CHAPTER 254

Adjustments toward Equilibrium of a Large Flood-Tidal Delta after a Major Dredging Program, Tauranga Harbour, New Zealand

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Abstract

The Port of Tauranga is located within a tidal inlet estuarine lagoon system which has been dredged to improve navigation for shipping since 1968. In 1992 a major dredging program deepened the entrance navigation channel through the ebb-tidal delta from 10 to 14 m, and the inner harbor channels to ~13 m. As a condition of the consent to dredge a detailed monitoring program was required which included annual hydrographic surveys over the flood and ebb-tidal delta as well as recording current meter records from morphodynamically sensitive locations to compare with records taken before the dredging. Results of the hydrographic surveys showed significant morphodynamic change of the flood-tidal delta had occurred essentially by the time the 6 month dredging program was completed. Comparison of the S4 current meter recordings showed current changes consistent with expectations of the EIA. Changes on the ebb-tidal delta were not expected but have occurred although not as rapidly, and seem to be ongoing.

Introduction: The Pre-dredging Assessment of Impacts

The Port of Tauranga was established last century within a meso-tidal estuarine lagoon enclosed by a Holocene barrier island and tombolo system (Fig.1). The inlet exhibits many morphological features typical of a meso-tidal inlet as presented by Boothroyd (1985), including a flood and ebb-tidal delta system and a narrow inlet gorge. Prior to dredging, channel depths reached 7-8 m through the delta systems with the narrow inlet gorge attaining 30 m.

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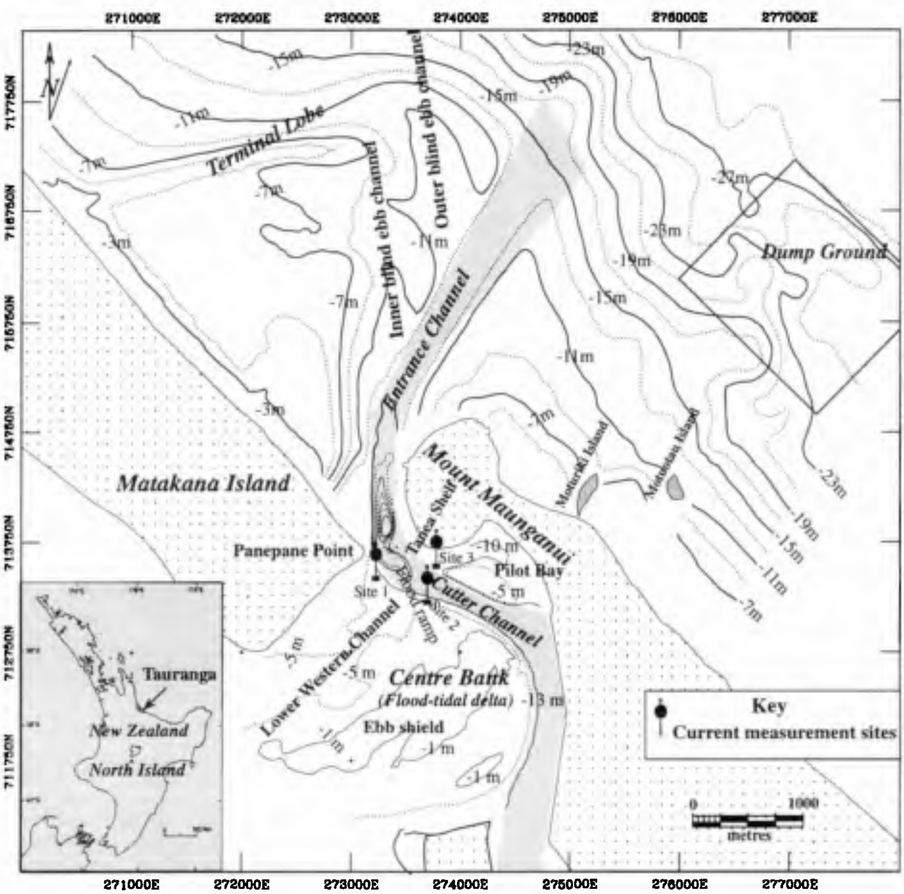

Fig. 1. Location map of Tauranga Harbour flood and ebb-tidal deltas and dredged shipping channels.

The port was expanded in the 1950s, and in the 1960s Wallingford Hydraulics Laboratory of the UK was commissioned to undertake a study investigating improvements for navigation approaches to the port. To improve port operations for ocean-going vessels, dredging of a navigation channel to depths of 10 m through both the flood and ebb-tidal deltas was carried out in the late 1960s. As was to be expected in a high current flow sandy tidal inlet located on a littoral drift shoreline, the navigation channels required significant maintenance dredging. Since the initial navigation channel construction through the tidal delta system, the average maintenance dredging has been ~70,000 m^3 per year, which was taken primarily from specific zones of channel deposition located either side of the inlet gorge, i.e., in the Entrance Channel through the ebb-tidal delta, and in the Cutter Channel which transects the flood-tidal delta.

In 1992, as part of further port expansion, a major shipping channel deepening and widening program was undertaken to deepen the channels from 10 to 13 m within the harbor, and to 14 m outside of the entrance. This involved dredging some 5.5 million m^3 of predominantly sandy material with some shell gravel (Healy et al., 1991).

A condition of the consent permitting the development, required the port company "*to monitor all aspects of the dredging programme and its impact upon the environment, and take such action as necessary to mitigate adverse effects that the dredging shall have.*" Accordingly, monitoring included annual full hydrographic surveys over the flood-tidal delta and adjacent channels, pre- and post-dredging measurement of current flows using RCMs, and surveys of barrier island shoreline change, in conjunction with biological monitoring. The monitoring continued until the end of 1995, some 4 years after the dredging.

The aims of this paper are to report on the morphodynamic changes that occurred after the dredging in this large tidal inlet and delta system, and make an assessment of the time it took for the inlet-tidal delta system to readjust to changed hydraulic conditions.

Morphodynamic Change

Morphodynamic change refers to change in bathymetry or landform created by the actions of the formative processes, in this case the currents and waves. Changing the conditions of the tidal inlet dynamic equilibrium, such as by inducing current flow hydraulic change will likely change the sediment transport pathways, and therefore lead to morphological change. The most sensitive areas are the ebb and flood-tidal deltas and the associated channels.

The projected impact on morpho- and hydrodynamics was studied at the EIA stage using 2-dimensional hydrodynamic modelling (Bell, 1991). The modelling indicated a substantial alteration to the current flow regime over the flood-tidal delta and shipping channel (the Cutter Channel), but no detectable impact on tidal currents over the ebb-tidal delta. Within the harbor the major impact predicted was that the shipping channel of ~13 m depth (c.f. original natural pre-dredged depths of 5-6 m) would act as a tidal "sink" on the ebb flow which would substantially alter the tidal cycle residual flow vectors over the flood-tidal delta (Fig.2). Accordingly, Healy et al. (1991; 1993) predicted as a result of the dredging that parts of the flood-tidal delta sediment transport pathways would be subject to change which would likely induce some morphodynamic change. What was not known was how long it would take for the flood-tidal delta to come to equilibrium after the dredging.

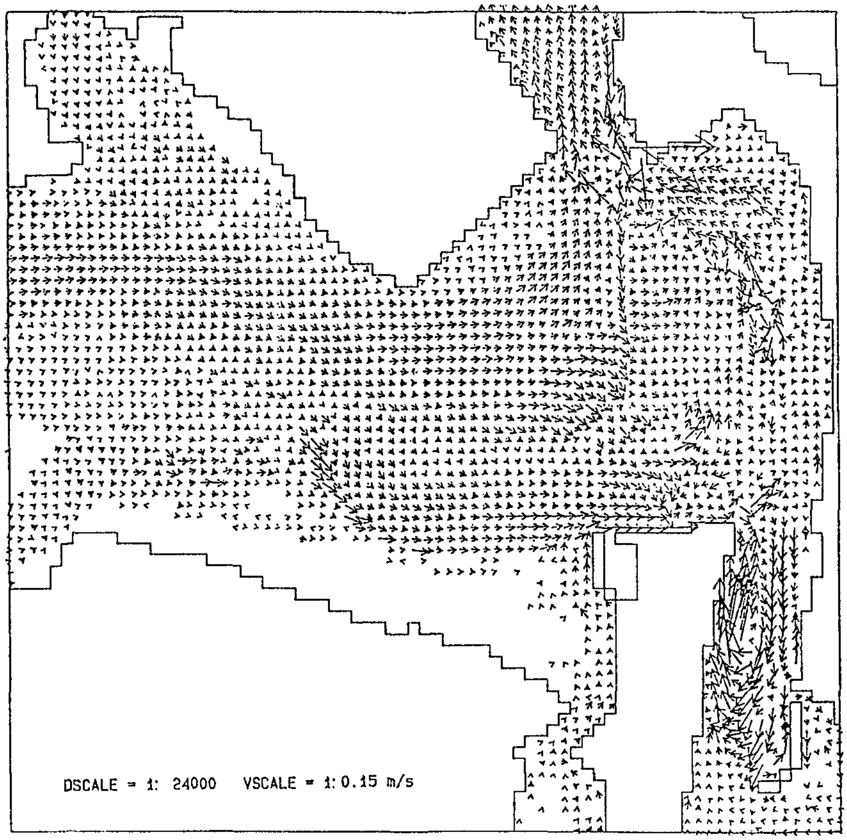

Fig. 2. Residual velocity vector differences showing the changes due solely to the deepened shipping channel in a spring tide (after Bell, 1991).

<u>Sedimentation Within The Dredged Channels</u>

Deepening an entrance channel to an inlet creates a greater hindrance to littoral drift and a more effective sediment trap. The long term effectiveness of the sediment trap is measured by the maintenance dredging requirement. For this case, since the channel deepening of 1992, the maintenance dredging has increased from a long term average of ~70,000 m^3 per year to ~110,000 m^3 per year for each of 1993, 1994, and 1995. An increase of this magnitude was expected, and to date has been remarkably uniform in amount per year. The sediment has accumulated on both the seaward and the harbor side of the inlet gorge.

<u>The Flood-Tidal Delta (Centre Bank)</u>

The flood-tidal delta is perhaps the most sensitive to morphodynamic change because it is formed largely as an interplay between the tidal current hydraulics and sediment supply, whereas the ebb-tidal delta may also be influenced by wave action. Centre Bank shows some features typical of the Boothroyd (1985) "horseshoe crab" morphological model of flood-tidal delta, but is distorted by alignment of the harbour in relation to the inlet entrance, and the consequent predominant ebb-tidal discharge flowing laterally across the feature rather than being diverted by the ebb shield around the delta. For Centre Bank the EIA showed that deepening of the shipping channels within the harbor would be expected to induce a much greater west-to-east component of flow across Centre Bank, and this would likely have an impact on the sediment transport pathways.

The availability of earlier hydrographic surveys over Centre Bank, and the regular soundings since 1989, allow a close monitoring of the changes. The changes in tidal channel and bank outline bathymetry for the 1 m and 5 m depths relative to chart datum (extreme low water spring tide level) are presented in Fig.3. The plots show that between 1982 and 1989 the Lower Western Channel where it crossed the flood-tidal delta, markedly reduced in depth with a greater proportion of the tidal flow being diverted around and to the south of Centre Bank, at which time the disparate, shallower small southern shoals were scoured away. In July 1992 the major dredging program was just being completed, and as a result of the greater west-to-east tidal flows across Centre Bank, the Lower Western Channel was already opening up again. By September 1993, the Lower Western Channel had re-established itself, coincident with shallow shoals also redeveloping on the southeastern margins, and increased area of shoaling on the eastern margin adjacent to the shipping channel. Since 1993 the flood-tidal delta morphology has not changed in broad outline (Mathew et al., 1995).

The net bathymetric differences exceeding 0.5 m between April 1990 and April 1994 are presented in Fig. 4. A broad zone of scour is evident along the Lower Western Channel, resultant upon the deepening of the channel. A zone of minor scour occurred along the outer ebb shield, with a parallel band of minor accretion, indicating a relocation of the distal ebb shield. Minor scour also occurred along the southeastern flank of Matakana barrier island. Accretion was marked on the flood ramp due to channel realignment, as well as an additional capping on the highest part of the inner ebb shield, and along the northeastern rim of the Centre Bank adjacent to the shipping channel.

J. Mathew (in prep.) has undertaken detailed analysis of the sounding data including detailed cross sections. The profiles showing the most change are presented in Fig 5. The sounding sections show post-dredging infilling and scour of parts of the Lower Western Channel, with only minor change on the other parts of the Centre Bank. In particular the shallowing of the ebb shield, interpreted as a strong possibility in the EIA (Healy et al., 1991), has partly occurred, but only up to 0.5 m vertical accretion over an area of ~ 600 x 300 m^2 , and this change likewise occurred rapidly after the 1992 dredging.

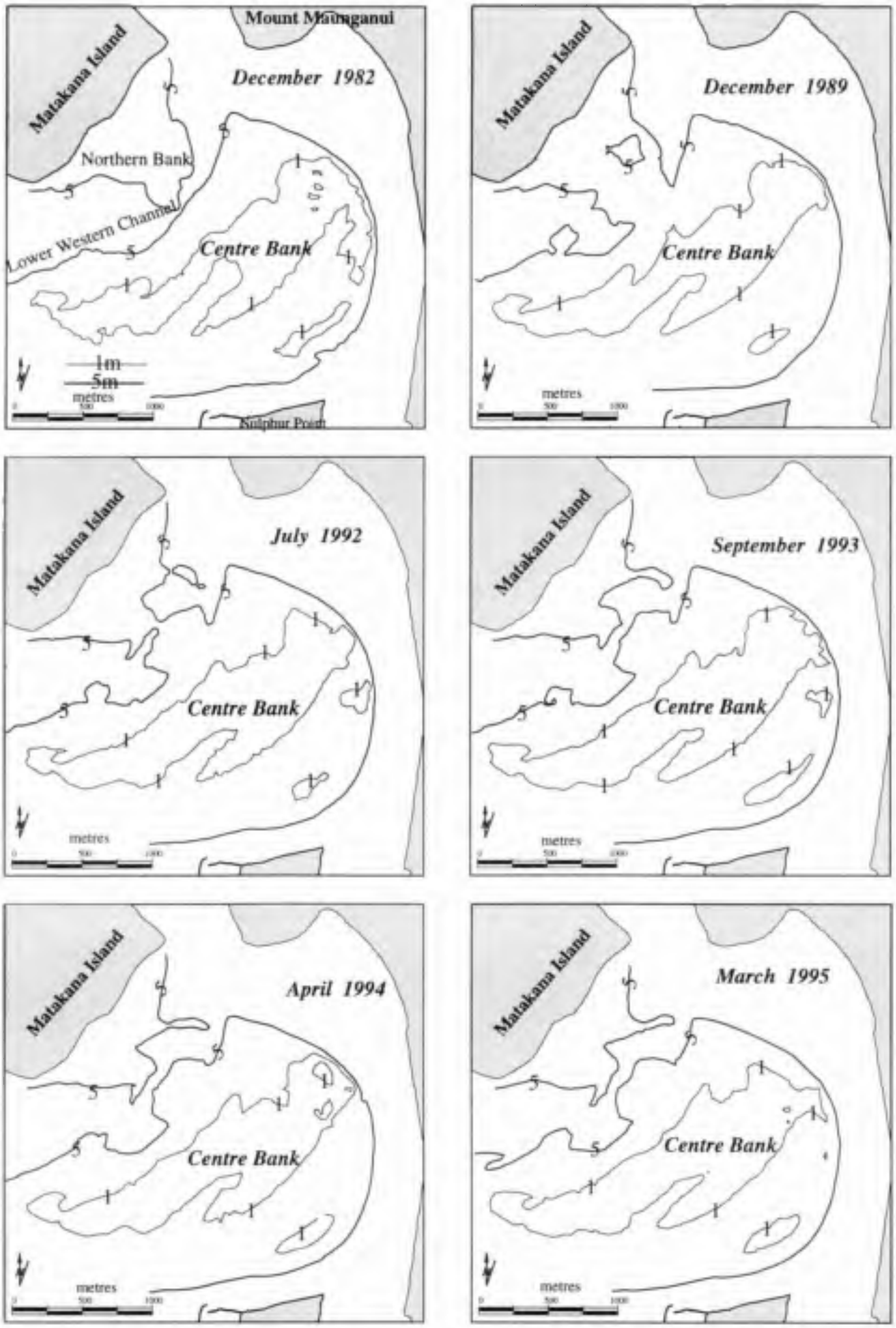

Fig. 3. Bathymetric changes in the Lower Western Channel between December 1982 and March 1995.

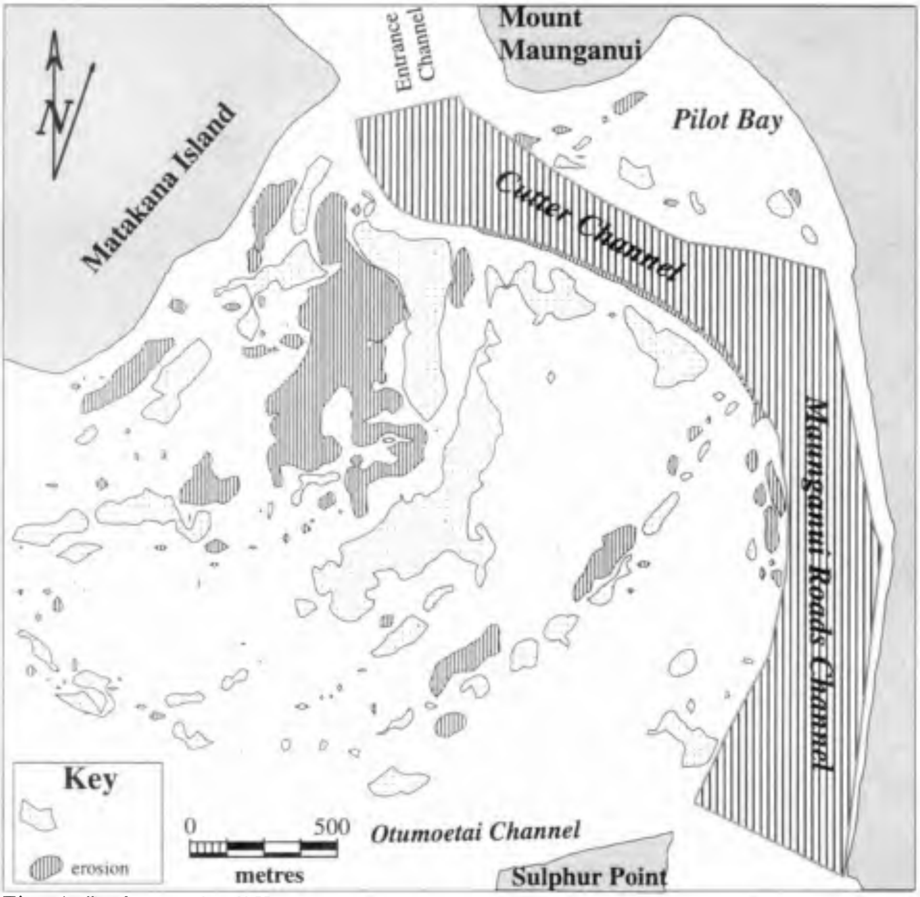

Fig. 4. Bathymetric differences on the flood tidal delta exceeding 0.5 m vertical extent between April 1990 and April 1994.

<u>Air Photo Record</u>

The annual vertical air photos flown since the major dredging have shown realignment of the direction of the sand waves which cap the topographical high of Centre Bank, geomorphically the ebb shield. Noticeable on the eastern sector of the ebb shield the sand wave bedforms have shown an easterly movement. The air photos also show a response of the flood ramp to the dredging and removal of part of a rocky shelf which had been protruding into the inlet gorge and was considered a hazard to navigation. This resulted in an expanded flood jet onto the flood ramp, and created a new area of scoured shell-gravel lag. Expansion of the flood jet was consistent with the higher current flows recorded after dredging by the S4 current meters, discussed below.

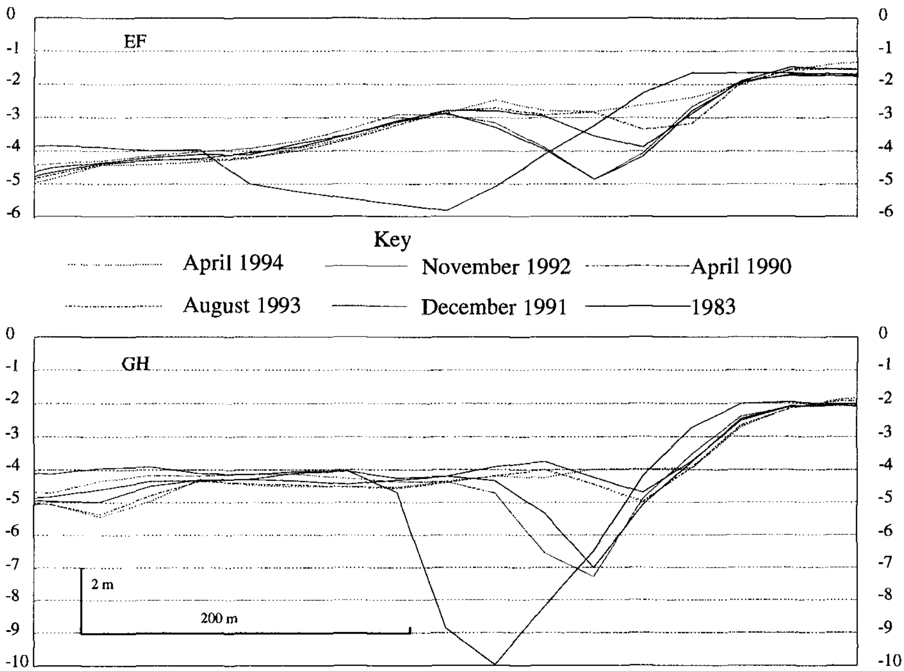

Fig. 5. Cross-sections across Western Channel showing deposition of up to 3 m in Lower Western Channel (EF) and up to 6 m in the blind flood channel (GH) between 1983 and 1994.

<u>Changes in Current Flows Near Panepane Point</u>

Current flows were monitored at 3 locations adjacent to the barrier island side of the inlet using S4 electromagnetic current meters. These were located in the Lower Western Channel, Pilot Bay Channel and on the edge of the Cutter Channel. The resulting data (Figs 6a-b) show some changes in velocities for the Cutter Channel site with greater flood tide dominance rising from 0.85 m/s to 1.20 m/s after the 1992 major dredging. In the Lower Western Channel near Panepane Point there was an increase in current magnitude from 1.00 m/s peak flood flow and 0.75 m/s peak ebb flow before the dredging to 1.25 m/s peak flood flow and 1.10 m/s peak ebb coincident with a directional change after the dredging. However a later deployment at the same site in 1994 showed that the current direction had resumed its pre - 1992 dredging alignment.

The observed increase in current speed at points measured is consistent with a re-aligned and laterally extended tidal jet as a result of removal of the Tanea Shelf from the inlet gorge. That, as expected, has induced some change in the affected sea floor, in particular the Lower Western Channel and flood ramp area.

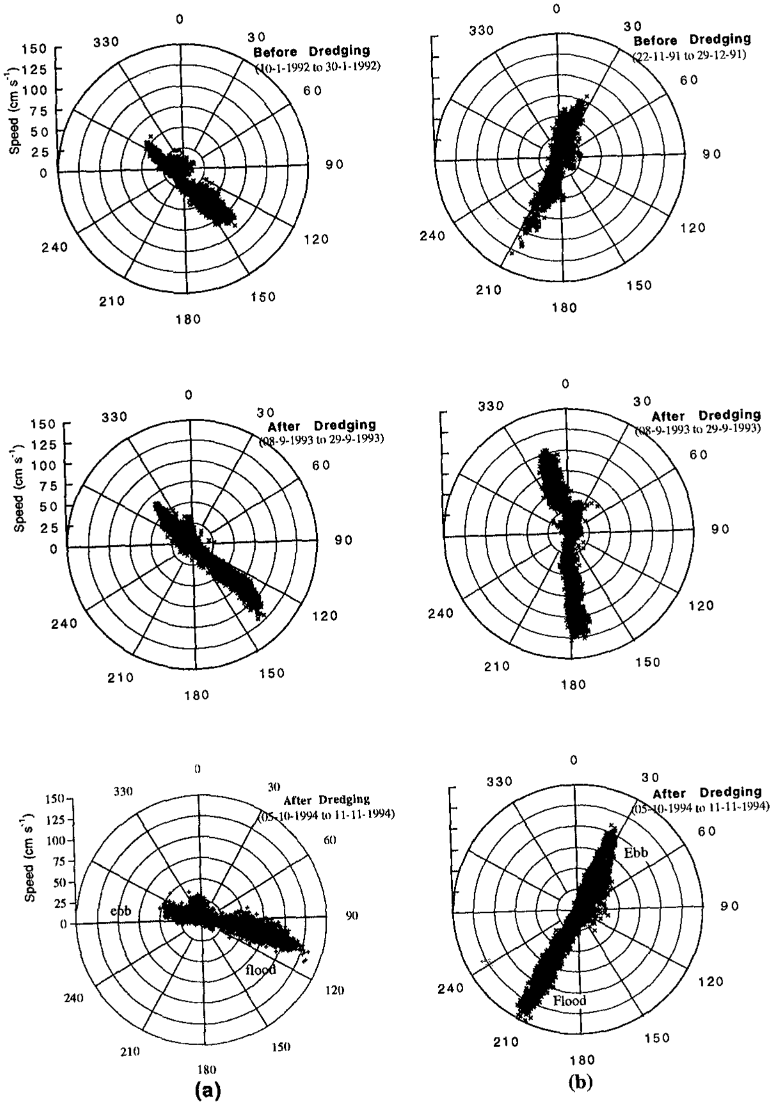

Fig. 6. Current velocities at 1 m above the bed before and after dredging at: (a) the edge of Cutter Channel and (b) at Lower Western Channel near Panepane Point.

The Ebb-Tidal Delta

Annual bathymetric surveys were also carried out over the ebb-tidal delta since 1989. Comparison of the surveys indicates that the ebb delta has been largely stable in terms of its gross morphology, for example the terminal lobe has not changed in location between 1989 and 1995 (Fig.7). The major identifiable change has been that a proximal (inner) blind ebb channel northwest of Mount Maunganui has tended to infill from about 13 m depth in 1989 to 10 m depth in 1995. A distal (outer) blind ebb channel has increased in size.

Overall there has been no sudden or substantial change to the ebb delta morphology which can obviously be linked to the entrance shipping channel deepening in 1992. This is consistent with the numerical model residual vector patterns carried out in the EIA which showed that there was unlikely to be identifiable difference from deepening the Entrance navigation channel from 11 m to 14 m.

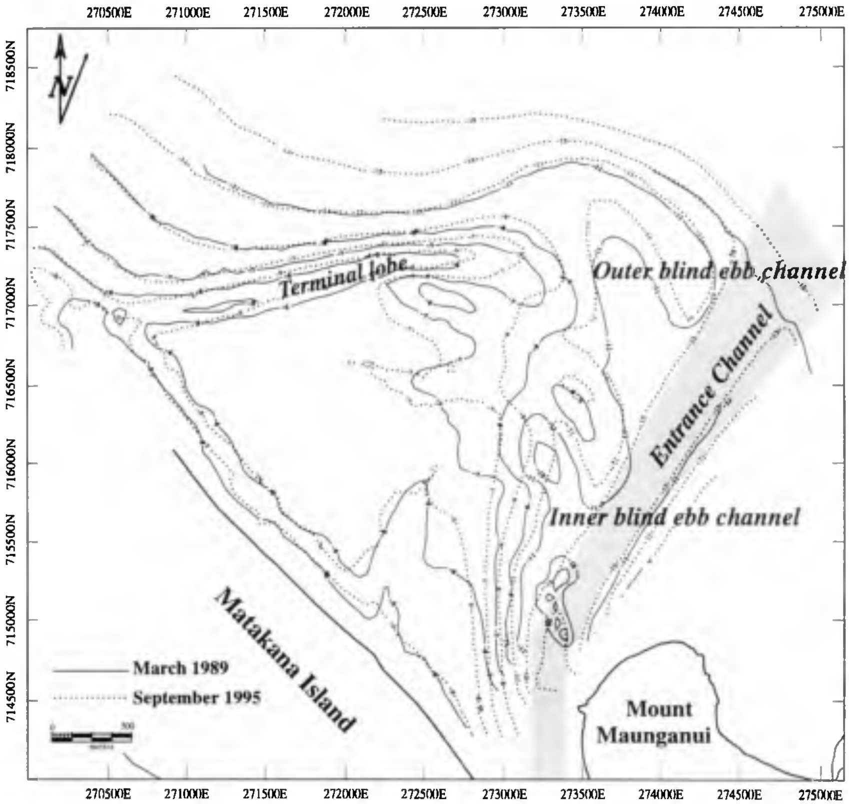

Fig. 7. Bathymetric differences on the ebb-tidal delta between March 1989 and September 1995.

Conclusions

Since the 1992 major channel dredging, the hydrographic surveys have shown that some areas of the flood ramp have accreted by up to 3 m in vertical extent while up to 2.5 m of scour associated with increased currents have occurred in the non-dredged semi-major Western Channel. Alignment of large 'dune' bedforms on the topographic high of the flood delta, morphologically the ebb shield, has changed significantly, but the depths have changed only by about 0.5 m, and overall the broadscale morphology of the flood-tidal delta has retained its coherency.

In terms of how rapidly the tidal inlet and delta system has adjusted to new conditions after the substantial hydraulic change to the tidal delta system consequent upon the 1992 dredging, it is clear that major readjustment for the flood-tidal delta was very rapid, and essentially occurred by the time the dredging was completed - over a 6 month period. On the other hand, the ebb-tidal delta adjustment has been much slower and seems to be ongoing.

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