Environment Canterbury

Timaru to Banks Peninsula Coastal Report Status of Gravel Resources and Management Implications

Report No R06/16

ISBN 1-86937-597-1

Prepared by:

Martin Single

MWH New Zealand Ltd
Christchurch

January 2006

Environment Canterbury
Your regional council

Report No R06/16
ISBN 1-86937-597-1

MWH New Zealand Ltd
Tower 2, Deans Park,
7 Deans Avenue
P O Box 13 249
Christchurch
Tel: 64-3-366 7449
Fax: 64-3-341 5345

58 Kilmore Street
P O Box 345
CHRISTCHURCH
Phone: (03) 365 3828
Fax: (03) 365 3194

Environment Canterbury
Your regional council

75 Church Street
P O Box 550
TIMARU
Phone: (03) 684 0500
Fax: (03) 684 0505

Website: www.ecan.govt.nz
Customer Services Phone 0800 324 636

Contents

1. Introduction

As part of Environment Canterbury's wider "Regional Gravel Management Investigation" MWH were commissioned to investigate and report on the potential annual sustainable supply of gravel for the region from the coast for the next 10 years. Three coastal areas were identified by Environment Canterbury for the investigation. These are Oamaru to Timaru, Timaru to Banks Peninsula, and Pegasus Bay.

This report covers the area from Timaru to Banks Peninsula. This area is also known as the Canterbury Bight, and includes three major coastal compartments:

1. Washdyke to Opihi River,
2. Opihi River to Rakaia River,
3. Rakaia River to Banks Peninsula (Kaitorete Barrier).

This report initially presents an overview of the Canterbury Bight coast before reviewing documented changes to the coastal geomorphology based on beach profile and cliff retreat studies. There are no known gravel extraction sites along this coast. However historically, sand has been mined from Kaitorete barrier, and beach sediments are excavated at river mouths to open channels to the sea to prevent flooding. These openings are carried out at Ashburton, Taumutu (southern end of Lake Ellesmere) and Birdlings Flat (outlet for Lake Forsyth). Excavated material is placed on the active beach to the north of the channel. On the basis of the assessed available gravel supply recommendations are made as to future gravel resource management for this section of coast.

2. Canterbury Bight Description

The coast between Timaru and Banks Peninsula covers a distance of approximately 135 kilometres. The coastal environment is characterised by narrow steep mixed sand and gravel beaches with the central area (from Opihi River to Rakaia River) backed by alluvial cliffs comprised of glacial outwash gravels. The cliffs are the eroded margins of the combined alluvial fans of the Rangitata, Ashburton and Rakaia Rivers. These cliffs are actively retreating due to coastal processes acting through a rise in sea level since the last glaciation.

The beach and alluvial cliff sediments are derived from greywacke (indurated sandstone) outwash gravels and sands. The Canterbury Plains is crossed by major rivers, streams and artificial drainage channels which deliver mainly greywacke sediment to the coast. Small amounts of argillite and limestone are also delivered to the coast by the braided rivers. The alluvial fan sands and gravels are poorly consolidated and extend more than 50 kilometres out to sea to the edge of the continental shelf. In the nearshore they are covered by a thin layer of fine sand.

It has been estimated (Flatman 1997) that between 2 and 5km of retreat of the coastal cliffs has occurred in the last four to six thousand years. The coast is almost entirely erosional, with long term rates of shoreline retreat in the range of 0.03 to 1.09 metres per year (average 0.43m/yr). Cliff height and the volume of the beach in front of the cliffs are controlling factors of the erosion rates.

However, there is also a strong temporal variability to the erosion, with rapid erosion occurring during, or as a result of, coastal storms, with relatively little erosion occurring during quiescent periods.

The coast between Timaru and north of the Opihi River is comprised of a low beach ridge backed by low-lying farmland or low loess cliffs. The area from Washdyke to the Temuka River is dominated by erosion processes. Long term erosion rates decrease northwards from about 2.5m/yr at Washdyke to about 1.1m/yr at the Opihi River.

The coast north of the Rakaia River also comprises a low mixed sand and gravel beach ridge backed by remnant lagoons and channels between the Rakaia River and Taumutu, and by dunes and Kaitorete Barrier along the margin of Lake Ellesmere to Birdlings Flat and Banks Peninsula. Erosion of the coast between the Rakaia River and Taumutu has occurred at rates of about 1m/yr, but can be greater during years with frequent coastal storms.

Kaitorete Barrier is a mix of sand and gravel. A series of prograding gravel ridges run almost its entire length, while an area of sand dunes runs along the western half of the barrier. The barrier is thought to have joined Banks Peninsula as long as 3000 years ago or as recently as 300 years, although the southern and inland areas of the landform are thought to have been vegetated about 9,500 years ago. Historically, the shoreline at Birdlings Flat has prograded at a rate of about 1.6 to 2m/yr for the last 150 years (Soons 1998). However there has been little change to the shoreline position in recent years (since 1977) (Gabites 2005).

The process environment is dominated by storm and swell waves from the south to south-east. The waves break close to the shore, generally in a single line of breakers, and form a line that delineates the beach from the nearshore seabed. The mixed sand and gravel beaches are different to sand beaches in that there is minimal transfer of gravel sediments on and offshore, and nearly all of the coarse sediment (sands and gravels) is transported in the swash zone. Fine sand is transported in the nearshore and on the seabed, and removed from the beach, but is not transported or resident on the beaches.

The dominant storm and swell waves are generated in the Southern Ocean and result in significant net longshore transport of sediment from the south to north. The main sources of transported sediment are erosion of the alluvial cliffs and input from the Rangitata, Ashburton and Rakaia Rivers. Short duration storms from the north-east can transport sediment to the south, but the net transport is northward at a potential rate of about 41,000m^3/yr. The volume of fine sand transported northward on the seabed is likely to be in excess of 400,000m^3/yr and is transported around Banks Peninsula, into bays such as Okains Bay and Port Levy, and onto a submarine spit feature north-east of the peninsula (the Banner Bank).

Flatman estimated that approximately 76% of the gravel volume loss of the beaches of Canterbury Bight can be attributed to abrasion and offshore transport of the resulting fine material.

3. Coastal Hazards

Erosion, sea water inundation through storm overtopping, freshwater flooding due to impoundment, and tsunami present hazards to human use of the Canterbury Bight. The barrier beach at Washdyke and north of the Rakaia River provides a natural buffer against sea water inundation during high energy storm events. However, it is insufficient to mitigate the hazard completely, and extensive sea water inundation can occur at Washdyke in most years. There has been no recorded damage by tsunami waves, but the potential for damage from a far field tsunami is recognised in hazard management and planning for the region.

Erosion is a widespread issue between Washdyke and Taumutu. Retreat of the cliff coast between the Rangitata and Rakaia Rivers has resulted in loss of farmland. Erosion is a result of wave action at the base of the cliffs removing the beach and cliff toe support. The cliff collapses and the resulting tallus sediment is distributed alongshore by wave and swash action. Along the Washdyke shore, erosion takes the form of depletion of beach volume and landward migration of the barrier beach.

A similar erosion hazard is incident between the Rakaia River and Taumutu. Storm run-up can result in seawater inundation at Birdlings Flat, but the coastal hazards present in the area of Lake Forsyth and around the margin of Lake Ellesmere result from impoundment of terrestrial waters behind the barrier beach.

4. Gravel Extraction

Environment Canterbury gravel extraction consent information shows no extraction from the coastal environment for the Canterbury Bight.

Informal gathering of semi-precious stones is carried out at Birdlings Flat and along Kaitorete Barrier.

Sand mining was carried out along a 1.2km stretch of dunes along Kaitorete barrier from 1952 until 1984. A 1984 extraction licence application extended the area to include 23.4ha of pingao covered dunes. Peak annual extraction volumes of about 312,000m^3 occurred in the mid 1970s. Sand mining is thought to have ceased in the late 1980s.

5. Beach Profile Changes

Environment Canterbury monitor 58 beach profile sites along the Canterbury Bight coastline north of the Opihi River, and a further 25 sites between Washdyke and the Opihi River. Surveys were installed and have been monitored since 1977 or since the early 1980s. The results of monitoring and investigations north of the Opihi River are presented by Gabites (2005).

The Washdyke area has been the subject of a number of studies due to the significant erosion hazard along this coast. These studies include thesis research at the University of Canterbury and work to assess erosion mitigation measures at Washdyke carried out the South Canterbury Catchment Board in the early 1980s. Work prior to 1988 is summarised by Todd in an annotated bibliography (Todd 1988).

Studies north of the Opihi River include the review by Todd (1988), and Masters thesis work by Flatman (1997), Hart (1999) and Paterson (2000).

Gabites (2005) lists and locates the beach profile sites north of the Opihi River. His summary notes that about three quarters of the sites show landward movement of the beach toe since the original surveys. Apart from sites near the Rangitata and Rakaia Rivers, near Taumutu, and at the northernmost end of the Bight, all sites show retreat of the shore. The river sites are likely to exhibit short term variation due to flood inputs of sediment to the coast, and changes to the position of the river mouth along the barrier beach. However, the only sites away from the rivers that shows seaward advance of the profile contours are at Birdlings Flat (profiles ECE3755 and ECE 3800). These two sites also show an increase in beach gravel volume.

The cliff section of shore between the Rangitata River and the Rakaia River also show erosion. The average rate of cliff retreat was found by Gabites to be approximately 0.5m/yr.

Patterns of volume change in the beach profiles indicate a net northward longshore transport of sediment. The greatest accumulation of sediment occurs between the Rakaia River and Taumutu, at Birdlings Flat, and at the mouth of the Rangitata River.

The shore south of the Rangitata River shows erosion through landward retreat of the beach contours and loss of beach sediment volume.

The beach volume in front of the cliffs shows the smallest amount of change. This reflects the addition of sediment to the beach from the cliffs rather than stability of the shore.

6. Gravel Supply

6.1 Analysis

A broad approach to determining the gravel supply can be carried out through gravel budget analysis. This approach considers the inputs and outputs of gravel to the system under study, with the outcome a determination of whether the budget is in balance, deficit or surplus. Flatman (1997) presents a gravel budget for the cliff section of coast from the Rangitata River to the Rakaia River. Hemmingsen (2004) has also calculated a gravel budget for the entire Canterbury Bight. However the results of this work are not publicly available at this time.

There is temporal and spatial variability to the gravel budget along the coast. The temporal variability arises through the irregular incidence of floods delivering gravel from the rivers, storm waves delivering sediment from cliff erosion, and waves transporting sediment through the coastal compartment from south to north. Wave action also removes gravel from the budget through abrasion of gravel. On sandy coasts, sand can be removed from the active beach by winds, forming dunes in the backshore. Gravel is removed from the foreshore due to wave overtopping of the barrier beaches, but it generally remains in the beach system and is counted in calculating beach volume. Sands and gravels are also lost from the budget by extraction.

6.1.1 Inputs

Estimates of gravel inputs to the coast from the rivers and cliffs is subject to a large amount of variation. Hemmingsen (2004) presents a summary of variations in estimates of sources and sinks of sediments for studies of the Canterbury Bight (Table 7.5, p263, Hemmingsen 2004). Total river supply to the coast will vary widely depending on which estimate is used in the calculation. The estimates used below come from a variety of sources, and so provide for a range of uncertainty. In effect the amounts of gravel supply are indicative only, the actual sediment (bedload, suspended or both) arriving at the coast will vary year to year due to supply variability along the river, and flooding variability in transporting the gravel downstream.

Inputs of gravel to the Canterbury Bight include point and line sources. The point sources are the rivers (Opihi, Orari, Rangitata, Ashburton and Rakaia), while the line sources are the cliffs. Although there is input of gravels from dredge spoil placement offshore of Washdyke, the volume and rates of placement are unknown and are a small component of the total gravel budget. It is unlikely that there is significant gravel transport north of Washdyke past the Opihi River, although some estimates suggest as much as 30,000m^3/yr could be transported north past the Orari River (Reinen-Hamill 1995).

The estimates for inputs of gravel to the Canterbury Bight coast range from 25,440 to 494,000m^3/yr from cliffs; 32,000 to 506,000m^3/yr from rivers; 30,000 to 206,000m^3/yr from longshore transport.

The bedload supply from the Ashburton and Rangitata Rivers was calculated by Flatman to be about 25,000m^3/yr$^-$ for the Ashburton River and about 28,000m^3/yr for the Rangitata River. These estimates compare closely with estimates by Reinen-Hamill (27,300m^3/yr and 19,400m^3/yr respectively). Hudson (2000) proposed a bedload supply of 69,000m^3/yr for the Ashburton, while Duncan and Hicks (2001) have proposed 155,000 to 200,000m^3/yr for the Rangitata.

Work by MWH for this project has calculated the possible gravel supply to the coast from the Temuka River via the Opihi River to be about 19,400m^3/yr and 16,000 m^3/yr for the Hinds River. The bedload supply from the Opihi, Orari and Rakaia Rivers can be estimated from work by NIWA to be about 5,000m^3/yr, 12,500m^3/yr and 73,500m^3/yr respectively, while Reinen-Hamill presents values of 11,500 m^3/yr for the Orari River, 0m^3/yr for the Hinds River and 45,000m^3/yr for the Rakaia River. Reinen-Hamill's input of sediment to the coast from longshore transport of 30,000m^3/yr from south of the Orari River may include the Opihi River input. Other estimates of bedload supply from the Rakaia River have been as high as 320,000m^3/yr.

The large range of values of bedload supply to the coast result in a large range of total supply from rivers. In calculating a total river supply, the high volumes for the Rakaia, Ashburton and Rangitata Rivers have not been used as it is likely they may represent a total bedload, of which most of the sand component is transported away from the coast. The values from NIWA, Reinen-Hamill, Flatman and the MWH studies are more likely to represent the gravel component of the bedload.

The total river supply of gravel to the Canterbury Bight coast is about 176,700m^3/yr (Opihi/Temuka 19,400m^3/yr; Orari 12,500m^3/yr; Rangitata 28,000m^3/yr; Hinds 16,000m^3/yr; Ashburton 27,300m^3/yr; Rakaia 73,500m^3/yr).

Flatman (1997) calculated the amount of sediment contributed to the coast from cliff erosion by multiplying the rate of cliff retreat for a section of coast by the average height of the cliff. This value includes fine material which may be lost from the shore, but the cliff sediment mixture of sand and gravel is similar to that found in the beach. Flatman estimated that total cliff supply of sediment to the Mid-Canterbury coast (south of about Wakanui) to be about 230,000m^3/yr. This value does not include the 25km of cliff coast between Wakanui and the Rakaia River. Gibb and Adams (1982) proposed a cliff erosion contribution of 500,000m^3/yr for the Canterbury Bight. Gabites (2005) presents an average cliff erosion rate of 8m^3/m/yr for the 61.21km of cliffed coast, although he notes that this may be influenced by a high erosion rate at one site. This gives a total of about 489,700m^3/yr of cliff erosion.

Using the cliff erosion value from Gabites, the total gravel supply to the coast is therefore 176,700 + 489,700 = 666,400m^3/yr.

6.1.2 Outputs

Outputs of gravel from the coastal system can occur through losses offshore, alongshore, onshore and through extraction. These losses are extremely difficult to assess, so most often they are calculated from the difference between the inputs to the system and the system balance (erosion or accretion).

Offshore losses on the Canterbury Bight are due to the winnowing of fine material from the beach. However the fine material is the result of abrasion processes. Flatman estimated that abrasion can result in a loss of about 76% of the sediment inputs, while others have suggested a range of abrasion losses from 9 to 98%. Hemmingsen (2004) found rates of reduction of gravels varied along the Bight, and ranged between 5% and 65%, depending on a number of site specific factors including the textural mix of the sediments.

There are no losses of sediment from Canterbury Bight beaches due to longshore sediment transport as the system is effectively isolated by Banks Peninsula and the basalt cliffs at Timaru.

Onshore losses of sediment occur usually on sandy shores, with wind processes moving sand to dunes. Although there are some dunes on Kaitorete Barrier, they are not actively growing, and volume changes to the dune area are included in the assessment of beach profiles.

6.1.3 Gravel Budget Balance

The state of the gravel budget balance can be determined from calculating the net erosion and accretion for the coast from the changes to the beach profiles, where the volume change for each profile is considered representative of the coast to a point midway between the profile and the next one to either side.

At present this is not known accurately. However from Todd's (1988) review and Flatman's (1977) work, the net change in the gravel budget for the area Washdyke to the Opihi River, and the area from the Rangitata River to the Rakaia River can be estimated to be losses of about -23,500m^3/yr and -27,500m^3/yr respectively. The coast north of the Rakaia River has undergone net accretion, but of an unknown amount. An inspection of the summary information on profile change (Gabites 2005) indicates that there may have been accretion of about 76,000m^3/yr, and the coast between the Opihi River and the Rangitata River has eroded by about -30,000m^3/yr. However, from Flatman's work, longshore transport north from the mid-Canterbury coast amounts to about 23.2% of the total gravel losses (total losses – loss due to abrasion) or 78,400m^3/yr. If this is added to the gravel supply from the Rakaia River (less losses due to abrasion) then the total accretion in gravel volume for the area north of the Rakaia River would be about 5,400 + 78,400 = 83,800m^3/yr.

Therefore the gravel budget balance is approximately:

-23,500 - 30,000 – 27,500 + 83,800 (to 76,000) = 7,800 to -5,000m^3/yr.

This indicates that Canterbury Bight is nearly in a state of gravel budget balance. It also be noted that there is an inference that losses from the southern parts of the system are accumulating north of the Rakaia River.

When looking at the gravel budget equation as the sum of inputs – outputs, then the balance of 7,800 to -5,000m^3/yr is made up of 666,400m^3/yr input minus 658,600 to 671,400m^3/yr ouput. Losses, due to all factors including sediment reduction, losses offshore, onshore and alongshore appear to be about the same as the inputs to the Canterbury Bight as a whole. However the Bight shows a range of gravel budget states, from erosion in the south and along the cliffs to the Rakaia River, to stability and slight accretion north of the Rakaia River.

7. Discussion and Recommendations

Looking at the Canterbury Bight coastal system as a whole, it is nearly in a gravel budget balance within an approximate range of –5000m^3/yr (net erosion) to +7,800m^3/yr (net accretion). However, this view obscures the findings that much of the coast is eroding, and therefore in budget deficit. At times there is a surplus of supply of sand and gravel at the coast near the Rangitata and Rakaia Rivers. This material is delivered to the coast during floods, and is distributed along the coast by southerly storm and swell waves. Therefore the gravel does not result in long term accretion to the coast near the rivers.

The only area that exhibits net accretion in the long term is Birdlings Flat. The actual amount of material building up in this area is unknown, but is thought to be a relatively small volume.

Further study of the changes to the beach profiles in this area is required to determine if there is a sufficient surplus of gravel that could be taken from the coast. However, it is likely that there is a high level of uncertainty as to the long-term nature of gravel build-up due to the variability of supply from the rivers and cliff erosion.

It is recommended that the volumes of gravel change for each profile site be examined to determine an accurate gravel budget balance for sections of the coast, noting that erosion and retreat of the cliffs behind the mixed sand and gravel beach continue to contribute to the beach gravel budget.

8. References

Duncan, M.J.; Hicks, D.M. 2001 Assessment of the potential effects of dams on selected South Canterbury rivers on sediment movement and coastal nourishment. NIWA Client Report CHC01/81 prepared for Environment Canterbury.

Flatman, M. R. 1997 Cliff *erosion and Coastal Change, Mid Canterbury.* Unpublished MSc Thesis, Department of Geography, University of Canterbury

Gabites, B. 2005 A Summary of Monitoring and Investigations on the Canterbury Bight Coastline. Environment Canterbury Report no. U05/77.

Hart, D. E. 1999 Dynamics of Mixed Sand and Gravel River Mouth Lagoons: Hapua. Unpublished MSc Thesis, Department of Geography, University of Canterbury

Hemmingsen, M. A. 2004 Reduction of greywacke sediments on the Canterbury Bight coast, South Island, New Zealand. Unpublished PhD Thesis in Geography, University of Canterbury.

Hudson, H.R. 2000 Ashburton River floodplain management strategy; an evaluation of morphological impacts of channel excavations in Blands Reach. Report 2000-02 prepared by Environmental Management Associates Ltd, for Canterbury Regional Council.

Kirk, R.M. 1992 Artificial beach growth for breakwater protection at the Port of Timaru, east coast, South Island, New Zealand. Coastal Engineering, 17, pp 227-251

Paterson, A. K. 2000 River Mouth Processes and Morphodynamics on a Mixed Sand – Gravel Beach. Unpublished MSc Thesis in Earth Sciences, University of Waikato.

Reinen-Hamill, R. 1995 Central Canterbury Bight – Stage 1 Report: Model Calibration and Validation. Report to Canterbury Regional Council. Tonkin and Taylor Ltd.

Soons, J. M. 1998 Recent Coastal Change in Canterbury – the case of Lake Forsyth/Wairewa. New Zealand Geographer 54 (1) pp7-14

Todd, D.J. 1988 Annotated Bibliography of South Canterbury. South Canterbury Catchment and Regional Water Board Publication no. 57.