Reach analysis of Waiau River tributaries immediately downstream of Mararoa Weir (Lake Manapouri Control Structure)

Report submitted to Waiau River Working Party as part of the Tributary River Reach Analysis project by

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Introduction

This report briefly summarizes information collected on the geomorphic character of Excelsior, Whare and Redcliff Creeks, the first three left-bank tributaries of Waiau River downstream of Mararoa Weir. All are relatively steep and short tributaries which drain from the Takitimu Mountains. All three catchments have vast volumes of material available for transport, supplied both by rapid erosion in the friable, volcanic Takitimu's and glacially-derived sediments in Waiau terraces. Reworking of materials from these sources have produced an extensive fan-complex along the western margin of the Takitimu's, within which tributary streams have incised.

The character of Waiau River at the three tributary confluences differs notably. Excelsior Creek joins Waiau River in confined Duncraigen (or Excelsior) reach, whereas Whare Creek joins at the head of Redcliff reach and Redcliff Creek joins at the broader downstream end of Redcliff reach. Such factors serve to modify tributary impacts on Waiau River, especially in terms of lateral constraint (accommodation space), bed condition (armouring) and potential for sediment reworking.

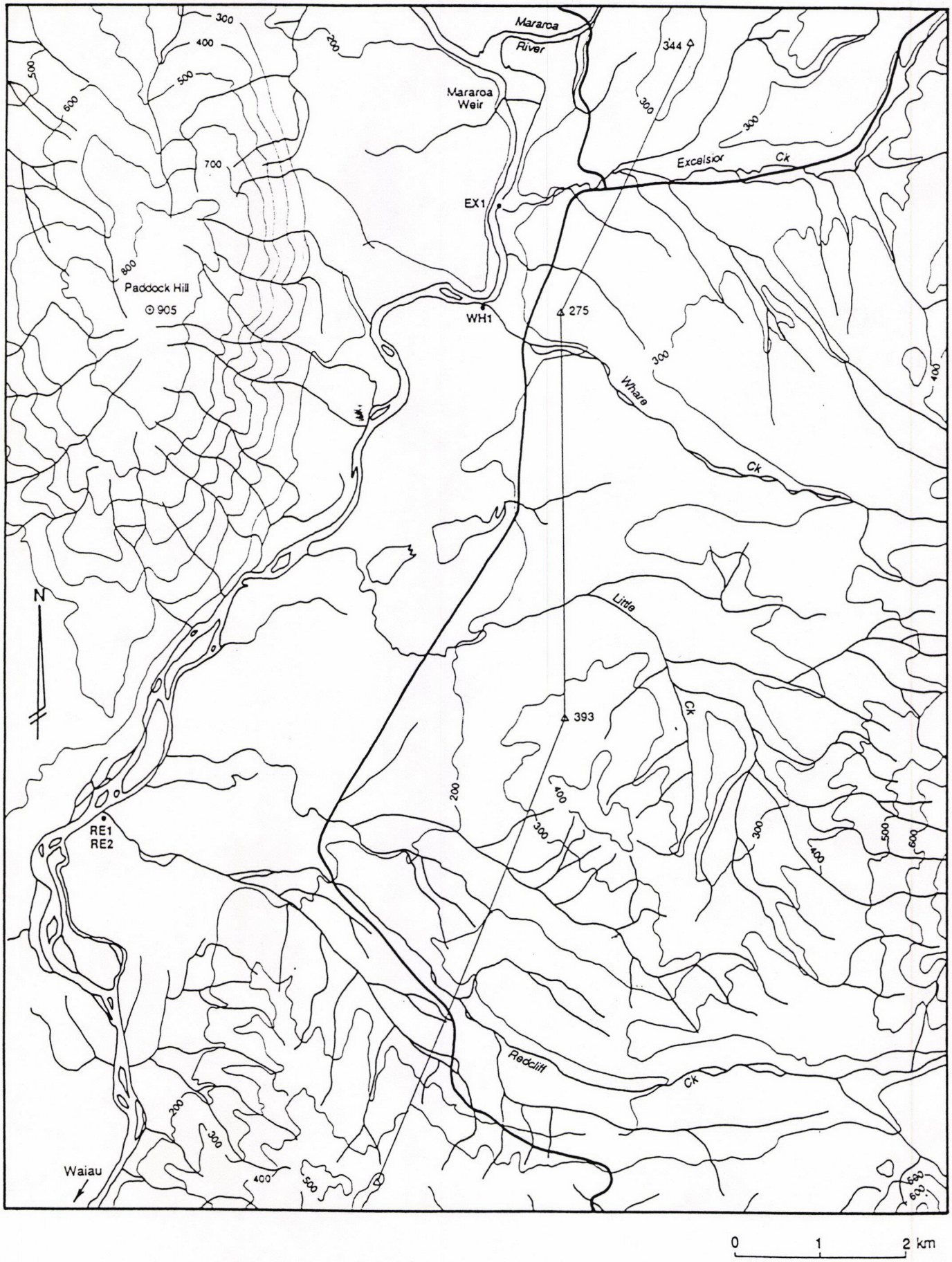
Analysis was restricted to the downstream end of each tributary, between Blackmount-Redcliff Road and Waiau River. I am extremely grateful to Sue Bennett and John Whitehead for their assistance and hospitality extended during this stay. Field work was completed in July 1993 with the assistance of Sue Bennett and Rob Mackillop. Sue also proof-read this report.

Background information

Impacts of flow regulation are most likely to be observed on those tributary catchments located immediately downstream of the point of regulation. Incision of the trunk river induces similar response in tributary streams, as they adjust to the altered base-level.

Upstream impoundment and reduction in discharge bring about change to the equilibrium condition of river channels, generally by reduction in width, depth and meander wavelength and increase in bed slope. Downstream of the regulation structure the channel contracts and incises into its bed, as regulated flows may be no longer competent to transport the sediments but can winnow the finer materials away. Channel incision results in a gravel lag or armoured surface. This effect is generated closest to the regulation structure. In general, degradation is fastest after closure and gradually slows with time. Over time the scour zone moves down-channel. Sections downstream of the degradation zone experience periods of aggradation as bedload pulses, comprising materials incised from both the trunk river and tributary catchments. Sediment accumulation tends to occur at tributary confluences, where shallow fan-deltas form. Such deposits may be effectively flushed, however, during major floods, resulting in pronounced variability in sediment transport conditioned by sediment availability.

Base map of Waiau River tributaries immediately downstream of Mararoa Weir



REACH NAME: LOWER EXCELSIOR CREEK

Geographic description of reach

Lower Excelsior Creek, the first left bank tributary downstream of Manapouri Control Structure, is a relatively short, steep system that drains part of the western Takitimu Mountains and Cheviot Hills. Excelsior Peak in the headwaters extends to 1543 m, while the Waiau confluence (approximately 15 km down-river) is at an elevation of about 180 m. Down-valley slope is exceedingly steep in the headwaters, but declines significantly downstream from Cheviot Downs. From this point, Excelsior Creek flows atop relatively broad glacially-derived valley fill, with swamps evident adjacent to Blackmount-Redcliff Road (GR 035996). The channel is moderately incised in this reach, but broadens notably down to Weir Road bridge.

Immediately downstream of Weir Road bridge Excelsior Creek has a moderately sinuous outline. A series of abandoned meander loops are evident, reflecting a series of incision phases. Similar features are evident at Home Creek, but in Excelsior Creek they are less pronounced and substrate materials are quite different. In Excelsior Creek outwash gravels with occasional enormous erratics form the channel bed, whereas sandy materials are prevalent in Home Creek. The down-valley configuration is also similar to Home Creek, as the channel drops steeply down the Waiau terraces in the 1 km river section upstream of the confluence. In this reach the river banks, flats and lower terraces are covered by dense broom and bracken, with very steep terrace risers.

Within-channel bars and areas of active erosion are seldom observed in the reach downstream of Weir Road Bridge. A relatively small fan has developed at Waiau confluence, but geomorphic impact on the Waiau is trivial, with negligible bank erosion on the opposite (right) bank of Waiau River.

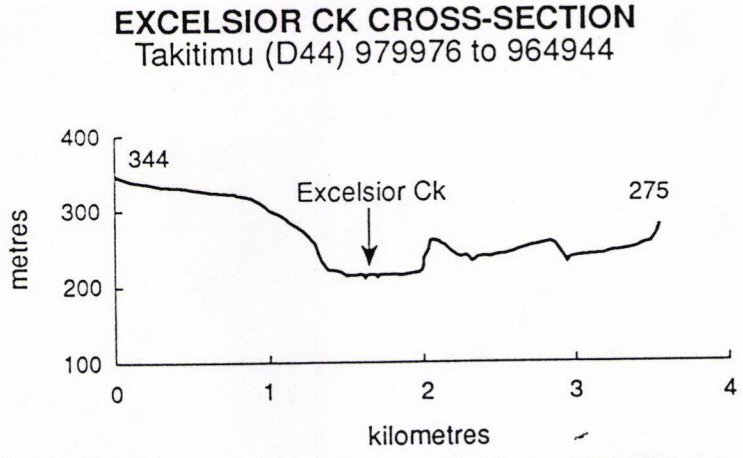
Analysts: GB, SB, RM Date of Analysis: 14.07.93

Grid co-ordinates of reach: Takitimu (D44) 1:50,000; 969961 (Weir Road bridge) to 957957 (Waiau Confluence).

Air photos used: Southland Regional Council, 14.04.92; Survey Number 981, Photo's 047 and 048

VALLEY CHARACTERISTICS

Valley cross section



Valley setting

Excelsior Creek drains part of the north-west section of the highly dissected Takitimu Mountains and Cheviot Hills. Beyond the foothills, the river flows atop glacial and glacially-reworked deposits, prior to falling relatively steeply down Waiau Valley terraces.

Extent of Valley flat

Excelsior Creek exits Cheviot Hills and the Takitimu Mountains as a narrow, steep-sided valley. The valley broadens considerably adjacent to Cheviot Downs, but narrows once more in the relatively confined 2 km section upstream of Tower Peak Road. The next 1 km section is less constrained, and the channel adopts a sinuous, meandering outline. Several abandoned meander loops are evident.

Terrace character

At least five prominent terraces are evident adjacent to Waiau River. The upper surface is several 10's of metres above the present channel. Terraces are generally composed of stratified fine gravels and sands, commonly with a fine-grained

cap. Terrace materials impose antecedent control on contemporary Excelsior Creek. Numerous massive boulders, up to several metres in diameter, form a local basal lag material on channel bed and bar surfaces.

At the downstream end of Excelsior Creek, beyond GR 962957, the lower iron-stained outwash-derived terrace, composed of stratified gravels and clasts up to 150 mm in diameter, has more than 1 m of recent bar deposits atop, reflecting sediment accumulation atop outwash materials prior to incision associated with flow regulation on Waiau River.

Extent of Alluvial flat
Since Excelsior Creek is generally incised into its fill, either in the form of abandoned meander loops immediately downstream of the bridge or notched terraces immediately upstream of Waiau River, alluvial flats are not well-developed, and constitute localized, discontinuous features.

Degree and character of channel constriction
Excelsior Creek is relatively unconfined in middle reaches (adjacent to the bridge) where the channel has adopted a meandering form, with occasional perched meander loops. Downstream the channel locally abuts against terraces, inducing localized erosion, but present rates of erosion appear to be relatively insignificant. The lower, steeper section of Excelsior Creek is not confined into a gorge like feature. Large boulders reworked from terraces effectively armor the channel, inducing channel stability. The scale of these boulders suggests that these are erratics or ice-rafted features, although some large boulders appears to be *in situ* within terraces. A further possible origin could be mass movement processes originating from the Takitimu's.

Character and impact of tributary streams
No major tributary streams join Excelsior Creek along its lower course.

Surficial geology
Substantial outwash terraces indicate the dominant role played by the glacial history in shaping the configuration of the landscape and hence sediment availability.

Vegetation
Valley side/flats: Pasture with occasional scrub. Local pine plantations on the upper terrace.

Alluvial flats/Bank/Bars: Channelized zone is densely vegetated along the lower course, with abundant broom, matagouri, bracken, etc. Lupins, rushes and occasional grasses appear to be the primary colonizer of bar surfaces.

Land use
Predominantly pasture. Local pine plantations.

Direct human impacts
Bridge; Introduced exotics; Extraction of gravels from lower terrace?

Relationship to Waiau River
The tributary bar has adopted a shallow fan form, which trails for about 750 m down-Waiau. A series of steps grade down the fan surface towards Waiau River. The lowest step is a narrow zone composed of relatively fine gravels (b_{max} 100 mm; mainly < 30 mm). The present channel cuts this surface with a diagonal up-Waiau orientation. The adjacent surface has an arcuate down-valley alignment, and is made up of coarser lag gravels. This was the surface sampled (EX 1; see below). The adjacent upper fan surface is about 75 cm higher, and also has an arcuate, down-valley form. This partially grassed surface has gravels up to 200 mm wide atop, but generally comprises clasts < 100 mm wide. At the tributary bar head there is a small accumulation of sandy mud, seemingly derived from deposits from Waiau River. This unit covers approximately 20 m^2, and is presently covered by small rushes and grasses.

Upstream of Excelsion confluence, Waiau River has adopted a pool-riffle sequence. This pattern does not appear to be modified by Excelsior Creek. A pool is located at the outside of the broad bend immediately upstream of Excelsior Creek confluence, and the 'natural' position of the Waiau channel would be against the right bank (i.e. opposite the small Excelsior tributary confluence bar). In other words, this pool-riffle sequence and channel position relate to high flow stage responses to valley alignment. The right bank of Waiau River immediately opposite Excelsior Creek shows

no evidence of recent erosion, and there is no discernible difference in the character of the vegetation and talus for several hundred metres along this steep, high terrace riser.

CHANNEL CHARACTERISTICS

Number of channels
Single-channelled, other than division atop the lower surface of the stepped fan/bar at Waiau confluence.

Channel geometry
Relatively narrow, shallow channel, that flows within an incised terrace for much of its lower course.

Sinuosity
Given the coarse nature of much of the basal material, Excelsior Creek is not freely meandering, but has an inset, moderately sinuous course in the 500 m section downstream from Weir road bridge. Once the channel becomes incised within Waiau Valley terraces, the channel condition is imposed and a series of relatively straight sections are observed, deflected at sharp angles down-valley.

Lateral stability of channel(s)
There is no evidence of ongoing lateral accretion/erosion, but abandoned bends in the section a few hundred metres downstream of the bridge clearly indicate former phases of meander development. This is not a freely meandering system, associated with the coarse basal gravel materials over which the channel flows and imposed lateral constraints.

Bar type and scale
Bars are virtually non-existent due to the relatively incised nature of the channel and the presence of large boulders on the channel bed. Within-channel sedimentation is restricted to the tributary bar/fan at Waiau confluence. This is a stepped feature with a lobate form, atop which various surfaces are evident. Upper surfaces are arcuate forms that are aligned down-Waiau, while the lower, finer-grained inset feature is aligned diagonally up-Waiau.

Bed/Bank character (extent and materials)
Banks are of highly variable character, and are only locally eroding. Broom and bracken have overwhelmed banks in the lower course. Extremely coarse subrounded boulders (b_{max} > 1 m) are evident in some mid-reach terraces, where well-bedded outwash gravels (b_{max} a few hundred mm) generally prevail. These mid-reach sequences are frequently capped by up to 1 m of finer-grained sands/silts. The inset channel in the lower course is up to 3 m deep. In one exposure the basal part of the bank is composed of outwash gravels, which are capped by up to 1 m of 'recent' channel bed and bar gravels which have subsequently been incised (Photo 10). This behaviour probably relates to base-level modification associated with flow regulation of Waiau River.

Flow character
Middle reaches are characterized by a riffle-pool sequence, with downstream transition from uniform to locally rapid flow.

Other comments
Fish observed in lower Excelsior Creek.

SAMPLE SITE CHARACTERISTICS

Sample number: **EX1** Analysts: GB, SB, RM

Grid reference: Takitimu (D44) 1:50,000; 957957

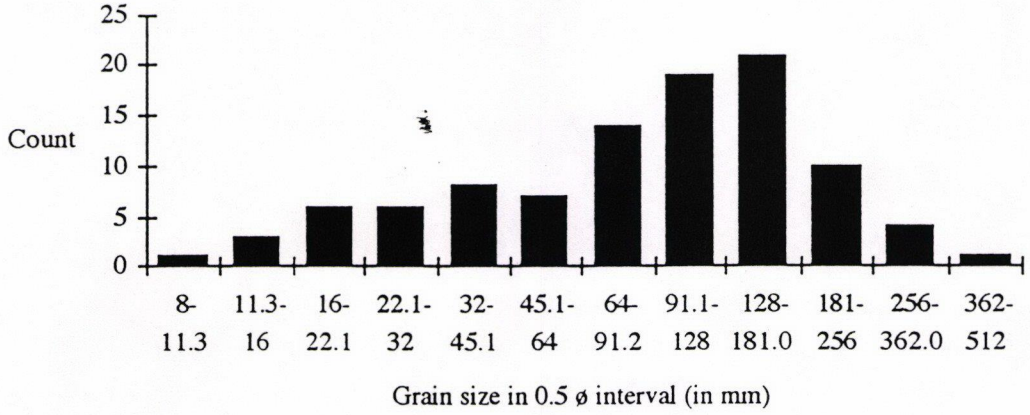
Sample type: 4 x 25 @ 1.0 m interval

Bar type: Tributary fan bar; sample transects aligned down-Waiau along arcuate-shaped unit. Bar tapers markedly down-Waiau.

Sample position on bar: Aligned down-Waiau along arcuate-shaped unit; positioned on a distinct step less than 1 m above finer-grained step.

'Particle characteristics'

Grain size distribution, Excelsior Creek (EX1)



D95 255 mm
D84 173 mm;
D50 98 mm Mean 110.40 mm;
D16 31mm;
D5 16 mm

Sorting: 73.83mm. Poorly sorted within sampled depositional unit, but deposits have been segregated into discrete units over the bar surface. This within-bar variability takes the form of a stepped gradation, with a finer zone adjacent to Waiau channel, marginal to a mixed fine/coarse gravel zone, adjacent to the sampled coarsest depositional unit, with two more steps characterized by a fine gravel and sand drape and a distinct fine gravel step.

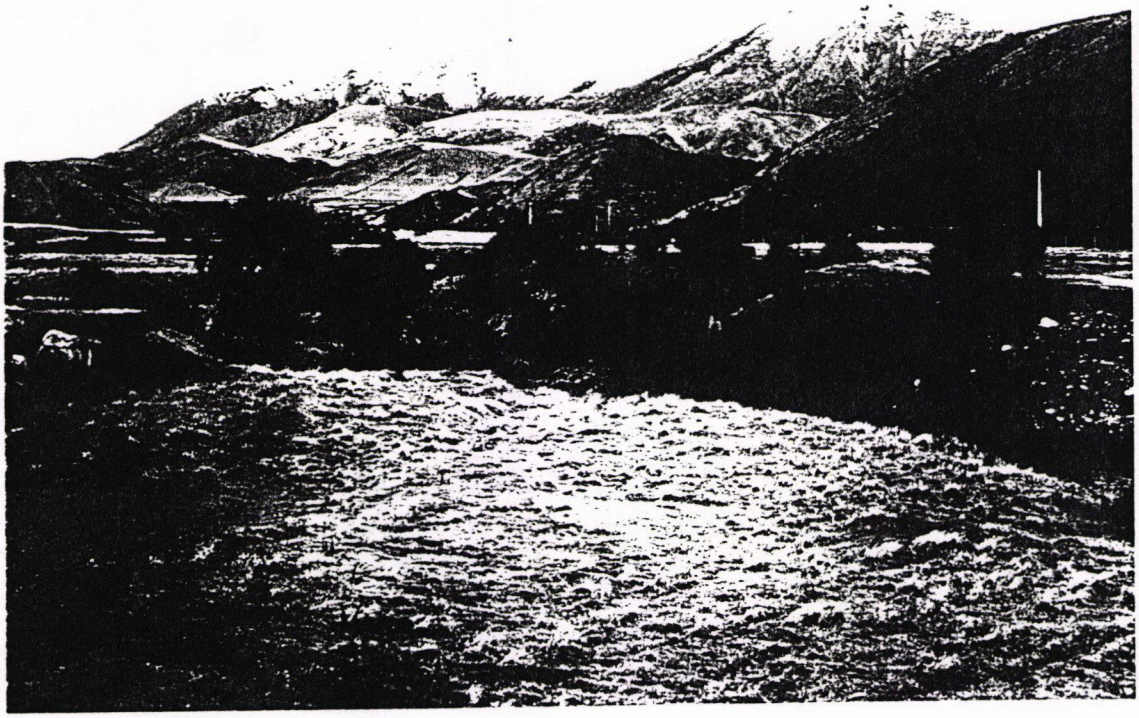
Packing arrangement: Relatively loose, with occasional buried clasts. Clasts are only poorly imbricated around the arcuate form. Surface is relatively well-ordered, and not jumbled, and has been winnowed down to 10 mm other than at the channel margin.

Shape: Blocky, subrounded.

Lithology: Mixed, with a large proportion of terrace-reworked materials.

Other characteristics: Bar surface is sparsely vegetated, with gorse, lupin, mullein, grasses and herbs (including watercress, monkey musk, rumex *sp*, clover). The 1-2 m wide band adjacent to the Waiau channel has more vegetation in the moist silts, especially grasses, rushes, watercress, monkey musk and rumex *sp*.

Excelsior Creek Photo 1
View upstream of middle reaches of Excelsior Creek. Note the stepped cross-section of the meandering channel in the foreground, with a large boulder on the shallow riser on the left hand side in mid-photo. Localized bank erosion is evident, whereas much of the bank is covered by broom, matagouri, occasional gorse and tussocks. The relatively small scale of the catchment is indicated by proximity of the Takitimu Mountains in the background.
14.07.93 EX-1/4A



Excelsior Creek Photo 2
View downstream of fine-grained abandoned meander channel infill just downstream of Weir Road bridge.
14.07.93 EX-1/31A



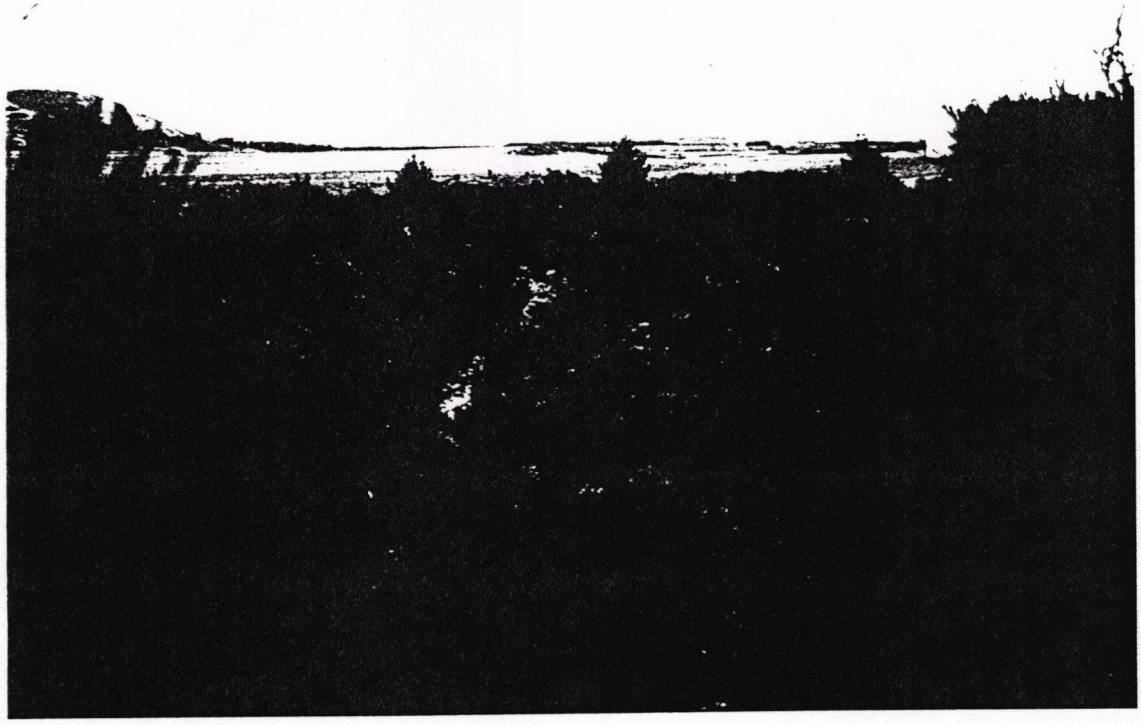
Excelsior Creek Photo 3
View downstream of the meandering outline of Excelsior Creek a few hundred metres downstream of Weir Road bridge. The dense broom on the terrace riser in mid-photo marks the transition point to the more incised, densely vegetated lower section of Excelsior Creek.
14.07.93 EX-1/30A



Excelsior Creek Photo 4
View downstream of left bank terrace exposure at GR 965958. Note the relative scale of boulders in the foreground; these are much coarser than materials evident in the terrace sequence. These coarser lag boulders, probably derived from glacially-transported or ice-rafted processes, constrain the contemporary channel.
14.07.93 EX-1/5A



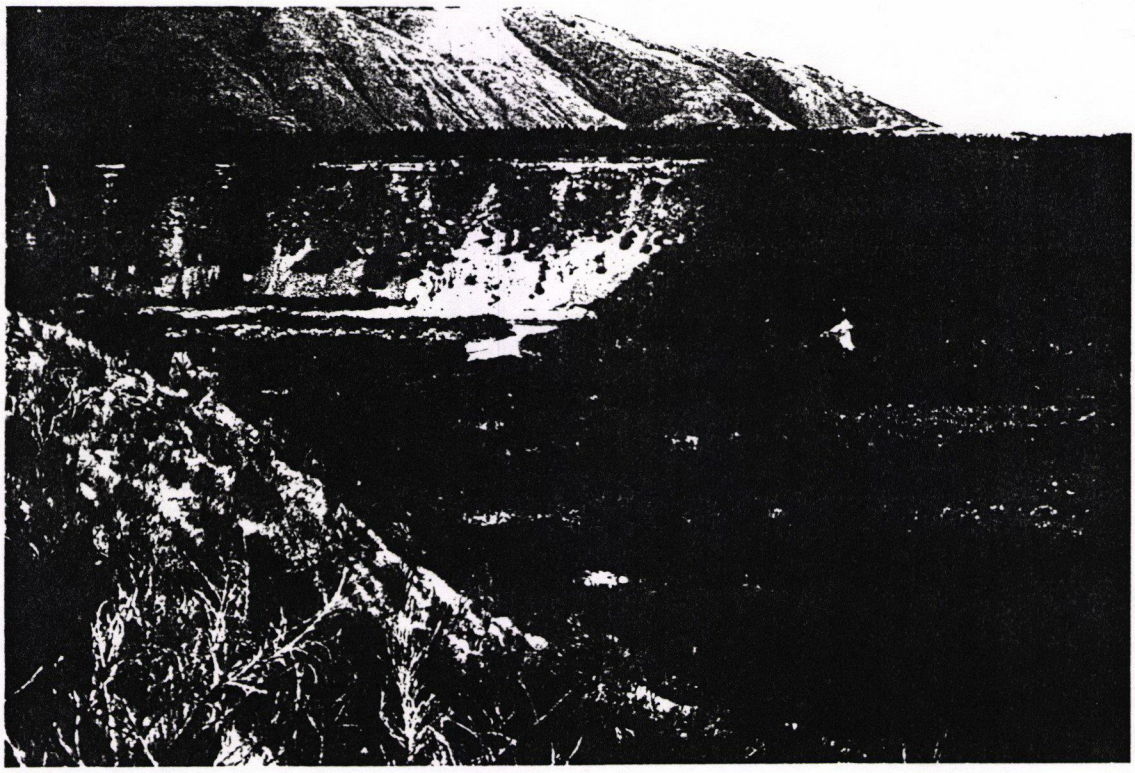
Excelsior Creek Photo 5
View downstream of the densely vegetated, relatively incised lower course of Excelsior Creek.
14.07.93 EX-1/7A



Excelsior Creek Photo 6
Incised terrace exposure at the head of the lower, vegetated section of Excelsior Creek. View is taken from the right bank, looking upstream. The only actively eroding part of this exposure is in the extreme left hand bottom corner of the photograph.
14.07.93 EX-1/29A



Excelsior Creek Photo 7
The lower vegetated reach of Excelsior Creek, looking downstream towards the right bank terrace of Waiau River. Note that erosion of this terrace starts opposite Excelsior Creek confluence, indicating tributary impact on the character of Waiau River.
14.07.93 EX-1/28A



Excelsior Creek Photo 8
Incised channel along lower Excelsior Creek, viewed upstream. Note the narrow width of the channel and the densely broom-covered banks.
14.07.93 EX-1/26A



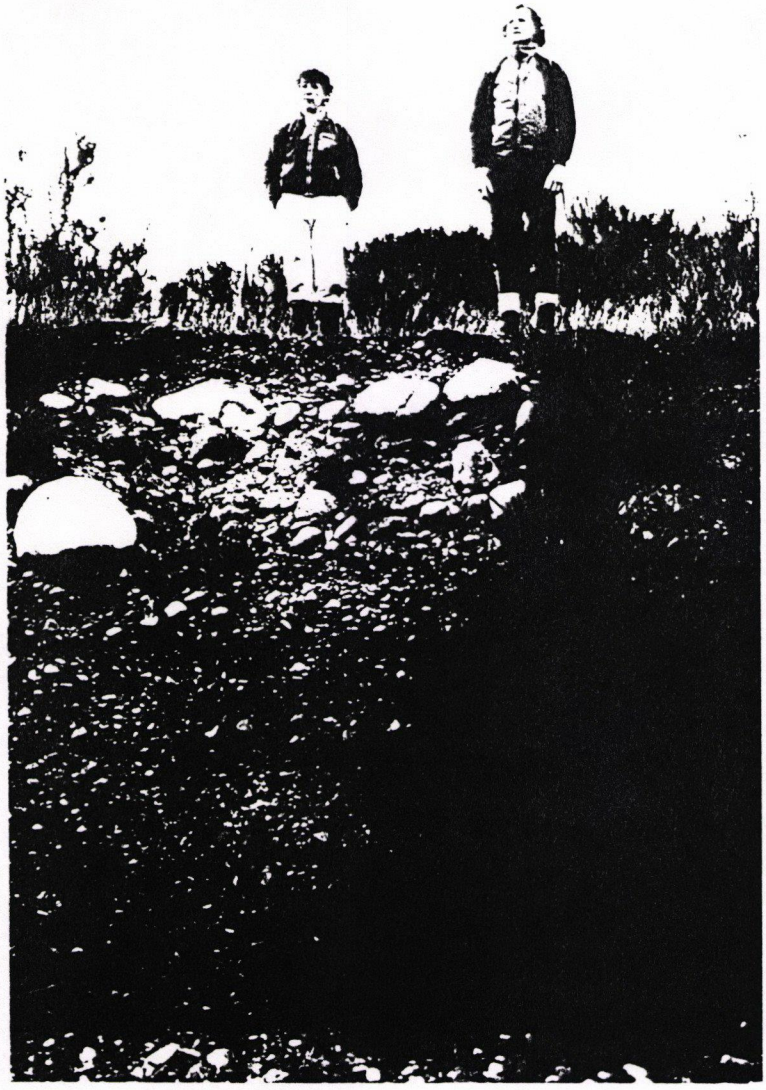
Excelsior Creek Photo 9

In its lower course Excelsior Creek seldom broadens more than a few metres. However, immediately upstream of the tributary confluence bar the channelized zone widens and some channel-marginal sedimentation occurs, as noted by the bank-attached bar in mid-photo. View taken looking upstream. The next photo (Photo 10) is a close up of the exposure beyond the bank-attached bar.

14.07.93 EX-1/23A



Excelsior Creek Photo 10
Right bank exposure at the outside of a bend in the incised lower course of Excelsior Creek (GR 958956). The lower 2 m of this exposure are composed of stratified outwash gravels, whereas the upper 1 m is composed of coarser bar channel materials deposited prior to incision.
14.07.93 EX-1 24A



Excelsior Creek Photo 11
Channel-marginal terrace on the right bank of Excelsior Creek immediately upstream from Waiau confluence. Note the cross-bedded nature of the relatively fine outwash materials. Most of these fines have been selectively removed along Excelsior Creek, and only the remnant coarser lag gravels remain.
14.07.93 EX-1 21A



Excelsior Creek Photo 12
View upstream of the steep-faced tributary fan-bar at Excelsior-Waiau confluence.
14.07.93 EX-1 16A



Excelsior Creek Photo 13
Overview of Excelsior Waiau tributary bar, taken looking downstream from the left bank Waiau terrace. Although the fan-like accumulation extends several metres into Waiau channel, it has barely modified the Waiau itself. Note how Exclesior Creek divides into various small channels as it flows down the relatively steep fan surface.
14.07.93 EX-1/12A



Excelsior Creek Photo 14
View down the Waiau channel showing the relatively steep profile of the fan accumulation at Excelsior/Waiau confluence. Note the large pool in the foreground, and the grasses that have developed on the sand mud accumulation immediately upstream of the confluence bar.
14.07.93 EX-1 14A



Excelsior Creek Photo 15
The relatively steep surface of Excelsior/Waiau confluence bar. On the day of analysis, Excelsior Creek was directed diagonally up-Waiau, and a distinct finer-grained accumulation was evident (on the right hand side in mid-photo).
14.07.93 EX-1 15A



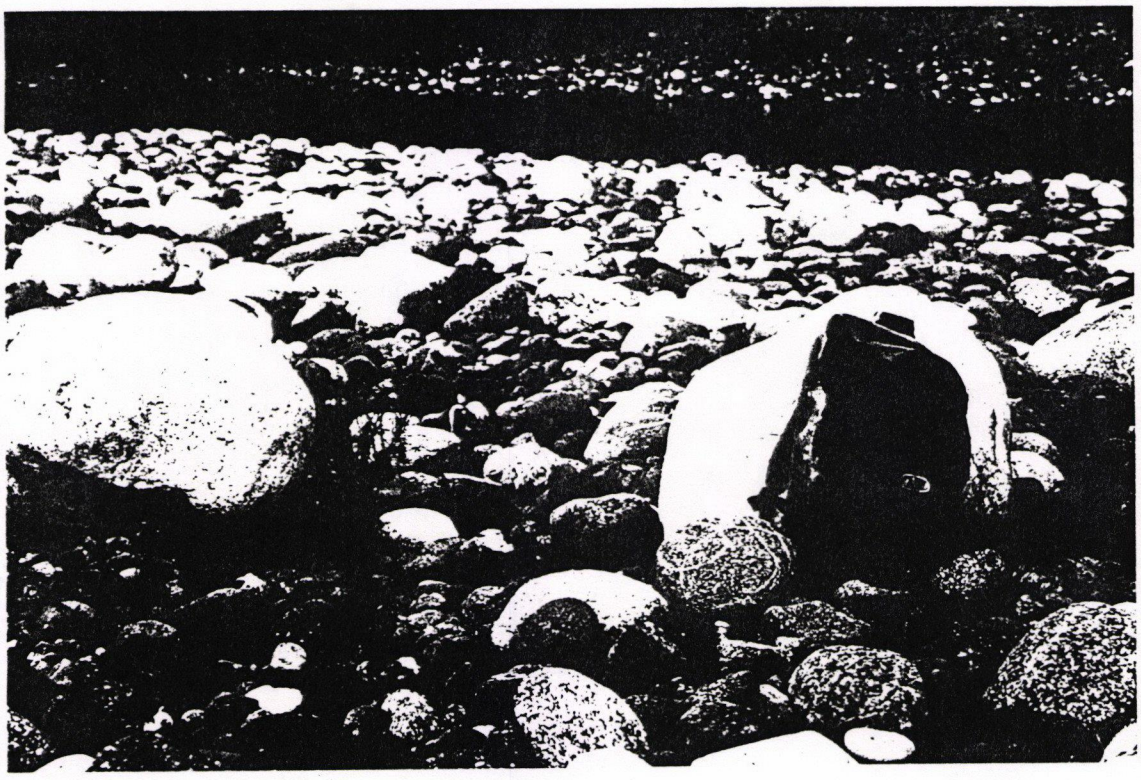
Excelsior Creek Photo 16
Fine-grained accumulation at the distal end of Excelsior/Waiau confluence bar. Such materials are readily reworked at higher flow stages of Waiau River.
14.07.93 EX-1 19A



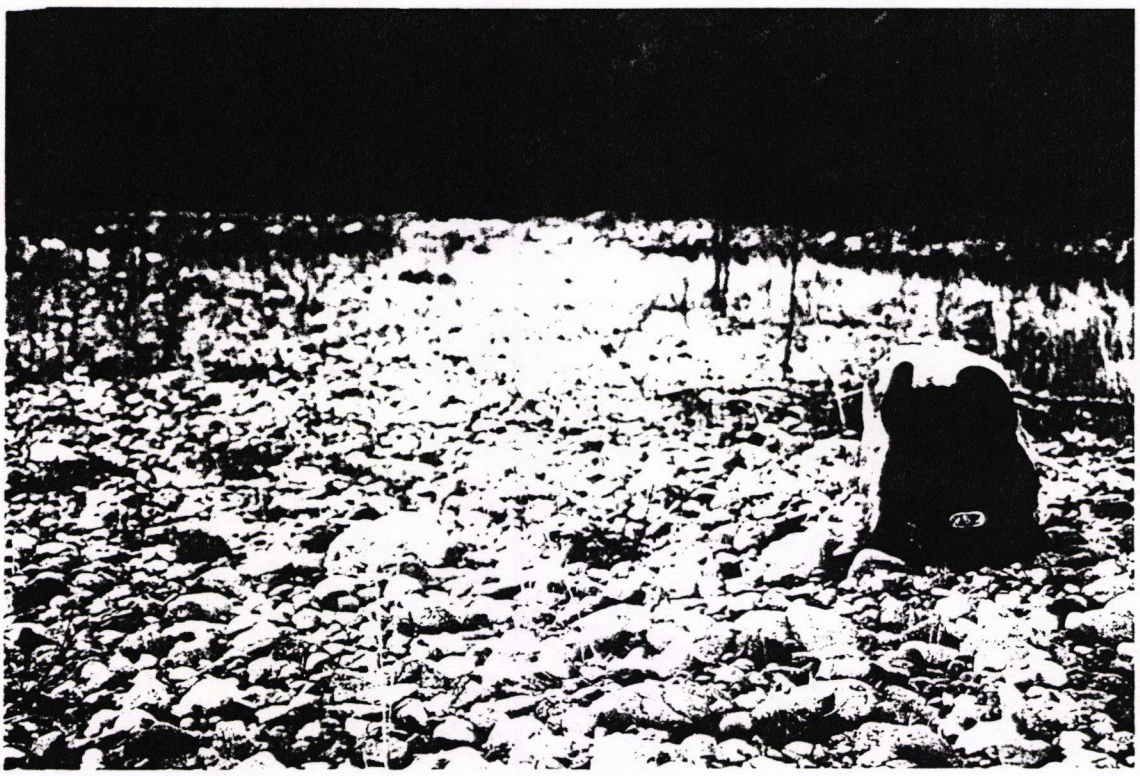
Excelsior Creek Photo 17
View downstream of sample site EX-1, located on an arcuate down-Waiau aligned unit on Excelsior/Waiau confluence bar.
14.07.93 EX-1 17A



Excelsior Creek Photo 18
Surface gravel composition at sample site EX-1. Note the diversity of clast sizes and lithologies (reflecting proximity to source from reworking of outwash terraces) and the relatively loose, non-imbricated nature of the surface.
14.07.93 EX-1 18A



Excelsior Creek Photo 19
Gravel composition on the upper stepped surface of Excelsion/Waiau confluence bar. Note the much finer-grained composition of this unwinnowed surface when compared to the lower, sampled stepped surface.
14.07.93 EX-1 20A



Excelsior Creek Photo 20
View upstream along Waiau River from Excelsior/Waiau confluence bar, with Mararoa Weir in the background.
14.07.93 EX-1/13A



REACH NAME: LOWER WHARE CREEK

Geographic description of reach
Lower Whare Creek, the second left bank tributary downstream of Manapouri Control Structure, drains part of the western Takitimu Mountains and Cheviot Hills. It drains a much larger catchment than Excelsior Creek, and has built a substantive, largely unvegetated tributary bar at Waiau confluence. The reach between Blackmount-Redcliff road bridge and Waiau confluence is characterized by a well-defined channellized zone, with extensive broom on bar and alluvial flat surfaces. A sequence of diagonal and mid-channel bar forms has developed, transitional downstream to alternating lateral bars. Along the lower course, the channel is clearly incised by a few metres.

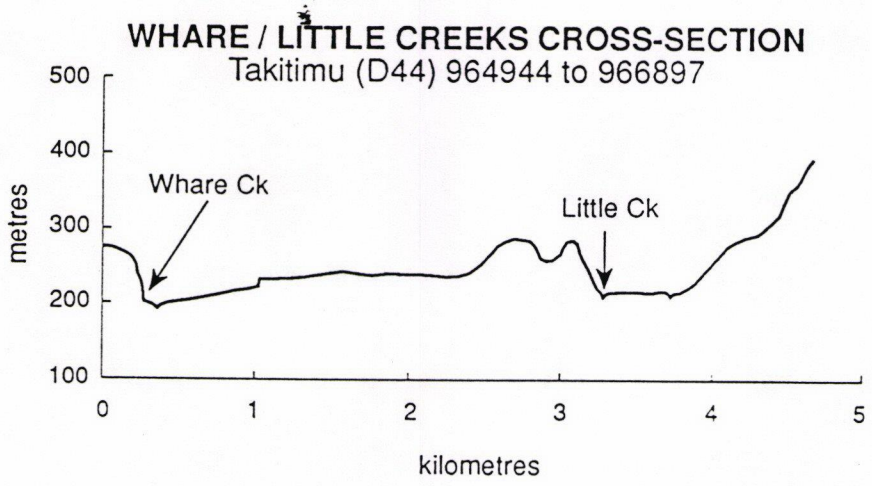
Analysts: GB, SB, RM Date of Analysis: 14.07.93 and 15.07.93

Grid co-ordinates of reach: Takitimu (D44) 1:50,000; 959949 (just downstream of Blackmount Redcliff Road bridge) to 956946 (Waiau Confluence).

Air photographs used: Southland Regional Council, 14.04.92; Survey Number 981, Photo's 46 and 47.

VALLEY CHARACTERISTICS

Valley cross section



Valley setting
Whare Creek drains part of the western Takitimu Mountains and Cheviot Hills. It has a straight, relatively steep course, confined by an enormous terrace on its right bank, many 10's of metres above the channel. Although the left bank is less constrained, several former channel positions are evident at differing elevations near the confluence.

Extent of Valley flat
Whare Creek has a relatively narrow valley, cut deeply within steep-faced terraces. The valley bottom is restricted to a few hundred metres in width upstream of Blackmount-Redcliff road bridge, and even at Waiau confluence the channel is laterally constrained by lower terrace features. Upper terrace surfaces trail down from the Takitimu's, whereas lower Waiau Valley terraces are aligned roughly north-south.

Terrace character
Upstream of Blackmount-Redcliff road bridge the right bank terrace is a massive, bedrock-based feature. Beyond the road, the right bank of Whare Creek is bordered by up to three terraces, which form part of the Waiau Valley terrace flight. Several perched terraces are evident on the left bank upstream of Whare/Waiau confluence, reflecting former positions of Whare Creek.

Extent of Alluvial flat
Alluvial flats are discontinuous features that have been abandoned as Whare Creek incises into its fill, and are generally perched a metre or so above a switching channel. Flats are covered by dense broom and matagouri. There is considerable evidence of abandoned channels on the surface of flats, with numerous old scour holes. Many clasts on the

surfaces of alluvial flats are lichen covered, and there is considerable moss and coral lichen on the abandoned flats adjacent to Whare/Waiau confluence.

Degree and character of channel constriction
Whare Creek is clearly confined, but incision appears to have been a more significant process in the past and there has been relatively little subsequent lateral expansion of channels. Evidence of relatively recent incision is provided by 'recent' fill of an abandoned secondary channel adjacent to a terrace riser. A well-defined channelized zone appears to be inset within the broader alluvial/valley flats.

Character and impact of tributary streams
No major tributary streams join Whare Creek along its lower course.

Surficial geology
Substantial outwash terraces indicate the dominant role played by the glacial history in shaping the configuration of the landscape and hence sediment availability. Waiau terraces merge with sediment derived from the Takitimu's, and up-Waiau catchment lithologies dominate the lower course of Whare Creek.

An exposure along the right bank of Waiau River opposite Whare confluence has about 6 m stratified, cross-bedded fine gravels at the base. These are abruptly transitional upwards to predominantly horizontally-bedded sands, which extend up to 8 m thick. This unit may actually fine upwards. A basal scour feature is evident in the basal part of the sand-fill at the upstream end of the exposure. This unit has a cross-bedded sand fill. The upper 6-8 m of the exposure has horizontally interbedded fine gravels and sands.

Vegetation
Valley side/flats: Pasture with occasional scrub. Local pine plantations on the upper terrace.

Alluvial flats/Bank/Bars: Whare Creek channelized zone is densely vegetated along its lower course, with abundant broom, matagouri, bracken, etc. Lupins, rushes and occasional grasses appear to be the primary colonizer of bar surfaces. Occasional willows are evident upstream of Waiau confluence.

Land use
Predominantly pasture, with some pine plantations in upland reaches.

Direct human impacts
Bridge
Introduced exotics, including broom and willows.

Relationship to Waiau River
Whare Creek has formed a substantive tributary bar as it merges with Waiau River. This unvegetated surface has splayed upstream for about 80-100 m, and tails downstream in a series of arcuate bar forms (deflected down-Waiau by interaction of high-stage Waiau-Whare flows). Steps on the fan surface are not as well-defined as at Excelsior confluence, although they may simply have been reworked. However, the slope of the tributary bar surface profile is also lower.

At the confluence, Waiau channel is presently constricted by the tributary bar to about 25 m wide, within a valley setting that extends up to 200 m wide. There is some evidence for reworking of coarse boulders on the right bank of Waiau River opposite the confluence. These jumbled boulders are not imbricated down-Waiau and cannot be sourced to the adjacent eroding terrace cliff, which is composed of stratified finer gravels and lacustrine sands. This drape of materials may reflect sediment build-up across the Waiau channel in the recent past (ie last decade or so).

CHANNEL CHARACTERISTICS

Number of channels

Immediately downstream of Blackmount-Redcliff road bridge, Whare Creek is divided into two shallow channels around a diagonal bar. At high flow stages a number of additional channels would be activated across the bar surface. Downstream of the highway bridge the channel splits around small mid-channel and diagonal bars. In its lower course, over the lower few hundred metres, Whare Creek is predominantly single-channelled, other than atop the tributary bar itself, where flow divides into three smaller channels.

Channel geometry

Whare Creek channel is typically up to 1 m deep and 10-15 m wide. The channel is less well-defined than Excelsior Creek, as the channelized zone is broader, and active bar surfaces are more extensive. This reflects the lesser degree of incisional control on the lower course of Whare Creek.

Sinuosity

The channel appears to switch from side to side within a very narrow channelized zone, and only in the lower course does this zone extend to more than 100 m in width. Accordingly, the channel has adopted a low sinuosity course.

Lateral stability of channel(s)

In general the margins of the channelized zone are quite well defined and tend to be stable, although there are notable exceptions, such as the eroding right bank terrace at GR 958944 which has a dangling fence line.

Bar type and scale

In the river section adjacent to Blackmount-Redcliff road bridge, diagonal and mid-channel bar forms predominate. Moving downstream, bars become alternating, bank-attached features, reflecting the lateral shifting behaviour of Whare Creek. All bar forms show indication of dissection at higher flow stages, and numerous chute and abandoned channels are evident. Most bars have irregular, jumbled surfaces on which clasts are poorly sorted and loose. Lower Whare Creek is a dynamic system; some eroded broom are evident atop bar surfaces reflecting bank erosion, and the channel alignment on the tributary bar actually changed overnight between analysis days (reflecting snowmelt in the Takitimu Mountains).

Bed/Bank character (extent and materials)

In general banks are 1-2 m high, and are composed of former bar and channel fill sequences. Such loose, non-cohesive materials are equivalent in size to deposits evident in the present channel and bars. Fines are seldom observed atop these banks. The right bank occasionally abuts against higher, more competent terrace materials. These exposures have vertical faces with numerous slumps and broken fencelines.

Flow character

A large number of riffles are evident, reflecting prominent gravel shifting. While white water is common, few pools were observed.

Other comments

Catchment area, sinuosity, degree of incision, terrace character, and consequences for sediment supply are quite different in Whare and Excelsior Creeks. This is reflected in the greater volume of sediment movement through Whare Creek, the larger proportion of active bar surfaces, and the greater build-up of materials at the confluence zone. Despite this, impacts on Waiau channel are restricted to localized erosion of the terrace riser on the right bank of Waiau River. Consequences of this erosion are not likely to extend very far downstream. Incisional history along the lower course of Whare Creek post-regulation is not as clear as that demonstrated by Excelsior Creek. It is possible that such localized effects are damped out in larger, more dynamic tributary systems, in which channels rework incisional products and former sediment accumulations are simply swamped out.

This is not a truly alluvial reach, as it is not reworking materials derived recently. Much of the channel bed deposits have been derived from outwash terraces and are significantly coarser than the materials which Whare Creek has the competence to carry. A large proportion of reworked channel deposits are plutonic rocks and seemingly record reworking of clasts from the Fiordland Complex that make up Waiau Valley terraces.

SAMPLE SITE CHARACTERISTICS

Sample number: **WH-1** Analysts : GB, SB, RM

Grid reference: Takitimu (D44) 1:50,000; 956946

Sample type: 2 x 50 @ 1.0 m interval

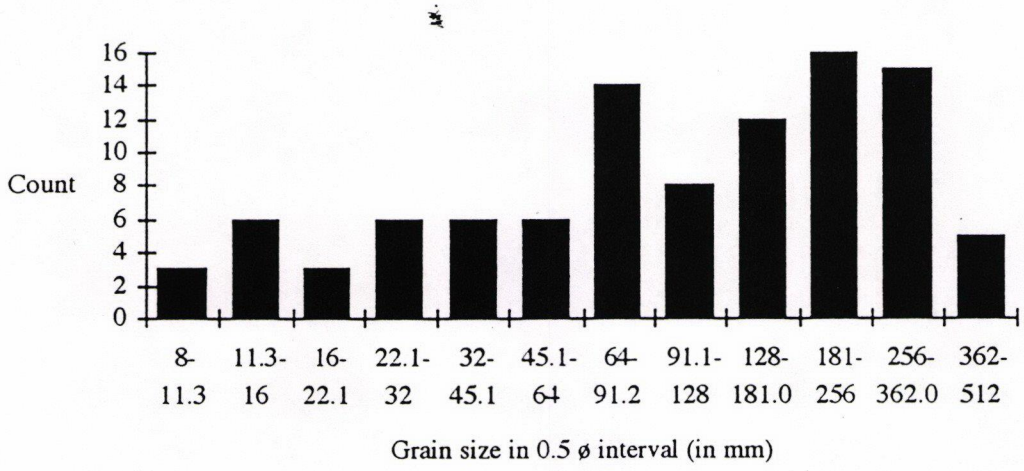
Bar type: Tributary fan/bar. Bar tapers down-Waiau, with a series of lobate units, rib features, and arcuate-shaped units aligned down-Waiau. Clast sizes are quite varied within individual depositional units, even in the recently reworked lower fan surface gravels. Sample was collected downstream from the present channel position of Whare Creek, within a discontinuous arcuate-shaped depositional unit.

Whare Creek joins Waiau River at the outside of a bend, and has induced erosion of the right bank of the Waiau.

Sample position on bar: Aligned down-Waiau along arcuate-shaped unit. Traverse 1 is located adjacent to the water, while traverse 2 is located 2 m inshore.

'Particle characteristics'

Grain size distribution, Whare Creek (WH-1)



D95	360mm		
D84	278 mm		
D50	113 mm	Mean	148.04 mm;
D16	28 mm		
D5	13 mm		

Sorting: 117.23 mm. Very poor, as indicated in the widely dispersed clast distribution in the histogram above.

Packing arrangement: Jumbled surface, with little order evident. Clasts are generally loose, and exhibit minimal imbrication or packing. Winnowing is irregular, and in the sampled area extends down to 10 mm. No pavement is evident, but some of the larger clasts are well-buried.

Shape: Blocky, subrounded, with a small proportion of blades.

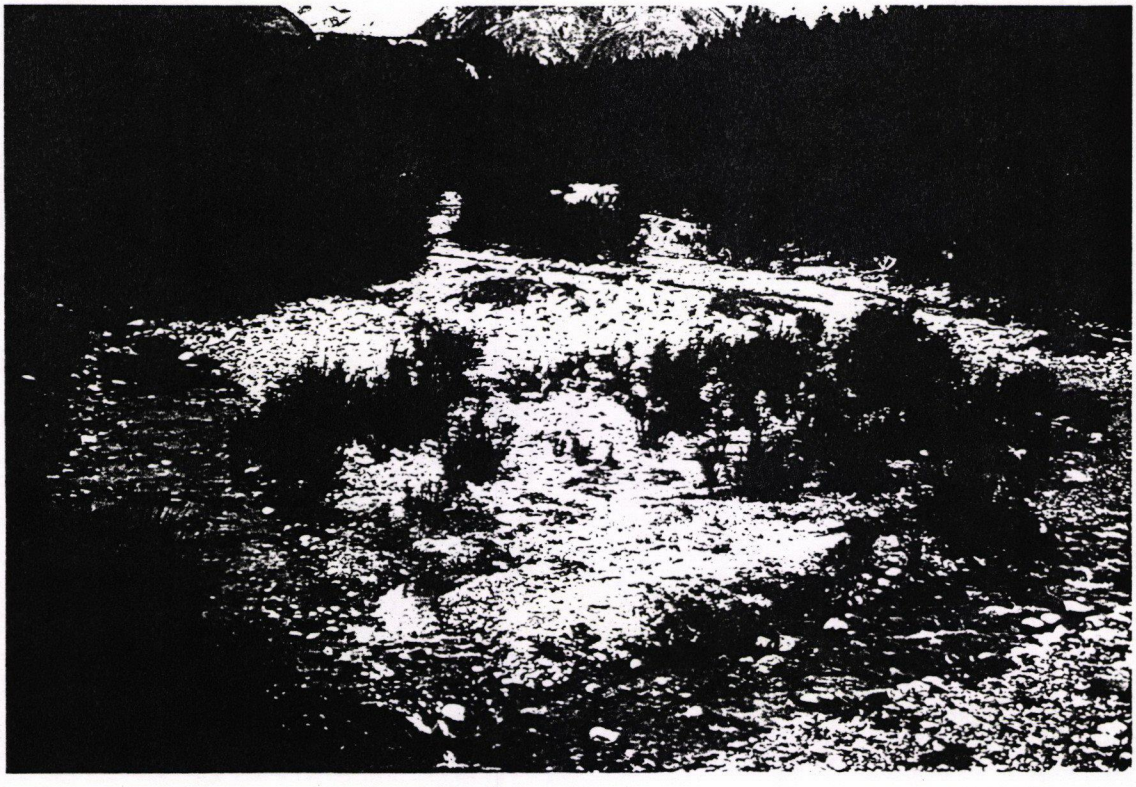
Lithology: Quite varied; majority of clasts appear to be reworked from Waiau Valley terraces.

Other characteristics: Some mud blocks are evident over bar surfaces, derived from loessic sequences at the surfaces of terraces. Area of bar sampled is largely unvegetated, even in the fines fraction. Broom and lupin are dense on adjacent surfaces, while gorse, tutu, grass, clover, Lotus, *Epilobium*, *Hypericum*, *Mimulus* and *Raulia australis* are scattered around the sample site.

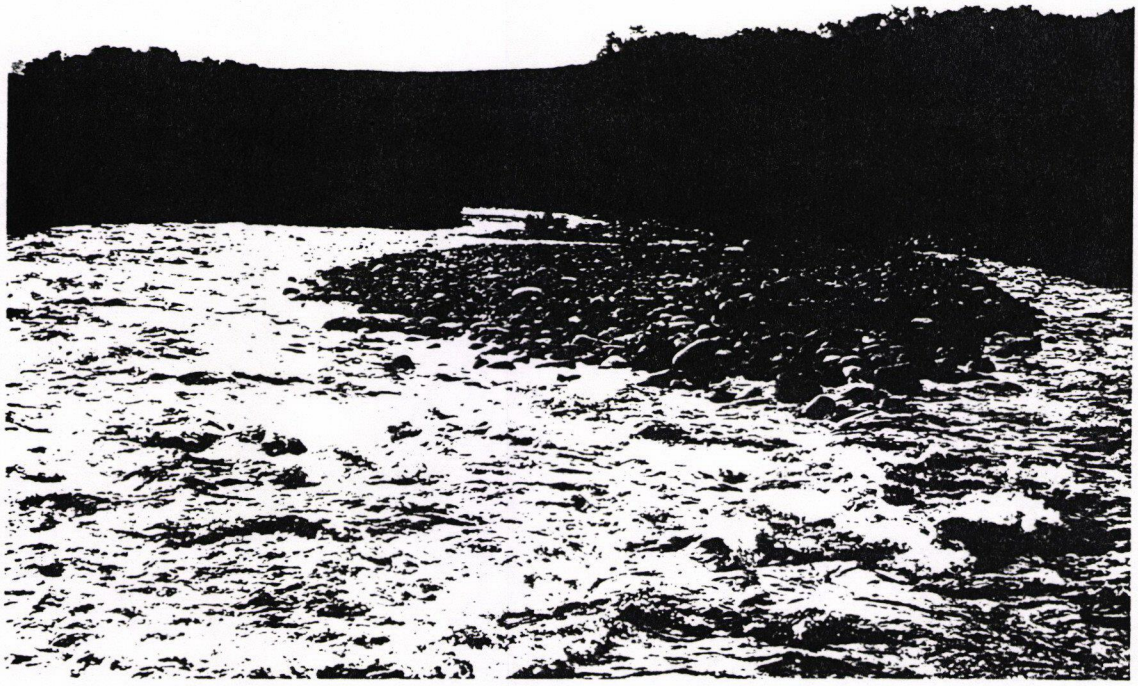
Whare Creek Photo 1
Overview of Whare Creek, looking diagonally upstream towards the Takitimu Mountains. Photograph is taken from one of the Waiau terraces adjacent to Whare/Waiau confluence. Note the extensive upper Whare terrace, which grades down-tributary. This bedrock-based terrace is transitional down-tributary to a series of inset Waiau Valley terraces, one of which is actively eroding (on the left hand side in mid-photo).
14.07.93 EX-1 33A



Whare Creek Photo 2
View upstream of Whare Creek, taken from Blackmount-Redcliff road bridge. Note the large terrace surface on the right bank (left hand side of photo) and the smaller, inset feature on the left bank. In this middle reach, Whare Creek is split around large diagonal bars, which are frequently covered by dense broom.
15.07.93 EX-2 37



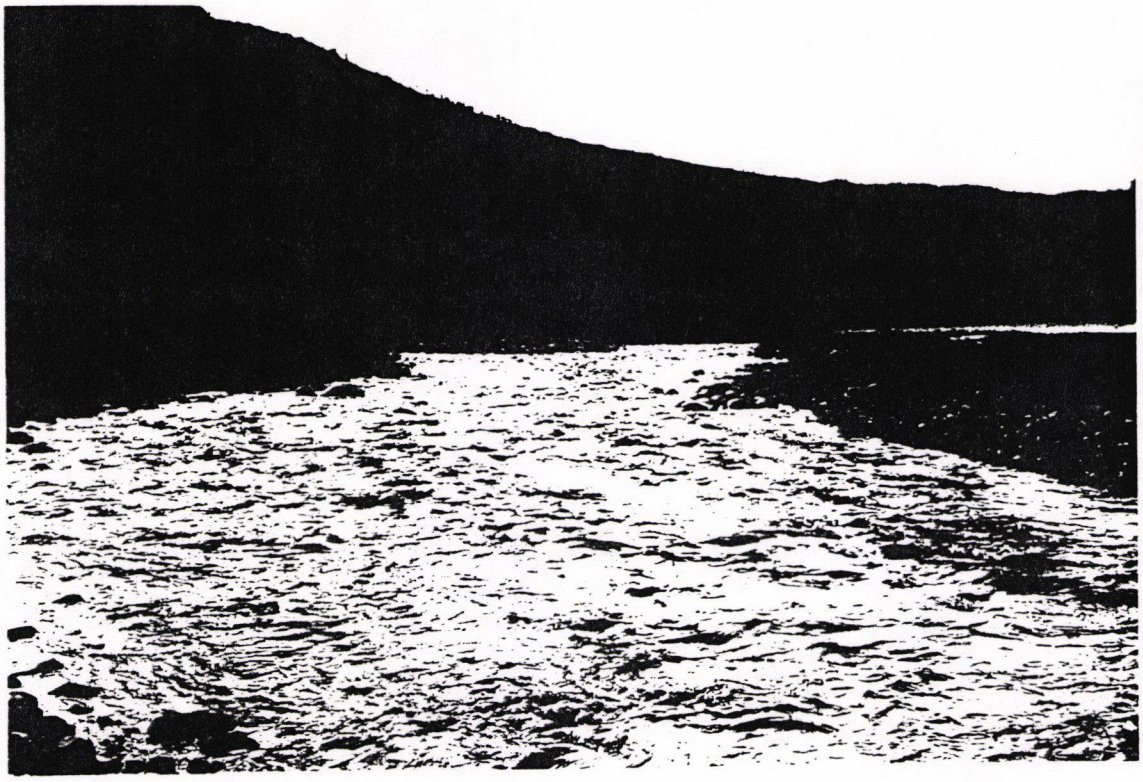
Whare Creek Photo 3
View downstream of diagonal bar on Whare Creek, a few hundred metres downstream from Blackmount-Redcliff Road (GR 958944). Note the 2 m high right bank composed of 'recent' bar and channel gravels (on the right side in mid-photo). These materials contrast starkly with the finer-grained eroding terrace materials in the centre of the photo.
15.07.93 EX-2 35



Whare Creek Photo 4
View upstream of lower section of Whare Creek, showing the relatively coarse nature of channel bed deposits, and point bar feature on the inside of a bend. Note the standed fence line following erosion of the 8-10 m high terrace.
15.07.93 EX-2 34



Whare Creek Photo 5
View looking downstream at channel division on Whare/Waiau confluence bar. Waiau River flows from right to left in mid-photo.
15.07.93 EX-2/33



Whare Creek Photo 6
View upstream of lower Whare Creek, viewed from the Whare/Waiau confluence bar. Note the 3-4 m high incised surface on the right hand side of the photograph, and the large boulder in mid-channel. The latter is probably an erratic or an ice-rafted feature.
15.07.93 EX-2 32



Whare Creek Photo 7
Whare/Waiau confluence bar, looking upstream along Waiau River. Note the diversity of clast sizes over the bar surface.
14.07.93 EX-1 36A



Whare Creek Photo 8
Close up photo of Waiau/Whare bar, taken the day after Photo 7. Snow melt in the intervening 24 hours had slightly adjusted the alignment of channels over the bar surface, such that the coarse gravel unit sampled on 14.07.93 was submerged on 15.07.93.
15.07.93 EX-2 31



Whare Creek Photo 9
View down-Waiau of sample site WH-1, showing the loose, jumbled surface of the tributary bar. Note the finer gravel lobe in mid-photo.
14.07.93 EX-1 35A



Whare Creek Photo 10
Eroding right bank of Waiau River immediately opposite Whare Creek confluence. About 6 m of stratified fine gravels and sands at the basal part of the exposure are transitional up-sequence to around 6-8 m of horizontally-bedded sands. The are inferred to be glacio-lacustrine or valley-dammed lake deposits capped by 8-10 m of stratified glacial outwash gravels.
15.07.93 EX-2 29



REACH NAME: LOWER REDCLIFF CREEK

Geographic description of reach
Redcliff Creek, the largest stream that drains the western part of the Takitimu Mountains, has a relatively straight channel with prominent terraces. Upper terraces are bedrock-cored, and slope considerably towards Waiau River. The lower 400 m or so of Redcliff Creek extend beyond these Takitimu-based terraces, and is incised into Waiau Valley terrace deposits. In this lower zone, Redcliff Creek is laterally much more expansive, and has formed a shallow fan surface. This feature is much larger than equivalent forms developed by Excelsior or Whare Creeks. Redcliff Creek tributary bar complex complex comprises fist-sized gravels which are much more fluvially reworked and sorted than the close-to-source terrace-derived materials that comprise Excelsior and Whare tributary bars. The tributary bar is not particularly stepped, and maintains a relatively uniform, shallow slope that extends some way across Waiau channel, restricting Waiau River to a width of less than 25 m at low flow stage. However, this fan is clearly a transient feature. The lower fan surface is unvegetated other than occasional rushes and lupins and there are discontinuous lobes of finer-grained materials (including sands) that are readily flushed down-Waiau at higher flow stages. Downstream-trailing lobate features are evident on the fan surface, reflecting high-stage interaction of Waiau/Redcliff flows.

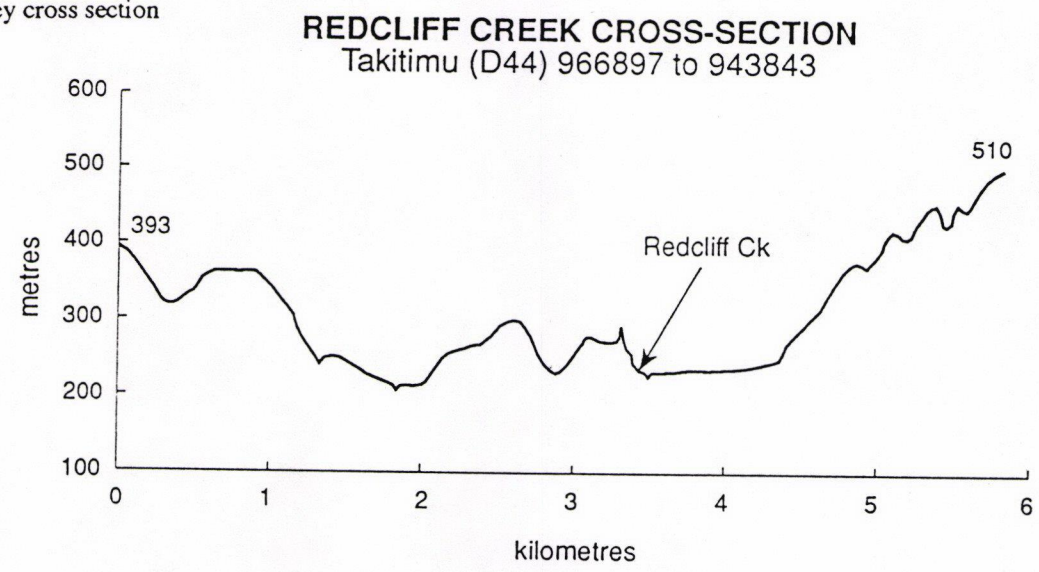
Analysts: GB, SB, RM Date of Analysis: 15.07.93

Grid co-ordinates of reach: Takitimu (D44) 1:50,000; 938878 (just downstream of Blackmount Redcliff Road bridge) to 912886 (Waiau Confluence).

Air photographs used: Southland Regional Council, 14.04.92; Survey number 981, Photos 041 and 042

VALLEY CHARACTERISTICS

Valley cross section



Valley setting
Redcliff catchment extends up to 1634 m (Spence Peak), with a range of additional peaks around 1600 m (eg Revelation and Family Peaks). This is a relatively narrow valley, with a massive bedrock-based terrace on its right bank, and bedrock confinement adjacent to Jericho Hill and Blackmount to the south.

Extent of Valley flat
Redcliff Creek is inset within major terrace features. Valley flats average about 1 km wide along the lower course. Upstream of Blackmount-Redcliff Road bridge there is an enormous bedrock-cored terrace, with minimal preservation of lower terraces. Downstream of the bridge, however, the upper terrace is less prominent and a series of Waiau Valley terraces flank the river.

Terrace character
Upstream of Blackmount-Redcliff Road bridge there is an enormous bedrock-cored terrace, with minimal preservation of lower terraces. This feature has an exceptionally steep, locally undercut terrace riser. Downstream of the bridge, however, the upper terraces is less prominent and a series of Waiau Valley terraces flank the river. Terrace forms are much greater on the right bank.

Extent of Alluvial flat
Upstream of Blackmount-Redcliff road bridge alluvial flats constitute a fairly extensive surface, up to several hundred metres wide, with numerous swamps evident. The relative breadth of alluvial flats reflects minimal preservation of lower terraces. Immediately downstream of the road bridge, alluvial flats have been modified by berms and the channelized area becomes more restricted. Flow becomes increasingly confined down-valley, and the proportion of active alluvial flats decreases. At the lower end of Redcliff Creek, flats are discontinuous features a metre or so above a switching channel. Discontinuous flats have been abandoned and dissected as channels incise into these surfaces. Flats are covered by dense broom and matagouri and are generally around a metre above the present channel.

Degree and character of channel constriction
Redcliff Creek locally abuts against terraces, but generally has adopted a well-defined channelized zone. A series of former surfaces are evident on the left bank adjacent to the confluence, reflecting a more expansive stage of channel shifting in the past.

Character and impact of tributary streams
No tributaries join Redcliff Creek along its lower course. Above Blackmount-Redcliff road bridge there are a series of small channels that drain the swampy sections of the alluvial flats. These tributaries run parallel to Redcliff Creek for a considerable distance prior to joining it. Remaining tributaries are headwater features that drain the highly dissected Takitimu Mountains.

Surficial geology
Substantial outwash terraces indicate the dominant role played by the glacial history in shaping the configuration of the landscape and hence sediment availability. Waiau terraces merge with sediment derived from the Takitimu's. Up-Waiau catchment lithologies dominate the lower course of Redcliff Creek downstream of Blackmount-Redcliff road bridge.

Vegetation
Valley side/flats: Terrace riser is densely vegetated, with Pittospermum, manuka, cabbage tree, flax, bracken, tussock, occasional pine and beech. Jericho Hill and areas marginal to Blackmount are areas of poor pasture, with manuka, matagouri, red tussock, fescue, toe toe, flax and grasses.

Alluvial flats/Bank/Bars: Pasture with occasional scrub. Downstream of Blackmount-Redcliff road bridge the channelized zone is densely vegetated, with broom dominant and occasional gorse, matagouri, manuka, toe toe, tussock, etc. Lupins, rushes and occasional grasses appear to be primary colonisers of the tributary fan/bar surface, with occasional broom, gorse, tutu, etc.

Land use
Predominantly pasture, with some pine plantations.

Direct human impacts
Bridge itself exerts negligible impact on Redcliff Creek, but protection structures (such as artificial groynes/stop banks and drains) associated with the bridge may have modified the relationship between the channelized zone and the adjacent alluvial flats by constraining the flow to a narrower zone. However, other than modifications to channel form, implications of this impact are not especially pronounced. There has been some gravel extraction on the fan surface at the confluence. Introduced exotics, including broom and willows, may also modify channel behaviour.

Relationship to Waiau River
Deposition of the tributary fan/bar by Redcliff Creek has pushed the Waiau against its right bank, but no distinct erosion is evident at present. Two styles of impact on Waiau River can be isolated:

a) Downstream control
Build-up of the fan may have modified the slope of Waiau River as it has backed up against the fan. A large bank-attached bar has built up on the right bank of Waiau River immediately upstream of Redcliff confluence. Waiau River has incised through this material at higher flow stage, resulting in better channel definition, and subsequent abandonment of secondary channels on the alluvial flats. These are now visible as perched features.

b) Upstream control
Waiau River clearly flushes fist-sized gravels down-valley from Redcliff tributary fan/bar. These clasts likely accumulate on Waiau bar surfaces downstream of the confluence. This zone is also coincident with significant

widening of the channelized area of Waiau River, and additional materials are also supplied to the channel by erosion of large terrace sequences on the right bank several hundred metres downstream of the confluence.

CHANNEL CHARACTERISTICS

Number of channels

Locally variable. One channel is common at low flow stage, but this generally divides into two and occasionally three channels around mid-channel bars. Numerous chute and abandoned side channels are also evident.

Channel geometry

Adjacent to Blackmount-Redcliff road bridge (GR 938878), Redcliff Creek is a wide, shallow stream, with abundant riffles in smaller channels. In the lower course, immediately upstream of Redcliff/Waiau confluence, Redcliff Creek is up to 20 m wide and less than 1 m deep, and very few pools and scour holes are observed. These may have been "drowned out" by within-channel aggradation.

Sinuosity

Generally low, with occasional low to moderate sinuosity bends (eg GR 934879).

Lateral stability of channel(s)

Immediately downstream of Blackmount-Redcliff road bridge the channelized area is distinctly broader than upstream, with concomitant increase in the area of active bar surfaces. Accordingly, the channel is more prone to lateral shifting in this area. Moving downstream, the channel locally erodes alluvial flats and terraces, especially at the outside of bends in which there has been within-channel build-up of sediment on the inside of bends (eg GR 934879). In general, however, downstream translation of bars appears to dominate over lateral shifting, but the channel cannot be said to be constrained. This behaviour may reflect the great availability of fine sized clasts which can be readily moved downstream.

Bar type and scale

Immediately downstream of Blackmount-Redcliff road bridge there is an extensive, dissected mid-channel bar. Such forms alternate downstream with laterally accreting forms. Bar styles reflect both formation of recently accreted forms and dissection of older forms. At GR 934879 flow is directed towards the left bank atop a series of diagonal bars. Such well-defined forms are the exception, rather than the rule, as downstream of GR 934879 channel-bar relationships are quite complex, with relatively straight sections with no bars evident and highly dissected areas with extensive gravel bar surfaces in which three or more channels may be observed. In some sections the channel switches from side to side in the channelized zone around lateral bars. These commonly have chute channels at their margins. Many bar surfaces are covered by primary colonizers such as broom (eg sampled bar at GR 913885).

Bed/Bank character (extent and materials)

While banks are relatively stable throughout much of the channelized zone, they are locally undercut whenever flow is diagonally oriented towards the margins. At GR 934879 the 2 m left bank is undercutting, threatening the road on the surface of the alluvial flats. The lower 40 cm of this bank is composed of basal gravels capped by interbedded fines up to 40 cm thick, with gravels up to 120 cm thick at the surface. In the lower course, banks are generally relatively shallow, with only occasional fine-grained caps. The channel does not have the incisional nature observed on Excelsior and Whare Creeks. Indeed, the terrace configuration at the lower end of Redcliff Creek is quite different, as the fan surface is much more extensive as the space between Waiau Valley terraces widens considerably. This factor, along with the highly active sediment transfer regime, presents much greater potential for significant channel adjustment

Flow character

Generally rapid flow, with supercritical flow (standing waves) wherever channels rejoin. Pool-riffle sequences are much better developed in the section immediately downstream of Blackmount-Redcliff road bridge than they are in the lower course.

SAMPLE SITE CHARACTERISTICS

Sample number: **RE 1** Analysts: GB, SB, RM

Grid reference: Takitimu (D44) 1:50,000; 912887

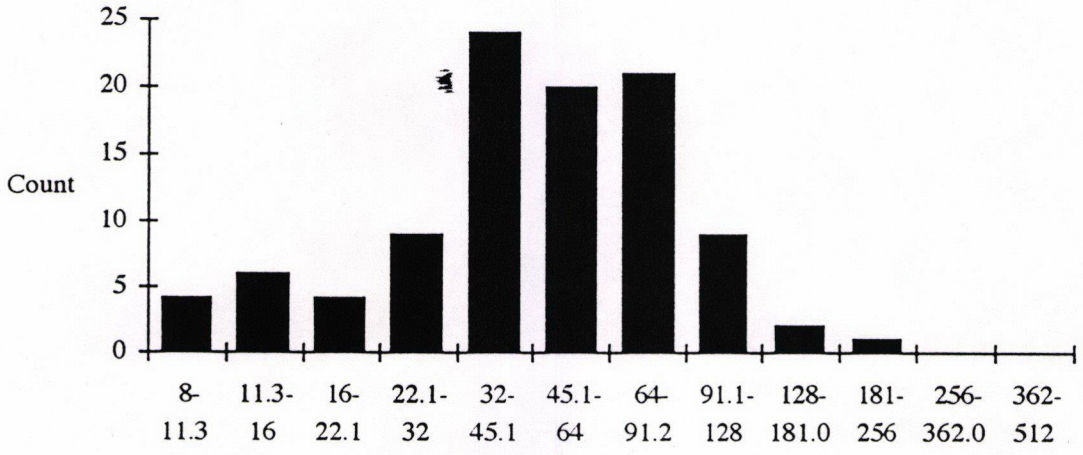
Sample type: 2 x 25 @ 0.5 m interval

Bar type: Tributary confluence bar at mouth of extensive shallow fan-shaped surface.

Sample position on bar: Sample transects aligned diagonally down-Waiau. Sample records 'typical' grain size being flushed through Redcliff Creek into Waiau River.

'Particle characteristics'

Grain size distribution, Redcliff Creek, RE-1



D95	112 mm		
D84	79 mm		
D50	48 mm	Mean	54.42 mm
D16	24 mm		
D5	12 mm		

Sorting: 32.65 mm. Overall fan surface is poorly sorted, but individual sampled lobe is moderately well sorted.

Packing arrangement: Loose, barely imbricated; readily reworked surface. Largely unwinnowed, with large areas of surface fines.

Shape: Blocky, subrounded, with a small proportion of blades/discs.

Lithology: Dominantly from Takitimu's (i.e. relatively small proportion of reworked Waiau terrace clasts).

Other characteristics: Area of bar sampled is unvegetated. Adjacent area has cover of fines, with pioneer lupins, etc. Adjacent to broom/gorse flats at margins of the fan, there is some gravel extraction. Large pool evident immediately downstream of Redcliff-Waiau confluence fan.

Sample number: RE 2 Analysts: GB, SB, RM

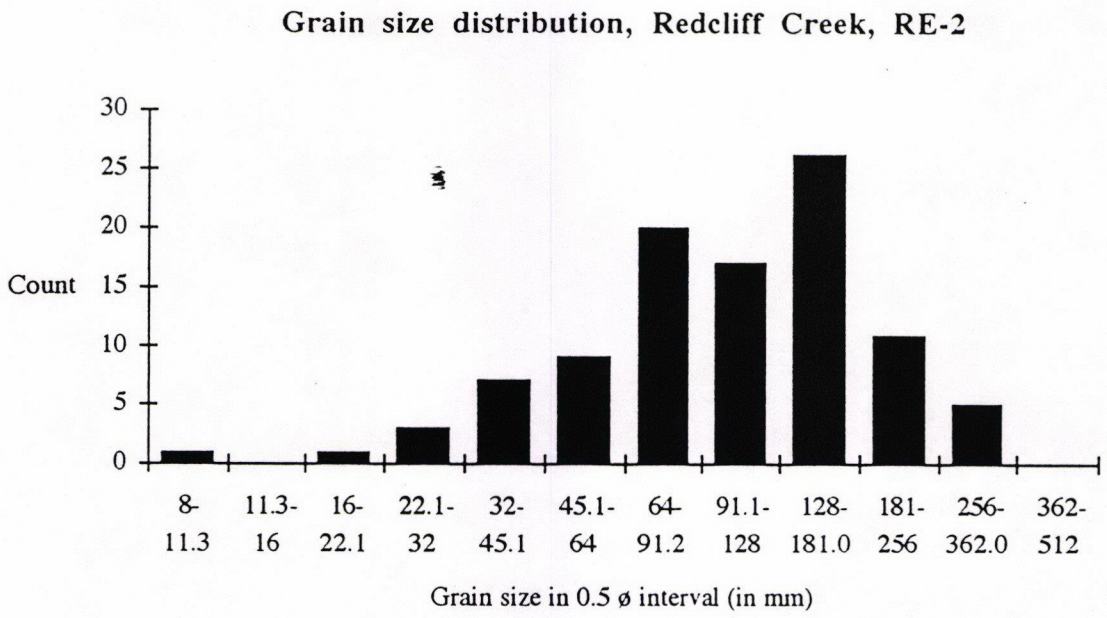
Grid reference: Takitimu (D44) 1:50,000; 913886

Sample type: 4 x 25 @ 1.0 m interval

Bar type: Large dissected bank-attached compound bar, several hundred metres upstream of Redcliff/Waiau confluence. Downstream of this point bar surfaces are dominated by finer-sized or mixed gravel populations associated with the build-up of finer clasts atop the basal lag gravels.

Sample position on bar: Sample transects aligned diagonally down a bar platform unit adjacent to a major chute (high flow stage) channel.

'Particle characteristics'



D95	246 mm		
D84	180 mm		
D50	110 mm	Mean	119.59 mm
D16	52 mm		
D5	29 mm		

Sorting: 65.60 mm. Quite poor.

Packing arrangement: Occasionally jumbled, but generally a packed basal gravel surface. Not imbricated.

Shape: Blocky, subrounded, with a small proportion of blades/discs.

Lithology: Largely Takitimu-derived (i.e. relatively small proportion of Waiau-terrace dervied clasts).

Other characteristics: Relatively young broom bushes 1-2 m tall, at 1-2 m centres. Also grass, *Epilobium melanocaulis*, *Raoulia australis*, clover, *Hypericum*, Lotus, gorse, tutu. At water's edgethere are tutu and monkey musk. Much dead broom strewn over bar surface.

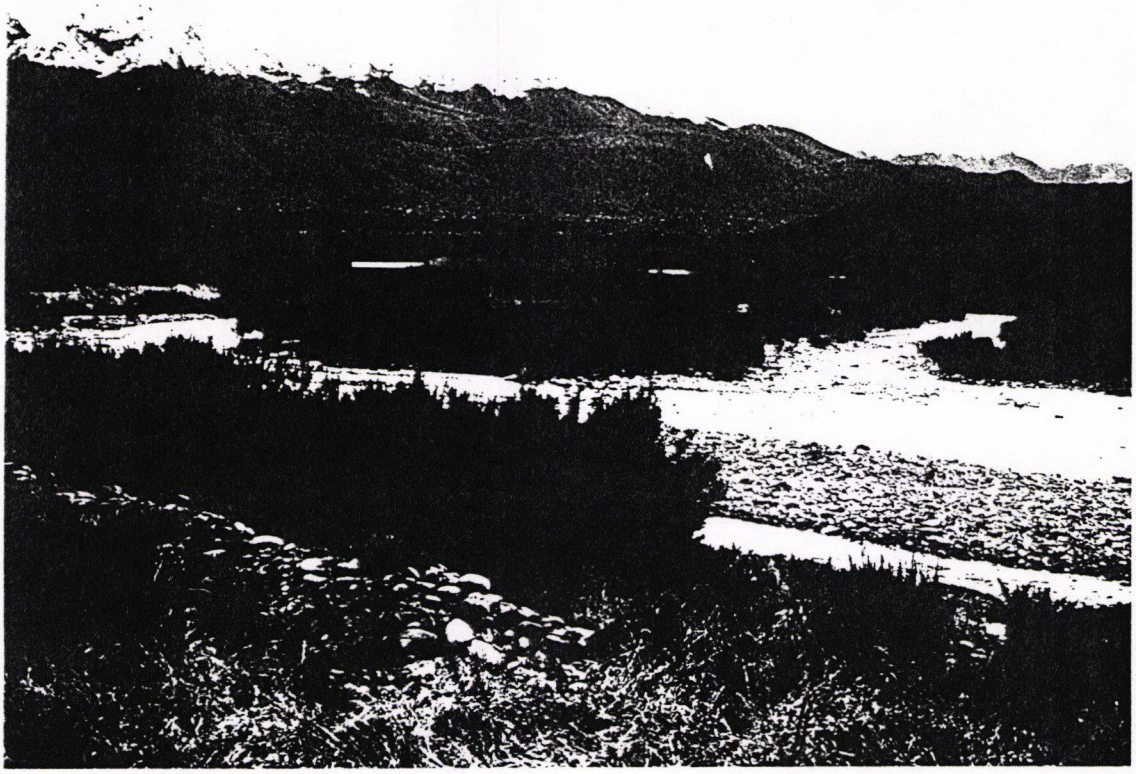
Redcliff Creek Photo 1
Upstream section of Redcliff Creek catchment, within the Takitimu Mountains. Note the prominent right bank terrace on the left hand side in mid-photo.
15.07.93 EX-2 27



Redcliff Creek Photo 2
View downstream of Lower Redcliff Creek, taken from Jericho Hill. Note how the channel is positioned against the right bank terrace along most of its lower course.
15.07.93 EX-2 28



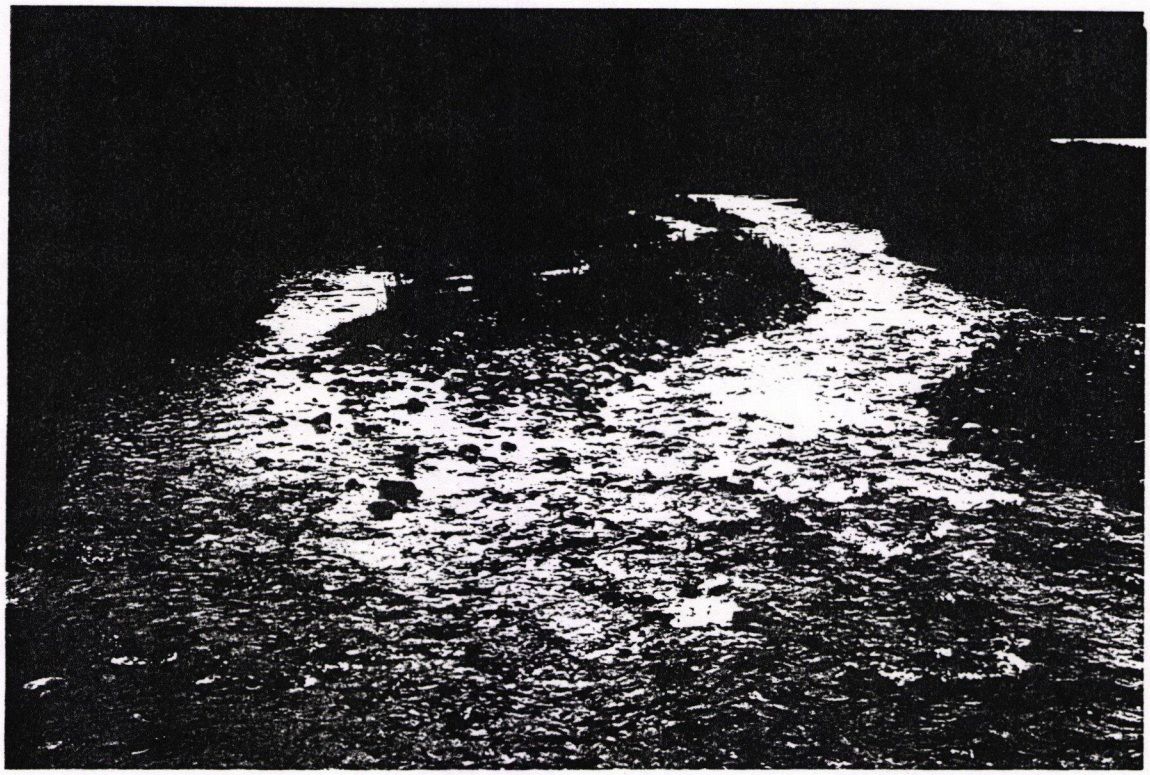
Redcliff Creek Photo 3
View downstream along Lower Redcliff Creek taken from Blackmount-Redcliff road bridge. In this subreach Redcliff Creek divides around substantive mid-channel compound bars covered by broom. Numerous high-stage channels are evident dissecting bar surfaces. Not also the mounded gravels in the foreground, protecting lateral shifting of the channel downstream of the bridge.
15.07.93 EX-2 26



Redcliff Creek Photo 4
Localized bank erosion on the right bank of Redcliff Creek (GR 934879). The channelized zone is narrower in this section, and flow is less divided than upstream (eg Photo 3).
15.07.93 EX-2 25



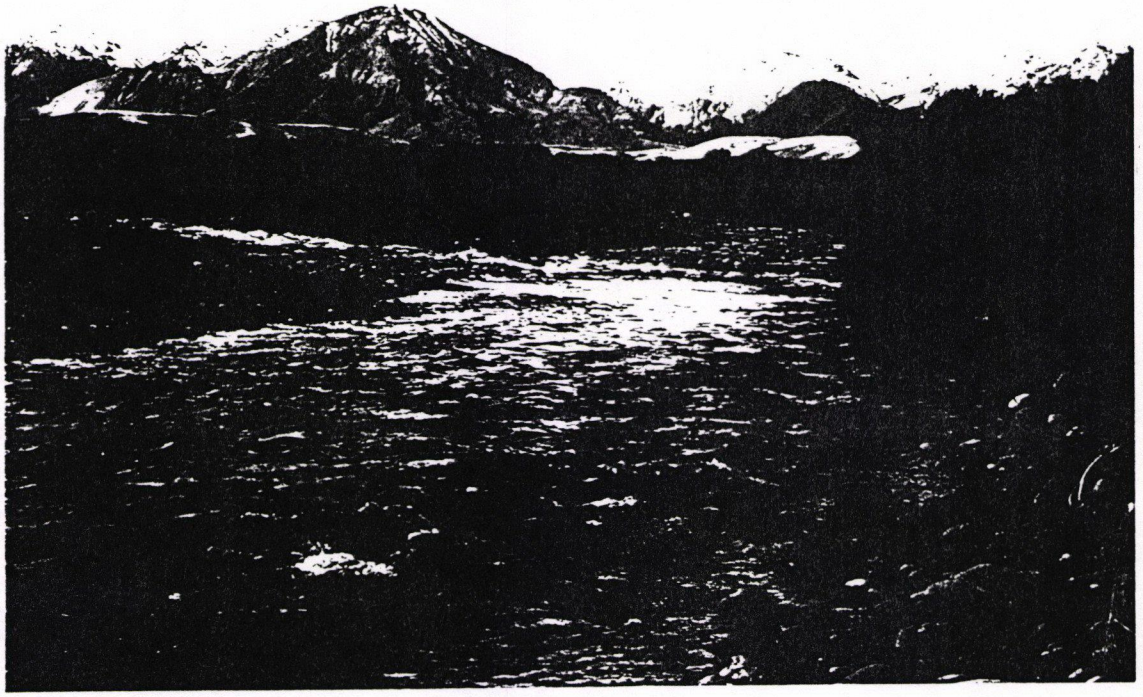
Redcliff Creek Photo 5
View downstream of Redcliff Creek, taken from eroding bank at GR 934879. Note the relatively narrow channelized zone, with occasional channel division over partially vegetated diagonal bars. Broom densely covers adjacent flats.
15.07.93 EX-2/24



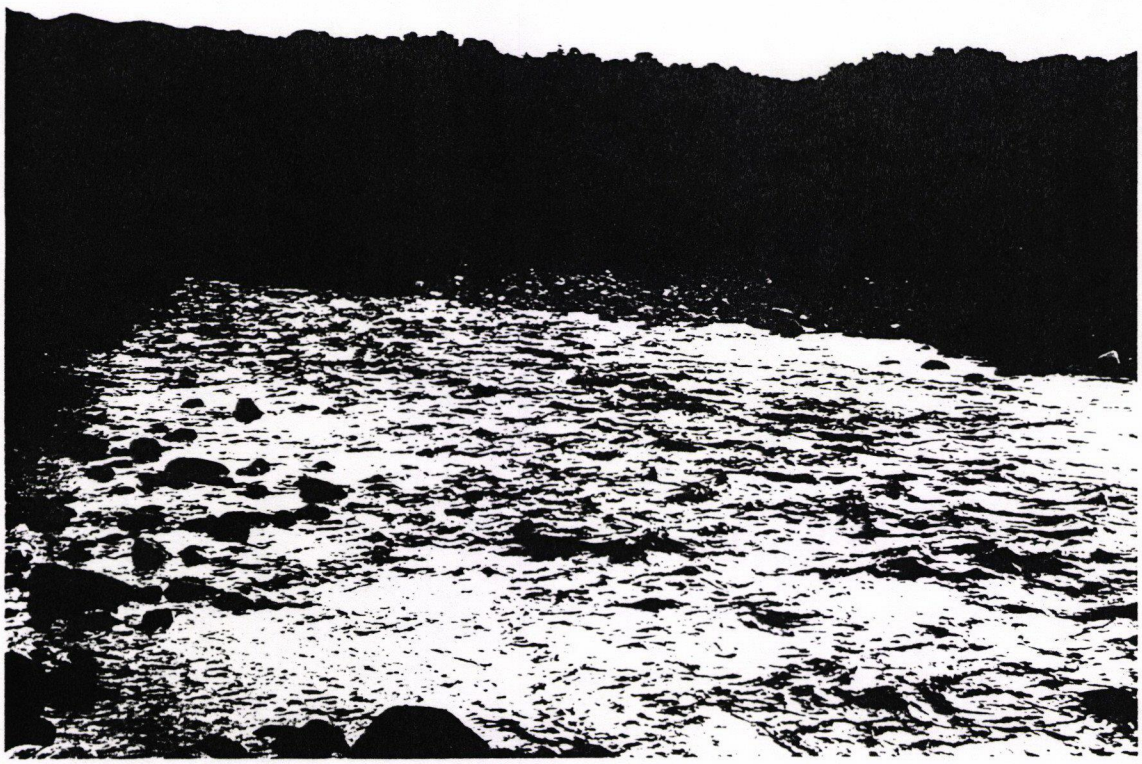
Redcliff Creek Photo 6
Sample site RE-2, located on a coarse clast bar platform adjacent to a high-stage channel that dissects a bank-attached compound bar at GR 913886.
15.07.93 EX-2/23



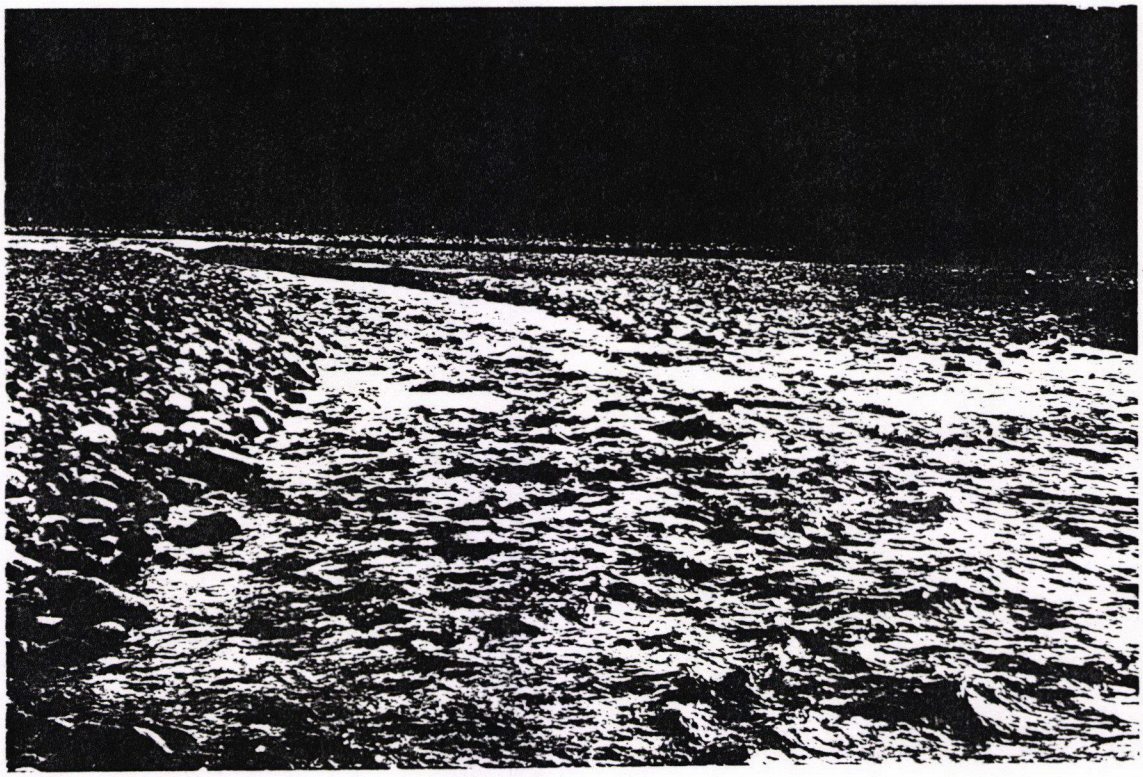
Redcliff Creek Photo 7
Lower Redcliff Creek, viewed upstream from the tributary confluence bar at Waiau River. Note the relatively steep channel surface, with prominent riffles at the downstream end of the mid-channel compound bar.
15.07.93 EX-2 20



Redcliff Creek Photo 8
Upstream end of Redcliff-Waiau confluence bar, showing the presently abandoned channel that would be readily reoccupied at higher flow stage. Such characteristics are common on fan-shaped surfaces.
15.07.93 EX-2 21



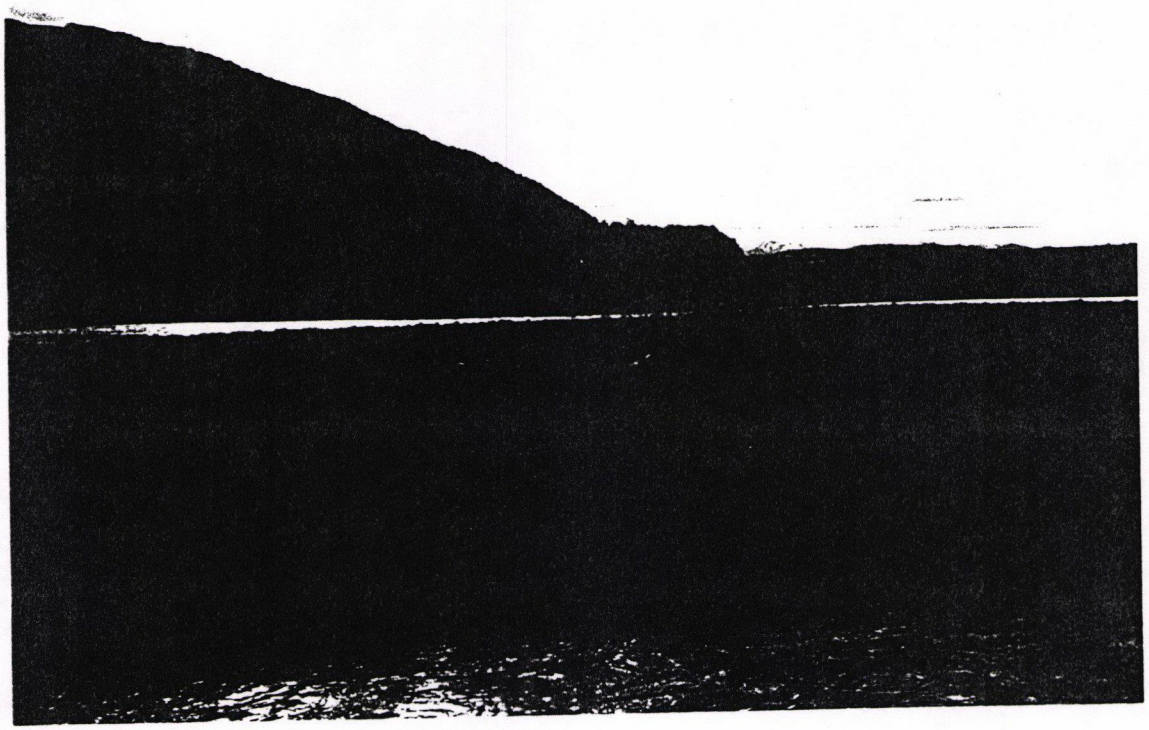
Redcliff Creek Photo 9
The present position of Redcliff-Waiau confluence, located at the downstream end of the fan/bar complex. Note the relatively shallow surface, with extensive drapes of sand and fine gravels. The left bank in mid-photo clearly shows the finer-grained caps atop coarser clasts. Note also how the shallow bank of Waiau River has numerous undercut grass clumps.
15.07.93 EX-2/17



Redcliff Creek Photo 10
Redcliff/Waiau confluence bar/fan surface. View is taken looking up Redcliff Creek.
15.07.93 EX-2/4



Redcliff Creek Photo 11
Upstream end of Redcliff/Waiau confluence bar/fan surface. View is taken looking up Waiau River. Note the abandoned channel of Waiau River on the left hand side in mid-photo and the extensive sheet of fine gravels and sand in the foreground.
15.07.93 EX-2 15



Redcliff Creek Photo 12
Abandoned channel of Waiau River opposite the head of Redcliff/Waiau confluence fan/bar.
15.07.93 EX-2 5



Redcliff Creek Photo 13
Redcliff/Waiau confluence bar/fan surface, viewed downstream along Waiau River.
15.07.93 EX-2/8



Redcliff Creek Photo 14
Drape of fine gravels atop Redcliff/Waiau confluence bar/fan surface. Sample RE-1 was taken in the mobile fraction on the right hand side of this photo.
15.07.93 EX-2/14

