THE NINETY MILE BEACH

The Ninety Mile Beach is a long, gently-curving sand beach which extends from red Bluff, near Lakes Entrance, south-westwards to Corner Inlet. There are similar beaches, interrupted by rocky headlands, east of Red Bluff as far as Point Hicks, and again in the Mallacoota district, near Cape Howe (Figure 2). At Lakes Entrance the beach consists of yellow, iron-oxide stained quartz sand, typically with more than 70% medium sand (0.25 mm – 0.50 mm) and nearly 20% coarse sand (0.5 mm – 1.00 mm). Between 5% and 10% of the sand consists of calcium carbonate (mainly shell fragments), and pH values, determined on solutions obtained when 20 gms of beach sand had been shaken in 40 ml distilled water for one hour, were in the range 8.0 to 8.5. Small proportions (up to 0.50%) of heavy minerals are present, notably ilmenite and tourmaline (Tan 1970).

For its whole length, the Ninety Mile Beach is backed by dunes. The beach profile varies in response to wave action: in calm weather, long, low ocean swell delivers sand to the shore and waves build up a convex ridge (beach ridge or berm) along the length of the beach, but during storms, steep, plunging waves scour away sand from the beach, removing the berm, lowering the profile, and sometimes cutting back the outer margin of the dunes. Much of the sand carried away under these conditions remains in the nearshore zone in the form of bars parallel to the shoreline, and often visible at low tide in the zone of breaking waves. The cycle of ‘cut and fill’ (Davies 1957) on the Ninety Mile Beach involves the transference of sand from the beach to these nearshore bars during storms, and from the bars to build a beach ridge during calm weather. One such sequence was observed on the beach east of Lakes Entrance in December 1967. On the 11th December the beach had well-defined berm, but this was eroded away during a storm on 12th – 13th, after which a distinct bar had formed 50 to 100 metres off the low tide shoreline. In four succeeding days of fine weather, gentle swell moved the sand back onshore, and by the 18th December the berm had been restored. In general the offshore profile, beyond the nearshore zone, is a smooth and gentle slope, but half a mile off the beach at Stockyard Hill reefs of sandstone outcrop at depths of 15 – 20 metres, marking the outer edge of the coastal shelf upon which the barriers have been deposited.

Waves that arrive in such a way that their crests are parallel to the shoreline set up a nearshore water circulation, within which water returns seaward by way of localised rip currents (McKenzie 1958), indicated by streaks of white foam that trail away from the beach. Sand bars in the nearshore zone are generally intermittent, with transverse channels related to points of exodus of rip currents. Waves that approach the shoreline obliquely, arriving at an angle, set up a deflected nearshore water circulation, and the combined action of transverse swash on the beach (beach drifting) produces a movement of sand along the shore. Beach drifting was verified experimentally at Letts Beach in 1958 by observing the movement of tracer material placed on the beach when strong easterly winds produced waves arriving obliquely from the east (7th – 10th February 1958) and when strong south-westerly winds drove in waves from that direction (20th – 22nd October 1958). In these experiments, dumped loads of leached white quartz sand were spread along the beach by wave action, and at the same time there was similar movement of miscellaneous strand debris, including bottles, driftwood, and marked shells. When the waves came in from the east, the material moved south-westwards along the beach, and when the waves came in from the south-west, movement took place towards the north-east. As south-westerly winds occur more frequently than easterly winds, it is likely that the predominant drifting is north-eastward, but at that predominant drifting is north-eastward, but at Lakes Entrance (Figure 15) the balance appears to be a fine one, for beach accumulation on either side of the protruding stone jetties has been on a similar scale, indicating that similar quantities of sand have arrived from either direction.

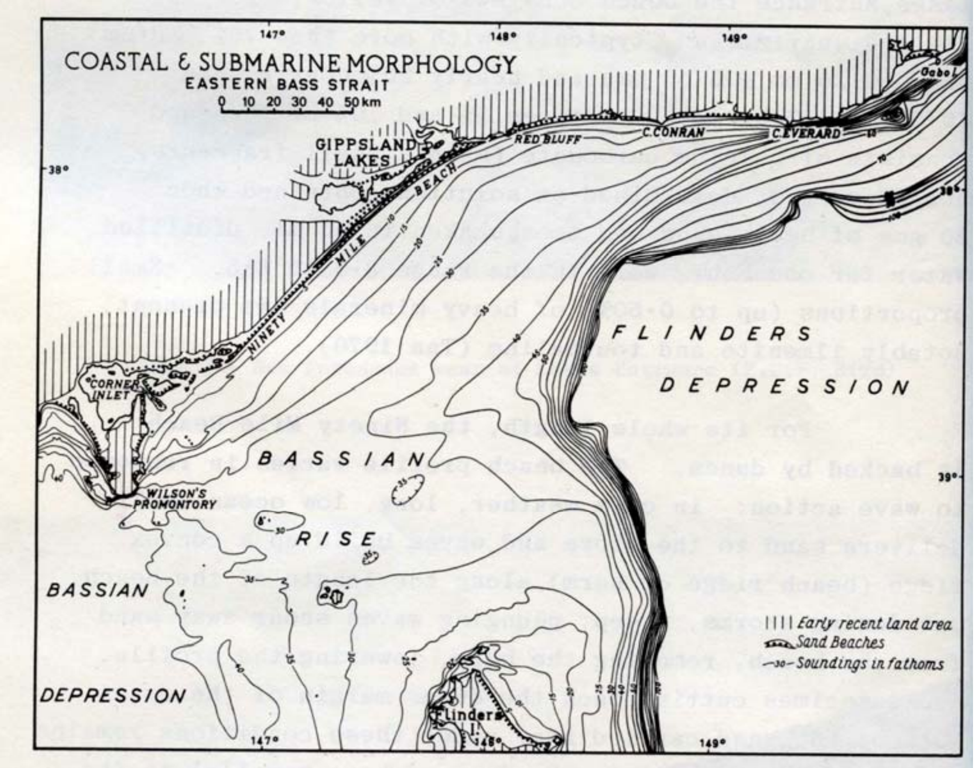

Figure 12 – Coastal & Marine Morphology – Eastern Bass Strait

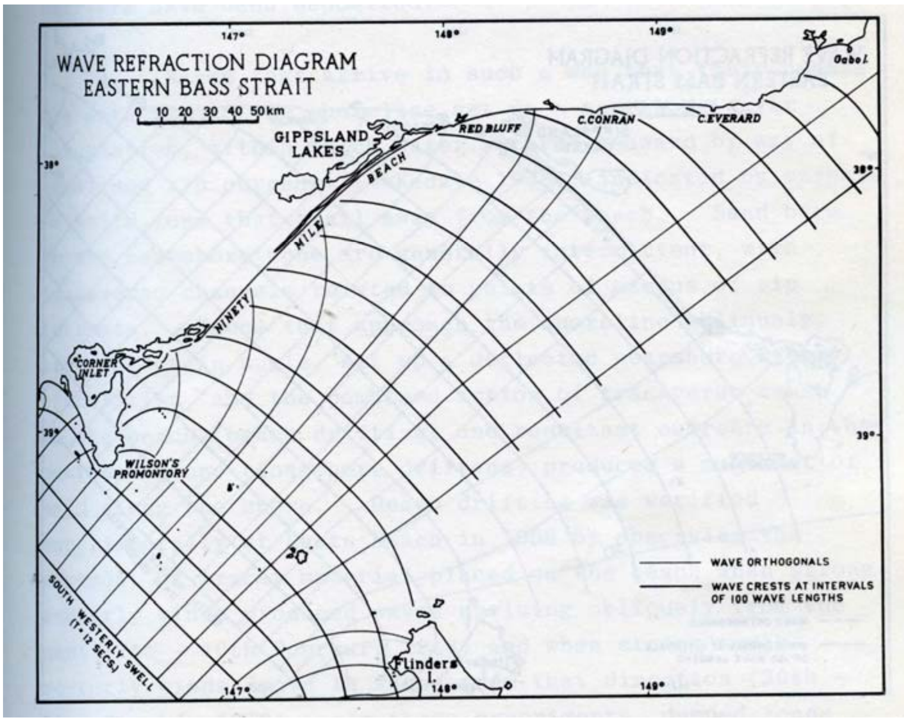

Figure 13 – Wave Refraction Diagram – Eastern Bass Strait

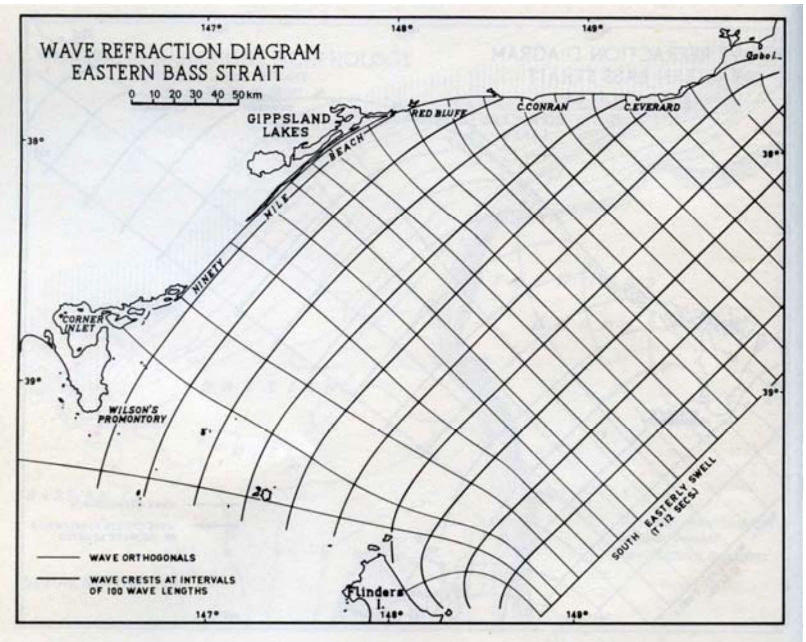

Figure 14 – Wave Refraction Diagram – Eastern Bass Strait

Beach ridges built by calm-weather ocean swell may become the foundations of foredunes, built when colonising grasses initiate the accretion of wind-blown sand derived from the foreshore (Plate 7). The process can be studied on the beach at Lakes Entrance (Figure 15), where rapid progradation of the shoreline after the opening of the artificial entrance led to the development of cuspate forelands on wither side of the harbour jetties. Three parallel foredunes, each roughly symmetrical in cross-profile and up to 4 metres high, have developed on the foreland west of the entrance. They surmount beach ridges built successively during the progradation of the shoreline under alternating conditions of 'cut' and 'fill' each ridge being colonised by dune grasses (chiefly *ammophila arenaria*) which led to sand accretion on the beach ridge alignments. The dune sand is better sorted than the beach sand, the proportion of medium sand (¼ mm – ½ mm) increasing to more than 95% in the foredunes (Figure 11, A and B). Each foredune has been truncated during an episode of 'cut' by storm waves, then fronted by a newer beach ridge built up by calm-weather ocean swell as a foundation for the next foredune. The intervening swale remains unvegetated, possibly because of unfavourable moisture or salinity conditions for invasion by grasses (the ecological problem posed by Bird (1960) remains unsolved), and the intervening swales remain as low-lying corridors. Given a sustained supply of sand, successions of parallel beach ridges and foredunes can be built in this way. It appears that tussocky grasses, such as F*estuca* and A*mmophila*, build up hummocky ridges on the berms formed on a prograding shore, whereas spreading grasses such as S*pinifex hirsutus* may lead to the gradual building forward of a beach terrace in the manner described by McKenzie (1958). At Lakes Entrance the tussocky grasses have dominated dune development, and well-defined ridges have been formed.

This progradation, however, has been quite localised. At the present time the Ninety Mile Beach shows evidence of general retrogradation, rather than progradation, the dunes behind the sandy shore being typically cut back as cliffs of crumbling sand (Plate 8). Beach ridges and incipient foredunes are built up by wave and wind action, particularly during summer periods, but they rarely survive for more than a few months before storm waves sweep them away and rejuvenate the sand cliff. It appears that 'cut' has exceeded 'fill' on the Ninety Mile Beach during recent decades, and the long-continued progradation of the sandy shoreline of East Gippsland represented by the development of the coastal barriers seems to have come to a halt. Davies (1957) observed similar evidence on many Tasmanian beaches, and commented that 'beach ridges are being eroded and it appears that not all of the conditions which favoured their construction now exist'. Local progradation alongside the Lakes Entrance jetties may have been partly due to accumulation of sand eroded from other parts of the shore, but away from this section the sand supply has not been sufficient to maintain progradation. Even at Lakes Entrance, the pogradation seems to have come to an end: the shoreline has fluctuated slightly during the past 35 years without showing any sustained gains, and it appears that a dynamic equilibrium has been attained, whereby sand arriving on these forelands is added to the developing foredunes, rather than advancing the shoreline. Nevertheless, the transverse beach profile here is in marked contrast with that on the rest of the Ninety Mile Beach, where shoreline retreat is continuing.

The extent of sandy shoreline recession is difficult to judge, because there are so few readily identifiable fixed points on early surveys that can be used to compare distances to past and present shore alignments. At Lakes Entrance, Thwaites' survey in May 1879 showed a beach-fringed shoreline (evidently at high tide) in relation to the alignments of channel piling under construction alongside the proposed artificial entrance, and to the positions of Rigby Island, Mount Barkly (now Jemmys Point), Bullock Island, Mount Cunninghame (now Lakes Entrance) spit. If this is imposed on the present configuration (at mean high tide) the extent of shoreline change can be measured (Figure 17). On this basis, the Ninety Mile Beach 1.5 kilometres south-west of the western pier has retreated about 350 metres, and the sector between 2 and 3 kilometres east of the eastern pier has retreated about 100 metres during the past century. The Ninety Mile Beach near Ocean Grange has also receded about 100 metres in this period, and a substantial volume of sand (several million cubic metres per kilometre) has been removed from the ocean shore. A small proportion of this sand has been blown landward into backshore dunes, but the bulk of it has been carried away by wave and current action, either along the shore or out on to the sea floor. Some of the longshore drift has been trapped in the prograded sectors on either side of the Lakes Entrance piers. Some may have moved on, past Red Bluff, into the eastward-drifting beach systems that extend to Point Hicks and beyond. And some has been retained a short distance offshore in the submerged bars that run parallel to the Ninety Mile Beach.

Shoreline erosion is too widespread to be attributable directly or indirectly to human interference although its effects have been accentuated locally where holiday-makers have damaged dunes. The onset of erosion may be due to an increase in storminess in coastal waters or to a slight rise in sea level during the past few decades. At Lakes Entrance the foredunes, marking the alignment of the Ninety Mile Beach before the entrance was cut in 1889, show little evidence of the cliffing and recession that have taken place along the rest of the beach. Within the past century tide gauge records evidence a slight rise in the mean level of the oceans, probably related to the change in world climate indicated by recession of glaciers and margins of ice sheets. Such a rise, by deepening water in the nearshore zone, would have increased the severity of erosion by storm waves and reduced the supply of sand to the shore, alternatively, the erosion may be the outcome of a diminution in sand supply from the sea floor (Bird 196b).

The outline of the Ninety Mile Beach has clearly been determined by wave action. Calm-weather ocean swell, which builds up the beach profile, forming beach ridges and the foundations of foredunes, is refracted by contact with the sea floor in such a way that it anticipates the coastal outline in shallow water offshore and on arrival fits it, the waves breaking simultaneously on long sections of the shore (c.f. Davies 1959). Analysis of daily (0900 hrs.) wave observations at Wilson's Promontory lighthouse to the east has shown that long waves (length exceeding 200 metres) come mainly from the south-west and the east at the former, while the latter has an additional southerly swell:

	NE	**N**	**SE**	**S**	**SW**	**W**	**NW**	**S**	**TOTAL**
Wilson's Promontory	0.9	26.9	2.0	0.4	68.5	1.3	-	-	100.0 %
Gabo Island	1.3	33.8	6.8	37.9	18.4	1.8	-	-	100.0 %

(Percentage frequency calculated from records for 1954 – 56 supplied by the Commonwealth Bureau of Meteorology.)

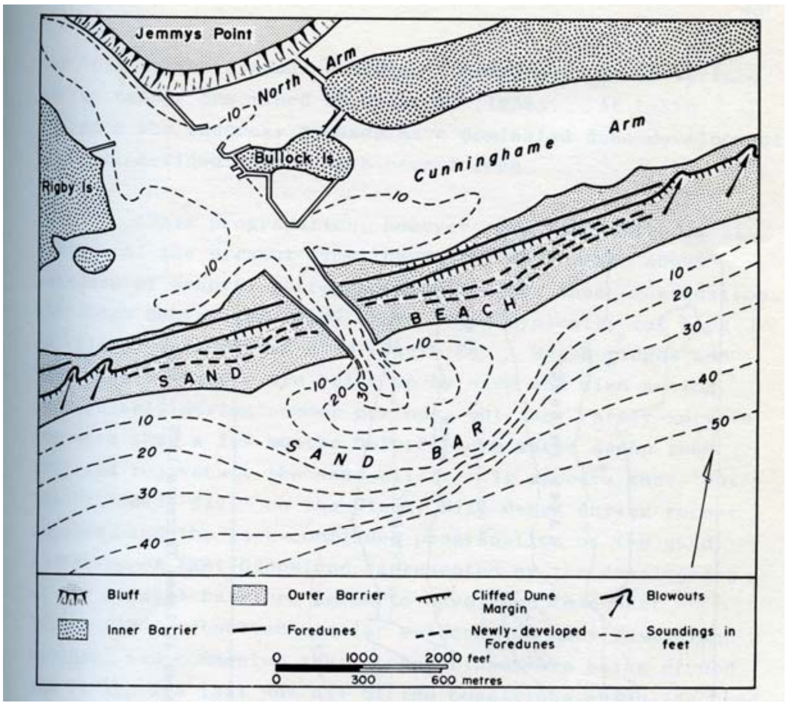

Figure 15 – Landforms at Lakes Entrance

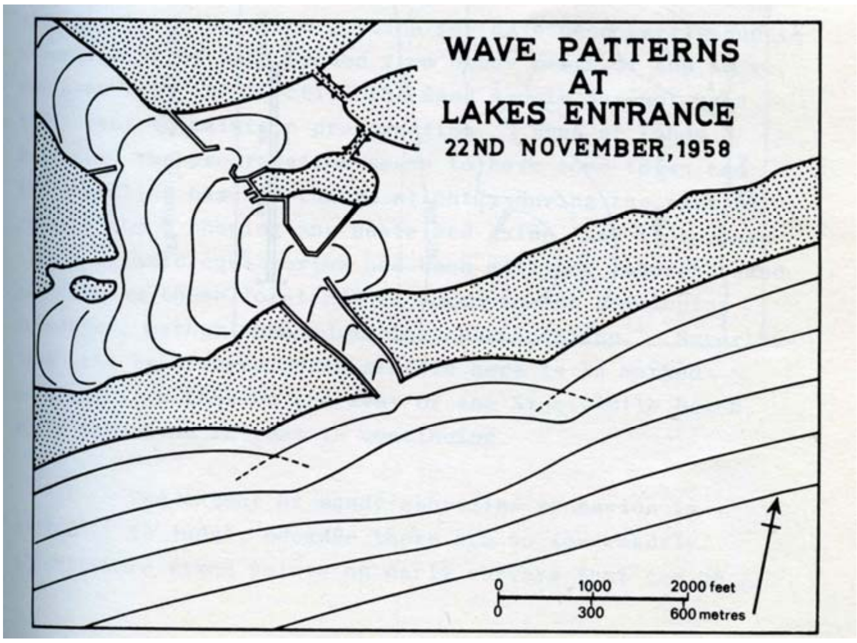

Figure 16 – Wave Patterns at Lakes Entrance

Given a knowledge of the submarine topography off the Ninety Mile Beach (Figure 12) it is possible to construct wave-refraction diagrams to trace the development of ocean swell patterns in this area. Measurements from sir photographs and observations from the coast shoe that the long, low constructive waves which build up the Ninety Mile Beach have a mean wave length of about 200 metres, equivalent to a wave period of 12 seconds. Diagrams of south-westerly swell of this length entering the area from the south of Wilson's Promontory show that it is considerably refracted before it reaches the East Gippsland coast (Figure 13). It cannot be said to anticipate or fit the outline of the Ninety Mile Beach, and the divergence of orthogonals indicates that the swell is greatly distended, and therefore weakened, by the time it arrives at the shore. On the other hand, a south-easterly swell, refracted as it crosses the continental shelf, anticipates and fits the outline of the Ninety Mile Beach, and also accounts fro the long easterly swell recorded at Wilson's Promontory and the southerly swell observed by the author during a plane trip over the eastern part of Bass Strait in November 1958. According to Davies (1964) south-easterly swell is dominant on the eastern coasts of Australia, New Zealand, South America, and Southern Africa in latitude 30ºS to 50ºS; coasts sheltered from the stronger south-westerly swells generated in the southern storm belt (latitude 50º - 60ºS). The south-easterly swell that approaches the Ninety Mile Beach evidently originates in the wave trains that radiate from storm centres in the southern Ocean south-west of Tasmania.

The outline of the Ninety Mile Beach, and of earlier shorelines marked by beach ridges and parallel dunes built during the progradation of the East Gippsland barriers, is therefore determined by the dominance of a refracted calm-weather ocean swell which approaches this coast from s south-easterly direction.

At Lakes Entrance the pattern of refraction is complicated where ocean swell encounters a looped bar that has formed outside the artificial entrance (Figure 15). The wave crests are retarded into a curve as they cross the bar, and part of this curve anticipates the outline of the outer sections of prograded cuspate sandy forelands which have developed on either side of the protruding jetties. Once over the bar, the central part of the refracted wave is diffracted in deeper water, close inshore, so that it moves in to fit the inner sections of the cuspate forelands (Figure 16). The outline of the prograded sandy shoreline is therefore determined by the local pattern of refracted swell, and when the waves arrive obliquely the shoreline is modified in such a way that the cusps migrate a few metres along the shore. The alignments of the low foredunes which have developed on these sandy forelands are parallel to the cuspate shoreline, and have also been determined by local patterns of refracted swell.

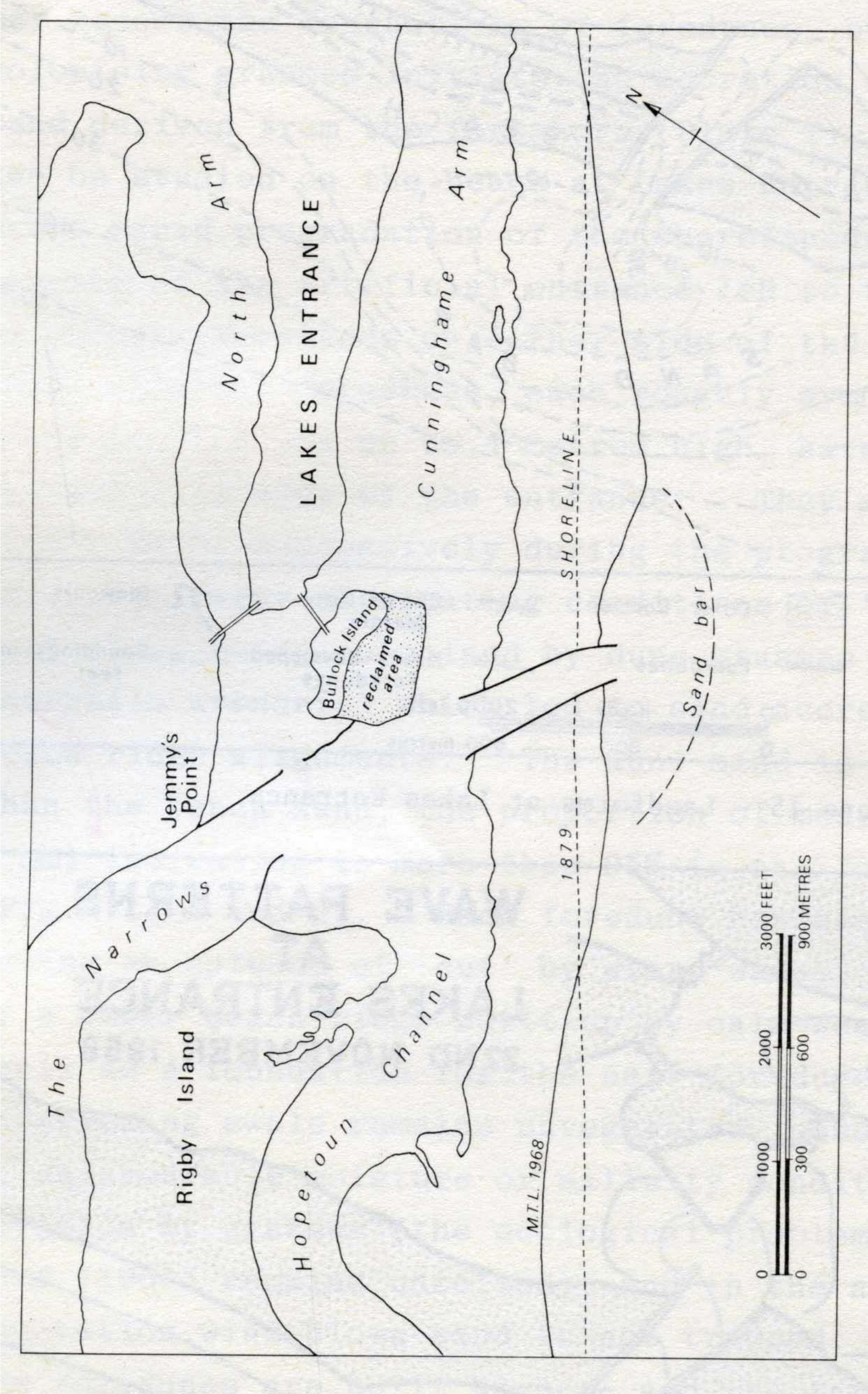

Figure 17 – Shoreline changes at Lakes Entrance 1879 - 1968