Recent sedimentation rates for the Rees-Dart braided river delta

MICHELLE WILD[1], THOMAS COCHRANE[1], TIM DAVIES[2], MURRAY HICKS[3], DAVID PAINTER[4] & GAVIN PALMER[5]

1 *Department of Civil & Natural Resources Engineering, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand*
maw56@student.canterbury.ac.nz

2 *Department of Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand*

3 *National Institute of Water & Atmospheric Research, PO Box 8602, Christchurch 8011, New Zealand*

4 *David Painter Consulting Ltd, PO Box 29012, Christchurch 8540, New Zealand*

5 *Otago Regional Council, Private Bag 1954, Dunedin, New Zealand*

Abstract An estimate of the recent sedimentation rates for the Rees–Dart river delta (New Zealand) is required for use in future physical and numerical models studying delta growth. A combination of historic aerial photos and a recent sonar bathymetric survey of the delta front were used to determine volumetric rates of sedimentation. Between 1966 and 2007, the average annual rate of sedimentation was approximately 2.7×10^5 m^3/year, which equates to a catchment denudation rate of 0.3 mm/year. The results also suggest that the delta growth may be dominated by large events, such as the November 1999 flood, because the average annual rate of sedimentation between 1998 and 2007 is significantly higher.

Key words sedimentation; deltas; rivers; braided; coarse-grained sediment

INTRODUCTION

In New Zealand, many steep, mountainous catchments generate large volumes of coarse sediment. This sediment is supplied to alluvial river systems by many processes including debris flows, landslides and bank erosion. Eventually this material is dispersed and deposited in water bodies (e.g. lake, ocean, or river), often in the form of prograding deltas. The Dart and Rees rivers supply large volumes of sediment to Lake Wakatipu, the third largest lake in New Zealand (Fig. 1). At the head of Lake Wakatipu the 632-km^2 Dart catchment and the 405-km^2 Rees catchment "merge" together in a valley of glacial origin to form a 2.5-km wide delta. The headwaters of both rivers lie in the steep, tectonically-active, high-rainfall Southern Alps. High seismicity, high rainfall, and the foliated, highly-erodible schist bedrock cause high erosion rates. The average sedimentation rate of the Rees-Dart delta is estimated for 1966 to 2007 using aerial photography together with recent sonar data of the lake area adjacent to the delta.

DATA

The data used to calculate sedimentation rates include high-resolution digital images of historic aerial photographs and lake sonar data. The sonar data was collected on 12 and 19 November 2007 using a "Lowrance fish-finding sonar and mapping GPS" (model LMS-527cDF iGPS). This sonar unit, hull-mounted on a small motorboat, collected soundings every 3–6 m (depending on the speed of the boat). Figure 1 shows the path followed during the sonar survey. A list of the available aerial photography is summarised in Table 1.

Lake Wakatipu at Willow Place (Site 75277) water levels were used to check that lake levels were comparable for each aerial photograph (see Table 1). One aerial photograph (taken during the 1988 flood event) was excluded because lake levels were >1m higher than the 1966 levels and some of the delta features were submerged.

Although some historical cross-section data are available, the data are mainly recent (i.e. post-1990 and post-1999 for the Dart and Rees rivers, respectively). The Dart River cross-sections start 0.9 km upstream of the delta–lake interface. Given the short length of record, and sparse data near the delta–lake interface, it is not possible to make any conclusions regarding the rate of aggradation of the river bed on the delta topset.

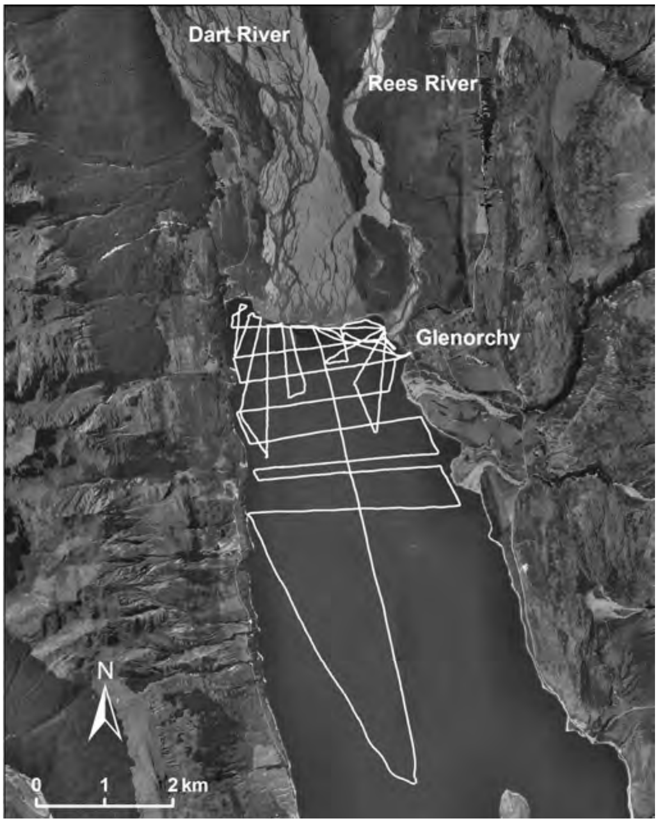

Fig. 1 Sonar data for Lake Wakatipu, collected on 12 and 19 November 2007.

Table 1 Available historic aerial photographs of the Rees-Dart river delta.

Year	Lake Wakatipu level (m)	Difference to 1966 level (m)	Photo scale	Ground sampling distance (m)	Colour?
1966	309.85	0	1:75 000	2.0	No
1977	310.19	+0.34	1:25 000	0.4	No
1998	309.92	+0.07	1:50 000	0.8	Yes
2001	309.78	–0.07	1:50 000	0.8	Yes
2007	309.83	–0.02	1:40 000	0.6	Yes

METHODOLOGY

The available aerial photographs were georeferenced using the co-ordinates of various historic landmarks in the vicinity of the delta. The co-ordinates of the landmarks (e.g. jetties and buildings) were obtained using a portable GPS unit with an accuracy of approximately ±2 m in the mode used for the survey. Figure 2 shows the digitised locations of the prograding delta–lake interface for the Rees-Dart delta in 1966, 1977, 1998, 2001 and 2007.

The volume of sediment accumulating at the Rees-Dart delta was then estimated using the GIS software program ArcGIS. Initially the November 2007 sonar data (Fig. 1) and 2007 delta front location (Fig. 2) were combined to generate a 25-m raster grid surface of the lake bed, up to and including the delta front. This grid was converted to a set of 5 m contours (Fig. 2).

The 1966 and 1998 lake bed contours were then estimated by modifying the 2007 contours in the vicinity of the delta, using the 1966 and 1998 delta front locations (shown in Fig. 2), and assuming that the delta front remains at approximately the 2007 slope (as measured near the centre of the Dart and Rees rivers at the delta–lake interface).

The 2007, 1998 and 1966 contours were then converted into raster grid surfaces, and volumetric sedimentation rates were determined by differencing the grid surfaces (Fig. 3).

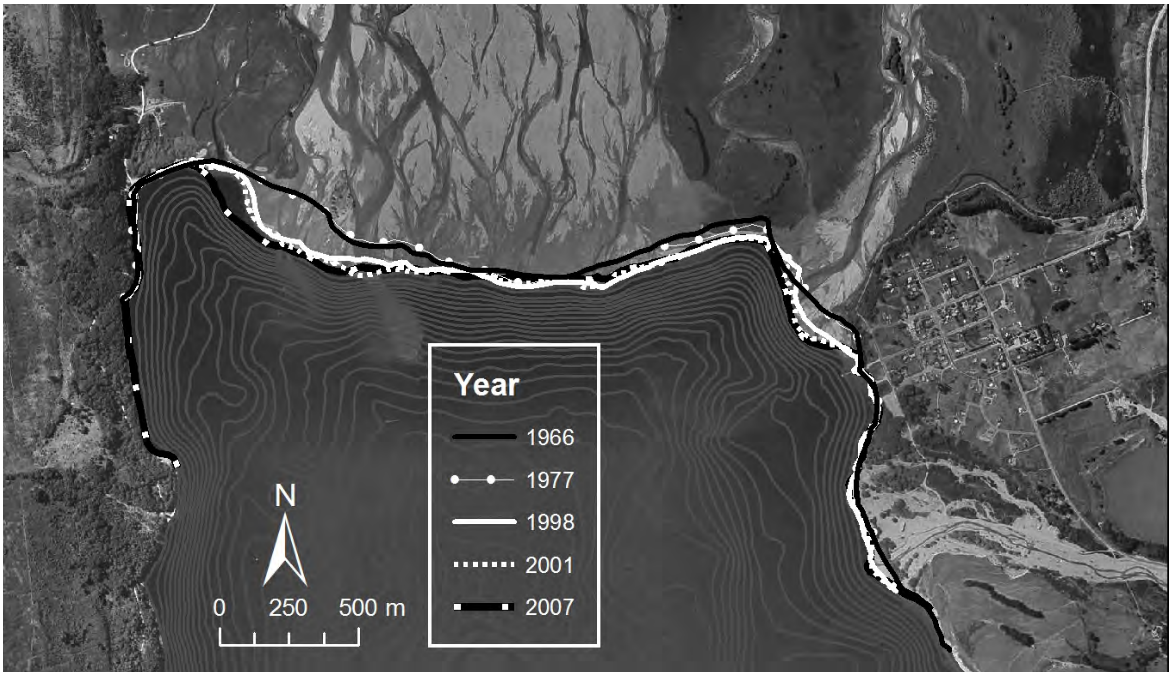

Fig. 2 Rees-Dart delta–lake interface for 1966, 1977, 1998, 2001 and 2007 shown on 2001 aerial photo (2007 derived 5 m contours are also shown in light grey).

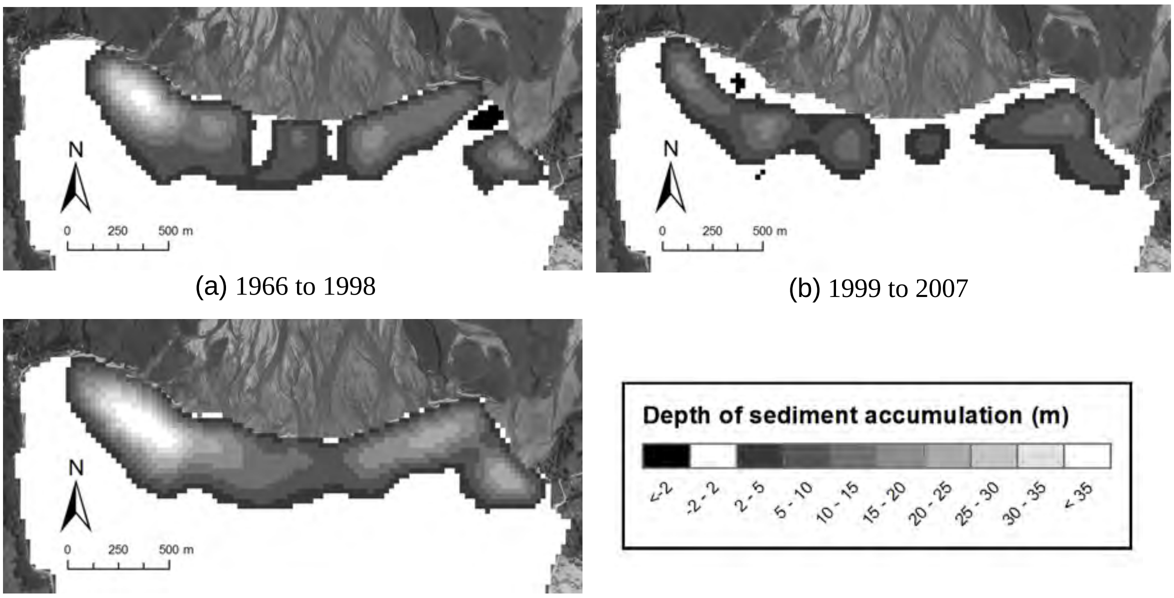

Fig. 3 The location and depth of sediment accumulated on the Rees-Dart delta for various time periods.

RESULTS AND DISCUSSION

A summary of the Rees-Dart delta sedimentation rates, calculated from the GIS volumetric analysis, is given in Table 2. The average annual rate of sedimentation from 1999 to 2007 is approximately double that of the previous 33 years, indicating that the large flood event that occurred in November 1999 (Fig. 4) is likely to have had significant influence on sedimentation rates. Comparisons can also be made with the adjacent Shotover River catchment which has an area of 1088 km^2, compared to the 1037 km^2 Rees-Dart catchment. The Shotover documented bedload estimate of 2.63×10^5 t/year for the period 1967–1999 (Hicks *et al.*, 2000) converts to a volumetric rate of 1.5×10^5 m^3/year (assuming a bulk density of 1.8 t/m^3). This is of the same order of magnitude as the Rees-Dart volumetric rate (which will have some suspended sediment load trapped along with the bedload) of 2.2×10^5 m^3/year for 1966–1998.

Estimated sedimentation rates for the Rees-Dart delta between 1966 and 2007 are also equivalent to a 0.3 mm/year average catchment denudation rate. This is in agreement with documented long-term uplift rates for the Rees-Dart catchment of less than 1 mm/year (Tippett & Kamp, 1993).

Table 2 Estimated sedimentation rates for the Rees-Dart delta.

Time range	No. of years	Volume of sediment ($\times 10^6$ m^3)	Average annual rate of sediment accumulation ($\times 10^5$ m^3/year)
1966 to 1998	33	7.2	2.2 ± 0.4
1999 to 2007	9	4.1	4.5 ± 1.6
1966 to 2007	42	11.3	2.7 ± 0.3

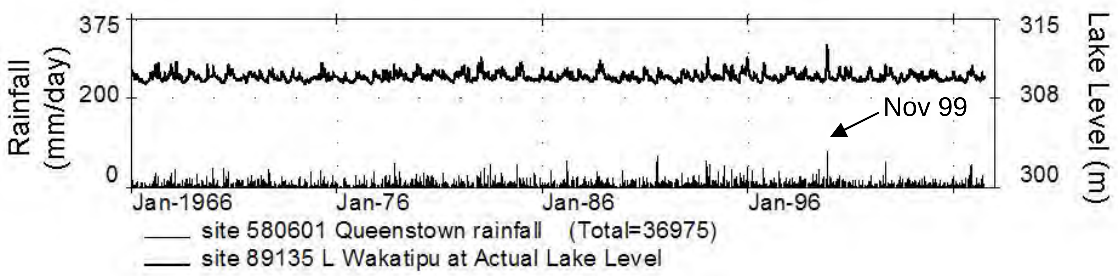

Fig. 4 Local rainfall (mm/day) and Lake Wakatipu lake levels (m above mean sea level) 1966–2007.

The methodology used in this study has several limitations. Firstly, an assumption is required that the delta front characteristics for each time period are similar to the data from the 2007 sonar survey. In addition, the aerial photos are limited to a ground sampling interval of 0.4–2.0 m, and the georeferenced location of the delta–lake interface also has errors associated with the GPS survey, since the delta topset is a dynamic environment with no permanent landmarks that can be georeferenced (i.e. survey points were located beyond the delta and river bed). Sensitivity tests have shown that the overall accuracy of the derived sediment volumes, calculated for each time period, is likely to be approximately $\pm 1.4 \times 10^6$ m^3. This volume is converted to an error range of 0.3 to 1.6×10^5 m^3/year for the average annual sedimentation rates for this study (Table 2).

Catchment sedimentation rates calculated using this method will provide more accurate estimates for catchments where sediment transport is bedload-dominated. This is because finer material may be removed from the delta area as suspended sediment or in turbidity currents. Sedimentation rates are also likely to be under-estimated if delta topset sedimentation is excluded (as in this case where there is a lack of historical cross-sectional information for the Rees and Dart rivers).

The calculated sedimentation rates from this study will be cross-validated with physical and numerical delta growth models. Results will also be used to estimate the potential extent of delta growth over the next century for the Rees-Dart delta.

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