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*The restoration of beaches contaminated by oil
in Chedabucto Bay, Nova Scotia*

E.H. Owens

1971

**Marine Sciences Branch
Department of Energy, Mines and Resources, Ottawa**

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**THE RESTORATION OF BEACHES CONTAMINATED BY OIL
IN CHEDABUCTO BAY, NOVA SCOTIA**

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ABSTRACT

Following the wreck of the "Arrow" in Chedabucto Bay, Nova Scotia, more than 150 miles of shoreline were polluted with Bunker C oil and a beach restoration programme was established which involved 30 miles of coastline. The beaches of this region vary from low-energy marsh environments to complex shingle spit systems, as well as many areas of eroding rock and till deposits. Only a few miles of beach are made up of sand-size material.

The contaminated sand beaches were cleaned relatively easily but although various manual and mechanical methods were implemented, no effective or efficient method of removing oil from shingle beaches was found. Oil on active shingle beaches was often buried up to a depth of 5 feet with clean and contaminated sediments having been thoroughly mixed by wave action. The amount of oil in these sediments was as low as 10 ppm and restoration of this type of shore involved the removal of large volumes of beach material. Where oil remained as a surface layer on the beach, a front-end loader proved to be effective in removing the contaminated layer.

In active beach environments normal wave processes will clean the beaches naturally unless there is so much oil or wave energy is so low, that the movement of sediments is prevented. On these paralysed beaches some attempt should be made to break up the surface so that wave action is able to rework and clean the beach sediments.



CONTENTS

	Page
ABSTRACT	i
LIST OF FIGURES, TABLES AND PHOTOGRAPHS	v
1. INTRODUCTION	1
2. PHYSICAL BACKGROUND	5
2.1 Geology	5
2.2 Surficial Sediments	5
2.3 Tides and Waves	7
3. THE COAST OF CHEDABUCTO BAY	10
3.1 South Shore	10
3.2 West Shore	10
3.3 North Shore	14
3.4 Summary	15
4. SHORELINE STABILITY	16
4.1 Till Cliffs	16
4.2 Beaches	17
5. OIL ON THE SHORE	20
5.1 Distribution	20
5.2 Behaviour of Oil on the Shore	20
5.3 Previous Beach Restoration Projects	28
5.4 Recontamination	31
6. BEACH RESTORATION	32
6.1 Deep Cove, February 1970	32
6.2 Selection of Beaches for Restoration	32
6.3 Manual Restoration	34
6.4 Contract Work	34
6.4.1 Arichat	34
6.4.2 Blackduck Cove	40
6.4.3 Indian Cove	43
6.4.4 Half Island Cove	49
6.4.5 Hadleyville No. 1	50
6.4.6 Other Contract Beaches	56
6.5 Summary	63
6.5.1 Sand Beaches	63
6.5.2 Cobble and Shingle Beaches	65
6.5.3 Recontamination	66
6.5.4 Machinery	66
6.5.5 Beach Profiles	67

	7. DISCUSSION	68
7.1	Selection of Beaches for Restoration	68
7.2	Regional Coastal Studies	69
7.3	Oil on Arctic Beaches	70
7.4	Concluding Remarks	70
	ACKNOWLEDGEMENTS	72
	REFERENCES	73

LIST OF FIGURES, TABLES AND PHOTOGRAPHS

Page

Figures

1.	Chedabucto Bay location diagram	2
2.	Locations within the study area	4
3.	Geology	6
4.	Surficial sediments	6
5.	Topography and bathymetry	8
6.	Profiles across Chedabucto Bay	11
7.	Beach profiles from Hallsands, U.K.	18
8.	Distribution of oil on the coast	21
9.	Beach profiles at Indian Cove	46
10.	Beach profiles at Hadleyville No. 1	54
11.	Beach profiles at Eddy Point	61

Tables

1.	Tidal ranges in Chedabucto Bay	7
2.	Summary of wind data, Canso, Nova Scotia	9

Photographs

1.	Cape Argos	March 27, 1970	12
2.	Moose Bay	June 9, 1970	13
3.	Hadleyville No. 2	July 10, 1970	23
4.	Hadleyville No. 2	July 10, 1970	24
5.	Blackduck Cove	April 25, 1970	25
6.	Hadleyville No. 2	July 10, 1970	26
7.	Jerseyman Island	June 21, 1970	27
8.	Deep Cove	March 1, 1970	33
9.	Slick Pickers	May 29, 1970	35
10.	Arichat	May 2, 1970	37
11.	Blackduck Cove	April 25, 1970	41
12.	Blackduck Cove	May 2, 1970	42
13.	Indian Cove	May 25, 1970	45
14.	Half Island Cove	June 3, 1970	51
15.	Hadleyville No. 1	May 30, 1970	53
16.	Moose Bay	May 21, 1970	57
17.	Eddy Point	June 12, 1970	60
18.	Walkerville	June 27, 1970	64

1. INTRODUCTION

Following the wreck of the tanker "Arrow" on Cerberus Rock, February 4, 1970, the oil spill of Bunker C affected more than 150 miles of shoreline in Chedaducto Bay, which has a coast of 380 miles from Point Michaud in the north-east to Cape Canso in the south-east (Figures 1 and 2). The Project Oil Task Force initiated a beach restoration operation and a total of 24 miles of coast was initially selected for the work programme which was carried out by the Department of Public Works during the period April to October, 1970. In April, a coastal geomorphologist was assigned to aid the restoration project and this paper reports the results of the observations and investigations of that part of the programme.

This operation was the first attempt to restore non-sand beaches without the use of dispersants. On certain beaches the work was followed very closely in order to gain knowledge which would be of value to future projects of this nature. These instances are reported in detail along with a broader discussion of the more general aspects of the operation. A full account of the entire beach restoration programme which deals with each area where work was undertaken and the techniques employed has been prepared by the Department of Public Works site engineer (MacKay, 1970). This report is complimentary to that of MacKay but is concerned primarily with the geological problems rather than the engineering, economic, or social factors, although these are discussed in the final section. Most of the investigations were of a qualitative nature, though data collection was undertaken wherever possible to supplement the subjective observations.

The use of earth-moving equipment for beach restoration was not recommended in this area and was found to be only partially adequate in removing all contaminated material. Sand beaches were cleaned by manual and mechanical methods with success but no satisfactory mechanical methods were available for the restoration of cobble and shingle beaches. This lack of effectiveness can be attributed to the fact that it was not possible to remove all the contaminated material from the polluted cobble beaches and to the movement of oil alongshore and offshore which led to the recontamination of several of the restored beaches.

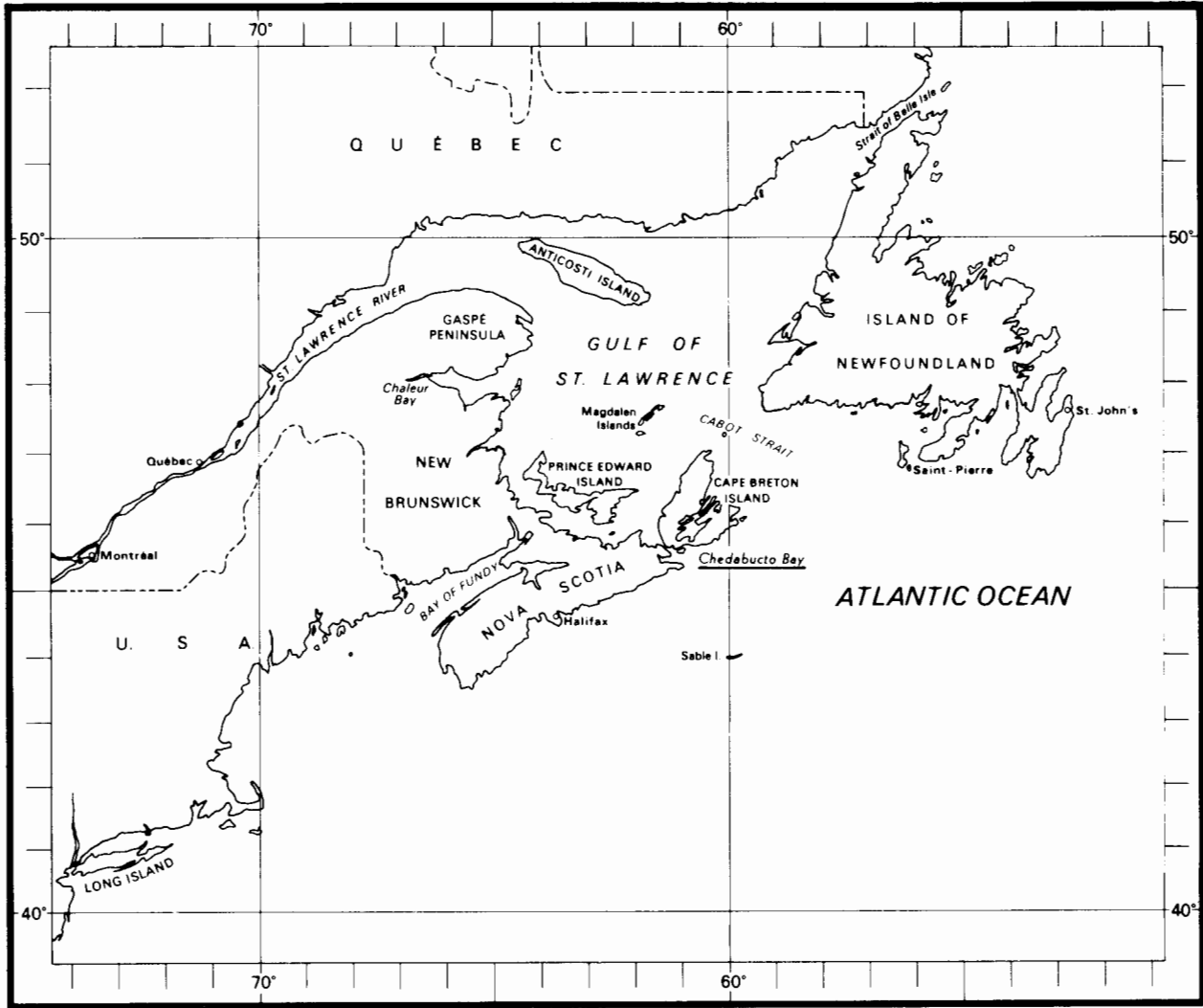


Figure 1. Chedabucto Bay location diagram.

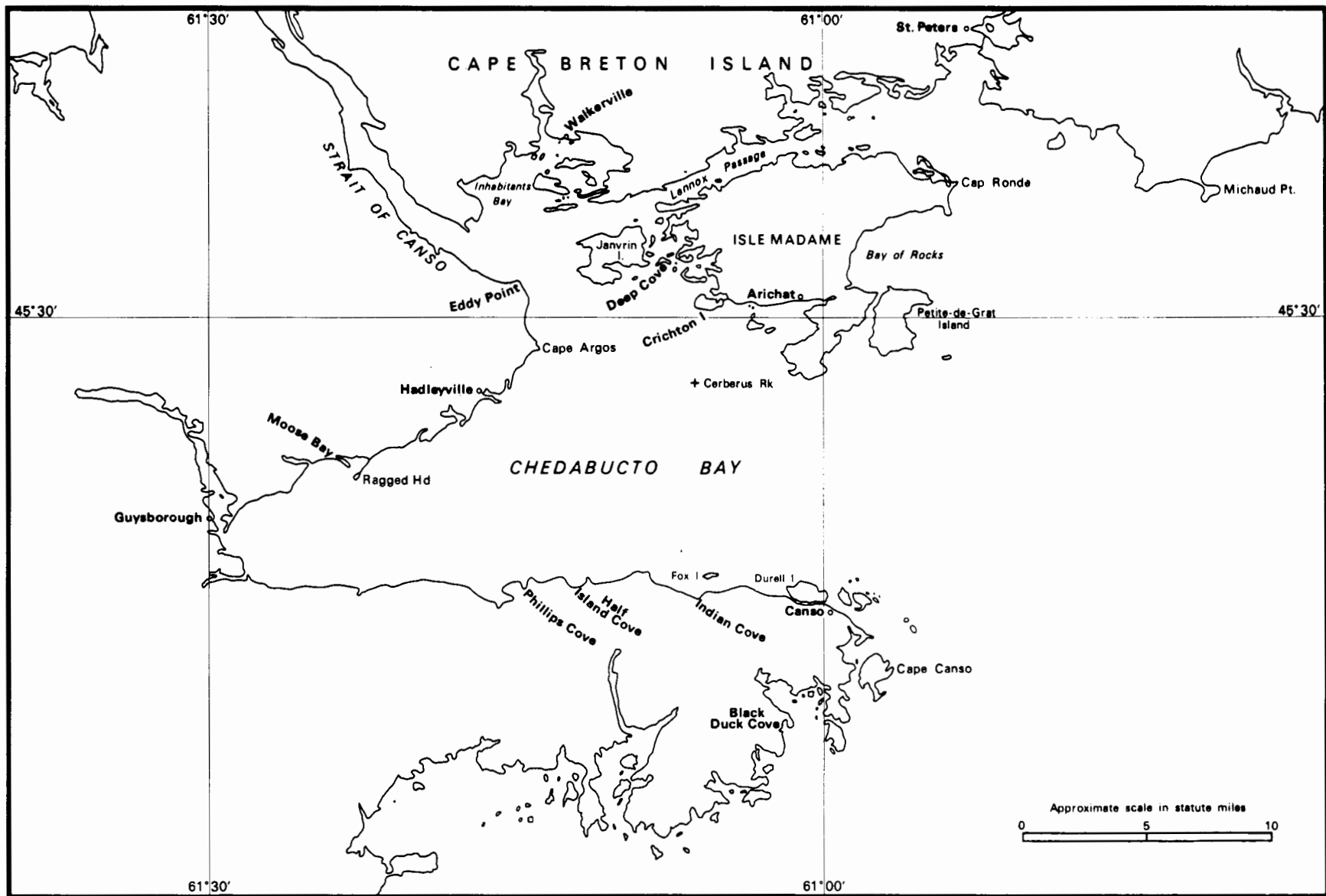
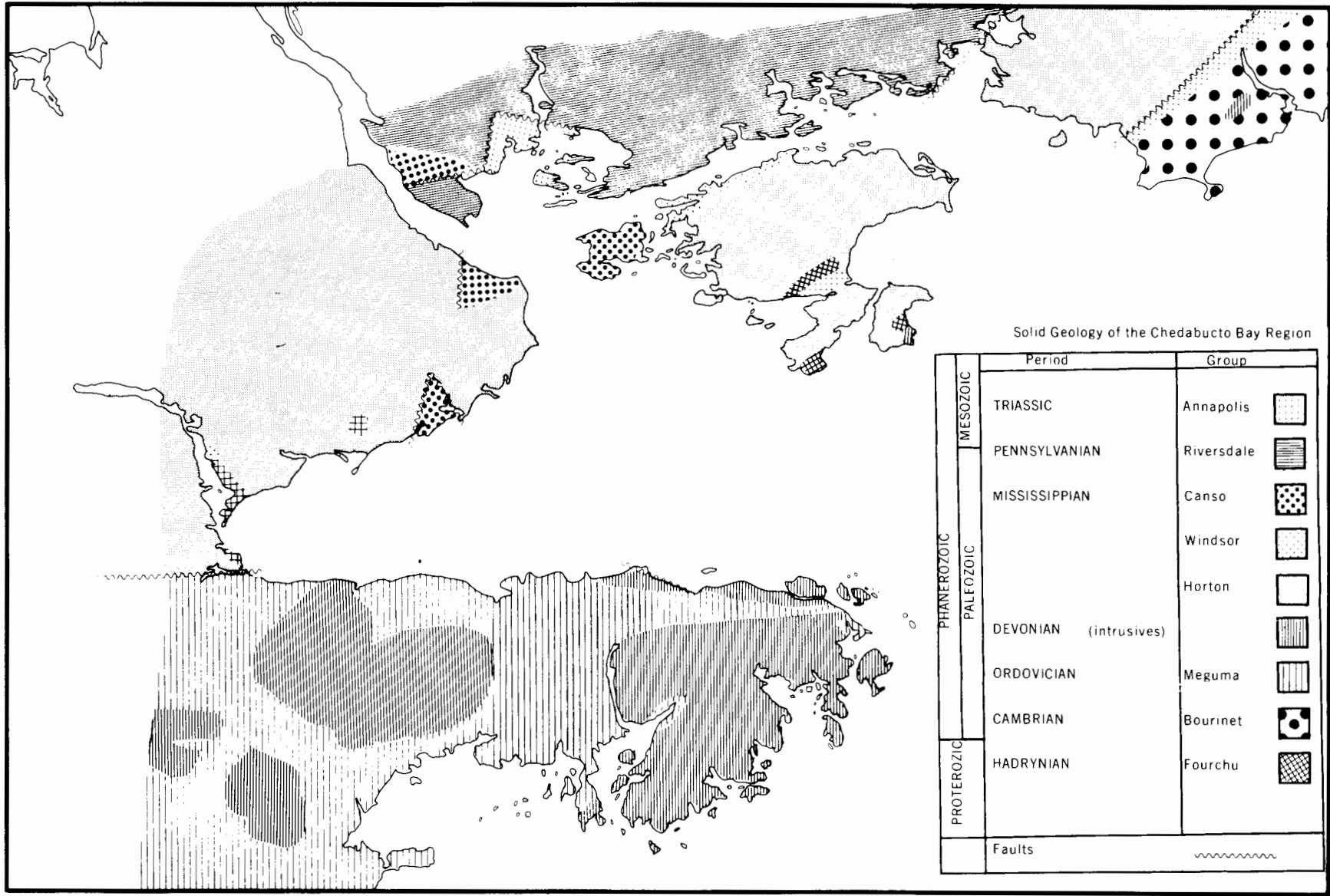


Figure 2. Locations within the study area.



2. PHYSICAL BACKGROUND

2.1 Geology

The major structural feature of this region is the Chedabucto fault or fault complex of the Acadian orogeny which separates the resistant metamorphosed rocks of the Meguma group in the south from the relatively less resistant late Paleozoic sediments which lie to the north (Figure 3). The fault zone defines the south shore of the Bay and can be traced eastwards onto the Nova Scotian Shelf (King and Maclean, 1970).

South of the fault zone the stable Meguma platform is made up of tightly folded Ordovician quartzites and slates which have been intruded by Devonian granites (Webb, 1969). This block has been eroded to give an uplifted peneplain which slopes gently southwards and the rise of sea level has led to an indented shoreline which is in marked contrast to the long straight coast of the fault zone.

The Carboniferous beds which characterize the area north of the fault consist in part of a small basin within the uplifted basement and are relatively less resistant conglomerates, sandstones, shales, and limestones which have been folded and metamorphosed. Erosion along the fold axes provides a clear example of the general north-east/south-west trend in the Lennox Passage area. The erosion of these late Paleozoic rocks has led to the development of an undulating lowland area which has been drowned to produce an irregular coastline.

2.2 Surficial Sediments

The areas of bedrock exposure (Figure 4, unit 6) are confined largely to the more resistant uplands south of the fault zone. Where sediments are present in this area they are often very stoney and not deep. The remaining areas west of the Strait of Canso have a cover of locally derived glacial till (units 1, 2 and 3) with a few local deposits of outwash material (unit 4) or post-glacial alluvial sediments (unit 5). These latter units account for less than 3 percent of the land area (Hilchey et. al., 1964).

East of the Strait of Canso the till deposits are derived from the Carboniferous rocks and differentiation on a general basis produces a simple textural pattern related to the bedrock parent material.

The till deposits, which constitute the major unit of surface sediments in this region, were laid down directly by the ice as an unstratified and unconsolidated mixture of clay, silt, sand, gravel and boulders.

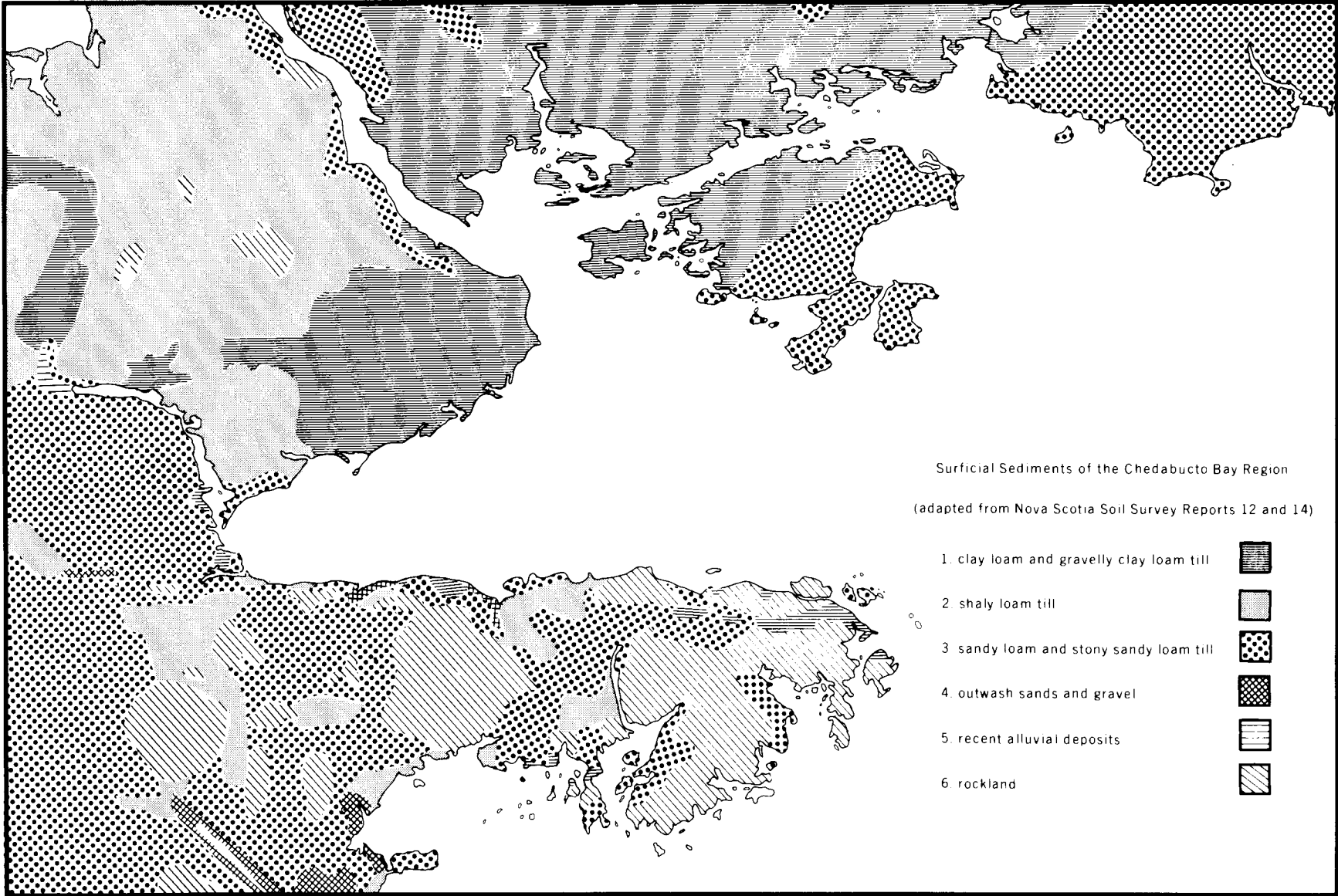


Figure 4. Surficial sediments.

The earliest ice advances which have been traced (Grant, 1971) indicate a west to east movement across Isle Madame. This was superceded by a flow to the north and north-west from a centre on the Scotian Shelf while the final phase of glaciation is related to the recession of an ice cover which had moved south over the area and which disturbed much of the existing till deposits.

2.3 Tides and Waves

The tides of this area are semi-diurnal, with mean and maximum ranges in the order of 4.3 and 6.6 feet respectively (Table 1). The tidal range is an important characteristic of the littoral zone as it affects the width of beach over which wave action can take place.

Table 1 Tidal ranges in Chedabucto Bay (Anon., 1970).

Location	Mean Tidal Range (ft)	Large Tidal Range (ft)
Canso	4.2	6.6
Guysborough	4.5	6.4
Port Hawkesbury	4.4	6.9
Arichat	4.2	6.3
Petit de Grat	4.4	6.6
St. Peters Bay	4.3	6.1

The east coast of Canada is a storm wave environment (Davies, 1964) where the most important waves in the littoral zone are those generated by local storms and a brief review of wind data and the occurrence of storms provides an indication of the seasonal variations in wave intensity. This part of Nova Scotia is exposed to the full force of waves from the east and south and those coasts which are directly open to these waves have high energy littoral environments. The relatively shallow areas in the north and west of the Bay (Figure 5) refract the incoming swell waves so that beach orientation is often a reflection of the offshore topography.

The summary of wind data for the meteorological station at Canso (Table 2) shows that the highest wind speeds are mainly from the north-west and occur in the period December to February. The generalized data indicate that the extent of the winter

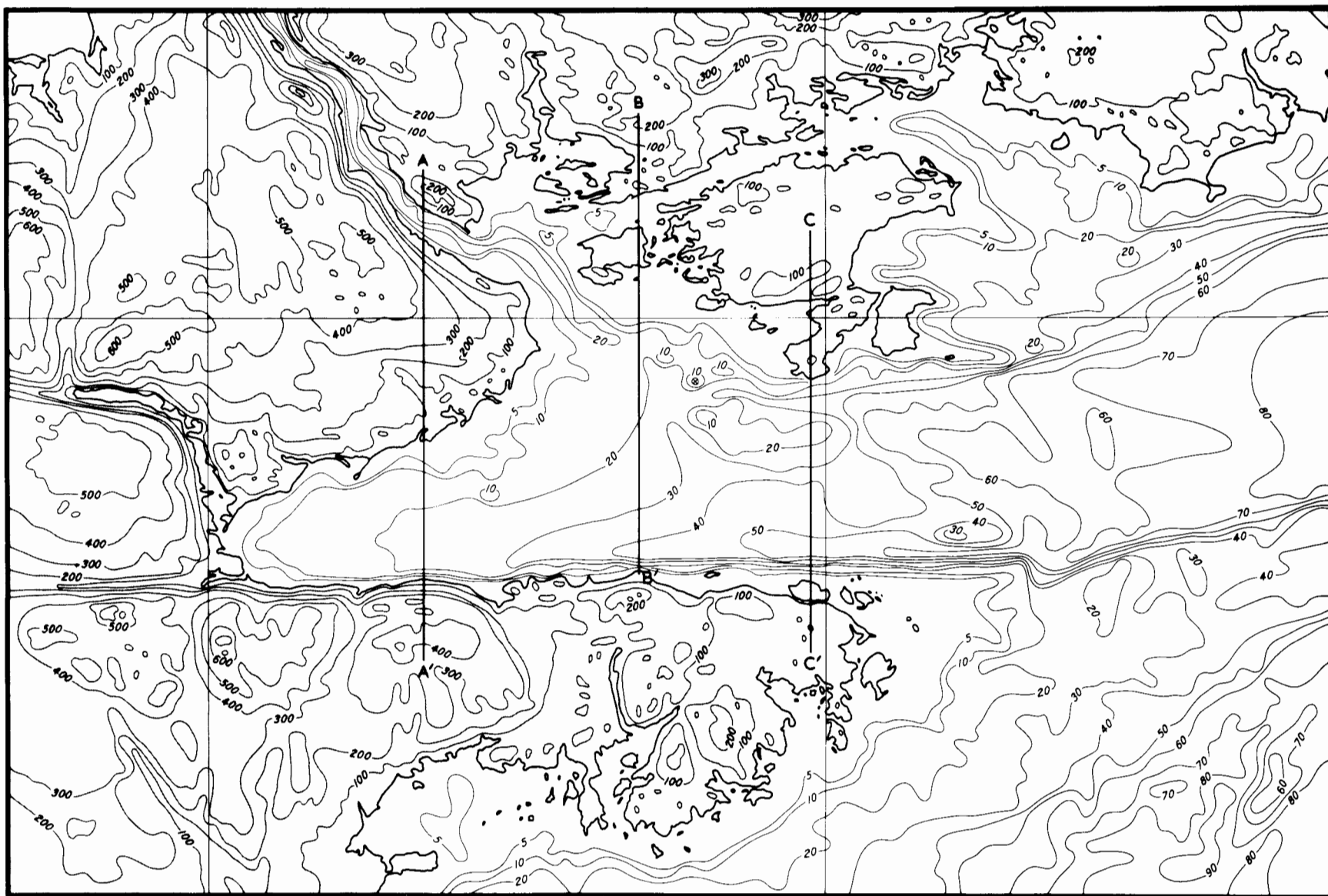


Figure 5. Topography and bathymetry. Heights in feet: depths in fathoms.

season, in terms of the wave climate and beach form, is probably from November to April, while the period of accretion and summer profiles is May to October when winds are from the south-west.

This agrees in general with Neu (1971) who states that from December to May "most of the wave energy occurs in the 7 to 12 seconds (wave) period band propagated from SSW to WNW". As part of the Project Oil investigation, Neu recorded wave data in Chedabucto Bay for 33 days in March and April, 1970. The results indicated that waves with a period less than 9 seconds were generated locally or over the adjacent shelf areas but that ocean waves with periods longer than 9 seconds prevailed 80 percent of the time.

Table 2 Summary of the wind data, 1964 to 1970, Canso, Nova Scotia (Anon., not dated)

	Average of the Monthly Mean Speeds (mph)	Prevailing Direction	Average of the Monthly Maximum Recorded Speed	Dominant Direction
Jan.	14.3	NW	42	NW/NW
Feb.	14.8	NW	40	NW
Mar.	13.8	NW	35	NE
Apr.	13.4	NW	33	NW/SW
May	12.7	SW	33	SW
June	11.6	SW	29	SW
July	10.6	SW	27	SW
Aug.	11.9	SW	29	SW
Sept.	11.4	SW	30	SW
Oct.	13.0	SW	34	SE
Nov.	13.7	NW/SW	36	NE
Dec.	14.8	NW	38	SE

3. THE COAST OF CHEDABUCTO BAY

The basic coastal trends are structurally controlled while the actual detail of the shoreline results from the erosion and submergence of the fault block. Grant (1970) estimated that submergence is taking place at a rate of about 0.5 feet per century through a combination of the eustatic rise in sea level and crustal subsidence. This has led to the drowning of lowlying coastal areas to produce a complex and irregular shoreline for much of the region (Owens, 1971a).

3.1 South Shore

The south shore of Chedabucto Bay between Canso and Guysborough is a straight, steep coast with a narrow offshore shelf (Figures 5 and 6). This is a resistant erosional shoreline composed largely of rock platforms and low cliffs with pocket beaches of shingle and coarse sand. The amounts of sediment in the littoral zone increase noticeably from east to west as indicated by the presence of spits and bars in the Salmon River - Guysborough area. South and west of Canso the irregular coast has resulted from the drowning of the southward sloping peneplain. Although this area was not examined in detail it was apparent that rock platforms with little beach material dominate the character of the shore. Occasional pocket beaches and spits interrupt the pattern but otherwise this area is an excellent example of a submerged resistant lowland. More sediment is available for reworking in the littoral zone of this region than along the south shore of the Bay, but in both cases there is a general scarcity of beach material.

3.2 West Shore

Between Guysborough and the Strait of Canso the relatively uniform south-east slope of the subaerial and submarine topography (Figure 5) gives rise to a generally straight shoreline. Few bedrock exposures occur and the coast is made up of actively eroding till cliffs (Photograph 1) alternating with wide accretional shingle beaches (Photograph 2). In an attempt to develop an equilibrium shoreline, beaches have built up across river exits and embayments while erosion is active where there are headlands and higher relief along the shore.

The till cliffs, which have a maximum height of 60 feet, are easily eroded by subaerial and marine processes but provide the beach zone with relatively little sediment. The till is composed largely of clay and silt sized material which is removed from the base of the cliff as a suspended sediment, leaving a few cobbles and boulders in the littoral zone. The beaches of the area are generally long and wide with

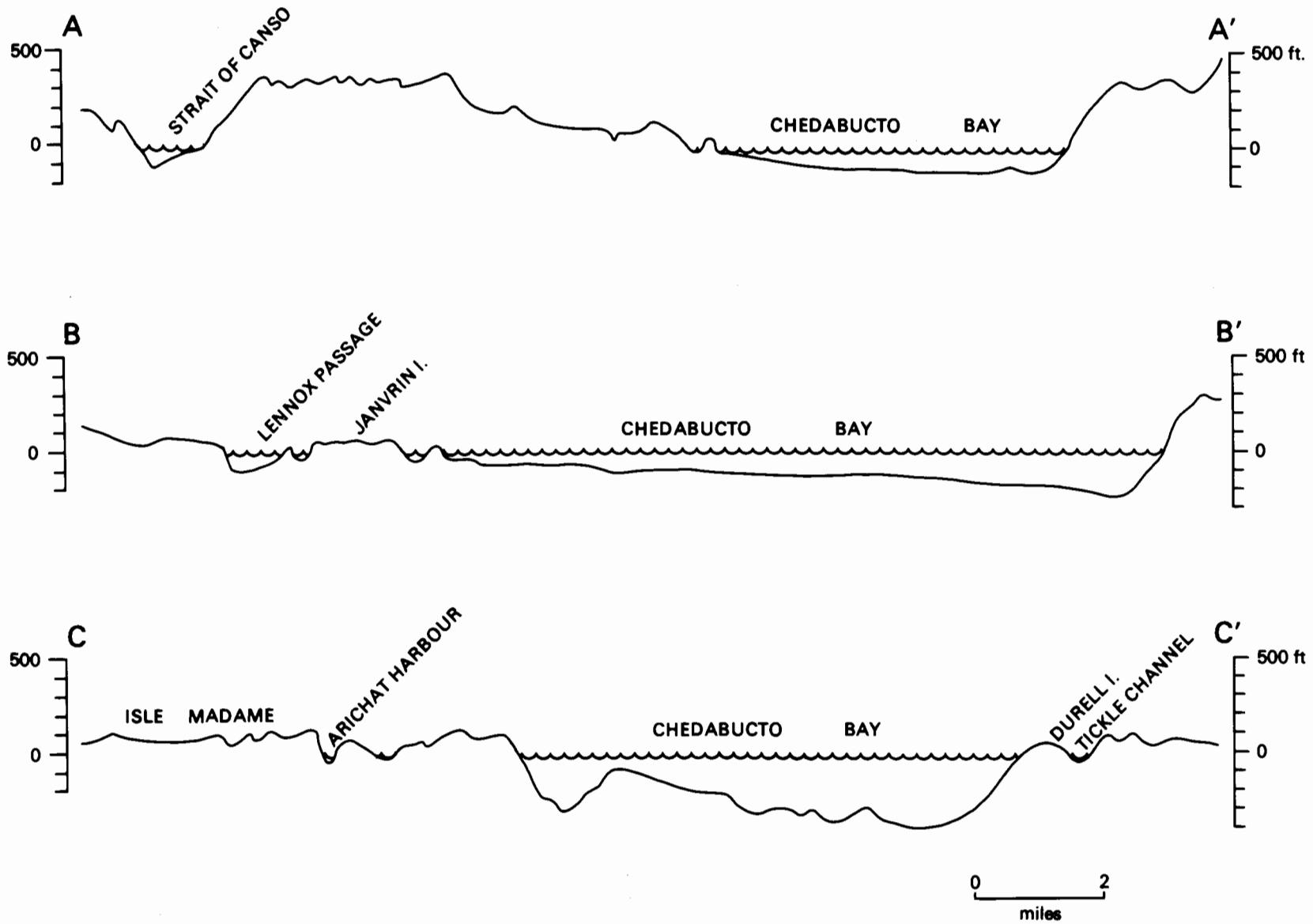


Figure 6. Profiles across Chedabucto Bay.



Photograph 1

CAPE ARGOS

March 27, 1970

Air view of a partially eroded drumlin and an actively eroding till cliff with a narrow but heavily polluted beach at its base. The beach material here is almost entirely derived from the erosion of the cliff.



Photograph 2

MOOSE BAY

June 9, 1970

Air view of the main section of the beach at mid tide before restoration. The main storm ridge is backed by a vegetated swale which in turn is replaced by a higher vegetation sequence. A squad of "slick pickers" is removing contaminated material manually (see also photograph 18), these are located by an arrow. No sections of this beach were paralyzed; although originally heavily polluted, most of the oil was buried or removed by normal wave action.

well-developed storm ridges and would appear to owe their growth to the landward movement of sediments from the offshore zone with the rise of sea level. It is doubtful that rivers and erosion of the till cliffs contribute significant amounts of coarse sediment under present conditions. Subsequent reworking and longshore sediment transport has produced some complex spit systems at several places along this coast. Where the till cliffs have narrow beaches at their base, waves attack the cliff directly and remove subaerially eroded material, but if the beaches are wide and there is a large sediment build-up, erosion is unlikely.

3.3 North Shore

East of the Strait of Canso, as far as Point Michaud, the drowning of an undulating lowland has given rise to a complex series of islands and inlets in an area of little local relief. Much of the coast is protected from direct wave action and beaches have not developed in these sheltered zones because of the low energy conditions.

The River Inhabitants is a particularly good example of a drowned valley. It flows into Inhabitants Bay which was the original flood-plain but is now a shallow bay with poorly developed beaches in a sheltered wave environment. South of Inhabitants Bay a series of well-developed bars and spits results from the greater availability of sediments and the higher energy level of the littoral zone, as this area is exposed to wave action from the south and east. The great variety of coastal types in this region results from the irregular nature of the drowned lowland area and the pattern of islands, bays and inlets. The beaches and spits of south Janvrin Island and Jerseyman Island are a direct contrast to the adjacent but sheltered areas of Port Royal or Arichat Harbour which do not receive the full force of waves from the Atlantic.

For most of the sheltered areas the coast is typified by a narrow beach, less than 100 feet wide, of coarse sediments resting on a till platform. This is usually backed by natural vegetation or a low till cliff which may not be subject to marine processes under normal conditions. There is rarely any evidence of storm ridge development, though bars and spits of limited size occur in most areas.

On the exposed shores of south Isle Madame and Petit de Grat the resistant Proterozoic and Devonian outcrops produce a rocky coast devoid of sediments which is very similar to the south shore of the Bay. To the north, in the Bay of Rocks, this gives way to a series of wide sand and cobble beaches oriented towards the refracted incoming waves from the east. Along the north shore, to the east of Lennox Passage, a large number of complex spits, bars and tombolos result from the

reworking of sediments in an energetic wave environment. As with the West Shore there is little indication that terrestrial sources are a major contributor of coarse material so that again the offshore zone appears to have been the major source for littoral sediments.

3.4 Summary

Apart from a few exceptions, in the north-east part of the Bay the beaches consist mainly of cobbles and boulders which are thrown up by wave action onto the higher parts of the beach to form a storm ridge. When these investigations commenced in April, steep winter profiles characterized most areas but by July these had been replaced by the more gently sloping accretional summer profiles, and these were still evident on all beaches in November. With this change in profiles came a marked increase in the amount of coarse sand and gravel in the intertidal zone.

Sand beaches are restricted to the Bay of Rocks, Point Michaud, and Blackduck Cove area, all at the eastern end of the Bay. These are wide, long beaches with shallow offshore zones and have well-established dune vegetation in the backshore areas.

The shoreline of Chedabucto Bay may be described as an erosional coast of rock and till exposures with pocket beaches. The growth of large accretional features is evident along the exposed north and west coasts but these beaches are supplied with little coarse material under present conditions. The sheltered coasts along the north shore have a limited sediment supply and are in a low energy wave environment with evident erosion in many areas as the region undergoes submergence.

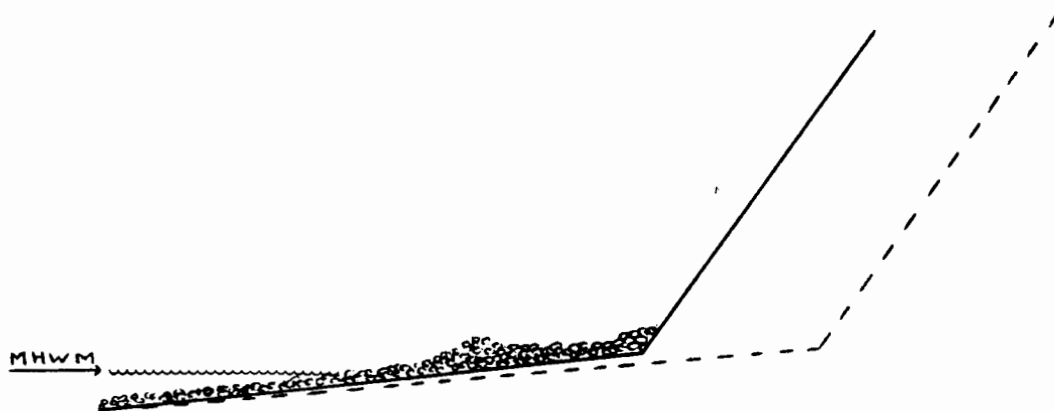
4. SHORELINE STABILITY

"A beach is nothing more or less than a protective apron of rock waste fronting the land. Where beaches are wide and in equilibrium, erosion is unlikely. Where they are narrow and starved of material, wave attack is directed against the land with little to absorb its full force" (Kidson, 1966).

Coarse beach sediments, larger than 3 inches, were moved landward from the offshore zone with the rise in sea level and any sediment loss by erosion or excavation must be equated with the capability of natural replacement. Under present conditions, material of this size does not move into the littoral zone from offshore, thus the supply of coarse material is very limited and large-scale sediment losses cannot be replaced naturally.

4.1 Till Cliffs

At the base of till cliffs which are in active retreat there is usually a narrow cobble and boulder beach (Photograph 1). This material is derived largely from the erosion of the free face, which is a limited supply source as most of the till is clay and silt sized material. The retreat of the cliff leads to the development of a small platform at the cliff base on which rests the thin cover of beach material. In the sketch below it can be seen that on removal of the beach mantle the till base is exposed and becomes subject to erosion by marine agents. The protection that is afforded by the thin beach mantle is not great but with the loss of this mantle the level of the till platform is lowered by marine erosion and this in turn leads to a temporary acceleration of cliff retreat until an equilibrium condition is achieved by erosion of the free face.



Those till cliffs which have wide beaches at their base are not normally subject to direct wave action and erosion is a result of subaerial agencies, although the talus may be removed by littoral processes. These cliffs would be unaffected by beach loss unless large volumes of sediments are excavated to the extent that marine processes could begin to erode the base of the cliffs.

In sheltered areas, such as Inhabitants Bay, wave action is limited so that often, marine processes are not active in cliff erosion except under storm conditions. In these instances, subaerial rather than marine erosion may be consistently active though the infrequent storm would produce more dramatic results in the long term. The removal of the beach sediments which front these cliffs will have the same effect as on more exposed shores.

4.2 Beaches

Beaches are constantly changing in response to a variety of processes which may alter in intensity with the season, tidal cycle, or weather conditions. This is a complex environment which is still only partially understood.

The beaches of the region are made up largely of cobbles and pebbles and these sediments are being eroded, reworked and transported as the littoral zone strives towards the equilibrium which the processes demand. Although sand and fine sediments are fed into the coastal zone, particularly during the summer months, these are not a major contributor to the growth of beaches and large constructional features, except for areas at the east end of the Bay.

The loss of large volumes of cobble and larger size material would be harmful to the shore environment in this region. An instance where this has occurred in a similar situation is reported by Robinson (1961) at Hallsands, on the south coast of England. As with most of the British coast, this beach owes its origin to the reworking of deposits during the post-glacial rise in sea level and is not now fed with coarse sediments from the offshore zone. At this locality there is no significant sediment supply from rivers or coastal erosion so that the beaches consist mainly of "fossil" material. Almost 500,000 cubic yards of shingle was removed in the period 1897 to 1902 along a half mile length of shore. This led to a recession of up to 20 feet between 1907 and 1957 in those sections of schist cliffs which had little protection at their base. The actual beach area to the north of the cliffs was lowered by as much as 12 feet and only the most southerly sections appear to have recovered in any way (Figure 7, profile 6).

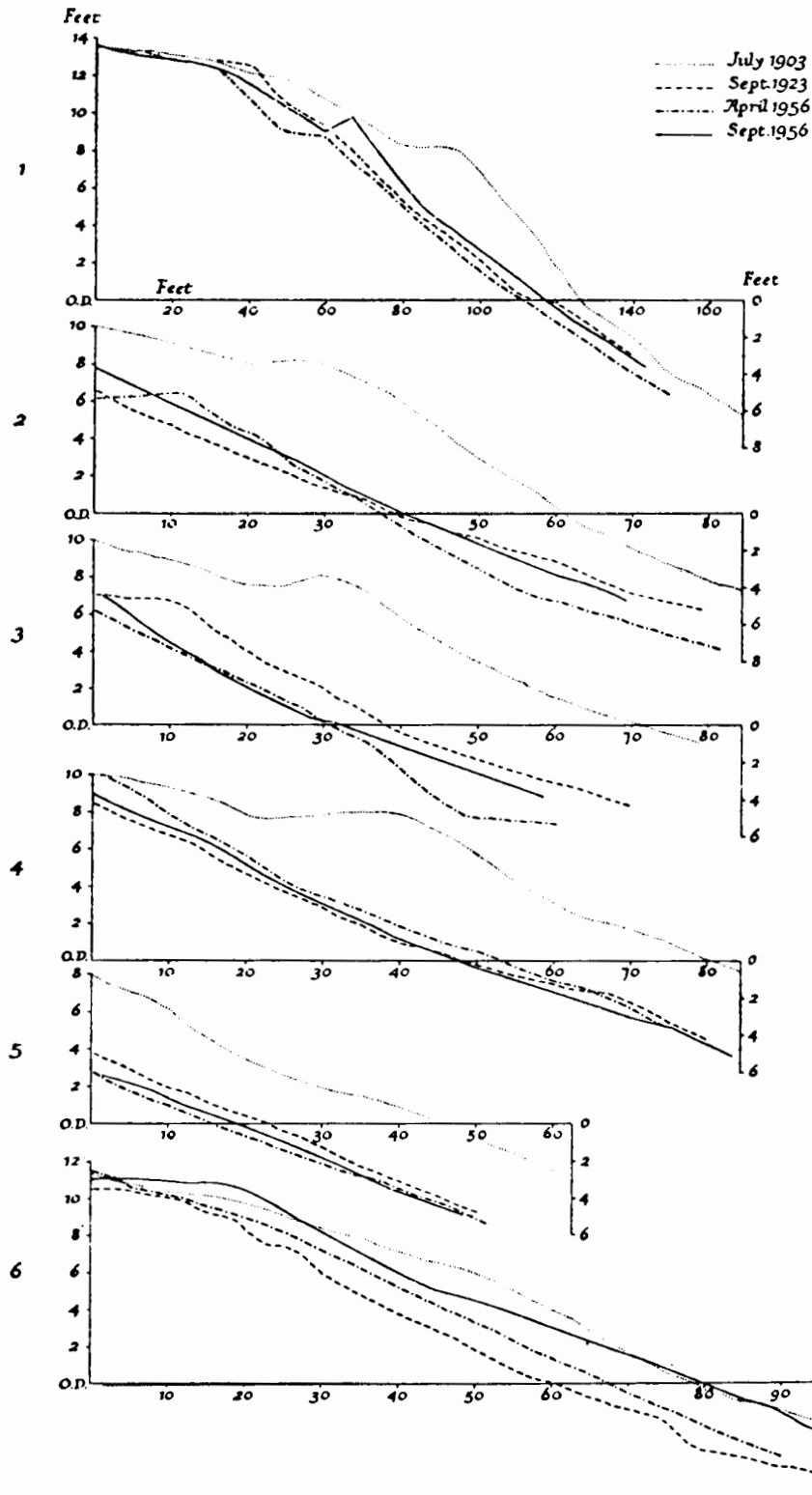


Figure 7. Beach Profiles from Hallsands, U.K. (Robinson, 1961)
 The changes in beach profiles along Sections 1-6
 between 1903 and 1956. Vertical exaggeration
 for Section 1 is 1:5 and for remainder 1:2.5.

Although material removed from a beach may be replaced by longshore drift, providing the loss is not too great, there would be a net decrease for the shore as a whole in a region such as Chedabucto Bay, as this material cannot be replaced rapidly. On beaches which have a marked movement of sediment in one direction, should material be taken from the up-drift end, there is a danger that the beach may not fully recover as this is a section which would not normally receive much "new" material. In the same way, removal of sediments from a spit near the point of attachment may be harmful as most of the accumulation is concentrated at the distal end. This would apply to any constructional feature such as a bar, tombolo, or foreland which is formed by the longshore movement of material.

While it is important to consider the loss of material in terms of the plan form of the beach, more critical perhaps is the effect on the beach in profile. The storm ridge, or the sand berm, is built above the normal high water mark and material lost from this zone will only be replaced during the infrequent occasions when wave processes are active on these sections of the profile, providing that material is available for replacement.

5. OIL ON THE SHORE

5.1 Distribution

Those coastal areas which were contaminated by Bunker C from the "Arrow" are outlined in Figure 8. This diagram is only accurate for the Bay itself as many of the areas in the north-east and to the south and west of Cape Canso were only surveyed at the reconnaissance level and only those areas where oil was actually observed are indicated. The shore affected by oil was more extensive than is shown and it should be noted that contamination extended as far as St. Esprit, on the north shore some 5 miles east of Point Michaud, and Sable Island, which lies over 100 miles south-east of the Bay (Figure 1). The major spills took place in February and March but oil leaked from the wreck throughout the spring and summer.

The distribution diagram does not take into account the severity of the contamination or the frequency of reoiling. The shores of Janvrin Island, Crichton Island and Jerseyman Island and the south shores of Isle Madame and Petit de Grat were heavily polluted in February and subject to frequent reoiling in the following months. The area of Inhabitants Bay was not contaminated by the end of February but was subsequently heavily oiled. To the north and east of Petit de Grat contamination was relatively light and not continuous. The shore of the east section of Lennox Passage was not polluted due to the construction of a dam in the middle section.

Along the west coast of the Bay, from Cape Argos to Guysborough, most of the shore was contaminated but the amounts of oil on the beach decreased towards the south-west. Similarly on the south shore, the area around Canso was severely polluted while to the west of Half Island Cove the degree of oiling decreased and some sections were only lightly oiled.

South of Cape Canso several of the inlets and embayments were badly polluted though a full survey of this area was not carried out. The distribution diagram does not indicate the true extent of oil on this section of coast.

5.2 Behaviour of Oil on the Shore

Field observations by Asthana and Marlowe (1970) and by Drapeau (1970) during February and March were carried out, in part, to provide an understanding of the nature and behaviour of oil on the coast. Their conclusions are summarized below.

Floating oil striking the shoreline behaves differently on different types of shore material.



Figure 8. Distribution of oil on the coast. x - Cerberus Rock

- a) Bedrock is coated by a uniform layer of oil in the intertidal zone. The oil is not removed during tidal submergence but when exposed, flows into crevices and hollows.
- b) Boulders and boulder beaches are affected in a similar way.
- c) On sand and gravel beaches the oil remained on the surface and behaved as discrete sedimentary particles with unique hydrodynamic characteristics. The oil particles tended to float free and become concentrated along the high water line. Oil did not permeate sand but acquired a surface coating of sand particles (Photograph 3) while on gravel it was observed to have permeated as much as 18 inches. Where oil had been buried and later exposed by the normal accretion and erosion processes, the oil layers were less readily eroded and formed ephemeral ledges (Photograph 4) which were seen to crumble under the influence of gravity and sunlight.

Drapeau also noted that within one month of contamination, gravel bars directly exposed to wave processes cleaned themselves naturally and effectively, while in protected areas the beaches remained polluted. This is particularly evident in Photograph 5 of Blackduck Cove. The lagoon remained heavily polluted throughout the summer while the exposed side of the spit was "cleaned" by the end of March. In many of the exposed areas the intertidal zone was rapidly cleaned leaving a concentration of oil where it had been deposited above the high water mark beyond normal wave action (Photographs 6 and 7). Although oil polluted much of the upper part of the intertidal zone, wave action is continuously active in this zone and any oil laid down above mean high water mark would remain undisturbed by normal processes. During periods of storm waves or spring tides the remainder of the beach would be subject to wave action so that eventually all contaminated areas would be cleaned naturally. On cobble and shingle beaches, oiled material originally in the intertidal zone was often moved up the beach by storm or swell waves and deposited as part of the storm ridge. This may have occurred on several occasions so that with subsequent exposure the contaminated material would appear as layers interbedded with clean sediments (Photograph 4).

Exposed beaches are generally capable of self-cleaning (Johnston, 1970) but there is a threshold beyond which beaches become "paralyzed" (Drapeau, 1970). This situation may arise as a result of either heavy contamination or insufficient wave action. The beaches of Arichat Harbour and Inhabitants Bay, for



Photograph 3

HADLEYVILLE No. 2

July 10, 1970

The east end of the beach was made up of coarse sand and the oil remained as large pans which had a surface layer of fines or was buried to a depth of several feet. No oil was visible in the intertidal zone.



Photograph 4

HADLEYVILLE No. 2

July 10, 1970

On the west end of this beach at low tide. The layers of oil, when exposed by wave action, are more resistant to erosion but quickly collapse through sunlight and gravity.



Photograph 5

BLACKDUCK COVE

April 25, 1970

Air view of spit, lagoon, and cove from the south at high tide. The lagoon is virtually cut off from the sea at low tide. This area was heavily polluted though the exposed section of the spit has been virtually cleaned by wave action whilst the beach in the lee of the spit remains paralyzed.



Photograph 6

HADLEYVILLE No. 2

July 10, 1970

The central section of the beach was characterized by a thick, continuous layer of oil ten to fifteen feet wide, above the high water line. This upper part of the beach, rarely affected by waves, remained paralyzed while the intertidal zone was cleaned by wave processes.



Photograph 7 JERSEYMAN ISLAND June 21, 1970

A badly contaminated cobble beach near the high water mark. Although this beach has been partially immobilized, wave action has begun to clean the area below the high water line by abrasion and burial. With storm waves the remainder of the beach will be combed down and the cleaning process will be extended to include all the contaminated material.

example, were paralyzed by a combination of both these factors while the heavily polluted but exposed beaches of Crichton and Jerseyman Islands remained mobile.

Four samples were collected for analysis of oil content by volume to determine the oil/sediment ratio on different beaches. Two were taken from the exposed, mobile beach at Moose Bay near the high water mark. The first was at a site which appeared clean and the second from material which appeared badly oiled. The results indicated 9 and 90 parts per million of oil, respectively. Two more samples were taken from the intertidal zone of a "paralyzed" beach at Arichat. These provided values of 4 and 5 per cent of oil. All the samples were from cobble beaches with a material size range of 1 to 6 inches.

5.3 Previous Beach Restoration Projects

The only restoration projects before the Chedabucto Bay operation resulted from the "Torrey Canyon" and "Santa Barbara" spills. Neither of these are directly comparable as the coasts of south-west England were cleaned with dispersents while the wide, firm, sandy California beaches were restored with relative ease.

The work of the Ministry of Technology, Warren Spring Laboratory, dates from 1960 and their involvement in the "Torrey Canyon" clean-up provided a practical demonstration of the various restoration techniques which are reported by Wardley Smith (1968a, 1968b, 1969, 1970). The fundamental conclusion from their experience is that no one method is adequate because of the variety of coasts and the amounts and types of oil involved. Despite this, it was stressed that the best defence is preparedness so that if oil does reach a shore the correct action may be taken immediately.

The various methods of restoration which were discussed are summarized below.

- a) Burning. In most instances this is not satisfactory because of inefficiency and cost. Most oils, particularly Bunker C, do not burn readily and require a great deal of assistance; even then the oil burns very slowly. Heating often makes the oil more mobile so that it penetrates deeper into the beach and contaminates more material.
- b) Absorbtion. The use of sawdust, peat moss, or similar material was found to be very useful but costly in terms of the labour required to spread and retrieve the absorbant.
- c) Surface Coating. A crust could be formed on the surface of the oil with the application of large

quantities of powder or fine particles. This stabilized the surface but was not satisfactory for preventing the oil from moving and did not contribute to the removal of the oil.

- d) Mechanical Removal. This method was found to be satisfactory for the removal of surface oil but not all the contaminated material was removed by the machinery. In combination with dispersants this method proved effective on cobble beaches. Machinery was developed to pick up contaminated material because of the unsuitability of available excavating or earth moving equipment, but this was elaborate, sometimes expensive, and not always successful.
- e) Manual Removal. Effective on most beaches but expensive because of labour costs. Techniques include raking, shovelling and spreading absorbant materials.
- f) Dispersants. Very effective in removing the oil, especially on cobble beaches, but toxic to marine life.

Each of these methods was considered in terms of applicability to different shoreline types.

- a) Marshes. Manual removal would be best but burning may be effective during the non-growing season. However, unless the oil is thick the marsh is best left so that it could recover naturally.
- b) Mud Flats. Although these areas would be left alone where possible, if restoration is necessary mechanical scraping or dispersants could be used for thick deposits.
- c) Sand. Again it would be best to leave cleaning to natural processes if possible but if action is necessary, manual or mechanical raking would be effective. If the beach is heavily polluted, material could be pushed into the sea at low tide and the beach then sprayed with emulsifier. The sand would be reworked, cleaned, and returned to the beach without any sediment loss to the littoral zone.
- d) Shingle. Apart from natural processes only dispersants could rid the beach of all contaminated material. No machinery was available which could clean the beach without the aid of dispersants.

- e) Rock. These areas are best left to the action of waves and weather but burning or dispersants could be applied if necessary.

Following the Santa Barbara spill on the California coast the United States Federal Water Pollution Control Administration (FWPCA) initiated an evaluation of earth moving equipment in oil contaminated beach restoration operations (FWPCA, 1970). This project was carried out on wide, firm, flat sand beaches which had oil on the surface or in the surface layers. The results of this technique analysis are given below.

- a) Grader/Scraper. This was found to be the best of the techniques evaluated. Contaminated sediments were pushed into wind-rows by the grader and then lifted by the scraper. This technique removed the least uncontaminated material but spillage from the scraper required a following pick-up crew. The grader became stuck on coarse sand unless expensive flotation tyres were in use and accuracy decreased if traction was low.
- b) Scraper. Used on its own the scraper had a high spillage and like the grader, it required a flat beach and became stuck easily.
- c) Grader/Front-end Loader. The loader was used to remove the wind-rows. Its performance in general is outlined below.
- d) Front-end Loader. This machine was the least efficient of those tested as it removed too much uncontaminated material and had a high spillage. The same deficiencies apply to bulldozers and tracked loaders as bulldozers were found to "grind the oil several feet into the sand".
- e) Ramp-Conveyor System. This method was developed to remove the material after the grader formed the wind-rows and was found to be valuable for very large operations.

Neither of these evaluations are directly applicable to the problems which were faced in Chedabucto Bay, as no wide, sand beaches required mechanical restoration and dispersants were ruled out of the programme. The conclusions from the work in Britain indicated that natural cleaning is best but even if restoration is necessary, shingle beaches were not cleaned properly by machines alone. The evaluation project by the FWPCA showed that the grader and bulldozer were the least efficient of the earth moving equipment tested. The performance was particularly bad if the vehicle had tracks, as clean and contaminated sediments were mixed by spillage and grinding.

5.4 Recontamination

Following the grounding and sinking of the "Arrow", large slicks contaminated over half of the shoreline in the Bay and leaks from the wreck continually spilt small amounts of oil throughout the spring and summer. These slicks were a great deal smaller and thinner than those of February and March but this oil did recontaminate many of the beaches along the north shore area.

Other sources of oil which led to shoreline recontamination were from the coastal areas themselves. The reworking of contaminated sediments by wave action led to the release of oil onto the water in small amounts. This was exemplified by the action of tracked vehicles working in the intertidal zone in the early phases of the project before better machine-operation techniques were developed. In particular at Arichat, which was the first area to be worked, a substantial amount of oil was released into the sea and this led to the reoiling of adjacent beaches (Section 6.4.1).

Oil was often contained in rock hollows and crevices above the limit of normal wave action. With spring tides or storm waves, some of these pools of oil were flushed, leading to recontamination of adjacent alongshore areas. This was judged to have been the reason for the reoiling of Indian Cove (Section 6.4.3).

6. BEACH RESTORATION

6.1 Deep Cove, February 1970

In mid-February, shortly after the sinking of the "Arrow", the Canadian Armed Forces bulldozed part of the bar at Deep Cove in an attempt to clean this beach (Photograph 8). It was estimated that some 3,000 cubic yards of sediment were excavated and removed during this operation (Asthana and Marlowe, 1970). This trial was not successful as oil and sediments were thoroughly mixed and not all the contaminated material was removed. This operation was also ineffective in terms of recontamination as this area was reoiled within a few tidal cycles and on several occasions subsequently.

The beach which was subjected to bulldozing is a narrow bar which joins two islands and the removal of large volumes of sediment was considered very damaging to the stability of the foreshore (Asthana and Marlowe, 1970). As a result of this experiment a recommendation was made to the Task Force that bulldozing should not be continued and that beach restoration should be restricted to manual methods (see also 6.4.6).

6.2 Selection of Beaches for Restoration

Before the assignment of the coastal geomorphologist to the programme, a series of beaches had been selected for restoration. These beaches included all accessible nationally rated shorelines (these are rated on a recreational basis), as well as community beaches in the area. The information regarding the location and extent of these beaches was supplied by the Emergency Measures Organization. Additional sections of coast were included in the programme as a result of public requests. In all, 30 miles of coast were restored by the Task Force.

The restoration programme was carried out by personnel of the Department of Public Works who determined whether beaches could be restored by manual or mechanical methods. Lightly oiled beaches were restored by squads of "slick pickers" (Section 6.3) while contracts were drawn up for the restoration of heavily contaminated sections. These were awarded to private companies after bids had been tendered.

No geological criteria were included in the decisions regarding which beaches were to be restored by the Task Force. Only after a section of coast had been designated were these criteria considered and the geological input was largely restricted to recommendations concerning those beaches actually under contract rather than advice related to the restoration programme as a whole in terms of the selection of beaches.



Photograph 8

DEEP COVE

March 1, 1970

Air view from the north of armed services restoration work. This is a long, narrow bar which joins two islands and is open to wave action from the south and east. At the east end of the beach a spit has grown north to partially close off a small lagoon which is being infilled with mud and silt transported alongshore. The sea at the near side of the bar and the lagoon, are ice covered. Material has been piled up by the bulldozers for later removal.

6.3 Manual Restoration

Those sections which were designated for restoration but which were only lightly oiled were cleaned effectively by squads of "slick pickers". These units, local labour under the Department of Public Works supervision, removed oil and contaminated material with shovels and rakes (Photograph 9). The material was placed in plastic bags which were collected and removed to an approved dump site.

Although this method of restoration is comparatively expensive in terms of labour costs, it is most efficient and effective as only contaminated material is removed. The loss of sediment from a beach is low, so this has very little adverse effects on beach stability and except where the oil is deeply buried, it is possible to remove virtually all the contaminated material.

The sand beaches in the Point Michaud area and in the Bay of Rocks were successfully cleaned by this method. These shores were not in danger of recontamination and remained clean throughout the summer. Shingle and cobble beaches were harder to clean as the oil did not remain in cakes and pans on the surface but this method is still preferable to the use of heavy machinery on lightly oiled beaches.

Any material which was buried and not removed manually would probably be exposed in the winter or spring when the beach is combed down under vigorous wave action. This oil would be subject to wave action throughout the winter and by the following summer there should be little evidence of any contaminated material on the exposed beaches.

6.4 Contract Work

This section includes detailed accounts and analyses of the contract work on five beaches and a more general report on some of the other beaches where machinery was used. Not all of the sites which were contracted or where machinery rental was used are dealt with (MacKay, 1970) but the operations reported cover a representative cross-section of the shoreline areas in Chedabucto Bay where projects were carried out. The location of the sites reported here is given in Figure 2.

6.4.1 Arichat

The contract for a 3,700 foot section of beach was awarded to a low bid of \$4,479 and the work was carried out over 9 days between April 30 and May 11, 1970 using a fixed-blade International TD15 bulldozer and an International TD9 skid shovel; both vehicles were tracked. A total of 422 cubic yards of material was removed and 40 cubic yards were brought in as clean replacement at Le Noir Forge.



Photograph 9

SLICK PICKERS

May 29, 1970

Air view of the restoration of a sand beach manually. Oil and oiled seaweed is shovelled into plastic bags which are collected for dumping. This method is very effective as spillage is negligible and only contaminated material is removed.

Description of the contract area

This is a sheltered location not exposed to the direct action of waves from the Atlantic with a tidal range in the order of 4 to 6 feet (Table 1). All of the contract area was badly oiled and the beach zone was effectively paralyzed; that is, oil prevented the normal movement of sediments by wave action. In detail the section may be subdivided into four units:

- 1) Between the Arichat wharf and Le Noir Forge the shore is characterized by a 20 to 25 foot till cliff (Photograph 10). The width of the beach zone averages 40 feet at low tide and is made up of sediments derived directly from the subaerial and marine erosion of the cliff. This beach mantle was rarely more than a foot thick, mostly gravel and cobble size with a few boulders and overlay the till platform which resulted from the retreat of the cliff. Sections of the backshore are undergoing active erosion but in general the supply of material into the littoral zone is minimal. As the stone content of the till is low, most of the eroded material is removed as suspended sediments.
- 2) A small prograding beach, about 100 feet long and 60 feet wide, fronts a low backshore in the area immediately west of Le Noir Forge. This beach appears to have resulted from accretion which occurred as longshore sediment transport was interrupted by the small headland on which Le Noir Forge was constructed.
- 3) The Le Noir Forge headland is a till bedrock area which has a beach of till-derived material at its seaward end. The two small beaches on either side of the headland are of gravel and are areas of more rapid accretion.
- 4) The east half of the area is made up of a series of three mid-bay bars and low active till cliffs. The bars have built out on a shallow platform which has a maximum width of about 150 feet. Sediment accretion on these small bars has deprived the intervening areas of material so that the narrow beaches have not prevented wave erosion of the backshore cliffs. The till cliffs are generally lower than the west section, being between 5 and 15 feet high. Various sections have been riprapped or protected with wood structures to prevent the erosion of property.



Photograph 10

ARICHAT

May 2, 1970

Air view of Le Noir Forge and west section at low tide. The bulldozer had made a "road" along the base of the active till cliff at the high water mark. This section was heavily contaminated and the beach zone was paralyzed. The contract area ended at the wharf.

Restoration

This contract was the first to be issued and work began on April 30. Contaminated material in the intertidal zone just to the west of the Le Noir Forge was heaped into piles and a "road" was bulldozed along the high water mark westwards toward the wharf. Some concern over the action of the contractor was expressed and it was decided not to remove any material beneath the cliff west of Le Noir Forge. As the "road" had already been bulldozed part of the way, the disturbed material on that section would be pushed against the base of the cliff but the contaminated material which had been piled up on the beach adjacent to Le Noir Forge would be removed.

On May 2, the "road" was bulldozed through to the west end of the contract section, near the public wharf and during May 2 and 3, the disturbed material in this section was pushed against the base of the cliff up to 4 feet above normal beach level. The piles of material west of Le Noir Forge were removed on May 5. The Department of Public Works site supervisor reported "fresh" oil on May 3 and 4 on those areas of the beach which had been subjected to machinery.

On May 6, a decision was made to remove and replace a section by Le Noir Forge which had been excavated to the till bedrock and areas were outlined in the east half of the contract where material should not be disturbed. During May 6 to 10, the areas designated for cleaning in the east section were dealt with by the contractor and on May 11 the contractor was released.

Effectiveness and Results of Operation

- a) The use of a bulldozer to drive a road through the west section thoroughly mixed contaminated and uncontaminated sediments. As the beach was scarcely wider than the resulting road the contractor should have removed the layer of contaminated material while progressively moving westward.

This action highlights an important point that the site supervisor should be aware of the implications of various actions so that he can make on the spot decisions which will be carried out by the contractor in order to prevent action which may be undesirable or endanger the stability of the beach.

- b) The removal of material from the beach at the foot of the till cliffs may have accelerated basal erosion. The beach consisted of a thin cover of till-derived sediments overlying a till platform which was exposed as the "road" was bulldozed across the beach. In order to minimize the possible adverse effects of this action the disturbed sediments were pushed against the base of the cliff.

No material was removed from this area but the disturbance of the beach material led to the washing out of the fines and the release of oil into the littoral zone. The fines were transported along shore, in a band some 6 feet wide adjacent to the beach, while the oil was redeposited in thin layers near the high water line (Section 5.4). The section would have been better left, although at least this beach was no longer paralysed.

- c) In the area of beach to the west of Le Noir Forge some 62 cubic yards of material was removed by the contractor, approximately a 12 to 18 inch layer of sediments. At the completion of the contract, this area was relatively clean, with only a small amount of reoiling near high water mark. On May 26 and 27, the beach was reoiled by a slick (not from the "Arrow") 30 feet by 5 feet which was 3 inches deep in parts. Peat moss was placed over the oil on the 28th and the contaminated material was removed manually to a depth of 12 inches on June 2. Some 2 feet of beach was removed in all and even those sections re-cleaned on June 2 had been slightly reoiled by June 3.
- d) On the seaward edge of Le Noir Forge promontory, some 20 cubic yards of material were removed. This exposed the till base and the replacement of 40 cubic yards of larger, boulder sized material has increased the stability of this small section of beach. The clean material used as replacement has been contaminated.
- e) In those areas east of Le Noir Forge which should have presented no difficulty for the contractor, i.e. only a shallow surface layer of material was contaminated, the use of a bulldozer with a straight blade was demonstrated to be particularly unsuitable. As material is pushed forward by the blade, clean and contaminated material is mixed. Spillage around the edge of the blade contributes to the inefficiency of the method as this material must be removed by a subsequent pass and is often ground in by the tracks of the vehicle. The only way in which the bulldozer could operate effectively was to pile up material for removal by other equipment and this tended to mix sediments rather than remove the contaminated layer.
- f) The cleaning of selected sections of a shoreline is not effective because oil from adjacent contaminated areas as well as from offshore, can lead to reoiling. All of the beaches subjected to cleaning had been reoiled by June 4, either from alongshore or offshore.
- g) The two basic criteria that all contaminated material should be removed and that there should be no danger of recontamination were not realized on this contract section.

- h) The Arichat beach was badly contaminated and much of the littoral zone was "paralyzed". From this aspect, the restoration operation at least made the beaches mobile once more, though this could have been achieved by the use of a tractor-drawn rake or hoe. The contract was the first to be awarded and many of the lessons learnt here were applied to later projects.

6.4.2 Blackduck Cove

The contract for this 4,600 foot section of coast in the north and north-east of the Cove (Photograph 5) was awarded for \$6,000 and the operation required 9 days between April 30 and May 12, 1970, using a fixed-blade Caterpillar D6C bulldozer and a Caterpillar 950 wheeled front-end loader. A total of 4,469 cubic yards of material was removed and 360 yards of clean boulders were brought in along the north shore.

Description of the contract area

The Cove is on the south coast of Nova Scotia but is not directly exposed to waves from the open sea. At the east end of the shallow cove a wide, medium to coarse grained sand beach is backed by a vegetated berm and brackish marsh. The beach is generally about 100 feet wide but at spring tides may be up to 300 feet wide. The abundance of sand in the offshore zone and the shallow nature of the cove indicate that there is an ample supply of sand-sized material for beach replenishment. The berm and backshore areas are stabilized by grass. Both ends of this section are areas of mud and silt accumulation presumably where the fines have been deposited by alongshore movement away from the centre of the beach.

The oil on the sand beach had "paralyzed" the sediments above high water and though some self-cleaning had taken place in the intertidal zone, oil had mixed with sand and seaweed to form large immobile cakes (Photograph 11).

The northern shore of the cove is a low silt/sand area which has a surface cover of large glacially derived boulders which protected a road and houses on the low till backshore from marine erosion. This area was heavily polluted and paralyzed.

Restoration

The contractor commenced work on April 30, 1970, in the sandy beach section. Contaminated material was bulldozed from the intertidal zone into large piles above high water for subsequent removal by the front-end loader (Photograph 12).

Concern was expressed over possible damage to the backshore vegetation by the machinery and the contractor thereafter maintained one track for the trucks.



Photograph 11

BLACKDUCK COVE

April 25, 1970

Air view of sand beach at the east end of the cove near high tide. Oil is present as a thick, continuous layer along the high water mark and along the edge of the vegetation. Thick patches of oil and seaweed "cakes" cover much of the intertidal zone but the beach is still mobile. The cobbles and boulders along the north shore in front of the cottages are also heavily polluted but this section is paralyzed.



Photograph 12

BLACKDUCK COVE

May 2, 1970

Air view of beach restoration work at low tide. A bulldozer has pushed the contaminated sediments above the high water mark for subsequent removal by a front-end loader. The contaminated material along the edge of the vegetation was removed by the bulldozer scraping backwards down the beach in order to minimize damage to the backshore. For the same reason, access to the beach from the backshore was carefully controlled to prevent the development of blow-outs.

The sand section was cleaned by May 2 and work then began on the north shore. The contractor agreed to remove material only from the upper part of the intertidal zone. An agreement was reached to replace one section where the road on the backshore was left open to wave action by the removal of the boulders.

Effectiveness and Results of Operation

- a) The clean-up of the sand area was a successful operation but by piling the material above water level, mixing of oiled and clean material took place. Although spillage by the bulldozer was high it was of a much lower magnitude than on a cobble or mixed beach. Ideally the material should have been lifted off the beach rather than pushed around for removal by other equipment.
- b) Controlled access to the beach by the trucks using only one track resulted in damage to only one area of vegetation rather than wide-spread disturbance. Where contaminated material was found near the edge of the berm vegetation, the bulldozer was used to scrape down, rather than dig or push up the material. This again helped to minimize damage to the vegetated zone, (the destruction of the vegetation could have led to blow-outs).
- c) At the extremities of the sand beach the bulldozer often sank above its tracks in the silt and mud. This led to a thorough mixing of contaminated and clean material. In "soft" areas like this, very little can be done with heavy machinery.
- d) The sand areas were easily cleaned as the oil was only on the surface and this type of material is more easily handled than gravel or cobbles. An angle-blade on the bulldozer may have been an improvement, as this would have reduced spillage.
- e) Although the sand beach was clean after the contractor had completed his work, it was reoiled on various occasions subsequently from alongshore areas. By the end of July the intertidal zone was again covered with cakes of oil, sand and seaweed over large areas and these were still evident in November. The heavily polluted lagoon at the west end of the Cove released some of its oil throughout the summer and this was transported alongshore towards the beach by incoming waves (Section 5.4).

6.4.3 Indian Cove

(Fox Island Main)

This 850 foot beach was contracted for \$2,000 and involved four days work between May 15 and May 20, 1970. A Caterpillar 950, wheeled, front-end loader removed 1,368 cubic

yards of beach material during this period. The volume of sediment excavated on subsequent occasions is not available.

Description of contract area

This is a small concave pocket beach set back between two rock headlands. The beach has a maximum width of 130 feet and the material varies from coarse sand in the lower parts of the intertidal zone to cobbles at the crest of the storm ridge, the typical mixed beach of this area, with the dominant size in the cobble range.

The well developed storm ridge in the eastern half is backed by a low vegetated swale and a brackish pond. In the west half there is a continuous level area of old beach material fronted by a poorly defined beach crest ridge. The oil was confined to an area above normal high water level as a 6 to 12 inch thick caked layer approximately 10 feet wide which extended for almost the entire length of the beach (cf Photograph 6).

Restoration

A small experiment using a front-end loader with a 3 cubic yard capacity bucket was carried out on May 13 to test the effectiveness of this equipment for lifting off the oiled carpet. The encouraging results led to the use of the front-end loader for this operation and the beach was cleaned between May 15 and 20.

By May 25, the eastern 300 feet had been badly reoiled in the high water mark zone from the adjacent oiled rock areas (Photograph 13). On June 11 to 13, a bulldozer with a front bucket was rented to re-clean the beach. Oil was removed from the rock areas manually and limestone was spread over the rocks to stabilize the remaining oil, but recontamination occurred on several occasions throughout June and July (Section 5.4).

Beach profiles

To provide some measure of the effects of sediment removal, the beach was surveyed by 17 levelled profiles on May 14, 21, 29, June 14 and November 11. Six of these profiles, all from the east end of the beach, are presented in Figure 9.

In order to ascertain the distribution of sediment removal across the beach, profiles were taken immediately before (May 14) and after (May 21) the contract work. The limits of the thick, continuous layer of oil on the beach are shown (Figure 9b) and it is evident that the beach had been able to clean itself except for those areas above the reach of normal wave action. Most of the sediment removal was from this zone and as was noted earlier (Section 4.2), this part of the beach is not an area of accretion except during periods of storm waves or spring tides. Sediment replacement is, therefore, not rapid in this zone.



Photograph 13

INDIAN COVE

May 25, 1970

The east section of this pocket beach at low tide, four days after completion of the contract work. Before restoration, a thick continuous layer of oil, six to ten feet wide, covered the length of the beach above the high water line. (see photograph 11). The figure is standing near the high water line. Recontamination was from alongshore and the oil concentrated in the upper part of the intertidal zone.

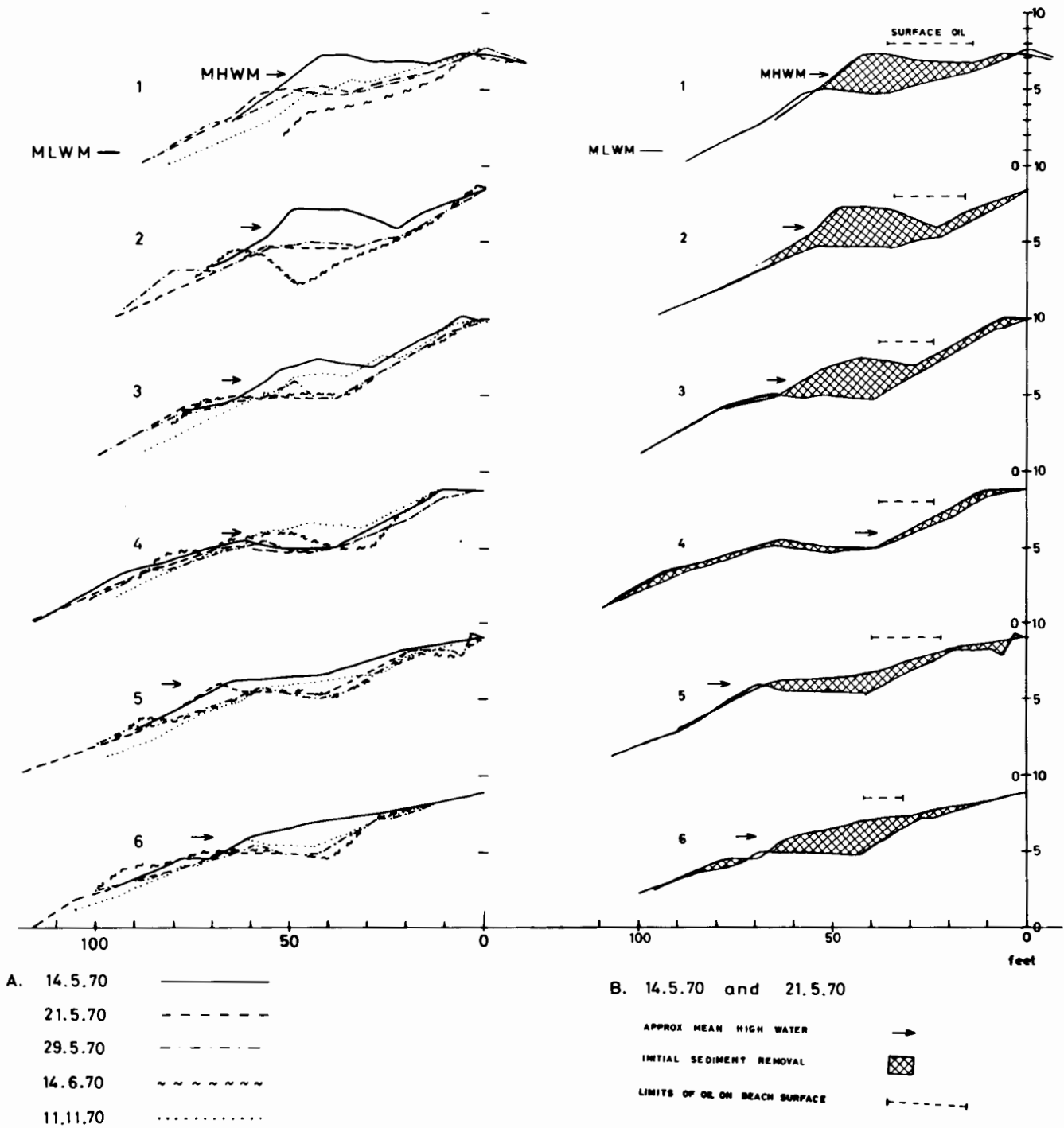
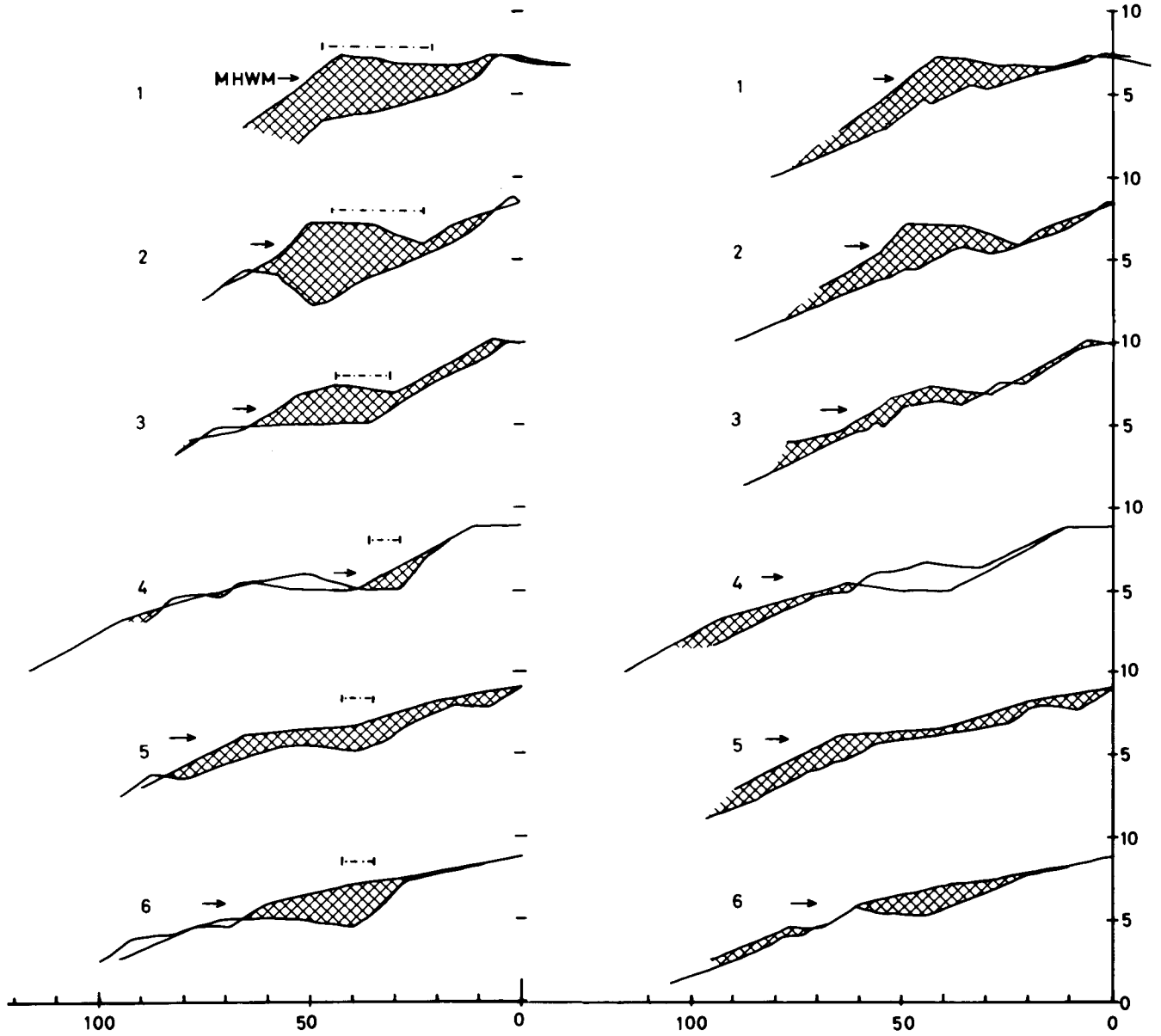




Figure 9. Beach profiles at Indian Cove.



C. 14.5.70 and 14.6.70

D. 14.5.70 and 11.11.70

TOTAL SEDIMENT REMOVAL 
 LIMITS OF REARING 

NET SEDIMENT LOSS 

As a result of a reoiling at the east end of the beach, further excavation took place and the effects of this are shown in Figure 9c, which compares the original situation with that following the second removal operation (June 14). Parts of this beach lost as much as five feet of sediments.

The fact that some replacement of material occurred during the summer months is indicated in Figure 9d. However, the profiles show that in the intertidal zone material had been removed by wave action. The beach had been unaffected by storm waves before November 11 and this should have been a period of net accretion in the intertidal zone. It is likely that the material was pushed up into the area around high water mark but the effect of winter storms combing down the beach may lead to a further lowering of the foreshore. Reprofiling during the spring of 1971 will give a better indication of any long term effects.

Effectiveness and results of operation

- a) A carefully handled front-end loader was able to remove the one foot deep oiled layer efficiently. The bucket was used to cut under the oil and lift it, disturbing little of the uncontaminated sediments. This worked well as long as the operator did not attempt to fill the bucket, in which case the effect was to push rather than lift and spillage was very high. From the point of view of the contractor, this method is wasteful as the loader bucket is filled to only about one quarter of its capacity. Thus the efficiency of his operation suffers.
- b) Beaches where the oil is only on the surface are relatively easy to clean mechanically, as it is necessary to remove little sediment. However, with the equipment available, spillage is high unless the operator is particularly careful. A machine which could get under the oil carpet, in the manner of a fork lift truck, would be ideally suited to this type of situation.
- c) This beach was generally well cleaned except for occasional patches of oil contaminated material which were spilled by the loader; these were removed manually.
- d) The mixing of oil covered pebbles or cobbles with fine material leads to a surface cover of sand and silt sticking to the stone, which disguises the oil beneath. Subsequent washing and reworking by wave action tends to remove the surface material and may give the impression that the beach has been recontaminated although in fact this is a result of the mixing of material during cleaning.
- e) Reoiling of the eastern section took place (within 4 days) during a period of spring tides as oil was released from pools and cracks in the adjacent rock areas (Photograph 13). High temperatures during the preceding week had encouraged

the oil to collect in hollows and this was then easily washed out by the waves. The actual timing of the reoiling coincided with the spring tides so that the pools of oil had not been within the range of normal wave action for several weeks (Section 5.4).

- f) The oil which recontaminated the beach was generally less than half an inch thick but would cause as much inconvenience as the thick layer removed earlier. Unless all sources of recontamination are dealt with, the chance of reoiling will remain. It is not practical to clean only one section of a coast, as oil from alongshore may spread to cleaned areas, which was demonstrated by the fact that this beach was reoiled several times.

6.4.4 Half Island Cove

This 1,500 foot section of beach was restored during a six day period between May 26 and June 15 at a cost of \$3,000. A Caterpillar 950 wheeled, front-end loader was used and 1,761 cubic yards of material were removed.

Description of the contract area

This is a wide, shingle beach partially set back from the general trend of the straight coast on the south shore of the Bay. The beach has a maximum width of about 80 feet and the lower intertidal zone is composed of fines and gravel while the storm ridge and upper beach zone are shingle. The alongshore movement of material appears to be from east to west.

The most easterly 600 feet of the contract area, commencing from a low rock platform, is backed by a 20 foot active till cliff. The next 500 feet form a ridge some 120 feet wide which has a lagoon in the rear. The central 200 feet were excluded from the contract. This area consists of a bedrock, boulder and shingle zone backed by a 5 foot active till cliff. The westerly 400 feet form a steep narrow beach with a shingle storm ridge, and a low wooded backshore. At one point, a rib of rock extends from the mid-tide zone seawards for almost 100 feet.

No oil patches were visible on the surface as all the contaminated material had been reworked by wave action and in parts had been buried to a depth of three feet. The rock platform just to the east of the contract section was badly oiled and much of this oil had collected in pools and cracks.

Restoration

The beach was surveyed with 16 levelled profiles on May 25, prior to cleaning which commenced on the 26th. A short experiment with a road grader was conducted on May 26 to the west of the contract section on a wide, low sloping part of the beach.

The contractor left the area on the 28th but as the work was not completed satisfactorily he returned on June 13 and 14.

On June 14 and 15 material was removed from one section of the beach below high water mark. This was used as clean replacement for Phillips Harbour which has been subjected to machinery. The profiles were resurveyed on May 30 and June 15.

Results and effectiveness of operation

- a) The tests with the road grader were not productive as this machine requires a firm, flat or low angle surface. While it was able to work with some efficiency along the flat crest of the ridge, difficulties were encountered on the low beach face slope. As has been reported elsewhere (Section 5.3), a grader is useful and effective on firm, low sand beaches where the oil is on the surface. On a gravel or shingle beach it is of no practical value.
- b) The basic problem in this contract area was to remove buried, contaminated material. At the first attempt the contractor merely scraped over the surface and as this was not acceptable, he returned and removed more beach material. There still remained a great deal of contaminated sediments after the contractor was released (Photograph 14). The only way in which the method employed could have succeeded would have been to remove most of the upper sections of the beach without spillage. This is both undesirable and impractical and may have led to adverse effects, such as increased erosion of the till cliffs or breaching of the lagoonal ridge.
- c) Even if the beach were cleaned adequately, there is a danger in this area of recontamination by oil from the adjacent rock platform and other areas alongshore.
- d) This beach was not paralyzed by the oil and wave processes had been active and effective in cleaning and burying much of the contaminated material. Following the restoration programme the beach was no cleaner in terms of recreational purposes, so that there was little net gain from the operation. There was no large-scale removal of sediment and no damage to the beach itself.

6.4.5 Hadleyville No. 1

This 4,500 foot beach to the west of Oyster Point was contracted out for \$9,450 and work took 8 days between June 2 and 11. A Caterpillar D6C bulldozer and a Caterpillar 950, wheeled, front-end loader removed 3,980 cubic yards of material.



Photograph 14

HALF ISLAND COVE

June 3, 1970

Close-up of contaminated cobbles after restoration. This may have resulted from spillage, mixing, or the exposure of buried oiled material. Scale is graduated in decimeters.

Description of contract area

This well developed, prograding, steep shingle beach is one of several similar formations on the north-west coast of the Bay. The longshore movement of material is to the east and large depositional ridges are evident at Oyster Point, just east of the contract area. Parts of the backshore have large well-preserved former storm ridges which attest to the gradual seaward progradation of the shoreline.

The intertidal zone has a maximum width in the order of 100 feet in the central parts of this section and the material distribution is fines in the lower intertidal zone with a shingle storm ridge above normal high water mark.

The shallow nature of the offshore area has allowed the beach to become oriented towards the dominant direction of refracted wave approach, that is, the south-east.

There was very little contaminated material visible on the surface of this beach. The oiled sediments had been reworked by wave action and were buried to a maximum depth of 4 feet. In some areas a layer of oiled material on the upper parts of the beach had been buried and the seaward edge eroded, so that a band of contaminated sediments was evident in the beach face slope (Photograph 15). The only method of cleaning with machinery involved the large-scale removal of mixed clean and oiled material.

Restoration

The contractor began work on June 2 and in many sections of the beach the bulldozer was used to pile up, above high water mark, material which was subsequently removed by the front-end loader. Where the oil was deeply buried, the loader made a cut down the beach and then excavated along the beach parallel to the ridge. The work was completed on June 11.

Beach profiles

Ten profiles were surveyed across the beach on May 21, June 13, July 12 and November 11, 1970. Five of these profiles, from the central and east sections, are presented in Figure 10.

The "before and after" situation is given in Figure 10b and it is evident that material was removed largely from those areas above mean high water mark. In some places over three feet of sediments were removed in order to excavate the buried oil. Profile 6 is an example of the removal of the storm ridge crest which is well above the limits of normal wave action.

One month after completion of the contract (Figure 10c) very little sediment replacement had taken place even though the rate of accretion should be at its maximum at this time of year. This can be attributed to the fact that the intertidal beach was relatively undisturbed by the machinery and that there was no wave action on the higher parts of the beach during this period.



Photograph 15

HADLEYVILLE No. 1

May 30, 1970

This was one of the worst parts of this beach, in the west section at low tide. Contaminated material has been buried and subsequently exposed as layers in the beach face slope. This well developed beach is backed by a series of vegetated swales and former ridges.

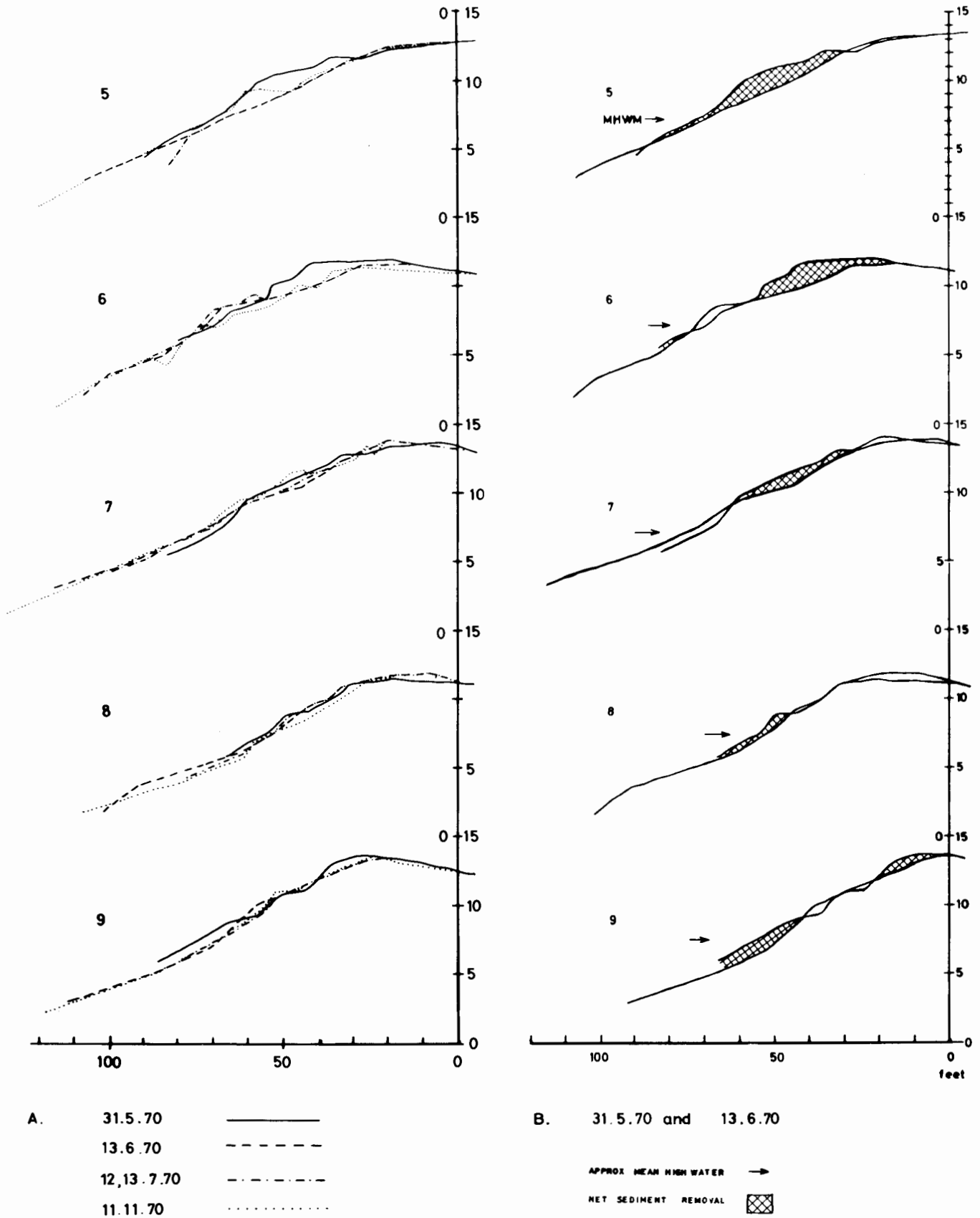
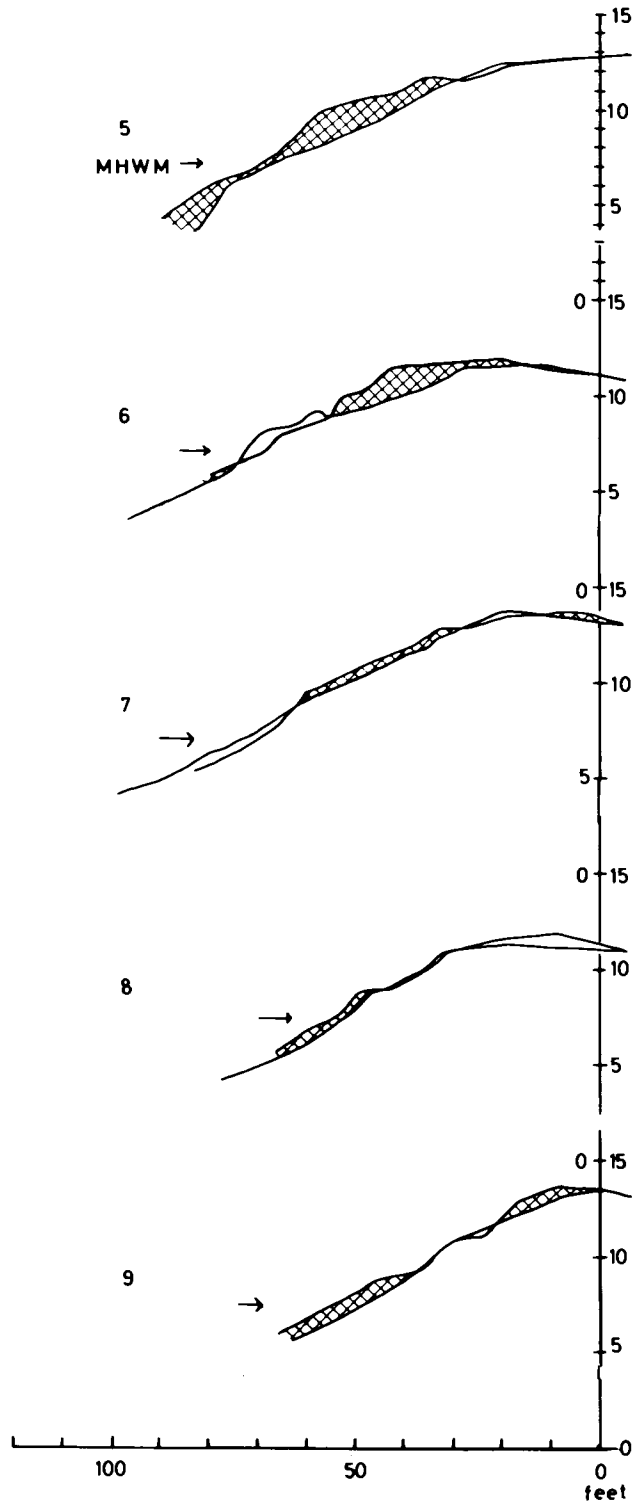
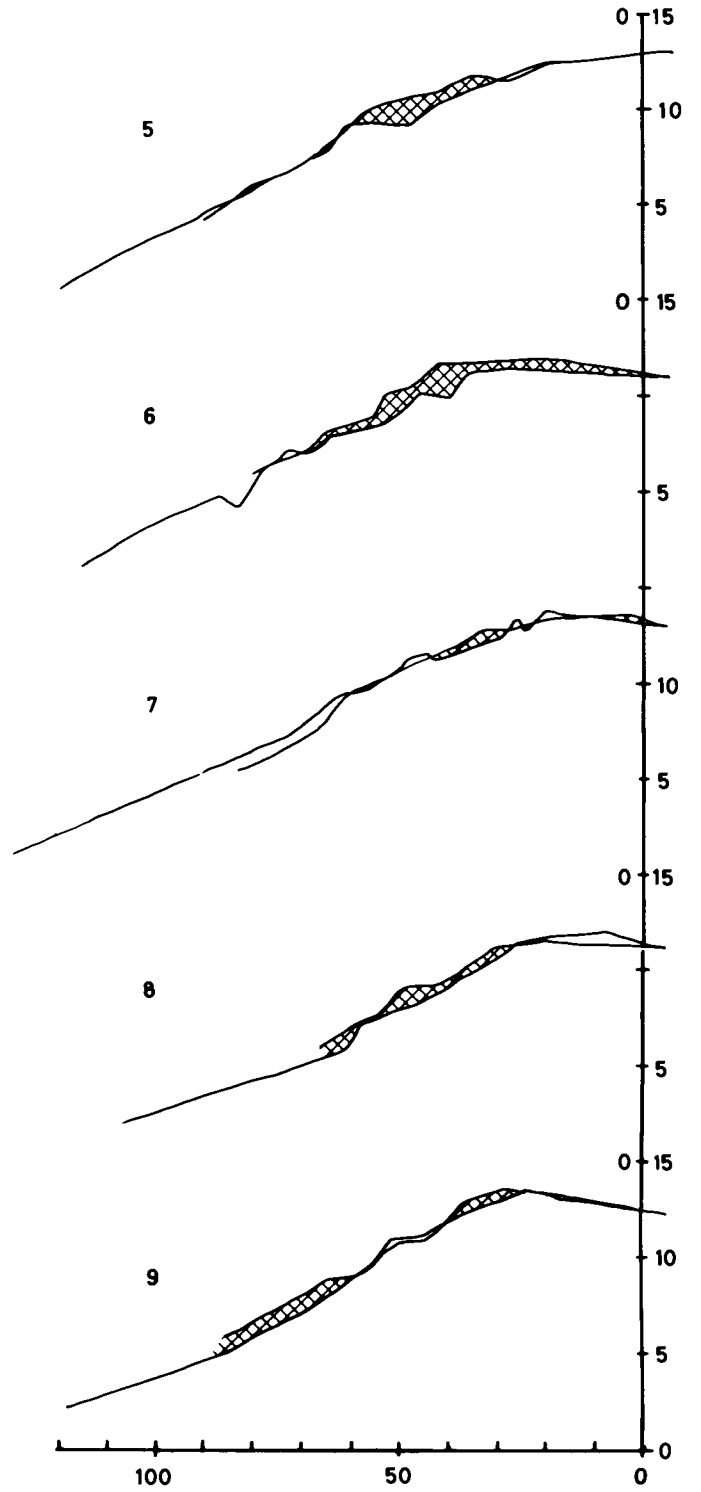



Figure 10. Beach profiles at Hadleyville No. 1.



C. 31.5.70 and 12.7.70



D. 31.5.70 and 11.11.70

NET SEDIMENT LOSS 

NET SEDIMENT LOSS 

Few changes took place in the fall and the November profiles (Figure 10d) record little significant erosion or accretion except for the presence of some small ridges near the high water mark. As most of the excavation took place above the intertidal zone, the profile changes on the lower part of the beach are probably due to normal variations in response to the littoral processes.

Effectiveness and results of operation

- a) In certain sections where the contaminated material was buried, removal of large volumes of sediments is very inefficient. Of the total amounts excavated, only a small percentage of the material was contaminated (Section 5.2). There is no adequate method for mechanical cleaning of beaches where oil is buried.
- b) Contaminated material was still evident after the contract had been completed. The oil on the cobbles acquired a surface coating of fines which were easily knocked off or washed off by wave action.
- c) Unlike Arichat, Blackduck Cove or Indian Cove this beach was not paralyzed and normal beach processes were active. Wave action will succeed in cleaning the beach where machinery can only be used to remove large portions of the beach. (This situation is similar to Half Island Cove.)
- d) The use of a bulldozer to pile up material for removal mixes clean and oiled material. This does not contribute positively to the clean-up operation.
- e) It is unlikely that removal of sediments would have any long-term adverse effects on this beach provided large volumes are not removed from any one location. This should not detract from a critical analysis of the operation which was basically an inefficient way of dealing with the problem. Mechanical methods are not suited to this type of cleaning. Natural processes are more effective and less costly.

6.4.6 Other Contract Beaches

Moose Bay

This large cobble beach and spit complex on the west coast of the Bay is one of the most impressive coastal features of the area (Photograph 16) (Johnson, 1925). The west half of this beach was restored manually (Photograph 2) while the eastern 5,000 feet were put out to contract for machine work.

The problems which were faced in this area were similar to those of Half Island Cove and Hadleyville No. 1 as the oiled material was deeply buried and in order to remove it, several feet of sediments were excavated.



Photograph 16

MOOSE BAY

May 21, 1970

Air view of the east end of Moose Bay at mid tide. The bedrock island of Ragged Head, lower right, is connected to the mainland by a double tombolo. This is the western of the two arms and it gives way to a wide, long beach. The eastern limit of the area which was later restored is indicated by an arrow.

The initial attempt at manual cleaning was not continued to the end of the designated section because of the expense, which was double that for machinery on a cost per foot basis. The manual method is less harmful to the beach as little uncontaminated sediment is excavated. Although this approach does not lead to the removal of all the oiled material, mechanical methods are little better as there is no suitable equipment available.

Hadleyville No. 2

This beach is distinguished from Hadleyville No. 1 as it is a separate coastal unit to the east of the area discussed above (Section 6.4.5). This beach area is little different from Moose Bay or Hadleyville No. 1 but is included as an example of the types of contamination which were experienced in the operation.

At the west end of this cobble beach oil had been reworked, buried, and subsequently exposed (Photograph 4). In the central area, a carpet of thick oil up to 15 feet wide was left above the limits of normal wave action (Photograph 6). At the east end of the beach cobbles gave way to coarse sand and here the oil remained as large discrete pans above the high water line (Photograph 3).

This area is a valuable example of how to deal with different situations using the methods available.

- a) The type of beach contamination in the west section represents a situation which is best left alone unless urgent requirements necessitate action. The waves had removed most of the surface oil by reworking and burial and the beach would continue to clean itself as this is an exposed beach which receives the full force of storm and swell waves from the east. To remove the contaminated material completely would require deep excavation which is harmful to the beach equilibrium and at present would be an inefficient method as no equipment is available which will remove all oiled sediments from cobble beaches.
- b) The thick cover of oil above the high water mark could be removed by a carefully operated front-end loader which has been shown to be effective in this type of situation (Section 6.4.3). No attempt should be made to remove the other sediments which have been reworked or buried by the waves for the reasons outlined above. The action taken would merely be to remove the surface layer of oil which has effectively paralyzed that section of the beach.

- c) The large pans of oil on the surface of the sand can be removed manually, as these are easy to pick up with a shovel. The use of men rather than machinery is recommended, as the spillage from the equipment could be ground and mixed with clean sand. Any oil which is buried will be reworked by waves as it is exposed during the winter months. Should some of this be left on the beach the following summer, pickers could again restore the contaminated areas.

Eddy Point

This foreland is made up of two cobble beaches which enclose a fresh-water lagoon on a shallow offshore platform (Photograph 17). According to local inhabitants the north-west shore is retreating at a rate of nearly one foot per year and as the upper part of this beach was covered with a continuous layer of oil, it was decided that this would be removed and then replaced with clean rip rap to serve as protection against any possible erosion resulting from sediment removal.

Profiles 1, 3, and 5 in Figure 11b were surveyed across this beach and show the effect of the restoration programme. Along the south-east limb of the foreland, the profiles 7, 9, 11, and 13 in Figure 11b show how the removal of buried oil led to excavation in the zone above high water mark, the area where beach replenishment is least active.

Subsequent surveys in July and November (Figures 11c and 11d) indicate that no significant replacement had taken place on the north-facing beach and by November the beach had lost what little sediment had built up immediately following restoration. Profile 7 was levelled across the point of the foreland, which is the most mobile section of this feature, and the loss of material is probably the result of normal processes rather than the contract work. On the steep south-facing beach some build up had taken place along the high water line but this has not been sufficient to return the beach to its previous level.

Deep Cove

Following the initial work on this beach (Section 6.1) further removal of contaminated sediments was carried out in June on the seaward side of the bar and in the lagoon. An angle-blade bulldozer was used in the lagoon area to remove the surface oil but the vehicle tracks acted to grind in the oil which had been buried. Although the machine was relatively efficient in scraping the surface, it did not affect the oil which was interbedded with the silt and mud except to mix it to a depth of several feet.



Photograph 17

EDDY POINT

June 12, 1970

Air view looking north. The lagoon is fresh water and rarely breached by the sea. The contract limits are given by the arrows.

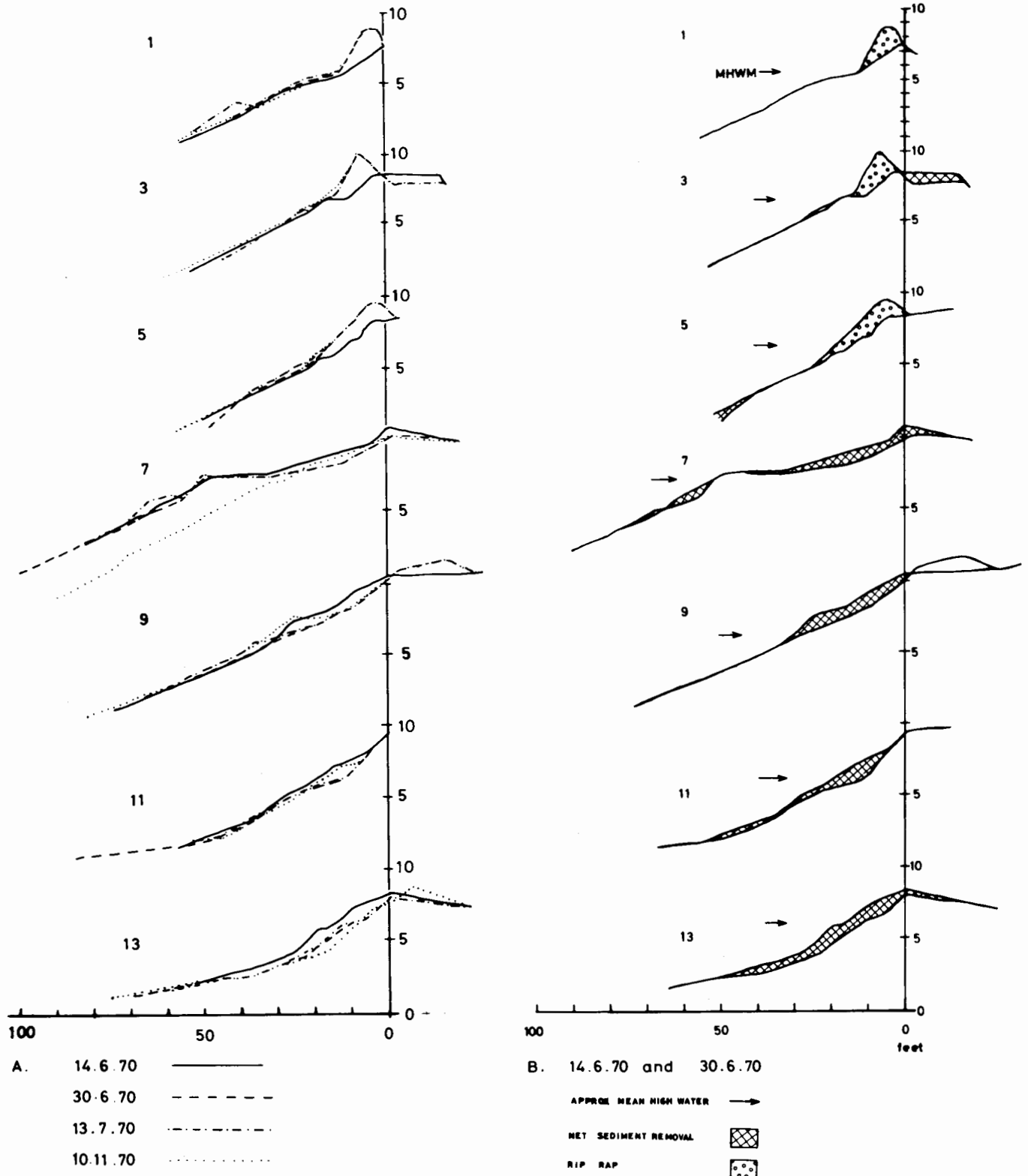
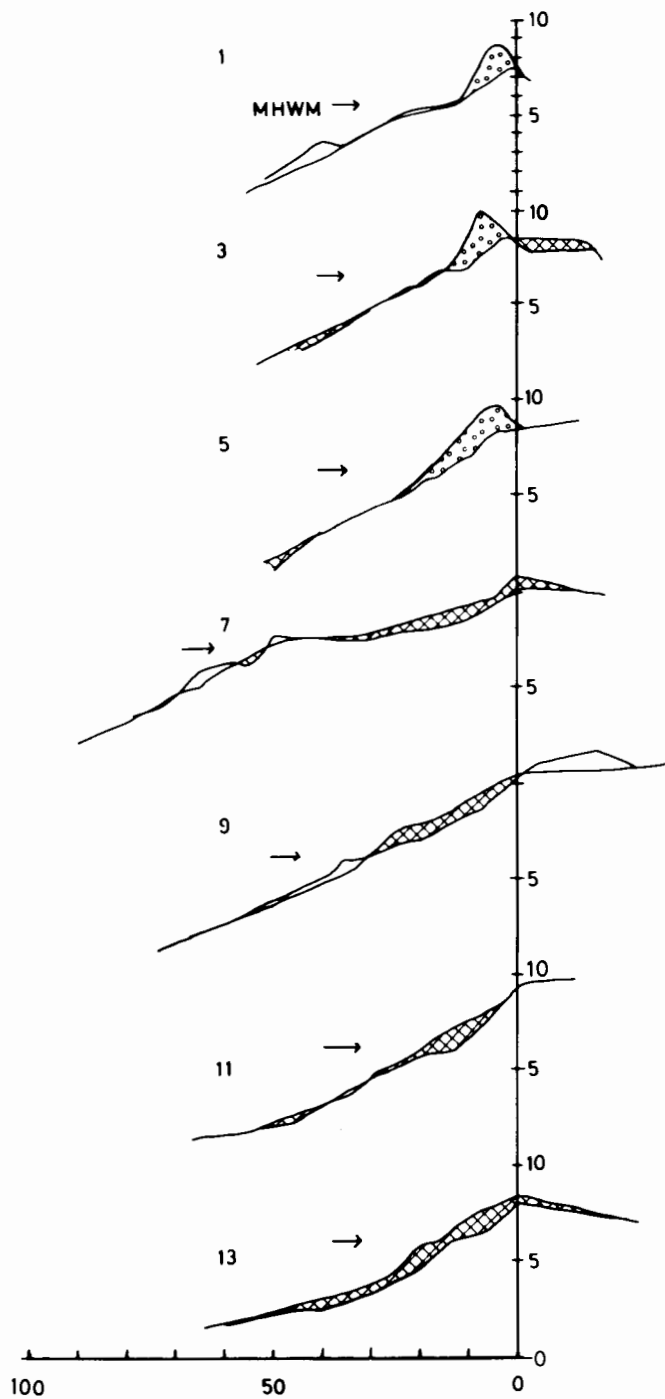
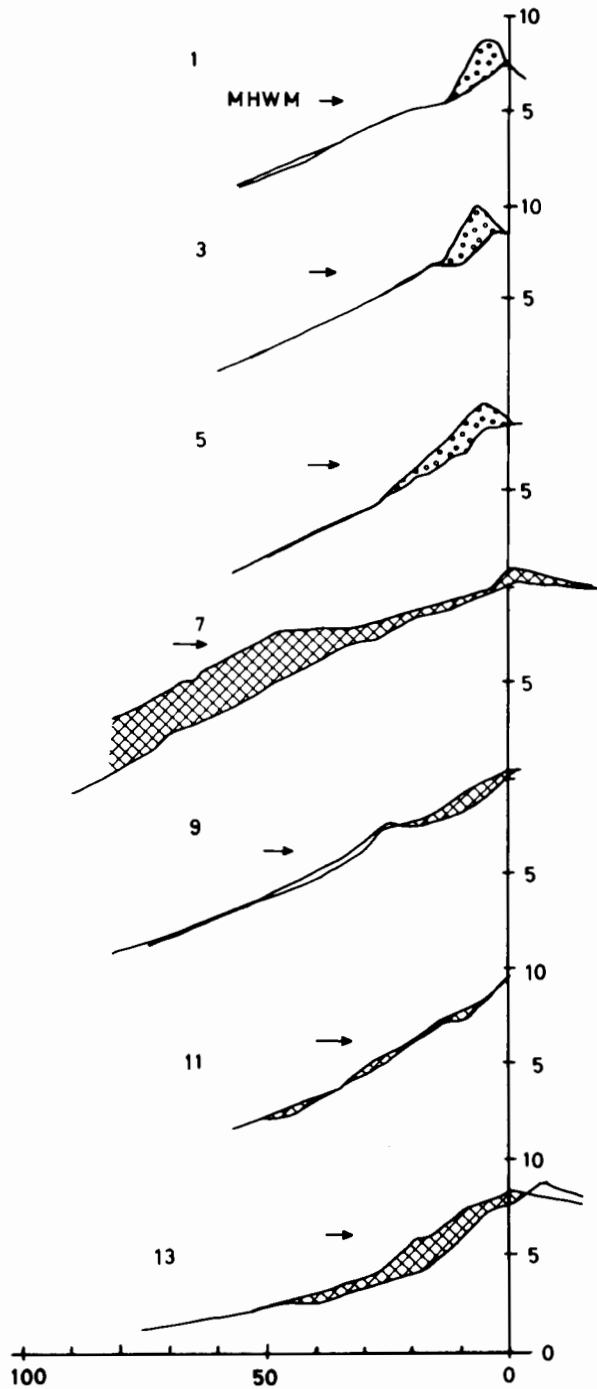


Figure 11. Beach profiles at Eddy Point.



C. 14.6.70 and 13.7.70

NET SEDIMENT LOSS 



D. 14.6.70 and 10.11.70

NET SEDIMENT LOSS 

The bar beach was restored again and material was replaced to prevent any major damage to this sensitive feature. Unfortunately the replacement sediments were taken from the spit which enclosed the lagoon and the cut into the spit which resulted will not be filled by natural processes as it is not in the active beach zone.

When this location was revisited in November it was evident that waves had washed over the road on the crest of the bar. Whether this would normally occur is not known but even if this is the case, there is clearly a serious danger that the bar could be breached. On such an unstable beach any interference with natural processes may easily accelerate erosion. Some rip rap was replaced in one section of the bar and this may help protect this part of the beach.

Walkerville

Several contracts were given to restore the paralyzed beaches in the sheltered areas of the north shore. One of the problems in this area was that oil was continuously moving alongshore from other contaminated areas.

This beach section near Walkerville on the north coast of Inhabitants Bay is in this sheltered area and has a very thin sediment cover which overlies a till platform and is backed by low till cliffs. The surface layer of cobbles was paralyzed by the oil and was removed by a bulldozer and a tracked front-end loader. This action exposed the fine, till-derived, sediment which overlay the bedrock and clean and contaminated material were mixed by the churning of the tracked vehicles (Photograph 18). With the removal of the surface layer of large material, the fines were removed by wave action.

In a situation like this it would have been preferable to rake over the paralyzed sections so that the beach material would be made mobile. Removal of sediment is harmful as the supply of cobble size material is very limited and erosion of the till platform and backshore may result from the loss of the protecting beach apron.

6.5 Summary

6.5.1 Sand Beaches

- a) On lightly oiled sand beaches self-cleaning will take place. If restoration is necessary the manual removal of contaminated material with shovels and rakes is very efficient and effective, as this method does not involve the removal of large volumes of uncontaminated sediments (Section 6.3).



Photograph 18

WALKERVILLE

June 27, 1970

This beach on the sheltered north shore of Inhabitants Bay has had its thin surface layer of cobbles removed. This has exposed a wet layer of fines about three feet deep. These clean sediments have been thoroughly mixed with contaminated material by the tracked bulldozer and front-end loader.

- b) If the beach is heavily oiled and restoration is essential, a well-operated, wheeled, front-end loader which can cut under the oil is an efficient method of removal. The aim of the machine operator should always be to lift material in small quantities rather than push it forward and fill the bucket. There will, however, be spillage which can be removed manually. No beaches in this area were suited to the use of graders.
- c) Sand beaches can be cleaned for recreational purposes as long as there is no danger of recontamination (Section 6.4.2).
- d) When machinery is working in the beach zone it is important to prevent damage to the backshore vegetation as this could easily lead to blow-outs.

6.5.2 Cobble and Shingle Beaches

- a) Natural processes are effective in cleaning this type of beach unless wave action is limited and/or pollution is very heavy. Paralyzed beaches are by definition inactive and there is little self-cleaning at these locations (Section 5.2).
- b) It was found that cobble beaches could not be cleaned for recreational purposes with the methods available. Machinery alone could not remove all of the contaminated material.
- c) Where oil lies on the surface of a beach it can be removed efficiently by a well-handled, wheeled, front-end loader (Section 6.4.3). Even in these situations there is spillage from the equipment but this could be picked up manually.
- d) A lightly oiled or reworked beach with buried oil can only be restored by excavation methods. This often involves the removal of 3 to 5 feet of sediments and these are usually taken from those areas above high water mark where natural replacement is slowest (Section 6.4.5). If the storm ridge or beach crest is in any way lowered, attempts should be made to replace all the excavated material (Section 6.4.6).
- e) Local contractors have been removing beach material for construction purposes on several of the beaches in this area for a number of years. The beaches do not seem to have been damaged, as far as is known, but the long term effects are not understood, so that this activity should not be used as an argument for large-scale beach excavation. The lesson from Hallsands is an important one (Section 4.2).
- f) Where oil is buried in the beach it should only be removed if it is absolutely necessary. The low amounts of oil in these reworked sediments, often as low as 10 parts per million, mean that large volumes of material are removed for very little oil.

- g) Mechanical restoration is best applied to the situations where oil is on the surface or where the beach zone is paralyzed. In the case of the latter, the object of restoration should be to remobilize the beach so that normal self-cleaning can be effective, rather than attempt to clean it by excavation (Section 6.4.1).

6.5.3 Recontamination

- a) No beaches should be cleaned if there is a danger of recontamination. This was evident in the instances where re-excavation was necessary (Section 6.4.3).
- b) It is not recommended that a contaminated shoreline be cleaned in sections as reoiling is likely unless the beaches can be protected or the adjacent oiled areas stabilized. Recontamination is usually light but is nevertheless undesirable.

6.5.4 Machinery

- a) Earth moving equipment is designed to excavate or remove large volumes of material and operators are trained to carry out this type of work. In order to use machinery for restoration purposes, time must be taken to train and supervise the operators so that they meet the requirements of this more delicate type of operation.
- b) Mechanical methods were found to be useful to remove surface oil from beaches and to remobilize paralyzed beaches. In the latter case, reworking of sediments rather than removal is more applicable. In particular, a well-handled, wheeled, front-end loader was found to be efficient to remove surface oil from cobble beaches (Section 6.4.3).
- c) Bulldozers were not satisfactory for restoration work, particularly the large 100 to 120 fly-wheel horse-power machines which were awkward to handle in confined areas. Spillage from the blade and grinding by the tracks were the major defects of this equipment, the same being true for all tracked vehicles.
- d) Material which is to be removed should be lifted directly from the beach. If it is piled up and later removed this doubles the chances of spillage and further mixing with clean sediments takes place.
- e) None of the machines were able to operate adequately on soft mud or silt areas. Even if traction was maintained this led to grinding and mixing to depths as great as four feet (Section 6.4.2).

6.5.5 Beach Profiles

- a) Accurately surveyed profiles across beaches are a valuable tool in establishing short and long term changes in the character of the beach as well as showing the immediate effects of excavation.
- b) The profile of a beach varies with each tidal cycle so that care must be exercised in isolating long term changes. Meaningful analysis requires a set of observations over a period of not less than a year. The results of the continuing survey programme on the Chedabucto Bay beaches will be reported at a later date (Owens, 1971b).

7. DISCUSSION

7.1 Selection of Beaches for Restoration After a Spill

In coastal areas affected by an oil spill, the decisions related to beach restoration should be based upon geological, wildlife and socio-economic factors. In the first instance, those shores which would require cleaning for tourist or other economic reasons should be established. The decision as to whether these beaches should be cleaned and the methods to be used would then be related to geological criteria. In certain instances, natural self-cleaning may be the acceptable solution; elsewhere the use of manual or mechanical methods may be required. Where cleaning is to be carried out, it is necessary to assess any possible adverse effects which this action could precipitate. For example:

- 1) removal of large volumes of material in an area of limited sediment supply could seriously affect the stability of the beach and backshore zones.
- 2) bars or lagoons could be breached by the disruption of the local shore environment as a result of sediment removal in particular localities.
- 3) destruction of backshore vegetation, particularly in sand areas, could lead to blow-outs and aeolian erosion.

In all instances, the possibility of upsetting the delicate balance of the shoreline must be considered when assessing the socio-economic requirements, for in most instances, natural self-cleaning is more effective and is more desirable from the geological viewpoint. Certain shores such as rocky cliffs or shingle ridges are virtually uncleanable unless dispersents are employed, and in these areas piecemeal restoration of some beaches should be considered in the light of recontamination from the alongshore areas which would not be cleaned.

The system of rating which was used for the selection of beaches in this operation is one based solely on recreational capability (Anon., 1967). This was the only available information on the beaches of this area but was not a rating based on applicable criteria. Moose Bay has been given, for example, a "2" rating but is in fact used only by members of the small local community. The same rating was given to Point Michaud which is completely different geologically and very popular as a picnic and bathing beach. Distinction between different types of beaches for restoration is best defined by the actual recreational use, wildlife considerations, socio-economic factors, and upon

geological characteristics such as material size, sediment supply, sediment movement, and wave energy conditions. With this in mind the selection of beaches for restoration should be based on:

- a) Does the beach need to be restored?
- b) Can the work be done effectively without damaging shoreline stability?

These aspects of the restoration project could be discussed in a regional study (Section 7.2) and once the priorities have been outlined they would only require minor modification according to the actual seriousness of the contamination on given shores.

7.2 Regional Coastal Studies

The correct assessment of areas to be restored and the methods to be used requires an understanding of the coasts involved. To date, only a few small sections of Canada's coast, which is the longest in the world, have been investigated geologically and geomorphologically. Should future restoration projects be necessary, this means that at least reconnaissance surveys would be required before planning the operation. Such a survey should be able to provide a detailed outline of those sections of coast which would require restoration, on a priority basis, according to the character of the shore and economic, social, or wildlife requirements.

The shoreline of Chedabucto Bay had been reviewed very briefly by Johnson (1925) but until field investigations were carried out during this operation, this was the total available information on the coastal environment. Some basic research on the nature of Canada's coasts must be regarded as a necessity for future operations. This information would also greatly benefit tourist and conservation programmes.

The coasts of western Europe and the United States have been studied at least at the reconnaissance level so that restoration projects in these areas have benefitted from the existing storehouse of information. Studies of this nature could be carried out readily in Canada, at least for the areas where spills are likely, by the use of aerial photography, topographic and bathymetric maps, with additional field work for areas requiring more detailed study (Owens, 1971a). The investigation of Canada's shoreline has been neglected and this operation has brought to light the lack of even the most basic general studies in this field.

7.3 Oil on Arctic Beaches

The arctic beaches are in a low energy environment where the intensity of wave and ice action varies with location and exposure (McCann and Owens, 1970). If oil were to pollute these coastal areas, the natural self-cleaning processes would act on a greatly reduced scale when compared to the exposed beaches of Chedabucto Bay. A more valid comparison would be the sheltered environments of the lagoon at Blackduck Cove or the beaches of Inhabitants Bay where wave action is very limited. In these areas it is expected that the oil will persist for several years before it is degraded by natural processes.

The lower energy conditions in the arctic mean that waves and wave-induced currents are relatively less effective in moving pebbles and cobbles when compared to lower latitude shorelines and this results in less transport and abrasion within the beach zone. Contaminated beaches would be cleaned only very slowly by this action and as there is less movement and redistribution it would be very easy for the littoral zone to become paralyzed.

If beach restoration is required in an arctic area it is important to consider that replenishment of a beach by natural processes takes place at a slower rate than in lower latitudes. Therefore, even if a beach appears to be building up, it may take a long time for any losses to be replaced. A documented example of the removal of beach sediments in an arctic location is given for the Point Barrow, Alaska area by Hume and Schalk (1964). It is reported that, as well as producing a shoreline retreat of 10 feet in 12 months, the lowering of the beach allowed ice floes to advance further inland and nearer shoreline installations. This mechanism of ice pushing up the beach is common in polar regions and such action would likely damage or destroy any fixed object in its path.

Although wave action is restricted in the arctic environment, ice may play an important role in reworking the contaminated sediments as broken ice is moved within the littoral zone (Owens and McCann, 1970). This would act to reorganize the oil and beach material but would do little to clean the beach. Biodegradation is particularly slow in this environment, so that the oil on a beach would be expected to remain much longer than in more temperate areas.

7.4 Concluding Remarks

The coastal zone is an extremely complex environment, being at the interface of land, sea and air. The processes which operate within this zone are numerous and not fully understood. Any one segment of coast is the result of a series of interactions which involve a great number of variables and should any one of these variables be altered significantly, this may lead to a trend towards a different equilibrium situation which will satisfy the new process demands.

Although the coast is largely a response to the active processes of winds and waves, its form and nature closely affect these processes. Beach slope, material size, and sediment supply, for example, are critical factors in assessing longshore movement and beach nourishment. The construction of groynes, jetties and other harbour facilities has led, in the past to unexpected alterations of the adjacent coast due to the generation of new and the adjustment of existing processes, resulting in a different process-response environment. A great deal of research has now been carried out in this area and coastal engineering is regarded as a field of study in its own right. In general, work has been concerned with the construction of artificial shorelines, but outside of a few isolated examples little is known of the effects of sediment removal. In one documented case, referred to earlier (page 17) beach material was used for construction purposes and this was followed by a shoreline recession of 20 feet in 50 years. This example is in an area where there is no present-day supply of sediment. The beach, once deprived of sediment, could not be replaced and this "demonstrates most effectively how dangerous it is to tamper with a beach, how wrong it is to make assumptions about the drift of beach material without a full investigation and how important it is to study each part of the coast intensively and not apply general ideas too readily." (Steers, 1964).

Regional studies of Canada's coastline should be undertaken to determine the features and character of different shoreline units. A knowledge of our coasts is essential if adequate contingency plans are to be formulated. During restoration projects, geologists should be consulted to assist in the planning and operation of programmes in order to take into account local shoreline and beach conditions. In particular, the selection of beaches to be restored and the application of the various restoration methods should be carefully considered.

The role of the coastal geomorphologist or geologist is to make the planners aware of the possible effects of a beach restoration operation. Detailed analysis of a shore area requires time, particularly to determine seasonal as well as long term changes. For this reason, the preparatory work necessary for the provision of adequate information for decision making, should be carried out before a spill occurs. If this type of research is not undertaken, it will be possible to provide only a cursory assessment of the coastal environment based on a qualitative judgement. The function of the geologist in this type of operation is a very important one, but one which should be ahead of, as well as working within, the operation.

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See also

Report of the Task Force - OPERATION OIL to the Minister of Transport:

Volume I - Report of the Task Force

Volume II - Report of the Scientific Coordination Team to the Task Force

Volume III - Reports of Other Units to the Task Force.

Ministry of Transport, Ottawa. 1970.