GEOLOGICAL ASPECTS OF THE BEACH RESTORATION PROGRAMME IN CHEDABUCTO BAY, NOVA SCOTIA, 1970.

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1. INTRODUCTION

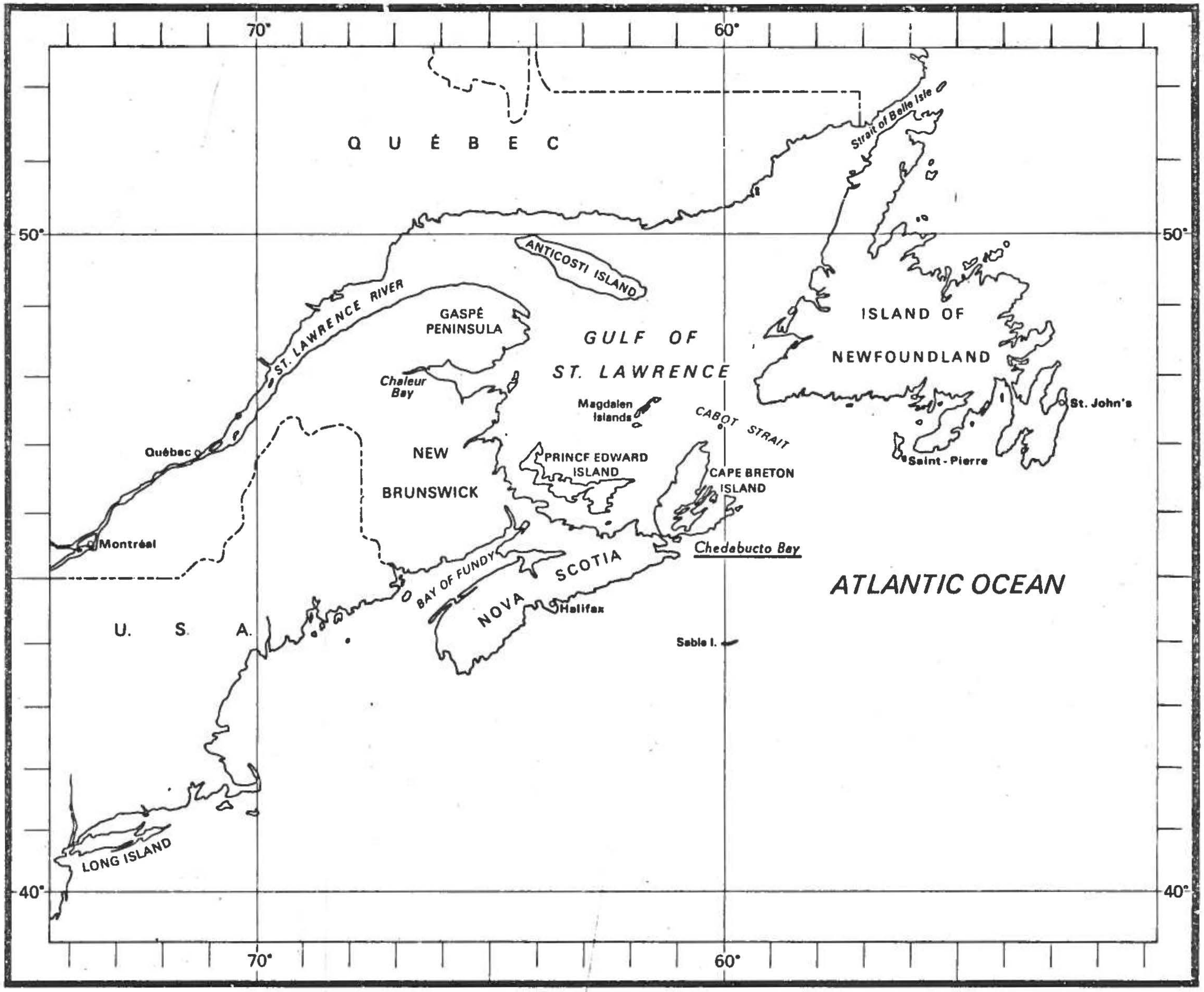
Following the wreck of the tanker "Arrow" on February 4, 1970, the oil spill of Bunker C affected more than 150 miles of shoreline in Chedabucto Bay, which has a coast of 245 miles from Point Michaud in the north-east to Cape Canso in the south-east (Figures 1 and 2). The Project Oil Task Force initiated a beach restoration operation and a total of 24 miles of coast was selected for the work programme which was carried out by the Department of Public Works during the period April to August 1970. In April a coastal geomorphologist was assigned to aid the restoration project and this report is the result 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. By definition this report is concerned primarily with the geological problems rather than the social or economic factors, though these are discussed in the final section. Most of the investigations were of a qualitative nature though some data collection was fitted in 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. No satisfactory mechanical methods were available for the restoration of cobble and shingle beaches though sand beaches were cleaned by manual and mechanical methods with success. The lack of success can be attributed to the fact that it was not possible to remove all the contaminated material from the polluted cobble beaches and the movement of oil alongshore and offshore led to the recontamination of several of the restored beaches.

Figure 1.

Location of Chedabucto Bay



70°
60°
50°
40°
QUÉBEC
Strait of Belle Isle
ANTICOSTI ISLAND
ST. LAWRENCE RIVER
GASPÉ PENINSULA
GULF OF ST. LAWRENCE
ISLAND OF NEWFOUNDLAND
Chaleur Bay
Magdalen Islands
CABOT STRAIT
St. John's
Québec
NEW BRUNSWICK
PRINCE EDWARD ISLAND
CAPE BRETON ISLAND
Saint-Pierre
Montréal
Chedabucto Bay
BAY OF FUNDY
NOVA SCOTIA
ATLANTIC OCEAN
Halifax
U. S. A.
Sable I.
LONG ISLAND

Figure 2.

Locations within the Work Area

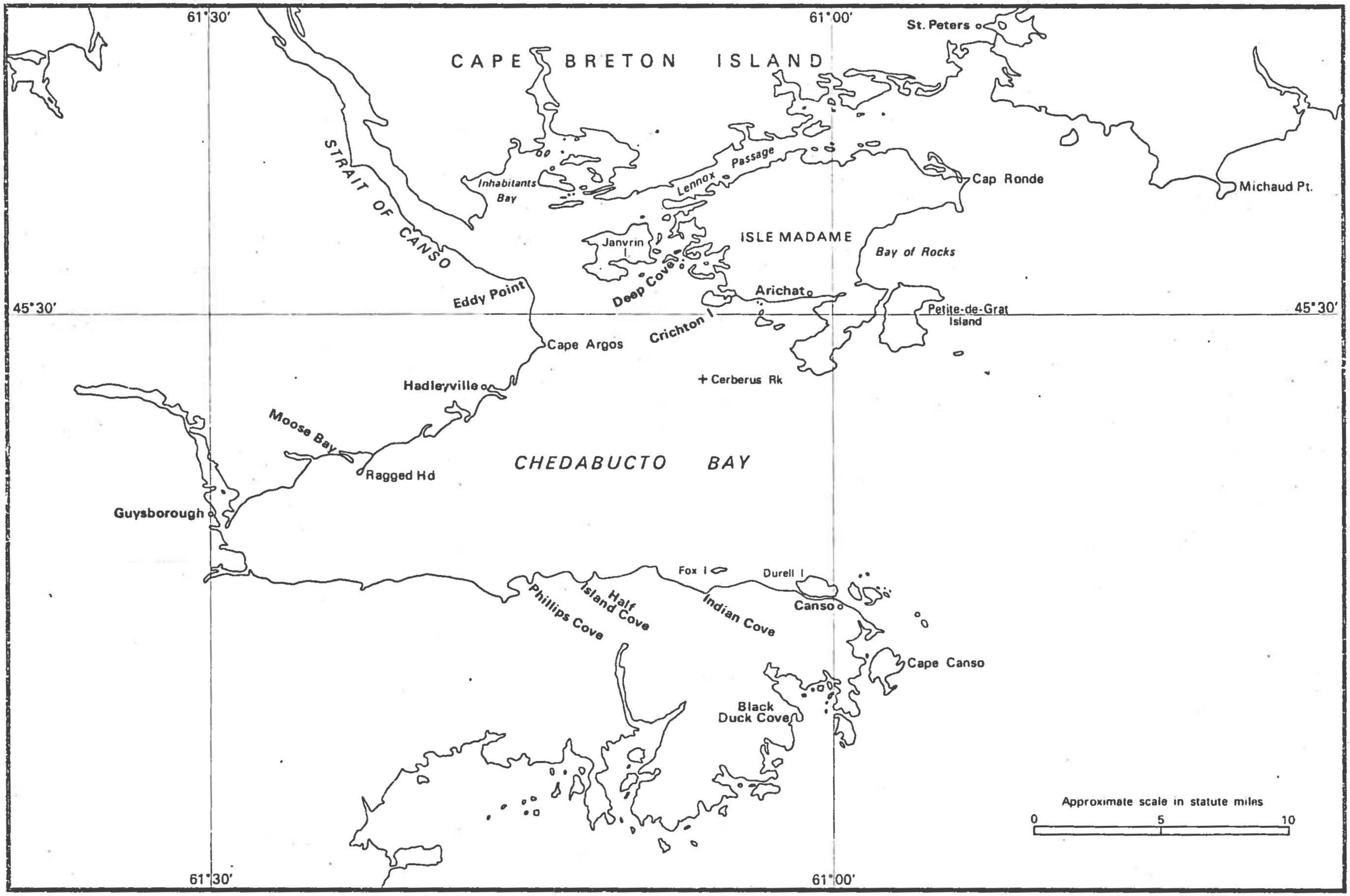


Fig. 1 Location Diagram

2. PHYSICAL BACKGROUND

2.1 Solid Geology

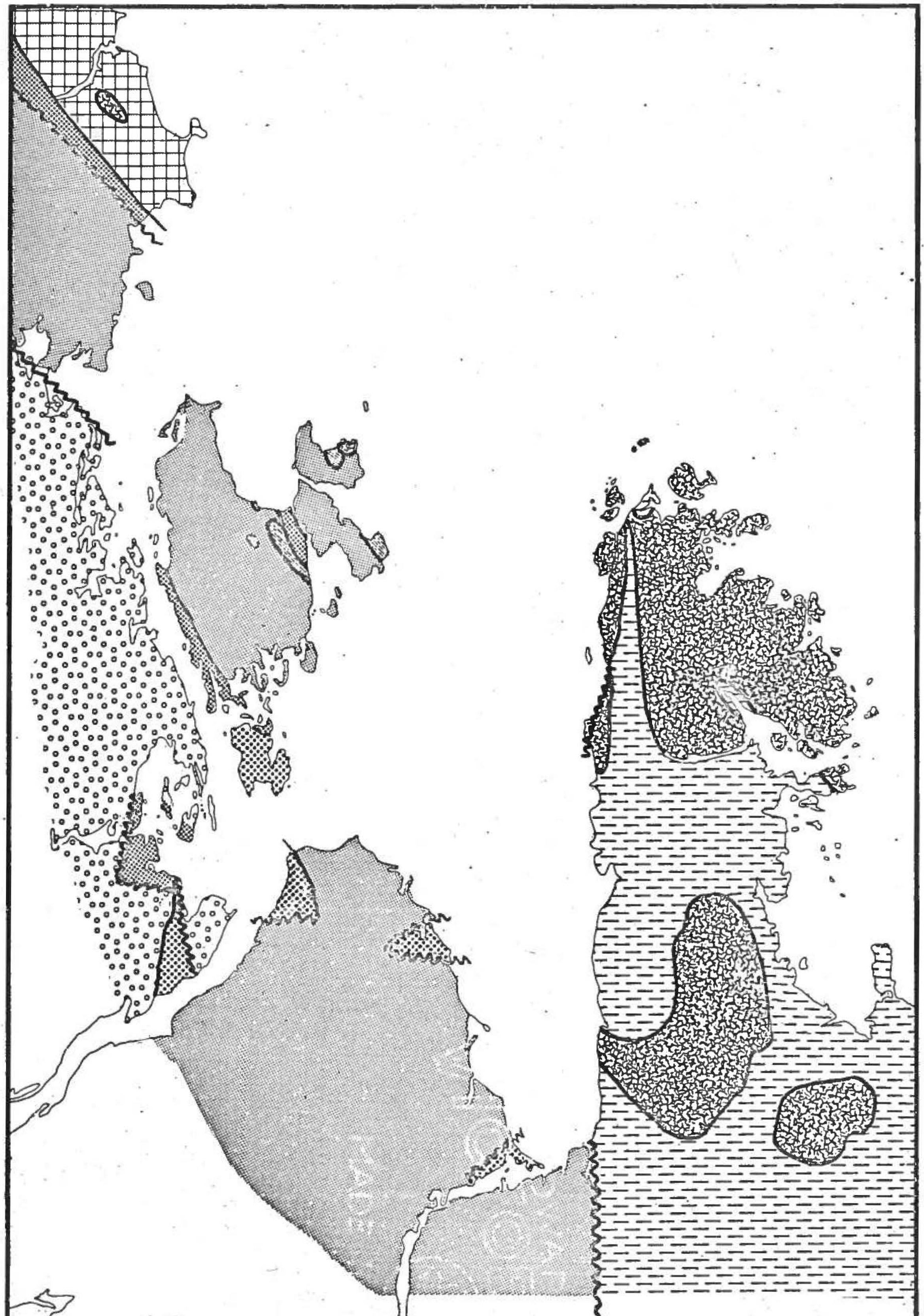
The major structural feature of this region is the Chedabucto fault or fault zone which separates the resistant metamorphosed rocks of the Meguma group in the south from the relatively less resistant late Paleozoic sediments which lie to the north (Figure 3). The fault zone defines the south shore of the Bay and can be traced eastwards onto the Nova Scotian shelf (Figure 5).

The Ordovician Meguma group is made up of tightly folded quartzites and slates which have been intruded by Devonian granites. This uplifted peneplain slopes gently southwards giving an indented shoreline which is in marked contrast to the long straight coast of the fault zone.

The Carboniferous rocks which characterize the area north of the fault zone are relatively less resistant conglomerates, sandstones, shales, and limestones which have been folded and metamorphosed. A clear example of the general north-east/south-west fold axes is given by the Lennox Passage shoreline and adjacent islands. The erosion of these late Paleozoics has led to the development of an undulating lowland area which has been drowned to produce an irregular shoreline.

Figure 3.

Solid Geology



2.2 Surficial Sediments

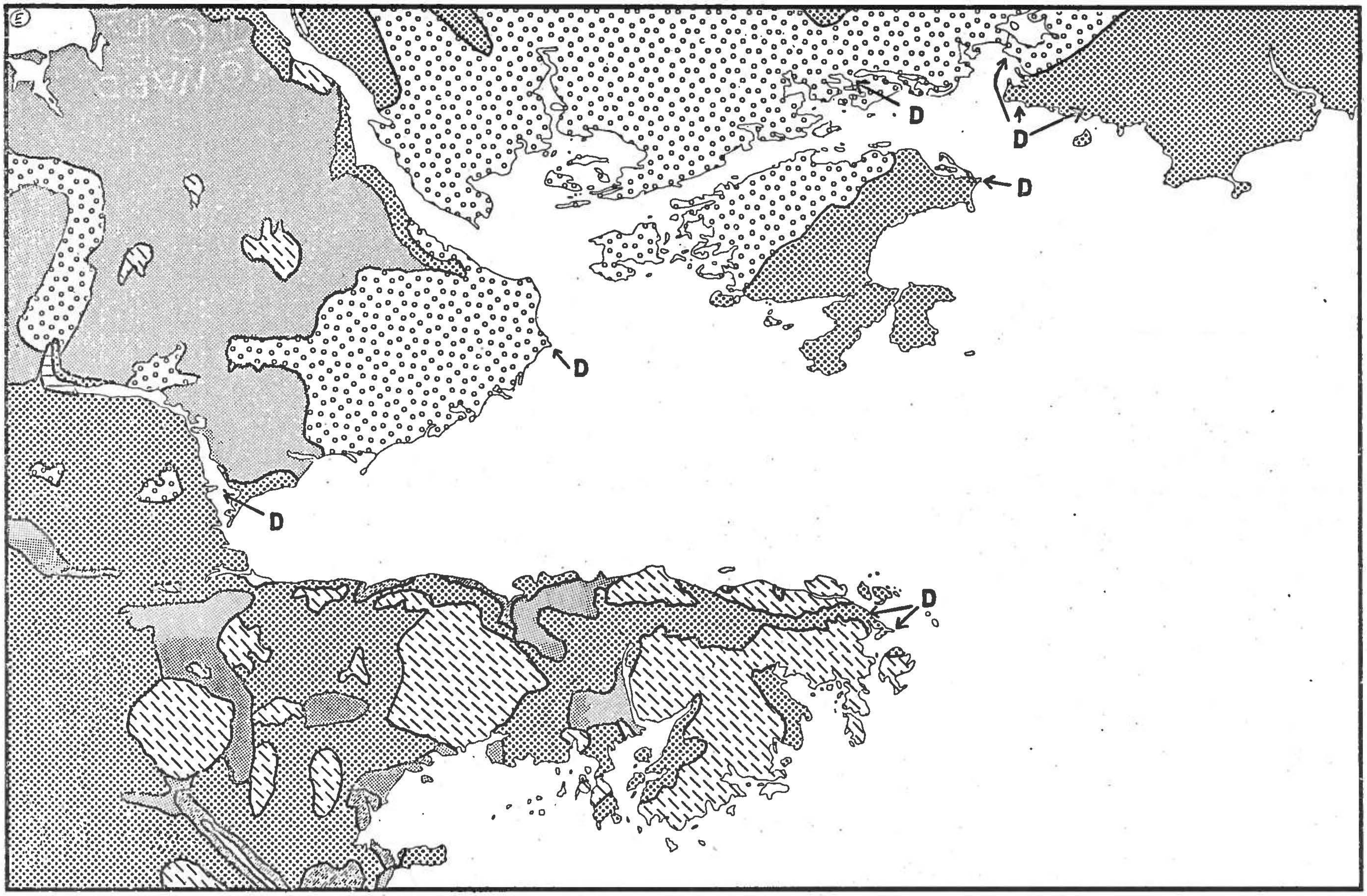
The areas of bedrock exposure (Figure 4, unit 5) are confined largely to the more resistant uplands south of the fault zone. Where sediments are present in this area they are often very stoney and not deep. The remaining areas west of the Strait of Canso have a cover of locally derived glacial till with a few local deposits of outwash material (unit 4) or post-glacial alluvial sediments (unit 6). These latter units account for less than 3% of the land area (Hilchey, Cann and MacDougall 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 thin 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. The broad direction of ice movement was north-south, though there are indications of an east-west trend on Isle Madame. Little work has been carried out on the glacial history of the region but Goldthwait (1924) describes several drumlin locations (Figure 4 and Photograph 38).

Figure 4.

Surficial Sediments


D
D
D
D
D
D

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 I). The tidal range is an important characteristic of the beach zone as the width of the intertidal area affects the amount of beach over which wave action can take place.

This is a storm and swell wave environment and the shore is exposed to the full force of these waves from the east and south. The 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 the beach orientation is often a reflection of the offshore topography.

Table I

Tidal Ranges in Chedabucto Bay

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.I

Tide and Current Tables, I970,
Canadian Hydrographic Service.

3. THE COAST OF CHEDABUCTO BAY

The basic coastal trends are structurally controlled whilst the actual detail of the shoreline results from the erosion and submergence of the fault block. Grant (1970) estimates that submergence is taking place at a rate of about one foot 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.

3.1 South Shore

The south shore of Chedabucto Bay between Canso Town and Guysborough is a straight, steep coast with a narrow offshore shelf (Figures 5 and 6). This is a resistant 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 Town 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.

Figure 5.

Topography and Bathymetry

- Cerberus Rock is marked x
- land areas tinted
- heights in feet, depths in fathoms

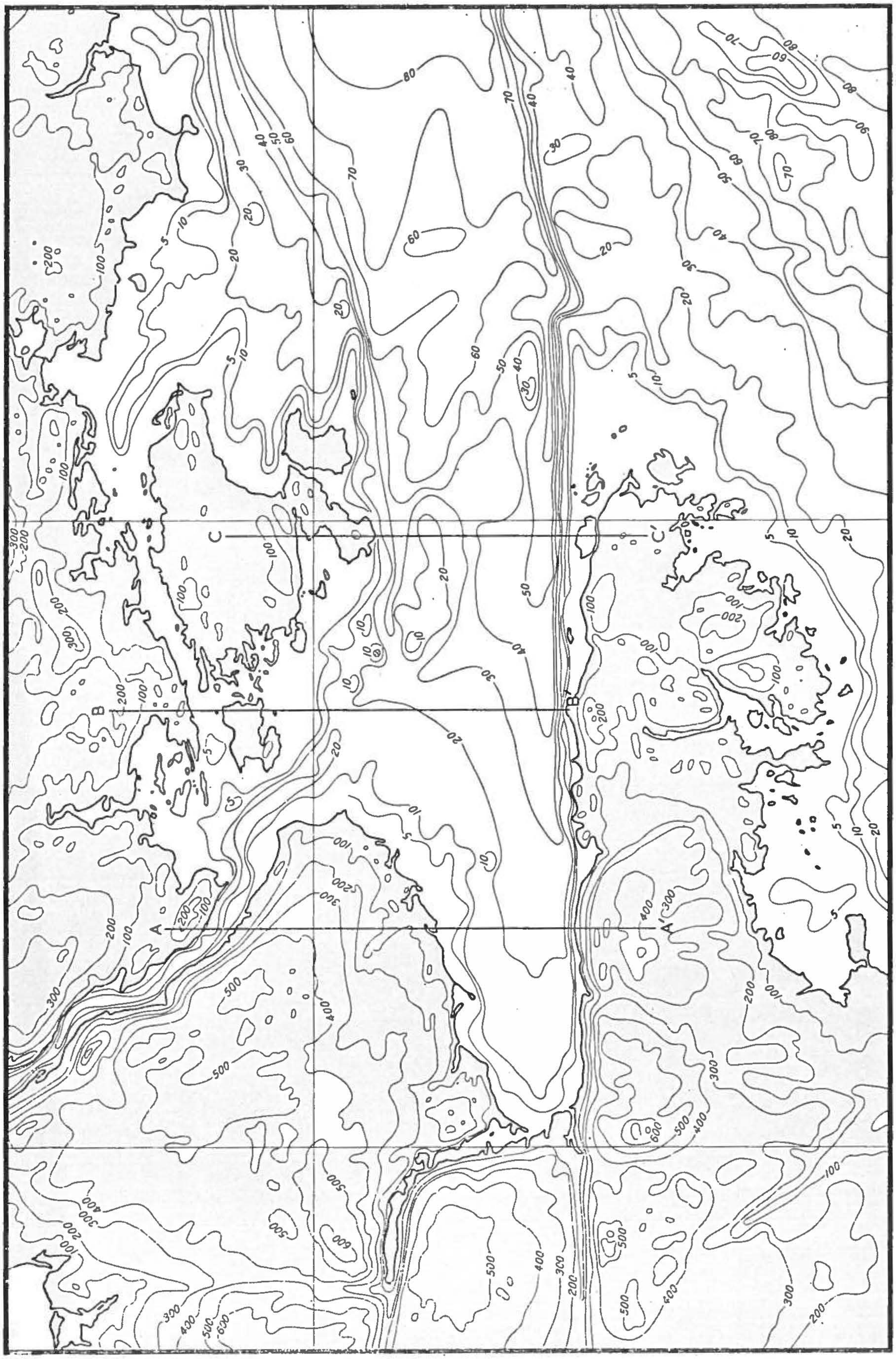
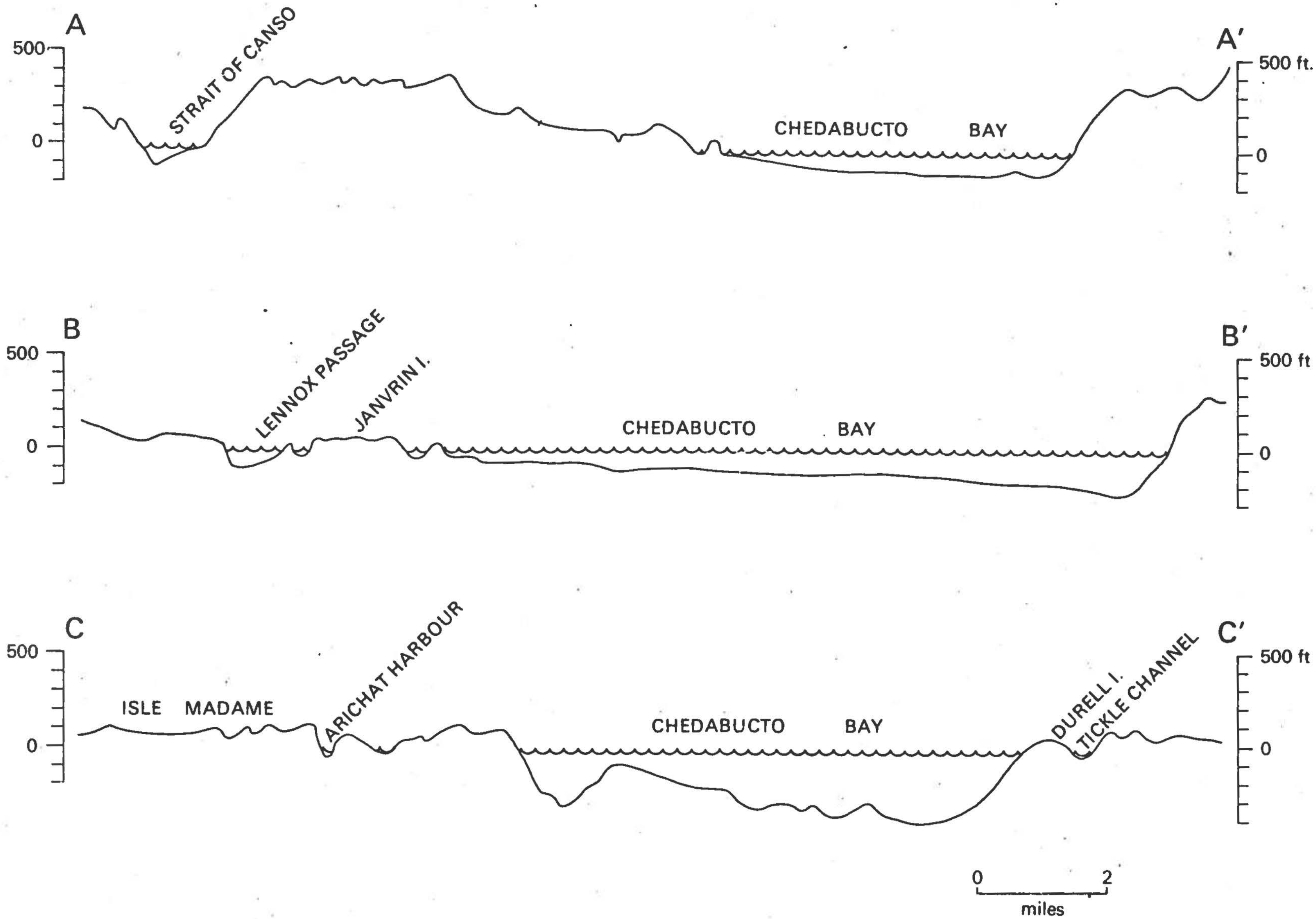

A
A'
B
B'
C
C'

Figure 6.

Profiles across Chedabucto Bay

(Location of Profiles given in Figure 5)



A
A′
500
0
500 ft.
0
STRAIT OF CANSO
CHEDABUCTO BAY
B
B′
500
0
500 ft
0
LENNOX PASSAGE
JANVRIN I.
CHEDABUCTO BAY
C
C′
500
0
500 ft
0
ISLE MADAME
ARICHAT HARBOUR
CHEDABUCTO BAY
DURELL I.
TICKLE CHANNEL
0
2
miles

Occasional pocket beaches and spits interrupt this pattern but otherwise this area is an excellent example of a submerged resistant lowland. More sediment is available for reworking in the littoral zone than along the south shore of the Bay as material has been moved onshore from the shallow offshore areas, but in both cases there is a general scarcity of beach sediments.

3.2 West Shore

Between Guysborough and the Strait of Canso the uniform south-east slope of the subaerial and submarine topography (Figure 5) gives rise to a relatively straight shoreline. Few bedrock exposures occur and the coast is made up of actively eroding till cliffs (Photograph 38) and wide shingle beaches (Photograph 21).

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 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 drift 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 eorded material, but if the beaches are wide and there is a large sediment build-up erosion is unlikely. In an attempt to develop an equilibrium shoreline beaches have built up across river exits and lowlying areas whilst erosion is active where there is higher relief along the shore. This area is evidently in the early stages of adjustment as erosion still characterizes much of the coast.

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 an example of a drowned river. It flows into Inhabitants Bay which was presumably 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 result from 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 shore. 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, 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 indicate longshore drift, so that normal processes are active but at a reduced scale.

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. To the north, in the Bay of Rocks, this gives way to a series of wide sand and cobble beaches. Similarly 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

With a few exceptions, in the north-east part of the Bay, the beaches consist mainly of cobbles and boulders. The larger sized sediments are thrown up by wave action onto the higher parts of the beach to form a storm ridge. When these investigations commenced in April the steep winter profiles characterized most areas but by July this had been replaced by the more gently sloping accretional summer profile. With this change came a marked increase in the amount of coarse sand and gravel in the intertidal zone (Photograph 16 and 25). Sand beaches were restricted to the Bay of Rocks, Point Michaud, and Black Duck Cove area, all at the eastern end of the Bay. These are all 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 where sediments have been moved landwards over the wide offshore zone as sea level has risen since the Pleistocene. These beaches are supplied with little coarse material under present conditions. The sheltered areas along the north shore have a limited sediment supply and are in a low energy wave environment.

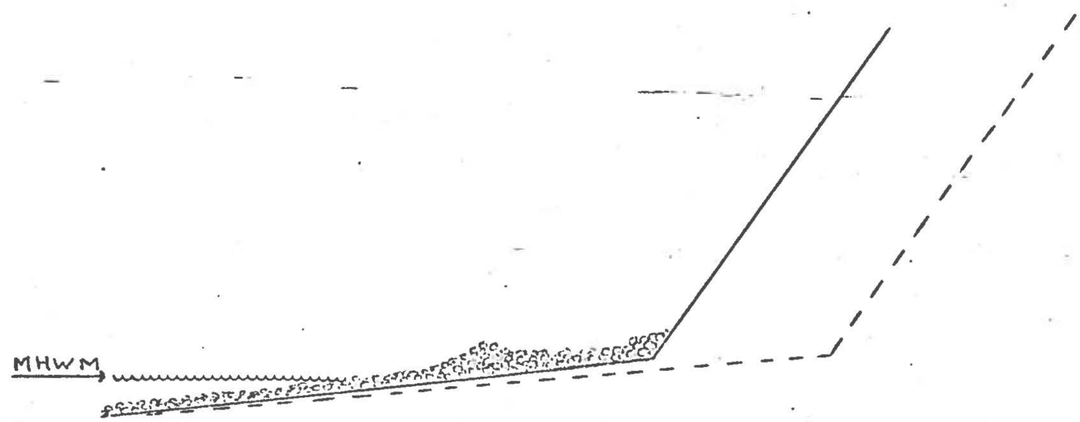
4. SHORELINE STABILITY

"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).

As coarse beach sediments, larger than 3 inches, are derived largely from the offshore zone in this region, any sediment loss must be equated with the capability of natural replacement. Under normal conditions material of this size does not move into the littoral zone from offshore, the sediments now in the beach area have been moved landward with the rise in sea level. Thus the supply of coarse material under present conditions 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 38). 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 has led 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 if this material is removed 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 a lowering of the level of the till platform follows which in turn would lead to a temporary acceleration of cliff retreat as erosion of the free face attempts to reach an equilibrium condition.

Those till cliffs which have wide beaches at their base are not 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 were involved to the extent that marine processes would 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, and removal of the beach which fronts these cliffs will have the same effect as on more exposed shores.

4.2 Beaches

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

The beaches of this region are made up largely of cobbles and shingle which are not being supplied by present processes. These sediments are being eroded, reworked and transported as the shore strives towards the equilbrium which the processes demand. Although sand and fine sediments are fed into the littoral zone, particularly during the summer months, these are not a major contributor to the growth of beaches and large constructional features, except for some 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 occured in a similar environment 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 areas 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).

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 naturally. 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

Figure 7.

Profiles at Hallsands, U.K.

(reproduced from Robinson, 1961)

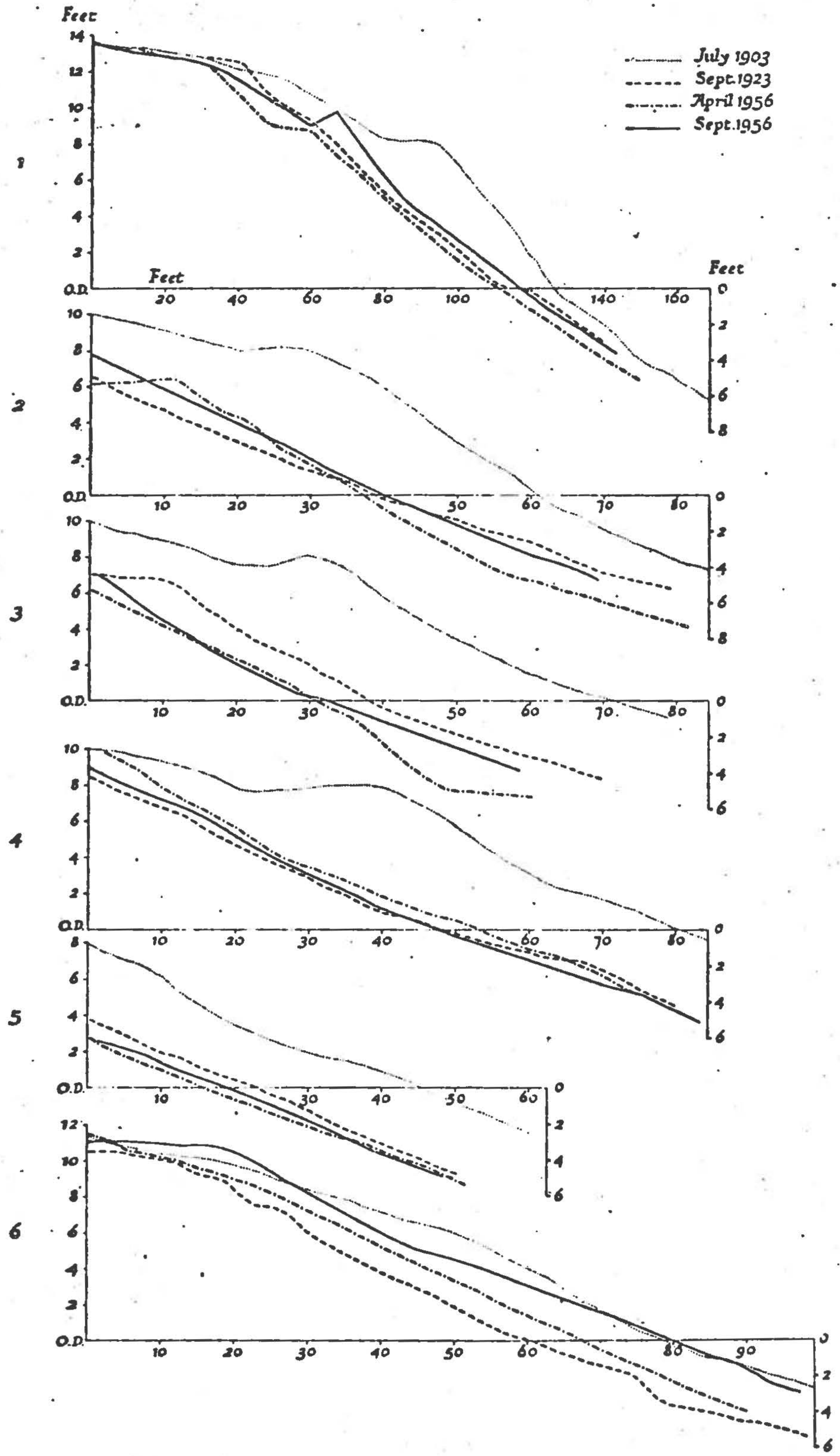


Fig. 8. The changes in beach profiles along Sections 1–6 between 1903 and 1956. Vertical exaggeration for Section 1 is 1:5 and for remainder 1:2·5

(reproduced from Geographical Journal, 1961, vol. CXXVII,1.)

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.

Whilst 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 profile. The storm ridge, or the sand berm, is built above the normal high water mark. Lost material 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 (Photographs 25 and 37).

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 thus 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, Crichton, Jerseyman, 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

Figure 8.

Distribution of Oil on the Coast

(Cerberus Rock is marked x)

x - Cerberus Rock

light and not continuous. The shore of the east section of Lennox Passage was not polluted following 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 severly polluted whilst 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 oiling 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.

(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 30) whilst 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 28) 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, whilst in protected areas the beaches remained polluted. This is particularly evident in photographs 5 and 6 of Black Duck Cove. The lagoon remained heavily polluted throughout the summer whilst 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 normal high water mark (Photographs 29 and 40). Although oil polluted much of the upper part of the intertidal zone, wave action is continuously active in this zone. Any oil laid down above mean high water mark would remain undisturbed by normal processes but 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 28)

Exposed beaches are generally capable of self-cleaning 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 example, were paralyzed by a combination of both these factors whilst 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 size range of 1 to 6 inches. Other samples were collected but the analysis of these is not yet complete.

5.3 Previous Beach Restoration Projects

The only project prior to 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 dispersants and the wide, firm, sandy California beaches are very different from those in Nova Scotia.

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 (1968 a,b; 1969). 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.

(i) 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.

(ii) 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.

(iii) 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.

(iv) Mechanical Removal. This 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 excavating or earth moving equipment, but this was elaborate, sometimes expensive, and not always successful.

(v) Manual Removal. Effective on most beaches but expensive because of labour costs. Techniques include raking, shovelling and spreading absorbant materials.

(vi) 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. <u>Marshes</u>. Manual removal would be best but burning may be effective during the non-growing season. However, unless the oil is thick it would be best to leave, so that the marsh could recover naturally.

b. <u>Mud Flats</u>. Although these areas preferably would be left alone, if restoration were necessary mechanical scraping or dispersants could be used for thick deposits.

c. <u>Sand</u>. Again it would be best to leave to natural processes if possible but if action were 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. <u>Shingle</u>. 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. <u>Rock</u>. These areas are best left 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 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.

1. <u>Grader/Scraper</u>. 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 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 was lost if traction was low.
2. <u>Scraper</u>. Used on its own the scraper had a high spillage and, like the grader, it required a flat beach and became stuck easily.
3. <u>Grader/Front-end Loader</u>. The loader was used to remove the wind-rows, its performance in general is outlined below.

4. 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 defficiencies apply to bulldozers and tracked loaders and bulldozers were found to "grind the oil several feet into the sand".

5. Ramp-Conveyor System. This 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 from the outset. The conclusions from the work in Britain indicate that natural cleaning is best but even if restoration is unavoidable shingle beaches were not cleaned properly by machines alone. The evaluation project by the FWPCA indicated that the grader or bulldozer were the least efficient of the earth moving equipment tested. The performance was particularly bad if the vehicle had tracks as it mixed clean and contaminated sediments 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 is 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 beach areas (see Section 6.4.i., page 43).

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 (see Section 6.4.iii., page 51).

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 beach at Deep Cove in an attempt to clean this beach (Photographs 34 and 35). It was estimated that some 3000 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.

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, 24 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" (see Section 6.3., page 39) whilst contracts were drawn up for the restoration of heavily contaminated sections and 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 so that 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.

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 Department of Public Works supervision, removed oil and contaminated material with shovels and rakes (Photograph 41). 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 by this method 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 not removed manually as it was buried would probably not be exposed until the fall or winter when the beach is combed down under vigourous wave action. This uncovered 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 which was followed closely. In addition there is a more general report on other beaches where machinery was used. Not all of the sites which were contracted or where machinery rental was used are dealt with but the operations which are reported cover a representative cross-section of the shoreline areas in Chedabucto Bay where restoration projects were carried out. The location of most of the sites reported here is given in Figure 2.

(i) ARICHAT

The contract for a 3,700 feet section of beach was awarded to a low bid of $4,579. 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 the Noir Forge.

Description of the Contract Area

This is a sheltered location not exposed to the direct action of waves from the Atlantic. The tidal range is in the order of 4 to 6 feet (Table I). All of the contract area was badly oiled and the beach zone was effectively paralysed, that is, the 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 the Noir Forge the shore is characterized by a 20 to 25 foot till cliff (Photograph 3). The width of the beach zone averages 40 foot at low tide and is made up of sediments derived directly from the subaerial and marine erosion of the cliff. These sediments were 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 would be 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 the Noir Forge (Photograph 3). This appears to have resulted from the prevention of longshore sediment transport by the small headland on which the Noir Forge was constructed.

3. The Noir Forge headland is a till bedrock area which has a beach of till-derived material at its seaward end (Photographs 1 and 3). 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 (Photograph 1). The bars have been built out on a shallow platform which has a maximum width of about 60 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.

Restoration

This was the first of the contracts to be issued and work began on April 30. Contaminated material in the intertidal zone just to the west of the Noir Forge was heaped into piles and a "road" was bulldozed along high water mark westwards toward the wharf (Photograph 3). Some concern over the action of the contractor was expressed at the evening meeting and it was decided not to remove any material beneath the cliff west of the 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. The contaminated material which had been piled up on the beach adjacent to the 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 the 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 it was decided to remove and replace a section by the 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 (Photograph 2) 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 whilst progressively moving westwards.

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 harmful to the beach zone.

(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 bedrock 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 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 (Photograph 1), whilst the oil was redeposited in thin layers near the high water line (see Section 5.4., page 35). This 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 the 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 the Noir Forge promontory some 20 cubic yards of material was removed. This exposed the till bedrock 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 the Noir Forge which should have been relatively easy 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 edges of the blade contributes to the inefficiency of this method as this material must be removed by a subsequent pass but is often ground in by the tracks of the vehicle. The only way in which the bulldozer could operate was to pile up material for removal by other equipment and this tends 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 sections, as well as from offshore, can lead to reoiling. All of the areas 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 and the intertidal zone is now largely oil-free. 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.

(ii) BLACK DUCK COVE

The contract for this 4,600 feet section of coast in the north and north-east of the Cove (Photograph 5) was awarded for $6,000. The operation required 9 days between April 30 and May 12, 1970 using a fixed-blade Caterpiller D6C bulldozer and a Caterpiller 950 wheeled front-end loader. A total of 4,460 cubic yards of material was removed and 360 cubic yards of clean boulders were brought in along the north shore.

Description of 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 had mixed with sand and seaweed to form large cakes in the intertidal zone, though some self-cleaning had taken place (Photograph 7).

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

Restoration

The contractor commenced work on April 30th, on 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 (Photographs 8 and 9). Some concern was expressed over possible damage to the backshore vegetation by the machinery and the contractor maintained one track for the trucks.

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 (Photograph 10).

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. The heavily polluted lagoon at the west end of the Cove in particular released more of its oil throughout the summer and this was transported along-shore towards the beach by incoming waves (see Section 5.4., page 35).

(iii) INDIAN COVE

(Fox Island Main)

This 850 feet of beach was contracted for $2,000 and involved four days work between May 15 and May 20, 1970. A Caterpiller 950, wheeled, front-end loader removed 1,368 cubic yards of beach material during this period. The amount 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 thin caked layer 10 feet wide, for almost the entire length of the beach (c.f. Photograph 29).

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 (Photograph 11).

By May 25, the eastern 300 feet had been badly reoiled in the high water mark zone, from the adjacent oiled rock areas (Photographs 12 and 13).

On May 11 to 13, a bulldozer with a front bucket was rented to re-clean the beach (Photograph 14). 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 (see Section 5.4., page 35).

Beach Profiles

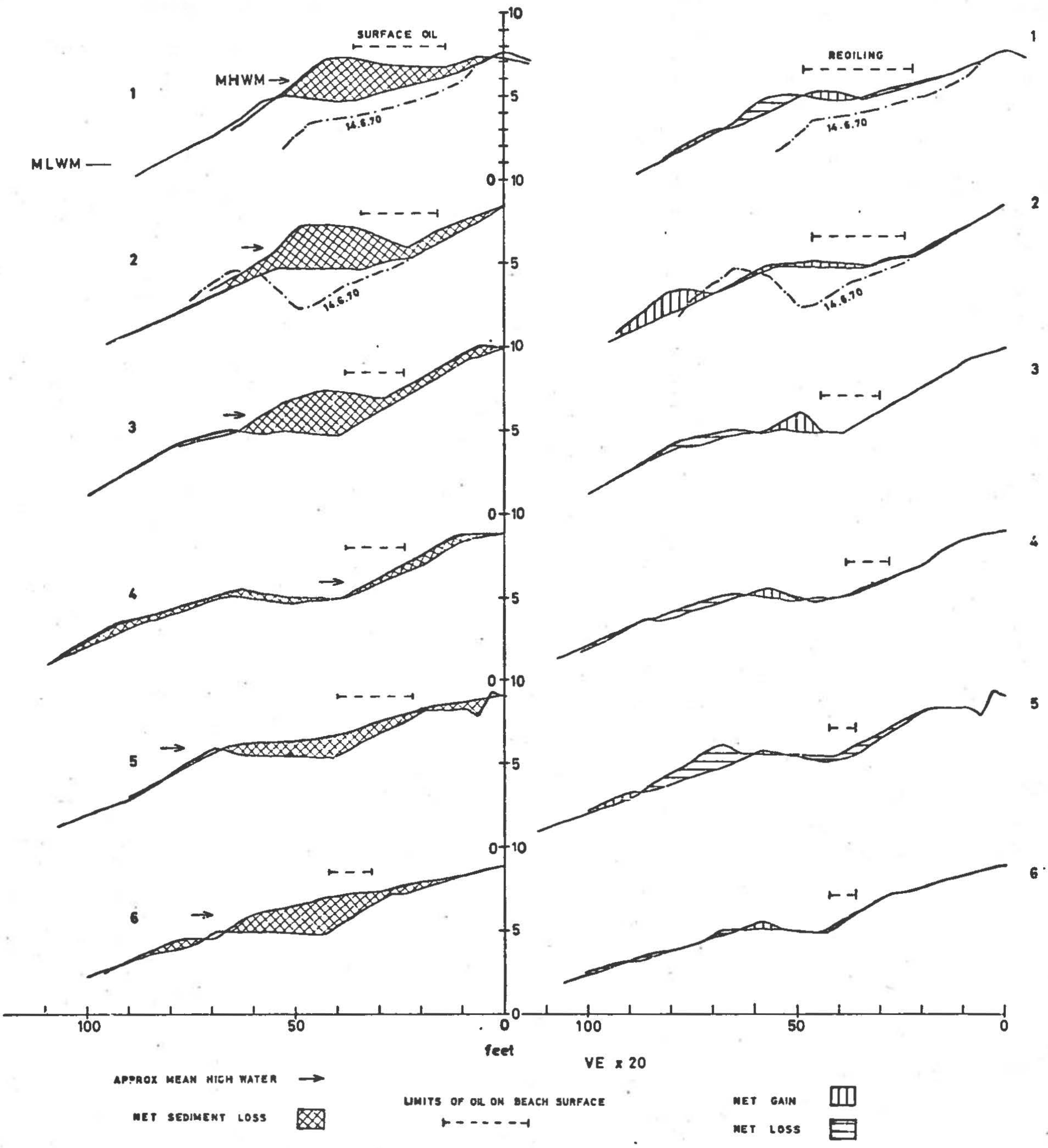
To provide some measure of the effects of sediment removal the beach was surveyed by 17 levelled profiles on May 14, 21, 29, and June 14. Six of these profiles are presented in Figure 9.

The first set of profiles (A) were taken immediately before and after the contract work in order to ascertain the distribution of sediment removal across the beach. The limits

Figure 9.

Profiles at Indian Cove

(profiles numbered from east to west)



A. 14.5.70 and 21.5.70

B. 21.5.70 and 29.5.70

INDIAN COVE (Fox Island Main)

of the thick, continuous layer of oil on the beach are shown 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 (see Section 4.2., page 23), this part of the beach is not a zone of accretion except during periods of storm waves or spring tides. Sediment replacement is, therefore, not rapid in this zone.

The second set of profiles (B) compare the situation immediately after restoration and just over one week later. Some sediment build-up took place near the high water mark but this was accompanied by reoiling which led to further sediment removal as shown by the June 14 profiles.

Parts of the east end of this beach lost as much as five feet of sediments. This is indicated on profiles 1 and 2 of 9A which show the beach on May 14 and June 14. Whether this material will be replaced is not known and these profiles are to be resurveyed to determine the long-term effects.

<u>Effectiveness and Results of Operation</u>

(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.

(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 (Photograph 26). 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 during a period of spring tides within 4 days as oil was released from pools and cracks in the adjacent rock areas (Photographs 12, 13, 14). 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 (see Section 5.4., page 35).

(f) The oil deposited on 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, as was demonstrated by the fact that this beach was reoiled several times.

(iv) HALF ISLAND COVE

This 1500 feet section of beach was restored during a six day period between May 26 and June 15 at a cost of $3,000. A Caterpiller 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 whilst 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 (Photograph 15). The next 400 feet is a ridge, some 120 feet wide, which has a lagoon in the rear.

The central 200 feet was excluded from the contract. This consists of a bedrock, boulder, and shingle zone, backed by a 5 foot active till cliff.

The westerly 400 feet is 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-ride zone seawards for almost 100 feet.

No oil patches were visible on the surface. All the contaminated material had been reworked by wave action. In parts this had been buried to a depth of three feet. The rock platform just to the east of the contract section is badly oiled and much of this has 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. This machine requires a firm flat, or low angle, surface. Whilst it was able to work with some efficiency along the flat crest of the ridge it was in difficulties on the low beach face slope (Photographs 18 and 19). As has been reported elsewhere (see Section 5.3., page 33) 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. As this did not prove acceptable he returned and removed more beach material. There still remained a great deal of contaminated sediments after the contractor was released (Photographs 16 and 17). The only way in which the method employed could succeed would be to remove most of the upper sections of the beach without spillage. This is both undesirable and impractical and it may lead 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.

(v) HADLEYVILLE #I

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

Description of Contract Area

This well developed prograding steep, shingle beach is one of several 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 material distribution is fines in lower zones and a shingle storm ridge above normal high water mark. The intertidal zone has a maximum width in the order of 100 feet in the central parts of this section.

The shallow offshore has allowed the beach to become orientated towards the dominant direction of 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 24). 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 material, above high water mark, 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 (Photograph 23).

Work was complete on June 11.

Beach Profiles

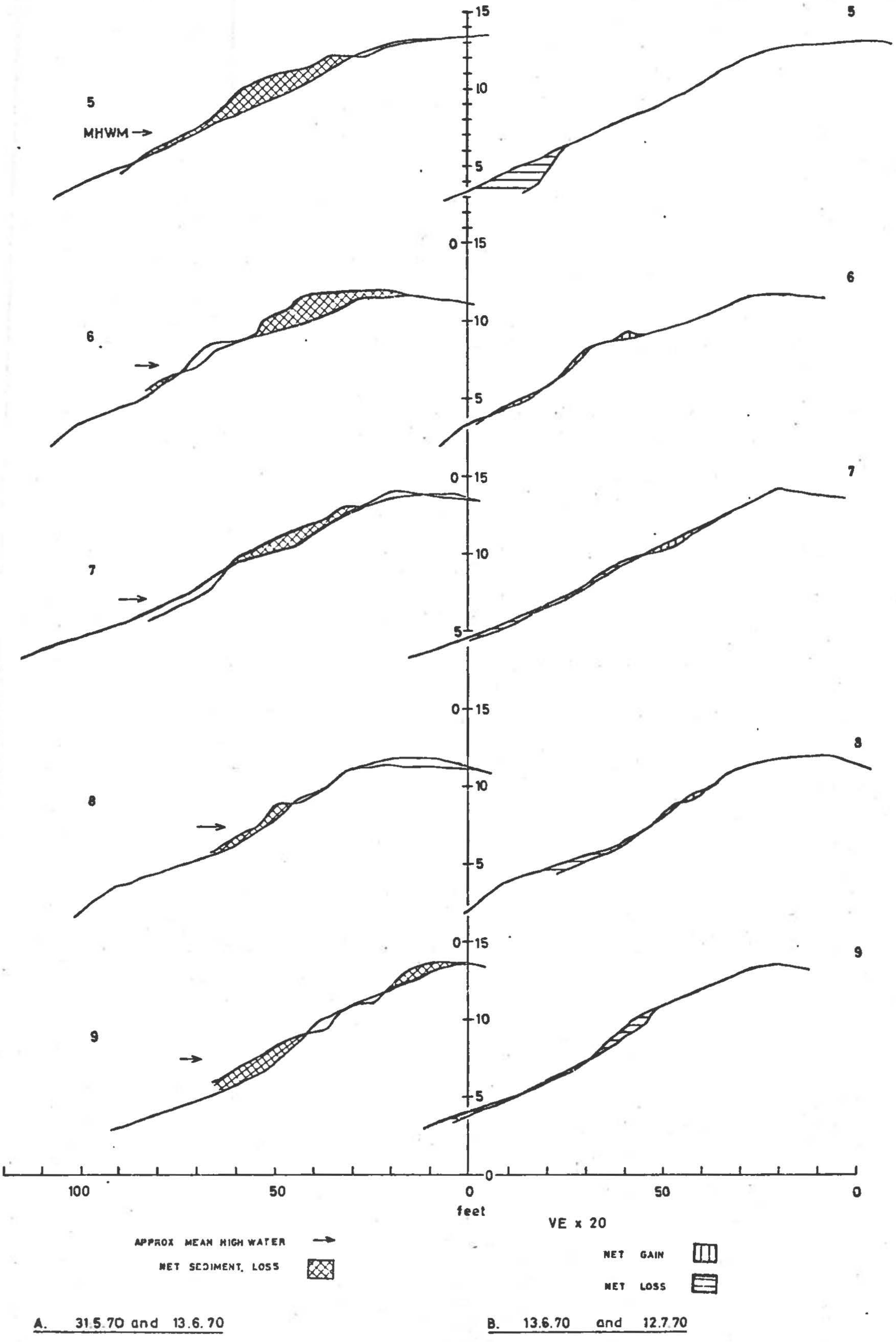
Ten profiles were surveyed across the beach on May 31, June 13, and July 12, 1970. Five of these profiles, from the central and east sections, are presented in Figure 10.

The "before and after" situation is given in Figure 10A 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 (Photograph 23). Profile 6 is an example of the removal of the storm ridge crest which is well above the limits of normal wave action.

Figure 10.

Profiles at Hadleyville #I.

(Profiles numbered west to east)



HADLEYVILLE

One month after completion of the contract (Figure 10B) very little material replacement had taken place even though the rate of accretion is at its maximum during the summer months. Small net gains of sediment near the high water mark were often offset by sediment loss within the intertidal zone.

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 (see Section 5.2., page 29).

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, Black Duck Cove or Indian Cove, this beach was not paralyzed and normal beach processes are 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, as this could lead to a breach. 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.

(vi) 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 20) (Johnson, 1925; page 363). The west half of this beach was restored manually (Photograph 21) whilst the eastern 5,000 feet was 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 #I in that the oiled material was deeply buried and in order to remove it several feet of sediments were excavated (Photograph 22). 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 considered less harmful to the beach as less uncontaminated sediment is removed. Although this method does not lead to the removal of all the buried material neither would the mechanical method because there is no adequate equipment available.

Hadleyville #II

This beach is distinguished from Hadleyville #I as it is a separate coastal unit to the east of the area discussed above (see Section 6.4.v., page 60). This beach area is little different from Moose Bay or Hadleyville #I but is included as a good example of the types of contamination which were experienced in the operation.

On the west end of this cobble beach oil on the beach was reworked, buried, and subsequently exposed (Photographs 27 and 28). In the central area a zone of thick oil up to 15 feet wide was left above the limits of normal wave action (Photograph 29). 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 30).

In recommending the application of restoration methods this area is a valuable example of how to deal with different situations using the methods available.

(i) The type of beach contamination in the west section represents a situation which is best left alone unless urgent requirements necessitate action. The waves have removed most of the oil by reworking and burial and the beach will 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.

(ii) The thick line 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 (see Section 6.4.iii., page 54). 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.

(iii) 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 easily 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 spring 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 31). The north-west shore is reported by the local inhabitants to be retreating at a rate of nearly one foot per year. As the upper part of the beach was covered with a continuous layer of oil it was decided to remove this and then replace it with clean rip rap which would serve as a protection against any erosion which may have been caused by the sediment removal. Profiles 1, 3, and 5 in Figure 11 were surveyed across this beach and show the effect of the restoration programme (see Photographs 32 and 33).

Along the south-east limb of the foreland the profiles 7, 9, 11, and 13 in Figure 11 show how the removal of buried oil again led to excavation in the zone above high water mark, the area where beach replenishment is least active.

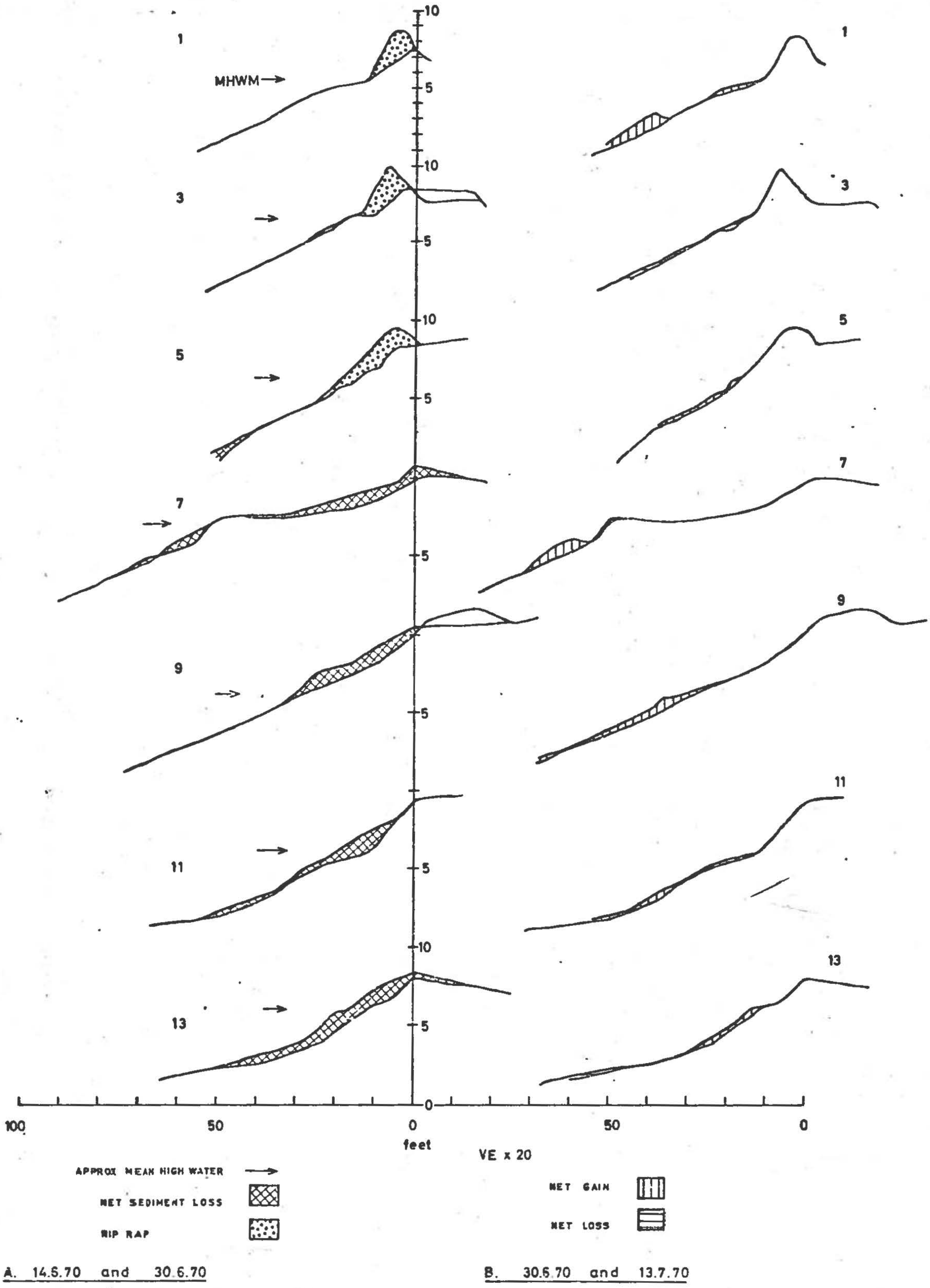
Deep Cove

Following the initial work on this beach (see Section 6.1., page 36) 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 (Photograph 36) 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.

Figure 11.

Profiles at Eddy Point

(Profiles numbered west to east)



MHWM
1
3
5
7
9
11
13
10
5
0
100
50
0
feet
50
0
VE x 20
APPROX MEAN HIGH WATER
NET SEDIMENT LOSS
RIP RAP
NET GAIN
NET LOSS
A. 14.6.70 and 30.6.70
B. 30.6.70 and 13.7.70

EDDY POINT

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 (Photograph 37) and the cut into the spit which resulted will not be filled by natural processes as it is not in the active beach zone.

Walkerville

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

This area near Walkerville on the north coast of Inhabitants Bay is in this sheltered area and has a very thin beach which overlies a till platform and is backed by low till cliffs. The surface layer of cobbles was paralyzed by the oil and this 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 39). With the removal of the surface layer of large material it is likely that the fines would be easily removed by any wave action.

In a situation like this it would be 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

a. Sand Beaches

(i) On lightly oiled sand beaches self-cleaning will take place but if necessary the manual removal of contaminated material with shovels and rakes is very efficient and effective. This method does not involve the removal of uncontaminated sediments (see Section 6.3., page 39).

(ii) 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. Although there will be spillage from this technique this can be removed manually. No beaches in this area were suited to the use of graders.

(iii) Sand beaches can be cleaned for recreational purposes as long as there is no danger of recontamination (see Section 6.4.ii., page 50).

(iv) 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.

b. Cobble and Shingle Beaches

(i) 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 (see Section 5.2., page 28).

(ii) 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.

(iii) Where oil lies on the surface of a beach it can be removed efficiently by a well-handled, wheeled, front-end loader (see Section 6.4.iii., page 54). Even in these situations there is spillage from the equipment but this could be picked up manually.

(iv) A lightly oiled or reworked beach with buried oil can only be restored by excavation methods. This often involves removal of 3 to 5 feet of sediments and this is usually taken from those areas above high water mark where natural replacement is slowest. (see Section 6.4.v., page 63). If the storm ridge or beach crest is in any way lowered attempts should be made to replace all the excavated material (see Section 6.4.vi., page 68).

(v) 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 arguement for large-scale beach excavation. The lesson from Hallsands is an important one (see Section 4.2., page 21).

(vi) 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 a lot of material is removed for very little oil.

(vii) 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 (see Section 6.4.i., page 47).

c. Recontamination

(i) No beaches should be cleaned if there is a danger of recontamination. This was evident in the instances where re-excavation was necessary (see Section 6.4.iii., page 56).

(ii) 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.

d. Machinery

(i) 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 to meet the requirements of this more delicate type of operation.

(ii) 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 (see Section 6.4.iii., page 54).

(iii) 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.

(iv) Ideally 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 more mixing with clean sediments takes place.

(v) 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 (see Section 6.4.ii., page 50).

7. DISCUSSION

7.1 Selection of beaches for restoration after a spill

Should coastal areas be 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 could be established. The decision as to whether these beaches would 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 by removal of sediment 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 should 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 zones or shingle ridges are virtually uncleanable, unless dispersants are employed, and in these areas piecemeal restoration of some beaches in the area 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 (Field Manual, Land Capability Classification for outdoor Recreation: Canada Land Inventory: Department of Forests and Rural Development; 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 hardly used except by a few members of the 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 beach for restoration should be based upon 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 a restoration project could be discussed in a regional study (see Section 7.2., page 78) 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 or 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 D.W. Johnson in 1919 but until field investigations were carried out during this operation this was the sum total of the available information on this coastal region. Some basic research on the nature of Canada's coasts should 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 on a reconnaissance scale 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. 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). Should oil pollute these coastal areas the natural self-cleaning processes would be 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 Black Duck 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 at least several years before it is degraded by natural processes.

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. This would act to reorganize the oil and beach material but would do little to clean the beach. Biodegredation is particularly slow in this environment so that the oil on a beach would be expected to remain much longer than in more temperate latitudes.

The restoration of arctic beaches will be dealt with in greater detail at a later date and the information derived from the work in Chedabucto Bay and from arctic beach studies will be applied to this problem.

7.4 The Role of Geologists in Beach Restoration Projects

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 new 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 of material 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 artifical 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 21) beach material was used for construction purposes and this was followed by a shoreline recession of 20 feet in 50 years. This example is 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).

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 has not been carried out it is possible to provide only a cursory assessment 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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A P P E N D I X

Photographs

(*) denotes Department of Transport Photograph

1. (*)

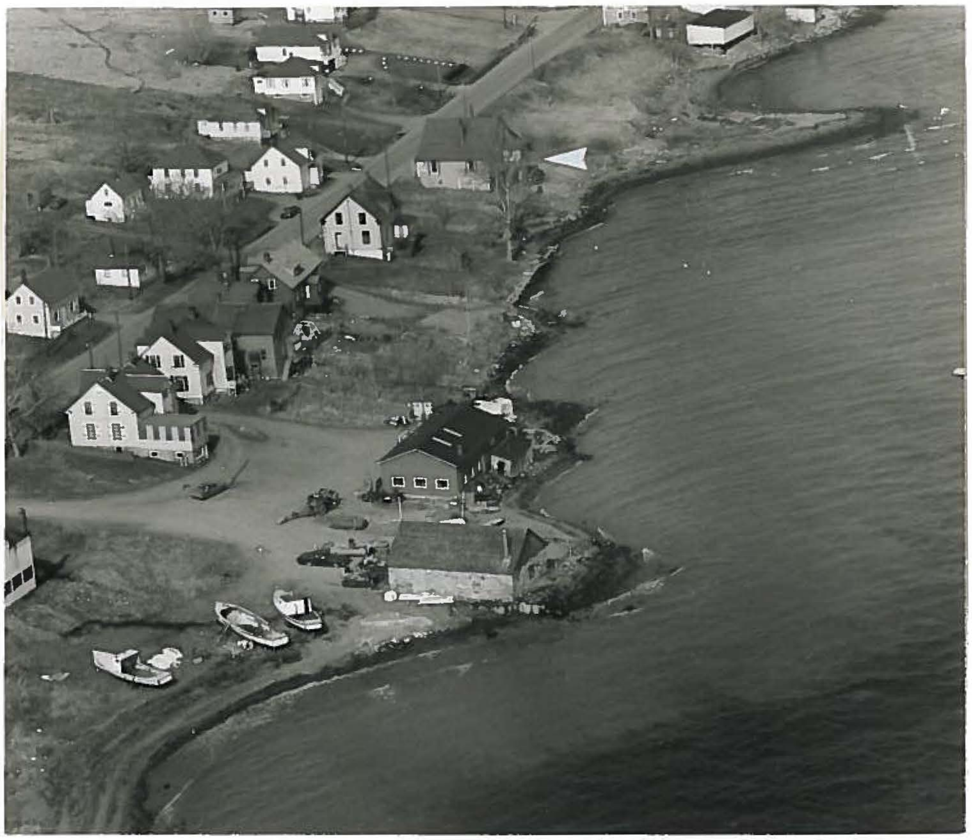
ARICHAT May 2, 1970

Air view of Noir Forge and east section of contract area at high tide. Work has commenced on the west section; with the rising tide fines have been removed from the beach in suspension and are visible moving east alongshore. Most of the beaches in the sheltered area of Arichat Harbour were heavily polluted and were "paralyzed".

2. (*)

ARICHAT June 9, 1970

Air view of east section at high tide after restoration. Material was removed from the foreland areas but not from the beaches backed by cliffs or crib-work. The arrow indicates the location of a building as a point of reference between photographs 1 and 2.



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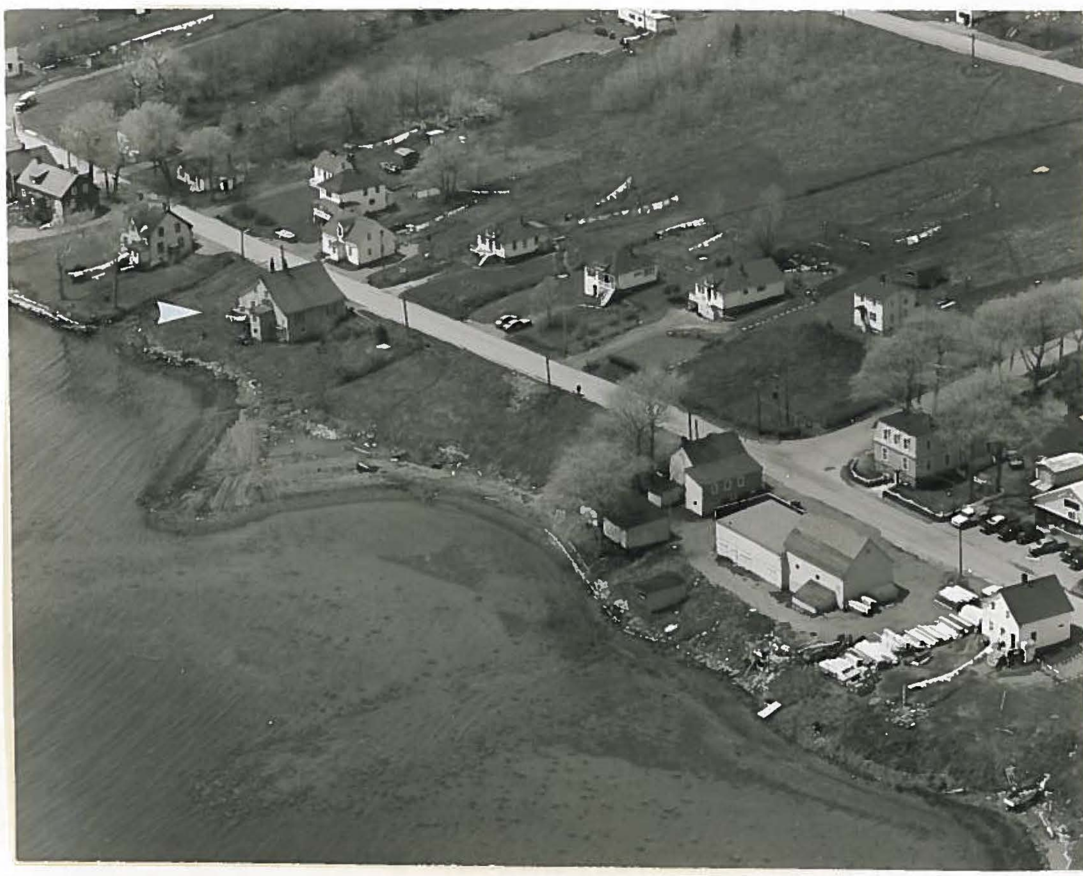

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3. (*)

ARICHAT May 2, 1970

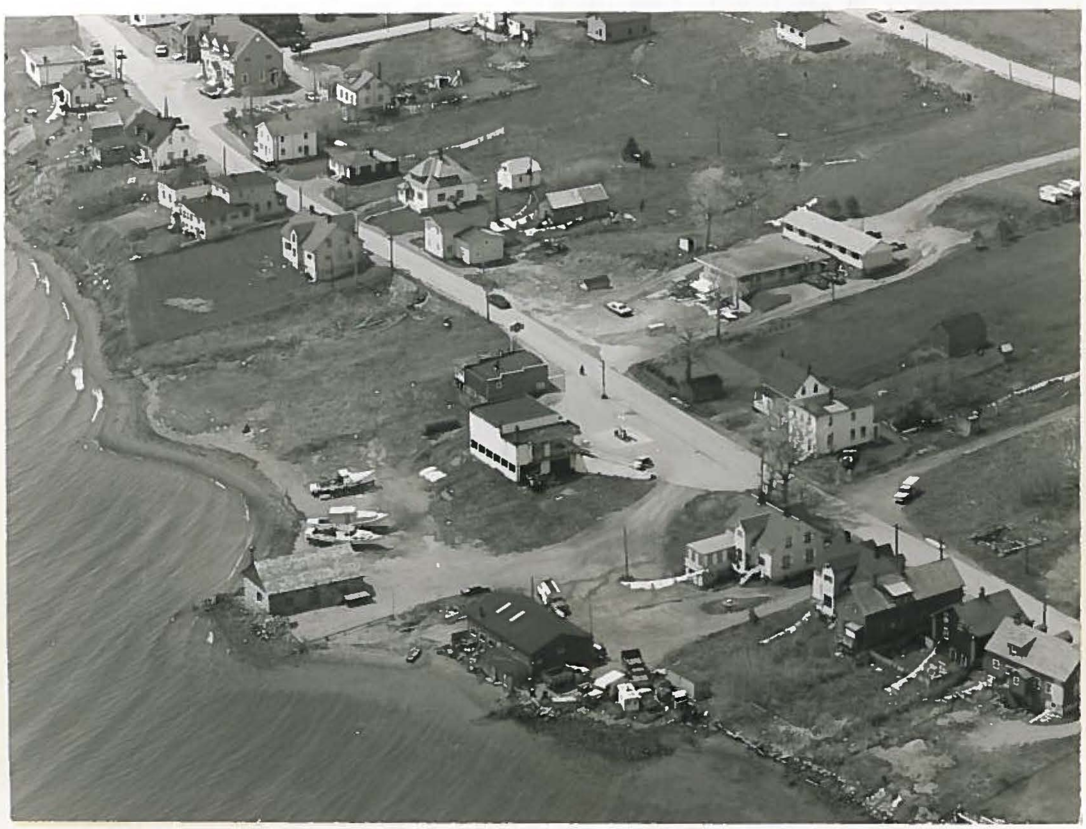
Air view of Noir Forge and west section at low tide. The bulldozer had made a "road" along the base of the active till cliff at the high water mark. This section was heavily contaminated and the beach zone was paralyzed. The contract area ended at the wharf.

4. (*)

ARICHAT June 9, 1970

Air view of Noir Forge and west section near high tide after completion of the contract work. The dark line near high water on the west section is the reoiling of the material which was pushed against the cliff base. Boulders have been brought in at the right of the Forge as replacement for some of the removed material. To the east of the Forge certain sections were not cleaned because of the danger of erosion or inaccessability to heavy equipment.

3



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5. (*)

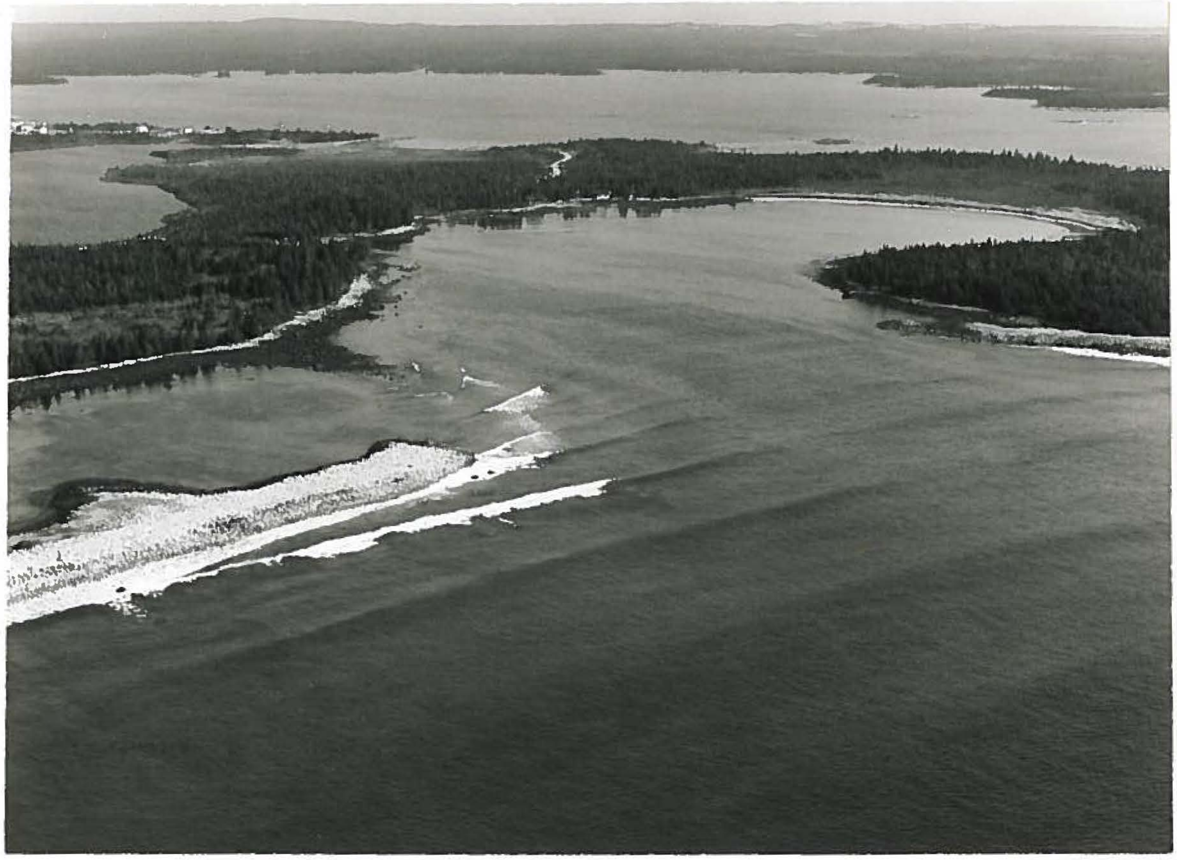
BLACK DUCK COVE   April 25, 1970

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 (see also below) whilst the beach in the lee of the spit remains paralyzed.

6.

BLACK DUCK COVE   July 10, 1970

The exposed side of the spit has effectively cleaned itself. Traces of oil are still evident in small amounts on the material where it has not been completely abraded. Despite the size of the beach material, this is a very active and mobile beach, during periods of storm waves these sediments were in constant motion.



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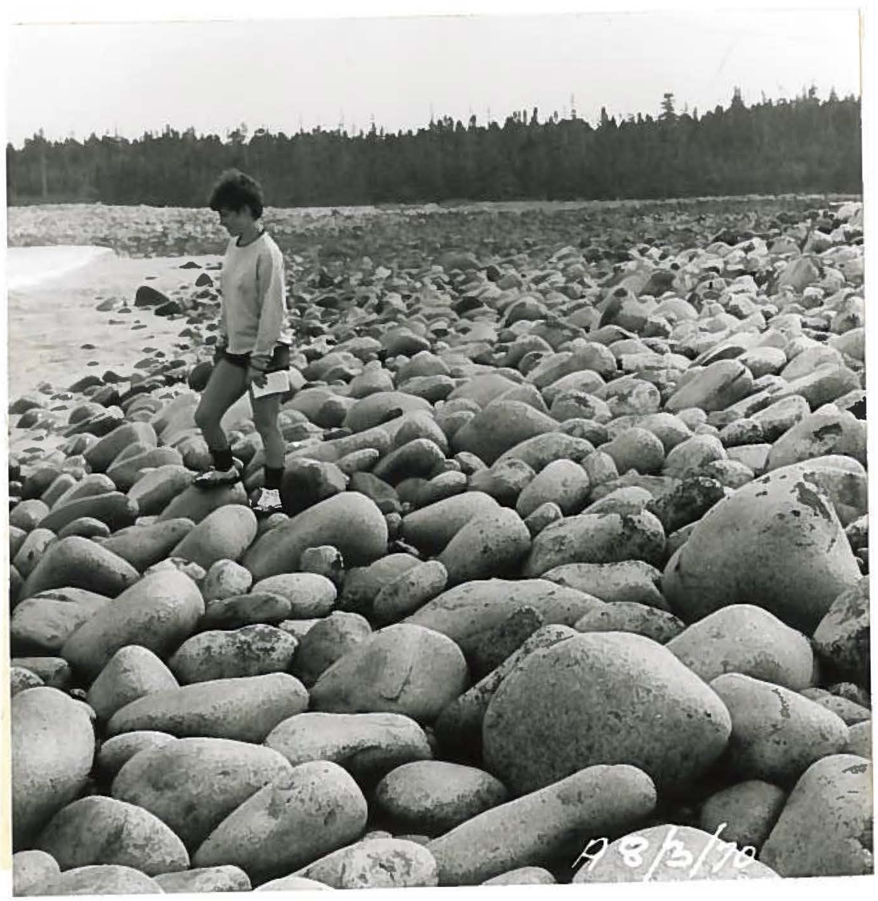

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7. (*)

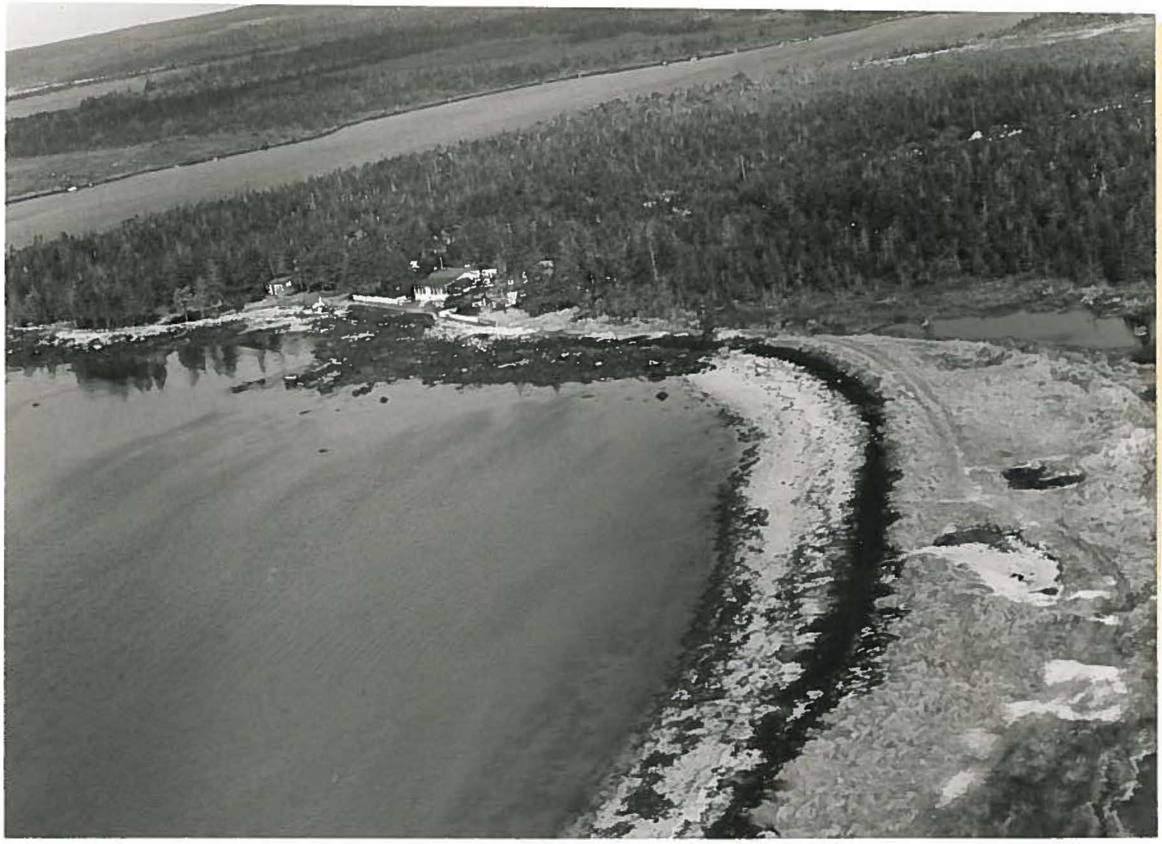
BLACK DUCK COVE April 25, 1970

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.

8. (*)

BLACK DUCK COVE May 2, 1970

Air view of beach restoration work at low tide. A bulldozer shoved 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.



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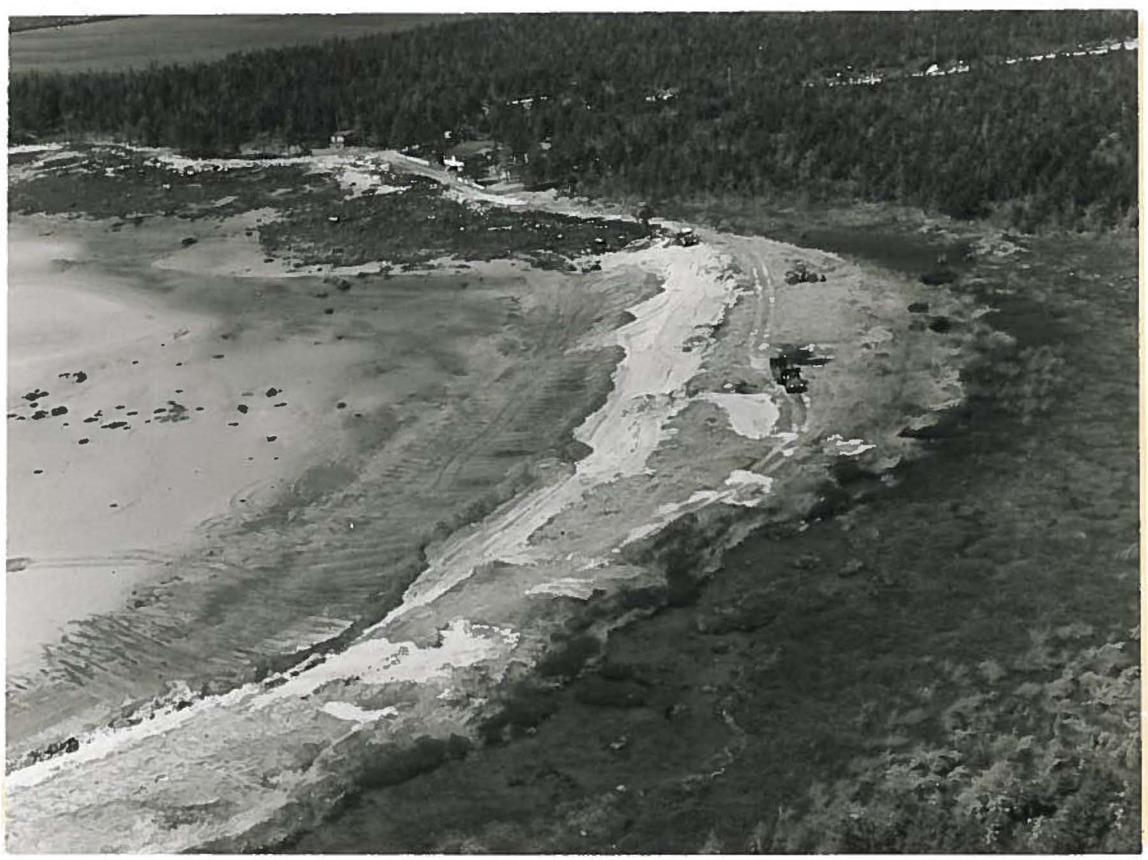

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9. (*)

BLACK DUCK COVE May 2, 1970

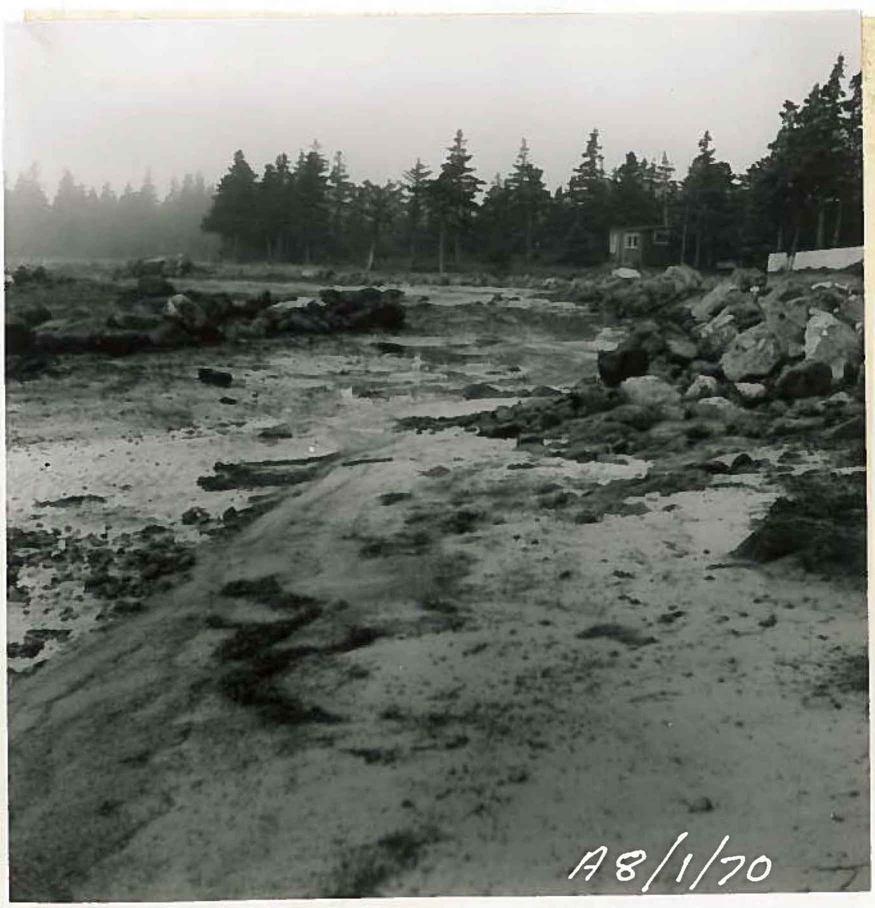
Close-up of the material shoved above high water by the bulldozer. This shows the thorough mixing of the sediments which led to the removal of more material than would have been necessary if a more efficient method of removal had been available.

10.

BLACK DUCK COVE July 1, 1970

Along the north shore of the cove most of the contaminated material, largely boulders, was removed from the upper part of the intertidal zone (c.f. photographs 7 and 8). The boulders on the right of the photograph were brought in as clean replacement to protect the road and cottages on the backshore. This material has been contaminated by oil moving alongshore from adjacent areas.

9



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11.

INDIAN COVE May 21, 1970

The east section of this pocket beach at low tide after completion of the contract work. The figure is standing near the mean high water line. Before restoration a thick continuous layer of oil, six to ten feet wide, covered the length of the beach above the high water line (similar to the beach in photograph 29). The intertidal zone had virtually cleaned itself.

12.

INDIAN COVE May 25, 1970

The same view as above at low tide four days later. The recontamination was from alongshore and the oil was concentrated at the high water mark.

11

12

13.

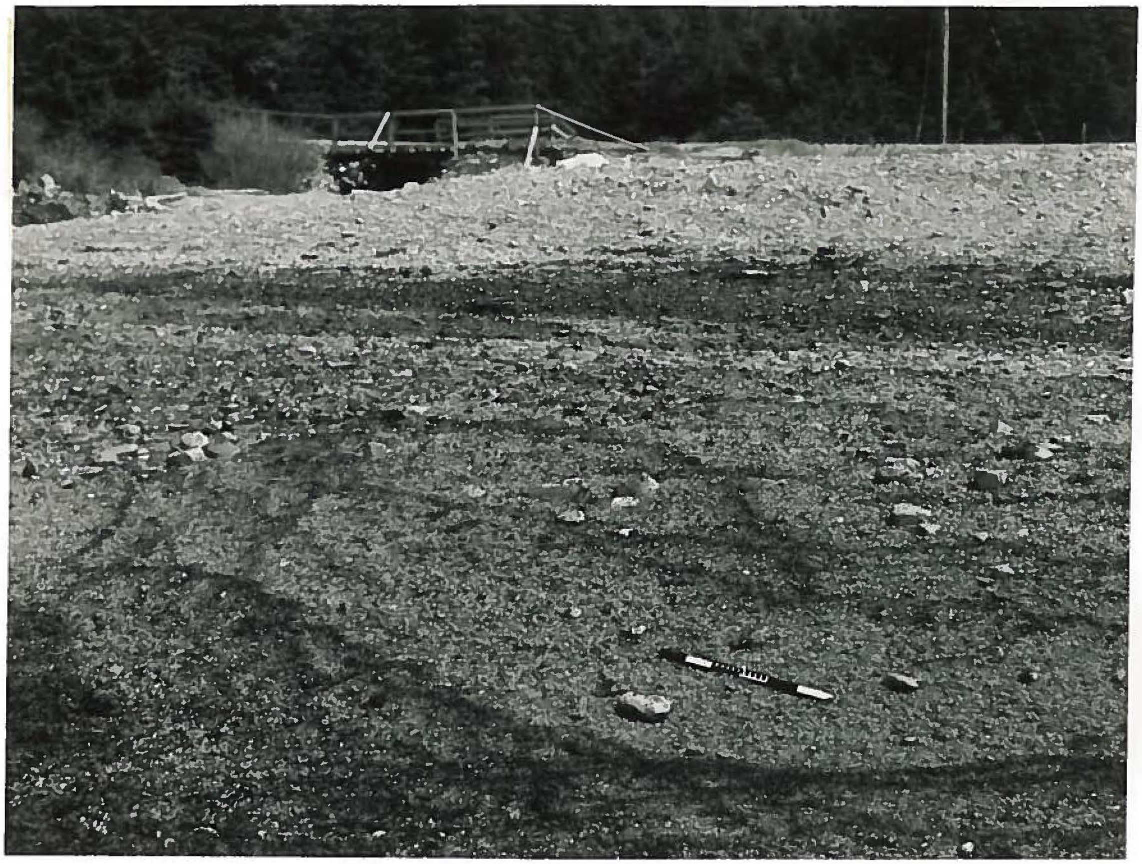
INDIAN COVE May 25, 1970

Wave-laid oil in the intertidal zone. Most of the oil is concentrated near the high water mark. The scale is in centimeters and decimeters.

14.

INDIAN COVE June 12, 1970

A tracked front-end loader is removing sediments from the east section at low tide. Oil was also removed manually from pools and hollows an the adjacent rock and boulder area which was thought to have been the source of recontamination.



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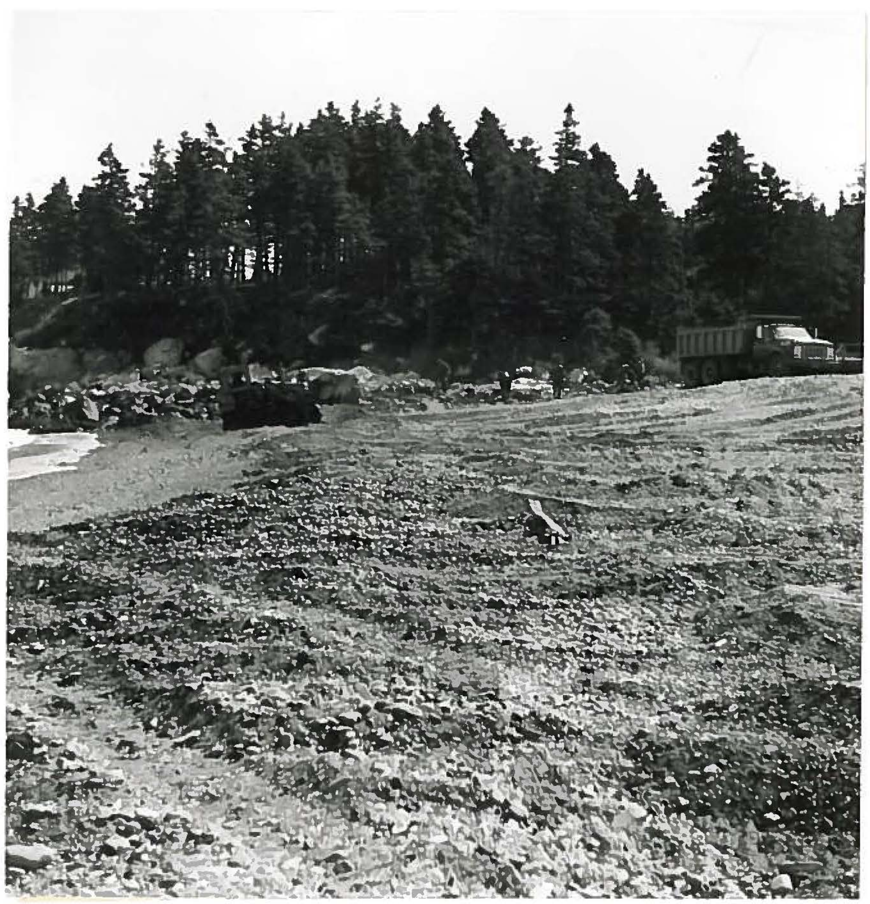

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15.

HALF ISLAND COVE May 22, 1970

General view of the beach at low tide from the east before restoration. The dark patches near the high water line are seaweed. Most of the contaminated material had been cleaned or buried by natural processes, no part of this beach was immobilized by oil.

16.

HALF ISLAND COVE June 3, 1970

The same section of beach at low tide after completion of the contract work. The dark patches in the left foreground are contaminated sediments (see photograph 17). This beach exhibits a summer profile gradation of cobbles on the upper part of the beach and a mixture of coarse sand, gravel, and cobbles in the intertidal zone.

15

16

17.

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.

17

18.

HALF ISLAND COVE May 26, 1970

Grader on west section making straight passes on a level section of firm gravel and coarse sand above the high water mark. It was possible to control the depth of material disturbed to about six inches.

19.

HALF ISLAND COVE May 26, 1970

Effect of a decrease in traction and a non-level surface on the performance of the grader. The machine was almost stuck and churned up the beach to a depth of two feet.

18

19

20.

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 (see below). The eastern limit of the area which was later restored is indicated by an arrow.

21. (*)

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 41), 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.

20

21

22. (*)

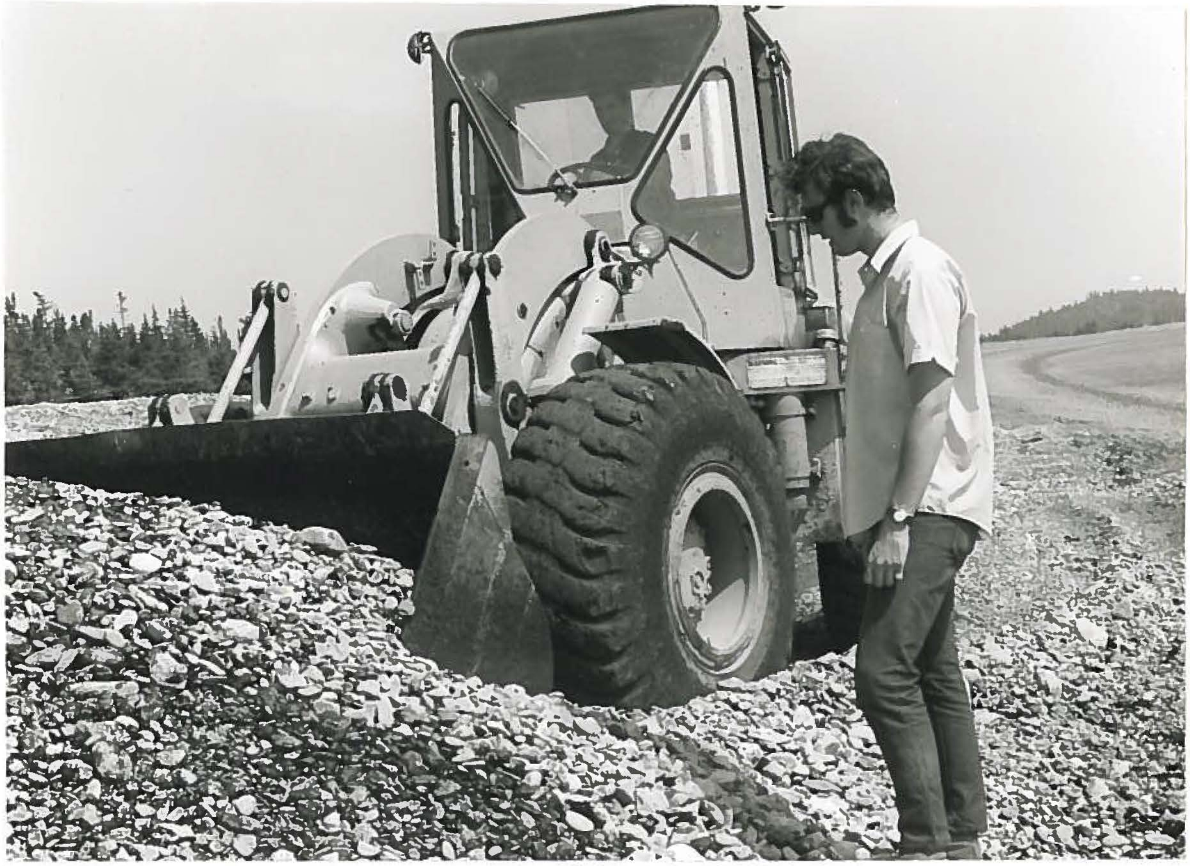
MOOSE BAY July 7, 1970

The front-end loader frequently removed up to four feet of beach material, much of which was uncontaminated. The amount of oil in the beach, as a volume, varied between 10 and 100 parts per million. This is a very active beach and most of the contaminated material had been reworked and buried or abraded.

23.

HADLEYVILLE #I June 3, 1970

This is a similar area to Moose Bay though more heavily polluted, it is an active beach which had succeeded in cleaning itself well. Again contaminated material was reworked and this shows the loader attempting to remove a buried layer. This machine is quite efficient if operated well but there is a great deal of spillage from the bucket as it shoves into the beach.



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24.

HADLEYVILLE #I. May 30, 1970

This is 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.

25.

HADLEYVILLE #I. June 13, 1970

The west section after restoration at low tide. Much of the storm ridge has been removed and the beach has a much lower slope than previously. Dark patches are seaweed.

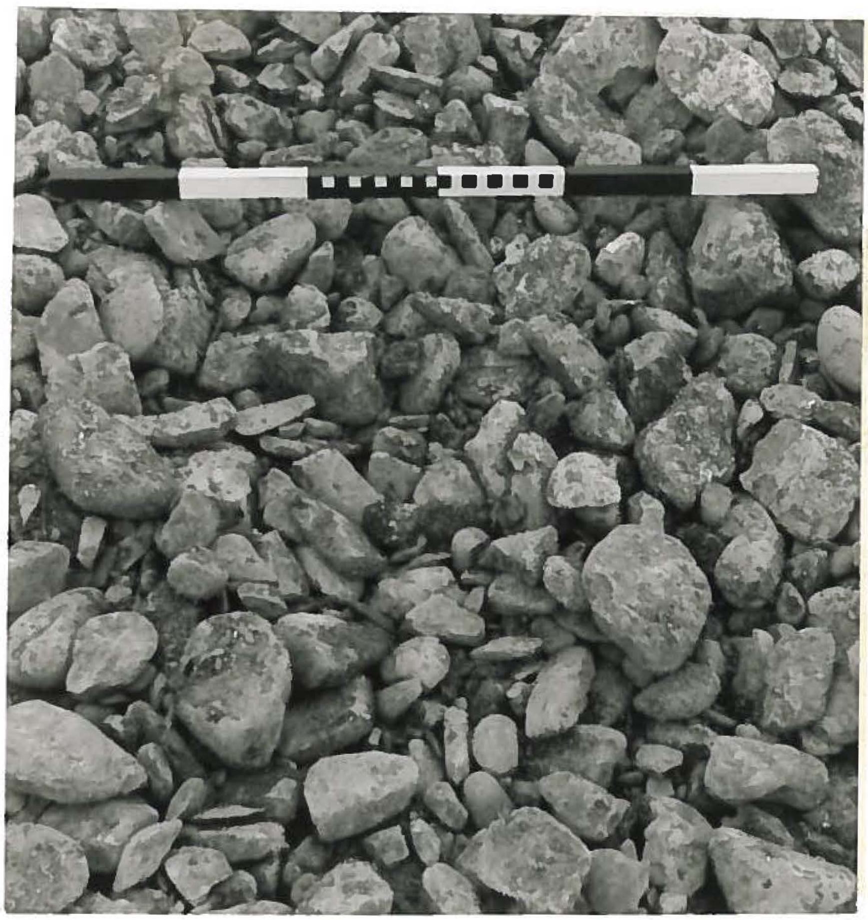
24

25

26.

HADLEYVILLE #I. June 13, 1970

Close-up of beach material after restoration. Contaminated pebbles are still evident and the oil on the material has a surface coating of fines due to the mixing of the sediments by the heavy machinery. This surface coating of fines was easily removed by wave action. The scale is in centimeters and decimeters.



26

27.

HADLEYVILLE #II.   July 10, 1970

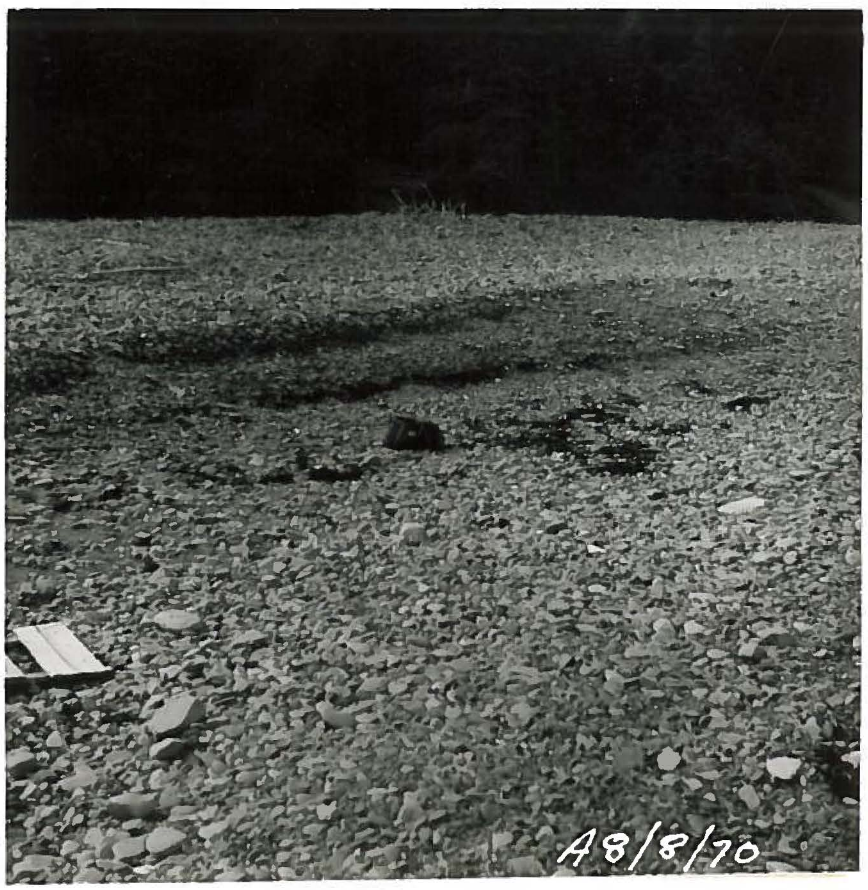
The west end of this beach, at low tide, is mainly cobbles with one or more exposed layers of buried oil in the beach face slope near high water mark.

28.

HADLEYVILLE #II.   July 10, 1970

The layers of oil, when exposed by wave action, are more resistant to erosion but quickly collapse through sunlight and gravity.

27



28

29.

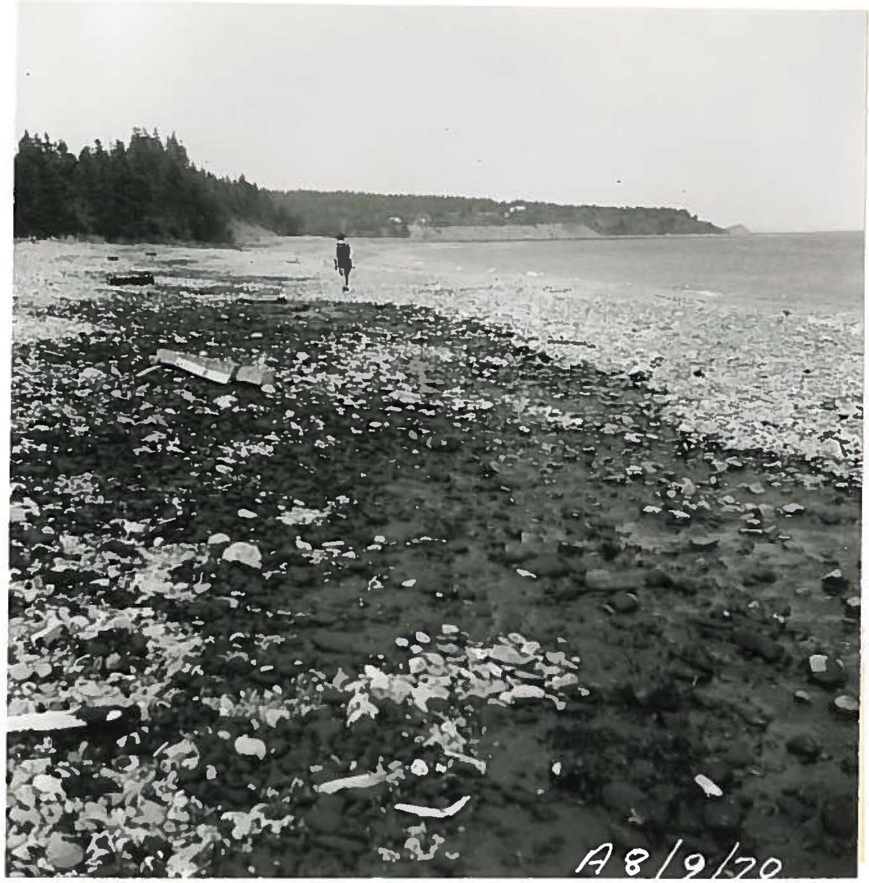
HADLEYVILLE #II. July 10, 1970

The central section of this 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 whilst the intertidal zone was cleaned by wave processes.

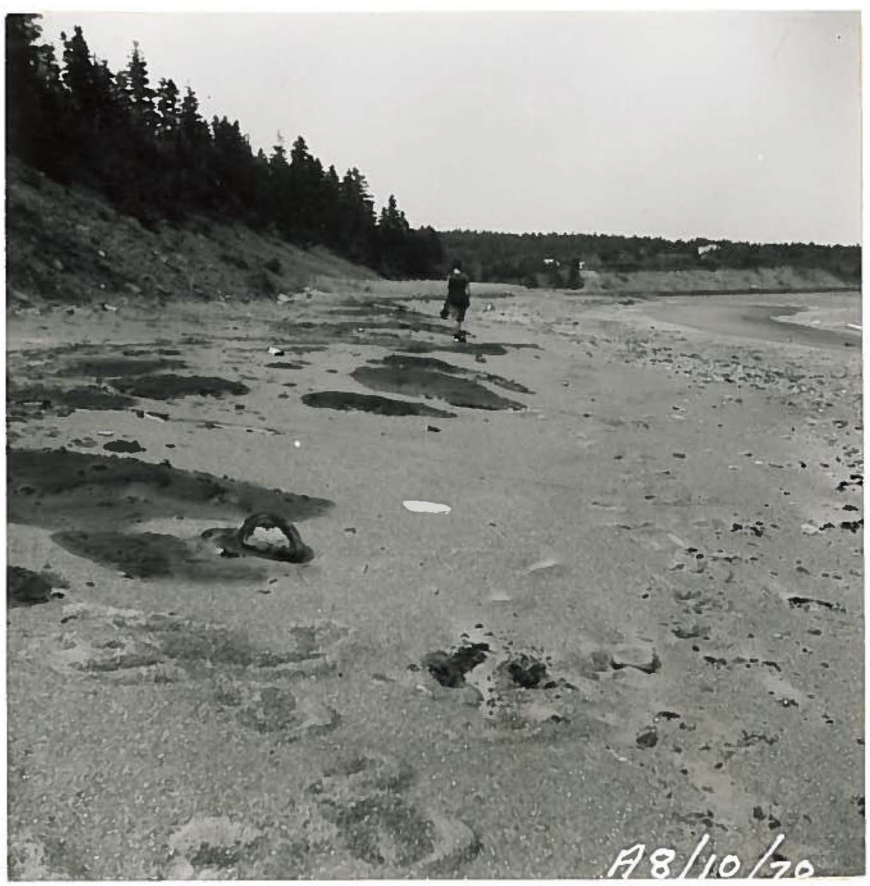
30.

HADLEYVILLE #II. 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.



29



30

31.

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.

31

32.

EDDY POINT May 26, 1970

The north beach at low tide before restoration. The oil is concentrated as a narrow belt above the high water line. This beach has been slowly retreating according to local inhabitants and is now some 40 feet to the south of its position 50 years ago.

33.

EDDY POINT June 29, 1970

After restoration, at mid tide. Along this north shore clean material was brought in as replacement and deposited at the beach crest to prevent breaching of the bar.

32

33

34. (*)

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 (see below) for later removal.

35. (*)

DEEP COVE March 1, 1970

Air view of beach from the south at high tide. This beach was heavily contaminated on frequent occasions and at this time much of the sea ice was covered with oil. In the central section of the beach, near the group of people, the bar is only 100 feet wide, the far side is hidden by snow and ice cover.

34

35

36.

DEEP COVE June 12, 1970

Air view of the lagoon. Contract work is in progress to remove contaminated sediment using an angle-blade bulldozer. The mud and silt-sized material was pushed into wind-rows and removed by a front-end loader. The spit is another example of self-cleaning on the exposed side and a paralyzed beach on the lee side (see also below).

37.

DEEP COVE June 29, 1970

As replacement for material removed from the bar the spit was excavated in the centre to a depth of more than six feet. The location of the excavation is shown on photograph 36. The high water mark on the beach is indicated by a line of seaweed. This beach, on the exposed side of the spit, has been cleaned by wave action though it was heavily polluted on several occasions. The lee side is still paralyzed (see above).

36

37

38. (*)

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.

39.

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.

38

39

40. (*)

JERSEYMAN ISLAND (SOUTH SHORE)   June 21, 1970

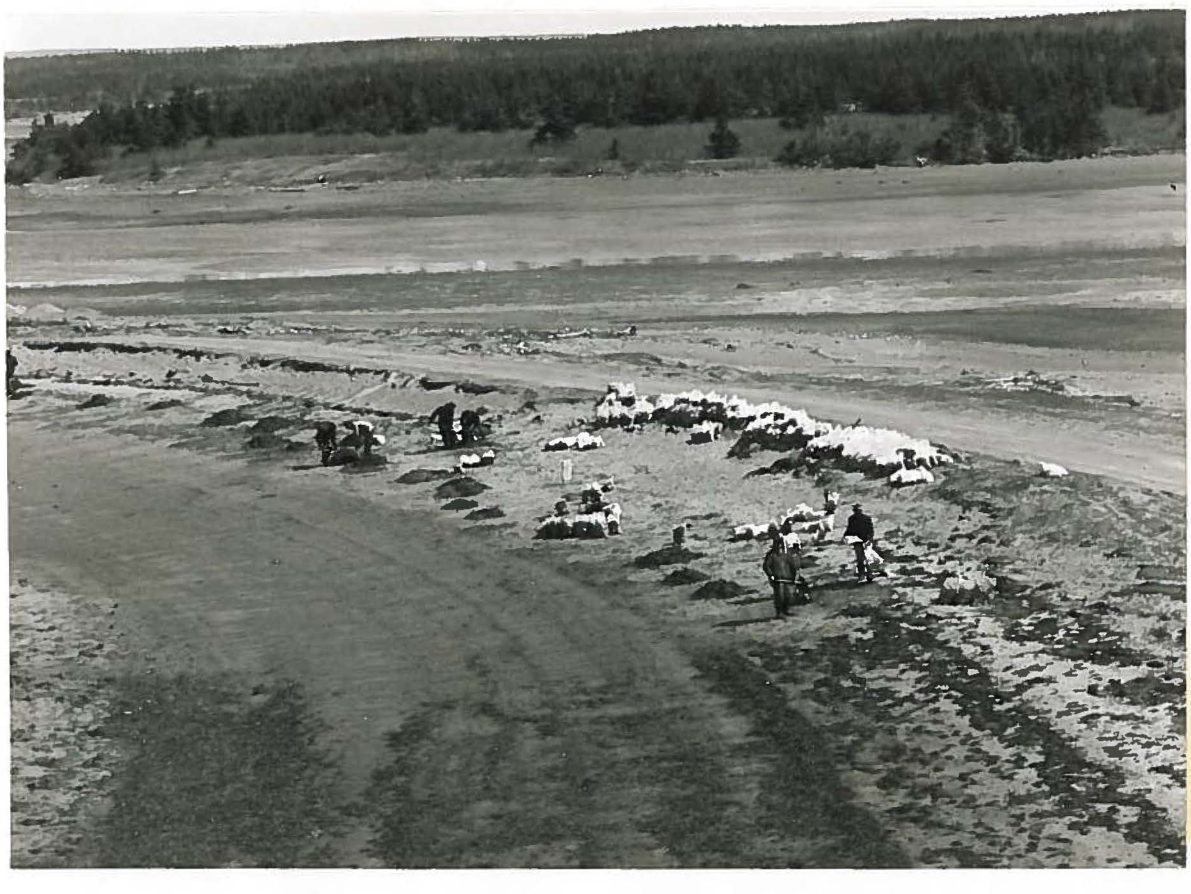
A badly contaminated cobble beach near the high water mark. Although this beach has been partially immobilized, wave action has begun to clean the area below the high water line by abrasion and burial. With storm waves the remainder of the beach will be combed down and the cleaning process will be extended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

41. (*)

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 negligable and only contaminated material is removed.

40



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