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CANTERBURY REGIONAL COUNCIL

CENTRAL CANTERBURY BIGHT

STAGE 2 REPORT

MODEL PREDICTIONS

Ref: 13686
February 1996

Report prepared for:

Canterbury District Council
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CANTERBURY REGIONAL COUNCIL

CENTRAL CANTERBURY BIGHT - STAGE 2 REPORT MODEL PREDICTIONS

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CANTERBURY REGIONAL COUNCIL

CENTRAL CANTERBURY BIGHT - STAGE 2 REPORT MODEL PREDICTIONS

1.0 INTRODUCTION

1.1 General

The Canterbury Regional Council are committed to evaluating the effects of predicted global climate change on the Canterbury coastline to assist ongoing coastal resource management decisions. Tonkin & Taylor Ltd was commissioned to predict future shoreline positions using Unibest, a numerical model along the central Canterbury Bight, from the Orari River to the Rakaia River (CRC Ref. MO5-0040, 1/02/1995), see Figure 1.1 for the site location. The first stage of the works involved the model calibration and verification (Tonkin & Taylor, June 1995). In this phase the successfully calibrated model was used to examine the expected effects of climate change on this coastal stretch.

1.2 Scope of Works

Future predictions of shoreline behaviour were carried out initially for seven scenarios of climate change

1. Status Quo (existing wave climate and conditions)
2. Sea level rise of 0.25 m
3. Sea level rise of 0.5 m
4. 50% reduction of wave energy from the southerly quarter and a corresponding increase in wave energy from the easterly quarter of 50% (similar to Hicks, October 1994)
5. 50% reduction in sediment supply from the rivers
6. Combination of run 2, 4 and 5
7. Combination of run 3, 4 and 5

A final combination of run 4 and 5 was also carried out (run 8) to investigate predicted coastline change without the effect of sea level rise.

The report is to be accompanied by a computer diskette of the results of the prediction runs in a format compatible with the Regional Council's Arc/info GIS.

1.3 Report Layout

The study was carried out by Richard Reinen-Hamill a coastal specialist. Quality assurance and control were done by John Duder, a Director of Tonkin & Taylor Ltd.

A description of the input parameters for the various prediction runs is included in Section 2. The results of the runs are described in Section 3. Overall conclusions and recommendations are in Section 4.

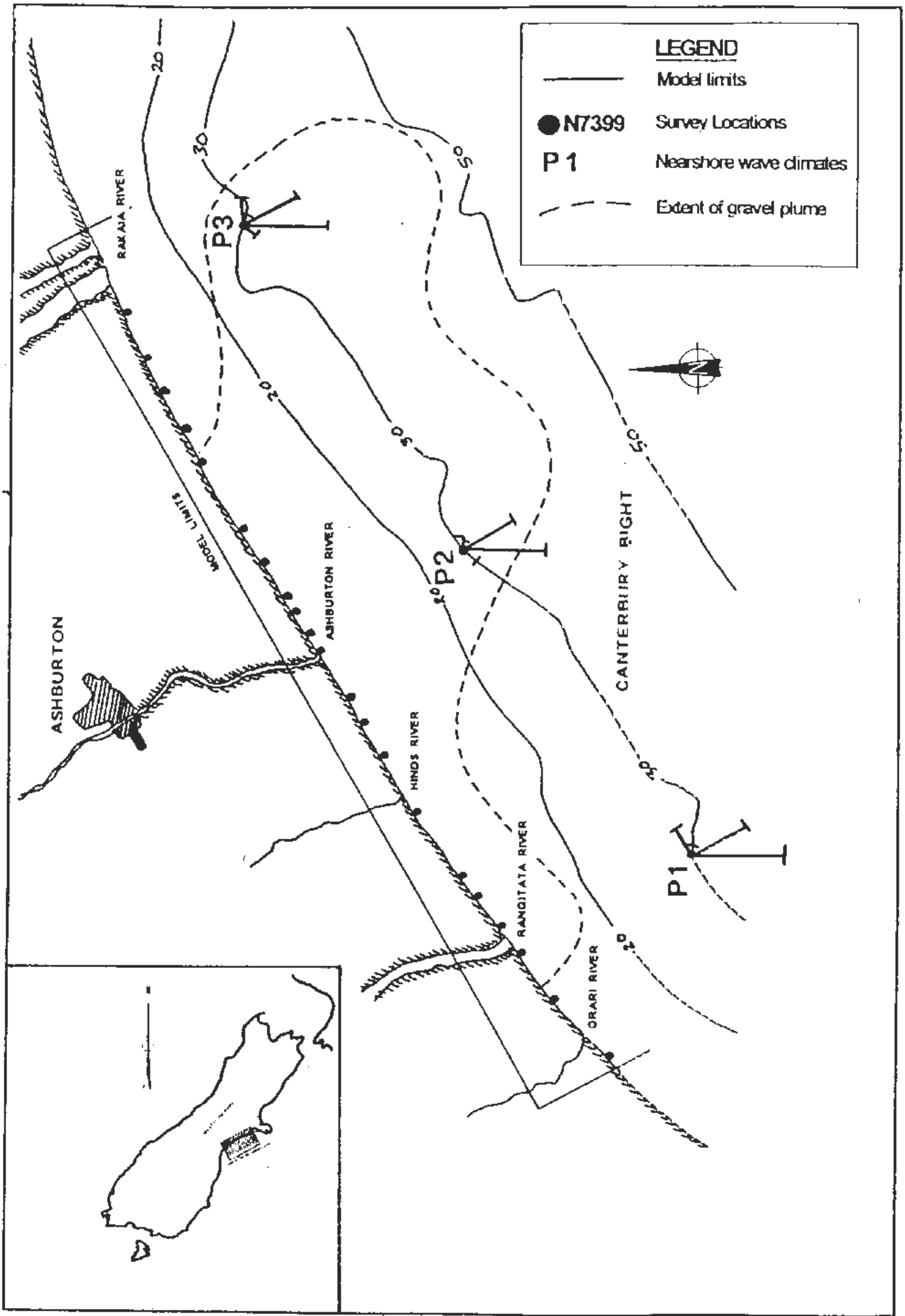

Figure 1 Location and site plan

2. INPUT PARAMETERS FOR FUTURE COASTLINE PREDICTIONS

2.1 General

In all model runs the base coastline for the future predictions was taken to be the 1984 coastline obtained from the 1:50,000 topographical maps NZMS 260 L37 and K38. The runs were continued to 2045, 61 years from 1984.

2.2 Sea Level Rise

Sea level rise influences sediment transport by increasing the wave energy that can reach the shore (due to increased water depth) increasing the sediment transport capacity.

In this study sea level rise was modelled by raising the sea level relative to the cross-shore profiles by 0.25 m and 0.5 m respectively without changing the profiles in any way and keeping the same rate of abrasion as a worst case scenario

2.3 Wave Climate Change

A future wave climate was obtained by doubling the energy of waves arriving from the easterly quarter and halving the energy of waves from the southerly quarter. This was achieved by respectively increasing and decreasing the wave height by a factor of 1.414. Easterly was defined as coming from 45 to 135 degrees and southerly from 135 to 195 degrees. This method is similar to that carried out by Hicks (Hicks, October 1994).

By examining the frequency of occurrence of waves from these sectors presented in the table of highest sea and swell on open sea east of Canterbury (Appendix 1) it can be seen that by halving the frequency of waves from the southerly direction and doubling the frequency for waves from the east results in a change in the total frequency from 100% to 90%. This implies that a total reduction in wave energy may occur which would effectively reduce the abrasion experienced along the coastline.

Two wave climate scenarios were carried out to give some insight to the effect a reduction in abrasion would provide. The first involved a shift in wave energies with no reduction in abrasion, followed by keeping the same shift in wave energy but reducing abrasion by 10% along the entire coastal stretch

2.4 River Yield Reductions

Reductions in river supplied sediment were applied to the Rakaia, Ashburton, Rangitata and Orari rivers to examine the effect on erosion. Table 2.2 shows the original modelled yield and the 50% reduction used in this phase.

Table 2.1:
Abrasion Rates

River	Distance along model, x (km)	Abrasion loss per cell (m^3/500m/yr)	90% Abrasion loss per cell (m^3/500m/yr)
Rakaia	3.50	1750	1575
Ashburton	39.50	1500	1350
Rangitata	67.0	2000	1800
Orari	78.0	3250	2925

Table 2.2:
Modelled River Yields

River	Original Modelled Yield (m^3/year)	Yield Reduced 50% (m^3/year)
Rakaia	45,000	22,500
Ashburton	27,300	13,650
Rangitata	19,400	9,700
Orari	11,500	5,750

3.0 RESULTS OF MODEL RUNS

3.1 Introduction

The 1984 and 2045 coastlines for the eight runs are enclosed in GIS compatible format, on the 3½" disc in Appendix B.

Figure 3.1 shows the difference between the 2045 and 1984-coastline for the business as usual case (Run 1). Table 3.1 summarises averaged rates of cliff line change along various coastal stretches for the eight runs. Figures 3.2 and 3.3 show the comparative difference the various climate change scenarios have made by comparing the difference in final coastline location of Runs 2 to 8 with the business as usual (Run 1) case. Figure 3.1 shows the comparison for Runs 1 to 5 and Figure 3.2 contains the results of the combination of climate changes, Runs 6 to 8. Annual average sediment budget for each of the eight runs are shown in Figures 3.4 to 3.12.

Table 3.1
Comparison of Average Modelled Cliff line Changes along Coastline (m/yr) from 1984 to 2045

Shoreline Stretch	Run 1 Base S	Run 2 slr=0.25 m	Run 3 slr=0.5 m	Run 4a energy wav+90%-%abr	Run 4b energy wav-abr	Run 5 river yield 50%	Run 6 comb. 1	Run 7 comb.2	Run 8 comb.3
Rakaia to 20,000 m	-0.31	-0.29	-0.28	-0.32	-0.35	-0.38	-0.42	-0.39	-0.39
20,000 m to Ashburton	-0.28	-0.27	-0.27	-0.23	-0.29	-0.32	-0.33	-0.32	-0.30
Ashburton to Hinds	-0.42	-0.43	-0.43	-0.36	-0.41	-0.46	-0.46	-0.46	-0.43
Hinds to Rangitata	-0.48	-0.41	-0.34	-0.60	-0.64	-0.51	-0.60	-0.54	-0.64
Rangitata to Orari	-0.68	-0.62	-0.57	-0.81	-0.86	-0.73	-0.81	-0.75	-0.84
TOTAL ALONG COAST	-0.41	-0.38	-0.36	-0.43	-0.47	-0.46	-0.50	-0.47	-0.49

3.2 "Business as Usual" Scenario (Run 1)

The "business as usual" scenario continues at similar rates of longshore erosion and coastline change as the 1942 to 1984 case reported earlier (Tonkin & Taylor, June 1995). Slight differences in the modelled rate are attributed to slight differences between the synthesised 1942 coastline used in the calibration stages and the 1984 coastline obtained from topographic charts used in this phase.

From Figure 3.1 and Table 3.1 it can be seen that erosion occurs along the entire coastline with generally more erosion south of the Ashburton River. There is also a trend of greater erosion around the river mouths. As no significant increase in erosion was observed in the historic records at monitoring sites adjacent to rivers, this is likely to be a model anomaly. The anomaly is probably due to an imbalance between the slight protuberances adjacent to the river mouths which causes locally increased sediment transport gradients, and the average rate of abrasion at these locations.

The modelled extent of erosion around the Orari River of around 35 m from 1984 to 2045 compares favourably with the modelled rate of around 40 m from model studies of the Washdyke-Opihi coastline (Hick, October 1994). The average retreat rate for the entire coastline is -0.41 m/yr which equates to an average of a 25 m retreat over 61 years.

3.3 Sea Level Rise of 0.25 m (Run 2)

Sea level rise creates deeper water at the coastline. As anticipated this allowed higher waves to reach the coastline (i.e. more energy). From Figure 3.2 it can be seen that with 0.25 m sea level rise erosion occurs at a slightly lower rate over the majority of the coastline, with the greatest reduction in erosion between Orari River and Hinds River. This implies that although gross rates of transport may be higher the net rates of longshore transport were less than Run 1. Table 3.1 shows a total rate of change of -0.38 m/yr which imply an average retreat of 23 m compared to 25 m for the "Business as Usual" scenario.

The sediment budget (Figure 3.5) shows that the rate of longshore transport is greater than the Run 1 situation due to the larger waves arriving at the coastline. However, the rate of change along the coastline is reduced between Hinds and Orari and Ashburton and Rakaia, indicating that the increased refraction has reduced the net transport rate along this coastline.

3.4 Sea Level Rise of 0.5 m (Run 3)

A similar pattern to Run 2 can be seen in Figure 3.2. Annual average erosion rates have decreased to -0.36 m/yr or -22 m over the 61-year period between 1984 and 2045.

Between Rakaia and Ashburton Rivers the change in wave refraction results in limited accretion from longshore transport. Between Ashburton and Hinds there is an increase in longshore transport resulting in increased erosion whilst limited accretion and reduced erosion occurs between the two river bound coastal cells south of the Hinds River. However, the reduction in longshore transport-based erosion is offset by the greater losses due to abrasion.

3.5 Wave Energy Shift + 90% Abrasion (Run 4a)

The easterly shift in wave energy and reduced abrasion cause the strongest shift in the equilibrium coast angle of all the climate trends modelled. The net result of this shift is a strong increase in erosion around the Orari River and accretion around the Rakaia River (refer Figure 3.2) as the coastline attempts to readjust to a new equilibrium coast-angle. This can be seen with the sediment budget shown in Figure 3.7. Although the shift in wave energy has resulted in lower overall longshore transport rates there is now an "erosion node" or zone of zero net sediment transport at the coastline adjacent to the Orari River. As sediment is transported away from this area on both sides erosion will occur (see Table 3.1). This erosion node was also observed in the previous model study (Hicks, 1994) with erosion between the northern model boundary and the Orari River and accretion to the south.

Between the Hind-Rangitata and Rangitata-Orari cells there is an increase in the longshore sediment transport gradient compared to the base case implying greater losses. Between Hinds and Ashburton the rate of change in sediment loss due to longshore transport is less than Run 1 due largely to the accumulation of sediment which appears to occur at the Ashburton River mouth (see Figure 3.2). This accumulation also occurs at the Rangitata and Rakaia rivers. However, the large and increasing longshore sediment gradient counteracts these local accumulations. Comparing the initial and final longshore transports from Figure 3.7 with Figure 3.4 (Business as usual) there is an increased transport gradient due to a reduction in the sediment supply from the coastline south of the Orari River.

The net effect of the wind energy shift is an average rate of erosion of -0.43 m/year or around 26 m from 1984 to 2045.

3.6 Wave Energy Shift + 100% Abrasion (Run 4b)

This run shows the effect on coastline erosion by changing the abrasion. The longshore sediment transport rates and sediment losses due to longshore transport remain similar to Run 4a. However, the net change in the coastline is now -0.47 m/yr or approximately 29 m by 2045.

3.7 River Yield Reduced 50% (Run 5)

Reducing the river yield produces significant local changes in coastline erosion (see Figure 3.2). In between the rivers there are no significant changes in coastline development compared to Run 1. The local increase in coastline erosion does create different coastline orientations and hence has an effect on longshore transport rates (see Figure 3.9). The net change in the coastline for this run is -0.46 m/yr or -28 m by 2045.

3.8 Combination 1: 0.25 m Sea Level Rise, Reduced River Yield, Wave Energy Shift and 100% Abrasion

The combined effect of these three climate changes compared to the "business as usual" scenario is increased erosion along the entire coastline (see Figure 3.3) with significant local increases in erosion at the river mouths due to a reduced river yield, and at the southern end of the modelled area between Orari and Hinds due to the increase longshore sediment transport gradients. Comparing the initial and final longshore transports from Figure 3.10 with Figure 3.4 ("business as usual") there is an increased transport gradient due to a reduction in the sediment supply from the coastline south of the Orari River.

In this run the loss of sediment due to longshore transport is of a similar order of magnitude to abrasion losses between the Ashburton and Rangitata Rivers, largely due to the effect of reduced river sediment.

The net change in the coastline for this run is -0.5 m/yr or -30.5 m by 2045.

3.9 Combination 2: 0.5 m Sea Level Rise, Reduced River Yield, Wave Energy Shift and 100% Abrasion

The increase in sea level rise to 0.5 m appears to slightly reduce the rate of coastline retreat compared to a rise of 0.25 m while still creating more coastline erosion than the Run 1 scenario (see Table 3.1 and Figure 3.3). This difference is due to the larger sediment transport rate at Orari River in this run due to the effect of deeper water allowing more influence of the southerly waves at this location.

The net change in the coastline for this run is -0.47 m/yr (approximately -28.7 m by 2045) compared with -0.5 m/yr for Run 6: Combination 1 and -0.41 for Run 1: Business as Usual.

3.10 Combination 3: Reduced River Yield, Wave Energy Shift and 90% Abrasion

This run ignores the effect of sea level rise by assuming the near-shore profile would adapt to the new enstatic sea level. From Figure 3.3 it can be seen that this produces greater rates of erosion along the coastline between Hinds and Orari but very similar rates of change north of the Hinds River compared with Run 1. Due to the erosion node around the Orari River, losses in this area are much higher as the coastline attempts to adjust to a new equilibrium position.

The net change in the coastline for this run is -0.49 m/yr (approximately -30 m by 2045) compared with -0.5 m/yr for Run 6 and -0.41 for Run 1.

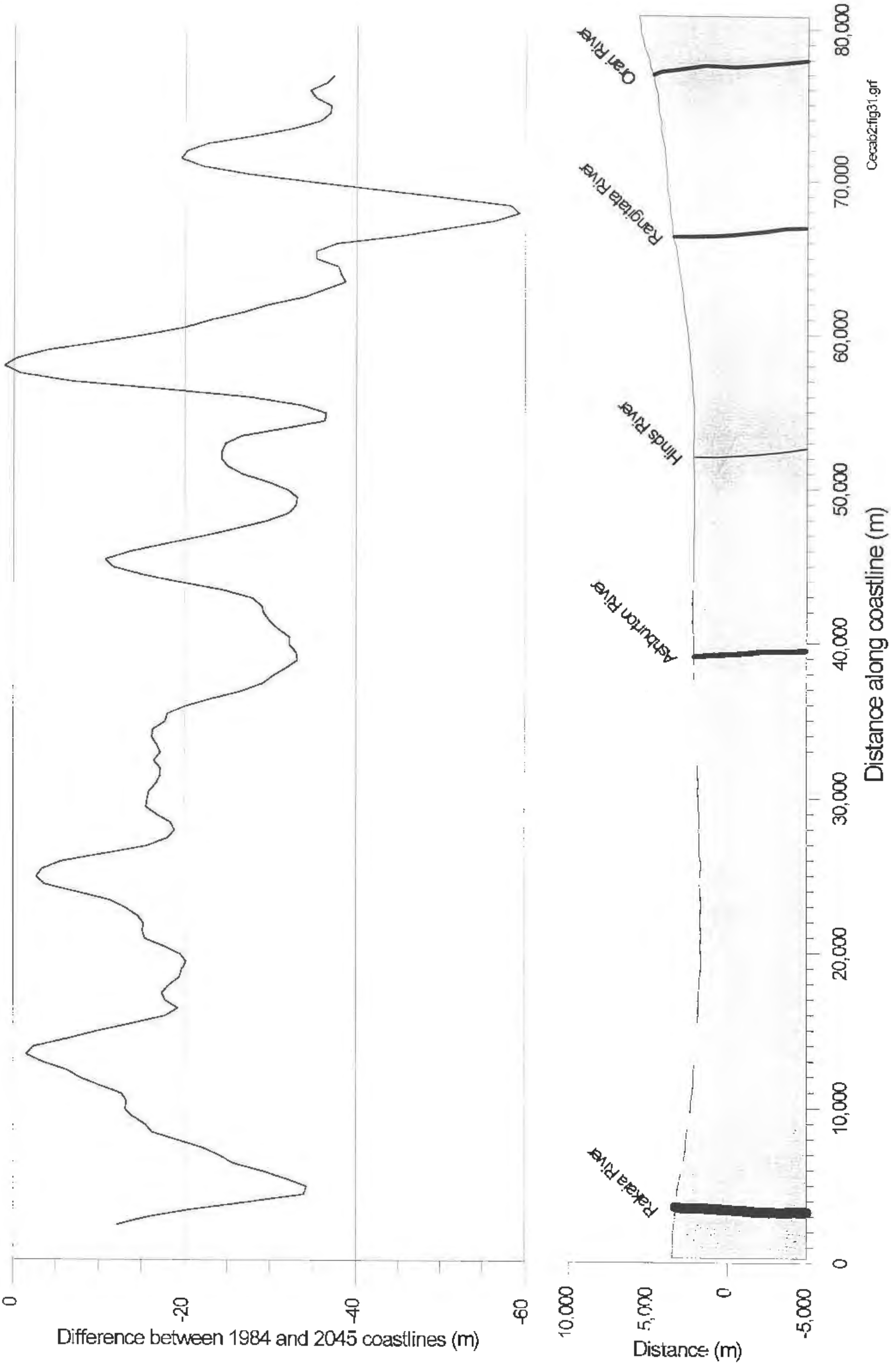

Figure 3.1: Difference between 1984 and 2045 coastlines, Run 1 (Business as usual)

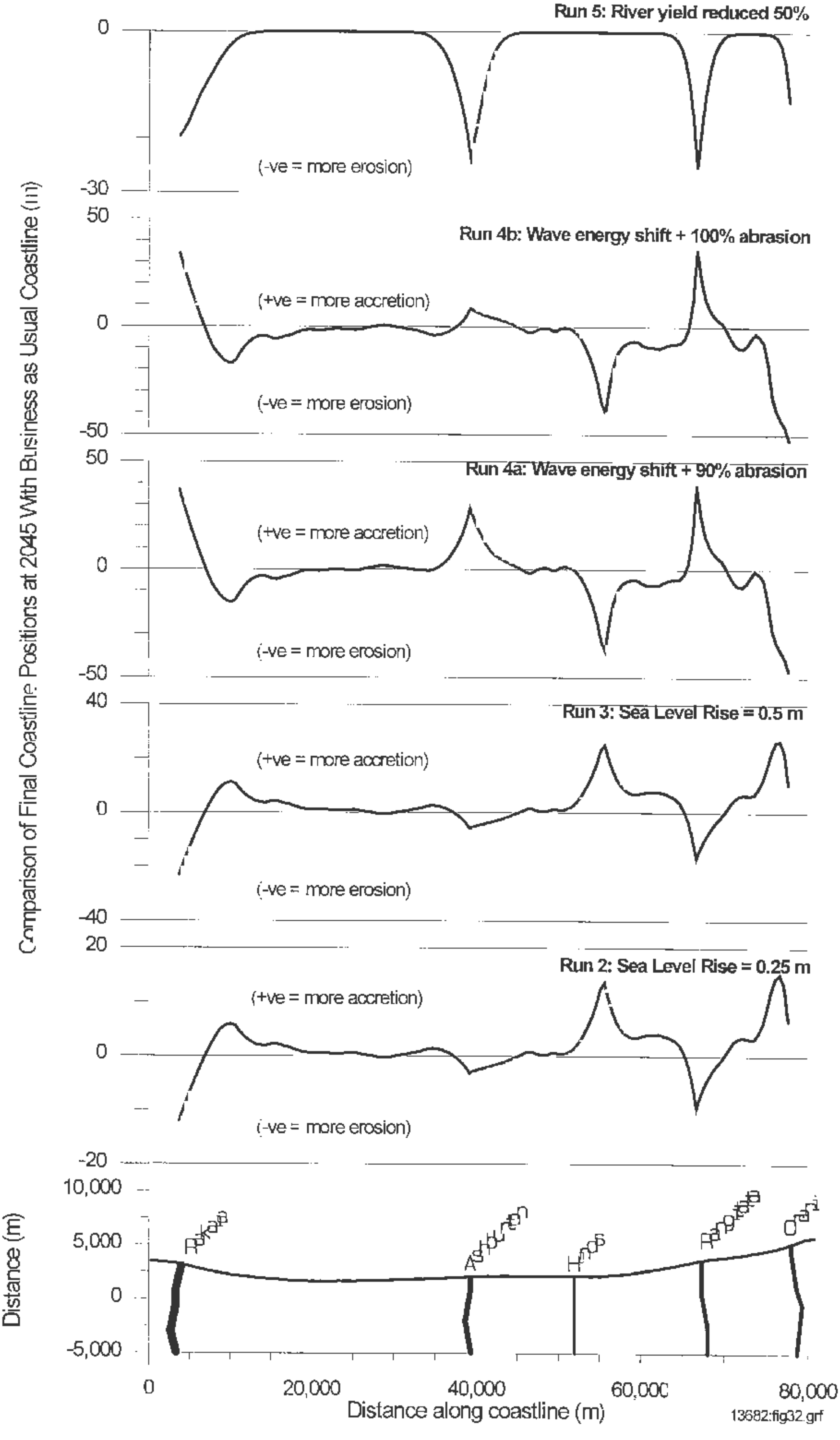

Figure 3.2: Comparison of coastline positions, Run 2 to Run 5

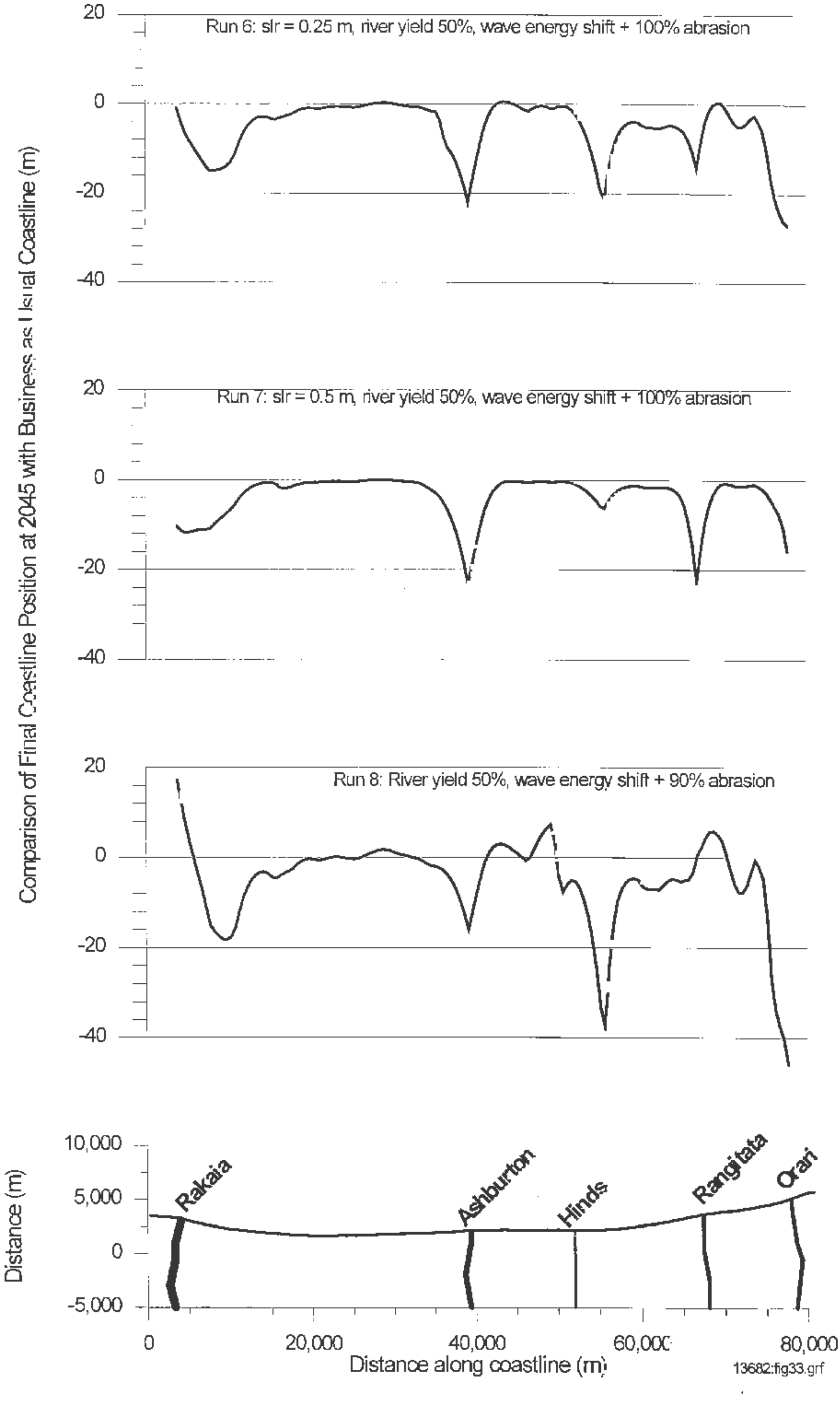

Figure 3.3: Comparison of coastline positions, Run 6 to Run 8

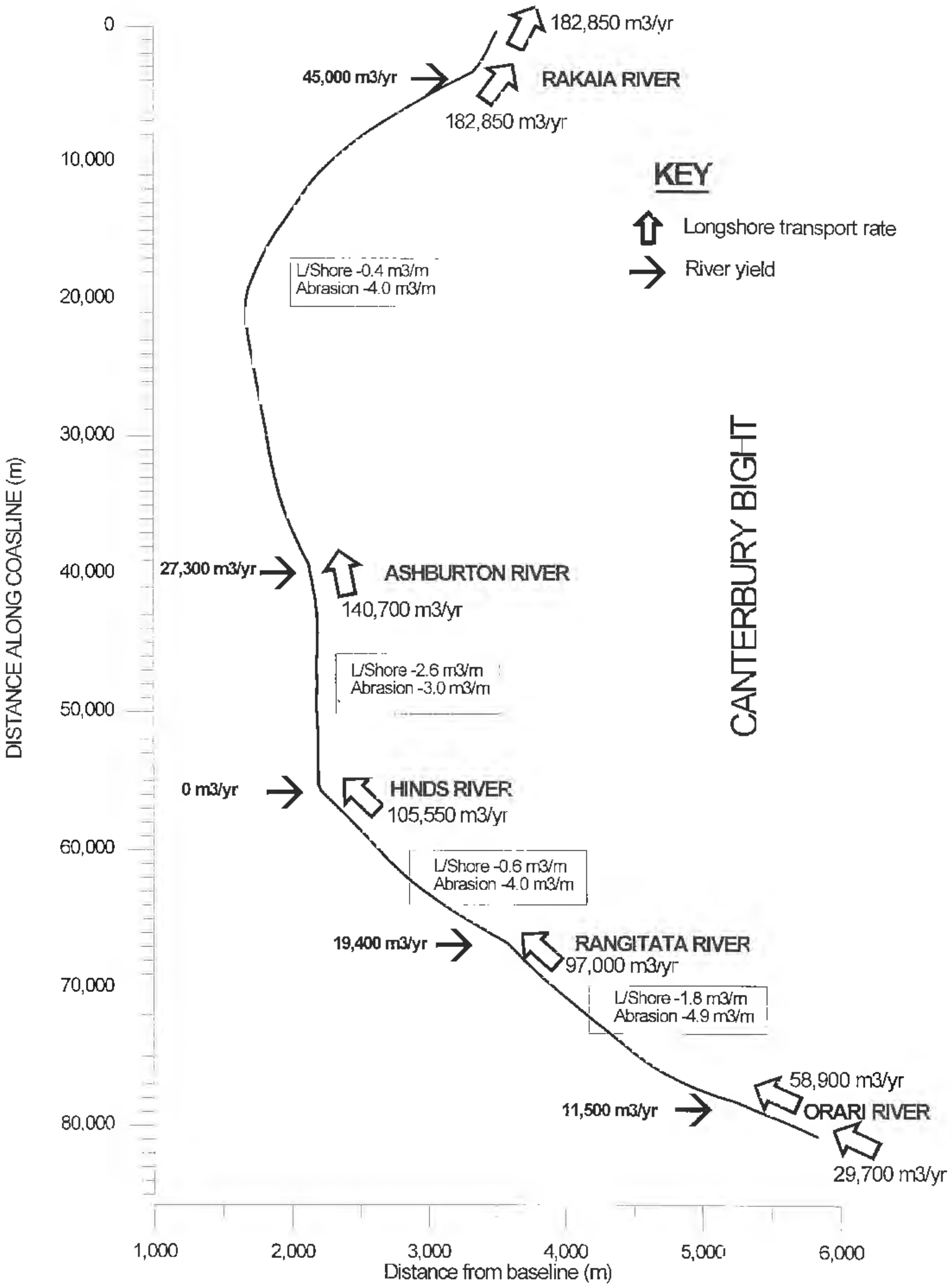

Figure 3.4: Average annual sediment budget - Run 1 (Business as Usual)

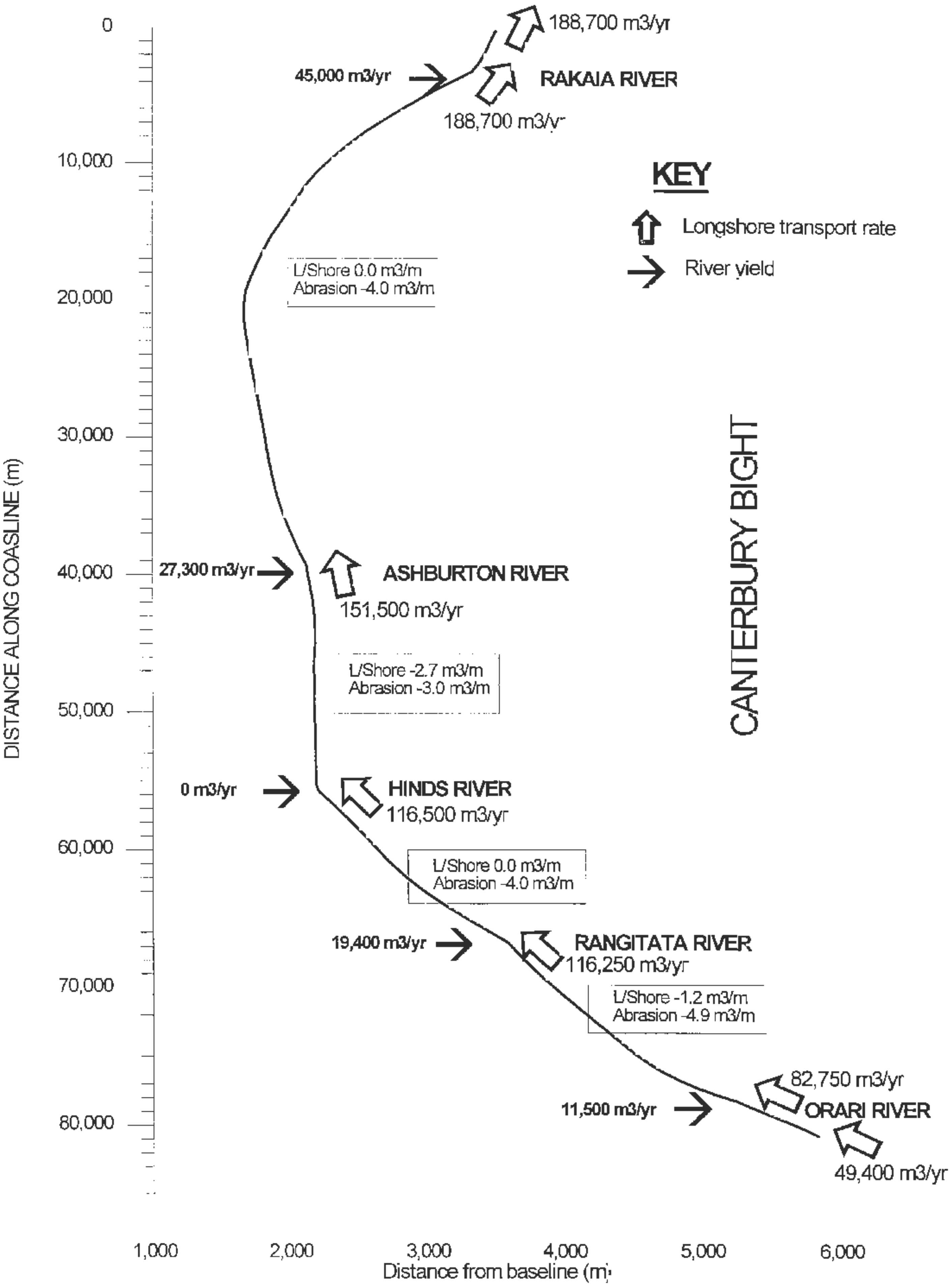

Figure 3.5: Average annual sediment budget - Run 2 (Sea level Rise = 0.25m)

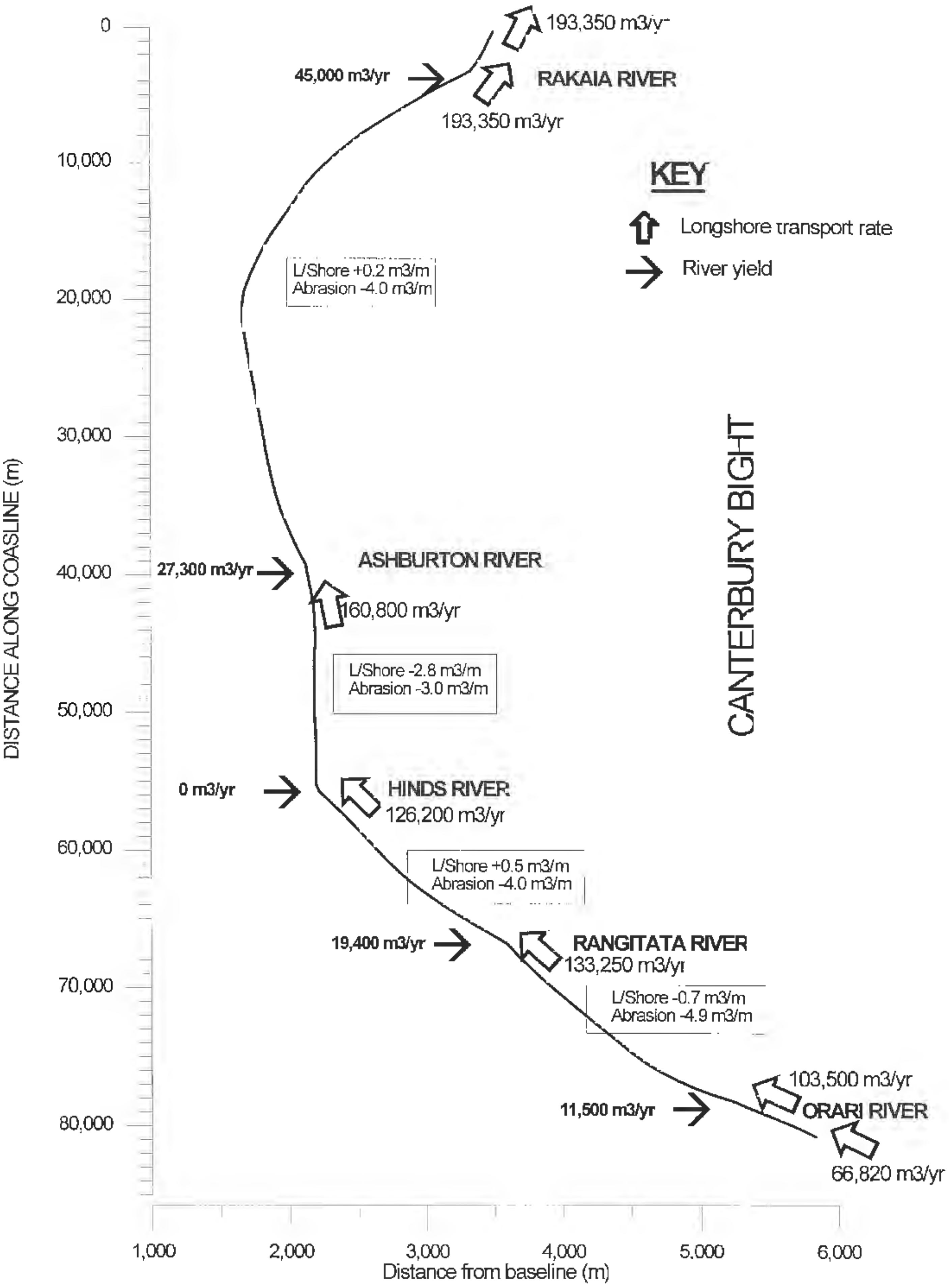

Figure 3.6: Average annual sediment budget - Run 3 (Sea level Rise = 0.5m)

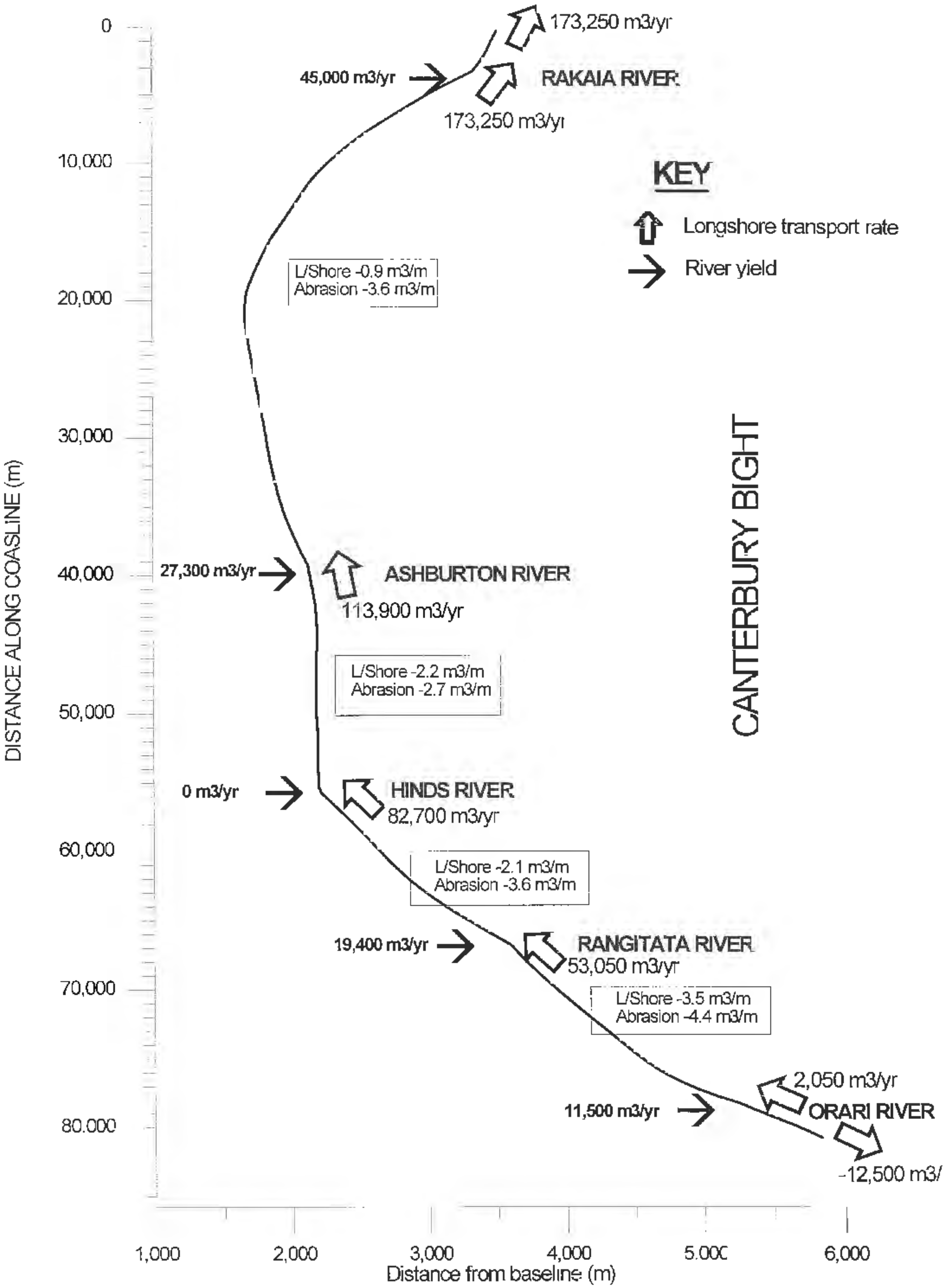

Figure 3.7: Average annual sediment budget - Run 4a (Wave energy shift – 90% abrasion)

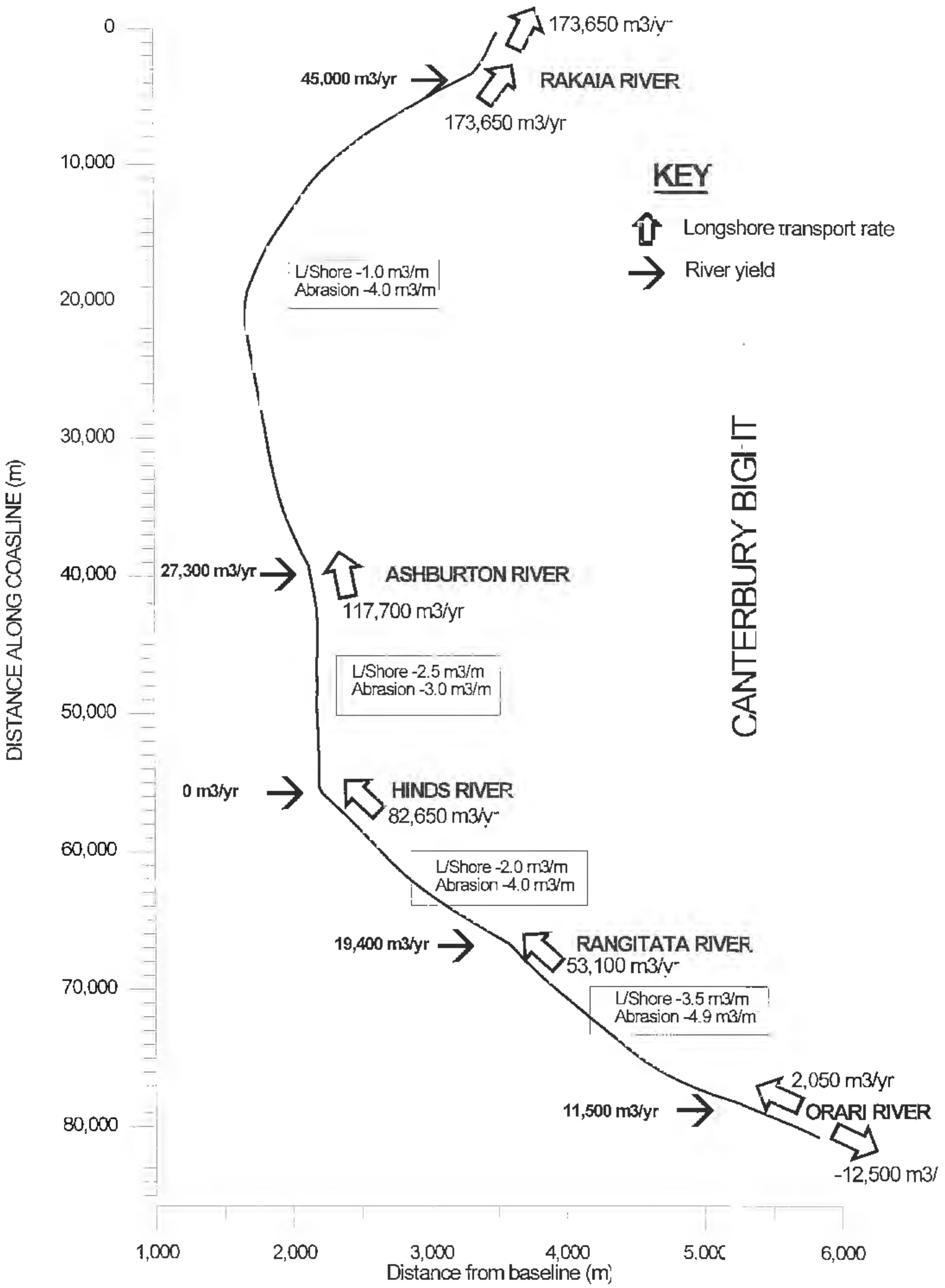

Figure 3.8: Average annual sediment budget - Run 4b (Wave energy shift + 100% abrasion)

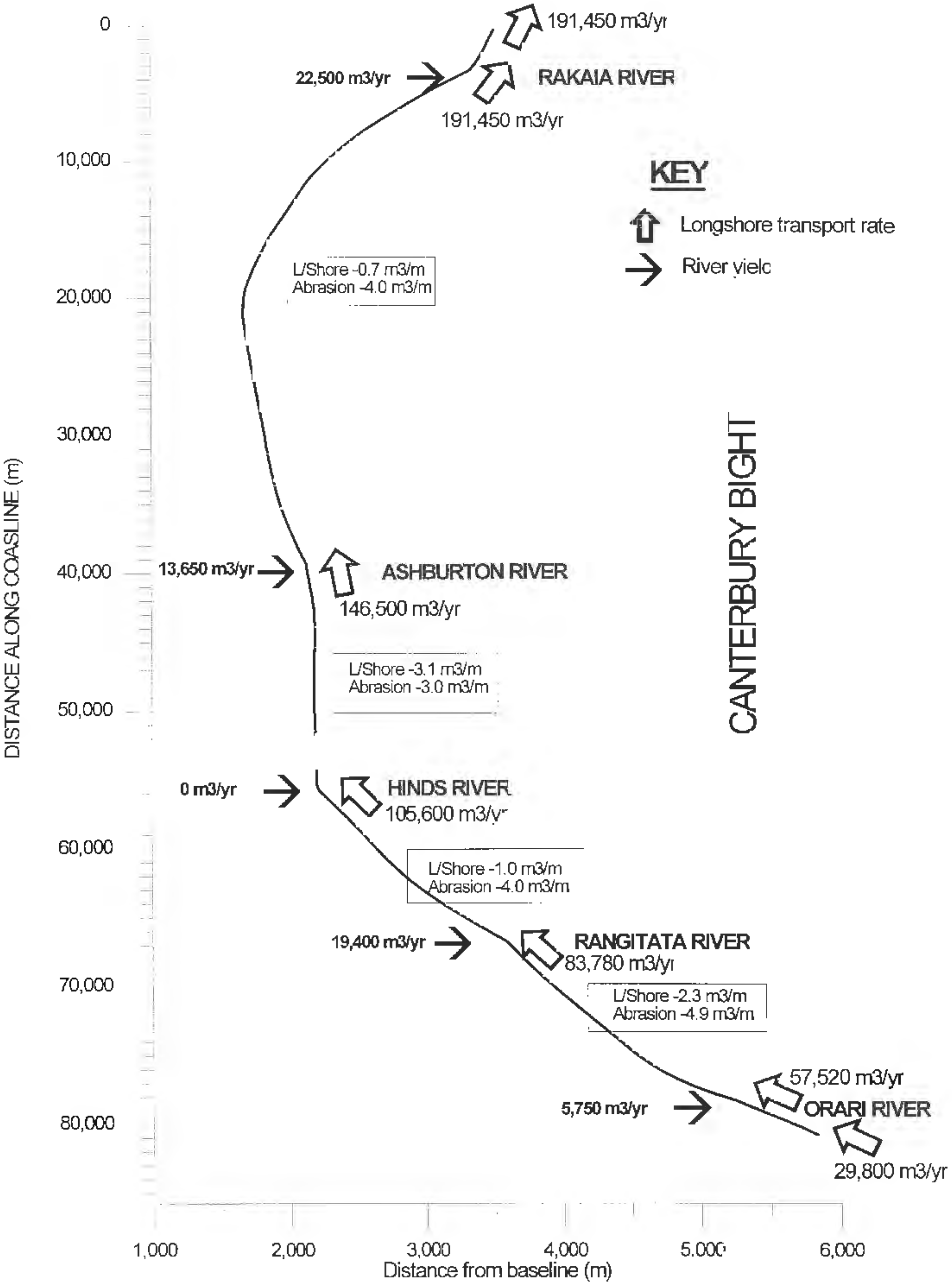

Figure 3.9: Average annual sediment budget - Run 5 (River Yield 50%)

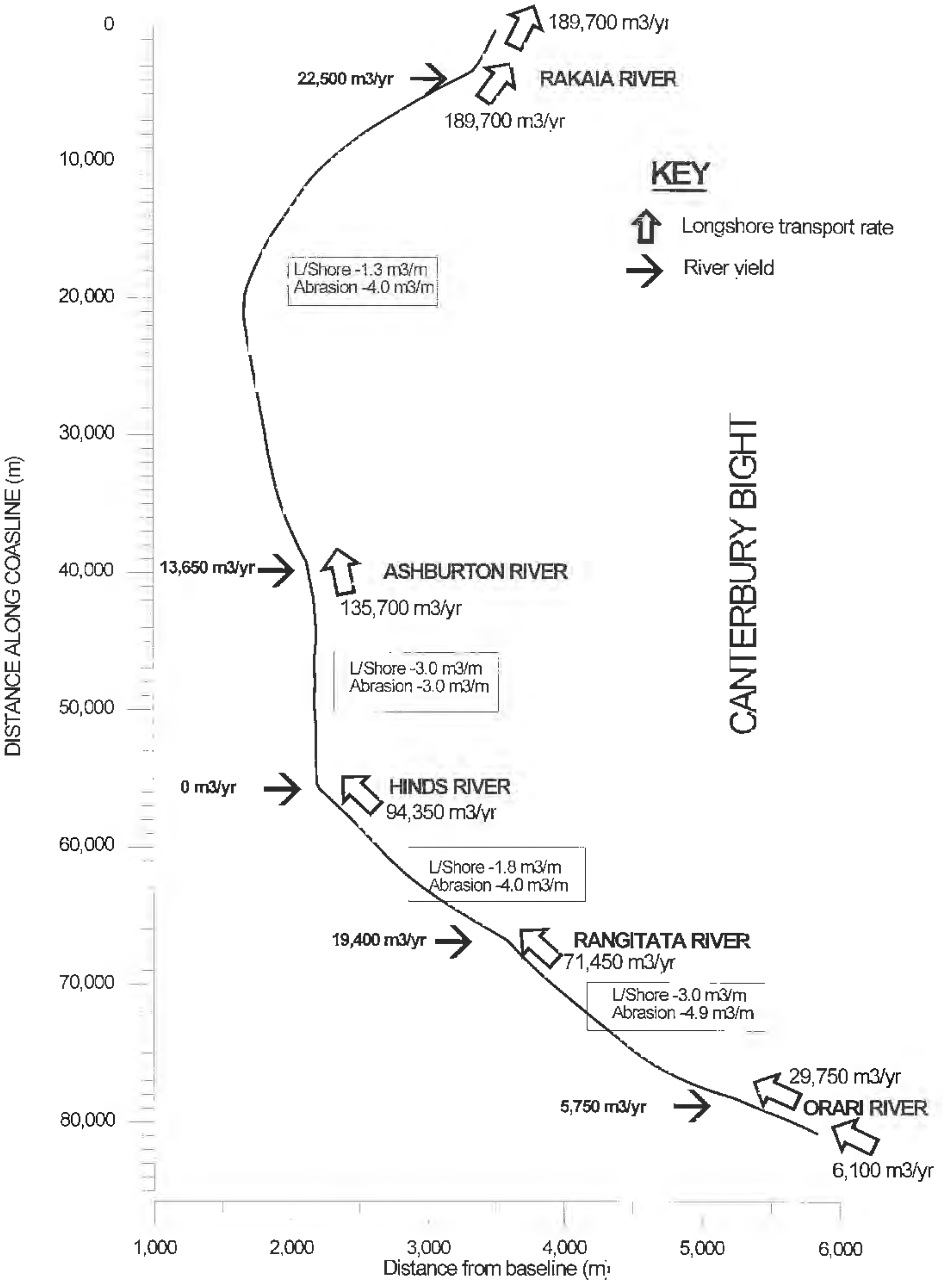

Figure 3.10: Average annual sediment budget - Run 6 (Combination 1)

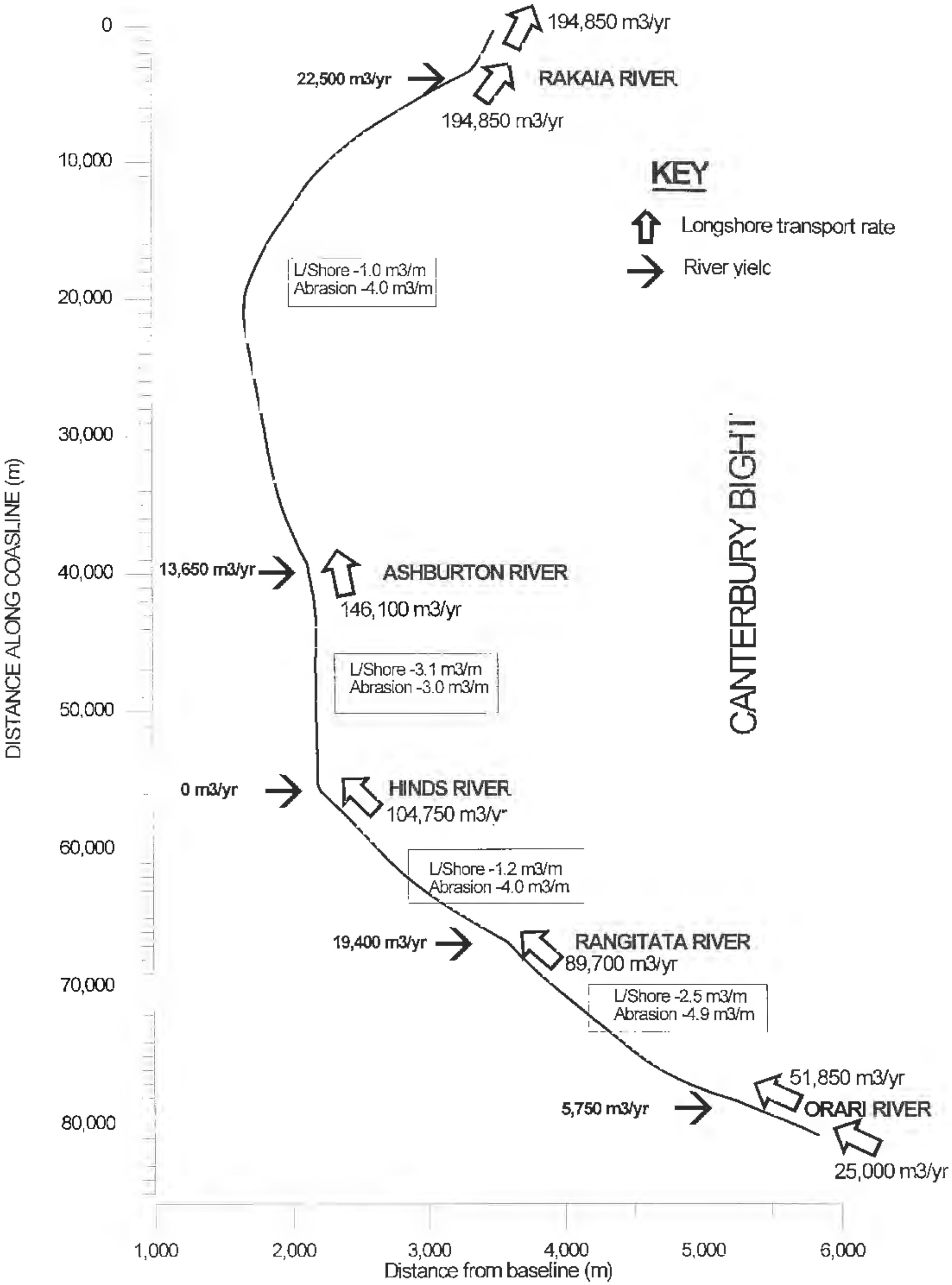

Figure 3.11: Average annual sediment budget - Run 7 (Combination 2)

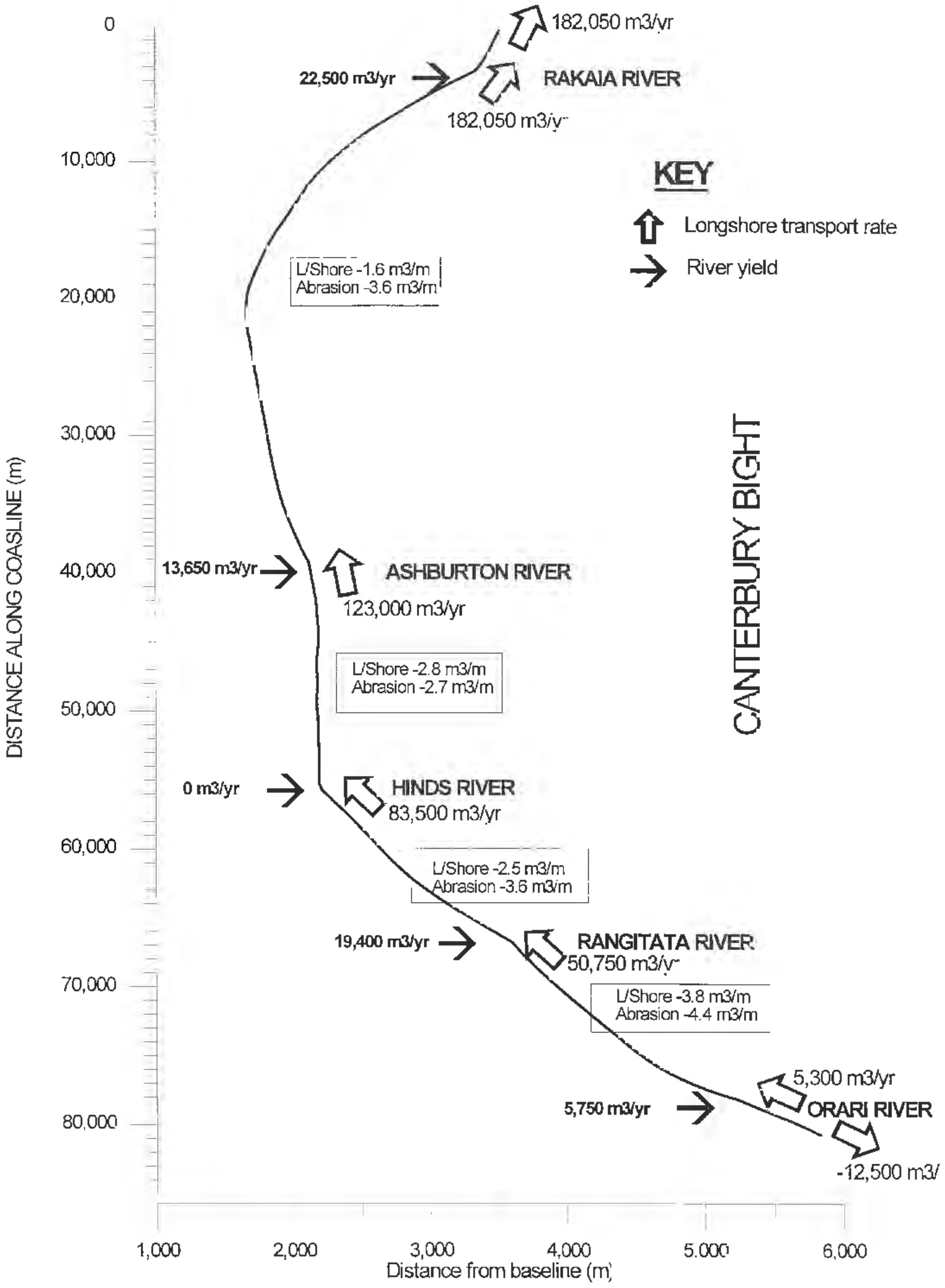

Figure 3.12: Average annual sediment budget - Run 8 (Combination 3)

4. CONCLUSIONS AND RECOMMENDATIONS

1) The various changes in the climate modelled by Unibest in Run 2 to 8 produce changes in the predicted coastline development between the Orari and Rakaia rivers (Run 1).

2) Sea level rise influences sediment transport by increasing the wave energy that can reach the shore (due to increased water depth) which increases the sediment transport capacity. However, there was an overal reduction in the net longshore transport due to the changes in angle of the approaching waves. A rise of 0.25 m appears to create more erosion than a sea level rise of 0.5 m

3) A shift in wave energy to the east causes a change in the equilibrium coast angle. This created an erosion node along the coastline adjacent to the Orari River which locally increased the rate of erosion along this area. Depending on the extent of the shift, this node location will vary. Although the rate of longshore transport is reduced due to the energy shift there are significant local effects around the erosion node.

4) Reducing sediment yields has the most significant local effect causing increased local coastline retreats of more than 20 m adjacent to the river mouths.

5) The combined trends increase coastline erosion compared to the base case up to a maximum of 22%.

6) Coastal areas which appear most sensitive to erosion caused by climate change are the coastlines immediately adjacent to river mouths and the coastline between the Hinds and Orari rivers.

7) As all the combined results (Run 6 to 8) produce rates of coastline retreat higher than the business as usual scenario and of a similar order of magnitude to each other the most severe case (Run 6) should be used to develop planning and coastal management strategies.

8) After another 5 to 10 years of physical monitoring this model should be tuned and recalibrated with the new data to provide a more sensitive and calibrated model for future predictions.

TONKIN & TAYLOR LTD
Environmental and Engineering Consultants

Report prepared by R.A. Reinen-Hamill
Approved for Tonkin & Taylor

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REFERENCES

Hicks, M.D., October 1994; Modelling Historical and Future Change of the Washdyke-Opihi Shoreline; unpublished report NIWA report No. CRC581, Christchurch, New Zealand

Tonkin & Taylor, June 1995; Central Canterbury Bight, Stage 1 Report, Model Calibration and Validation; unpublished report prepared for Canterbury Regional Council

APPENDIX A:

OFFSHORE WAVE DATA (supplied by CRC)

- Table C1.1 Probability that highest of sea and swell occur in the given height and direction class on open sea east of Canterbury (1970 -1991)

Significant Wave Height (m)	Wave Direction (deg.N)												
	-15.: 15.	15.: 45.	45.: 75.	75.: 105.	105.: 135.	135.: 165.	165.: 195.	195.: 225.	225.: 255.	255.: 285.	285.: 315.	315.: 345.	Total
< .25	.64	.09	.03	.07	.07	.20	.71	.25	.07	.01	.05	.07	2.24
.25: .75	1.05	1.11	.94	.42	.31	1.10	1.43	.31	.12	.07	.09	.50	7.46
.75: 1.25	3.80	3.03	1.72	1.25	.87	4.29	5.46	1.02	.14	.24	.43	1.09	23.33
1.25: 1.75	3.97	3.03	1.60	.90	.83	5.27	6.12	.98	.37	.17	.29	1.10	24.64
1.75: 2.25	2.81	2.06	1.27	.85	.76	4.45	5.89	1.25	.38	.09	.08	1.23	21.11
2.25: 2.75	.96	.42	.51	.34	.28	2.16	2.96	.75	.13	.03	.04	.47	9.05
2.75: 3.25	.43	.38	.26	.30	.13	1.82	2.74	.64	.14	.03	.03	.22	7.13
3.25: 3.75	.10	.09	.05	.07	.05	.42	1.02	.22	.04	.01	.	.05	2.14
3.75: 4.25	.09	.09	.10	.04	.05	.54	1.11	.26	.05	.	.	.03	2.37
4.25: 4.75	.01	.03	.01	.	.04	.09	.20	.13	.	.	.	.	.51
4.75: 5.75	.	.	.	.	.	.	.	.	.	.	.	.	.
5.75: 6.75	.	.	.	.	.	.	.	.	.	.	.	.	.
> 6.75	.	.	.	.	.	.	.	.	.	.	.	.	.
Total	13.88	10.33	6.50	4.24	3.38	20.34	27.65	5.82	1.44	.64	1.01	4.76	100.00

Season . . . . . : All Year

Period . . . . . : 1970 to 1991

No. observations : 7625

Table C1.1 Probability that highest of sea and swell occur in the given height and direction class on open sea east of Canterbury.

APPENDIX B

3m diskette containing coastline data for Runs 1 to 8

- Run 1 TXT
- Run 2 TXT
- Run 3 TXT
- Run 4a TXT
- Run 4b TXT
- Run 5 TXT
- Run 6 TXT
- Run 7 TXT
- Run 8 TXT