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BEACH CHANGES AT THE LONG POINT LIGHTSTATION, LAKE ERIE

A Progress Report on the Monitoring of a Shore Protection System

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RESEARCH AND DEVELOPMENT

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by

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There have been a number of individuals who have assisted in the beach surveys and data reduction to whom we extend our gratitude. Mr. Scott Hanville deserves particular mention for his help in this regard. We are most appreciative of the warm hospitality invariably shown by Mr. Bill Ansley, lightkeeper at Long Point, who always extended a warm welcome during our brief visits to carry out our surveys. Surveys were made possible with the provision of Canadian Coast Guard helicopters by the Ministry of Transport and the kind cooperation of the MOT pilots. For typing and editing, we would also like to thank Mrs. S. Judge and Mrs. K. Nault.

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1.0 INTRODUCTION

The size and shape of Long Point, the largest sand spit in the Great Lakes system, have changed considerably since its formation beginning some 4,000 years ago. It now extends 37 km into Lake Erie, forming a natural divide between the central and east basins of the lake (Figure 1).

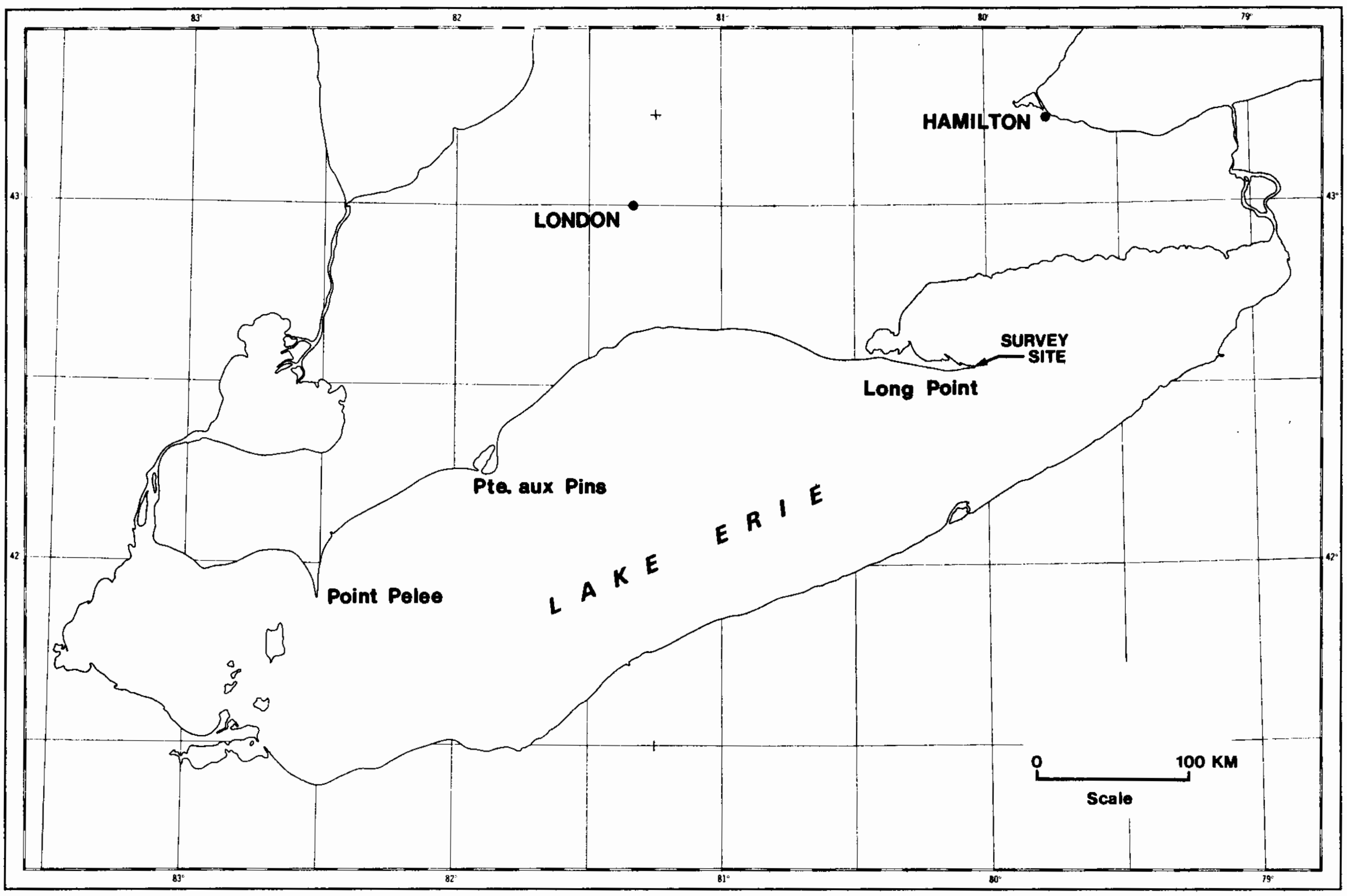

Figure 1. Location Map

Continuous shifting and migration of its shoreline positions, in response to changes in lake levels and storm events, indicate that the Point is still in a process of evolving. This fact has resulted in the need to relocate lighthouse facilities twice since 1830, and most recently, the construction of a series of groynes to protect the existing site built at the tip of the Point in 1916.

Observations of Great Lakes shoreline structures show that the most dramatic alterations to coastal environments occur when there is an interruption of longshore sediment transport (Inman 1978) and, furthermore, that there is a general relationship between the size of the structure and the magnitude of impact. It is generally difficult to establish a cause-effect relationship when damage occurs as a result of artificial structures due to the complexities of shore processes. However, the problem of shore damage due to littoral barriers is now widely recognized. This is especially critical with the placement of this structure as the fragile beach and dune environment of Long Point is being managed primarily as a wildlife preserve by both private and government agencies.

A monitoring program was developed, therefore, to: (i) ensure early detection of any adverse affects to adjacent shores, and (ii) to advise on remedial action. This is an interim report on the monitoring program.

2.0 CASE HISTORY

Prior to the installation of the groynes in July 1978, a study was undertaken by James F. MacLaren Ltd. to recommend an effective and environmentally sound scheme for "erosion control". Based on an analysis of the shore processes, their report to the Ministry of Transport (MOT) in March 1976 recommended:

> "A series of four timber groynes.....", in addition to, "temporary revetment structures in the form of tubular sand filled fabric bags (Longard Tubes).....to protect the lightkeeper's dwelling while the groynes are filling and during extreme storms. Snow fences may be used to trap sand and help maintain cover over the tubes."

Two years later, in March 1978, the MOT arranged for the construction of the groynes which were to be completed by August 1 of that year. Contract specifications which varied from the original scheme submitted by the consultants were prepared by the engineering staff of MOT. Changes included the use of concrete-filled nylon fabric bags (Fabricast Molded Blocks), instead of timber for construction of the groynes, and the proposed shore protection was to be extended another 244 m (800 ft) eastward with the addition of four groynes. The temporary revetment of Longard Tubes to front the lightkeeper's residence was omitted; however, the recommendation for snowfencing to be placed in sections along the entire protected reach normal to the northeasterly fetch was retained to assist beach reformation.

The proponent (MOT) considered the potential of this project for having an adverse impact on the environment to be insignificant and, therefore, the Department of Fisheries and Environment (DFE) (subsequently changed to Department Of Environment (DOE) and Department Of Fisheries and Oceans (DFO)), who administer the federal Environmental Assessment and Review Process (EARP), was not consulted. An informal examination of the proposal by DFE, however, identified a number of aspects related to this project which were of potential environmental concern. These included:

- increased erosion to adjacent unprotected beaches due to interruption of littoral drift by the groynes;
- depletion of sand dunes which were to be the source of aggregate for the concrete mixture used in the construction of the groynes; and
- aesthetic impacts resulting from the introduction of a shore-hardening device in an area which is otherwise void of any man-made structures - a unique condition on the Great Lakes.

A number of site visits and meetings were held between DFE and MOT to discuss ways of overcoming these concerns and alternatives to their proposed protection. DFE recommended that any structural program be postponed for one to two years as a trend toward lowering lake levels was anticipated at the time. A natural extension of the beach could therefore be expected based on water level variations vis-á-vis beach width data (MacLaren 1976). However, MOT was not prepared to accept any further risk of erosion damage to their facilities, particularly the lightkeeper's residence, authorizing construction for July 19, 1978. The groynes and snow fencing are shown in Figure 2 as they appeared two weeks after construction.

MOT did, however, make alterations to their proposal. Based on DFE recommendations, MOT agreed to an alternate source of sand to be used as aggregate in the construction of the groynes. It was to be taken from the extreme unvegetated tip of the Point, where a continuous supply of sand from littoral drift on the south side of the Point quickly replenishes the area, rather than from dunes. Based on a wave energy hindcast, Wood (1960) estimated littoral drift rates at the tip of Long Point (south shore) to be about 1.7×10^6 yd^3 annually. MOT also agreed to take appropriate action if in the future the groynes were shown to be causing any definite undesirable environmental impacts. It was also mutually agreed that the DFE begin a monitoring program immediately following construction of the groynes to assess effects to adjacent shores.

Further details of the case history are provided in Appendix 1.

Figure 2.

Aerial Photograph of Fabricast Molded Block Groynes and Snow Fencing at Long Point. (August 3, 1978.)

3.0 MONITORING PROGRAM

3.1 Survey Accuracy

Accuracies for the subaerial portion of the beach profiles using topographic survey methods are within 0.03 m vertical and 0.05 m horizontal (Shaw 1978).

3.2 Pre-construction

Onshore and offshore profiles have been surveyed annually at the tip of Long Point by DFE (OAS) since 1973. This is part of an ongoing Canada/Ontario agreement to monitor shore erosion on the Great Lakes. A master plan of profile station E-4-21 is shown on Figure 3.

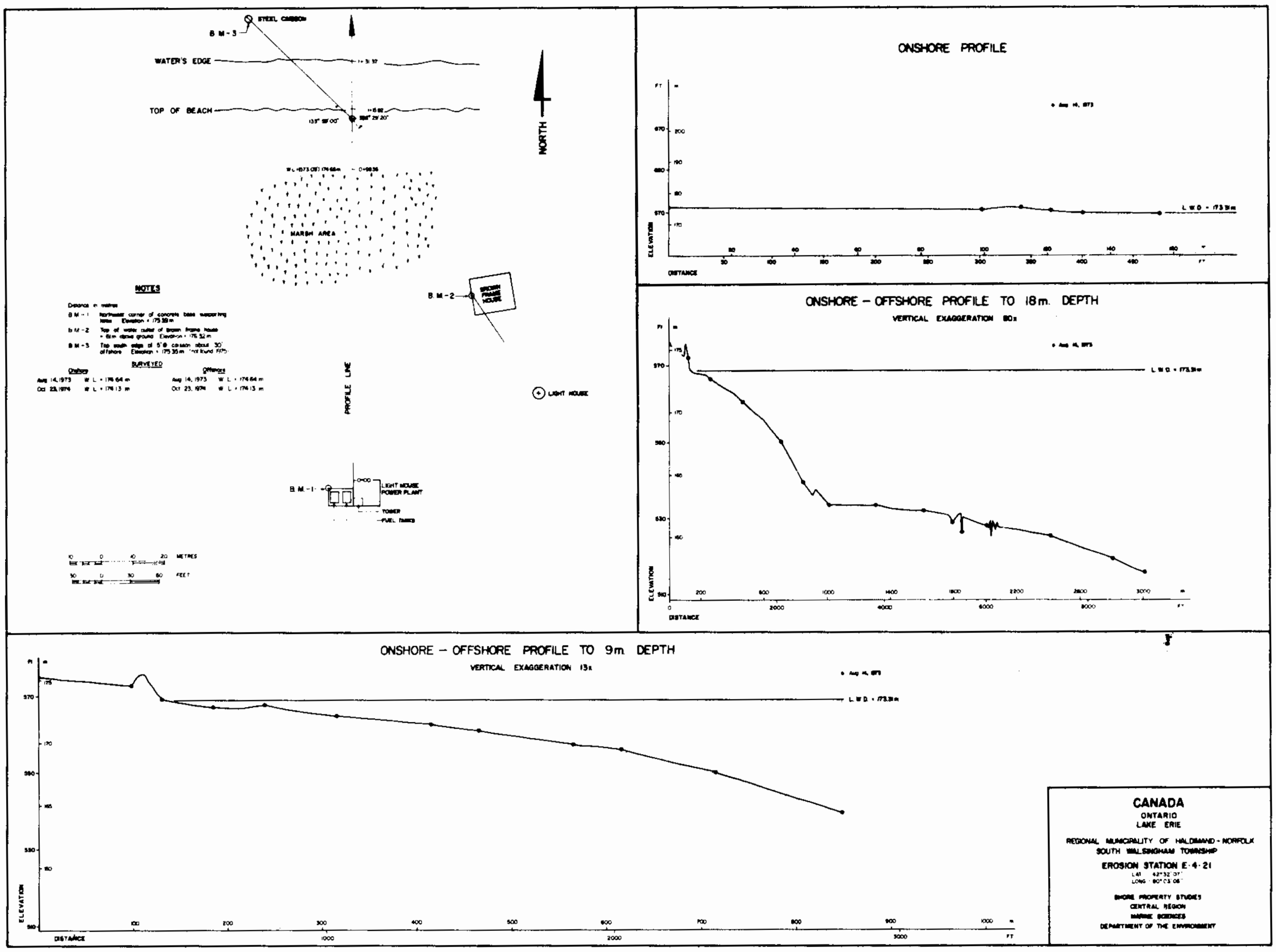

Figure 3. Master Plan of Erosion Station E-4-21

3.3 Post-construction

Under the Canada/Ontario monitoring program, erosion station E-4-21 was surveyed on July 20, 1978, the day following construction of the groynes. On August 3, Ocean and Aquatic Sciences (OAS) expanded the survey coverage to include the area of the groyne field by adding another three profiles near the E-4-21 site. The baseline, profiles and location of groynes are shown on the site plan in Figure 4. Beach surveys are undertaken in the spring, mid-summer, fall, and after storm events. Six surveys have been completed since the groynes were installed.

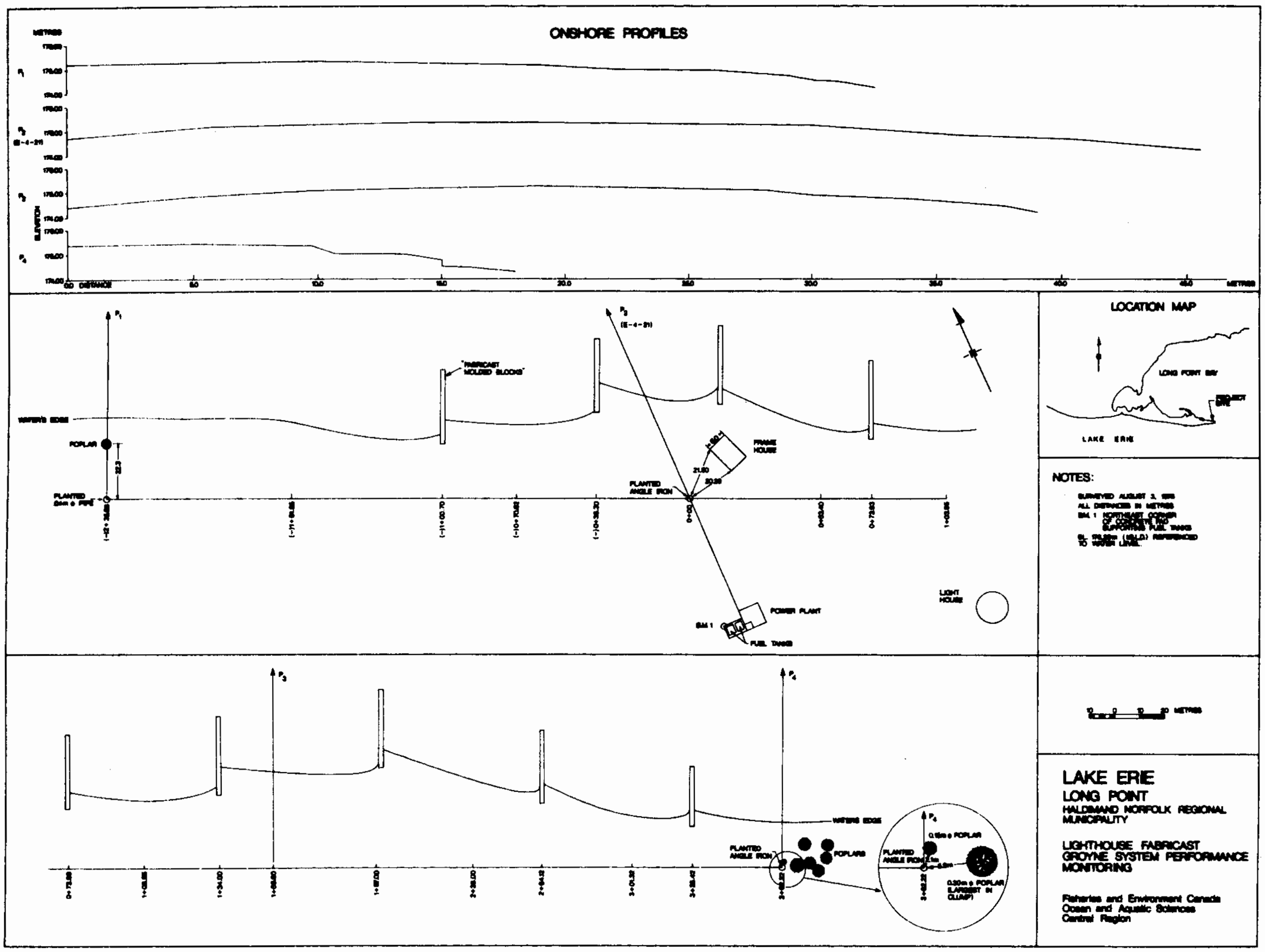

Figure 4. Site Plan of Long Point Groynes and Survey Lines

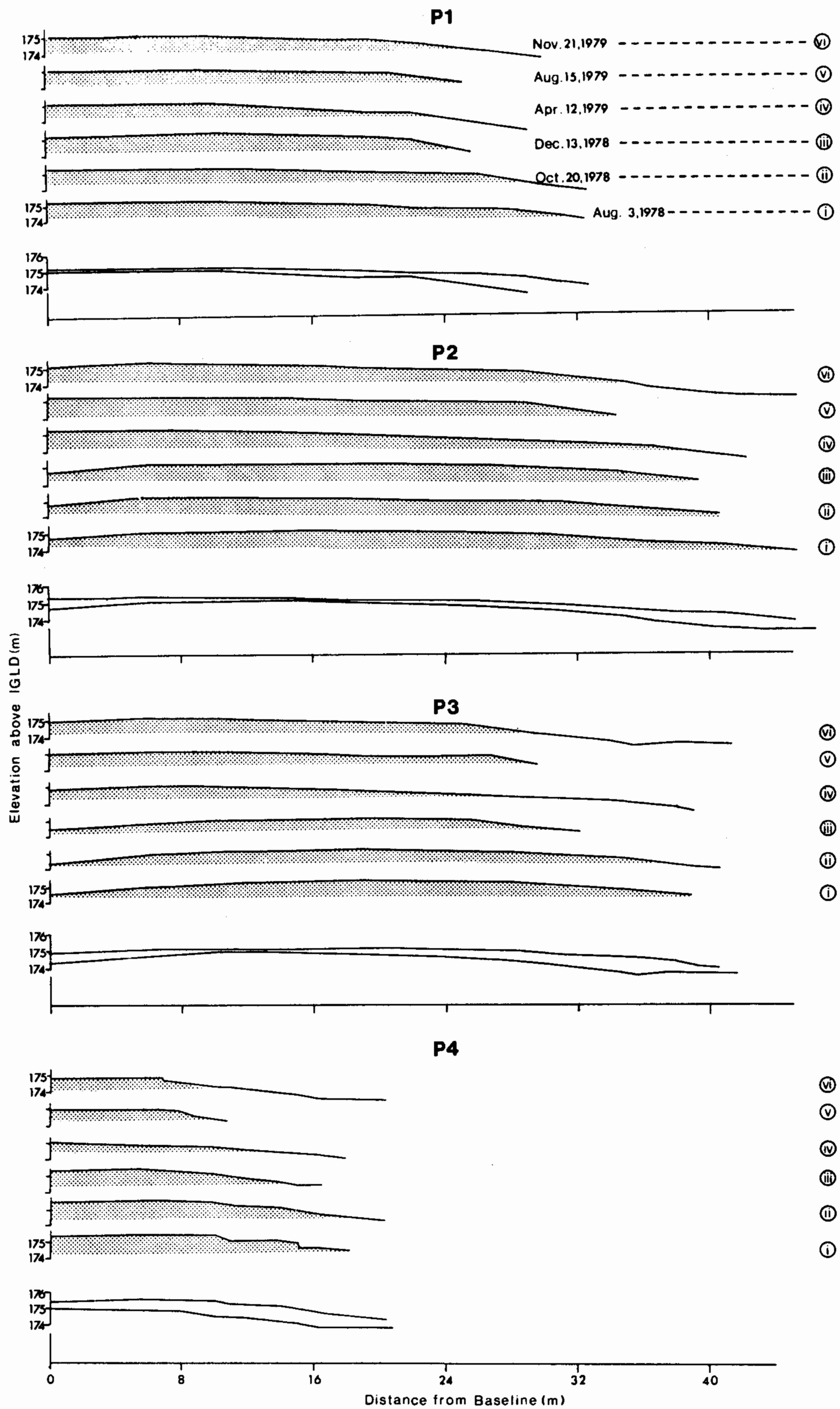

Figure 5. Beach Profiles After Construction of Groynes

4.0 OBSERVATIONS

Three sets of data can be used to assess the relative impact of the groyne structures on beach changes in the area. These include the comparison of profile and volumetric data for each of the four survey stations for the period of record; the comparison of these observations with that of preconstruction monitoring at E-4-21; and changes in the shore plan based on water's edge position at the time of surveys (reduced to a common datum).

4.1 Post-project Profile and Volumetric Data

The four monitoring sites shown in Figure 4 have been surveyed six times since shore protection was installed in July 1978. Individual beach profiles and the dates are shown for each survey in Figure 5 as well as a composite plot or sweep zone indicating the overall magnitude of change in profile for the entire survey period.

All cross-sections show recession in spite of shore protection and a drop in lake level of 22 cm. The net change for the August 1978 to November 1979 survey interval indicates an average loss of 7.1 m when referenced to a fixed elevation of 174.25 m (IGLD). Ironically, one of the stations within the groyne system (P2) had the highest recession with an 8.3 m* loss. This may be explained by the fact that adjustments in sediment accumulation continue to take place in response to reversals in longshore current. East of the groyne system, the beach at P4 retreated 7.2 m while the west beach (P1) had the least loss (5.5 m). Although maximum beach retreat did not occur simultaneously for the four sections of beach, Table A.1 (Appendix) shows that the protected reach and east beach sustained the highest recessional loss ranging between 9.0 and 9.7* m.

Sweep zones show profiles of maximum deposition and scour conditions. These do not vary significantly, suggesting that reaches (P2 and P3) within the groyne field remain as dynamic as reaches (P1 and P4) at each end of the groyne system.

Relative volumetric losses (erosion) during the post-construction period (Table A.2 of the Appendix) contrast significantly in comparison to the recessional data. The end profiles (P1 and P4) continue to show beach material losses two to three times that of beaches within the groyne system (P2 and P3). Protected beaches had a net average loss of 2.8 m^3/m while unprotected beaches had a net average loss of 8.7 m^3/m.

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*This value has been adjusted to compensate for the angle (24^{o}) at which profile line P2 intersects with the shore.

This has been recorded throughout the entire monitoring period. Maximum erosion losses occurred after the spring storm of April 1979 and also in August 1979 with all profiles showing signs of subsequent beach recovery.

It is also interesting to note that profile P2, which receded the most during the full fifteen-month survey interval, eroded the least with a loss of 1.9 m^3/m. This fact illustrates the lack of any direct relationship between recession and erosion which is so often assumed to be the case.

4.2 Comparison with Pre-project Conditions

Pre-project observations of beach changes are available for station P2 from annual surveys undertaken by the Canada/Ontario Great Lakes Shore Erosion Monitoring Program. This data is graphically shown in Figure 6, while recession and erosion rates are included in Tables A.1 and A.2 of Appendix 2.

The highest recession rates during the survey period occurred during the early years of the monitoring program beginning in 1973. Both profile plots (Figure 6) and recession figures show continuous retreat of the beach, especially during the high water years of 1973 and 1974 when recession rates averaged about 10 m/yr. Since 1976, the beach at this location has receded about two metres.

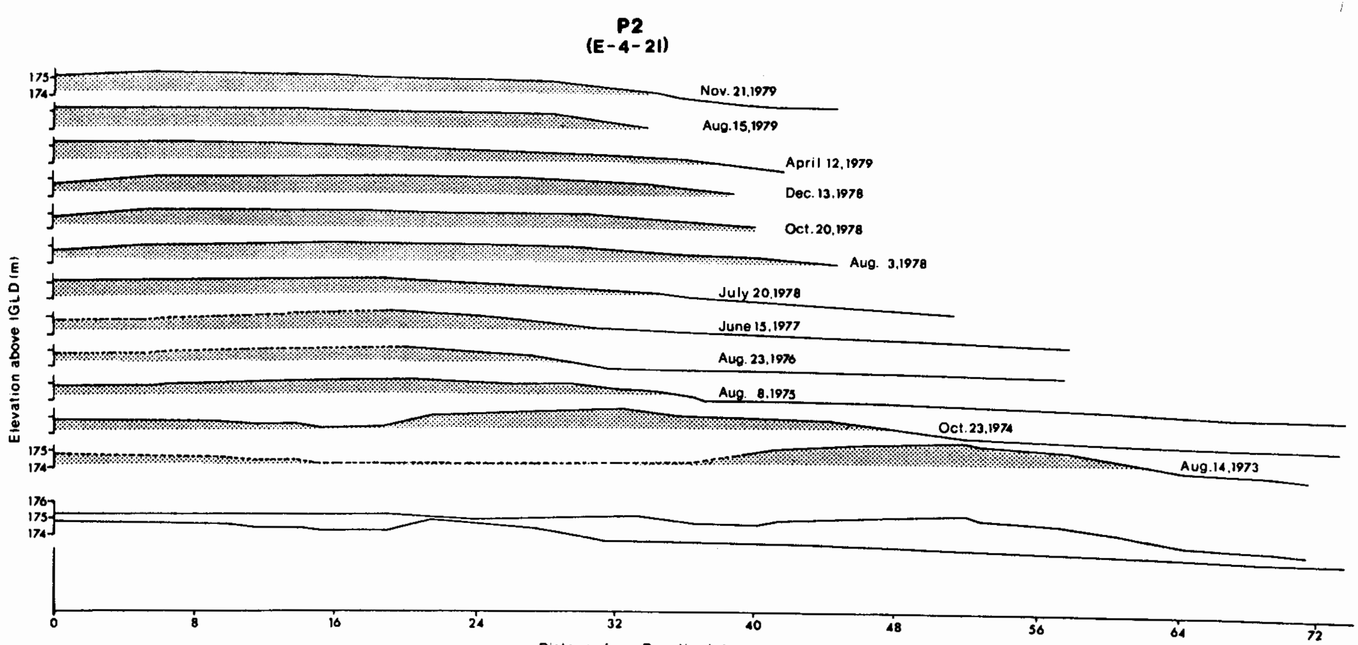

Figure 6. Long-term Observations of Beach Changes

Again, volumetric data (Table A.2) show that the actual amount of beach has changed insignificantly at P2. Since 1973, the beach has lost 4.1 m^3/m. Maximum erosion occurred in June 1977 when losses reached 15.0 m^3/m when compared to 1973 conditions. As of November 1979, conditions are comparable to the amount of beach material present in late 1974. This data appears incongruous to the recession data which indicated losses of up to 10 m/year and a recovery which is 32.9 m short of the 1973 shore position (174.25 m).

At this site, however, the beach is a barrier beach fronting a low-lying hinterland, some of which is submerged. Erosion, therefore, has occurred as a landward migration of the beach whereby much of the eroded material is displaced as overwash inland. Profiles in Figure 6 illustrate this process. The actual amount of beach material above elevation 174.25 m, therefore, may have changed in position but not in volume. Because most of the beach at the groynes is backed by a low-lying hinterland, the authors assume it will continue to migrate inland as there is no obstruction to movement in that direction. At P2, the hinterland has been filled by overwashed sands so migration or recession may actually slow down relative to other reaches where infilling continues.

4.3 Changes in Beach Plan

Figure 7 shows how the exposed beach area has changed from August 1978 to November 1979.

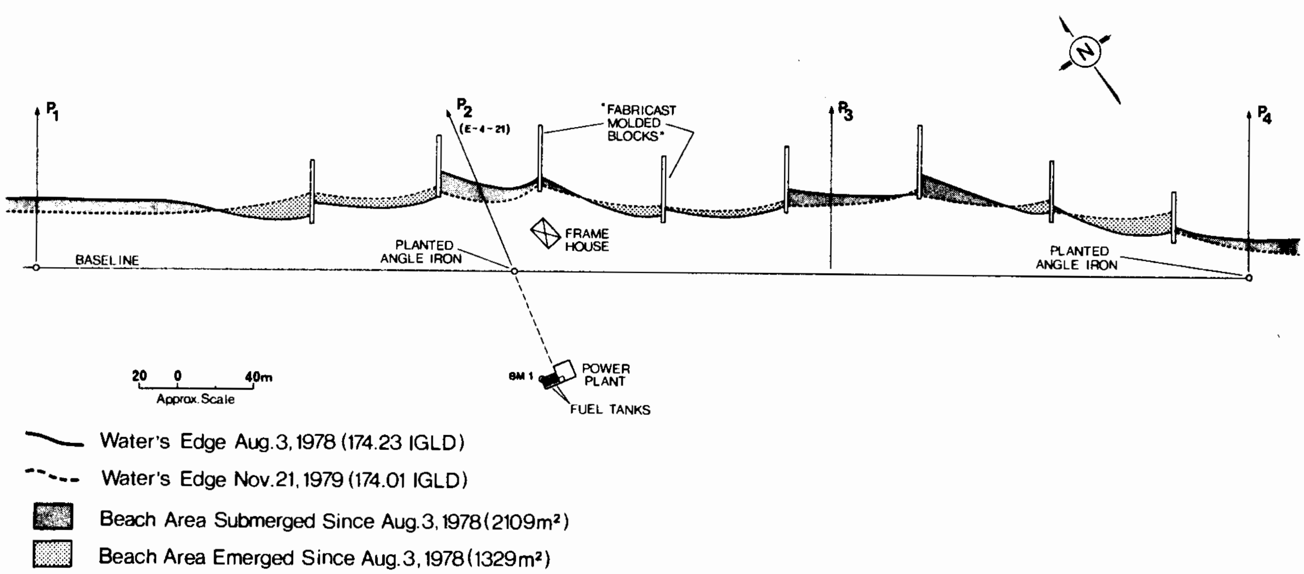

Figure 7. Changes in Beach Area From August 1978 to November 1979

During this period, Lake Erie water level dropped 22 cm, which would normally yield more dry beach area. At all four profiles, however, the area of exposed beach was reduced, which is consistent with the recession data using a common fixed water level of 174.25 m. In total, 2100 m^2 of dry beach area has been lost since groyne installation. This has been partially compensated for with a build-up of about 1300 m^2 of new beach material at other locations in the system. This results in a net loss of 800 m^2 of beach area.

The beach east of the groyne system is receding relative to visual references such as trees near the shore. Because of this, the baseline has been extended eastward in order to verify this in quantitative terms.

5.0 SUMMARY

Both recession and volumetric data indicate a continuing loss of beach at the Long Point lighthouse facilities. Average recession at the four profile locations between August 1978 and November 1979 was 7.1 m, referenced to a common elevation of 174.25 m (IGLD). Erosion or volumetric losses averaged 5.8 m^3/m with the greatest loss at profiles east and west of the groyne system (9.3 m^3/m and 8.2 m^3/m respectively). This resulted in the inundation of about 800 m^2 of beach area in spite of a 22 cm drop in lake level.

Some incongruities were also noted in relation to recession (linear measure) and erosion (volumetric measure) rates. For example, one of the protected reaches (P2) had the highest recession rate yet evidenced the least volumetric loss. Furthermore, although the beach at P2 has receded 32.9 m since 1973, there has only been 4.1 m^3/m of material eroded. This is the result of beach migration inland across a low-lying hinterland where the beach position changes but the actual cross-sectional area remains nearly the same. Because much of this reach of shore is characterized by a barrier beach fronting a low hinterland, migration will likely continue.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The beach is continuing to show signs of recession especially at critical areas such as in front of the lightkeeper's residence and at the east and west ends of the groyne system. The effectiveness of the groyne system is being reduced because of a shifting longshore current which does not permit any long-term beach accumulations to become established. Furthermore, a low-lying hinterland provides little resistance to inland migration of the barrier beach, where overwash material is displaced into the backshore rather than forming a berm at higher elevations which would retard recession.

Based on these observations, if a temporary measure (10 years) to arrest beach retreat is desired, it is recommended that an artificial nourishment program be implemented on a demand basis rather than rebuilding or expanding the existing groyne system. Because the amount of drift along the north shore does not appear sufficient enough to maintain an adequate protective beach within the existing groyne system, nourishment would provide for more of a direct control in compensating for the beach material which washes inland.

Coakley et al (1978) illustrate the feasibility of this approach with sample calculations of the amount of material needed to provide protection over a 12 year period based on a typical recession rate of 5m/yr.

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APPENDIX 1

Case History - Chronology of Events Leading to the Protection of the Long Point Lightstation

Case History - Chronology of Events Leading to the Protection of the Long Point Lightstation

March, 1976 - James F. MacLaren Ltd. submitted a report to Ministry of Transport (MOT) recommending groyne protection to reduce shore erosion. The scheme was to include four timber groynes and a temporary revetment fronting the lightkeeper's residence.

March, 1978 - MOT awards a contract to build eight concrete groynes and a snow fence wind-break to promote dune formation.

April 25, 1978 - Department of Fisheries and Environment (DFE) representatives met with MOT engineering staff to discuss the proposed erosion protection plan and its potential for adverse impacts.

May 5, 1978 - DFE review proposal and make recommendations to MOT regarding the design of the groyne system and means of reducing the potential environmental damages, especially in relation to littoral drift processes.

June 6, 1978 - DFE and MOT representatives visit site to discuss proposed groynes and long-term plans. After inspection, it was recommended that MOT should not proceed with the groynes for at least another year as the beach could recover naturally under the apparent trend toward lower lake levels. Furthermore, it was recommended that sand be taken from the extreme tip (unvegetated) of the spit, an area which is being constantly nourished by littoral drift, rather than from sand dunes because of blowout potential associated with the latter.

June 12, 1978 - Provincial Ministry of Natural Resources (MNR) contacted MOT stating that the proposed structure may require approval under the Public Lands Act or the Beach Protection Act.

June 15, 1978 - MOT advised MNR that the groynes were to be built on federal property and that to rebuild the lightstation would be more destructive to the environment and much more costly than the proposed protective works.

June 23, 1978 - At a meeting DFE and MOT agreed to:

(i) monitor of the effectiveness of the groyne system;

(ii) consider jointly with Ontario the long-term problems of multiple use of the Point and recommend how uses may be harmonized; and

(iii) if as a result of monitoring the groynes prove to have an adverse effect, Transport would be responsible for appropriate action including, if necessary, removal of the groynes.

July 19, 1978 - Construction of eight 34 m groynes was completed.

Aug. 3, 1978 - DFE (Ocean and Aquatic Sciences) established a monitoring base-line including four beach profiles. CCG helicopter was used for transportation of crew and equipment from CCIW.

Aug. 9, 1978 - OAS reported by memo to MOT, DFE and MNR that the baseline had been established, and observations taken in August indicate that there had been very little disturbance to the area during the construction phase.

Aug. 25, 1978 - A report by DFE (Hydraulics Research Division), based on a site visit and review of the consultant's report (James F. MacLaren 1976), recommended artificial beach nourishment as a comparable protection alternative.

Aug. 29, 1978 - DFE/MOT/MNR meeting to discuss a monitoring program. Criteria were established upon which OAS was to receive notice from the Long Point lightkeeper for possible resurveys, (winds > 20 knots over a period of 24 hr.). Also, ground controlled aerial photographic surveys were to be undertaken.

Sept. 14, 1978 - Long Point lightkeeper reported to OAS winds in excess of 20 knots for a period longer than 24 hr.

Oct. 20, 1978 - OAS resurveyed with CCG helicopter support.

Nov. 22, 1978 - Long Point lightkeeper advised OAS of winds greater than 35 knots on November 17 and 18.

- Snow fence damage was incurred.

Dec. 5, 1978 - Long Point lightkeeper reported on further storms in the area.

Dec. 13, 1978 - OAS resurveyed with CCG helicopter support.

Jan. 4, 1979 - OAS advised MOT and other government agencies of survey observations. The data showed a general loss of beach material with the greatest volume loss west of the groyne field. Snow fencing was shown to have little effect in building up beach sand.

April 9, 1979 - Long Point lightkeeper reported that a storm of April 6, 1979, caused structural damage to residence - part of concrete block foundation collapsed under wave attack. Also, snow fencing was completely wiped out.

April 12, 1979 - OAS resurveyed with CCG helicopter support.

Aug. 15, 1979 - OAS resurveyed with CCG helicopter support.

Nov. 21, 1979 - OAS resurveyed with CCG helicopter support.

Nov. 27, 1979 - Long Point lightkeeper advised OAS of winds up to 54 knots over 24 hr from SW and W. No damage was reported.

Dec. 3, 1979 - OAS, during an aerial photography flight (CCG helicopter), undertook a quick resurvey of the water's edge position relative to the established baseline and extended the baseline eastward another 150 m. Outer ends of some groyne structures were observed to be settling as a result of undermining.

Dec. 11, 1979 - Long Point lightkeeper called OAS reporting on NW winds which had exceeded the criteria for two days on Dec. 7-8. Waves overtopped groynes and outer end sections were dropping. Beach appeared to be higher in the area around the lightkeeper's residence and to the west while the beach east of the residence appeared to be receding.

Dec. 17, 1979 - Lightkeeper called re high winds of Dec. 10th and 11th (SW-NW) and again on the 15th and 16th (N). Ice build-up was also noted along the shore.

APPENDIX 2

Table A.1. Linear changes (recession) in beach profiles as measured from the baseline to the contour line of 174.25 m above IGLD. Distances are in metres.

Table A.2. Volumetric changes (erosion) in beach profiles. Volumes are in cubic metres per metre.

Table A.1. Linear changes (recession) in beach profiles as measured from the baseline to the contour line of 174.25 m above IGLD. Distances are in metres.

Profile	Pre-construction							Post-construction							
	Aug 73	Oct 74	Aug 75	Aug 76	June 77	July 78	Max Recession	Aug 78	Oct 78	Dec 78	Apr 79	Aug 79	Nov 79	Max Recession	Net Recession
P1								32.4	31.6	25.4	25.4	25.8	26.9	7.0	5.5
P2* (E-4-21)	65.9	53.3	41.5	34.9	35.5	41.0	31.0	41.3	39.7	36.9	35.1	31.6	33.0	9.7	8.3
P3								39.1	39.1	34.2	35.7	30.2	31.6	8.9	7.5
P4								19.8	19.8	16.4	14.9	10.8	12.6	9.0	7.2

*Figures have been adjusted to compensate for the angle at which the profile line intersects shore.

Table A.2. Volumetric changes (erosion) in beach profiles. Volumes are in cubic metres per metre.

Profile	Pre-construction							Post-construction							
	Aug 73	Oct 74	Aug 75	Aug 76	June 77	July 78	Max Erosion	Aug 78	Oct 78	Dec 78	Apr 79	Aug 79	Nov 79	Max Erosion	Net Erosion
P1								27.3	26.3	21.2	16.5	18.5	19.1	10.8	8.2
P2* (E-4-21)	33.3	31.0	21.8	20.5	18.3	29.1	15.0	31.1	31.3	31.8	28.3	27.8	29.2	3.3	1.9
P3								27.4	27.0	23.2	21.6	23.5	23.6	5.8	3.8
P4								15.8	16.5	12.6	6.5	5.8	6.5	10.0	9.3

*Figures have been adjusted to compensate for the angle at which profile line intersects shore.

APPENDIX 3

Photographic Documentation

Plate 1. Fabricast molded block groyne as it appeared fifteen days after construction (Photographed August 3, 1978)

Plate 2. Aerial photograph of groyne system showing drift accumulation of east sides of groynes and sections of snow fencing (Photographed August 3, 1978)

Plate 3. Aerial photograph shows drift accumulation on west side of groynes, indicating a reversal in littoral current. (Photographed October 20, 1978)

Plate 4. Photograph shows impact of Spring storm in April 1979. High winds and waves completely removed snow fencing from steel support rods. (Photographed April 12, 1979)

Plate 1. FABRICAST MOLDED BLOCK GROYNE AS IT APPEARED FIFTEEN DAYS AFTER CONSTRUCTION (PHOTOGRAPHED AUGUST 3, 1978)

Plate 2. AERIAL PHOTOGRAPH OF GROYNE SYSTEM SHOWING DRIFT ACCUMULATION ON EAST SIDES OF GROYNES AND SECTIONS OF SNOW FENCING (PHOTOGRAPHED AUGUST 3, 1978)

Plate 3. AERIAL PHOTOGRAPH SHOWS DRIFT ACCUMULATION ON WEST SIDE OF GROYNES, INDICATING A REVERSAL IN LITTORAL CURRENT. (PHOTOGRAPHED OCTOBER 20, 1978)

Plate 4. PHOTOGRAPH SHOWS IMPACT OF SPRING STORM IN APRIL 1979. HIGH WINDS AND WAVES COMPLETELY REMOVED SNOW FENCING FROM STEEL SUPPORT RODS. (PHOTOGRAPHED APRIL 12, 1979)