Staff Report

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Report To:	**Planning and Development Committee**		
Date of Meeting:	February 1, 2021	**Report Number:**	PDS-007-21
Submitted By:	Faye Langmaid, Acting Director of Planning Services		
Reviewed By:	Andrew C. Allison, CAO	**Resolution#:**	PD-029-21, PD-113-21
File Number:	PLN15.2.2	**By-law Number:**	
Report Subject:	Cedar Crest Beach – Property Loss Study		

Recommendations:

1. That Report PDS-007-21 be received; and
2. That all interested parties listed in Report PDS-007-21 and any delegations be advised of Council's decision.

Report Overview

This report provides background information on the Cedar Crest Beach – property loss study requested by Council, including the final Port Darlington West Embayment Shoreline Change Assessment report prepared by Zuzek Inc. (January 25, 2021). The final report details a historical shore trend analysis, field data collection, and results of modelling. It identifies both positive and negative impacts associated with the artificial littoral barriers that bound this reach of Lake Ontario shoreline and the other factors that contribute to both shoreline recession and accretion within the embayment situated between the St. Marys Cement headland and the Port Darlington jetties, in Bowmanville.

1. Background

1.1 The reach of Lake Ontario shoreline that is the subject of this report, referred to hereafter as the Port Darlington West Embayment, extends from St. Marys Cement eastward to the piers at the mouth of Bowmanville / Soper Creek (approximately 1,800 m). The area is subject to multiple natural hazards, including lake flooding, erosion and dynamic beach, and riverine flooding from the adjacent Westside Creek and Bowmanville / Soper Creek watersheds and marsh systems. The Port Darlington West Embayment is shown in Figure 1.

Figure 1: Key Map – Port Darlington West Embayment

1.2 Report CAO-006-19, dated June 17, 2019, outlines the history and background of the actions that have been taken over the past 4 years by the Central Lake Ontario Conservation Authority (CLOCA) and the Municipality with regard to the multiple natural hazards which are present. As a result of Report CAO-006-19, Council passed Resolution #C-275-19 on July 2, 2019. This resolution had several requests of staff. An outline of these requests and the actions taken were reported in CAO-010-19.

1.3 The purpose of this report is to address the following action from Resolution #C-275-19:

> *That Clarington Staff provide a report to Council on the quantum of waterfront property and public beach that have been lost along Cedar Crest Beach Road since the St. Marys / Votorantim dock expansion took place due to erosion and all other environmental factors and report back to Committee in September 2019.*

1.4 Section 3.8 of CAO-010-19 outlines the work by Municipal and CLOCA staff with regard to review of historical records, aerial photographs, subdivision plans and land ownership records, a review of which clearly demonstrates ownership of a "beach" has not been public. Unlike the beach at Port Darlington West Beach Park, dedication of a beach block was never part of the subdivision plan along Cedar Crest Beach Road.

1.5 Report PSD-012-20, dated April 27, 2020, outlines the steps that occurred relating to approval of the scope of work, budget ($30,000) and consulting firm to complete the assignment. On May 25, 2020, Council approved resolution #C-235-20, approving the approach for consultant selection and providing for the award of contract for the completion of the requested study to Zuzek Inc., and directing staff to report back to Council with the results of the study, once completed.

1.6 The scope of the assignment undertaken by Zuzek Inc. builds off the technical investigations completed recently for the Lake Ontario Shoreline Management Plan (Zuzek Inc., 2020). The Lake Ontario Shoreline Management Plan was originally prepared in 1990 for the Central Lake Ontario, Ganaraska Region and Lower Trent Conservation Authorities. It provided shoreline management direction for each authority's respective shoreline area, extending approximately 135 km along the north shore of Lake Ontario. In 2018, an update of this plan was jointly initiated by these three Conservation Authorities, with support from the affected municipalities. The final Lake Ontario Shoreline Management Plan (Zuzek, 2020) was endorsed by the CLOCA Board on January 19, 2021.

1.7 The technical report prepared by Zuzek Inc., Port Darlington West Embayment Shoreline Change Assessment (January 25, 2021), is provided as Attachment 1.

2. Summary of the Shoreline Change Assessment Findings

2.1 The following sections present a synopsis of the approach and key findings from the assessment undertaken by Zuzek Inc. Refer to the complete technical report (Attachment 1) for detailed information on the data collection, modelling and analysis methods. A summary of the study conclusions is found in Section 4.0 (Attachment 1).

2.2 The scope of the shoreline change assessment included the following:

- Review of construction history in the area for potential littoral barriers;
- Analysis of shoreline change for the regional study area;
- Analysis of sediment bypassing at the potential littoral barriers that were identified;
- Study of development history impacts on shoreline evolution; and
- Preparation of a technical report.

2.3 To inform the analysis, a field investigation was undertaken to gather comprehensive local data on the nearshore conditions for the Port Darlington West Embayment. A collection of historical aerial imagery from 1954 to 2018 was also provided by the Municipality and CLOCA for the analysis.

2.4 The assessment considered the entirety of the Port Darlington West Embayment. The natural conditions and historical development within this area influence how the shoreline adjacent to Cedar Crest Beach Road has evolved. To provide for comparison it was important to establish an understanding of how the shoreline functioned prior to development. Accordingly, the assessment also undertook modelling of local conditions based on three scenarios, as follows:

- Scenario A: Pre-1800’s (historical natural shoreline);
- Scenario B: Mid-1800’s to mid-1970’s (Port Darlington jetties present; St. Marys Cement dock not yet constructed); and
- Scenario C: Post-1970’s (current conditions).

2.5 The analysis of shoreline change for the Port Darlington West Embayment identifies that the study area shoreline was a dynamic barrier beach system prior to development of the shoreline with roads and buildings. Further, it confirms that Cedar Crest Beach has been receding since at least 1954 and continues to do so today. A comparison to similar, near by, undeveloped and uninterrupted shoreline areas showed that these areas have also been receding over the same time period (1954 to 2018). The technical report prepared by Zuzek Inc. indicates that “recession is the predominant natural long-term shoreline trend for the north shore of Lake Ontario.”

2.6 Based on the volume of sediment accumulated on the fillet beach immediately west of the St. Marys Cement headland, the assessment estimates that this headland has reduced the volume of sand and gravel transported into the Port Darlington West Embayment by approximately 660 m^3/year. Notwithstanding, the results of scenario modelling demonstrated that multiple factors would have limited the likelihood of the accumulation of large volumes of sediment along Cedar Crest Beach prior to construction of the dock and prior to construction of the Port Darlington jetties. These include current direction and speed, shoreline orientation, and a low total-load of sediment suitable for transport.

2.7 Overall, the assessment indicates that several environmental and physical factors have contributed to beach loss along the western half of the Port Darlington West Embayment. These include:

- A natural long-term shore recession trend along the north shore of Lake Ontario;
- Shoreline orientation that is not conducive to sediment deposition;
- Reduction in sediment supply due to the construction of the St. Marys Cement headland;
- The construction of homes too close to the water's edge on top of a dynamic eroding low-lying barrier beach; and
- The construction of vertical shoreline protection structures that are not conducive to beach building.

2.8 Positive impacts identified in the assessment which are associated with the constructed artificial littoral barriers that border the Port Darlington West Embayment include:

- Stabilization of the eastern half of the Port Darlington West Embayment due to the Port Darlington jetties, contributing to the existence of the beach at Port Darlington West Beach Park; and
- Protection of the eroding bluff shoreline within the footprint of the St. Marys Cement headland, which contributes to the stability and anchoring of the western boundary of the Port Darlington West Embayment.

3. Next Steps

3.1 It is important that shoreline management be both sustainable and holistic. The updated Lake Ontario Shoreline Management Plan (Zuzek Inc., 2020) recently released by the Central Lake Ontario, Ganaraska Region and Lower Trent Conservation Authorities provides updated hazard limits and management recommendations for several shoreline reaches within the Municipality, including but not limited to the Port Darlington

West Embayment. CLOCA and Ganaraska Region Conservation Authority Staff will present the results of the broader study to Council, in the near future.

3.2 The development of an implementation strategy to respond to all identified shoreline vulnerabilities and risks, increase community resilience, and protect from coastal hazards will be needed. Such a strategy should establish priorities, roles and responsibilities, and opportunities to collaborate on actions, and be developed in consultation with all stakeholders.

4. Concurrence

This report has been reviewed by the Director of Public Works who concurs with the recommendations.

5. Conclusion

5.1 Council and residents are seeking more specific information on how the St. Marys Cement dock and other environmental factors have contributed to beach loss along Cedar Crest Beach, in Bowmanville. The purpose of retaining a consultant with coastal engineering expertise was to assist with a technical analysis of shoreline recession along Cedar Crest Beach and the contributing factors. A comprehensive assessment was undertaken by Zuzek Inc., including a historical shore trend analysis, field data collection and modelling.

5.2 The technical report prepared by Zuzek Inc. provides a more complete understanding of the factors that have and will continue to influence the evolution of the shoreline along Cedar Crest Beach Road. It quantifies the interruption of sediment transport resulting from the construction of the littoral barriers within this shoreline area, including the St. Marys Cement headland and the Port Darlington jetties, and identifies several other factors which also contribute to beach loss and the on-going shoreline recession trend along Cedar Crest Beach. Positive impacts associated with the human-made littoral barriers that bound the Port Darlington West Embayment are also identified. Benefits include shoreline stabilization that has contributed to the establishment of the public beach at Port Darlington West Beach Park and to the stability of the western boundary of the Port Darlington West Embayment.

5.3 The technical report prepared by Zuzek Inc. contributes to a growing understanding of natural and human-made factors that are influencing the evolution of the Lake Ontario shoreline throughout Clarington and helps to better inform management decisions. Following the upcoming release of the updated Lake Ontario Shoreline Management Plan, a strategy that prioritizes actions to increase the resilience of Clarington’s waterfront will be needed. The Lake Ontario Shoreline Management Plan will be the subject of a future report to Council.

5.4 It is respectfully recommended Council receive Staff Report PDS-007-21.

Staff Contact: Amy Burke, Acting Manager, Special Projects, 905-623-3379 x 2423 or aburke@clarington.net.

Attachments:

Attachment 1 – Cedar Crest Beach Shoreline Change Assessment (Zuzek Inc., January 25, 2021)

Interested Parties:

The following interested parties will be notified of Council's decision:

Steve Brake, Director of Works
Sean Bagshaw, Manager of Infrastructure, Works Department
Chris Darling, Central Lake Ontario Conservation Authority
Perry Sisson, Central Lake Ontario Conservation Authority
Chris Jones, Central Lake Ontario Conservation Authority
Ruben Plaza, St. Marys Cement
Don Huff, ECO Strategy
Jeff Mitchell, President, Port Darlington Community Association
Victoria Caballero
Patrick Corcoran
Alison Fellowes
Gord Giffin
Joan Giffin
Susie Plumpton
Corinne Racioppa
Tony Racioppa
Rick Rossi
Bill Sims
Brad Winton
Roberta Winton

Attachment 1 to Report
PDS-007-21

Port Darlington West Embayment Shoreline Change Assessment

Prepared for:

Municipality of Clarington

January 25, 2021

Prepared by:

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Zuzek inc.
ONE WORLD

View of Cedar Crest Beach Shoreline (top) and St. Marys Cement Headland (bottom) from the Port Darlington Navigation Channel on August 7, 2020

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PETER J. ZUZEK
PRACTISING MEMBER
1121
ONTARIO

P. Zuzek, P.Geo.
January 25, 2021

Disclaimer:

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1.0 INTRODUCTION

Cedar Crest Beach is located on the north shore of Lake Ontario immediately west of Port Darlington and east of the St. Marys Cement (SMC) facility in the Municipality of Clarington. Refer to Figure 1.1. The Port Darlington navigation channel has been stabilized with jetties since at least 1860, a period of 160 years. Lake filling to create the main SMC Headland occurred between 1974 and 1979, with the western portion constructed in the late 1990s. This report summarizes the shoreline change assessment for the Port Darlington West Embayment completed by Zuzek Inc. and SJL Engineering Inc.

Figure 1.1 Port Darlington West Embayment

1.1 Scope of Investigation

The scope of the shoreline change assessment is summarized in the following bullets and builds off the technical investigations completed recently for the Lake Ontario Shoreline Management Plan (Zuzek Inc., 2020):

- Review of construction history for potential littoral barriers.
- Shoreline change analysis for the regional study area.
- Sediment bypassing analysis at potential littoral barriers.
- Study of development history impacts on shoreline evolution.
- Reporting.

1.2 History of SMC Headland

Operation of the SMC plant in Bowmanville began in 1967/68, with the lake filling for the main eastern pier occurring from 1974 to 1979. Prior to the construction of the SMC Headland, the shoreline consisted of an eroding bluff and small embayment protected by a barrier beach. The newer western portion of the headland was constructed in the late 1990s (Municipality of Clarington, 2017). An aerial picture of the original eastern headland following construction is provided in Figure 1.2. The influence of the SMC Headland on sediment bypassing will be investigated in the study, along with Port Darlington jetties.

Figure 1.2 Original SMC East Headland (image courtesy of SMC)

2.0 SHORELINE CHANGE

Section 2.0 of the report summarizes the findings of the shoreline change assessment for local conditions in the Port Darlington West Embayment, the adjacent shoreline, and regional trends. Evaluating the long-term shoreline change trends at the site and the north shore of Lake Ontario is necessary to put the observed changes in context, evaluate potential sources of new sand and gravel to the embayment, and evaluate long-term shoreline trends at other similar sites.

2.1 1863 Map

By the early to mid-1800s, Lake Ontario featured an extensive series of harbours and ports, which facilitated trade and commerce in the region and provided recreational opportunities for the growing population of the province. A map published in 1863 by Chewett & Co. of Toronto for the ports on the lake is presented in Figure 2.1 (Public Archives Canada).

In 1863, the jetties at Port Darlington sheltered the interior embayment, as noted on the inset map of Figure 2.1. The Cedar Crest Beach shoreline to the west was depicted as a narrow undeveloped barrier beach.

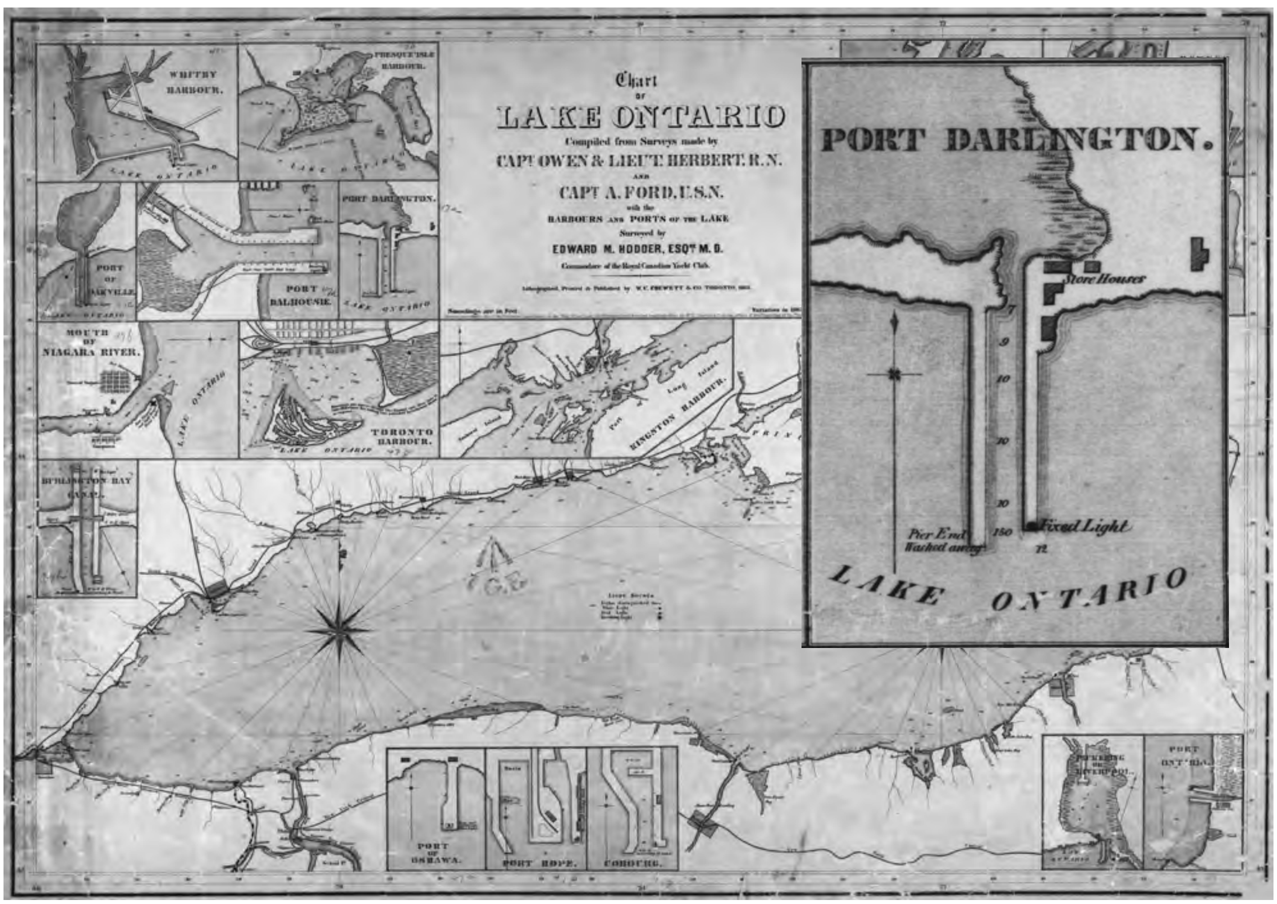


Figure 2.1 Map of Lake Ontario Ports and Harbours in 1863

2.2 1878 Map

A second historical map of the area was obtained from the Atlas of Durham and Northumberland Counties. It was geo-referenced with Geographic Information Software (GIS) using coordinates of known features, such as Lots and Concessions and the street network. Refer to Figure 2.2. The jetties in the historical map correspond to the current navigation channel to the existing port lands. The atlas also indicates that the Port Darlington Harbour Company was created in 1837, suggesting almost a 200-year history in the area.

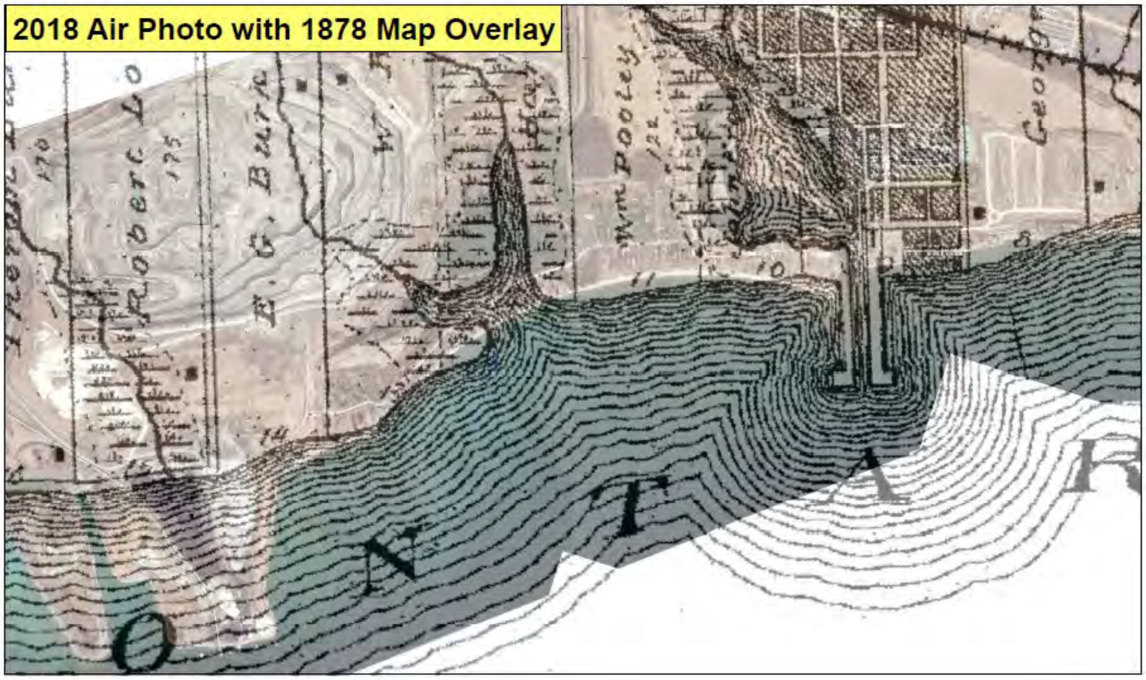


Figure 2.2 1878 Map of Study Area Overlaid on 2018 Aerial Photograph

From the historical 1878 map, it is important to note that the Cedar Crest Beach shoreline, west of Cove Road, was depicted on the map as a barrier beach and an inlet over 100 m wide. While the cartographic accuracy of these historical maps is not consistent with modern technology, there is clearly a large inlet to the current embayment and marsh region. This finding is significant, as it demonstrates that the study area shoreline was a dynamic barrier beach system with a large inlet prior to development of the shoreline with a road and permanent buildings.

2.3 1954 to 2018 Shoreline Trend

Aerial imagery of the study area was available for nine temporal periods from 1954 to 2018. A map with the geo-referenced aerial photographs is provided in Appendix A with the 2018 waters edge overlaid to evaluate shoreline changes. A summary of the changes from 1954 to 2018 is provided in Figure 2.3. The 1954 shoreline position was corrected to account for differences in water level between the 1954 and 2018 images.

Adjacent to the west jetty at Port Darlington, the shoreline has been migrating slowly lakeward, noted as a zone of accretion in Figure 2.3. The central portion of the Port Darlington West Embayment has been stable from 1954 to 2018 (no significant recession or accretion trend). The shoreline for the western portion of the embayment has been receding from 1954 to 2018, with an average long-term recession rate of 0.17 m/yr.

Figure 2.3 1954 to 2018 Waterline Comparison

Between the Darlington Nuclear Generating Station and the SMC Headland, changes in the position of the glacial till bluff crest were also measured. The bluff has been eroding at an average annual recession rate of 0.22 m/year from 1954 to 2018. Refer to Figure 2.4.

Figure 2.4 Bluff Recession West of SMC Headland

2.4 SMC Headland Fillet Beaches

Prior to the construction of the SMC Headland, the bluff shoreline corresponding to the footprint of the headland was receding and contributed approximately 178 m^3/year of sand and gravel to the shoreline. Refer to Figure 2.5 (top panel). With a net sediment transport direction of west to east (Zuzek Inc., 2020), this material would have historically been transported eastward into the Port Darlington West Embayment.

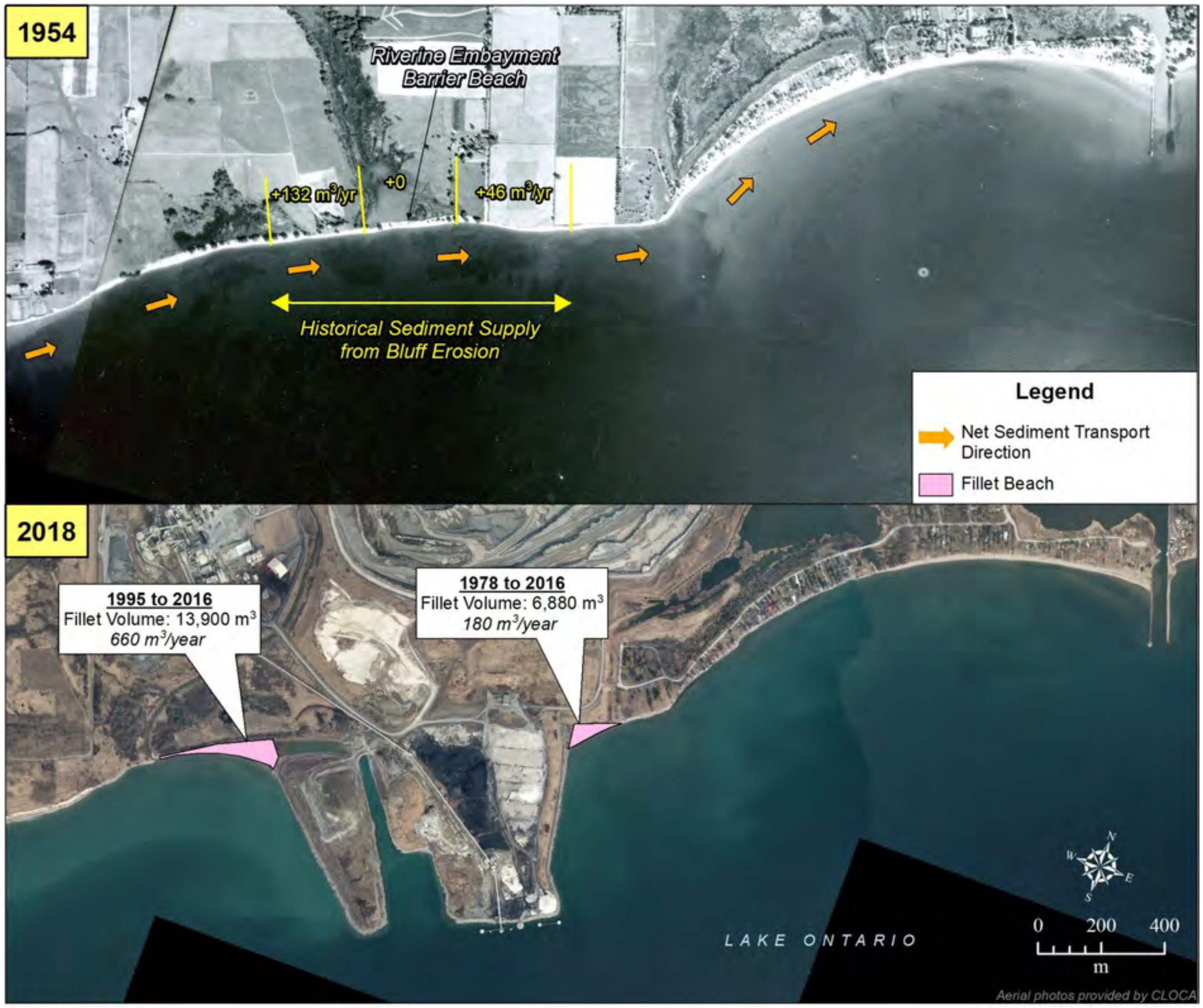


Figure 2.5 Pre-lakefill Shoreline Recession and Current Fillet Beaches

The spatial extent of the east and west fillet beaches associated with the existing SMC Headland are mapped in the bottom panel of Figure 2.5. From the late 1990s to 2016, the west fillet beach has trapped approximately 14,000 m^3 of sand and gravel, or 660 m^3/yr. From the late 1970s to 2016, the smaller east fillet beach has trapped roughly 7,000 m^3 of sediment or 180 m^3/yr.

Based on this shoreline change assessment, the SMC Headland has reduced the volume of sand and gravel transported into the Port Darlington West Embayment by roughly 660 m^3/yr. Conversely, roughly 180 m^3/yr has been retained within the embayment (in the SMC Headland east fillet beach) that would otherwise have been transported out of the embayment to the east or west.

2.5 Port Darlington Fillet Beaches

As noted in Section 2.1, the Port Darlington jetties have been in place since at least the mid-1800s, with the Harbour Company being established in 1837. The west jetty has been trapping sand and gravel that was moving west to east along the shoreline for at least 160 years. As seen in Figure 2.6, the volume estimate for the west fillet beach is approximately 55,000 m^3, which translates into an annual accretion rate of 340 m^3/year. This is likely an underestimation of the total volume of eastward transport, as additional sand and gravel have accumulated in the navigation channel. This additional volume was not estimated, and historical dredging records were not investigated.

Figure 2.6 Port Darlington Fillet Beach Volume Estimates

2.6 Regional Shoreline Trends

Extensive information on regional shoreline change trends was recently developed for the Lake Ontario Shoreline Management Plan (Zuzek Inc., 2020), which provides important context on the historical trends for the Port Darlington West Embayment. Three sites with similar shoreline conditions were evaluated. Where appropriate, waterline corrections were applied to the shoreline data in the Shoreline Management Plan.

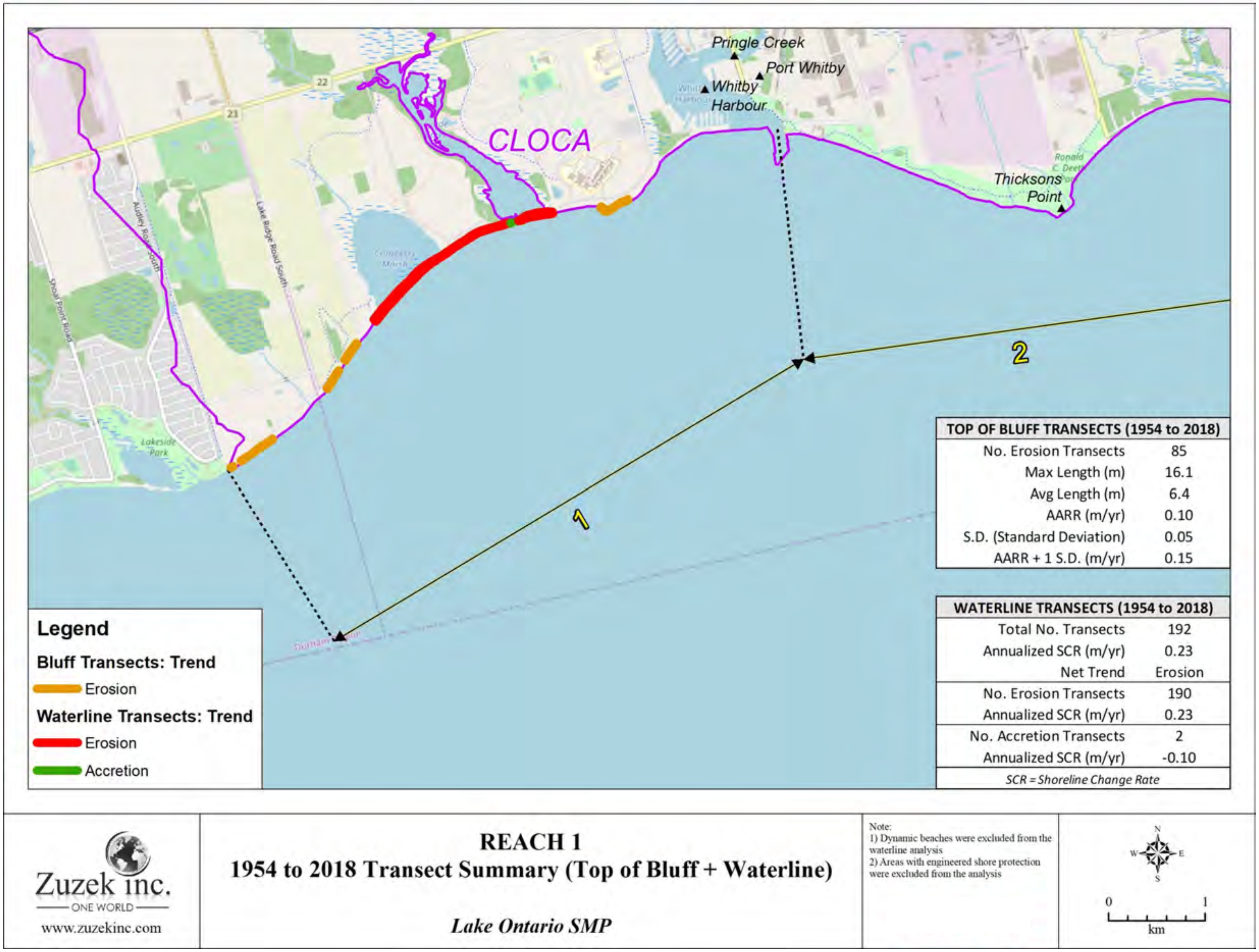
The 1954 to 2018 shoreline trend data for Reach 1 of the Shoreline Management Plan study, which includes the Cranberry Marsh and Lynde Shores Conservation Area, is presented in Figure 2.7. This reach is not only close in proximity to the Port Darlington West Embayment, but it also has a similar shoreline orientation (SW to NE), features barrier beaches protecting coastal wetlands, and has a jettied navigation channel at its eastern extent (Whitby Harbour). The central portion of the reach, which features beaches, has a long-term recession rate of 0.23 m/yr from 1954 to 2018. Refer to Figure 2.8 for the actual waterline comparison at the barrier beach. As evident from this comparison, even in a natural undeveloped state, barrier beaches along the north shore of Lake Ontario erode and have been receding since at least 1954.

Reach 3 from the Lake Ontario SMP is another relevant example, as it features the sandy shorelines and barrier beaches fronting the Oshawa Second Marsh and Darlington Provincial Park.

These beaches also have a long-term recession rate of 0.36/m/yr, on average, from 1954 to 2018. Refer to Figure 2.9.

The final shoreline change example from the Lake Ontario SMP comes from Reach 7, which covers the shoreline from Port Hope to Cobourg. The central portion of Reach 7 (Figure 2.10) features a sand and cobble beach shoreline fronting a large natural area, including Carr's Marsh. The long-term recession rate for the beach portion of the shoreline ranges from 0.9 m/yr to upwards of 1.3 m/yr, as seen in Figure 2.11.

The shoreline change measurements from these other beach sites with similar shoreline characteristics has shown recession is the predominant natural long-term shoreline trend for the north shore of Lake Ontario. Prior to the construction of the Port Darlington jetties and the SMC Headland, the shoreline of the Port Darlington West Embayment and the adjacent cohesive bluffs would have featured a similar long-term recession rate.

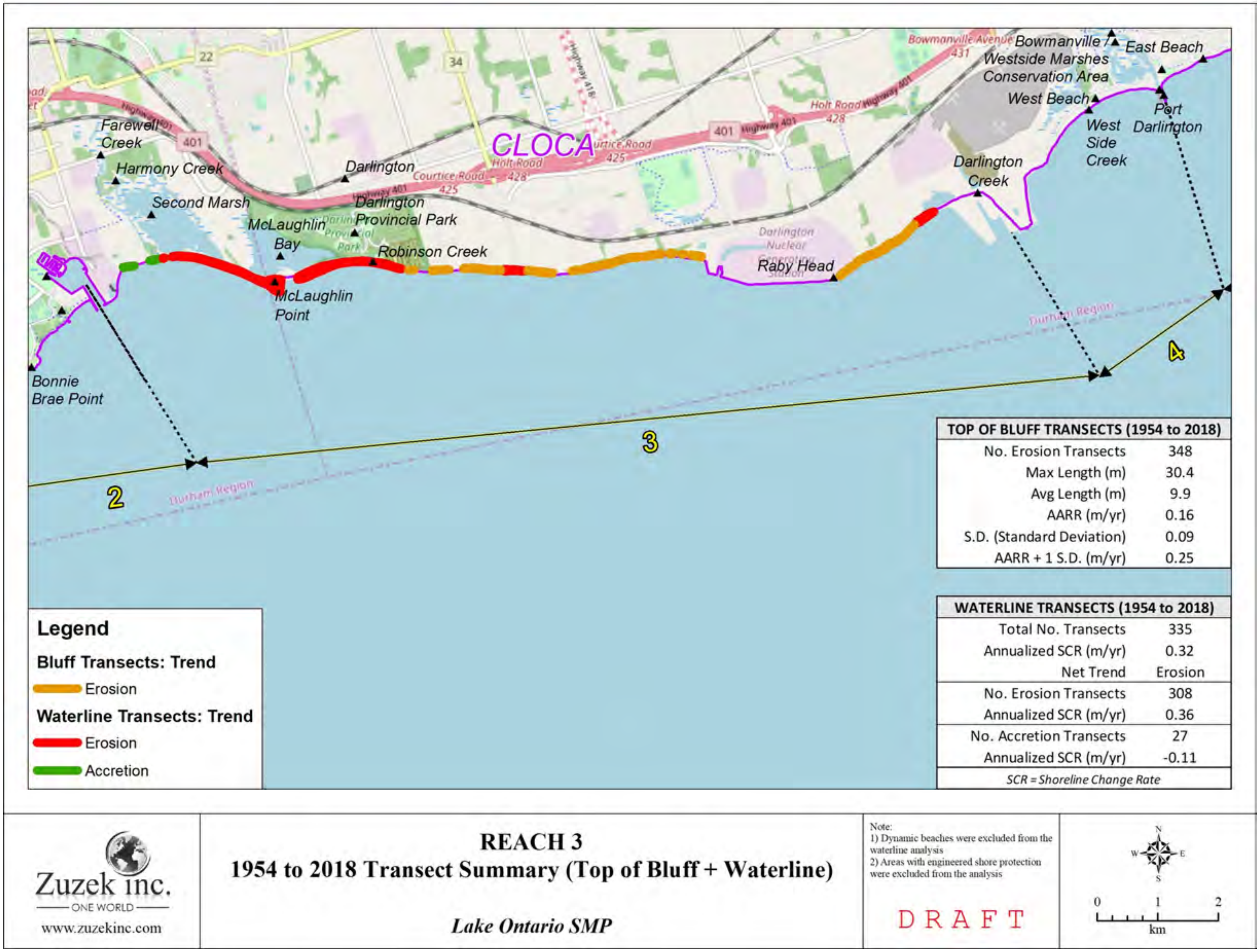


TOP OF BLUFF TRANSECTS (1954 to 2018)	
No. Erosion Transects	85
Max Length (m)	16.1
Avg Length (m)	6.4
AARR (m/yr)	0.10
S.D. (Standard Deviation)	0.05
AARR + 1 S.D. (m/yr)	0.15

WATERLINE TRANSECTS (1954 to 2018)	
Total No. Transects	192
Annualized SCR (m/yr)	0.23
Net Trend	Erosion
No. Erosion Transects	190
Annualized SCR (m/yr)	0.23
No. Accretion Transects	2
Annualized SCR (m/yr)	-0.10
SCR = Shoreline Change Rate	

Figure 2.7 Shoreline Trend Data for Reach 1, Lake Ontario SMP (Zuzek Inc., 2020)

Figure 2.8 Barrier Beach Recession Rates at Cranberry Marsh



TOP OF BLUFF TRANSECTS (1954 to 2018)	
No. Erosion Transects	348
Max Length (m)	30.4
Avg Length (m)	9.9
AARR (m/yr)	0.16
S.D. (Standard Deviation)	0.09
AARR + 1 S.D. (m/yr)	0.25

WATERLINE TRANSECTS (1954 to 2018)	
Total No. Transects	335
Annualized SCR (m/yr)	0.32
Net Trend	Erosion
No. Erosion Transects	308
Annualized SCR (m/yr)	0.36
No. Accretion Transects	27
Annualized SCR (m/yr)	-0.11
SCR = Shoreline Change Rate	

Figure 2.9 Summary of Reach 3 Shoreline Change Rates (Zuzek Inc., 2020)

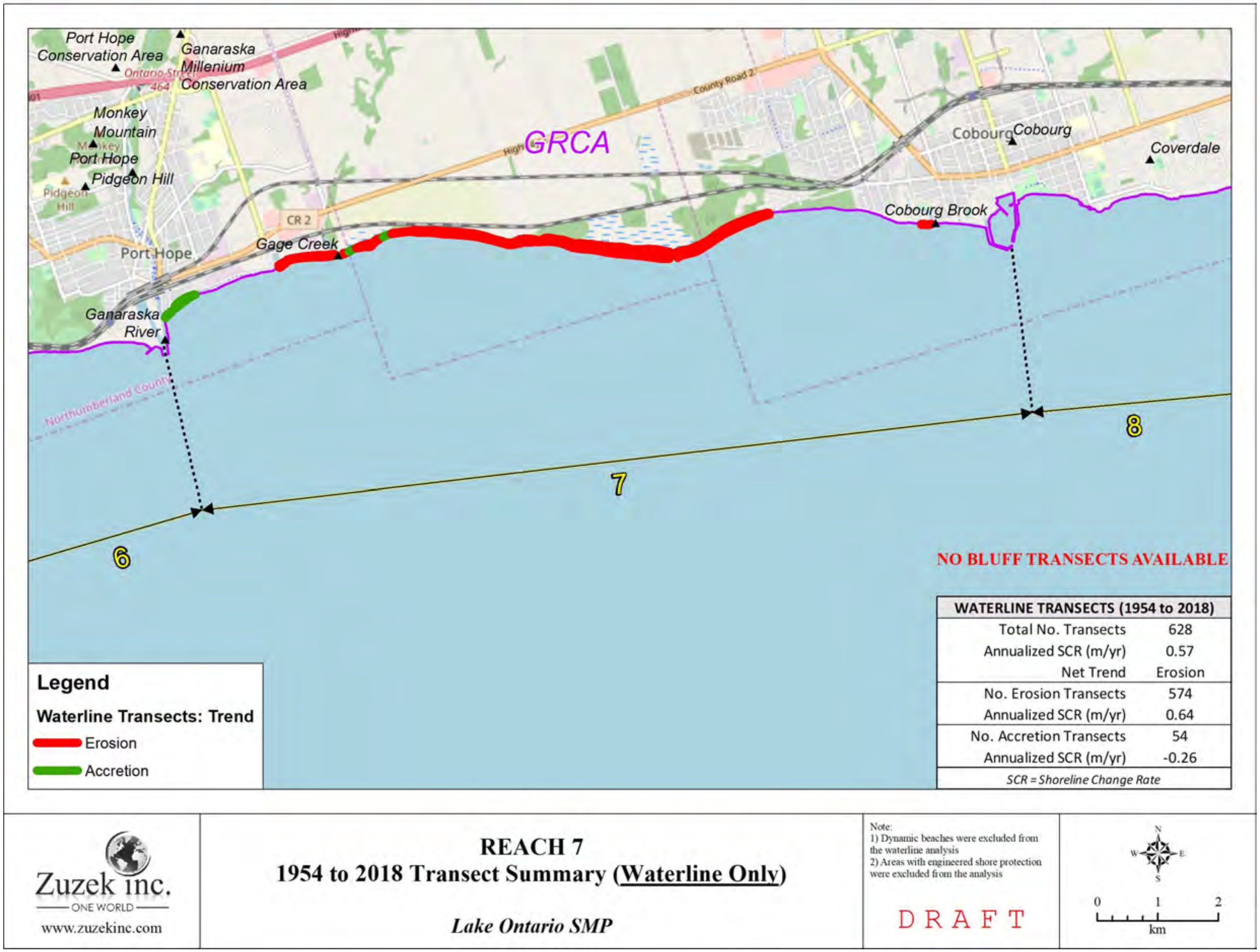


Figure 2.10 Reach 7 Shoreline Change Rates

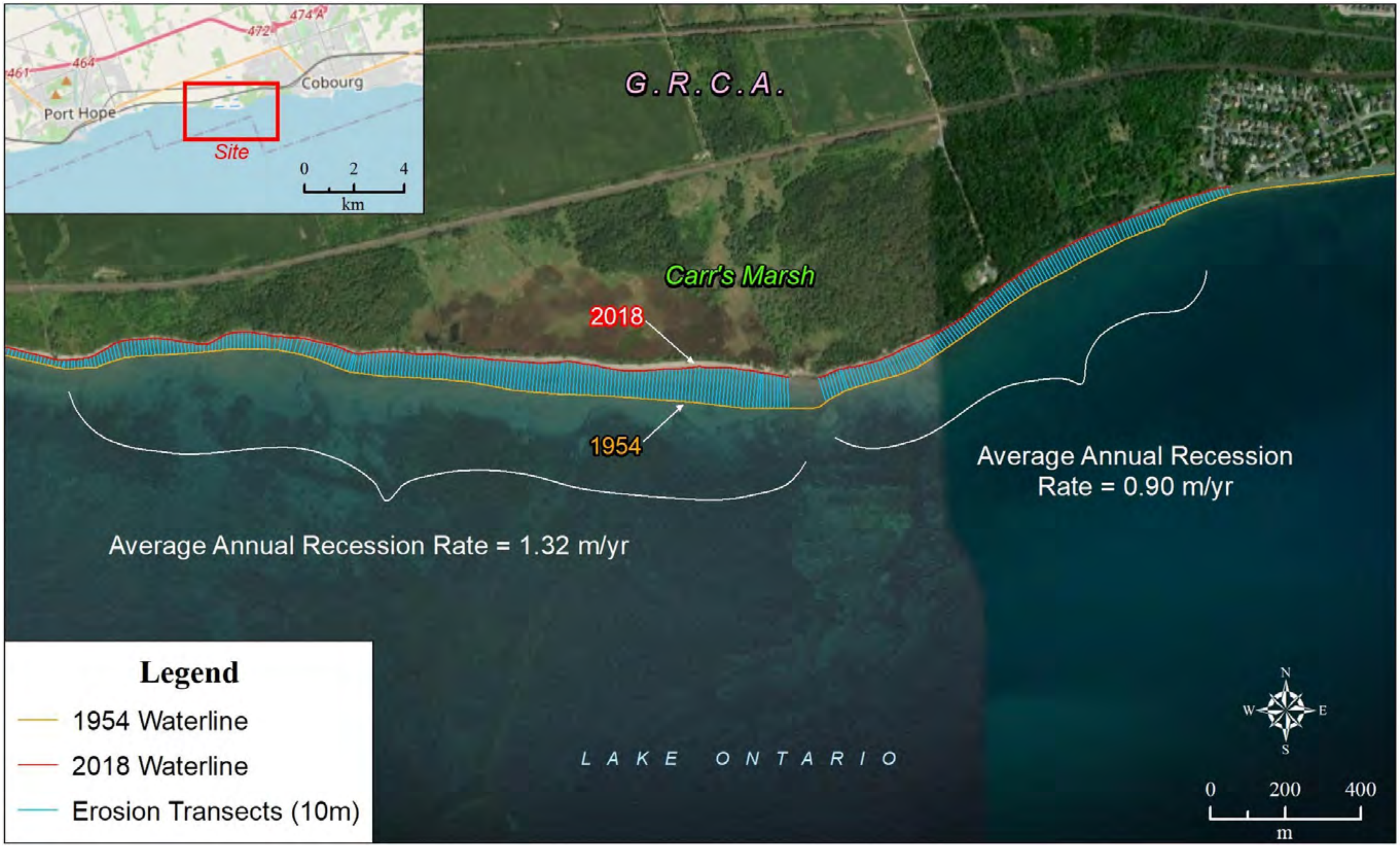


Figure 2.11 1954 to 2018 Shoreline Recession Data for Carr's Marsh

3.0 DATA COLLECTION AND MODELLING

Field data collected for the investigation and detailed local-scale numerical modelling are discussed in Section 3.0 of the report.

3.1 Bathymetric Survey and Sonar Data Collection

A detailed bathymetric survey of the nearshore zone in the Port Darlington West Embayment was completed on August 7, 2020. Figure 3.1 provides a picture of the survey boat (left) and SOLIX transducer mounted on the back of the boat (right). The SOLIX is a single-beam bathymetric system for recording lake bottom depths and sonar images of the bottom substrate. The survey track used to navigate the boat is presented in Figure 3.2 and the resulting colour-coded depth data collected with the SOLIX is plotted in Figure 3.3.

Figure 3.1 Survey Boat (left) and Transducer Mount (right)

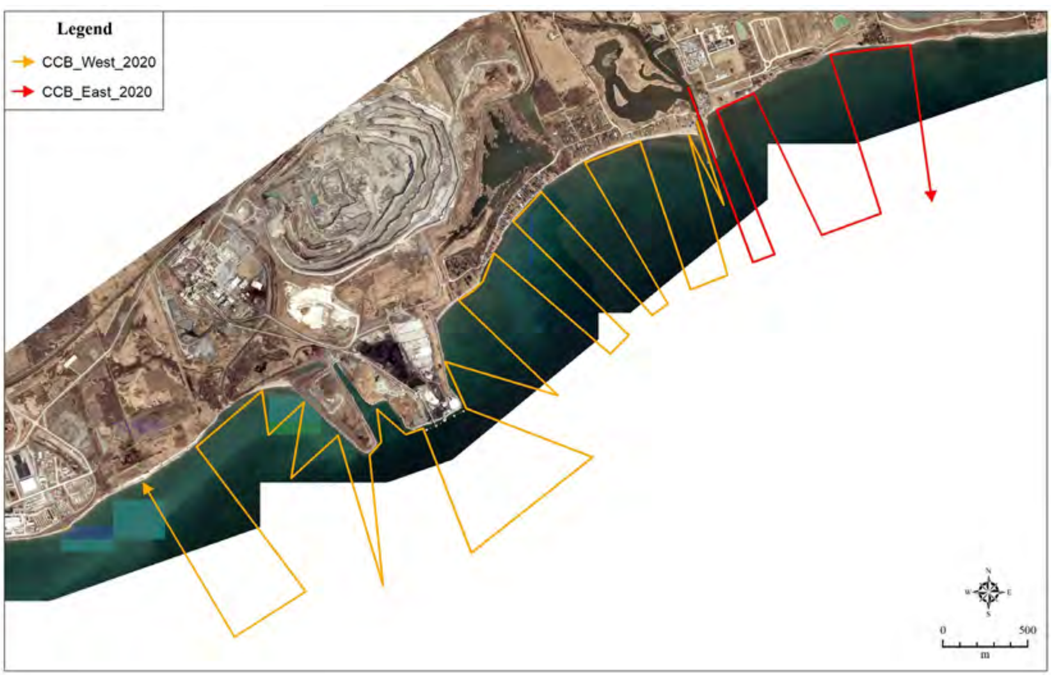


Figure 3.2 Boat Tracks West and East of Port Darlington

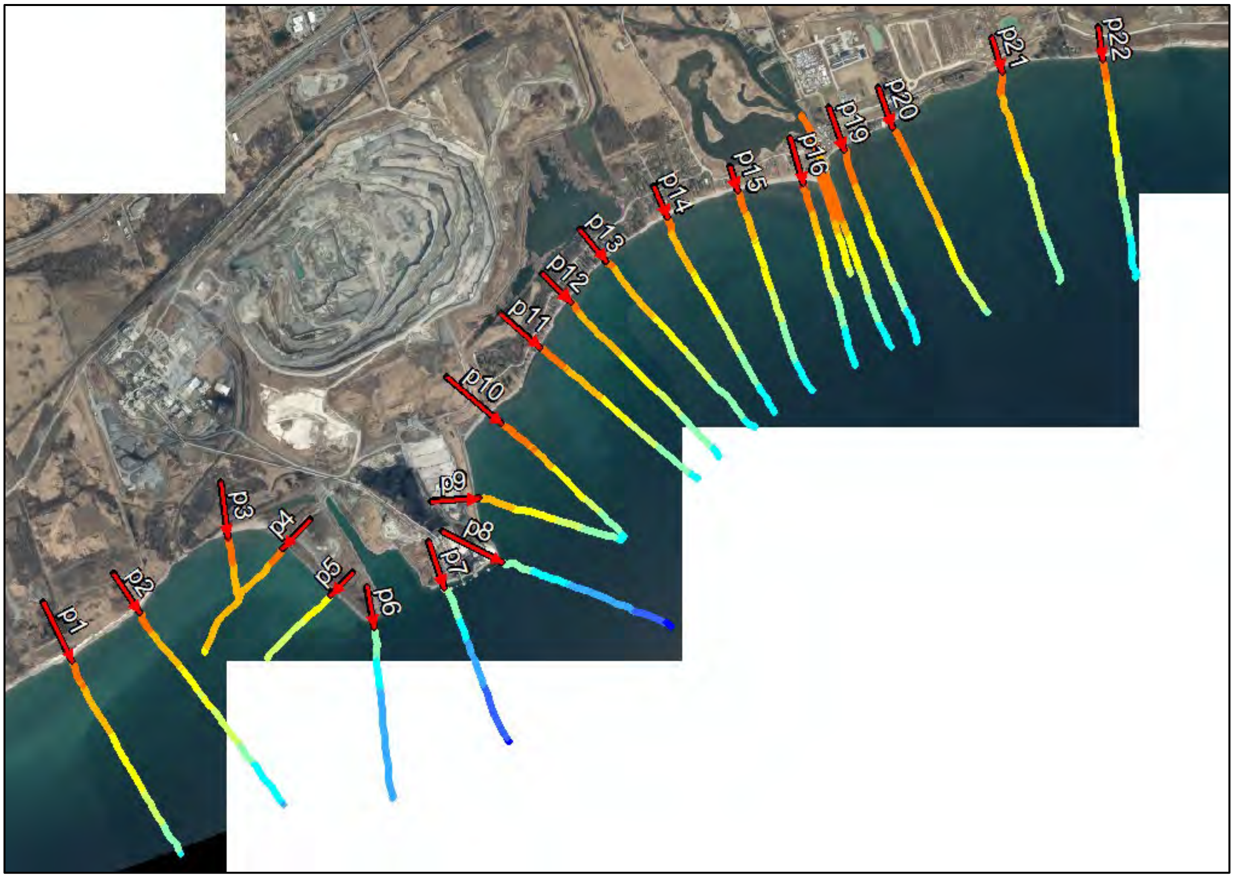


Figure 3.3 Bathymetric Data Points Colour Coded by Depth

3.1.1 Profile Data and Substrate Mapping

The key findings from the profile data and substrate mapping are summarized below:

- **Profile 1 West of SMC Headland**: Located along the eroding bluffs west of the SMC Headland, Profile 1 features a steep bluff face with crest elevations over 30 m above the lake (Figure 3.4, top). The nearshore profile is very flat, featuring a nearshore slope of approximately 1:100 (V:H). The sonar imagery captured a significant cobble lag deposit that blankets the lake bottom. Refer to the middle panel of Figure 3.4, which includes a plan view map showing the boat location (left), a cross-section of the sonar image under the boat (middle), and an image of the lake bottom 25 m to the right and left of the boat (right). Underwater pictures, also presented in Figure 3.4, verify the interpretation of the sonar.

- **Profile 6 SW Tip of SMC Headland**: Profile 6 captures the shoreline and lake bottom conditions at the southwest corner of the SMC Headland (Figure 3.5). The lake bottom is very deep, 8 m at the toe of the armour stone protecting the headland. The middle panel of Figure 3.5 captures the edge of the armour stone and the transition to the lake bottom. Based on the intensity of the sonar signal and flat slope of the lake bottom (middle and bottom panel of Figure 3.5), the substrate features soft/muddy material. There is no evidence of a sandy bypassing shoal or bed features that indicate the sand is being transported around the headland.

- **Profile 8 SE Tip of SMC Headland**: Profile 8 records the conditions at the southeast corner of the SMC Headland. Like Profile 6, the lake bottom is very deep at the pier (~10 m) and progresses quickly to a depth of 15 m. There is no evidence of a sand lake bottom, sandy bypassing shoal or bar system that could facilitate the movement of sediment around the headland. In contrast, the sonar imagery suggests the lake bottom features soft/muddy sediment.

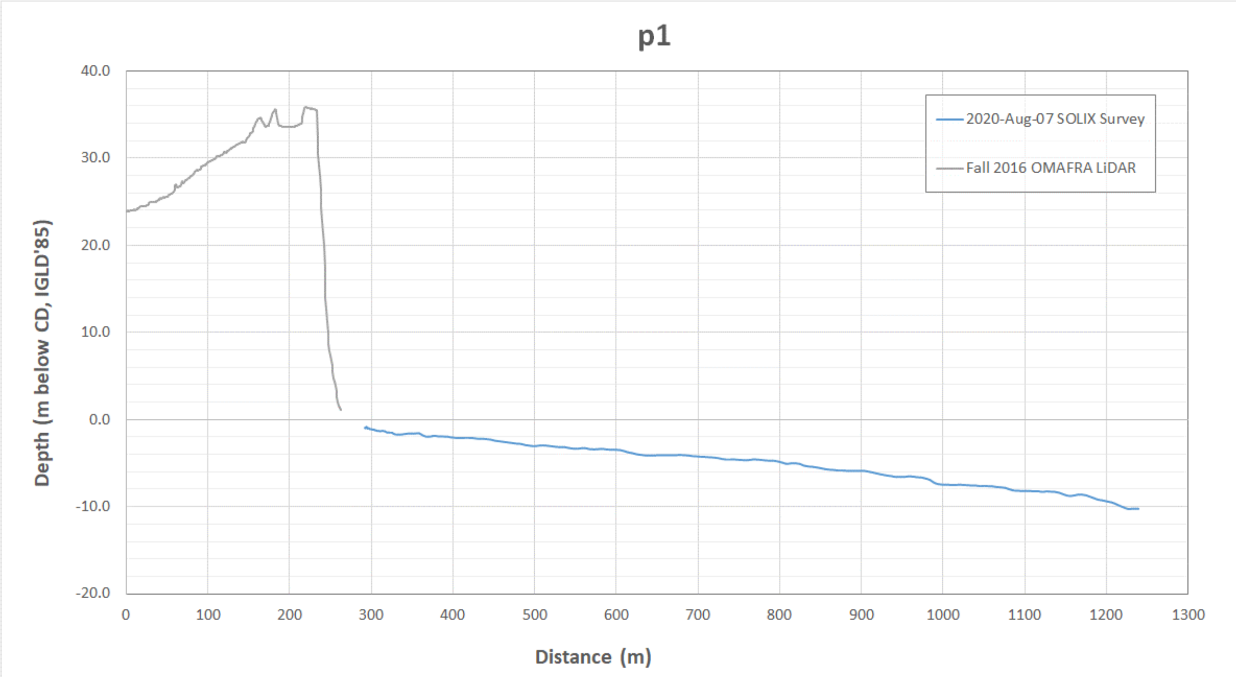
- **Profile 13 Cedar Crest Beach Road**: The land elevation is low (< 3m) along Cedar Crest Beach Road and drops off quickly at the waters edge (see Figure 3.7, top), which mostly features shoreline protection structures. A cobble lag deposit was mapped on the lake bottom except close to shore, where the bottom substrate changes to sand. Refer to the middle panel in Figure 3.7. The substrate mapping was confirmed with underwater pictures, as seen in the bottom images of Figure 3.7.

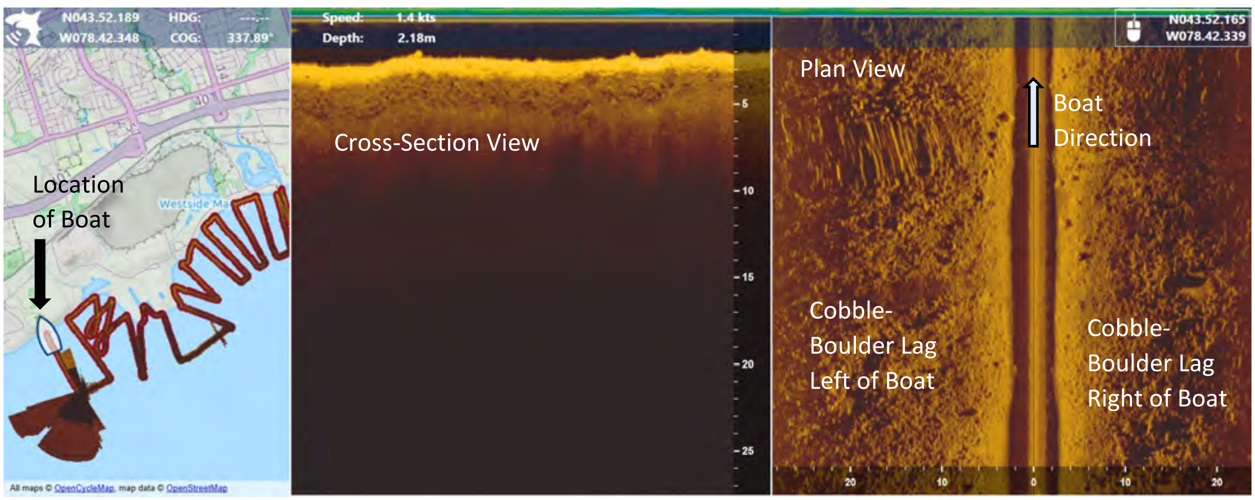
- **Profile 14 Cove Road**: Profile 14 in Figure 3.8 is typical of the beach and nearshore conditions along Cove Road. The homes are set back further from the waters edge and a wide beach transitions to a shallow gently sloping nearshore. The slope at the waters edge (approximately 150 m on the x-axis) is much gentler than Profile 13 (175 m on the x-axis of Figure 3.7, top panel) which is typical of the nearshore along Cedar Crest Beach.

- **Profile 20 Eroding Bluffs East of Port Darlington**: Profile 20 is typical of the shoreline and nearshore conditions east of Port Darlington (Figure 3.9). Steep eroding bluffs define the shoreline, and the nearshore profile is flat, featuring a slope similar to Profile 1 (1:100) between the waters edge and the 4 m depth contour. The sonar mapped an extensive cobble-boulder lag deposit between Lines 19 and 20. Refer to Figure 3.10. No significant sand deposits were identified with the mapping.

At West Beach, a mixed sand-cobble beach transitions to a narrow sandy nearshore, followed by an extensive cobble-lag deposit. Refer to Figure 3.11. There are no major sand deposits in the study area other than the fillet beaches and the largest sand deposit (West Beach) only exists because of the artificial littoral barrier formed with the construction of the Port Darlington jetties 160 years ago. Immediately offshore of the SMC Headland and in depths greater than 10 m, the lake bottom consists of soft sediments (mud).

In summary, the sonar mapped large areas in the nearshore of the Port Darlington West Embayment and the shoreline to the east and west dominated by cobble-lag deposits. Sand is generally limited to the waters edge and accumulations in the small fillet beaches adjacent to the littoral barriers.





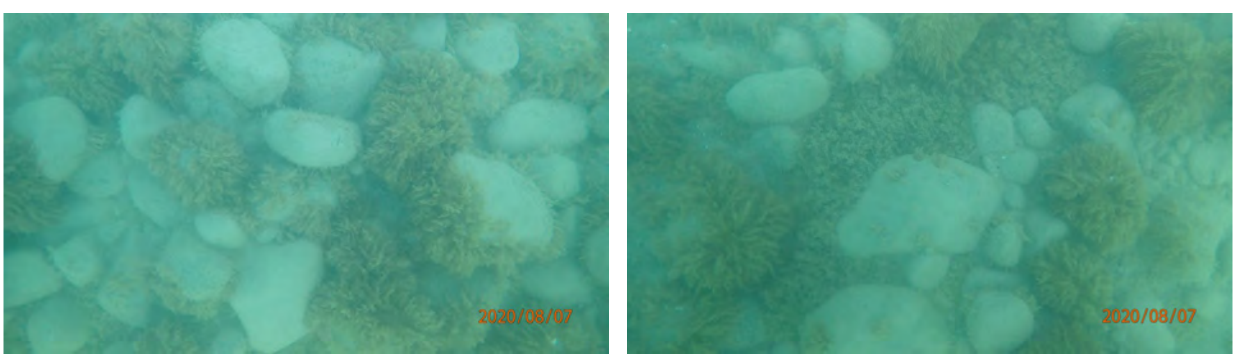
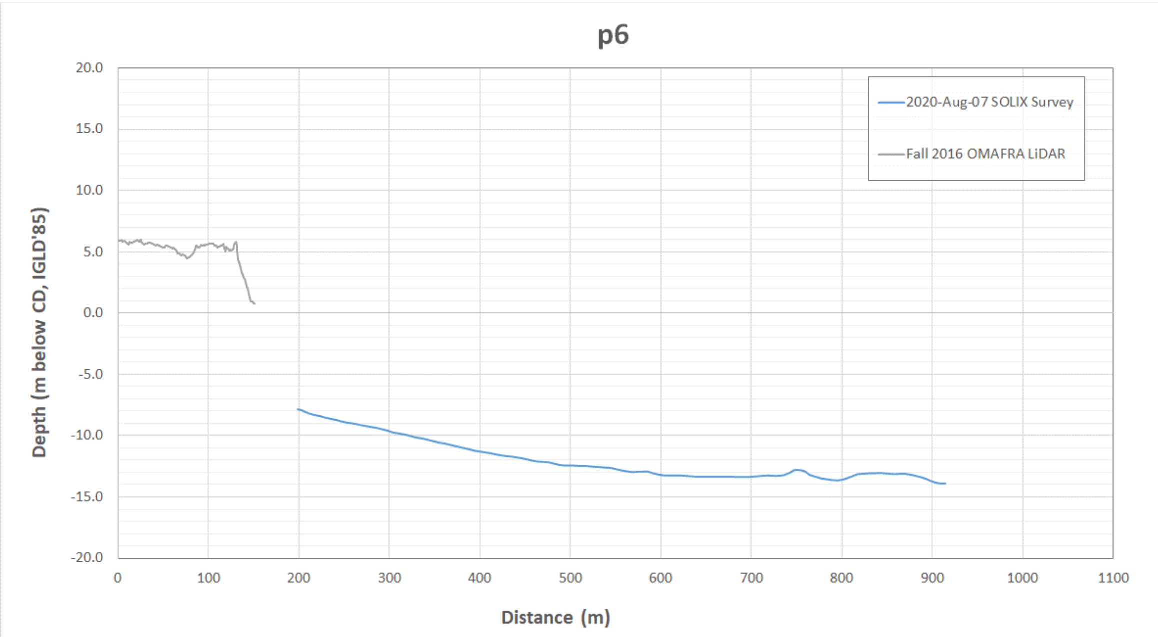
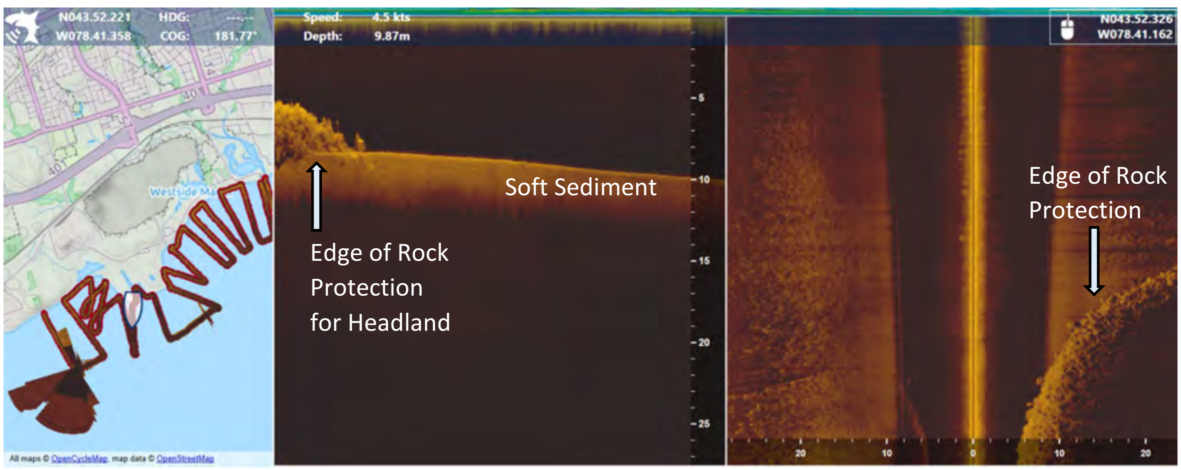


Figure 3.4 Profile 1 (top), Sonar Imagery (middle), Underwater Pictures of Cobble Lag (bottom)





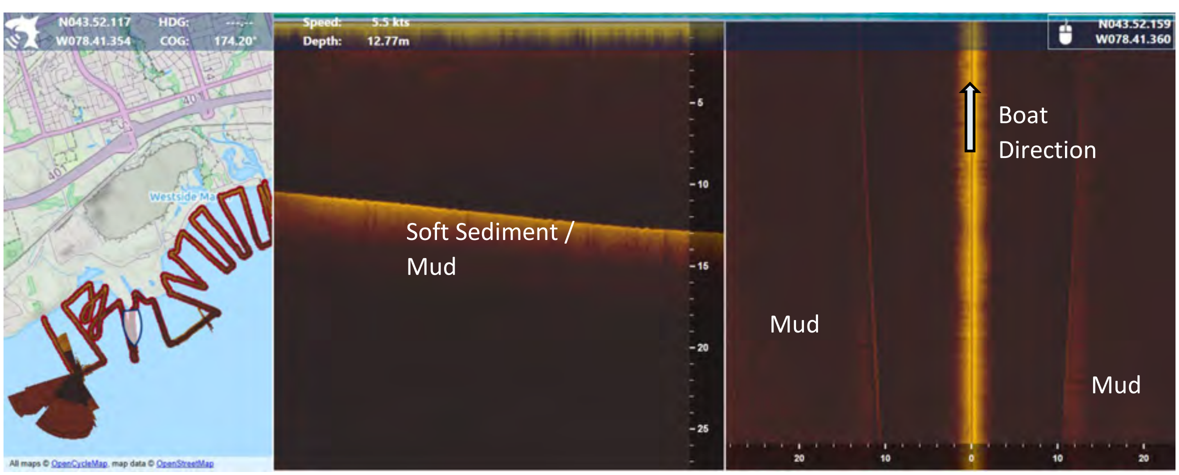


Figure 3.5 Profile 6 at Southwest Corner of SMC Headland

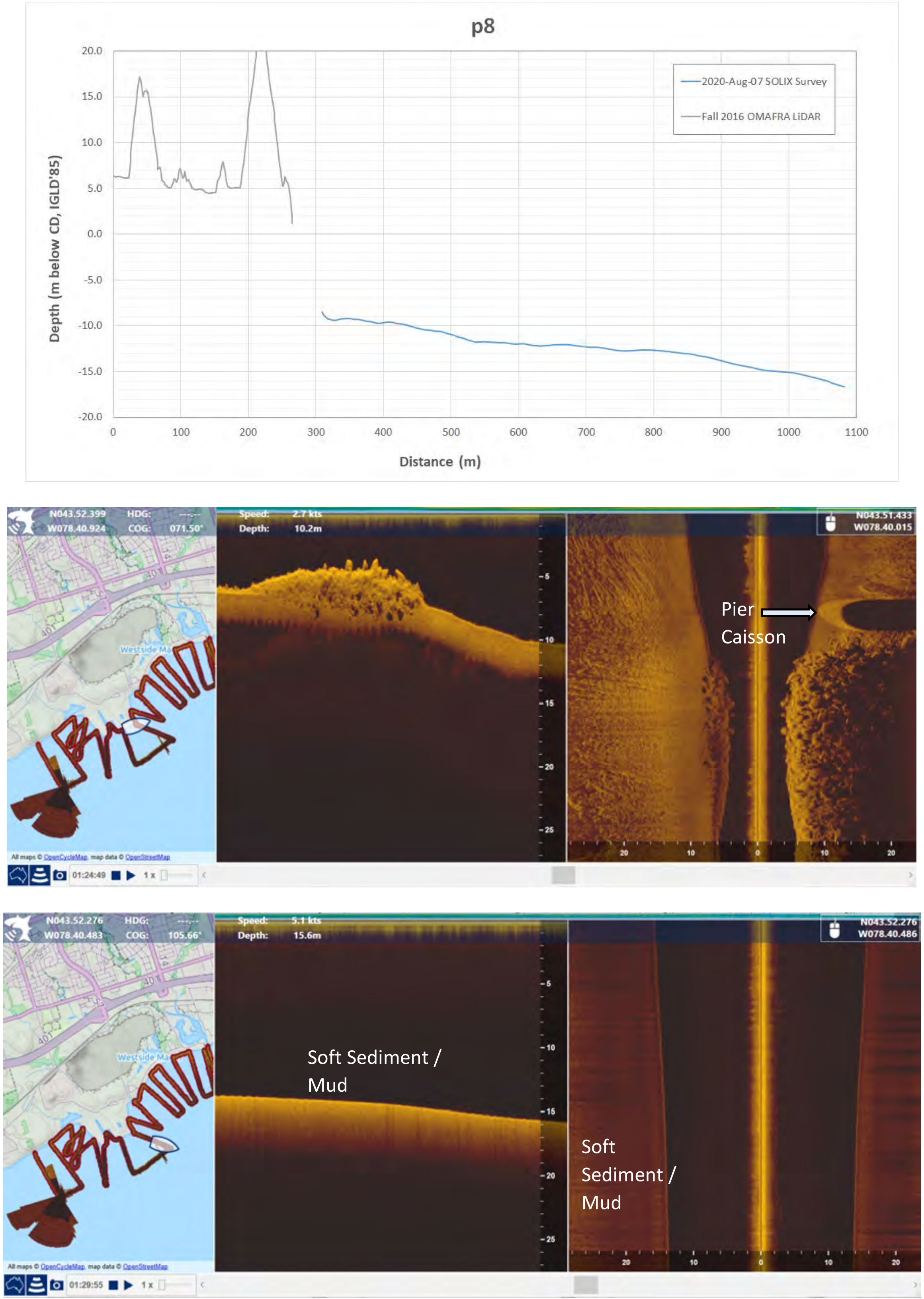


Figure 3.6 Profile 8 (top), Sonar of Wharf Armour Stone and Concrete Caisson (middle), Mud Lake Bottom (bottom)

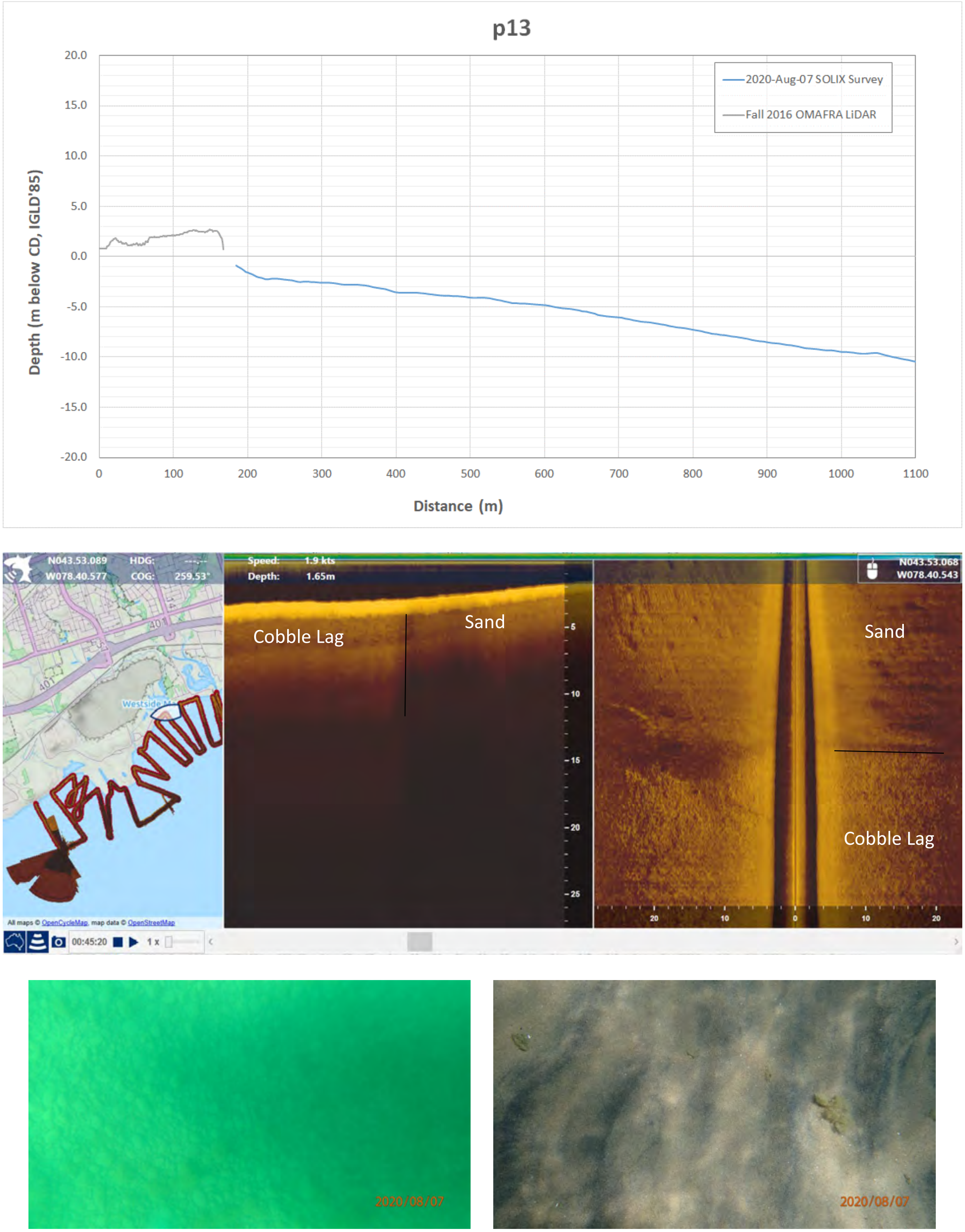


Figure 3.7 Profile 13 (top), Sonar Imagery of Transition from Cobbles and Sand Substrate (middle), Underwater Picture of Cobble Lag (bottom left) and Sand Substrate (bottom right)

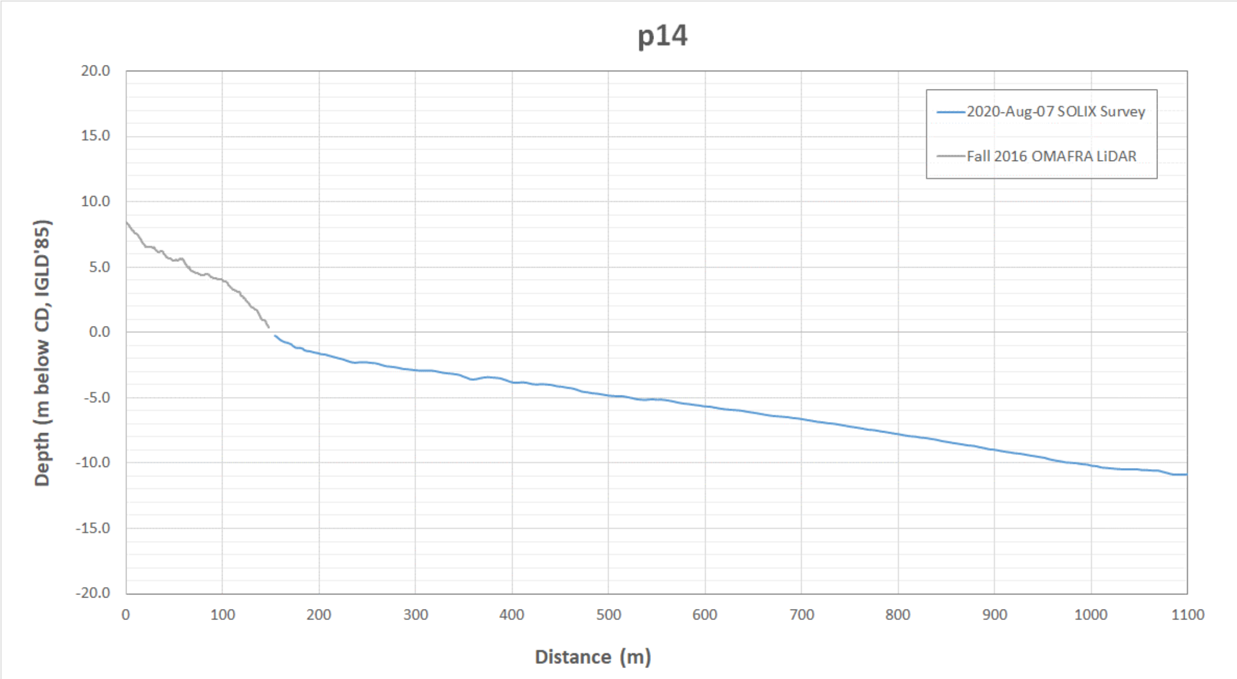


Figure 3.8 Gentle Nearshore Slope and Natural Beach Conditions at Profile 14

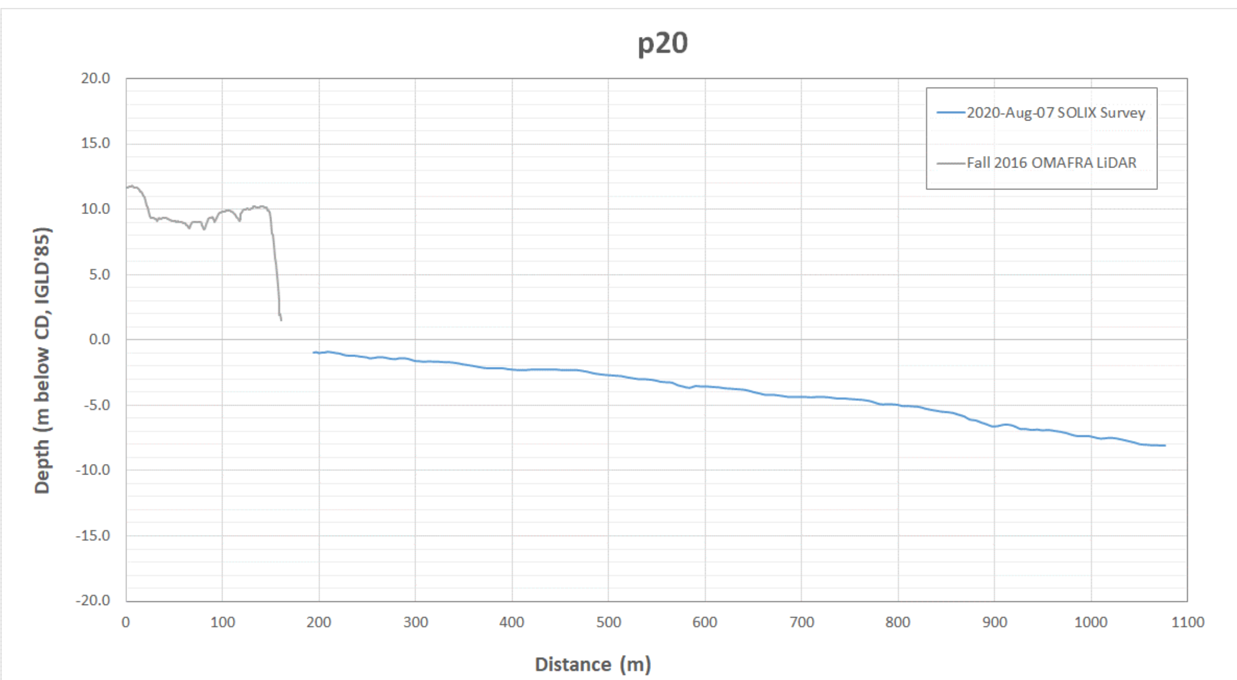


Figure 3.9 Eroding Bluff Shoreline East of Port Darlington

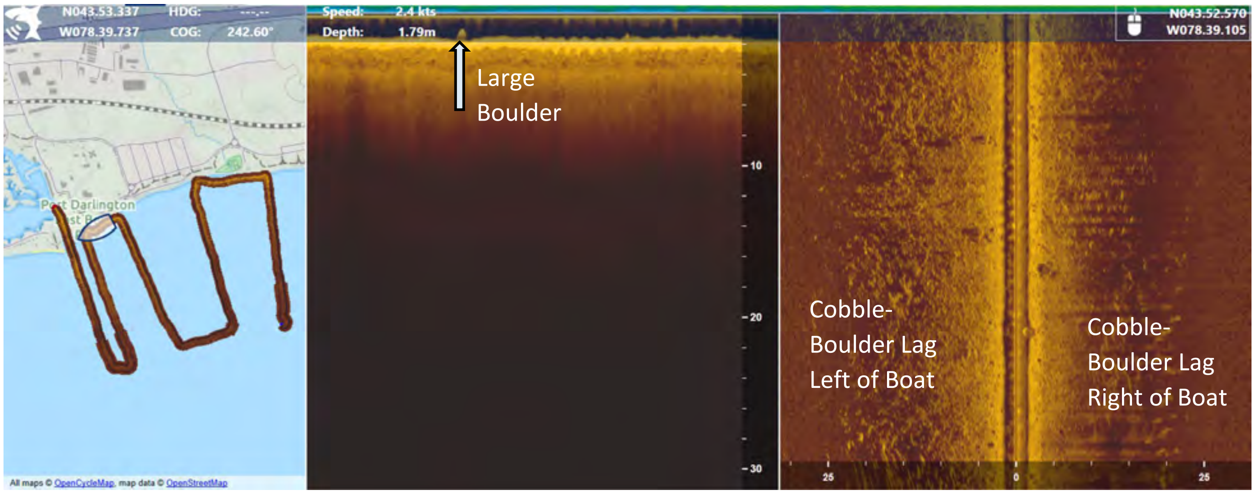


Figure 3.10 Cobble-Boulder Lag Deposit in Nearshore between Line 19 and 20

Figure 3.11 Alongshore View of West Beach

3.2 Numerical Modelling of Waves and Sediment Transport

Numerical simulations of waves, currents, and longshore sediment transport potential were investigated with a high-resolution coastal model for the study area. The results are summarized in the following sections.

3.2.1 Offshore Wave Climate

The offshore wave climate affecting the north shore of Lake Ontario in the vicinity of Cedar Crest Beach was assessed with the Wave Information Study (WIS) database. The WIS is a United States Army Corps of Engineers (USACE) sponsored project providing hourly wave climatologies for all major shorelines throughout the United States. Included in this study was a 45-year wave hindcast for Lake Ontario covering the period from 1970 to 2014. In a wave hindcast, historical wind fields are used to drive a wave generation and propagation model to produce a timeseries of historical waves around the perimeter of the lakes. The model is then calibrated to measured wave buoy data, where available, to verify the predictions. The WIS database is the most accurate and complete wind-wave dataset available for Lake Ontario.

Offshore waves were assessed from WIS station 991178, located at a depth of 36 m (below chart datum), and approximately 5.4 km south of Port Darlington. A statistical analysis of storm events was conducted on the offshore wave data for the period from 1960 to 2014 inclusive. Storm events are the primary cause of coastal erosion, flooding events, and the transport of sand and gravel along the north shore of Lake Ontario. As such, it is important to understand the wave characteristics and particularly the directionality of storm events impacting the Cedar Crest Beach shoreline and surrounding areas.

Significant storm events were isolated from the offshore WIS dataset and ranked. The events were binned based on peak wave direction. Of the ranked events, 74% were shown to arrive from 230 degrees (+/- 10 deg) and 23% from 100 degrees (+/- 10 deg). The remainder of storm events (less than 5%) arrive from a variety of other southerly directions. The wave climate can therefore be characterized as having two principal directions (bimodal) from which significant wave energy is produced. Due to the general shoreline orientation along the north shore of Lake Ontario, the dominant SW wave direction (230 deg) will produce west to east longshore sediment transport along the shoreline. Conversely, the secondary ESE wave direction (100 deg) will produce east to west longshore sediment transport.

Further statistical analyses of the offshore waves were completed to determine the magnitude of storm events associated with a variety of return periods. The significant wave heights corresponding to the top 45 storm events (one per year, on average) were fit to several statistical distributions for extreme value analysis. The offshore significant wave height associated with a variety of return periods were then calculated from the best fitting distribution and are listed in Table 3.1. The significant wave height corresponding to each storm event in the storm list was also plotted against the corresponding peak wave period (T_p) to determine an appropriate relationship between wave height and wave period during major storm events, with the results listed in Table 3.1.

Table 3.1 Offshore Wave Conditions Corresponding to a Variety of Return Periods

Return Period (years)	Significant Wave Height (m)	Peak Wave Period (s)
1	4.36	8.4
2	4.70	8.7
5	5.12	9.1
10	5.44	9.3
25	5.90	9.8
50	6.27	10.1
100	6.67	10.5

3.2.2 Longshore Sediment Transport Potential (CERC-Formula)

As a component of the recent Lake Ontario Shoreline Management Plan (SMP) undertaken by Zuzek Inc. (2020), offshore waves at WIS station 991178 were transformed to the shoreline using the Delft3D-Wave model to estimate longshore sediment transport potential calculations at various locations along the Lake Ontario shoreline. The wave model grid had a spatial resolution of 50 x 50 metres, making it too coarse for detailed analyses of sediment transport pathways near the shoreline. However, it was sufficiently accurate to inform broad sediment transport potential calculations using the CERC formula at various locations along the north shore of Lake Ontario. One such calculation was made at the center of the embayment where Cedar Crest Beach Road meets Cove Road. At this location it was determined that sediment transport has the potential to move in both directions along the shoreline depending on the incident wave direction, away from the centre of the embayment towards the SMC Headland to the west and the Port Darlington jetties to the east. This finding is consistent with the bimodal storm population found in the WIS hindcast data. The net sediment transport direction was to the east and the potential transport was determined to be low, on the order of 2,000 m^3/yr. Potential transport is the theoretical maximum volume of sediment that can be transported along a shoreline with unlimited sediment supply on the lake bottom, which is not the case for Cedar Crest Beach, where cobble-boulder lag deposits dominate the nearshore. Therefore, actual sediment transport rates would be much lower.

3.2.3 Detailed Wave, Hydrodynamic and Sediment Transport Modelling

To examine sediment transport potential and sediment transport pathways at high resolution, detailed wave and hydrodynamic models were setup covering the shoreline from the Darlington Nuclear Generating Station to 2.2 km east of the Port Darlington jetties. The CMS-Wave (wave model) and CMS-Flow (hydrodynamic and sediment transport) models were used in a coupled manner, both featuring a spatial resolution of 10 x 10 metres. Bathymetry for both models was interpolated from depth contours courtesy of the National Ocean and Atmospheric Administration (NOAA). The CMS-WAVE model domain and bathymetry is presented in Figure 3.12.

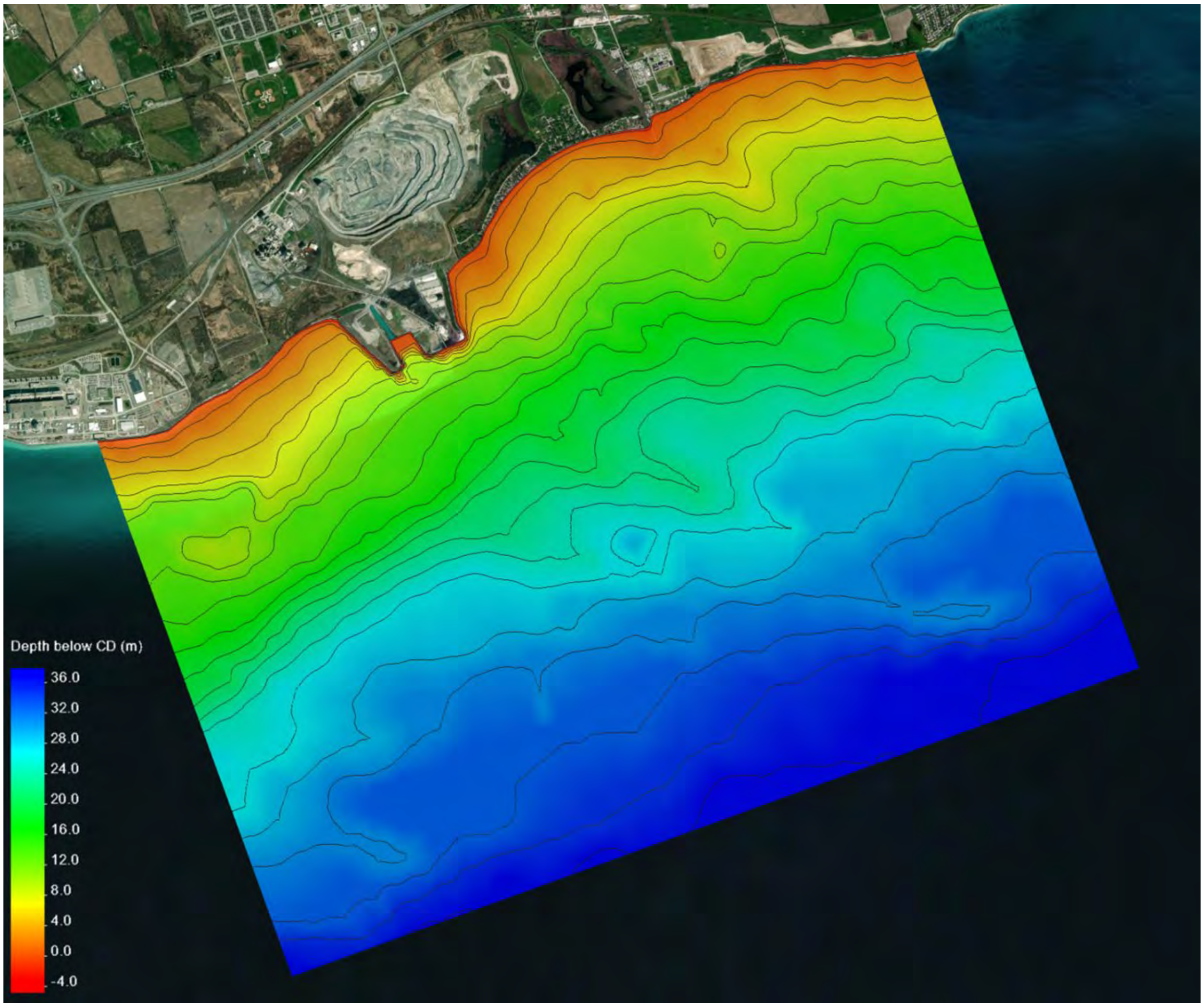


Figure 3.12 CMS-Wave Model Domain and Bathymetry

The CMS-Wave/Flow models were used to investigate nearshore currents and sediment transport pathways resulting from both SW (230 degree) and ESE (100 degree) storm wave directions. The wave height and wave period used in the simulations was representative of a storm that would be exceeded 5 to 6 times per year, on average (H_s = 3.0 m, T_p = 7.5 s). The models were run for the following three scenarios:

A. Pre 1800s (no SMC Headland or Port Darlington jetties, just the historical natural shoreline),

B. Mid-1800s to mid-1970s (Port Darlington jetties present, but no SMC Headland),

C. Post-1970s (existing conditions including SMC Headland and the Port Darlington jetties).

Running the model for the three scenarios listed above provided a comparison of simulated nearshore hydrodynamics and sediment transport pathways for each period. This provided the data to investigate the impacts of the Port Darlington jetties and the SMC Headland on important physical processes that influence shoreline evolution.

Figure 3.13 presents the CMS-Wave model results for all three scenarios and for both SW (primary) and ESE (secondary) wave directions. Colour contours represent significant wave height in metres (refer to the legend) while vectors visualize the direction of wave propagation.

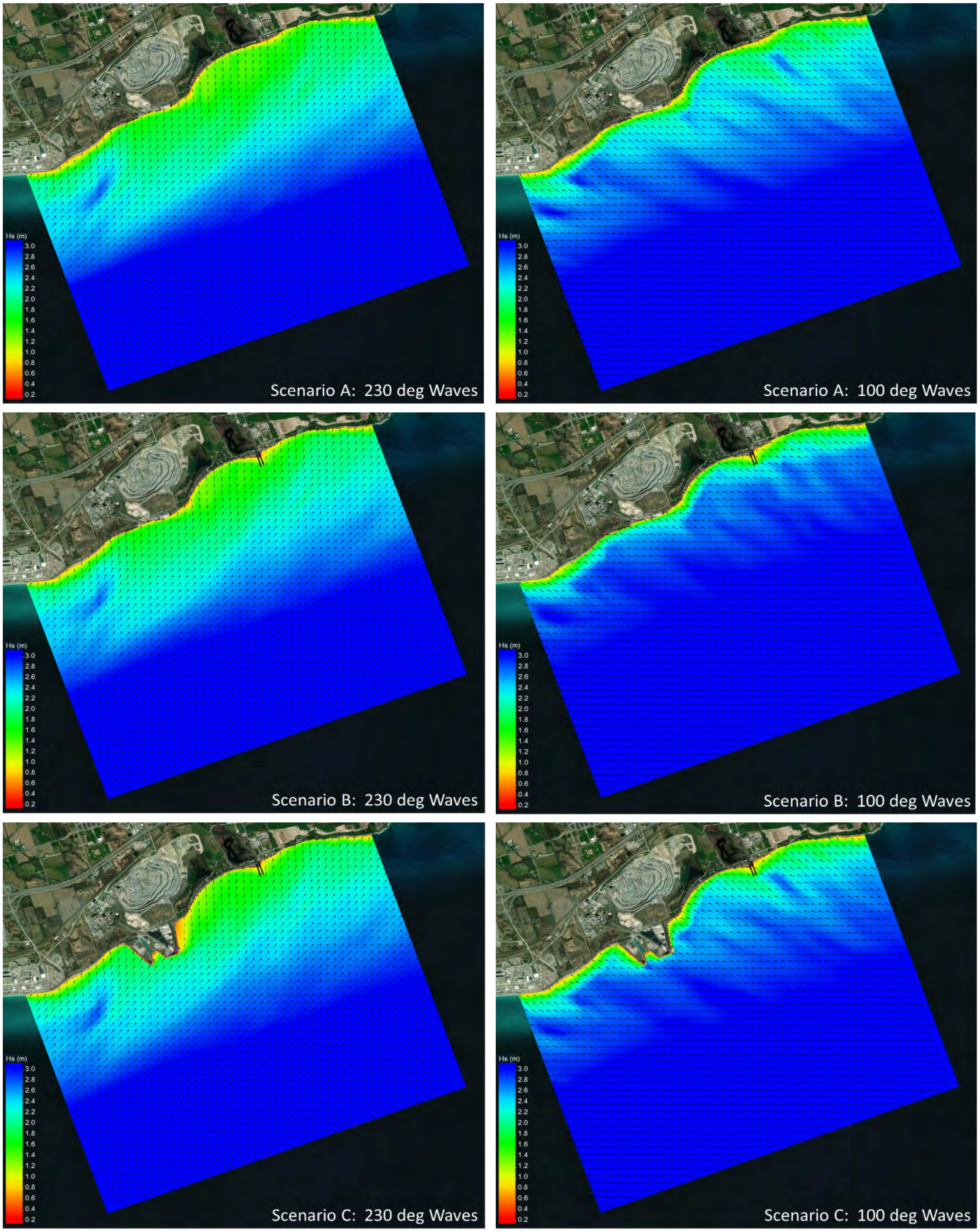


Figure 3.13 CMS-Wave Model Results for Three Scenarios and Both SW and ESE Waves

From Figure 3.13 it is clear waves arriving from the SW direction (230 deg) begin breaking and dissipating their wave energy much further offshore than waves arriving from the ESE (100 deg). The SW waves approach the shoreline from a much more oblique angle resulting in significant refraction compared to the ESE direction. The result is a much wider surf zone, as is evident in Figure 3.13.

There is little difference in significant wave height or wave direction between the three scenarios presented in Figure 3.13, except close to shore where there have been changes in the shoreline geometry due to the littoral barriers. For example, waves tend to break along the SMC Headland in Scenario C since the southern tip is in relatively deep water (~10 m). For the SW wave condition, the headland creates a sheltered zone with relatively low wave energy and significant wave diffraction on its eastern side.

3.2.3.1 Hydrodynamic Modelling

Figure 3.14 and Figure 3.15 present the results of the CMS-Flow hydrodynamic modelling for all three scenarios described above, zoomed in on the Port Darlington West Embayment. Contours are representative of current magnitudes while vectors indicate both the speed (vector length) and direction of nearshore currents throughout the model domain. Inputs to the hydrodynamic model included the wave conditions (wave heights, periods, directions, radiation stresses, etc.) from the wave model simulations presented in Figure 3.13 above, and a constant water surface elevation of +1.0 m CD (+75.2 m IGLD85'), which is representative of a typical spring/summer water level.

As seen in Figure 3.14 below, the dominant SW (230 deg) wave direction produces a west to east longshore current generally running parallel to the waterline for all three shoreline geometry scenarios. Interestingly, for Scenario A and B (no SMC Headland), the longshore current begins to diverge from the shoreline at the west end of Cedar Crest Beach Road and travel across the embayment some distance from the shoreline before dissipating offshore. This implies that mobilized sediment would potentially follow an offshore bar that bypasses, in part, the Port Darlington West Embayment during the dominant SW wave conditions for Scenario A and B. The hydrodynamic modelling also shows an accelerating longshore current along the Cedar Crest Beach shoreline for Scenario A, which would not be conducive for sediment deposition or natural beach building. In other words, prior to the construction of the Port Darlington jetties, the area likely featured narrow beaches adjacent to the receding shoreline. For Scenario B, the current decelerates at the east end of the embayment as it nears the Port Darlington west jetty, which has resulted in the formation of the west fillet beach.

With the presence of the SMC Headland in Scenario C there is a decreasing longshore current that moves towards the Headland from the west, leading to the accumulation of a small west fillet beach (refer to Section 2.4). Further offshore, the currents are moving across a large cobble-boulder lag deposit and the SONAR data suggests there is no sand and gravel in this region to transport towards the tip of the SMC Headland. The currents that do develop along the south side of the Headland (bottom panel, Figure 3.14) are discontinuous and primarily associated with wave breaking on the armour stone protecting the slope. These modelling results are supported with the SONAR data, which did not capture any signs of bedload transport (lake bottom features such as sand sheets or sand bars). The SONAR mapped a lake bottom consisting predominantly of soft sediment (silts and clays) or mud.

Hydrodynamic modelling results presented in Figure 3.15 for the less common ESE (100 deg) wave direction show an east to west longshore current for all three scenarios. With and without the presence of the Port Darlington jetties and SMC Headland, this current tends to decelerate from the centre of the Port Darlington West Embayment near the west end of Cove Road to the west end of Cedar Crest Beach Road, potentially creating a depositional area in the west half of the embayment. However, there are two lines of physical evidence that indicate the volume of sediment available for transport from east to west is low. First, the SONAR data mapped a large cobble-lag deposit in the nearshore, not sand. Second, there is no sediment trapped in the east fillet beach at Port Darlington. In other words, 160 years after the construction of the jettied navigation channel, no measurable volume of sediment has accumulated against the east jetty, indicating there is little to no supply of sand and gravel from the east, let alone a supply that could bypass the jetties from the east and enter the Port Darlington West Embayment.

With the construction of the SMC Headland, the east to west current resulting from ESE waves still decelerates but a counterclockwise eddy also develops against the eastern side of the headland (bottom panel of Figure 3.15). The convergence of the decelerating current and the eddy result in a dead zone with low hydrodynamic energy. If sediment was being transported from east to west, the SMC Headland would actually increase the rate of sedimentation in the Port Darlington West Embayment by acting as a barrier to further westward sediment transport. In other words, the Headland is a benefit to the stability of Cedar Crest Beach during ESE storms.

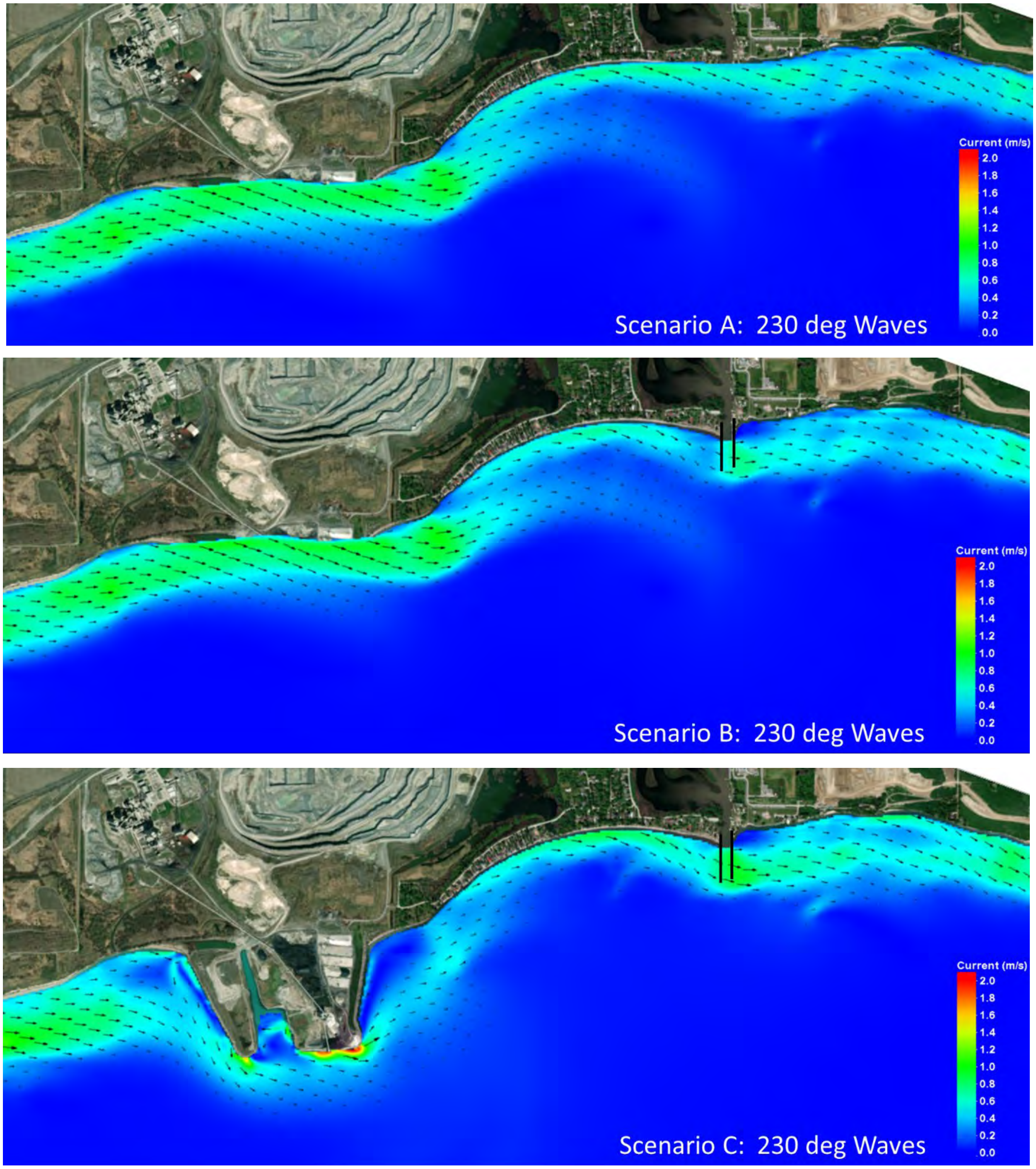


Figure 3.14 CMS-Flow Model Results Showing Nearshore Currents for all Three Scenarios and the SW (230 deg) Waves

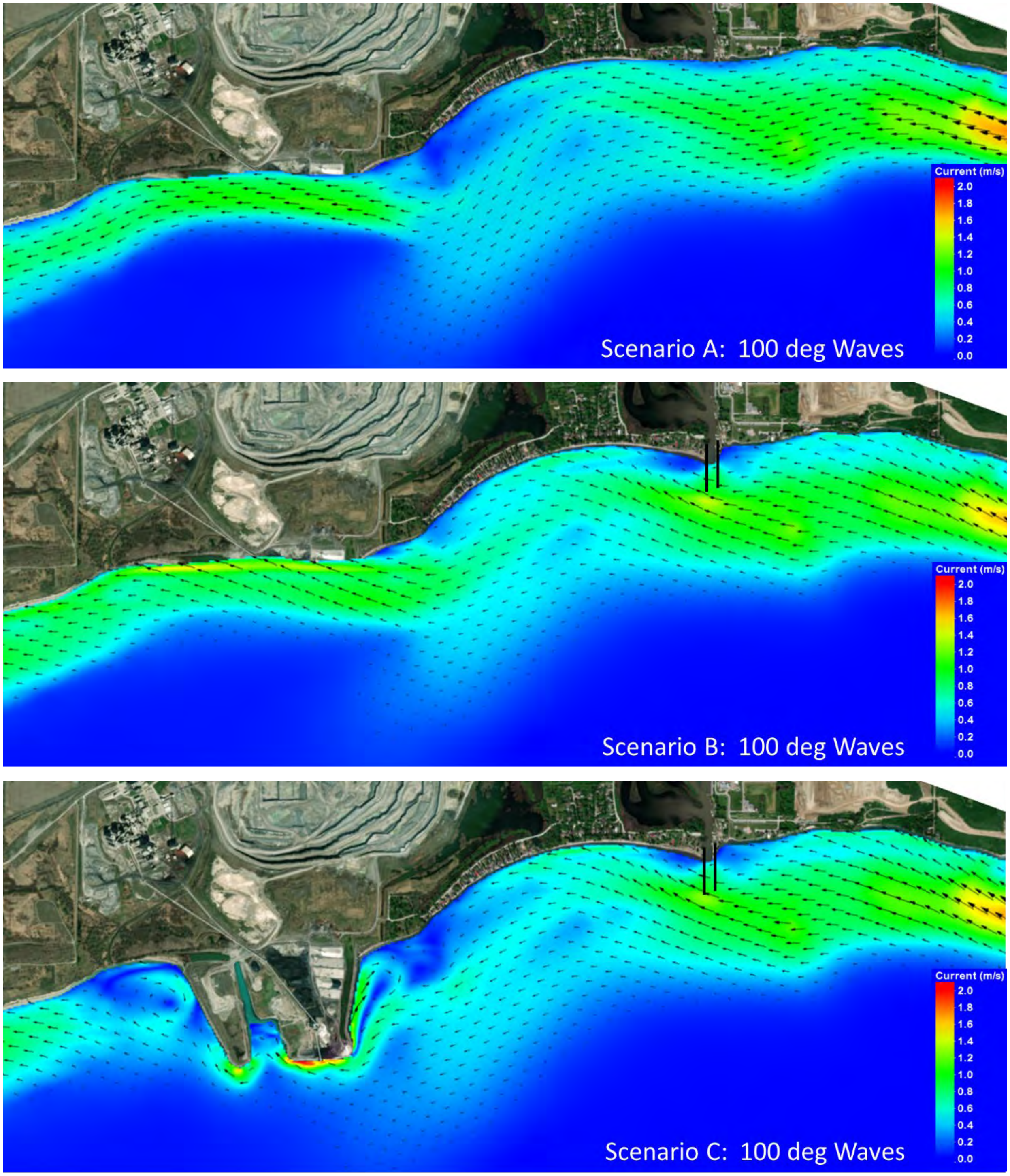


Figure 3.15 CMS-Flow Model Results Showing Nearshore Currents for all Three Scenarios and for ESE (100 deg) Waves

3.2.3.2 Sediment Transport Modelling

Figure 3.16 and Figure 3.17 present sediment transport capacity (coloured contours) and sediment transport direction predictions for the three shoreline scenarios and two wave directions discussed above. Sediment transport capacity is the maximum total-load (combined bed load and suspended load) that could be mobilized and moved in the water column for the input wave condition and is measured in kg/m^3. The total-load capacity can only be realized if sufficient sources of sediment suitable for transport are present, such as a continuous sand cover across the lake bottom. Together, the sediment transport capacity and direction of transport gives an indication of how sediment would move through the nearshore under each wave direction and shoreline geometry scenario if a continuous supply of sediment were present (which we know is not the case in this study area). Areas of decreasing sediment transport gradients (in the direction of transport) can theoretically be depositional zones, while an increasing gradient in sediment transport capacity would indicate possible areas of erosion (of the lakebed and beach).

The sediment transport model outputs presented in Figure 3.16 for the dominant SW wave condition generally affirm the observations made in Section 3.2.3.1 above. In particular, they illustrate that the introduction of the Port Darlington jetties in the 1800s created a deceleration in the longshore current and reduction in sediment transport capacity which led to the creation of the west fillet beach. Without the Port Darlington jetties, the sediment transport capacity is relatively consistent from west to east along this stretch of coastline meaning the embayment would not have been a sediment sink. Sediment would move through the embayment, possibly maintaining narrow beaches along the shore, while the majority of sediment would be transported further to the east.

Figure 3.16 also indicates that the introduction of the SMC Headland in the late 1970s has created a barrier to the longshore sediment transport capacity from west to east during dominant SW wave conditions. However, based on the volume of the west fillet beach adjacent to the SMC Headland, the supply of sand is very small (annual accumulation rate of 660 m^3/year). There was no physical evidence of sand accumulation in an offshore shoal or being transported around the Headland.

When the Scenario A and B sediment transport capacity results are compared in Figure 3.17, it appears that the construction of the Port Darlington jetties in the mid-1800s had the potential to trap sediment on the east side of the east jetty. However, after 160 years of existence, there is no east fillet beach, suggesting the supply of sand from the east is close to zero.

It is also evident from Figure 3.17 that prior to the construction of the SMC Headland, an ESE wave event could mobilize sediment and transport it to the west away from the Port Darlington West Embayment. However, the Headland now acts as a barrier to sediment transport to the west, which is a benefit for the Port Darlington West Embayment.

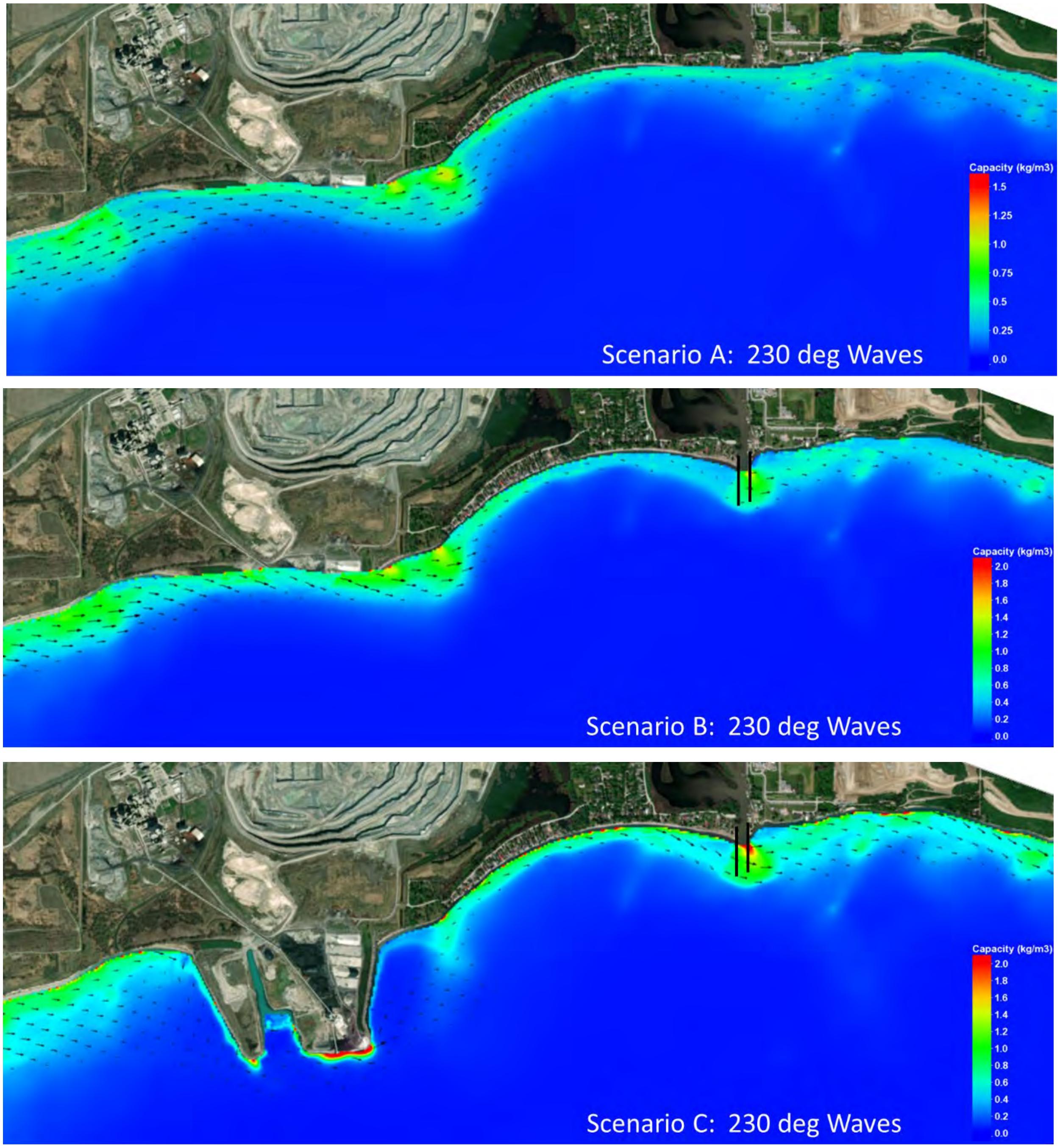


Figure 3.16 CMS-Flow Model Results Showing Simulated Sediment Transport Capacity and Direction for all Three Scenarios and SW (230 deg) Waves

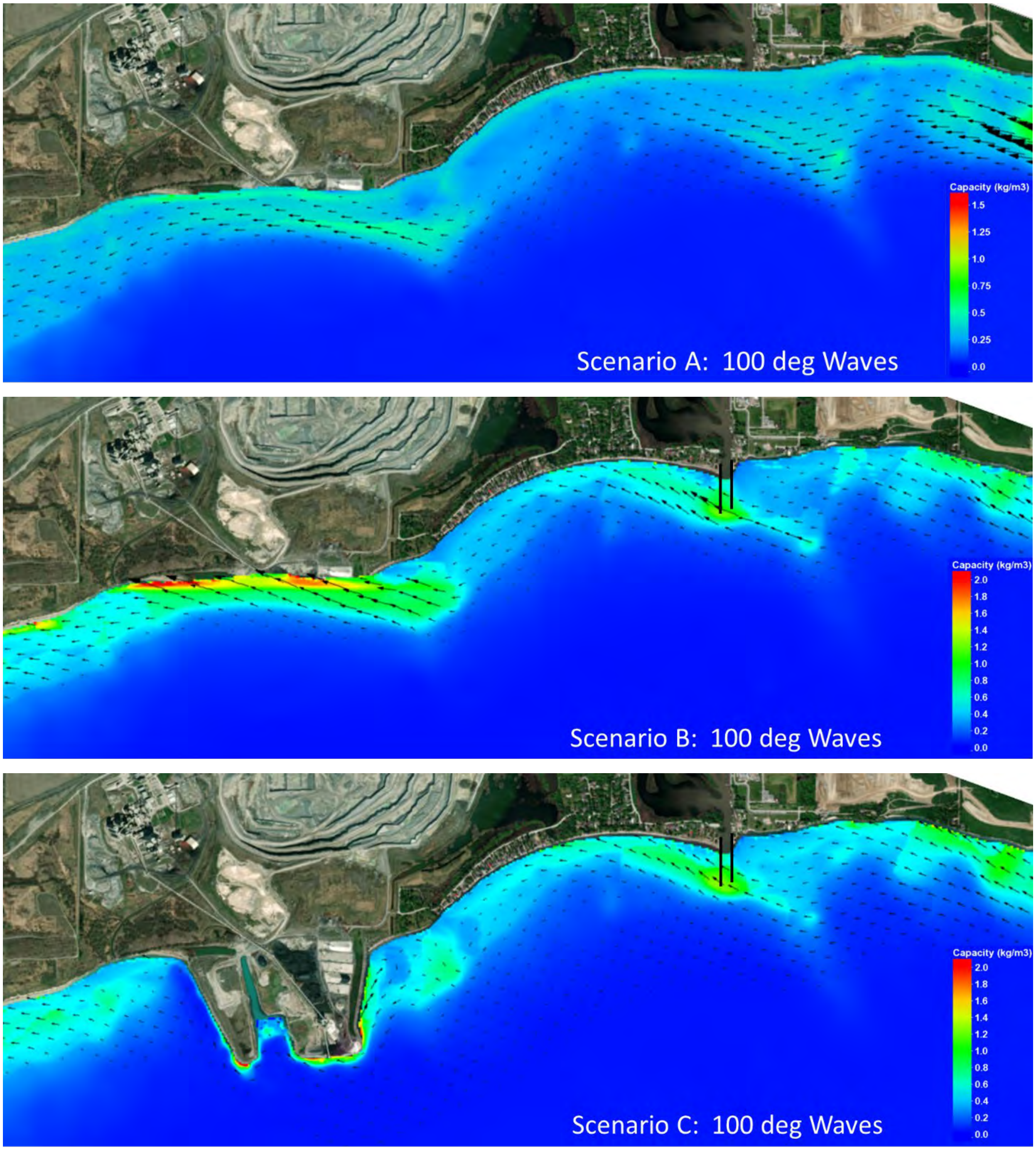


Figure 3.17 CMS-Flow Model Results Showing Simulated Sediment Transport Capacity and Direction for all Three Scenarios and for ESE (100 deg) Waves

3.2.3.3 General Modelling Conclusions

Overall, the results of the hydrodynamic and sediment transport modelling indicate that under existing conditions, sediment would tend to move away from the center of the Port Darlington West Embayment towards the Port Darlington jetties to the east and the SMC Headland to the west depending on the wave direction. Given that the dominant direction is from the SW by a significant margin, more material is transported eastward and has built the fillet beach known as

Port Darlington West Beach. If the Port Darlington jetties were not in place as was the case pre-1800s, this sediment would have been transported eastward and would not have accumulated along the shoreline in this region.

The SMC Headland is a barrier to longshore sediment transport arriving from the west under SW waves, however, the volume of sand and gravel available for transport is very small as evident by the size of the west fillet beach. During ESE wave events, the SMC Headland acts as a barrier to sediment transport from the east, providing some local benefit for Cedar Crest Beach (i.e., reduces the loss of sediment to the west).

Finally, for the dominant SW wave direction the shoreline orientation fronting Cedar Crest Beach Road is not conducive to sediment accumulation, even for the pre-development Scenario A shoreline. Sand and gravel would move along the shoreline, but it is very unlikely that large accumulations of sediment existed at this location in the past. This observation is independent of the presence of the Port Darlington jetties or the SMC Headland and consistent with the findings of the recently completed Lake Ontario Shoreline Management Plan (Zuzek Inc., 2020).

3.3 Influence of Development History on Shoreline Recession

As outlined in Section 2.2, when the jetties were constructed at Port Darlington, the Cedar Crest Beach shoreline was a natural barrier beach with a hydraulic inlet connecting the interior wetlands to Lake Ontario. The 1878 map is reproduced in Figure 3.18. The inlet corresponds with the current marsh outlet between Cove Road and Cedar Crest Beach Road. Based on our knowledge of the regional shoreline trends from the recently completed Shoreline Management Plan (Zuzek Inc., 2020), the cohesive headlands and barrier beach were receding before the construction of the Port Darlington jetties.

Since their construction, the Port Darlington jetties have trapped enough sand to stabilize the eastern half of the Port Darlington West Embayment and change the long-term shoreline trend from recession to accretion. The potential negative impacts to the downdrift shoreline to the east of the jetties was not investigated.

In the western half of the embayment, the homes were built much closer to the shoreline, as seen in the 1954 aerial photograph in Figure 3.18 The numerical modelling has shown this segment of shoreline does not feature an orientation conducive to sediment deposition. Therefore, regardless of the local modification to the shoreline with the construction of the Port Darlington jetties and SMC Headland, this portion of the Port Darlington West Embayment continues to erode.

Several factors have contributed to the recession of the beach for the western half of the embayment, including:

- A reduction in the volume of sand moving from west to east along the shoreline due to the SMC Headland.

- Construction of homes on top of the former dynamic barrier beach, as noted in Figure 3.18.

- Shoreline armouring with reflective structures that contribute to toe scour and lakebed downcutting.

- Disruption of natural cross-shore sand transport processes that allow beaches to recover naturally from periods of high lake levels due to home construction and shore protection on the beach crest, which in turn reduces the overall resilience of the beach to periods of high lake levels.

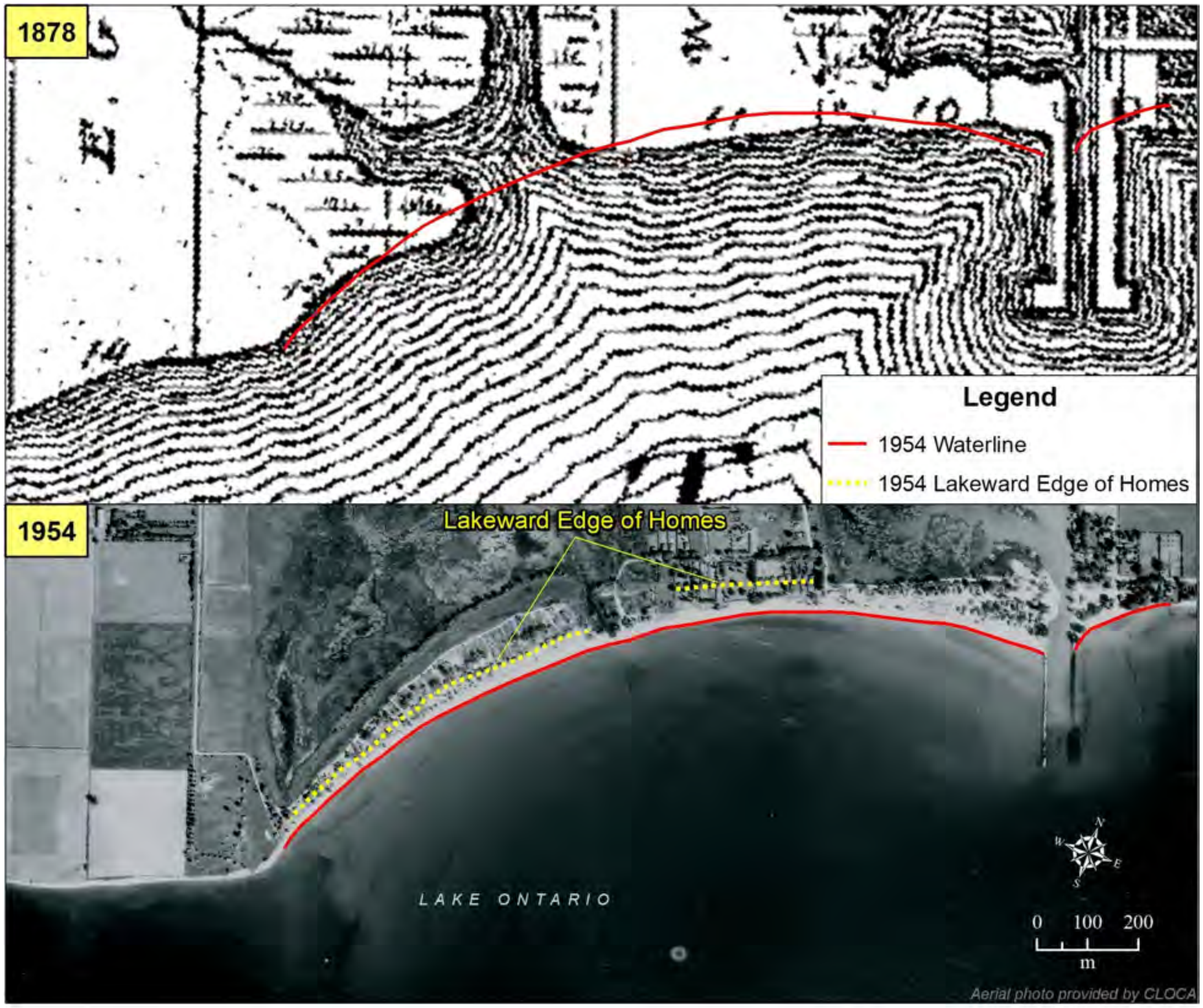


Figure 3.18 Map from 1878 and 1954 Aerial Photograph

4.0 CONCLUSIONS

Section 4.0 of the report summarizes the study conclusions for the three temporal periods (Scenario A to C) and the overall impacts of the littoral barriers and shoreline alterations in the Port Darlington West Embayment.

4.1 Early 1800s (prior to the Port Darlington Jetties)

The Scenario A shoreline is reflective of the early 1800s period prior to the construction of the Port Darlington jetties. The key study findings pertaining to this period include:

- The regional shoreline change data from the Lake Ontario Shoreline Management Plan (Zuzek Inc, 2020) suggests the entire study area featured a long-term recession rate based on the presence of erodible glacial till bluffs and sand barrier beaches fronting coastal wetlands.

- Without the SMC Headland or Port Darlington jetties, in the early 1800s southwest storm events generated longshore currents that transported sand and gravel from west to east along the regional shoreline. There were no 'natural' barriers capable of trapping sand and gravel along this shoreline. Due to the natural shoreline orientation in the Port Darlington West Embayment, the sediment transport modelling suggests that local beaches would have been narrow with low potential for sediment retention.

4.2 Mid-1800s to Late-1970s (Port Darlington Jetties)

The mid-1800s to late-1970s represents Scenario B, when the Port Darlington jetties were present, but the SMC Headland had not been constructed. The major conclusions are:

- Based on the rate of accumulation in the west fillet beach adjacent to the SMC Headland, approximately 660 m^3/yr of sediment was historically transported from west to east into the Port Darlington West Embayment during this period. In Scenario A (pre-1800s) this sediment would have moved through the embayment and continued to the east. However, the presence of the Port Darlington Jetties post-1800s has significantly altered the physical processes and historical shoreline trends in the Port Darlington West Embayment by trapping much of this sediment in the west fillet beach. Consequently, following the construction of the jetties the shoreline trend switched from recession to accretion for the eastern half of the embayment.

- Without the SMC Headland, the bluff shoreline west of Cedar Crest Beach was receding. As the bluffs continued to retreat inland (northward), the protection they provided to Cedar Crest Beach was slowly decreasing and contributing to the instability in the western half of the Port Darlington West Embayment.

- Sediment arriving from the west during SW storms moved along the shoreline in the western half of the embayment but likely did not accumulate in this region due to the shoreline orientation. In other words, a dynamic beach was present along the shore, but it featured a long-term recession trend, as the site conditions were not conducive to the accumulation of large volumes of sand and gravel.

- Although not a focus of this investigation, the Port Darlington jetties have deprived the shoreline to the east of their natural supply of sand and gravel.

- The construction of homes close to the shoreline in the western half of the Port Darlington West Embayment has negatively impacted the beach and its ability to respond naturally to lake level fluctuations.

4.3 Late-1970s to Present (Jetties and SMC Headland)

The last temporal period, the present, is Scenario C when both the Port Darlington jetties and SMC Headland are present. Key findings include:

- The SMC Headland reduced the supply of sand and gravel to the Port Darlington West Embayment during SW wave attack by approximately 660 m^3/year, which would impact the beach stability. However, if present the majority of the sediment would have moved to the east end of the embayment where the historical long-term recession trend has been reversed by the presence of the Port Darlington jetties. In other words, it would not have accumulated along the shoreline of Cedar Crest Beach.

- The presence of the SMC Headland has also protected approximately 1.2 km of eroding bluff shoreline to the west of the Port Darlington West Embayment, which has and will continue to contribute to the stability of the shoreline by anchoring the western boundary of the littoral sub-cell. In other words, without the SMC Headland natural bluff recession would undermine the stability of Cedar Crest Beach.

4.4 Summary of Benefits and Impacts of Shoreline Alterations

Section 4.4 summarizes the benefits and impacts of the major shoreline alterations in the Port Darlington West Embayment over the last 200 years:

- The Port Darlington jetties have stabilized the eastern half of the Port Darlington West Embayment.

- The Port Darlington jetties have also starved the shoreline to the east of its natural supply of sand and gravel for more than 160 years.

- The SMC Headland has reduced the supply of sand and gravel to the Port Darlington West Embayment by approximately 660 m^3/yr, which is one factor that has contributed to the loss of the beach for the western half of the embayment. The Headland has also stabilized the eroding bluffs, which has and will continue to create benefits for the western half of the embayment.

- The construction of homes on the crest of the barrier beach in the western half of the embayment has reduced the resilience of the beach to periods of high lake levels. The construction of concrete and armour stone walls has made the problem worse by reflecting incoming wave energy towards the lake bottom, leading to scour and lowering of the lake bottom.

In summary, there have been positive and negative impacts associated with the artificial littoral barriers that define the Port Darlington West Embayment. For example, the eastern half of the embayment has benefitted significantly by the sediment trapped against the Port Darlington jetties. The SMC Headland is one of five factors that have contributed negatively to the current flooding and erosion hazards along Cedar Crest Beach:

- A reduction in sediment supply to the Port Darlington West Embayment due to the SMC Headland.
- The embayment shoreline features a natural long-term recession trend.
- The shoreline orientation is not conducive to the accumulation of sand and gravel.
- Homes were constructed too close to the waters edge and on top of a dynamic receding low-lying barrier beach.
- Vertical shore-parallel protection structures were constructed on the beach that are not conducive to beach building.

REFERENCES

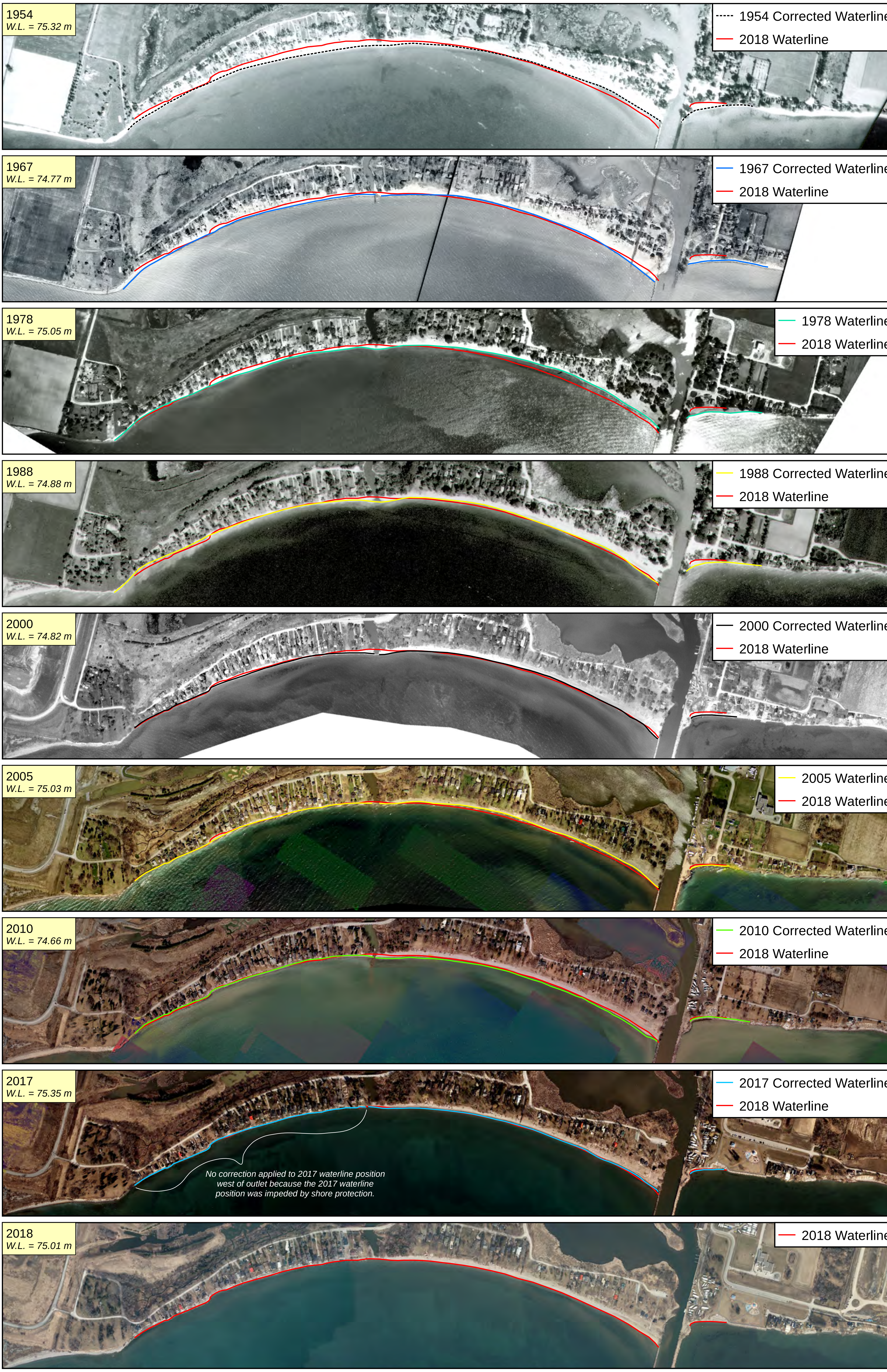
Municipality of Clarington (2017). Technical Note on History of St. Marys Cement Facility.

Public Archives Canada. National Map Collection. Reproduced with permission.

Zuzek Inc. (2020). Lake Ontario Shoreline Management Plan.

APPENDIX A

Historical Shoreline Change Data



CEDAR CREST BEACH

Waterline Comparison 1954 to 2018

Waterline positions were corrected relative to the 2018 photo with a water level of 75.01 m (IGLD'85).

Note:
1954/67/78 aerials provided by CLOCA.
All other aerials provided by Mun. of Clarington.
Monthly mean water levels (W.L.) referenced to IGLD85 for April of photo year, except for: '54 (May), '78 (June-Aug), '88 (May).

0 100
m

N

Zuzek inc.
ONE WORLD