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THE EFFECTS OF BEACH GRAVEL MINING IN THE GREYMOUTH ENVIRONS

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Department of Conservation, Hokitika

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1.0 INTRODUCTION

This report was commissioned by the West Coast Conservancy of the Department of Conservation, Hokitika (DoC) to assess the coastal stability and potential environmental effects from commercial beach sand and gravel mining (hereafter referred to as "gravel" mining) operations in the Greymouth area (Figure 1). The report was prepared in response to:

- An application by the licensed operator, Westroads Ltd (Westroads), to increase the annual gravel volume it is permitted to extract from the beaches.
- Concerns from local residents, DoC and the West Coast Regional Council (WCRC) about the potential adverse environmental effects, namely coastal erosion, from an increased extraction rate.

The Grey River training works, constructed over 100 years ago, have significantly altered local coastal stability. To the south of the river (Blaketown to South Beach) massive accretion has occurred as northerly drifting coastal sediments are trapped against the river training works. Conversely, to the north of the river at Cobden, significant historical erosion has occurred as the beaches are being starved of sediment that is trapped on the south side of the river training works.

On the accreting Blaketown section of beach, large scale commercial gravel operations have been undertaken for many years, with as yet, little identifiable adverse effects to the local beaches. However, erosion phases have been superimposed on the long-term accretion trend although it is unclear whether these have been caused by natural processes, gravel extraction, or a combination of both. Nonetheless, public and official concern has recently been expressed stemming from the presumption that increasing the gravel extraction rates may lead to increased coastal erosion rates.

Therefore this report has been prepared to assess the impacts of beach gravel mining and to determine an appropriate extraction rate for the area. The areas covered in this report include:

- A description of the study beach.
- A background to the mining licence application.
- A literature review of relevant coastal research relating to the area.
- An assessment of coastal stability based on the literature review, and the analysis of survey data, plans and aerial photographs.
- An assessment of potential environmental effects of the mining operation.
- Recommendations on possible future extraction rates.
- Recommendations on possible measures to alleviate, mitigate, or remedy potential adverse effects.

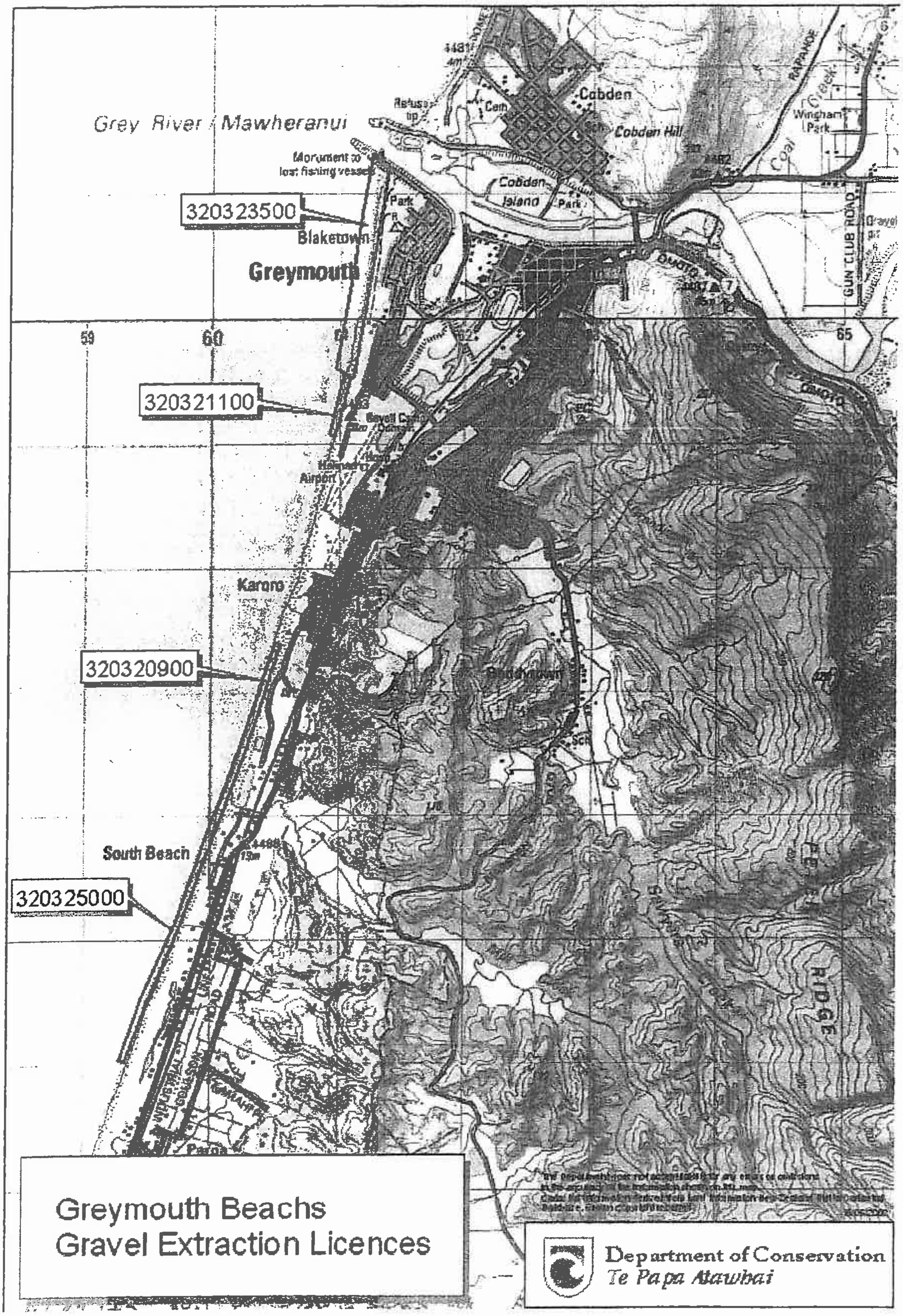

Figure 1. Location Map Showing Beach Extraction Licences (DoC. 2002).

1.1 Project Brief and Objectives

Details of the project brief provided by DoC are presented in the following Table.

Table 1: Project Brief Provided by DoC.

Issue	Increased gravel extraction from the Greymouth beaches.
DoC Concerns	Potential adverse effects on the beach profile and increased risk of coastal hazard.
Significance of Issue	Significant, particularly in relation to maintaining the integrity of the coastal zone.
Actions Required By Consultant.	**1.** To assess, describe, and provide a detailed report on the potential adverse effects on the beach profiles/sediment budget as a result of gravel extraction in the area in the short, medium and long term and therefore increased levels of coastal hazard to the area from Point Elizabeth to Camerons in the South. **2.** Also describe possible measures to mitigate against all potential adverse effects as well as an assessment of locations the gravel take can be increased (if any) **3.** To provide an assessment of the level of gravel extraction is recommended to ensure that no adverse effects occur.

To meet the requirements of the above brief, the main objectives of the report are to:

- Identify long and short-term trends in coastal stability and sedimentation.
- Determine if current or proposed gravel extraction rates will have any adverse effects on the coastal environment.
- Suggests an appropriate future rate of gravel extraction.
- Provide recommendations to reduce any potential adverse environmental effects from the beach gravel mining operation.

Discussions with DoC staff[1] indicated that the study should focus on the Blaketown Mining Licence area (ML 3203235 & ML 3203211), as this is where the vast majority of gravel is extracted from, and where recent public expressions of concern have been concentrated.

[1] Hamish McLauchlan, Mining Officer, Department of Conservation, Hokitika.

1.2 Background to Current Mining Licenses

Gravel mining has been undertaken in the area for many years, and the area covered by the Blaketown licences (ML 3203235 and ML 3203211) is the main source of aggregate for the construction industry (eg for concrete, road material, railway ballast etc; McLauchlan, pers. comm.) in the Grey and Westland districts. Therefore, the gravel resource from the Greymouth beaches has major significance in terms of the West Coast economy and industry.

As shown in Figure 1, the study area includes four mining licences, all of which were issued in March 1993 for a period of 20 years. Details of the licences are presented in Table 2.

Table 2: Current Mining licences.

Licence No.	Location	Mining Area (ha)	Operator	Permitted Annual Take (m^3/yr)	Extraction Rate (m^3/m^2/yr)
ML 3203235	Blaketown Tiphead - Merrick St	25.7885	Westroads Ltd	6,000	0.02
ML 3203211	Merick St – Airport Frontage	2.543	Westroads Ltd	5,000	0.20
ML 3203209	Karoro - SH6 Overbridge	8.07	Westroads Ltd	6,000	0.07
ML 3203250	Overbridge - South Beach	9.84	NZ Pipe Co.	6,000	0.06

As can be seen in Table 2, Westroads hold three of the licences and they have an agreement with the New Zealand Pipe Company Ltd. to extract gravel from the southern most licence site (ML 3203250). Under present mining conditions, Westroads are permitted to extract 23,000 m^3/yr of gravel from the four mining licenses covering a total area of 46.2415 ha, located on the beach between the Blaketown tip-head and South Beach.

Due to market expansion and diversification (requiring gravel for purposes other than those mentioned above), Westroads have lodged an application to increase their annual gravel take. Although the additional volume requested has not been specified in the application, Westroads have stated that they wish to take the maximum allocated by licensing authorities.

Several authors have recorded the potential for adverse effects from beach gravel mining at Greymouth over the last 20 years (Pfahlert 1984; Neale & Lauder 1988; Benn & Neale 1992, 1993; Benn *et al.* 2002). In light of such information, the current mining licences are subject to several mining conditions (standard and special) aimed at reducing potential adverse environmental effects such as coastal erosion. Of these the most relevant to this study are covered under 'Erosion Control' in the Third Schedule of each licence and are presented below:

- *"Mining shall be confined to the active beach area to the seaward of any dunes or vegetated areas.*

- *The inspector of Quarries shall direct the licensee to cease mining of gravel and sand from the area if it is determined by the WCRC, in consultation with the Grey District Council, that permanent loss of beach gravel has occurred as a result of the mining operations and/or natural erosion processes.*
- *The maximum quantity of material to be removed in any time period may be specified by the WCRC in order to minimise the possibility of erosion.*
- *Up to three surveys per year to establish the possibility of permanent loss of beach gravels shall be carried out by the licensee and, at times during the year, determined by the WCRC. If it is determined by the WCRC in consultation with the Grey District Council, that permanent loss of beach gravel has occurred as a result of mining operations, the licensee shall carry out any preventative and/or remedial work so determined, and to the satisfaction of the WCRC".*

Special conditions added to the above conditions include:

- *"The licensee shall restrict access to existing access tracks. No new access tracks shall be formed.*
- *The licensee shall not extract any material from above the normal mean high tide mark nor within a distance of 20 metres of the seaward side of any dune or vegetation.*
- *The licensee shall not remove more than 6000[2] cubic meters of material per annum unless monitoring indicates that the resource is increasing...*
- *The licensee shall cease operations at any time if the Regional Conservator, the West Coast Regional Council or the Ministry of Commerce gives notice that the extraction rates are exceeding the replenishment rates, or if erosion of the beach or dune is occurring or likely to occur.*
- *The licensee shall not leave any holes or unlevelled reject piles on the beach..."*

[2] This is 5000 m^3/yr on ML 3203211.

2.0 GENERAL DESCRIPTION OF THE STUDY COAST.

2.1 Description of Coastline

The coastline examined in this report extends for about 20km from Point Elizabeth, 7 km north of the Grey River, to Cameron's, 13 km south of the Grey River and approximately 2 km north of the mouth of the Taramakau River. The four beach gravel mining licenses extend over a total distance of around 7.3 km from Blaketown tip-head to South Beach, although this is not continuous; a gap of about 1.7 km exists between the southern terminus of ML 3203211 and the northern end of ML 3203209 (see Figure 1). As already mentioned, the main focus of the investigation is around the Blaketown area covered by ML 3203235 and ML 3203211. This area extends from the Blaketown tip-head to around half way along the aerodrome frontage, a distance of about 2.2 km. The southern terminus of ML 3203235 is at Merrick Street whilst ML 3203211 commences here and terminates along the aerodrome frontage.

The beaches are composed of mixed sand and gravel, and are typical of coarse grained beaches in that they are relatively steep and narrow compared to fine grained (sand) beaches. Except for the northern extremity near Point Elizabeth, the entire study beach is backed by a low-lying hinterland. Much of this around the Cobden-Greymouth-Blaketown area is reclaimed tidal lagoons, and further south, numerous creek mouths and old channels enter or back the beach. The beach at Blaketown is composed of coarser sediment and devoid of sand dunes when compared to the beach further south around South Beach to Cameron's. This trend has been explained by the winnowing of fine sediments by wind and as they drift north along the coast from the Taramakau River, and to the rapid artificially influenced accretion at the Blaketown tip-head (Pfahlert 1984; Benn & Neale 1992). Much of the Blaketown backshore has also been levelled for urban development, particularly sports fields.

Since construction of the Grey River mouth works in the 1880s, a massive coastal accretion wedge has formed between the Blaketown tip-head, adjacent the training works, and South Beach, approximately 5km to the south (see Figure 1). The accretion wedge is widest at the tip-head and decreases in width towards the south, where it diminishes completely somewhere in the South Beach area. The accretion has occurred largely as a result of the river works trapping the dominant northerly littoral drift sediment. Correspondingly, on the down drift side of the river works to the north of Greymouth, the coastline at Cobden has eroded significantly (Gibb 1978; Pfahlert 1984). Short term erosion phases have also been superimposed on the long term accretion at Blaketown-South Beach (Pafhlert 1984; Benn & Neale 1992, 1993) and these may be due to natural causes, the on-going commercial gravel extraction, or a combination of both.

Assets at risk from coastal hazards were identified by Benn & Neale (1992) as:

- **Point Elizabeth to Cobden**: Very few assets are at risk, besides the Point Elizabeth Road, which commonly gets buried by beach sediments in times of coastal storms and may eventually succumb to erosion.

- **Cobden**: Houses and properties, streets, and the Greymouth rubbish dump are potentially at risk by coastal erosion and sea flooding.
- **Blaketown-aerodrome frontage**: Few assets are at risk and a wide buffer zone (wide beach, sports fields developed on old beach deposits, aerodrome field) is available to guard against all but the most severe of coastal storms. Some wave overtopping does occur along this beach but causes little inconvenience or damage at present. However, since 1992 new houses have been constructed close to the low-lying backshore at Blaketown (eg: Robinson St).
- **Aerodrome to South Beach**: The main assets at risk are in the southern portion of this zone around Karoro. In the early 1990s the Karoro oxidation outfall pipe lost several sections due to coastal erosion and the ponds themselves were threatened. It was noted that if the erosion trend continued, several industrial properties in the vicinity might also be affected in the near future. Rock protection work was placed around Watson Creek/Domain Terrace Reserve area to protect the reserve from coastal erosion.
- **South Beach to Camerons**: Few assets are at risk in this area although little is known about historical coastal stability.

2.2 Coastal Processes

Local coastal processes and sedimentation have been described in most detail by Pfahlert (1984), and the following is a summary of his assessment.

The Grey River was identified as a major source of sediment for Blaketown Beach, although it was noted that only a small portion of its total load was deposited on the beach, as most was suspended fine sediment that was deposited on the continental shelf. This was based on the difference between the measured accumulation rate at Blaketown Beach of around 15,000 m^3/yr and the sediment yield from the Grey River, calculated by previous researchers at between 140-322 kt/yr. (equivalent to 78,000 to 179,000 m^3/yr at the standard conversation rate of 1.8 t/m^3).

Pfahlert stated:

"Bedload from the Grey River is deposited on the beach (Blaketown) *and transported south by longshore currents. Under south-west angles of wave approach, both this sediment and some unknown quantity from south of the study area are moved back to the north. The evidence presented by the wave, current and sediment analysis indicates that this sediment is largely trapped by the breakwater thereby preventing its transport to Cobden Beach".*

Three separate sediment transport regimes were found to be acting parallel to the shore. These were:

1. A littoral drift zone landward of the 11.22 m isobath in which significant longshore and onshore transport occurred.
2. A shoal zone in which neither strong nor negligible transport occurred.

3. A two way longshore drift system transported material in both the northerly and southerly direction along the beach, at around $10^4 m^3/yr$ to $10^5 m^3/yr$. The northerly drift direction was the dominant.

These transport directions can be explained by wave and current analysis: About 63% of the waves approached the coast from a W-SW direction and the remaining third from the NW-N quarter. Very similar ratios were found for longshore currents on the open coast between Blaketown and Karoro. Mean and significant wave heights were given as 1.5 m and 2.4 m respectively; respective mean and significant wave periods were given as 10.1 and 12.2 seconds. It is thus a high-energy open coast.

A combination of a low sediment supply to the beach, high wave energy and the artificial influence of the Grey River mouth training works, gave net erosion rates of between -1.35 m/yr to -2.4 m/yr for the Rapahoe-Cobden area. From Blaketown to south Beach (about 5km) sediment accumulation was measured at about $15,000 m^3/yr$ and shoreline advance averaged +2.9 m/yr for the period 1874 to 1981. This accretion rate was lower than that presented by Gibb (1978, see Section 3.2.2), possibly due to being measured over a much longer time span, and from more sites.

Pfahlert provided evidence to suggest that as time progressed, the rate of sediment accumulation on Blaketown Beach was decreasing, with an associated increase in sediment by-passing the Grey River mouth, to be deposited on Cobden Beach. Pfahlert explained this as:

"When the breakwaters were initially constructed, the quantity of material which accumulated on the Blaketown Beach each year was high, because the area available for it to accumulate was large. As time passed the rate of accumulation has fallen because there is lees space for it to accumulate in"

It was calculated by Pfahlert that about half of the original volume of sediment that accumulated on Blaketown beach in 1884 (about $18,000 m^3/yr$) is now bypassing onto Cobden Beach (about $9,000 m^3/yr$). If this trend continued (assuming no change in sediment supply), Blaketown Beach would stop prograding in 2067 and all sediment would by-pass onto Cobden Beach.

3.0 ASSESSMENT OF COASTAL STABILITY

3.1 Methodology

Coastal stability in this report was based on the analysis of the following information sources:

- Reviewing relevant coastal research literature.
- Aerial photographs held by the WCRC.
- Beach profile survey data held by the WCRC.

Literature Review

The literature review provided historical, descriptive and quantitative data relating to coastal processes, erosion and accretion rates, beach volumes and historical shoreline positions. This established baseline information to which the most recent data derived from the air photo and survey analyses could be compared. From this comparison trends in coastal stability and beach volumes could be established.

Aerial Photograph Analysis

Trends in shoreline changes since the early 1980s were determined from photocopied aerial photographs held at the WCRC, using standard techniques to determine changes in the position of beach vegetation line. Photo mosaics were available from 1980, 1986, 1999 and 2001 with respective scales of 1: 8,000, 1:4,000, 1:8,000, and 1: 10,000. As these were photocopied mosaics, it was accepted that the accuracy is not as great as individual stereo photos printed on photographic paper due to each section of the mosaics being at slightly different scales, and possible reproduction distortion. However, they are of sufficient accuracy to enable gross trends to be identified. Where possible, measurements were made as close as possible to the profile survey sites established in the early 1990s, as well as at other appropriate sites. Later sections of the report show that the ground survey information verifies the air photo analysis.

Attempts were made to plot the most recent shoreline position onto Pfahlert's map of historical shorelines, which showed a succession of positions of the MHWM from 1874 to 1981. However, this was unsuccessful as the reproduction quality of Pfahlert's maps was not precise enough, and searches of the LINZ databases failed to find maps at suitable scales showing MHWM and covering the whole area. Enquires at the Grey District Council (GDC), who administer the Greymouth Port, for recent maps of the harbour area were also unsuccessful.

Beach Profile Analysis

Short to moderate term beach dimensions, positional changes, and volumes were calculated from comparisons of surveyed beach profiles undertaken in 1992-1993 and 2002. These profiles are shown in Appendix 1. Calculations for beach height, width, and slope were calculated for the foreshore area between the beach crest and the 1m above sea level contour, and sediment volume calculations were made for the total active beach envelope and foreshore, also above the 1m contour. The 1m above MSL contour was used for practical reasons, as the MSL contour was often not reached in the surveys, and the area of beach between the 1m contour and MSL is subject to significant daily fluctuations under the influence of tidal cycles. Volume calculations must therefore be considered an absolute minimum, as a significant volume of sediment between the 1m contour and MSL has not been considered in the calculations. It should also be noted that volume calculations for Cobden and the area between Paroa Hotel and the Taramakau River were not possible due to the lack of profiles in these area. One of Benn & Neale's (1992-3) profiles is located near the Taramakau River mouth at Pandora Ave (Cameron's) but this has not been re-surveyed since 1993 and thus comparisons to recent surveys could not be made.

3.2 Literature Review

Coastal processes and stability, and gravel extraction issues in the area have been researched and discussed by Coode (1879), Gibb (1978), Pharlert (1984), Neale & Lauder (1988), Benn & Neale (1992, 1993), and Benn *et al.* (2002). Of these, Pfahlert's work is the most comprehensive and detailed to date. The major findings of these reports are briefly summarised below.

3.2.1 Coode (1879)

As the designer of the Greymouth harbour/river training works, Coode provided the first observations of coastal gravel movement around the Grey River mouth from Cobden to Blaketown. In his proposed harbour design report, Coode expected, and predicted accretion to simultaneously occur on Blaketown Beach along with the construction of the Blaketown tip-head. For the Packers Quay area, Coode reported that *"This area will be filled by accretion as the breakwater advances, and should be scrupulously reserved for standage ground"*. A plan accompanies the report showing the predicted new High and Low Water Marks after the initial breakwater construction.

3.2.2 Gibb (1978)

Gibb presented coastal erosion and accretion rates for the whole country, based on the analysis of air photos, cadastral maps, ground surveys, field observations and anecdotal evidence. Four of Gibb's sites are located in the present study area, ranging from the Blaketown tip-head to Point Elizabeth: Unfortunately Gibb does not present any data for the southern part of the current study area, between Blaketown and Cameron's. Data for the four sites was based on the MHWM position from successive cadastral maps. Details of these sites are presented in Table 3.

Table 3: Local Coastal Erosion and Accretion Rates From Gibb 1978

Aprrox. Location	Grid Ref. (NZMS 260 Series)	Beach Type	Survey Interval (Years)	Net Accretion (+) or Erosion (-) (m)	Rates (m/yr)	Net Rate m(/yr)
Blaketown Tip-head	J31 631632	Gravel	1930 -1944 1944 -1968	+88 0	+6.29 0.0	+2.32
Cobden (Hall St)	J31 622626	Gravel	1888 -1910 1910 -1971	-20 -50	-0.91 -0.82	-0.83
Pt Elizabeth Rd	J31 632672	Gravel	1910 -1935 1935 -1971	-14 -24	-0.36 -0.67	-6.62
Pt Elizabeth Track	J31 633675	Gravel	1888 -1936	-30	-0.63	-0.63

3.2.3 Pfahlert (1984)

Significant findings of Pfahlert's work have already been discussed in Section 2.2 (Coastal Processes). The main findings of Pfahlert with relevance to gravel extraction on the beaches relate to sediment supply and historical coastal stability. Sediment supply to the beaches came from the Grey River, and coastal erosion and littoral drift from further south, although the relative quantitative input of each was not quantified. Pfahlert's calculation of sediment accumulation at Blaketown, in the order of 15,000m^3/yr, was considered a bare minimum, as a large section of the Aerodrome frontage was not included in his calculations, due to a lack of sufficient historical information.

At Blaketown Beach, sediment accumulation was found to have occurred for the 5km from the Blaketown tip-head to the southern boundary of Pfahlert's study area around Karoro. Accretion was found to be greatest in the north, adjacent to the tip-head and decreased towards the south (Karoro area).

Historical shoreline positions from Rapahoe to Karoro for period 1874-1981 are provided on a series on maps.

3.2.4 Neale & Lauder (1988)

This report provides a general description of coastal processes on sand beaches and gravel beaches, focussing on ways to reduce adverse effects associated with black sand mining and gravel extraction. Although the report was not DoC policy, it presented the department with useful guidelines for its jurisdiction relating to mining activities below MHWM, and on other Crown land in the coastal zone. Lists of suggestions and recommendations are presented to help establish if a beach is suitable for mining and ways of reducing potential coastal erosion and sea flooding relating such operations.

3.2.5 Benn & Neale (1992)

This report discussed coastal processes and hazards in the West Coast Region and summarised previous coastal research. Also included were a summary of the Blaketown–Cameron's gravel mining licenses and a description of the potential adverse effects a proposed increase in gravel mining at the time may have had on the beach concerned. In relation to beach mining and the current study area, the main findings were:

- Despite long-term accretion due to the Grey River mouth works, the beach crest at the Karoro oxidation pond eroded 19m in the three years between 1989 and 1992 (Grey District Council, 1992). Several sections of the outfall pipe had succumbed to erosion and it was recorded that the ponds themselves and some industrial sites may be threatened if erosion continued. The authors stated: *"Gravel extraction may contribute to the problem and a monitoring programme has been initiated"*. To the north of the oxidation pond, erosion was also described from around the Watson Creek/Domain Terrace Reserve area, and that rock protection work was placed to protect the reserve.

- Between Paroa and Blaketown the historical accretion was described and the mining licenses covering the area were described in detail (operators, extraction rates etc). It was stated:

  "Recent applications for renewal of these licenses may increase the extraction rate ... This may create a new erosion problem, or add to the existing erosion phase at Karoro. Inaccurate reporting of extracted volumes by licensees is also of concern. To help ensure erosion does not result, a beach profile monitoring programme has been commenced by The West Coast Regional Council and Department of Conservation. Conditions on mining licenses have also been implemented by the Ministry of Commerce, Energy Division".

The mining conditions of the time were presented in Appendix 10 of the report.

3.2.6 Benn & Neale (1993)

This report presented a preliminary analysis of the coastal surveying programme established by Benn & Neale (1992, see above) to determine the potential effects of gravel mining. Six cross sections were established between Greymouth and the Taramakau River (Figure 2) and were surveyed at monthly intervals for 12 months (January 1992-93), to establish baseline data. It should be noted that beach sediment volume calculations were not made at the time. From these results[3] it was found that:

- The beach was narrow and steep which is typical of coarse grained beaches. (Sediments were observed to be coarser at Blaketown than towards the Taramakau River in the South).
- The average height for the beach (including dunes) was 5.3masl, and 4.5 masl excluding the dunes.
- The average active foreshore width was 60.45m (storm berm to MSL) and the average active foreshore slope (storm berm to MSL) was 7.16°.
- Besides accretion at the Pandora Ave profile (under the influence of changes at the Taramakau River mouth), all other profiles showed remarkable stability over the 12 months survey period. It was noted that: *"No trends in erosion or accretion are discernable from Blaketown to Paroa Hotel, the area from which gravel is extracted"*

It was concluded that the then current rates of gravel extraction were not having any significant adverse effect on the beach concerned. Nonetheless, it was noted that any increase in gravel take may alter this situation, and that likely impacts were difficult to determine until detailed sediment budgets were calculated. It. was thus recommended that the profiles be monitored at 6 monthly intervals and after significant coastal storms, and that further analysis of the profile data be undertaken, with particular reference to beach volume changes and sediment budgets.

[3] The measurements presented in Section 3.2.6 above differ slightly to those presented later in this report, as they include the Pandora Ave Profile (not included in this study as it has not been resurveyed), and they were average measurements for the 12 month survey period. Measurements for 1992 quoted later in this report refer to the January 1992 baseline profile only.

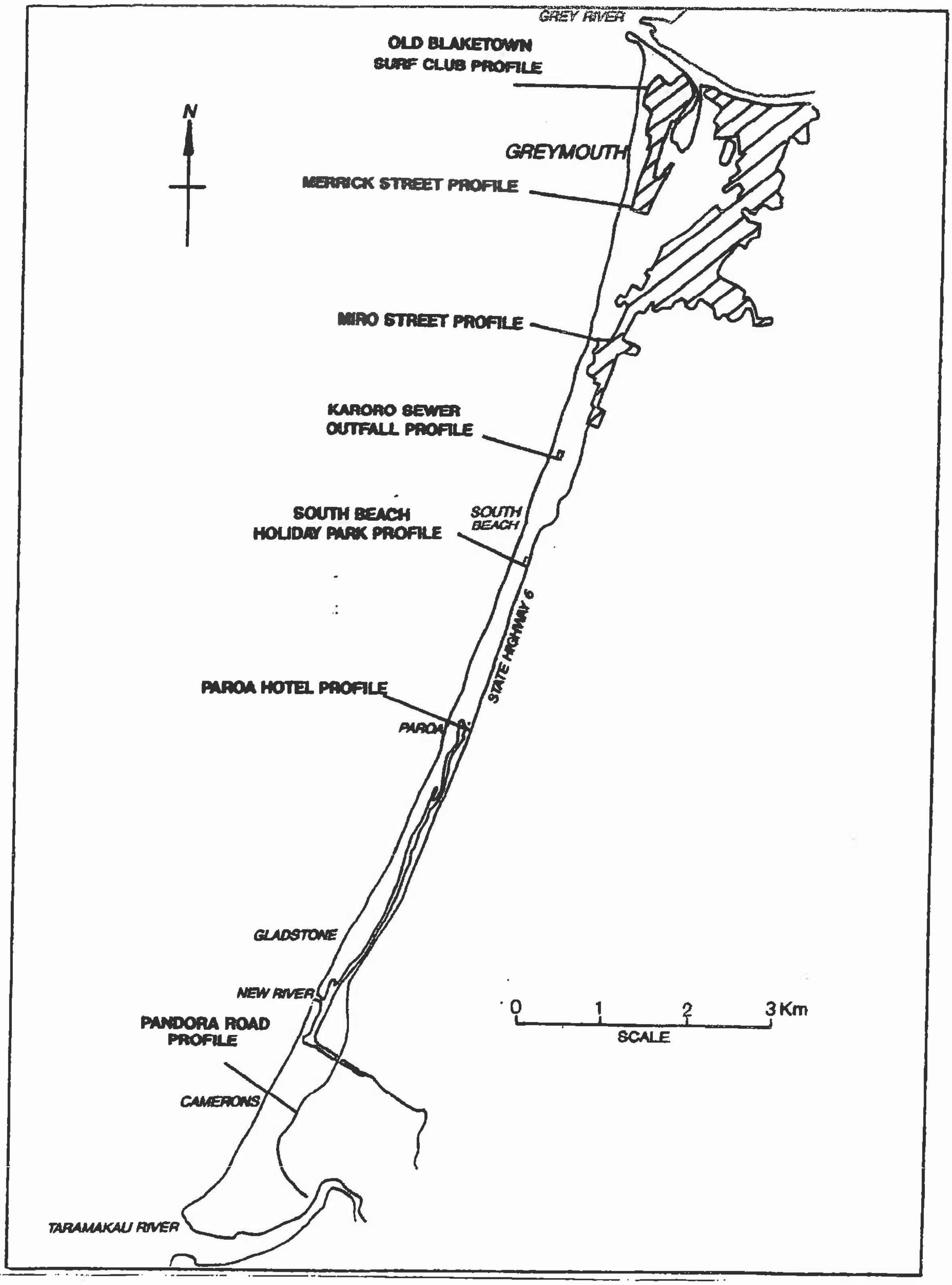

Figure 2: Cross Section Profiles (Benn & Neale 1993).

Note: Karoro Sewer Profile = Grey District Council Profile and the Pandora Ave Profile has not been resurveyed.

3.2.7 Benn, Todd & Owens (2002)

Chapter Four of this report updates and expands upon Benn & Neale (1992), in reviewing coastal processes and hazards in the West Coast Region and identifying areas at risk. The potential impacts of gravel mining on local beaches were recognised with the possible aggravation of erosion in the Karoro area being noted. A recommendation was made to establish coastal profile networks at high risk urban areas and where key infrastructure is at risk (e.g. roads, oxidation ponds). Specifically mentioned were South Beach-Karoro and Cobden-Rapahoe. The South Beach-Karoro area was also recognised as an area where regular (eg 10 yearly) aerial photography should be undertaken due to the potential risk of coastal instability to urban developments and infrastructure.
The report noted that:

"Profile analysis adds accuracy to coastal positional changes determined from historical accounts and air photos, and allows for the calculation of beach sediment budgets to be undertaken. This is particularly important when assessing resource consents for beach mining and gravel extraction operations..."

3.3 Air Photo Analysis

The results of the air photo analysis of changes in the position of the beach vegetation line between 1980 and 2001 are presented in Table 4. In all 14 sites were examined, and of these 10 were in the mining licence areas.

Table 4: Vegetation Line Movements 1980-2001

Specific Location	General Location	Grid Refs (NZMS 260)	Period	Net Change (m)	Rate (m/yr)
Paroa Hotel	Paroa	J32 592533	1980-1999	32	1.52
Old Channel, Kamihi Place	South Beach	J32 594543	1980-2001	44	2.09
Holiday Park	South Beach	J32 599955	1980-2001	14	0.66
Oxidation Pond	Karoro	J32 606566	1980-2001	6	0.23
Miro St.	Karoro	J32 606580	1980-2001	12	0.57
South End Aerodrome	Blaketown	J32 607505	1980-2001	6	0.28
Mid Aerodrome	Blaketown	J32 609589	1980-2001	16	0.76
Merrick St.	Blaketown	J32 610594	1980-2001	23	1.09
Robinson St.	Blaketown	J31 613603	1980-1999	9	0.47
Blaketown Surf Club	Blaketown	J31 613608	1980-2001	36	1.89
Tiphead	Blaketown	J31 614612	1980-2001	0	0
Bright St.	Cobden	J31 619621	1980-2001	52	2.47
Ward St.	Cobden	J31 621622	1980-2001	45	2.14
Kettle St.	Cobden	J31 622626	1980-2001	7.0	0.33
AVERAGE				**21.5**	**1.03**

Note: No suitable coverage for area south of Paroa Hotel.
Grid references are for the point where the measurement profile crosses the beach.

From Table 4 it can be seen that at all sites the vegetation line has advanced seaward (accretion) over the last 20 years, with the average rate of advance being just over 1m/yr. This is despite the ongoing gravel extraction in the region, and follows the long-term accretion trend for Blaketown to

South Beach identified by Gibb (1978) and Pfahlert (1984).

The general trends of movement of the vegetation line for different areas of the study beach can be summarized as follows:

- Paroa-South Beach has advanced on average 30 m at a rate of 1.4 m/yr.
- Karoro has advanced on average 9 m at a rate of 0.4 m/yr.
- Blaketown has advanced on average 15 m at a rate of 0.7 m/yr
- Cobden has advanced on average 31 m at a rate of 1.4 m/yr.

Within mining licence areas, the most significant advances (accretion) have occurred in the South Beach-Paroa area, with lesser amounts of accretion in the Blaketown-Merrick St area. The advance in these areas is verified by survey data and volume calculations described in the following sections.

It is notable that the areas of lowest recorded progradation (apart from the Blaketown tip-head) at Karoro oxidation pond, the south end of the aerodrome, and Robinson Street, are all sites where outfall pipes and popular access tracks enter the beach. From the readily identifiable features on the air photos it could be seen that the beach immediately adjacent to the Blaketown tip head has been stationary for the last 20 years. At this point, the beach may have reached a new long-term equilibrium position in relation to the altered coastal conditions imposed by the breakwater structures, and gravel removal.

However, it is noticeable that in general the lowest rate of shoreline advance occurred in the Karoro area, between the two mining areas. This was an unexpected pattern, which was not picked up from the earlier work of Gibb (1978) and Pfahlet (1984) due to a lack of sites used in those reports. It is considered that this pattern may just reflect the occurrence of access tracks and outfall pipes at these sites as mentioned above, or could be due to the Karoro area being between the immediate accretionary areas from river supply during floods in the Taramakau and the Grey Rivers. Hence, this area only receives sediment from net northward longshore transport, therefore experiencing less accretion than the sites closer to the major gravel bearing rivers.

Also of significance is the seaward advancement of the vegetation line at Cobden over the last 20 years. This indicates a medium term accretion trend, which is a possible reversal from long-term erosion recorded by Gibb (1978) and Pfahlert (1984). Unfortunately no survey data exists to determine this more precisely, although there is other evidence to verify that accretion is actually occurring. For example it is apparent from the air photos that the beach plan shape has changed from smooth concave curve in 1980 to a distinct convex bulge in recent photos. A combination of the vegetation line advance, the apparent sediment bulge on Cobden Beach, and the stationary position of the beach at the Blaketown tip-head supports Pfahlert's (1984) hypothesis of sediment by-passing the Grey River from Blaketown onto Cobden Beach. Additional new evidence from monthly soundings at mouth of the Grey River, which has yet to be analysed in detail, supports this hypothesis. These soundings over the last 5 years indicate a pattern where gravel deposited by the river in the vicinity of the mouth (usually after floods) is moved around the Cobden tip-head by the dominant littoral drift and deposited on Cobden Beach. In exceptional cases this gravel can form an exposed spit/bar extending from the Cobden tip-head towards the beach, and in effect forms a sheltered lagoon. The gravel from the spit/bar then gradually migrates onto Cobden Beach under local wave action (Trouncin, pers. comm). However, more detailed sediment and survey analysis from both Blaketown and Cobden beaches would be necessary to confirm the processes and quantify of sediment involved.

3.4 Beach Profile Changes.

3.4.1 Short Term Changes: 1992-1993.

The longest sequence of successive short-term profiles of the study beach was 12 months of monthly surveys from January 1992 to January 1993 as presented by Benn & Neale (1993) (see section 3.2.6, and profile locations are given in Figure 2). These profiles can be considered representative of local beach fluctuations during stormy years, as 1992 was noted for frequent heavy seas and significant coastal erosion along the West Coast, especially in the Hokitika to Greymouth area.

The maximum envelope of beach change during the 12-month period is presented in Table 5. The contour position fluctuations are the maximum horizontal difference in position of the individual contours between any two surveys; hence they do not represent the net erosion or accretion over the year. Similarly, the vertical fluctuations are the maximum change in elevation at any one point on the profile over the 12-month period and therefore are not representative of the net depth of cut or accumulation over the year. Therefore, the results presented in the Table represent the horizontal and vertical envelope that beach profiles occupied over the 12-month period.

Table 5: Horizontal and Vertical Beach Fluctuations January 1992 – January 1993

Profile	Contour Position Fluctuations – Horizontal Distance (m)						Maximum Vertical Fluctuations (m)
	MSL	**1m**	**2m**	**3m**	**4m**	**5m**	
Paroa Hotel	37.6	8.8	11.6	16.4	17.2	5.2	1.40
Sth Beach Hol. Park.	16.0	9.6	8.8	8.4	0.8	0	1.36
Miro St	24.0	10.4	8.4	8.8	4.8	0	1.30
Merrick St	19.2	12.8	12.8	15.6	6.4	x	2.00
Blaketown Surf Club	26.4	26.4	18.0	18.0	12.4	x	2.16
AVERAGE	**24.64**	**13.6**	**11.92**	**13.44**	**8.32**	**5.2**	**1.64**

Note: X Denotes Beach elevation less than 5m.

It can be seen from Table 5 that the beach surface can undergo considerable short-term fluctuations, especially during stormy years such as 1992. This is normal beach behaviour and is to be expected. As a general rule, the beach will build up during periods of calm conditions as sediment is deposited on the foreshore and crest regions, and will erode (become lower and wider) under stormy conditions as sediment is removed offshore, or as rollover occurs. It is also normal for the largest fluctuations to occur on the mid-lower foreshore as this area is continuously under the influence of wave run-up and backwash processes. In contrast, the upper foreshore and back shore are influenced by less frequent storm wave activity. This general pattern can be seen from the contour fluctuations presented in the Table, with the magnitude of fluctuations reducing with elevation up the foreshore.

Table 5 also shows that the beach surface elevation can range by more that a metre within a month at all sites, with the maximum elevation change in order of 2 m at the northern ends of the study beach. Again, these changes in beach elevation are a response to storm and swell wave conditions - the beach surface will cut down under the influence of storm waves, and will build up under swell waves.

The above results indicate that recent apparent erosion and down cutting of the beach at Blaketown, as reported by residents, may be due to coastal storm activity rather than mining, as the latter half of 2002 was noted for its abundance of heavy seas (Neale; Shearer; Trouncin, pers.comm).

Benn & Neale (1993) inferred the ability of the beach to recover its position and volume quickly after storm activity, and they noted that despite large fluctuations over the 12 month survey period, the beach showed "*remarkable stability*" and insignificant net change occurred at the profiles.

This overall net stability, despite being a year of high coastal storm activity, is reflected in the very small net volume change over the 12-month period as shown in Table 6.

Table 6: Beach Volume changes: January 1992 – January 1993

Profile	**Jan 1992 (m^3/m)**	**Jan 1993 (m^3/m)**	**Net Change**	
			m^3/m	**%**
Paroa Hotel	116.39	137.49	+21.10	+18.1
Sth Beach Hol. Pk.	89.51	78.77	-10.74	-12.0
Miro St	106.14	93.53	-12.61	-11.9
Merrick St	97.59	93.58	-4.06	-4.2
Blaketown Surf Club	119.26	134.60	+15.34	+12.9
AVERAGE	**105.77**	**107.59**	**+1.82**	**+1.7**

3.4.2 Medium Term (10 Year) Beach Surface Changes 1992-2002.

The net changes over a medium term period of 10 years from January 1992 to September 2002 are presented in Table 7. As noted earlier, the profiles presented in Appendix 1 do not show the total extent of the surveys from which these calculations are based, particularly the January 1992 surveys.

A comparison of Tables 5 and 7 indicates that medium term changes in the beach surface are generally of smaller magnitude than the short term fluctuations outlined earlier. This is consistent with normal beach behaviour patterns.

Table 7: Net Beach Contour Position and Elevation Change: January 1992 – September 2002.						
Profile	**Net Contour Position Change – Horizontal Distance (m)**					**Maximum Net Elevation Change (m)**
	1m	**2m**	**3m**	**4m**	**Crest**	
Paroa Hotel	+6.3	+4.0	+8.4	+7.1	0	+0.88
Sth Beach Hol. Park.	-8.6	+5.0	+8.8	+12.8	+13.9	+1.32
Miro St	-6.5	-5.6	-9.6	-13.2	-19.1	-1.84
Merrick St	-8.0	-2.9	-3.0	+1.1	-4.4	+1.04
Blaketown Surf Club	-8.0	-7.8	-1.6	+4.5	+15.7	+1.44
Average	**-4.96**	**-1.46**	**+0.60**	**+2.46**	**+1.22**	**+0.56**
Standard Deviation	**6.34**	**5.72**	**7.90**	**9.74**	**14.30**	**1.36**
Note: + = net accretion, - = net erosion						

The results in Table 7 indicate that there is a general trend of the lower beach retreating and the upper foreshore advancing, hence a net reduction in beach width and steepening of the foreshore slopes. However, it is recognised that there is a great deal of variation between sites, as indicated by the high standard deviation values. The results also show some weak indications of a spatial trend, with the more southern sites at the Paroa Hotel and the South Beach Holiday Park showing more constant advance over the whole profile width than the northern three sites.

Both the cross-shore and alongshore trends are not consistent with a beach accreting against a down drift barrier, under which it would be expected to see the shoreline advance over the whole profile, and the greatest accretion to occur against the barrier at the terminal end of the transport. It is therefore considered possible that both the lower foreshore erosion and alongshore trends are influenced by the mining operation, which is undertaken on the lower beach and concentrated at the northern end of the study beach.

Miro Street, located in the centre of the study area and between the two mining areas is an anomaly to the general trends, being the only site to display a net retreat at all contours over the 10-year period. The erosion at this site also contrary to the advance of the vegetation line over the 20 year period from 1981, and from consideration of beach plan shape equilibrium is not considered to be a long-term reversal to erosion. As shown in Appendix 1, the erosion has resulted from a change in the profile shape from the 1992 situation where there was a prominent crest berm separating the foreshore and backshore, to a continuous foreshore slope without a berm in 2002. In contrast, at the other sites crest berms were largely absent in 1992, but were present in the September 2002 surveys (see Appendix 1). The resulting changes in the beach height and slopes are presented in Table 8. Foreshore widths are not presented as movements in the position of the crest berm have largely influenced these. At all sites the beach/dune boundary has remained largely consistent, hence the change in the beach width is largely represented in the movement of the 1 m contour as presented in

Table 7, which shows that at all sites except Paroa Hotel, the beach has decreased in width by 7-8 m.

As can be seen from Table 8, the crest berm elevation has increased at all sites, with the rate of increase being the greatest at the northern most two sites, where increases in the order of 0.8-1 m are 2-2.5 times the average height increase. As a result of this greater increase in elevation, in conjunction with the reduction in beach width, foreshore slopes at these northern sites have become considerably steeper than they were in 1992.

Table 8 Crest Elevation and Foreshore Slope Changes: January 1992 – September 2002

Profile	Crest Elevation (m)		Foreshore Slope(°)	
	1992	Change to 2002	1992	Change to 2002
Paroa Hotel	4.94	0	4.08	-0.41
Sth Beach Hol. Park.	4.35	+0.03	3.55	+2.59
Miro St	4.61	+0.21	7.12	-1.86
Merrick St	4.36	+0.99	6.60	+3.50
Blaketown Surf Club	4.72	+0.79	4.12	+3.03
AVERAGE	**4.60**	**+0.40**	**5.09**	**+1.37**

Note: Crest elevation is in m above MSL

3.4.3 Medium Term (10 Year) Beach Volume Changes: 1992-2002

Beach volumes for each profile from 1992 and 2002 were calculated for the total active beach envelope, from the landward point of the active profile envelope to the 1m contour, thus includes backshore volume. These results are presented in Table 9.

Table 9: Total Beach Volume Changes above the 1 m Contour) January 1992 – September 2002.

Profile	Jan 1992 (m^3/m)	Sept 2002 (m^3/m)	Net Change		Rate ($m^3/m^2/yr$)
			m^3/m	%	
Paroa Hotel	116.77	139.88	+23.11	+19.8	+0.04
Sth Beach Hol. Park.	87.00	109.73	+22.73	+26.1	+0.04
Miro St	119.34	93.58	-25.76	-21.6	-0.06
Merrick St	98.18	100.02	+1.84	+1.9	+0.01
Blaketown Surf Club	119.26	122.04	+2.78	+2.3	+0.01
AVERAGE	**108.11**	**113.05**	**+4.94**	**+4.6**	**+0.01**

It can be seen from Table 9 that all profiles except Miro Street have gained in volume over the last ten years with the greatest increase occurring in the South Beach – Paroa area. The greater accretion recorded in this area may be the result of less mining activity than further north, or could be due to the presence of a sediment 'slug' moving northwards along the coast from the Taramakau River towards Blaketown. Neale (1987) identified and recorded the movement of such sediment slugs along similar beaches on the South Canterbury coast. Since coarse sand and gravel sediment is injected to the coast from the Taramakau River[4] in pulses during floods, it most likely continues to move along the coast in a 'slug', which shows up as a higher than average beach volume as the slug passes a particular point. Due to the high frequency of floods in West Coast Rivers, (Benn *et al.* 2002 indicates at least 14 in this area from 1992 to 2002) and the unknown travel times or dispersal rates, it is not possible to identify individual floods responsible for the possible slugs.

The small volume increases at the northern end of the study beach are in spite of the retreat of lower beach contours in this area, and are largely as a result of the increases in beach height with the development of the crest berm. Given that the mining licence conditions state that gravel shall not be extracted from *"above the normal high tide mark nor within 20m of the seaward side of any dune or vegetation"*, it is likely that that this berm has not been mined, hence remains as an accretionary feature.

The sediment losses from Miro Street are due to the loss of the crest berm between 1992 and 2002. This is consistent with an erosional profile, and is again an anomaly to the general pattern of beach accretion between Blaketown and Paroa over the 10 year period. From consideration of coastal processes and the 20 year changes from air photographs (Table 4), which indicate that this area of coast is accreting, it is assumed that the observed losses and profile changes do not represent a reversal to on-going sediment losses from this area. It is considered that the losses are most likely due to the presence of a sediment 'slug' during the 1992 survey and the subsequent absence in 2002, rather than the area being a localised sediment source that is feeding sediment in both directions to the adjacent coast. However, it is important to recognise that due to the slower supply of material to this stretch of coast, it can suffer from medium term sediment losses.

Multiplying the average volume of the total study beach for 1992 and 2002 by the 7500 m from Blaketown Tip head to Paroa Hotel Profile gives an approximate volume for the total beach above the 1 m contour of 810,825 m^3 and 847,875 m^3 respectively. This indicates that in 10 years the beach has gained +37,000 m^3 of material at an average rate of +3,700 m^3/yr, despite the fact that up to –23,000m^3 is being removed annually. Adding the extraction volume[5] to the accumulation rate equates to a total annual input above the 1m contour of at least +26,700 m^3/yr. This is considered a

[4] As yet, the sediment input of the Taramakau River to the beach system is unknown, although it is assumed to be significant, based on the similarity of rainfall, geology and topography to the Grey and other surrounding catchments, and to observations from air photos, field work and survey data. Saltwater Creek may also be a significant sediment contributor, as the Paroa Hotel profile is located at Saltwater Creek mouth and the South Beach Holiday Park profile is about 1.5km downdrift.

[5] Potential coastal effects from gravel extraction in the lower reaches of the Grey River (dredging and mining) are not included in this report as these are a separate set of processes and outside the scope of this report.

minimum value as the sediment below the 1m contour is not included in the calculations. Although this figure is nearly twice as high as the 15,000m^3/yr presented by Pfahlert (1984), the figures are considered comparable as Pfahlert's calculations were for a 5 km length of beach (did not include a large length of the beach along the aerodrome frontage) giving an average accumulation rate of 3 m^3/m/yr, compared to the 3.56 m^3/m/yr over the 7.5 km in the current study.

3.5 Summary of Beach Changes

From the above methods of assessment it can be seen that *most* indicators show the beach has continued to accrete slowly over the last 20 years. These indicators include the position of the beach vegetation line and contour positions, beach height, and sediment volumes. It is considered that changes in beach width and slope indicators are due to the gravel mining operations, but that these indicators alone do not imply net erosion. The medium trend progradation follows the long-term trend identified by Gibb (1978) and Pfahlert (1984) for the period 1874 to 1981, although it is occurring at a slower rate than has been historically recorded.

The main findings of the air photo and survey analysis are:

1. The vegetation line over the last 20 years has advanced seaward at all sample sites including Cobden, which has traditionally been eroding, and at Miro St, which has displayed recent foreshore retreat.
2. Accretion between Blaketown and Paroa follows the long-term trend that has been occurring since 1874.
3. Accretion at Cobden implies a reversal from the long-term erosion trend to one of accretion, although more evidence is needed to substantiate this.
4. All profiles, except Miro Street, show signs that the beach has been accreting for the last 10 years, despite a combination of stormy years and gravel extraction.
5. Maximum accretion has occurred in the South Beach-Paroa area. This is considered to be due to the frequent supply from the Taramakau River and less mining at this end of the beach.
6. Accretion at the Blaketown-Merrick St area is due to the sediment sink at the Blaketown tip-head, with the rate of accretion being much reduced due to the effects of gravel mining.
7. Miro Street is an anomaly to the other profiles as it is the only one to show erosion and net sediment loss over the last 10 years. The reason for this pattern at this site are uncertain, but are considered could be due to either local influences at the site (eg beach access), the phase of movement of sediment 'slugs' through the area, or the location not being in the immediate receiving area for sediment discharged from flood events in the Taramakau and Grey Rivers.
8. At no site has the landward toe position of the active beach, including Miro Street, migrated landward (net erosion).
9. Disregarding short-term fluctuations, the beach overall continues to demonstrate "*remarkable stability*" as described by Benn & Neale (1993).

4.0 ASSESSEMENT OF POTENTIAL EFFECTS

The findings of this study concur with that of Benn & Neale (1992) that gravel extraction appears to have had minimal adverse effect on the beach to date. All evidence suggests the beach is still slowly accreting with no evidence of net profile retreat despite the continued and increasing gravel take over the last 20 years. However both long-term and short-term adverse effects could well occur if the gravel extraction and monitoring is not undertaken carefully and sensibly. These potential effects are described below.

4.1 Short-Term Effects

It is most likely that if gravel extraction does have any adverse effects on the beach, these would be short term events, which through common sense can be avoided. These effects include creating large holes in the foreshore by concentrating the extraction in a particular location and in a short period of time, and creating a mass movement slump of the foreshore by creating an excessively high and steep excavation scarp. Both of these scenarios would promote short-term localised beach erosion by creating concentrated areas of wave run-up/backwash and the natural movement of material to recreate an equilibrium profile shape. However, as long as the extraction rate is less than the long-term rate of supply, the effects will remain short-term.

4.2 Sediment Volume Effects.

Although the evidence in this report suggests the beach is still following the long-term trend of sediment volume gain, there is much still unknown about the sediment budget for the beach. This includes sediment inputs and losses as well as transport directions and rates both along and across the beach. The volumes calculated in this report were based on minimal information from five profile sites, and spanning a period of 10 years between surveys. Therefore the sediment volumes presented must be seen as a guideline only. More accurate determination of volume was not possible within the confines of this investigation, although establishing this should be of prime importance in the near future (see Section 6.0).

It is likely that a significant increase in annual gravel extraction could reduce the overall beach volume by exceeding the annual natural sediment input volume derived from local rivers, onshore and littoral transport. Such a volume reduction could lead to an over steepening of foreshore slopes resulting in beach crest failure, lowering and retreat, which inturn increases the possibility of beach rollover, and hence increases the risks of sea water inundation of the coastal hinterland. With the appropriate guidelines and conditions in place, together with regular monitoring, these potential effects should not occur (or be allowed to occur) as a result of gravel extraction operations. However, it needs to be recognised that the beach will still undergo natural erosion phases at various times, which will call for the re-assessment of the permitted extraction volumes during those periods.

5.0 RECOMMENDED GRAVEL EXTRACTION RATES AND LOCATIONS

5.1 Current Extraction Rates

For the last 10 years[6] gravel has been extracted from the beach by various operators at around a rate of 23,000 m^3/yr. Prior to this, Benn & Neale (1992) identified extraction rates at somewhere between 18,000 m^3/yr (declared) and 23,000 m^3/yr (permitted). In 1993, Benn & Neale stated there was no evidence to indicate that gravel extraction operations were having any long-term effect on the beach.

Evidence produced in this report implies that this is *still the case* as the beach vegetation line and contour lines have continued their seaward advance (accretion), and there has been a net beach volume gain since 1992. Based on this evidence, there is *no reason* why gravel can not continue to be extracted at its current rate of 23,000 m^3/yr, so long as the mining conditions and monitoring are adhered to. Mining in ML 3203209 (Karoro area) can continue at the current rate (6,000 m^3/yr) although caution should be expressed, as short term erosion around the Karoro oxidation pond and at Miro Street[7] immediately to the north of the licence area has occurred over the last 10 years. Provisions are in place in the current Mining Licences to halt or reduce gravel extraction at this, or any other site, should problems occur.

5.2 Proposed Increased Extraction Rates

In light of the information presented thus far, there is little evidence to indicate why a trial period of increased extraction volume cannot be undertaken, so long as it is strictly monitored and mining licence conditions are adhered to. As mentioned above, there are sufficient provisions in the mining licence conditions to halt operations immediately if such a trial (or current rates of extraction) was determined to be having adverse effects on the beach. (See Section 6.0).

As Westroads do not specify the quantity of material they wish to extract, it is recommended that they be granted a two year trial period allowing for a 10% increase in the annual extracted volume. This equates to an additional 2,300 m^3/yr, giving a total extraction rate of 25,300m^3/yr (i.e. a total of 50,600m^3 for the two years, at 25,300m^3/yr). This increase is approximately 60% of the annual net volume gain of 3,700 m^3/yr above the 1m contour for the last 10 years. Limiting the take to less that the recorded average accumulation rate and to a two year period allows for the uncertainties over the supply of material and the role of the movement of sediment 'slugs' in beach volume changes, and should not result in long-term adverse effects if the extraction is found to be greater that the supply over this period.

Based on the volume and contour evidence, the additional 2,300 m^3/yr should come from primarily from the Paroa –South Beach licence (ML 3203250) as this area as displayed the most shoreline

[6] Since 1993 when the current mining licences were issued.

[7] Although a volume reduction has been recorded and foreshore contours have regressed since 1992, there has *not* been a landward retreat of the active beach toe.

advance and the sediment gain over the last 10 years. The additional extraction rate over the mining area of this licence is 0.02 m^3/m^2yr, which is half of the average annual sediment accumulation rate over the last 10 years in this area (see Table 9), therefore should not result in over-extraction. A much lesser amount of the additional material could be taken from the Blaketown mining licence (ML 3203235) without adverse effects, however it is considered that licence ML 3203211 in the Merrick St –Airport area be excluded from the increased take as this area already has by far the densest concentration of permitted extraction at 0.2 $m^3/m^2/yr$ (see Table 2). Likewise, licence ML 3203209 from around the Karoro oxidation pond and at Miro St area is excluded on precautionary grounds as this area has been subject to the largest recent short term erosion phases.

After a two year trial period, the effects of the increased extraction rate should be reviewed and a re-assessment of the extraction rate can then be made.

6.0 RECOMMENDATIONS TO REDUCE POTENTIAL ADVERSE EFFECTS

As stated in Section 4, the beach gravel extraction to date has had no or little adverse little effects on the beaches south of Greymouth. Nevertheless, several potential effects were identified that may occur if the extraction operation is not undertaken in the correct manner or if sufficient monitoring is not carried out. This section of the report provides recommendations aimed at reducing these potential adverse effects.

It is thus recommended that the following measures be undertaken immediately, regardless of whether Westroads are allowed to increase their rate of extraction or not:

1. The WCRC and DoC continue to enforce the mining licence conditions and monitoring requirements that are already in place. These measures are considered the minimum requirements for future coastal dynamics investigations and monitoring. By and large, there are already sufficient provisions in the current mining licence conditions and monitoring requirements/recommendations to reduce or mitigate any adverse potential or actual effects. However, it is apparent that the enforcement/monitoring have not occurred as effectively as possible in the past. For example, during the 1990s surveying of the beach cross section profiles was not carried out at the frequency required under the mining licence conditions: The conditions require that the licensee carry out up to three surveys per year, and any additional ones as required by the WCRC. However, it is noted that in recent times the WCRC has rectified this situation and the required monitoring is now being sufficiently enforced.

2. Standardise the units of gravel extraction. For example, the mining licences quantify gravel removal in volume (m^3), whilst the operators declare their take in weight (t). To further this confusion, Westroads use a conversion rate for dry mixed sand of 1.6 t/m^3, and the WCRC operations group (Lowe[8] pers. com) use a conversion of 2 t/m^3, which is the density of saturated mixed sand (CERC, 1984). This could lead up to a 20% variation in the volume gravel being considered amongst the licensing authorities and the operator. It is recommended that the average between these two values, of 1.8 t/m^3, be used, which the standard density used for this type of beach in many research papers including Hicks (1996) and Benn (2002). Alternatively, a simple approach would be for the WCRC and DoC to supervise the weighing of three truckloads of beach material that is representative of the material being mined. These truckloads should come from three different locations so as to include variations in the composition of the beach material (sand/gravel ratio). The average weight of the three truckloads would establish the density of material (t/m^3) to the satisfaction of all parties concerned.

[8] Rick Lowe, Operations Manager, WCRC

3. Ensure gravel extraction is spread out over time and space. Concentrating extraction in a specific place and within a short time frame could lead to beach instability by creating large holes in the foreshore, and leaving insufficient sediment on the beach for it to undergo its normal onshore-offshore cycle of sediment transport. Therefore, the suggestion of Neale & Lauder (1988) is supported, whereby extraction operations should be spread throughout the year by limiting extraction in any one week to 5% of the annual volume allowed. It is likely that an increase of up to10% of the annual volume allowed in any one week would also be acceptable. This means that extraction operations would have to be spread over at least 10-20 weeks of the year. It is recognised that under this extraction regime, Westroads may need to stockpile material from some extraction periods in anticipation of large gravel orders.

4. For recording purposes it would also be helpful to establish definite start/end dates of each year in which the gravel is extracted and declared. The dates of Westroads financial year would be most appropriate in this repect.

5. Survey the *seven* established profile sites between Blaketown and the Taramakau River (Blaetown Surf Club, Merrick St, Miro St, South Beach Hoilday Park, NZ Pipe Co, Paroa Hotel and Pandora Ave) to:
   - Quantify more precisely beach volumes and changes.
   - Help identify the Taramakau River (and possibly Saltwater Creek) input to the sediment budget.
   - More accurately monitor the *effects* of the operation.

   It is considered that surveying the *seven* profiles is the minimum necessary for determining sediment volumes and patterns over the length of beach being mined. This includes two control profiles outside the area being mined (e.g. Pandora Ave, Miro St). These seven profiles should be surveyed at the same frequency as currently required (i.e. up to three times annually), after significant coastal storms, or at any other time at the discretion of the WCRC.

6. Aerial photographs of the beach be taken biennially (corresponding to the start and end of the two year trial period), or after significant coastal storms. Aerial photos provide a useful to back up the survey monitoring of effects and changes, as the total coastal environment can be observed and compared amongst successive photos. In contrast, profile surveys are very site specific, and often the accompanying detailed field notes are not readily available for analysis.

7. Ground based photographs be taken from common points at the profile sites (or other appropriate sites), at least once a year, coinciding with the time of the profile surveying, or after significant coastal storms. Like aerial photographs, ground based photos provide backup for the survey information.

8. Undertake sediment size sampling from all profile sites to determine whether there has been changes in beach sediment size distributions since the sampling undertaken by Pfahlert (1984). Sampling should be undertaken on a 10 yearly basis.

9. The proposed 2,300m^3/yr increase in gravel extraction be divided between South Beach (ML 320325000) and Blaketown (ML 320323500). This split should be in the order of 1,800 m^3/yr from South Beach and 500 m^3/yr from Blaketown. This division is based on the contour and sediment volume data outlined in Sections 3.4.2 and 3.4.3.

10. If Westroads are allowed to increase their extraction rate, the following additional monitoring programme should be established as part of the two year trial:

   - Determine a minium beach profile at each of the profile monitoring locations, below which extraction cannot take place. Under this method, monitoring locations are placed in a grid pattern across the beach profile within the mining area, with a minimum beach elevation following extraction being known at each monitoring location. Such an approach is used in a similar gravel extraction operation on the foreshore of South Beach, Timaru monitoring locations being marked by large posts. On each post is a stainless steel band, indicating the minimum beach elevation, such that if the band is not visible, gravel can be extracted down to the depth where it does become visible, and if the band is already visible above the beach surface, gravel extraction cannot take place at that time. This approach allows rapid identification by all parties of the landward limit of gravel extraction, and the depth of extraction. However, it should be stressed that this marker post method is only relevant if minimum survey profiles are adopted and readily identification of the extraction is required.

   A similar idea is actually presented in the mining licences, which state that if required by the WCRC, the licensee shall clearly mark the operational boundaries with pegs, coloured tape or other approved means. For the study beach, it is proposed that the lowest surface of the 1992 profile envelope should be used as a guideline for minimum beach profile.

4.3 Sediment Size and Beach Morphology Effects

The prolonged extraction of the larger sediment sizes on the beach could over time, lead to an overall sediment size reduction, with the effects being similar to those described above. Coarse sediments, such as those targeted by the gravel extraction operation, are more resistant to movement by wave action; hence provide better protection against erosion. They also allow steeper natural beach slopes to be maintained and allow waves to build higher crest berms than sand beaches for the same volume of sediment. The removal of this larger sized material has two effects on beach morphology, both of which result in increased erosion potential.

The first effect is that foreshore slopes are reduced, which without additional sediment inputs result in crest heights also being lowered. Therefore the beach becomes more susceptible to overtopping and rollover erosion. The second effect is a reduction in the ability of the beach to dissipate wave energy by percolating wave run-up through the sediment voids, and thus wave run-up heights are increased, resulting in greater beach overtopping and associated rollover erosion, and increased foreshore scour resulting in greater off-shore sediment losses.

Although the information currently available on beach morphology changes does not support the above trends, there is no comparative sediment size data available. Pfahlert (1984) found the mean grain size on study beach decreased from 4 mm (small pebble) adjacent to the Blaketown tip-head, to 1 mm (very coarse sand) at South Beach, 5km to the south. To determine if gravel extraction has had any influence on sediment size over the years, sediment samples would need to be collected and compared to the findings of Pfahlert, and again at some stage in the future.

7.0 CONCLUSION

This report has assessed the effects of commercial gravel mining on the beaches in the Greymouth area and was based on three independent lines of evidence, namely the analysis of a literature review, air photos, and ground survey information. From this evidence the main findings were:

1. The beach has been accreting for the last 20 years. This is consistent with the long-term trend, and is supported by all lines of evidence used.
2. The beach geometry undergoes rapid and significant short-term fluctuations (erosion and accretion) due to natural processes (coastal storms and quiet periods). These fluctuations are superimposed on the long-term accretion trend. Thus, periods of natural erosion are to be *expected* on a relatively frequent basis.
3. The beach tends to recover quickly from short-term erosion phases, as indicated by the 12 month beach profiles taken in 1992-3. This was a significantly stormy year.
4. There has been a net gain in beach volume from 1992 to 2002. However, the volume increase and net profile envelope changes are within the range of short-term profile changes.
5. Gravel mining may cause short-term adverse effects on the beach, such as creating holes if the extraction is concentrated in particular places. With sensible extraction operation and monitoring these can be overcome.
6. Under current extraction rates, gravel mining appears to have *little, if any* moderate to long term adverse effects on the beach.

Based on the evidence and analysis presented in this report, it is concluded that gravel extraction can continue at its current rate of 23,000 m^3/yr, and that a trial period of two years be granted allowing the annual extraction rate to be increased by 10%, which equates to an increase of 2,300 m^3/yr, taking the total allocable take to 25,300 m^3/yr.

Such a trial should be subject to the existing mining licence and monitoring conditions and the additional monitoring recommended in this report: This includes the surveying of the *seven* established profiles, biennial aerial photography, and ground based photography coinciding with profile surveying. It is also recommended that extraction be spread out over time and space, the proposed increase in gravel extraction being predominantly from the South Beach mining area and a lesser amount from the Blaketown licence area, a standard sediment density be applied to determine extraction volumes, and minimum beach profiles be determined below which extraction is not permitted.

8.0 REFERENCES

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Disclaimer

This report has been prepared for the benefit of Department of Conservation, Hokitika with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

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19 February, 2003
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APPENDIX 1

Coastal Profiles: January 1992-September 2002.

Note: the elevations (height) given on the Blaketown Profile have not been corrected for the new peg datum. Therefore add 1.7m to all heights.

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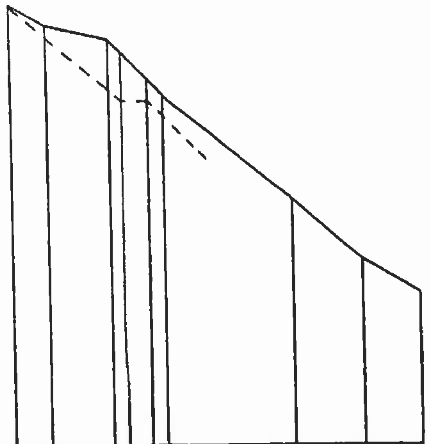
Coastal Profiles: January 1992-September 2002.

Note: the elevations (height) given on the Blaketown Profile have not been corrected for the new peg datum. Therefore add 1.7m to all heights.



Datum R.L. -3.000

Height diff				0.831	0.366				
Height				2.860	2.849				
Natural surface	4.497	4.138	3.810			2.941	1.170	0.147	-0.437
Chainage Hz scale 1:800 Vt scale 1:80	17.99	24.38	35.49	37.60	42.20	44.85	67.49	79.67	89.75

Cross section #36 Paroa Hotel

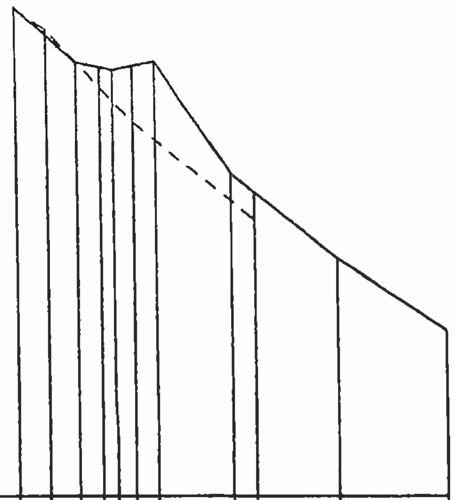
The solid line is the Sep 2002 section

The dashed line is January 1992

Origin <Not applic>
Scale Horiz 1:800 Vert <Not applic>

PAROA TO BLAKETOWN BEACH SECTIONS

Surveyed by:
Reference: WESTROADS



Datum R.L. -3.000

Height diff		-0.095		0.336		0.928			0.479		
Height		4.894		3.944		3.379			1.684		
Natural surface	5.274		4.357		4.239		4.384	2.490		1.030	-0.211
Chainage Hz scale 1: 800 Vt scale 1: 80	59.18	64.60	69.64	73.80	76.17	79.60	83.46	96.46	100.60	114.93	133.66

Cross section #35 South Beach Holiday Park

The solid line is the Sep 2002 section

The dashed line is January 1992

Origin <Not applic>
Scale Horiz 1:800 Vert 1:80 <Not applic>

PAROA TO BLAKETOWN BEACH SECTIONS

Surveyed by:
Reference: WESTROADS