

Appendix D

Specific Silt-producing Events

Event E3 (Figure 30), which occurred between 17 and 21 August 1989, produced the largest waves and most extensive silt plume recorded during the period that silt plumes have been observed, i.e. since April 1989. Winds were generally southeasterly, initially 20 kn for about 12 hours on 18 August, then after a brief lull rising to 30 kn early on 19 August and after a time dying away at an increasing rate to virtually nothing at midnight on 21 August. Day time high tides were about 2.7m but night time tides were higher, about 3.0m. Average breaking waves at station 2 on 19 and 20 August were 0.6 to 0.7m, while the maximum breaker height was estimated as 1.0 to 1.2m. Both these values are the maximum possible for the water depths on the reef flat during the day time high tide. Wave periods were 5 to 6s. Erosion of the beach face scarp at station 2, where consolidated silt deposits existed, was reported on 19 August. On both that day and the following day a large silt plume extended right across the reef flat south of the wreck. However there was no silt plume just before midday on 21 August when that day's observations were made, the average breaker height having fallen to 0.2m.

Wave action during event E3 was also strong at station 1 particularly on 19 August but no erosion scarp was observed. However "a mound of boulders" - coral rubble was observed at the run-up limit for the higher high tide on 20 August. Some rain occurred during the 48 hour period preceding the formation of the extensive silt plume on 19 August. There is no evidence to indicate whether this rain was a contributing factor to the development of the silt plume.

Events E2 (Figure 29) and E7 (Figure 34) during 25 to 29 July 1989 and 29 January to 1 February 1990 respectively represent two typical silt plume producing events about six months apart. In both cases the wind speed exceeded 20kn with wind directions southsoutheasterly to southeasterly on the first occasion and eastsoutheasterly during the second. Event E2 was somewhat more intense than Event E7. In both cases no rain was recorded. During the earlier period tides were quite small with day time high tides about 2.5m and night time high tides about 2.0m. Silt plume widths at station 2 during three days of this period were at least 15m with a maximum of 30m on 27 July 1989. Narrower plumes were observed at station 1. In contrast during the later period (Event E7) high tides were generally 2.6 to 2.8m. However the maximum silt plume width at station 2 was only 15m, plumes were only observed there on two days and no plumes were observed at station 1. However on both occasions the silt plume extended along the shoreline behind the boat harbour as far north as the northern line of concrete blocks on at least one day. During event E2 an erosion scarp was reported at both stations 1 and 2 and on 28 July when conditions were subsiding a build up of rubble together with more exposure of consolidated silt was noted at station 2. No erosion was recorded for event E7 and no scarp was present at station 1 during this event.

During both events E2 and E7 breaking wave heights were similar at stations 1 and 2. During the earlier period on 27 July the average breaker height observed was 0.5m which was almost the maximum possible with a tide height of 2.5m. At station 2 the wave period was 5.4s and waves were coming across the reef flat from the southwest, a direction consistent with ocean waves refracted across the reef rim after travelling up Wistari Channel. The recorded observations indicate that there was no significant breaking on the reef rim. On other days of both events, observed average breaker heights did not exceed 0.3m. During event E7 local wind generated wind waves of 1.5 to 2.0s were more visible but 4 to 5s waves were also present.

Events E2 and E7 illustrate the complexity of the situation. On the earlier occasion tides were low but waves were large and silt was available to be put into suspension. On the later occasion smaller waves at higher tides were able to remove silt from portions of the spoil dump not frequently exposed to wave action. The absence of rain may have meant that more fine material was present in the surface layers of the spoil dump than would have been the case after a wet period.

Events E5, E6 and E4 (Figures 32, 33 and 31) on 19 to 22, 27 to 30 November 1989 and 17 to 21 September 1989 respectively explain some of the apparent anomalies concerning the formation of silt plumes. In event E5, 25 to 30kn eastsoutheasterly winds at low high tides ($\leq 2.4\text{m}$) caused only small waves breaking on the spoil dump beach. No silt plume was produced. Waves were observed breaking on the reef rim. Some rain was recorded on 20 November. In contrast during event E6 winds were less intense, 15 to 20kn, and more easterly. That is the spoil dump was well sheltered from them. Wave heights were small, 0.2m or lower, but day time high tides were higher at about 2.8m and a silt plume was observed.

In both events E5 and E6 the spoil dump was sheltered from the effects of the wind because it was blowing along the long axis of the reef and island. In the earlier case, the low tides caused ocean waves to break on the reef edge and no significant wave energy reached the spoil dump. Hence no silt plume occurred. In the later case, the tides were higher and, while the waves reaching the spoil dump were no higher than on the previous occasion, longer period waves (about 6s) were present. It is possible that these longer waves caused greater run-up which reached higher levels of the spoil dump where silty material had not been removed by previous wave action or recent rainfall. The width of the plume during event E6 may have been increased by offshore directed currents generated by the offshore wind. Observations record a silt plume form consistent with this action. It should also be noted that the observations on 28 November which give a silt plume width of 14m but a wave height of only 0.1m were made some time after high tide when the wave height may have been less than the one which produced the silt plume. Furthermore, it is always possible that unrecorded human activities such as regrading the beach face and removal of rubble disturbed the sediments on the spoil dump beach and caused the silt plume.

Event E4 two months earlier presents a different situation. Day time high tides were at least 2.8m, and average breaking wave heights were 0.5m. The scarp was eroded back underneath the jetty exposing more rubble and more consolidated silt. Tractor activity was noted at station 1. No rain was recorded. Despite all these favourable silt-producing conditions, the plume observed was narrow, only 2 to 4m wide. In this case the winds, while generally only 15kn but occasionally reaching 20kn, were northnorthwesterly. The spoil dump was directly exposed to the waves coming over the reef edge and relatively little reduction of wave height occurred because of refraction. The onshore winds generated onshore movement of water on the reef flat and so the silt plume was confined close to the shore, remaining essentially within the surf zone under all conditions.

The final two events E1, 25 May to 1 June 1989, and E8, 11 to 30 March 1990 show conditions near the beginning and the end of the current observation period. During event E1 (Figure 28) winds were between 20 and 30kn for about three days. Initially easterly on 27 May 1989, they become southeasterly after midday on 28 May. Tides were average in range with significant diurnal inequality. Day time tides were smaller than the night tides. A total of 85mm of rain was recorded on the three days, 26 to 28 May. Following the rain, average breaker heights at station 2 were 0.5m on 29 to 31 May. On 29 May it was noted that there were "monster waves breaking on [the reef] crest". The waves breaking on the beach were the maximum possible for the low high tide of 2.4m. An extensive very turbid silt plume up to 70m wide was produced by these conditions (Photo 11). This situation was aggravated by the reshaping of the beach face and erosion scarp by earthmoving equipment the previous day. The plume was extremely turbid under the jetty on 29 May due to the presence of silt disturbed during the previous day's operations. Conditions would probably have been worse during the higher night tide early on 29 May 1989.

Event E8 (Figure 35) extending from 11 to 30 March 1990 is the longest sustained windy event during the period of observation. Winds reached 30kn on 13 March and remained over 15kn for 15 days and over 20kn for half that period. Initially southeasterly to eastsoutheasterly, they

gradually swung northwards to become easterly on 24 March and then northeasterly on 27 March. The latter part of the period was wet with heavy rain totalling 180mm recorded during the period 26 to 29 March. Tides varied from high spring tides just below 3.0m through neap tides with a high water of only 1.7m (range 0.4m) on 19 March and up to high spring tides ≥ 3.0 m at the end of the period. Hence the known major potential silt-plume-generating factors all occurred during this event although their extreme values did not occur simultaneously. There is no record of significant human disturbance to the spoil dump during the duration of this event.

As the wind rose on 13 March, it was observed that the "whole reef [was] turbid and milky". The reasons for this are not clear (!) as the winds at the time of observation had only reached 20kn and the waves observed were not large. On the following day (14 March) after local winds had peaked at 30kn during the preceding night, the reef flat was not as milky, although the silt plume originating from the spoil dump in the vicinity of the jetty was somewhat more extensive than on the previous day. Waves coming from south of the reef were breaking on the reef edge along Wistari Channel and travelling across the reef flat. Wave heights were large, 0.6m at station 2, and were clearly being limited by the water depth over the reef flat in front of the spoil dump. Wave periods from 3 to 8s were present. Big rocks were moving on the beach. On 15 March the wind dropped, the waves were smaller and no silt plume was recorded. It appears that during this initial phase of event E8, the locally generated wind waves were sufficiently large on 13 March to stir up fine material on the reef flat and that this material was removed from, or dispersed over, the reef flat during the subsequent ebb tide. This process continued with the larger waves on 14 March, effectively cleaning the reef flat of available turbidity-generating material.

Between 17 and 22 March 1990, the winds were sustained generally above 20kn. Tides were low and hence observed breaking wave heights were low, although waves were observed breaking on the reef edge to the south virtually all the time but only occasionally on the northern reef edge. Waves of about 6s period were present most of the time. A silt plume was observed north of the jetty behind the boat harbour on 17 and 18 March. The waves observed on 18 March, particularly at station 1 were the largest possible in the very shallow water depth (0.8m) over the reef at high tide on this day. It is probable that they stirred up or eroded silt deposits on the reef flat between the spoil dump beach and the boat harbour. Subsequently on 19 to 21 March observed silt plumes were negligible.

As the high tide levels increased again after 21 March, wave heights increased to 0.3m and silt plumes reappeared. Plumes observed between 23 and 27 March were "streaky", that is, their seaward edge was not a smooth curve but was broken by one or more narrow tongues of turbid water extending seaward from the surf zone. The cause of this type of silt plume is not clear as its first occurrence on 23 March preceded a period of high high tides (3.0m) beginning 25 March, large waves (0.5m) on 26 March and a period of heavy rain between 26 and 29 March. It may have been associated with the shift in wind direction through easterly on 24 March to northeasterly on 27 March. From 25 March waves were breaking on the northern reef edge rather than the reef edge to the south. After 24 March the silt plume generally extended south from the jetty. On 26 March when 0.5m high waves of 5 to 6s period were approaching the spoil dump from the northwest, together with 2s waves from the southsoutheast, it was recorded that the "whole reef is cloudy". The silt plume was not particularly extensive although it was streaky. Again the cause of the cloudiness is not certain. However consideration of the observer's sketches of the silt plumes shows that the source of their turbidity was the spoil dump in the vicinity of the jetty and station 2. There is little evidence of silt being generated from other parts of the spoil dump. Cloudiness over the reef flat is, as previously suggested, likely to be caused by resuspension of sediments previously deposited there or possibly produced there.

During event E8, the silt plume width was always less than 10m, apart from streaks, and the rain near the end of the event did not have any observable influence upon the occurrence or size of the silt plumes.