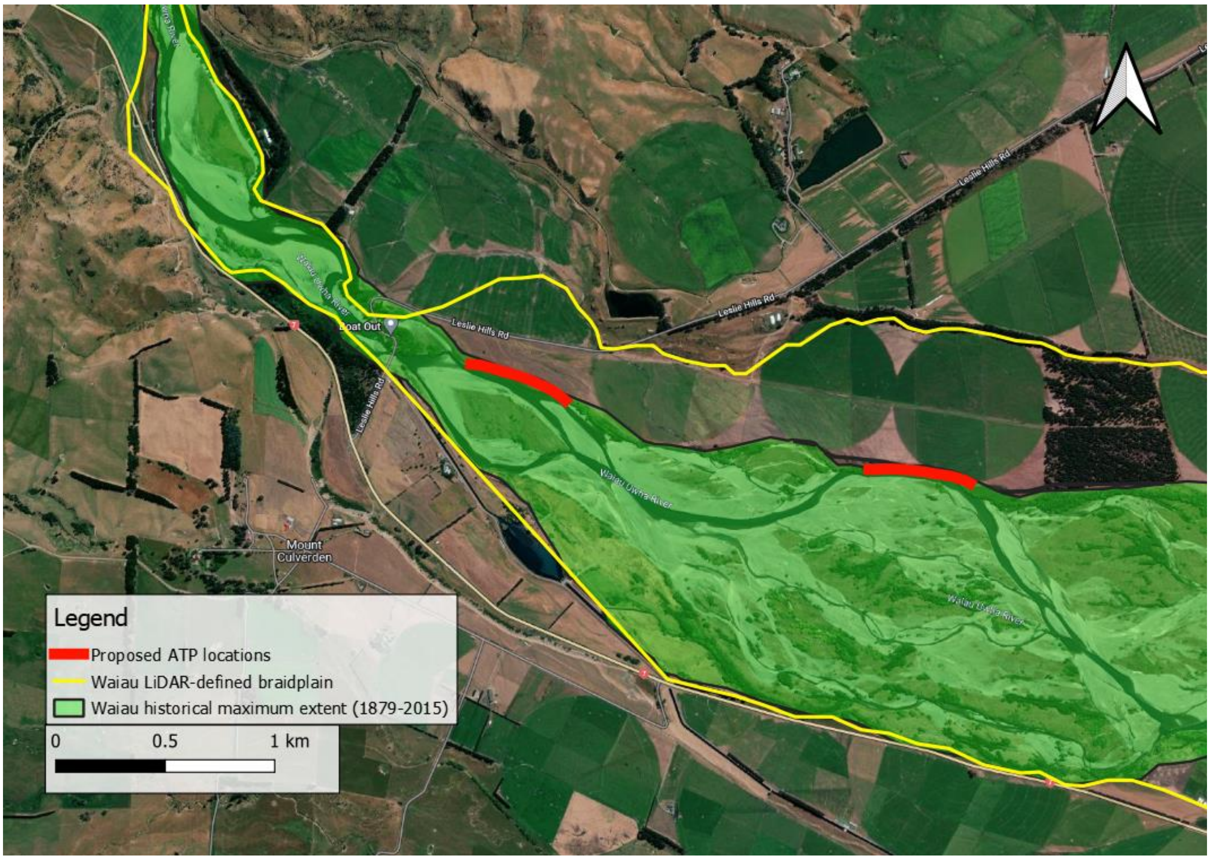

Figure i. Map showing the historical maximum extent of the Waiau River braid plain, and the LiDAR-defined ‘contemporary’ braid plain.

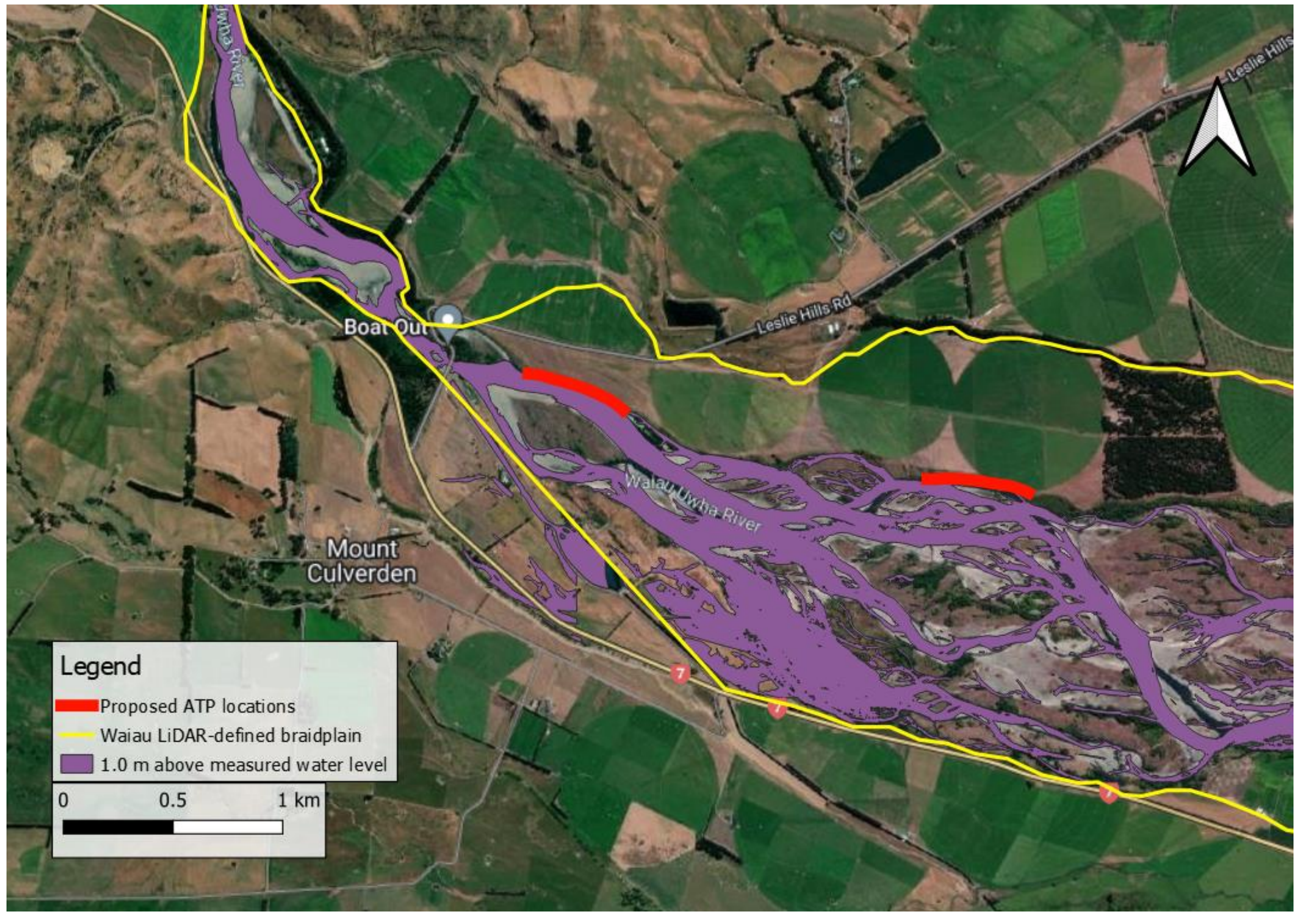

Figure ii. Marked area is at (or below) 1.0 m above water level, as measured during LiDAR survey.

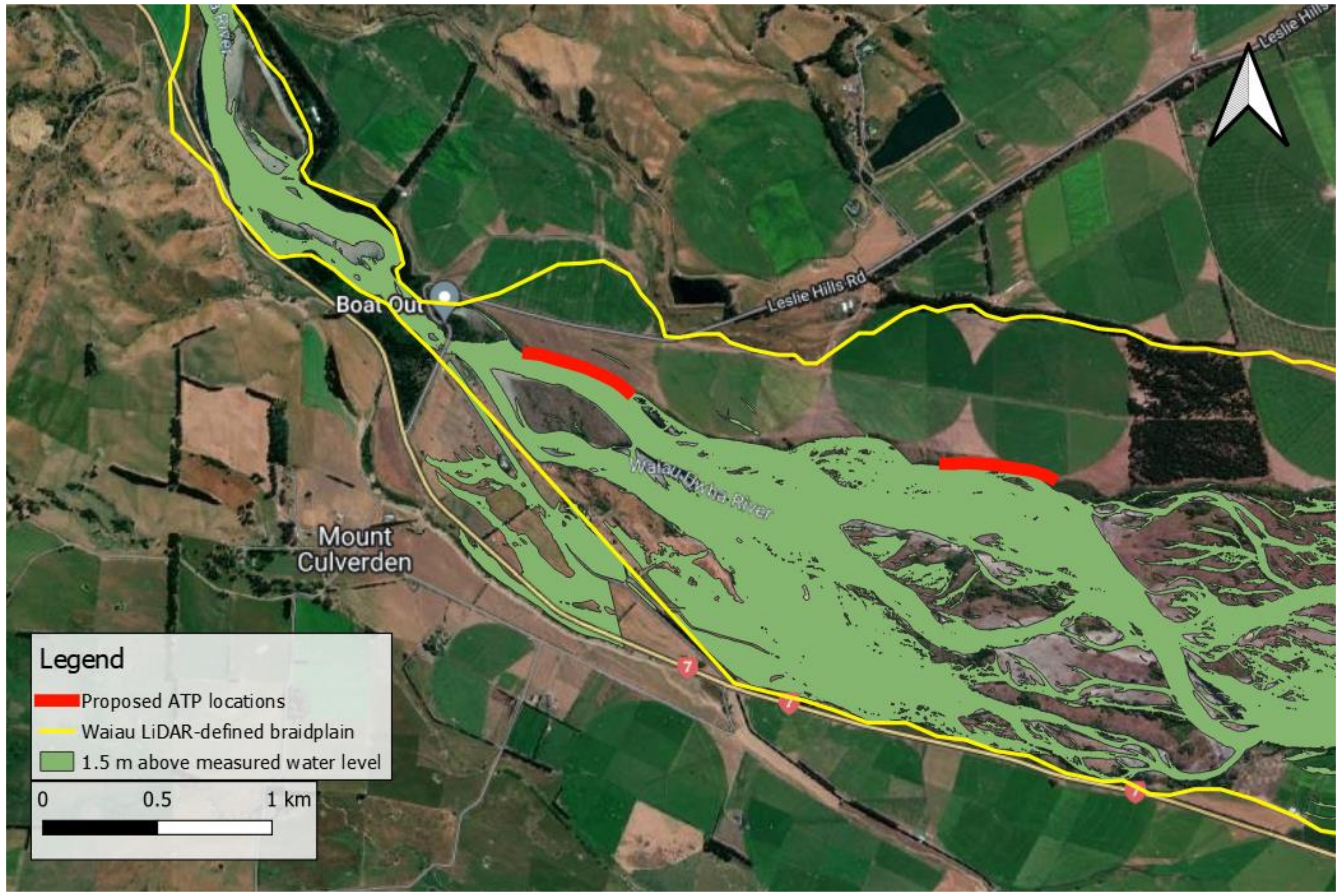

Figure iii. Marked area is at (or below) 1.5 m above water level, as measured during LiDAR survey.

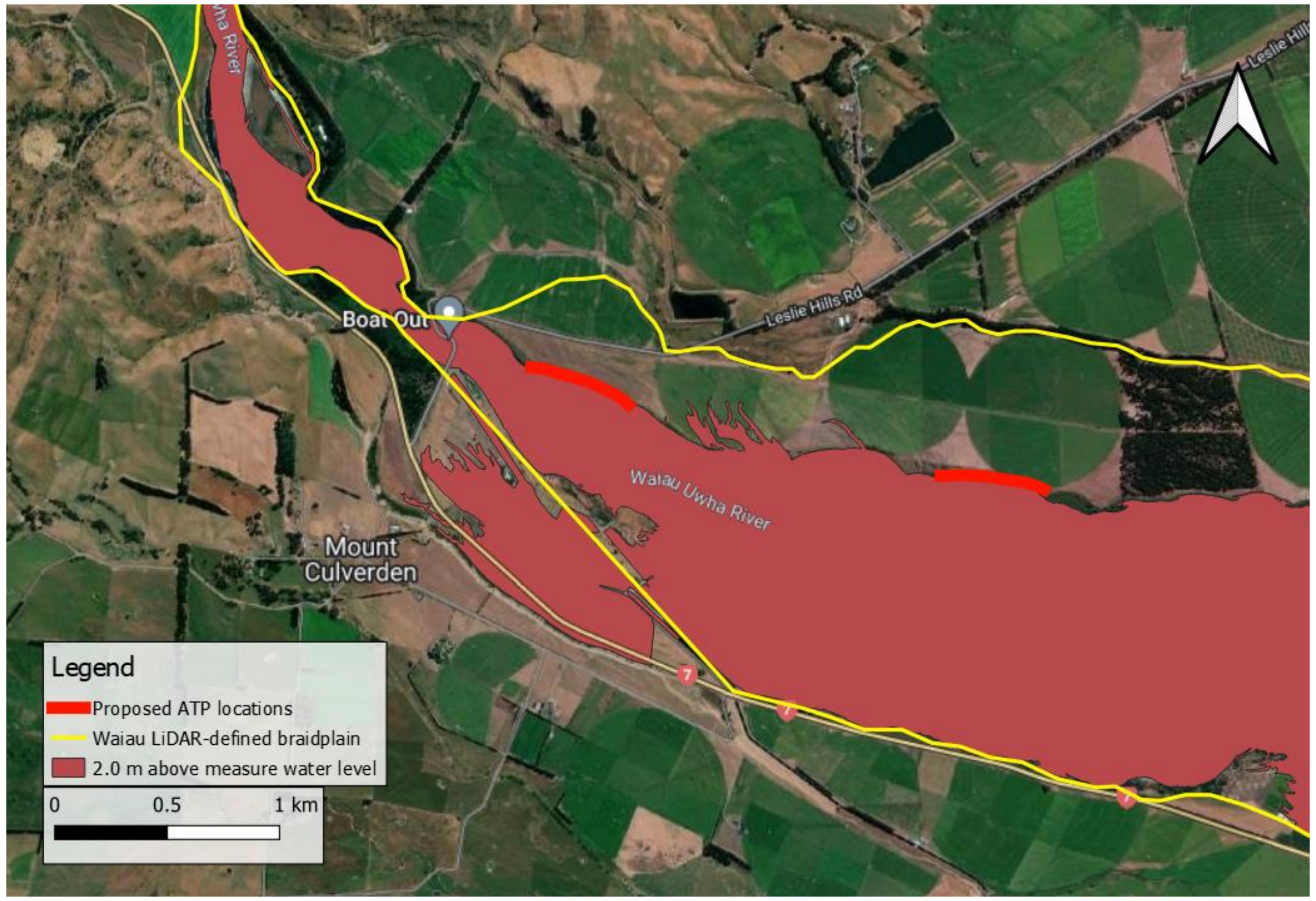

Figure iv. Marked area is at (or below) 2.0 m above water level, as measured during LiDAR survey.

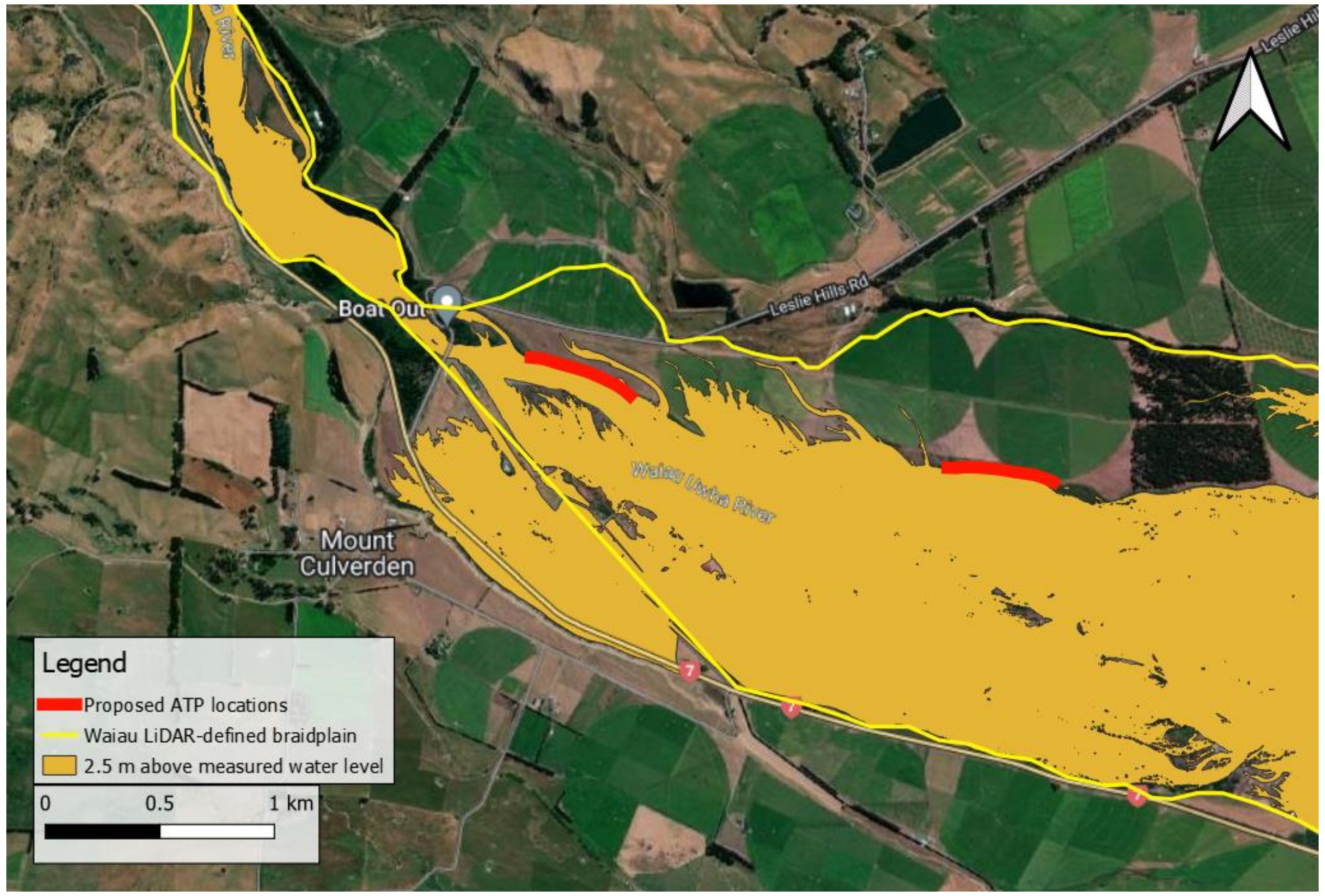

Figure v. Marked area is at (or below) 2.5 m above water level, as measured during LiDAR survey.

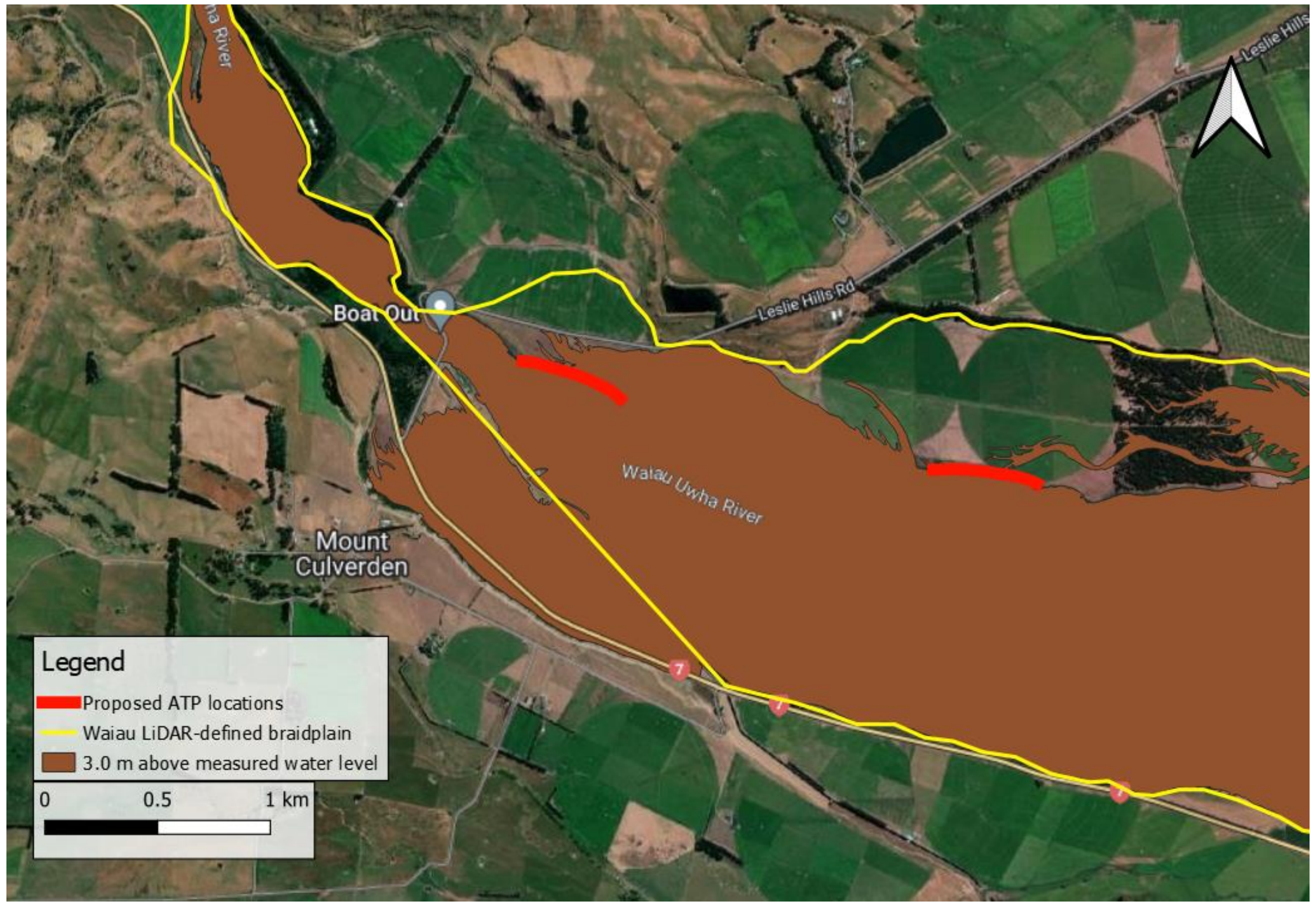

Figure vi. Marked area is at (or below) 3.0 m above water level, as measured during LiDAR survey.

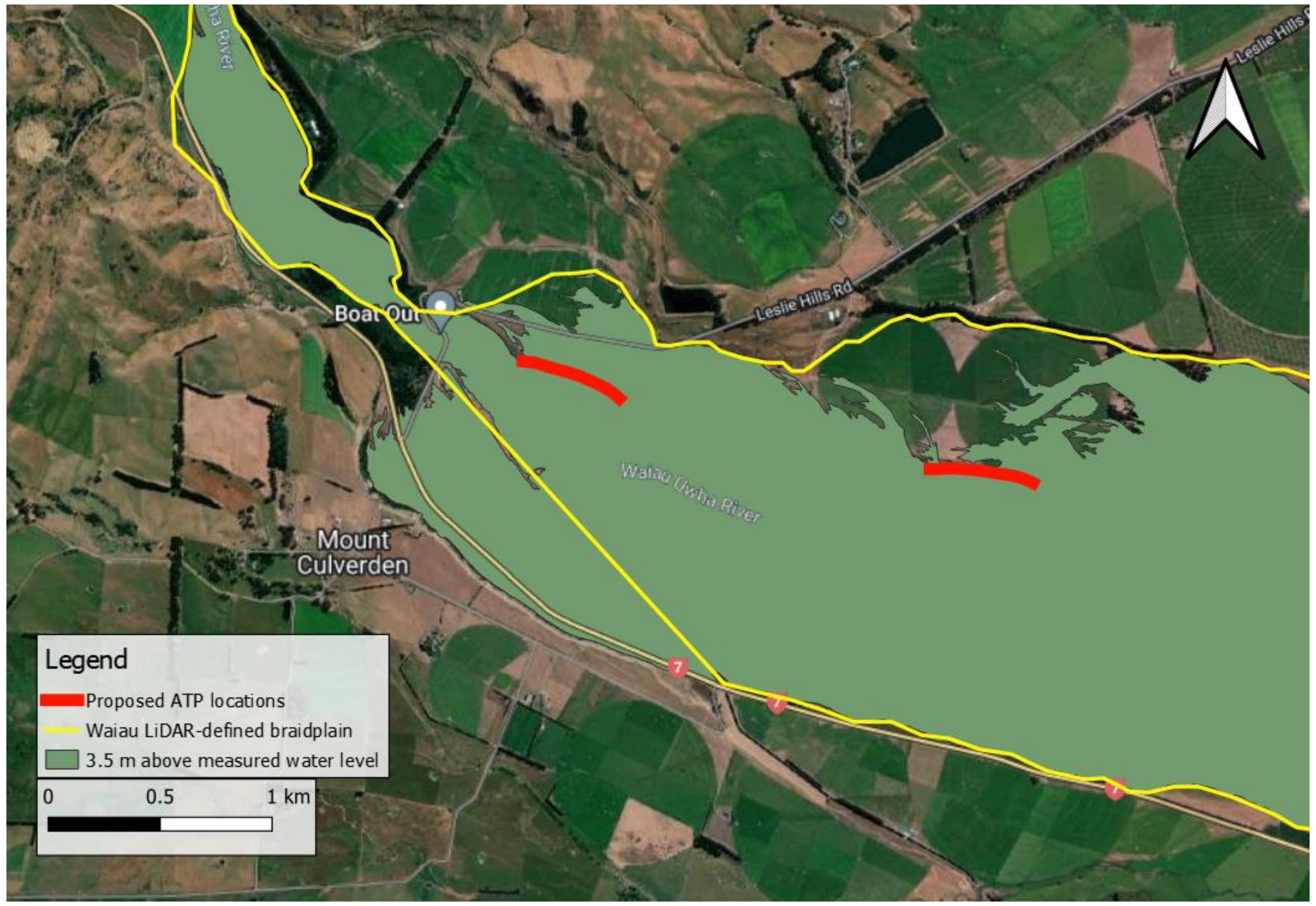

Figure vii. Marked area is at (or below) 3.5 m above water level, as measured during LiDAR survey.

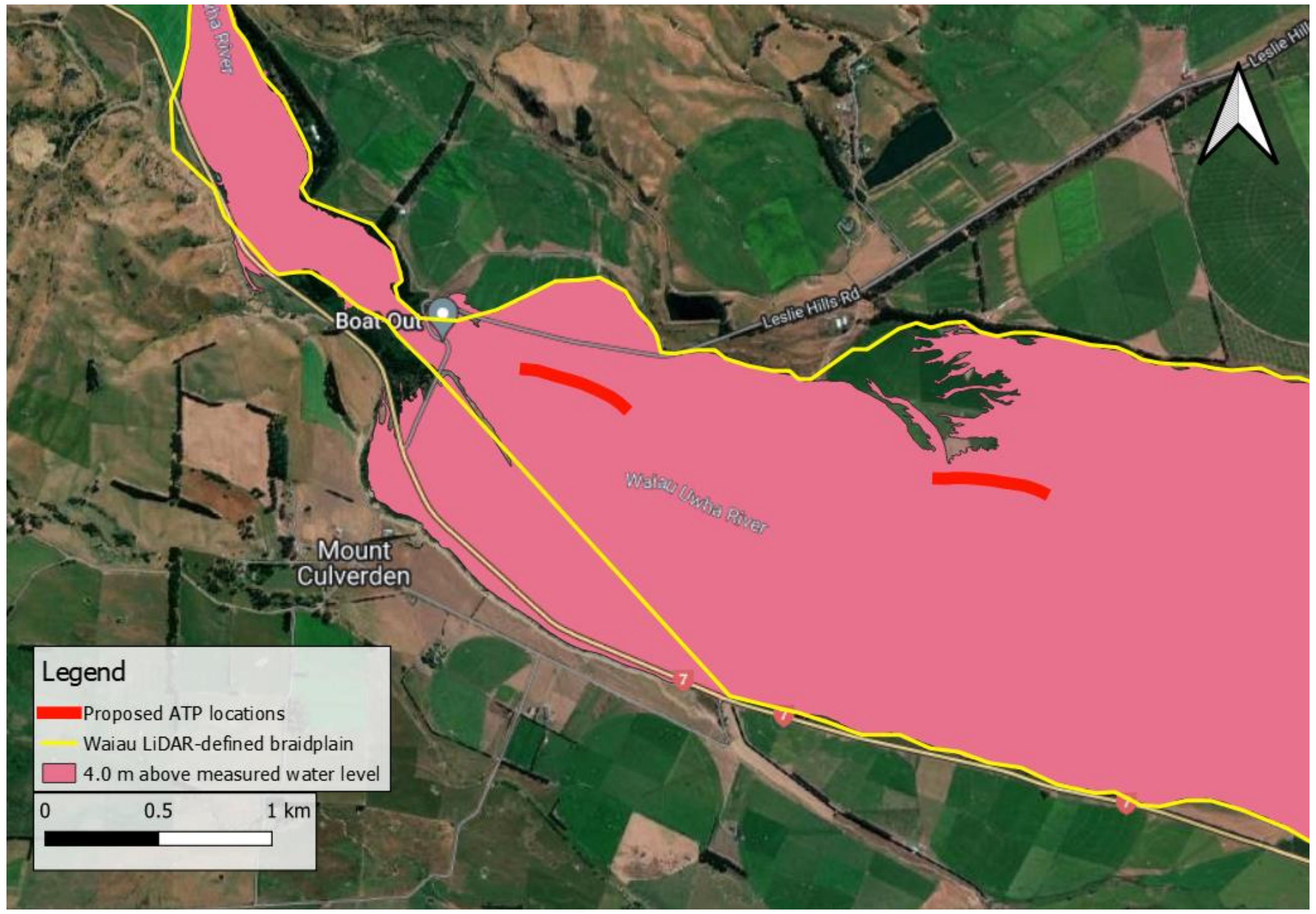

Figure viii. Marked area is at (or below) 4.0 m above water level, as measured during LiDAR survey.

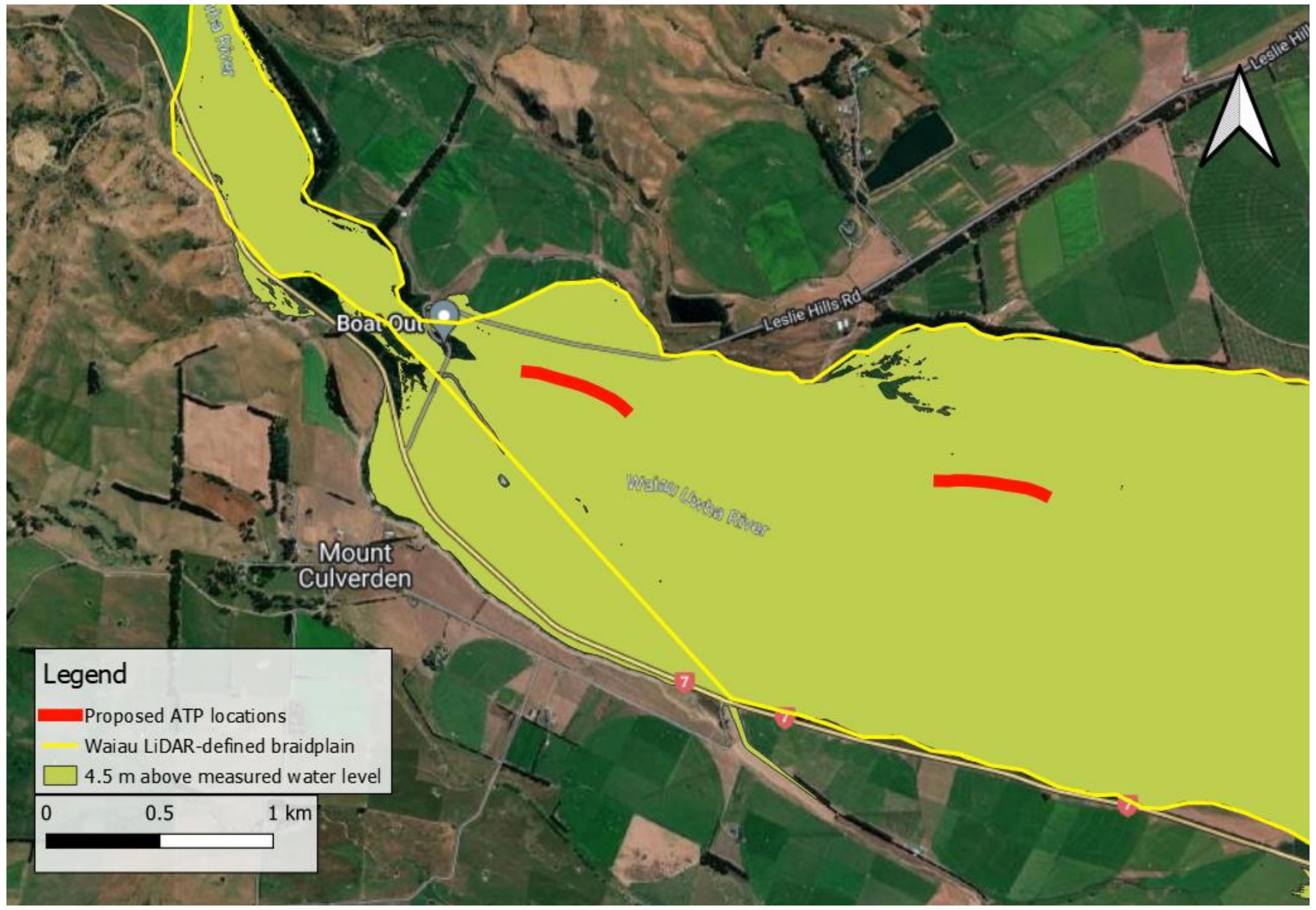

Figure ix. Marked area is at (or below) 4.5 m above water level, as measured during LiDAR survey.

Appendix II. Site Photographs

Figure i. Downstream-most proposed ATP reach. Note the visible erosion, but no indication of water egress over the bank toe.

Figure ii. Drone footage of downstream ATP reach.

Figure iii. Upstream-most proposed ATP reach. Less erosion than downstream, but still present. No signs of water egress over the bank toe.

Figure iv. Drone footage of upstream ATP reach.