Erosion Investigation
Armstrong West Revetment - Ausable River, Port Franks, Ontario

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1 Introduction

Ecosystem Recovery Inc. (ERI) was retained by the Ausable Bayfield Conservation Authority (ABCA) to complete an erosion investigation on the southeast portion of Chicken Island, fronting the Ausable River, in Port Franks, Ontario. The existing shoreline area is protected by an existing erosion control structure commonly referred to as the Armstrong West Revetment. The structure which was constructed in 2006 is approximately 300 m long and is maintained by ABCA. ABCA holds a maintenance and access easement over the first 5 m of the shoreline from the back side of the revetment. The erosion investigation consisted of a review of historic contract documents, historical site photos, a field investigation and topographic survey, documentation of field investigation findings and recommendations for future enhancement works.

1.1 Background

The Ausable River is a turbid, low-gradient watercourse which flows into Lake Huron within the village of Port Franks. There have been historical issues with bank erosion and ice jams near the mouth of the river. In response to historical erosion issues an erosion control structure was constructed along the southeast side of Chicken Island. Historical site photos can be found in **Appendix A**.

The Armstrong West structure was constructed in December 2006. It is composed of rip-rap revetment consisting of 600 mm of angular stone varying in size between 100 – 600 mm extending approximately 1.0 m below the riverbed. The design of the revetment incorporated a side-slope of 2.5:1 from the riverbed up to an intended elevation of 178.00 m. Bendway weirs were also designed and constructed perpendicular to the flow of the river along the bank revetment. The weirs consisted of trapezoidal rock formation with a 1.0 m top width and 2:1 side slope to the riverbed. The stone sizing for the bend way weirs was similar to that of the bank revetment and consisted of 100 – 600 mm rip-rap.

The bend way weirs were designed to re-establish and protect the bank of the river by providing deposition areas to promote sedimentation while directing higher-velocity flows into the central portion of the river channel. Post-construction surveys were completed in late 2006 and 2008. The surveys note that the top of the revetment was in an elevation range of 177.35 – 177.91 m, up to 0.65 m below the original design elevations. The discrepancy in top elevation resulted from variances in site conditions at the time of construction.

At the time of construction of the revetment, low water conditions were prevalent. The primary purpose of the Armstrong West erosion control structure was to promote deposition of mobilized sediment 'behind' the bendway weirs while providing immediate protection of the channel banks by the construction of a continuous layer of rip-rap revetment along the secondary Ausable River channel. As part of the detailed design process hydraulic modeling was completed to assess the erosive power of water under a range of flood-flow conditions and select the appropriate rip-rap gradation for the bendway weirs and channel bank revetment. Hydraulic modeling of the Ausable River was also completed to assess the weir configuration's impact on the hydraulic capacity and resultant hydraulic grade-line (flood stage) of the secondary channel. It is understood that flood-protection was not the primary purpose of the structure when it was constructed but was a consideration when the top of revetment design profile was originally established.

1.2 Climatic Conditions

With Lake Huron nearing record high water levels due to a combination of high precipitation and warmer than usual temperatures through recent winters, shoreline features and river deltas are being subject to higher than normal erosion potential throughout southern Ontario. In September 2020 Environment Canada (LEVELNews) reported that the Lake Huron basin beginning-of-October water level was 82 cm above the monthly average and at the same level as it was a year ago (177.25 m). Although Lake Huron's 2020 season rise in water levels has been less than average the fact that the lake started the year at record levels has led to additional flood and erosion risk during periods of prolonged wave runup. Ausable Bayfield Conservation Authority notes that recent storm events have caused the water to rise above existing erosion control structures near the mouth of the Ausable River at the terminus of Shipwreck Walk extending approximately 300 meters to the north demonstrating the potential to cause erosion of the sand dunes flanking the river.

2 Field Observations

The field investigations and survey portion of the erosion assessment took place on November 27 and December 9, 2020 and were attended by Ross Wilson of ABCA, Nicholas Krygsman, Brent Smolarz and Jake Carman from Ecosystem Recovery Inc. (ERI). The initial field investigation was attended by Ross Wilson and Nicholas Krygsman. The initial investigation focused on gaining an understanding of the general site conditions, confirming the scope of work and establishing the limits of the topographic survey. A photo inventory of the site conditions can be found within **Appendix B**. The survey portion of the assessment was completed by Jake Carman and Brent Smolarz on December 9, 2020. The survey data was tied into existing features and site benchmarks established by the Conservation Authority during previous surveying exercises. Subsequent to the survey, ABCA provided digital copies of AutoCAD base mapping of the Armstrong West revetment, including property parcel data.

Based on observed site condition, the existing conditions of the Armstrong West revetment has been documented in three approximately equal length reaches: the southern 100 m, the northern 110 m and the middle 90 m. These reaches were discretized because they correlate with physical changes in revetment or adjacent topographical conditions. The impacts of high lake levels also appear to be impacting the revetment differently in the three distinct reach lengths. The three reaches are identified and described as follows:

<u>Reach 1</u>

Reach 1 consists of the southern 100 m of revetment, adjacent to and overlapping with Clarke Lane, Lot 35 and the southern half of Lot 22. This reach is primarily characterized by its relatively well-established vegetation along the bank above the stone revetment. Above the stone revetment there is a bench/flat area of approximately 3.5 meters in width. Beyond the flat bench the area is relatively densely wooded with some small to medium sized areas of exposed sand dunes mixed in. The vegetation on the bench covers approximately 80% of the ground. The combination of dune grass, woody vegetation, and the root mass of trees in relatively close proximity to the river likely provides an extra level of erosion protection, leading to this reach demonstrating the least erosion impact of any area on the site.

<u>Reach 2</u>

Reach 2 consists of the middle 90 m of revetment, starting on the south of the middle of Lot 22, extending to the northern portion of Lots 14–15. This reach was defined based on the characteristics of the existing ground beyond the rip-rap revetment. The existing ground undulates in grade along the 90 m length with a significant low area observed behind the stone revetment adjacent to Smuggler's Lane. Areas north and south of Smuggler's Lane generally consist of a 3.5 m wide sand bench followed by medium to tall (2.5 – 5.0 m high) sand dunes behind the top of the stone revetment. The sandy bench and sand dunes are sparsely vegetated (approximately 30%), which has resulted in this reach being more prone to the erosion from surface runoff, ice flows, and the flow of the river in combination with localized wave action.

Areas within the extents of the Smuggler's Lane road allowance were generally observed to be low-lying and demonstrated more evidence of river and wave erosion impacts when compared with any other area on the project site. The stone revetment in this area is generally lower than in Reaches 1 and 2, likely due to the pre-2006 topographic conditions that existed within Smuggler's lane and the inability of the contractor to tie into existing ground with the originally proposed top of revetment elevation. This area has also been used as a boat and supply access route to the majority of the dwellings in the area. Ross Wilson of ABCA noted that the residents rely on the use of ATVs to transport people and supplies from the beach area, resulting in the area within and adjacent to Smuggler's Lane demonstrating a variety of erosion issues. A low-lying area was documented behind the erosion revetment in the north-eastern portion of Lot 23. This area is characterized by standing water and saturated sediment/organic muck which appears to have been deposited in the area as a result of river processes pushing over the stone revetment and the sediment settling within the pool of standing water behind the rip-rap. Since this area also represents the natural low point in the local topography it is plausible that a portion of the accumulated sediment originates from local stormwater runoff and wind-swept debris collecting behind the revetment. The sediment was distinctly different in composition than the predominate sandy soil behind the revetment throughout the project site and is illustrated in **Photo B-7**.

Photo B-10 illustrates a lengthy erosion scar that is evident along the majority of the central portion of the revetement. The erosion scare was also observed along the toe of the sand dunes on the east side of Smugglers Lane adjacent to the ATV trail located within ABCA's 5 m wide easement. This erosion scar forms a bench in the sandy soils and varied in height between 0.27 and 0.74 m. Based on site conditions it appears that the scar is likely a result of the low-lying nature of the local topography, ATV traffic adjacent to the sand dunes and the erosive forces from high-water wave action experienced through the summer and fall of 2020. The stone revetment in this reach was not as prominent with a lower density of the stone at the top of the revetment compared to that of Reach 1 or Reach 3. Based on site observations it was concluded that this may be a result of continuous wave action (wind and wake) dislodging the stone from the top of the revetment and ice jams/debris pulling stones from the revetment into the river, thus decreasing the stone placement density.

Reach 3

Reach 3 consists of the norther 110 m of revetment starting at the northern edge of Reach 2 at Lots 14–15 and extending to the northern limit of the revetment. This area is characterized by competent rock revetment and the accumulation of soil and vegetation above and behind the revetment. This area consisted of the rock revetment rising from the bank followed by a sandy soil bench of approximately 3.5 m, then a series of large sand dunes (up to 5.0 m high) interlaced with paths leading back to nearby cottages. The bench above the revetment is moderately vegetated (approximately 60%), and the sand dunes are well vegetated on top (approximately 70%) and sparsely vegetated along the river-facing side (approximately 30%).

A predominate feature of Reach 3 is the accumulation of sandy soil and debris on top of the stone revetment. As the stone revetment terminates into the existing soils above/behind, a notable step was observed consisting of native sand and organic debris which has built up behind the revetment. It is likely that these sands and organics are perched on top of the revetment as a result of erosion in the adjacent sand dunes and the stepped condition is maintained as new material erodes down the sand dune slopes and moved along the bench towards the river. This 'step up' in soil elevation behind the stone revetment is visible in **Photo B-15** with an observed height of 0.2 – 0.4 m.

3 Detailed Topographic Survey and Base Plan Preparation

In accordance with the terms of the proposal, a detailed topographic survey of the existing Armstrong West revetment has completed on December 9, 2020. The survey involved the collection of approximately 300 points along the full length of the 300 m erosion control structure and aimed to delineate the current configuration of the revetment. Topographic data was collected at evenly spaced sections perpendicular to the shoreline or at noteworthy transition points between topographic features. These features included break lines, vegetation, significant inflection points, pathways and waterbody features. The survey was completed using a Spectra SP60 GPS unit paired with a Trimble TDC600 data collector.

The primary goal of the survey was to detail the physical configuration of the rip-rap revetment both in terms of offset from the waters edge and elevation relative to the as-constructed survey data. Collection of cross-sectional information ensured that the true 'top' of revetment could be interpreted along the full length of the erosion control structure. Extending the cross-sections beyond the top of the revetment allowed for accurate interpolation of the existing ground features within the 5 m ABCA easement.

Post-survey processing was completed in Autodesk Civil 3D. In the CAD environment the individual survey points were compiled into three-dimensional feature lines and overlaid with an aerial photo and property parcel information. Additionally, the 2008 as-built survey data from the site was digitized from PDF versions of the mapping creating a secondary top-of-revetment surface. The two topographic survey surfaces where then overlaid and a top-of-revetment profile created along the full length of the erosion control structure. **Figure 1** below (full size figure included in Appendix C) illustrates the compiled topographic surface information from the Armstrong West revetment erosion investigation site.

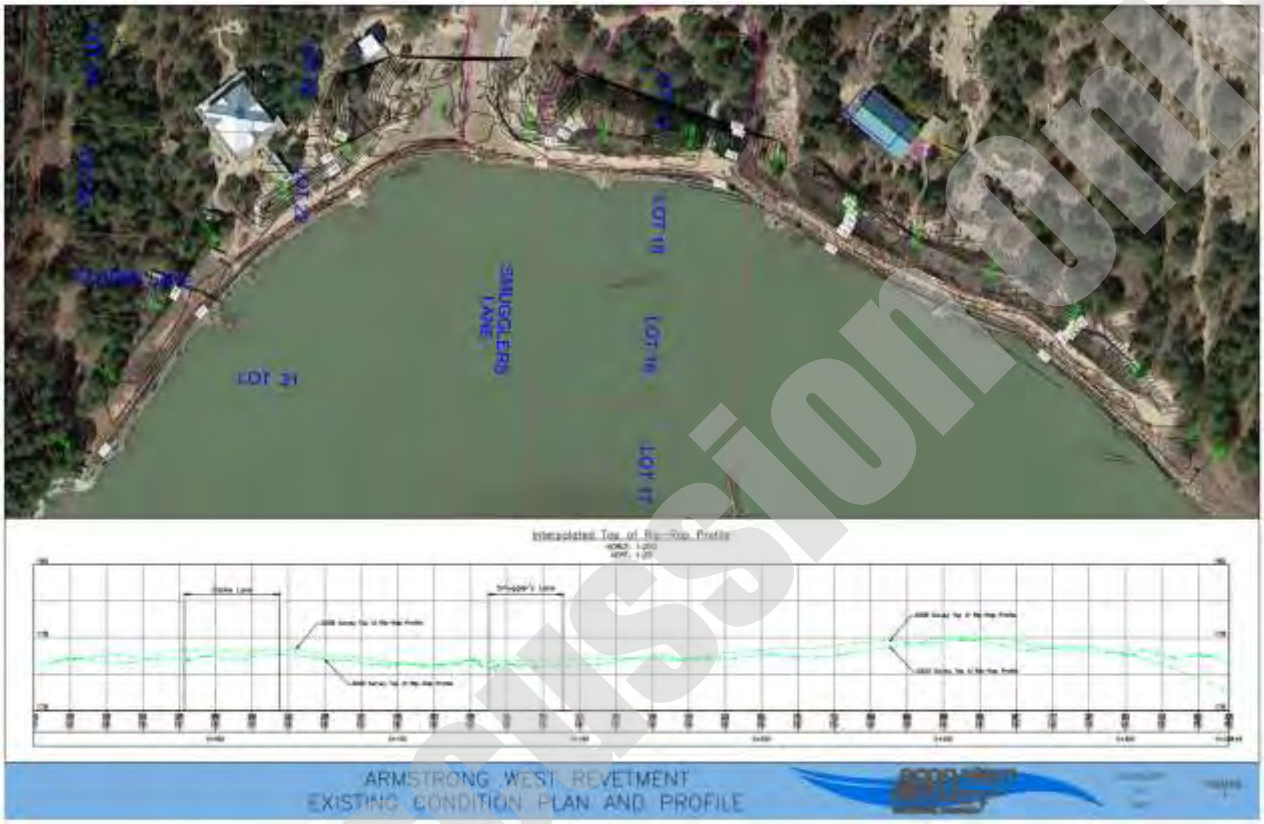


Figure 1 - Existing Condition Survey and As-built Profile

4 Comparison of Current and As-Build Survey Top-of-Revetment Profile

Upon completion of the survey and post-survey data processing the current and as-built top-of-revetment profiles were carefully examined. The comparison process involved plotting several top of revetment profiles for the 2008 and 2020 versions of the surveyed revetment surfaces and using cross-sectional information generated in Autodesk Civil3D to verify that representative points along the revetment were included in the profile data. Several iterations of the 2008 and 2020 top-of-revetment profiles were examined prior to establishing the final horizontal and vertical alignment for the Armstrong West revetment structure. **Figure 1** illustrates the final 2008 and 2020 versions of the top-of-revetment profiles along the full length of the Armstrong West structure. It is noted that despite the fact that the horizontal alignment of the top-of-revetment profiles differed slightly within Reach 2 of the Armstrong West structure the 2008 as-built survey top-of-revetment elevations were compared directly to the profile generated by the 2020 survey points. **Table 1** summarizes the elevations of the 2008 and 2020 top-of-revetment surveys on ten-meter intervals for the full length of the Armstrong West structure. The horizonal alignment stationing starts at the southerly end of the structure and follows the 2020 survey points defining the limit of the existing rip-rap. The table is broken up into the subject reaches (1-3) for clarity. A negative value indicates that the 2020 top-of-revetment survey points were found to be at a lower elevation than the 2008 as-built survey. The purpose of this examination was to determine if settling or displacement of the existing rip-rap channel bank revetment had occurred since construction and to establish a current profile for future comparisons to be based on.

Table 1 - 2008 As-Built vs. 2020 Survey Profile Comparison

Reach 1											
Alignment Station	0+000	0+010	0+020	0+030	0+040	0+050	0+060	0+070	0+080	0+090	
2008	n/a	177.43	177.34	177.36	177.63	177.68	177.66	177.67	177.54	177.44	
2020	177.25	177.40	177.49	177.44	177.39	177.46	177.50	177.52	177.39	177.31	
Difference	***n/a***	***-0.030***	***0.150***	***0.080***	***-0.240***	***-0.220***	***-0.160***	***-0.150***	***-0.150***	***-0.130***	
Reach 2											
Alignment Station	0+100	0+110	0+120	0+130	0+140	0+150	0+160	0+170	0+180	0+190	
2008	177.32	177.26	177.35	177.37	177.39	177.41	177.44	177.41	177.41	177.57	
2020	177.26	177.23	177.38	177.27	177.21	177.24	177.35	177.45	177.41	177.44	
Difference	***-0.060***	***-0.030***	***0.030***	***-0.100***	***-0.180***	***-0.170***	***-0.090***	***0.040***	***0***	***-0.130***	
Reach 3											
Alignment Station	0+200	0+210	0+220	0+230	0+240	0+250	0+260	0+270	0+280	0+290	0+300
2008	177.65	177.70	177.74	177.89	177.88	177.99	177.99	177.88	177.71	177.63	177.56
2020	177.51	177.47	177.51	177.86	177.80	177.89	177.90	177.71	177.73	177.75	177.53
Difference	***-0.140***	***-0.230***	***-0.230***	***-0.03***	***-0.080***	***-0.100***	***-0.090***	***-0.170***	***0.020***	***0.120***	***-0.030***

Table 2 provides a summary of the comparison between the 2008 as-built and 2020 existing conditions survey profile data.

Table 2 - Profile Comparison Summary

Reach Number	Range (m)	Maximum Difference (m)	Average Difference (m) over Reach
Reach 1	+0.080 to -0.240	-0.240	-0.094
Reach 2	+0.040 to -0.180	-0.180	-0.069
Reach 3	+0.020 to -0.230	-0.230	-0.087

As a point of discussion, it is noted that the topographic data obtained as part of the 2008 as-built survey and the 2020 existing conditions survey was collected using two different methods. The 2008 survey was completed using a Topcon Total Station utilizing a project bench-mark established for the site prior to construction. Total station survey equipment is widely accepted as having a vertical accuracy of about 1.5 mm over a distance of approximately 1,500 m. As previously indicated the 2020 survey was completed using a Spectra SP60 GPS unit paired with a Trimble TDC600 data collector. The survey equipment utilizes the Cansel/Trimble geodetic control network for real-time survey grade correction services and has a vertical and horizontal accuracy of +/- 30 mm. The relatively flat topography and lack of forest canopy cover at the Armstrong West site meant that the data collection was conducted at the highest level of horizontal and vertical accuracy available when utilizing survey-grade GPS technology.

In addition to the tabular summary of as-built and existing condition top-of-revetment elevations, the following general observations are noted:

- The existing top of revetment is generally situated below the 2008 as-built top-of-revetment on average of about 10 cm and ranged from 2 cm above to about 24 cm below the as-built survey records from the site. The elevations ranges noted in the tables fall outside of the expected error tolerance of the GPS survey equipment.
- In a number of instances, the revetment is currently 24 cm below the 2008 as-built top-of-revetment profile while other areas were recorded as being up to 8 cm above the original profile.

- Lake Huron water levels observed during the month of December had a mean of 177.14. This mean lake level is approximately 10 cm below the lowest point on the top of revetment (2020) corresponding to the Smuggler's Lane Right-of-way (ROW)

5 Observations Regarding the Performance of the Existing Revetment

As previously noted, site observations and detailed topographic survey of the Armstrong West revetment suggests that since 2008 there has been noteworthy displacement of the top of rip-rap revetment profile. On average the top-of-revetment elevations are approximately 10 cm below the 2008 as-built survey of the revetment but there are areas that were recorded as being both above the original survey and upwards of 25 cm below the original survey points. Although data collection and equipment error explain some of the discrepancies in elevations, it is apparent that portions of the revetment may have settled over the last decade. Other areas of the revetment, particularly those areas located at a higher elevation compared to the 2008 survey, may have been mechanically displaced by the movement of water, ice and freeze-thaw cycles over the last ten years.

Observations regarding the 'performance' of the Armstrong revetment are summarized as follows:

- The fact that the 2020 profile is generally located below the 2008 as-built profile elevations suggests that the revetment appears to be settling. The noted settling could be in part due to changes in the sandy soils bearing capacity due to being fully saturated by prevailing high-water levels.
- Mechanical displacement (both up and down) of the top portion of the revetment could be a result of a combination of high-water levels and ice movement along the shoreline, particularly along the lower portions of the revetment which display minimal freeboard to current water levels.
- The combination of high-water levels and wave action overtopping the revetment (and subsequent drainage back over or through the revetment) may be pulling some of the supporting sand through the voids within the revetment leading to further settling of the top of revetment.
- Vehicular traffic may be leading to the mechanical displacement of the sand supporting the 'back' of the revetment and subsequent settling or flattening of the top portion of sloping revetment. Mechanical displacement, particularly rutting of the sandy soil supporting the top of the revetment could also be displacing the rip-rip upward to a small degree.
- Vehicular traffic is directly impacting the growth of vegetation on the dunes flanking the revetment compromising the stability of the dune from the action of wind, waves and surface water runoff. Because the dune sand supports the overall shape of the revetment more significant global changes in the stability of the sand dunes may be impacting the configuration of the revetement.
- Vehicular traffic is concentrated within the middle portion of the Armstrong West structure which also correlates to the lowest portion of the revetment, impacted the most from high water levels, and may be considered to be accelerating the other processes noted in previous points.
- The construction of the rip-rap revetment and bendway weirs was completed using a barge and bucket dump placement method. Although as-constructed surveys have been done to verify that material was placed in a uniform and continuous layer, spatial variation in the integrity of the revetment system may exist and therefore some degree of 'movement' of the rip-rap is expected to occur over the lifespan of the erosion control system. The purpose of rip-rap revetment is to remain somewhat flexible while providing susceptible soil protection from the action of flowing water and in the case of the bendway weirs, suitable hydraulic conditions to promote accumulation of mobilized sediment and transported substrate.

Based on site observations, the completed survey and the general design parameters used to establish the configuration of the revetment it appears that the Armstrong West structure is generally functioning adequately in terms of maintaining its ability to protect the existing shoreline from the action of water, waves and ice. Some degree of degradation and displacement of the very top portion of the revetment has occurred as a result of prevailing high-water levels, saturated soil condition, and regular exposure to ice and wave action that may not have been entirely expected at the time of construction. Some of the degradation of the top portion of the revetment appears to be accelerated by vehicular traffic within the ABCA easement flanking the revetement that is displacing soil and damaging the stabilizing characteristics of the natural vegetation. Wheel ruts and mechanical displacement of the sand dunes along the 'outside' of the ABCA easement is causing further damage to the naturally occurring dune-grass vegetation causing localize areas of erosion and sluffing during extended periods of high-water levels.

The primary deficiency identified for the Armstrong West revetment relates to the lack of freeboard within the central portion (Reach 2) of the 300 m long erosion control structure based on current Lake Huron water levels. At the time of construction, the objective of the erosion control structure was to protect the channel banks up to the 1:100-year water level projections in the Ausable River (largely controlled by lake levels). During construction modifications were made to the design based on site conditions and the top-of-revetment profile was lowered to elevations in the 177.35 to 177.95 range within Reach 2. The design modification was necessary due to the low-lying ground elevations beyond the structure and therefore the inability to extend the sloping revetment to the design elevation without extensive grading beyond ABCA's easement. This design modification reduced available freeboard for the structure, which at the time had little to no impact on the performance of the revetment. Rising lake levels and recent storms have resulted in flooding conditions throughout the Ausable River delta and like other areas within Port Franks, the frequency of inundation and flood conditions have had a direct impact on the area surrounding the Armstrong West erosion control structure.

The area of low-lying ground within the Smuggler's Lane right-of-way and a portion of Lots 22 and 23 was noted as being fully saturated with pockets of standing water along the back side of the revetement during field investigations completed in late December 2020. Erosion scars on the dunes beyond ABCA's easement indicate that water levels and wave action had recently overtopped the revetment and inundated the area. The high-water levels within the river, combined with the sandy soil conditions beyond the revetment, results in saturated ground conditions and limited capacity for water to percolate through the upper soil strata. It is anticipated these conditions will persist with high lake levels and standing water will be prevalent as a result of revetment over-topping or the accumulation of surface water runoff from the local drainage area. Raising the top of the revetment would reduce inundation from high water levels or wave action but would have no effect on the elevated groundwater table and the soils ability to freely drain unless the ground surface was raised enough to create a positive hydraulic gradient from the ground surface to the water levels within the adjacent channel. For the low-lying ground around Smuggler's Lane, this would require the placement of approximately 0.5 – 1.0m of fill over an area of approximately 1,700 square meters.

Although not specifically designed as a flood control structure, the fact that the rip-rap revetment extended up the banks of the Ausable to an elevation close to the maximum monthly mean water level recorded in 1986, meant the erosion control structure (in combination with the channel banks) provided the adjacent area with protection from high-water conditions in the river. The fact that a construction phase design change was made which lowered the top of revetement profile through the middle portion of the structure reiterates the fact that the inherent success of the erosion control system did not rely specifically on achieving a certain elevation standard or flooding criteria, rather a continuous system of channel bank erosion protection.

6 Summary of Potential Enhancement Alternatives

A number of enhancement options have been developed for the Armstrong West Revetment based on site conditions and the assessed performance of the existing erosion control structure. The following section provides a brief overview of the details of each enhancement.

Alternative 1 – Do Nothing
The 'Do Northing' alternative involves accepting the current level of service of the existing erosion control structure. Although the lack of freeboard of the structure is resulting in frequent inundation of the low-lying area adjacent to the revetment there is potential that lake levels will recede, and this situation will improve. Under lower water level conditions there is adequate freeboard at the lowest points along the top-of-revetment profile to protect the adjacent land area from the action of flowing water, waves and ice. Raising the top of the revetment either by extending the slope and infilling behind it or building a rip-rap capped berm could potentially become a barrier during low water level conditions and make river access difficult or require the construction of different dock system to maintain boat access.

Under the do-nothing scenario, the low-lying ground within the Smuggler's Lane right-of-way and Lots 22 and 23 will likely remain saturated with pockets of standing water. Although a slow process, continuous natural infilling (wind-swept sand, sediments and accumulating biomass) will result in a broad range of emergent shoreline vegetation communities establishing itself and stabilizing the sand dunes. Re-vegetation would be somewhat reliant on limitations put on vehicular traffic and ATV usage in the area immediately adjacent to the existing revetment. Currently Lake Huron water levels are on a downward trajectory after nearing record levels in 2021. The cyclic nature of the Great Lakes water levels suggests that periods of extreme high-water levels are general followed by a steady recession. Climate change influences appear to be impacting the period length between extreme high and extreme low lake levels within the Great Lakes basin.

Alternative 2 – Raise the Top of Revetment to 178.00 (original design)

Alternative 2 is premised on executing the objectives of the original revetment design by providing approximately 0.5m freeboard to highest monthly mean water level (1986) recorded which is understood to loosely correspond to the 1:100-year water level within the Ausable River. Two sub-alternatives have been considered under this general alternative. The first sub-alternative involves construction of a rip-rap capped berm to a top elevation of 178.00 within ABCA's 5.0 m wide easement. The second sub-alternative involves extending the current revetment slope to and elevation of 178.00 and infilling the remaining low-lying area to a constant elevation. Either constructing a berm or infilling the low-lying areas beyond the revetment is required to achieve a stable bank configuration to support the rip-rap revetment.

Figure 2 illustrates the general configuration of a berm having a 2.0 m top width and 2:1 side-slopes occupying a majority of the 5.0 m wide ABCA easement. The berm would consist of a 600 mm thick layer of rip-rap over a core of native fill material.

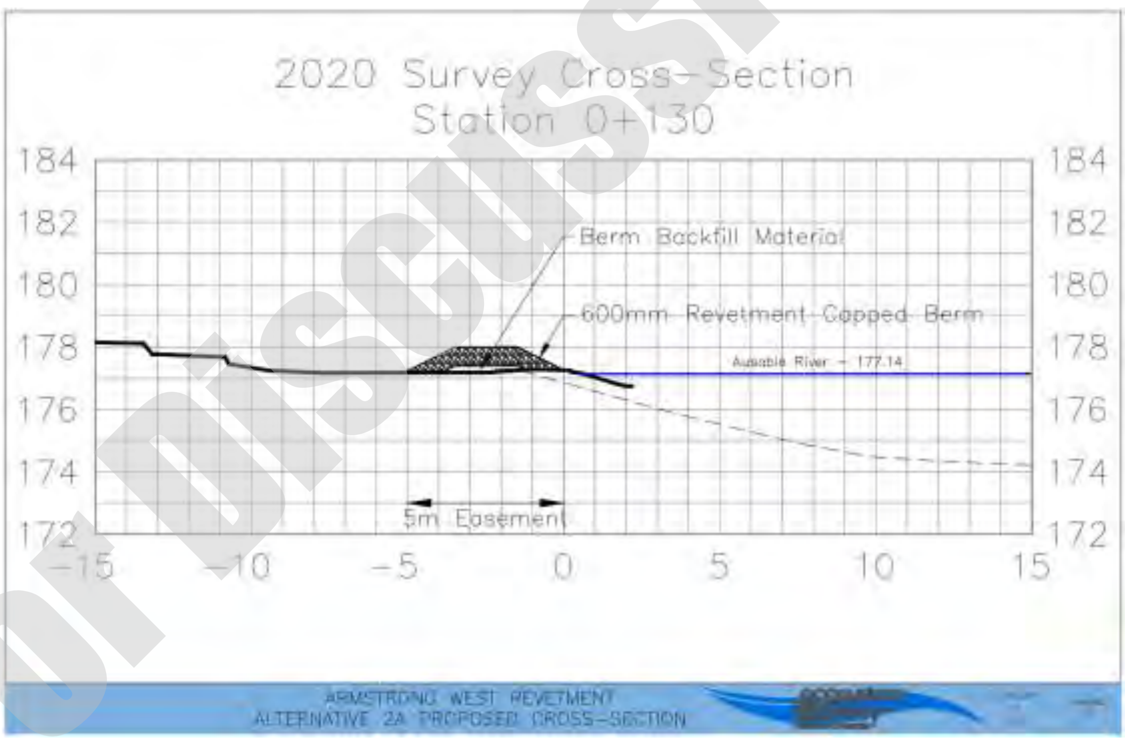


Figure 2 - 600mm Revetment Capped Berm

Figure 3 illustrates the general configuration of a 2:1 revetment extension to an elevation of 178.00 and backfilled with native fill material. The revetment extension, similar to that of the original erosion control structure, would consist of a 600 mm thick later of rip-rap and terminate at the fill level of 178.00.

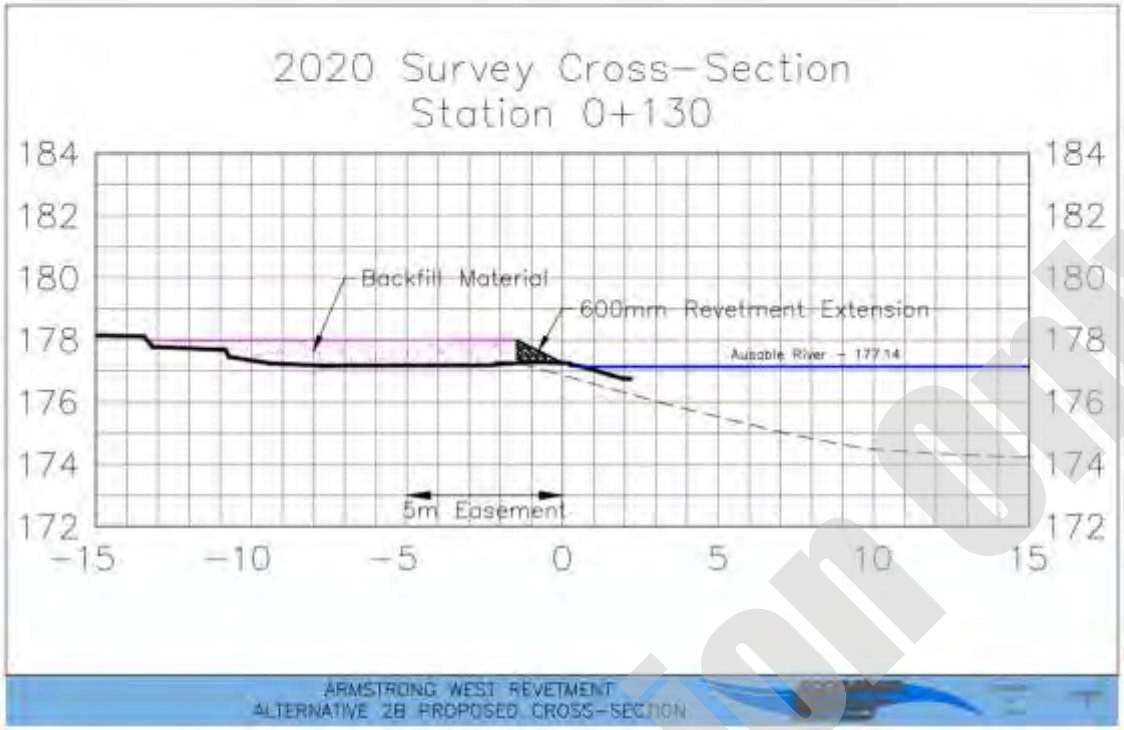


Figure 3 - 600mm Revetment Extension with Backfill

To achieve a consistent top of revetment elevation of 178.00, the full length of the existing revetment would have to be enhanced. In a number of locations the erosion control structure would have to be raised 0.78 m and on average 0.6 m over Reach 1, 0.7 m over Reach 2 and on average 0.3 m over Reach 3. For Alternative 2A the 2.0 m wide berm would occupy almost all of the 5.0 m ABCA easement, tying into higher ground throughout most of Reach 1 and 3, while creating a raised berm structure throughout a majority of Reach 2. For Alternative 2B, the revetment extension would occupy 1.0-2.0 m of the easement and the native material backfill supporting the revetment would then tie into higher ground beyond the back of the revetment. Within Reach 1 and 3 the tie in point maintaining a finished grade elevation of 178.00 would occur within the ABCA's easement. Within Reach 2 the finished grade would extend more than 15 m from the current limit of the revetment in order to achieve positive drainage towards the river.

As with any channel berming works aimed at containing higher flow conditions inherent complication comes by way of providing adequate drainage of the land on the 'inside' of the flood protection structure. Typically retaining walls, earth berms and dikes include provisions for 'internal' drainage of surface water runoff by way of ditching, storage structures or complex pumping systems. The construction of Alternative 2A would result in a portion of Chicken Island overland drainage system being cut off, particularly within the northerly portion of Lot 23 and within the Smuggler's Lane right-of-way. Runoff generated by the local drainage area would collect in the low lying on the inside of the berm and pond up (similar to what is happening today) until such time as it infiltrates the ground, seeps through the porous revetment or evaporates. Alternative 2B addresses this issue by way of filling the low-lying area on the inside of the revetment.

Figure 4 and **Figure 5** included in **Appendix C** illustrates the plan, profile and section views of the rip-rap capped berm and revetment extension concepts described as Alternative 2A and 2B. **Table 3** summarizes the key design characteristics of Alternative 2A and 2B.

Table 3 - Summary of Alternative 2 Design Characteristics

Design Characteristic	Alternative 2A	Alternative 2B
Target Elevation	178.00	178.00
Station Range of Required Enhancement	0+000 to 0+300	0+000 to 0+300
Total Length of Enhancement	300 m	300 m
Volume of Rip-Rap Revetment	625 m^3	190 m^3
Volume of Native Fill Material	194 m^3	1494 m^3

Alternative 3 – Raise the Top of Revetment to 177.50

Alternative 3 is premised on improving the level of service of the lowest portion of the existing erosion control structure by raising the minimum elevation of the revetment to 177.50. Achieving a minimum elevation of 177.50 would in turn provide the erosion control structure with zero freeboard to the highest monthly mean water level on record and approximately 0.4 m of freeboard to the current (December 2020) Ausable River water levels. The improvement work would be limited to Reach 1 from Station 0+000 to 0+035 and Reach 2 from Station 0+085 to 0+185. The remaining portion of the existing erosion control structure is located at or above an elevation of 177.50.

For Alternative 3A, the 2.0 m wide berm would occupy almost all of the 5.0 m ABCA easement and create a very low-height berm structure within Reach 2. For Alternative 3B, the revetment extension would occupy less than 1.5 m of the easement and the native backfill supporting the revetment would then tie into higher ground beyond the back of the revetment, similar to Alternative 2B. Within Reach 1 the tie in point maintaining a finished grade elevation of 177.50 would occur within the ABCA easement. Within Reach 2 the finished grade would extend less than 10 m from the current limit of the revetment except for the low area within the north portion of Lot 23 and throughout most of the Smuggler's Lane right-of-way. The low-lying nature of this area would require grading in excess of 15 m from the current limit of the revetment in order to achieve positive drainage towards the river. The physical configuration of Alternative 3A and 3B is the same as what is illustrated in **Figure 2** and **Figure 3** except at a lower top of berm and top of revetment elevation within the specified Station ranges.

Similar to Alternative 2A and 2B, Alternative 3A would essentially cut off overland drainage characteristics on the inside of the revetment structure and impact the area within Smuggler's Lane and the northern portion of Lot 23. Drainage of accumulated surface water would rely on infiltration, seepage through the porous revetment capped berm and evaporation. Alternative 3B on the other hand would address this concern but would require the placement of a large volume of fill material or extensive reshaping of the adjacent sand dunes. A minimum ground elevation of 177.50 would be required to provide positive drainage towards the river.

Figure 6 and **Figure 7** included in **Appendix C** illustrates the plan, profile and section views of the rip-rap capped berm and revetment extension concepts described as Alternative 3A and 3B. **Table 4** summarizes the key design characteristics of Alternative 3A and 3B.

Table 4 - Summary of Alternative 3 Design Characteristics

Design Characteristic	Alternative 3A	Alternative 3B
Target Elevation	177.50	177.50
Station Range of Required Enhancement	0+000 to 0+035, 0+085 to 0+185	0+000 to 0+035, 0+085 to 0+185
Total Length of Enhancement	135 m	135 m
Volume of Rip-Rap Revetment	216 m^3	30 m^3
Volume of Native Fill Material	N/A	338 m^3

Alternative 4 – Maintain Existing Top of Revetment Elevation with Enhanced Ground and Slope Stabilization

Alternative 4 is like Alternative 1 (Do Nothing) in that the existing top of revetment profile would be maintained at the current elevations along the full length of the existing structure. The revetment itself would not be improved and therefore the current overtopping condition would persist within Reach 2 of the erosion control structure during periods of high water, wave run-up or ice jams. Unlike the other alternatives, Alternative 4 would focus on stabilizing the unvegetated portion of the overbank and sand dunes directly adjacent to the existing revetment.

To maintain public access to boat docks along the revetment the current 'roadway' would be stabilized with a geotextile overlain with a base of crushed stone. The road 'base' would be graded with course enough material to allow it to infill with sand and organic matter and eventually re-vegetate. The road base would provide a more durable surface for ATV traffic and address the mechanical displacement of the sand that supports the back of the existing rip-rap revetment therefore mitigating future settling. The crushed stone base would provide structural support of the ATV traffic while the underlain geotextile would prevent the crushed stone material from settling into the unconsolidated upper soil strata. Delineation of the 'roadway' would provide a discrete path for ATV traffic to use and reduce off-tracking and future impacts on vegetation along the roadway therefore improving the overall stability of the ground and slope adjacent to the existing revetment. The crushed stone base would also provide some degree of surface erosion protection for the low-lying ground directly adjacent to the revetment.

As evident in the site photos included in Appendix B, well-established vegetation within Reach 1 and 3 is providing excellent protection of the shoreline from the action of flowing water, waves and ice. In these areas there is no direct vehicular access impacting the growth of dune grass and other emergent vegetation communities. The biomass associated with the dune grass, emergent vegetation and larger trees has formed (and continues to form) a protective layer for the underlying sandy soils therefore stabilizing the slope that supports the existing revetment and providing excellent erosion protection from conditions that result in overtopping of the existing structure. Alternative 4 identifies an elevational 'band' within which exposed soils would be targeted for vegetative planting enhancement with the objective of forming a secondary erosion control buffer for the full length of the existing erosion control structure. The erosion control buffer would allow the watercourse to overtop its banks and spill onto the adjacent floodplain during high-stage conditions but would minimize the impacts on exposed dune sand during periods of inundation while promoting some deposition of suspended solids and organic matter that would lead to further dune nourishment. Alternative 4 would require construction activities within ABCA's 5 m easement and in the dune areas immediately adjacent to the existing revetment.

Figure 8 included in **Appendix C** illustrates the plan, profile and section views of the enhanced ground and slope stabilization concept described as Alternative 4. **Table 5** summarizes the key design characteristics of Alternative 4.

Table 5 - Summary of Alternative 4 Design Characteristics

Design Characteristic	Alternative 4
Target Elevation of Vegetative Enhancements	179.00
Station Range of Required Enhancement	0+000 to 0+300
Total Length of Enhancement	300 m
Volume of Road Bed Material (300mm Thick)	118.2 m^3
Area of Geotextile	392 m^2
Area of Planting Enhancement	1177 m^2

7 Recommendations

Based on site observations, a detailed topographic survey and an overall assessment of performance it is concluded that the existing Armstrong West Revetment is functioning sufficiently as an erosion control structure. However, the prevailing high-water level within the Ausable River (Lake Huron) is resulting in a reduced level of service with respect to flood protection. The lack of freeboard has resulted in more frequent overtopping of the revetment and localized flooding on the inside of the erosion control structure. Although flood protection was not the original design intent of the structure, the configuration of the revetment and topography of the overbank within Reach 1 and 3 does allow it to function as such.

Alternative 1 (Do Nothing) provides no enhancement of the erosion or flood controlling capabilities of the structure, instead relies on receding water levels to improve the level of service of the revetment. It is noted that Lake Huron water levels continue to trend downwards following a cyclic historic pattern of water level fluctuations. Alternatives 2 and 3 have been developed based on the objective of improving the level of service of the Armstrong West structure both in terms of erosion and flooding protection. A higher degree of erosion protection is achieved by way of the construction of a rip-rap capped berm or revetment slope extension to a higher elevation than existing conditions. The berming or filling required to construct the proposed revetement enhancements in turn provide an enhancement to the flooding proofing characteristics of the structure but complicate internal drainage characteristics. Alternative 4 was developed on the basis of accepting the current flood proofing capabilities of the structure and enhancing the erosion control characteristics of the overall revetment 'system' (river bank). Alternative 4 achieves the noted enhancement by stabilizing the area accessed by motorized vehicles and revegetating the areas having poor ground cover thereby reducing the risk of significant bank erosion during high water conditions.

Since each of the four defined alternatives achieves different objectives (ie. erosion control enhancement vs flood control enhancement) it is difficult to compare them directly based on area of impact, material volumes or associated construction cost, the later of which is not explicitly discussed as part of this investigation. Based on an overall assessment of potential enhancement alternatives it is recommended that the existing Armstrong West Revetment be enhanced by way of construction of a stable, durable and erosion resistant access road adjacent to the existing revetment paired with strategic revegetation of highly erosive soils exposed in the area flanking the structure. The roadway, occupying the ABCA easement from Station 0+065 to Station 0+185, would reduce the degree of mechanical displacement of sand along the back of the revetment and therefore stabilize the top of the existing structure while providing a defined path for ATV traffic accessing the shoreline. Reduced off-tracking of vehicular traffic, in combination with strategic plantings, would promote establishment of erosion resistant vegetation and achieve the desired level of ground/slope stabilization. As demonstrated by the north and south portion of the Armstrong West structure, vegetation provides both effective and adaptable erosion protection of sandy soils under a broad range flow and water level conditions. A competent layer of vegetation can quickly regenerate if displaced by the action of ice and debris. The existing revetment is capable of performing even if completely submerged. The robust nature of the original revetment structure ensures that the competency of the submerged toe of slope will not be compromised under fluctuating water levels. The bendway weirs will continue to effectively control channel velocities and promote deposition even if prevailing elevated water levels submerge the individual structures.

Ecosystem Recovery Inc.

Nicholas Krygsman, P.Eng.
Water Resource Engineer and Project Manager

Appendix A

Historical Site Photos

Photo A-1: Post-construction rock revetment and bend way weirs, looking south (taken 2006)

Photo A-2: 2006 Historical Air Photo

Photo A-3: 2008 Historical Air Photo

Photo A-4: 2010 Historical Air Photo

Appendix B

Existing Condition Site Photos

Photo B-1: Southern end of Reach 1, looking south

Photo B-2: Southern end of Reach 1, looking north.

Photo B-3: Vegetated bench of Reach 1, looking north.

Photo B-4: Northern end of Reach 1, looking south.

Photo B-5: Southern end of Reach 2, looking north.

Photo B-6: Southern end of Reach 2, looking north.

Photo B-7: Low-lying area on Lot 23, looking south.

Photo B-8: Smuggler’s Way, looking west

Photo B-9: North end of Lot 23, looking south.

Photo B-10: South end of Lot 14, looking west.

Photo B-11: South end of Lot 14, looking north.

Photo B-12: North end of Lot 14, looking north.

Photo B-13: North end of Lot 14, looking south.

Photo B-14: North end of Lot 14, looking south.

Photo B-15: Sand bench above stone revetment.

Photo B-16: Midway into Reach 3, looking north.

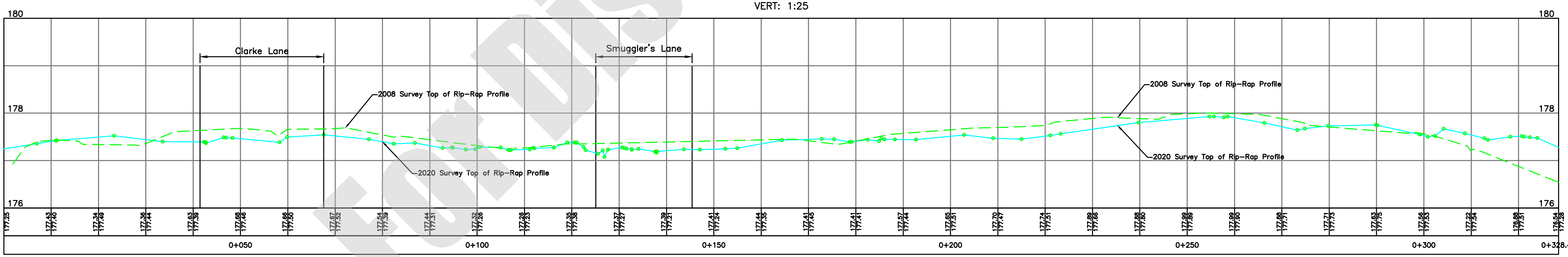
Photo B-17: North end of Reach 3, looking south.

Appendix C

Full Sized Figures (Figure 1, 4, 5, 6, 7 and 8)

Interpolated Top of Rip-Rap Profile

HORIZ: 1:250
VERT: 1:25



ARMSTRONG WEST REVETMENT
EXISTING CONDITION PLAN AND PROFILE

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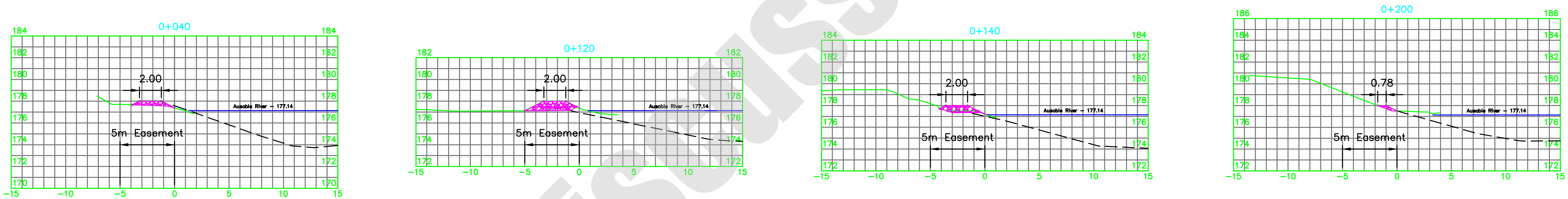
FIGURE
1



Interpolated Top of Rip-Rap Profile

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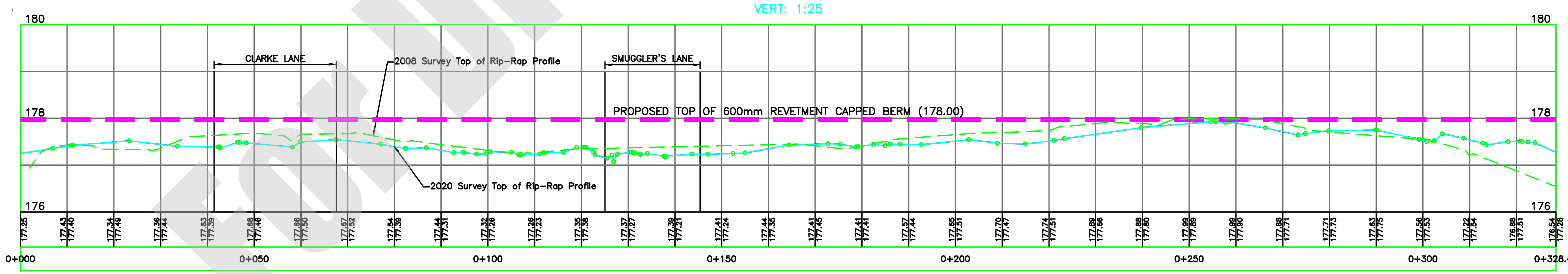
VERT: 1:25



ARMSTRONG WEST REVETMENT
ALTERNATIVE 2A PLAN–PROFILE–SECTIONS

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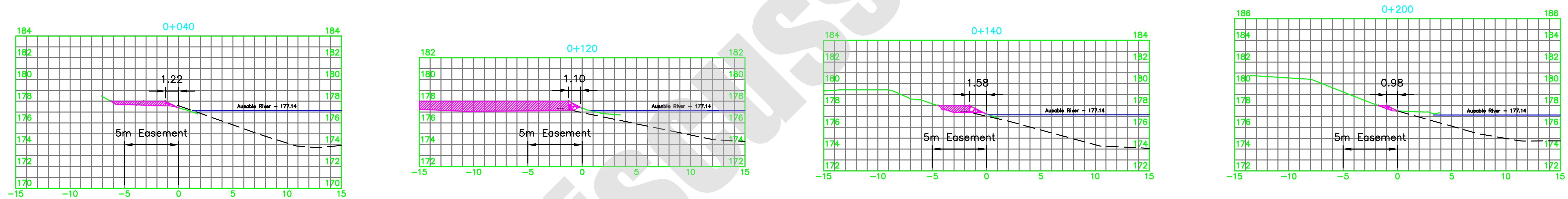
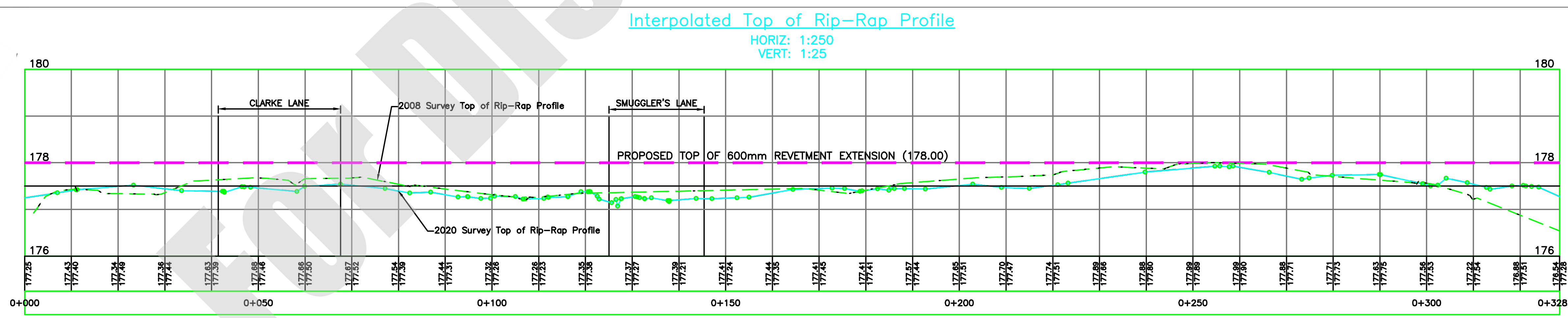
FIGURE 4





ARMSTRONG WEST REVETMENT
ALTERNATIVE 2B PLAN–PROFILE–SECTIONS

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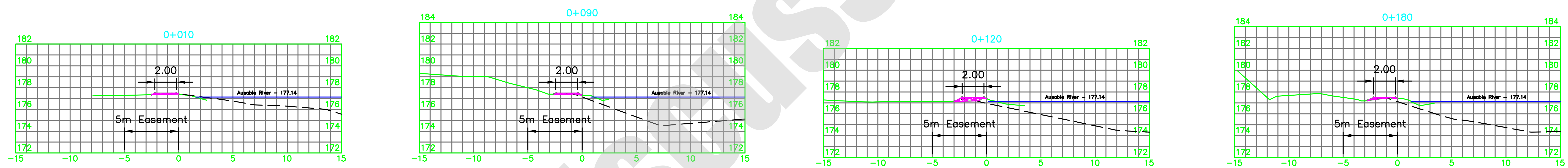
FIGURE
5



Interpolated Top of Rip-Rap Profile

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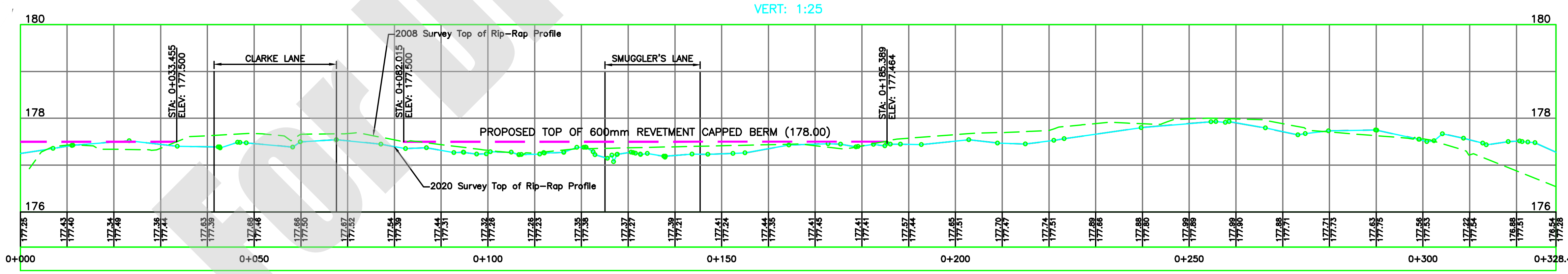
VERT: 1:25



ARMSTRONG WEST REVETMENT
ALTERNATIVE 3A PLAN–PROFILE–SECTIONS

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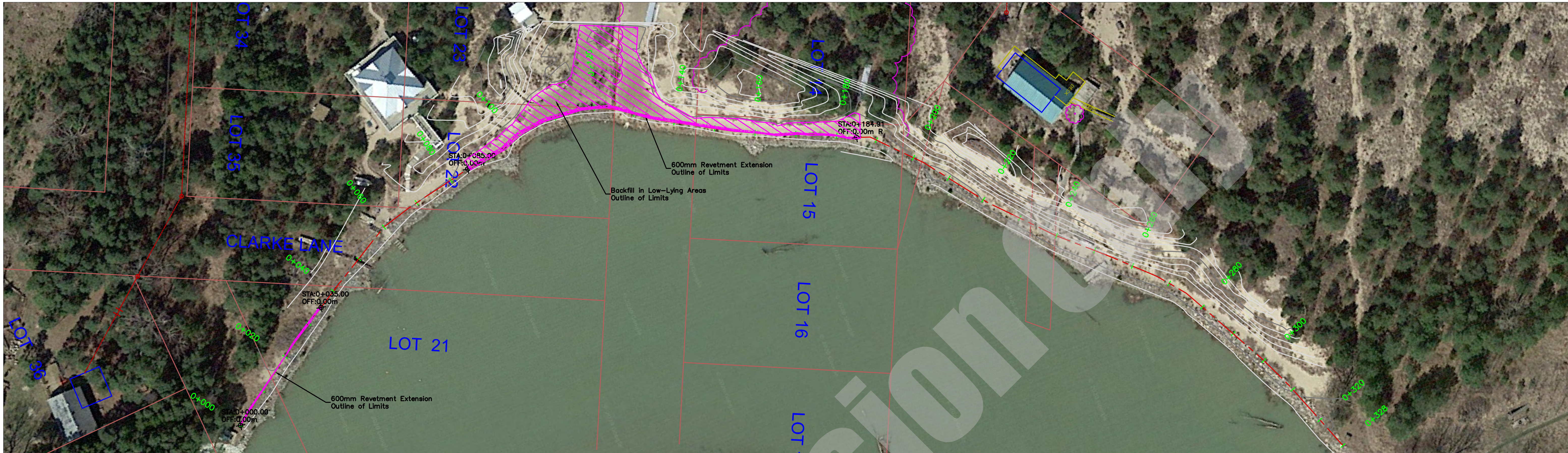
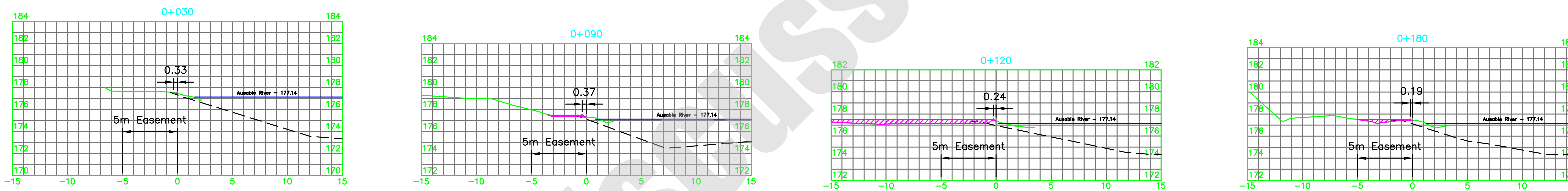
FIGURE 6





Interpolated Top of Rip-Rap Profile

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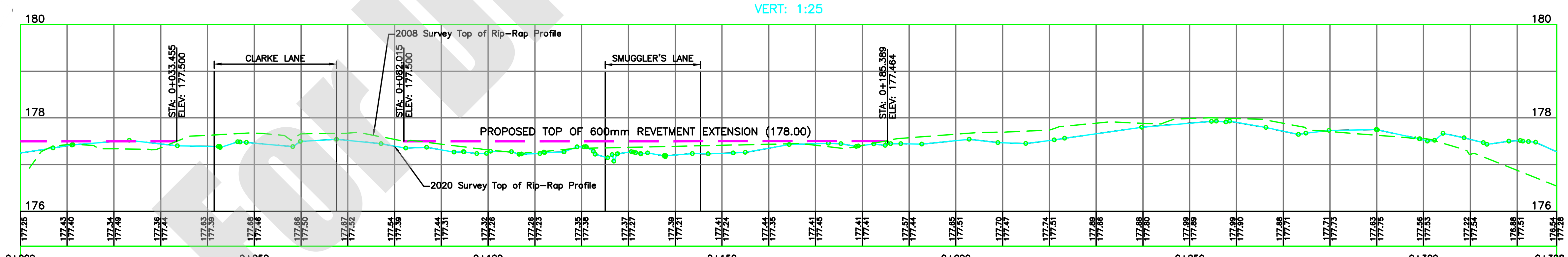
VERT: 1:25



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ALTERNATIVE 3B PLAN-PROFILE-SECTIONS

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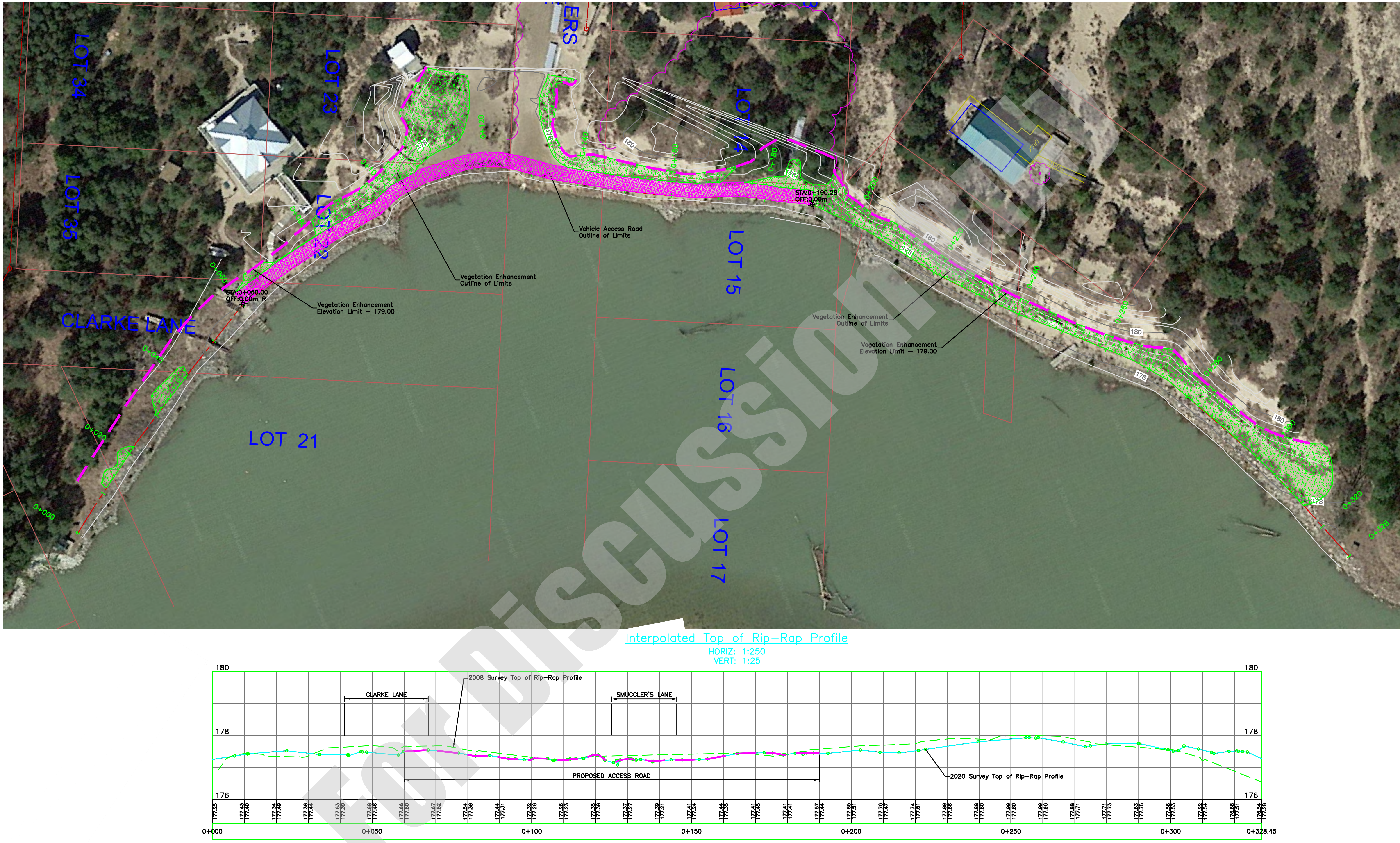
FIGURE 7



ARMSTRONG WEST REVETMENT
ALTERNATIVE 4 PLAN–PROFILE

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FIGURE
8