RJHall and Associates Ltd
24 Pohutukawa Crescent, Parklands
Cell: 027 444 0137

Date: 31/05/2024

Job Number: 1196-03-24

Noel Becker,
Waikaka Gold Ltd
1616 Riversdale Waikaka Road
No 7 RD, **GORE, 9777**

Email: **Noel Becker** noel.becker@waikaiagold.co.nz **(letter sent as email)**
CC: **Bob Hall** bobhall@xtra.co.nz

Dear Noel,

RE: Updated Diversion Details, Flood Hazard Analysis, and Flood Mitigation Evaluation Summary Report – Waikaka River (REVISION B)

1 EXECTUTIVE SUMMARY

RJHall and Associates Ltd have been engaged to provide an updated assessment for temporary diversions of the Waikaka Stream, updates as follows:

- Updated diversion plan (four smaller river diversions c.f. one original diversion)
- Individual diversion time (2 years typical)
- Analysis of 20 year recurrence interval flood through Waikaka Stream, and adjacent floodplain (Q_{20} (5% annual exceedance probability))
- Proposal for flood mitigation works (stop banks)

The update to the diversion plan has been provided to reduce to overall impact within the Waikaka Stream system. And presentation of proposed flood mitigation works, which are designed to reduce the risk of inundation of the work sites resulting from flooding of the Waikaka Stream.

The diversion works presented here incorporate the fundamental of prior reporting by RJHall and Associates Ltd, with the updated developments presented within this document.

All diversions are to be in cut, however some locations out of stream embankment filling works is required. These embankment fill works are required to contain higher flows regimes, and all diversion sections are designed to carry the 20 year flood with a supplementary freeboard of 300mm.

In addition to the temporary diversions, it is proposed that flood mitigation banks are provided for the wider stream area, this is to reduce the potential for flooding of the work site area.

Typical flood mitigation embankments have been targeted in potential breakout zones which were identified by 2D flood modelling. The main embanked heights are typically with less than 1.5m in height, with one localised area greater that this at 1.9m (Bank 2). The average height is estimated to be less than 1.0 – 1.2m in height. As the bank heights are located along potential breakout regions, the embankments are not continuous along the full length of the site.

2 DIVERSION PLAN

The proposed update to the diversion plan and diversion centreline long sections are presented in Appendix A, Figure 1a to Figure 1d, with the layout plan presented below in Figure 2.

The proposed diversions have the same typical profile as per the original diversion design report (refer Figure 1), with a shallow low flow bed (1m below berm) this is set in a sinusoidal pattern along the diversion reach. The wider berm width is set at 20m, and 3:1 batters (H:V) out to natural ground level. The proposed diversion is designed to carry a minimum 20 year flood with a minimum 300mm freeboard. The bed profile is set at a constant bed gradient along the given diversion in the order of 0.002 to 0.003 (0.2 to 0.3%) this is designed to match into existing low flow bed levels, some adjustment of levels and alignment may be required on site to match into current bed levels, and undertaken to ensure smooth transitions between the proposed diversion and the existing bed and berm profiles.

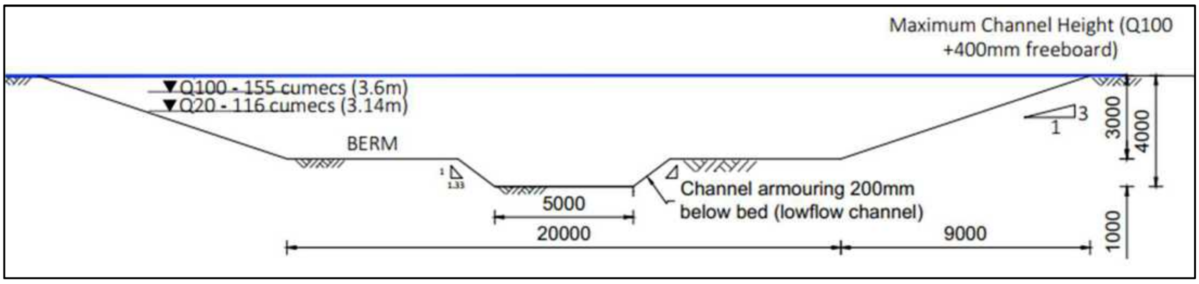

Figure 1 - Typical Diversion Profile

It is noted that where the natural ground level adjacent to the channel is lower than the proposed bank height a bund will be provided to prevent spill of the 20 year flood into the wider floodplain. In general, this is provided for each of the diversions, with a typical profile demonstrated in Figure 3, where a typical section is cut through the alignment of Diversion 2 at a chainage of 60m.

As above, where bunds are required the plan area of the bund will be stripped of topsoil, and filled to the required height. Typical dimension of the embankment profiles are:

- Embankment height set based on 20 year flood capacity (+300mm);
- Minimum crest width 1.5 m;
- Side batter angles 2:1

The fill material for the embankment will be composed of inorganic clean gravel or silty gravel granular fill, and will be well compacted. The embankment will spread with 100 to 150mm of topsoil, and regrassed. Maintenance of grass and weed will be by occasional, controlled, grazing.

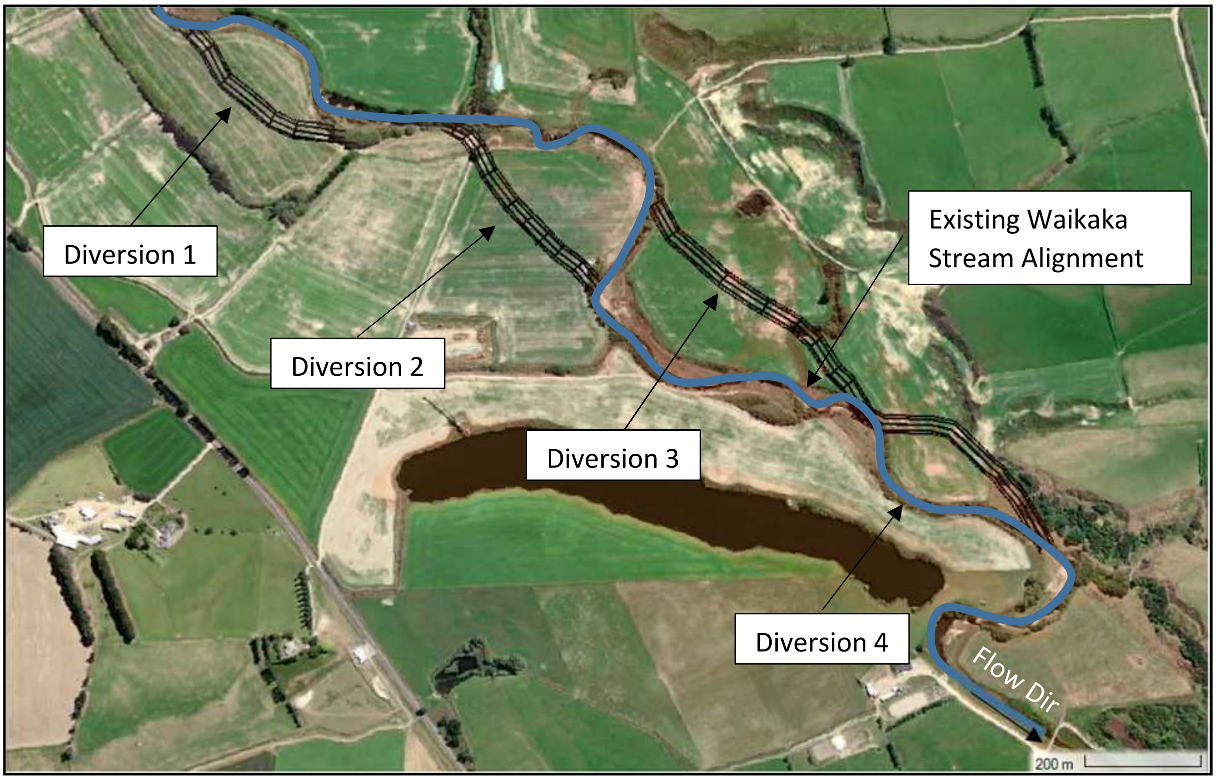

Figure 2 - Waikaka Stream - Updated Diversion Locations

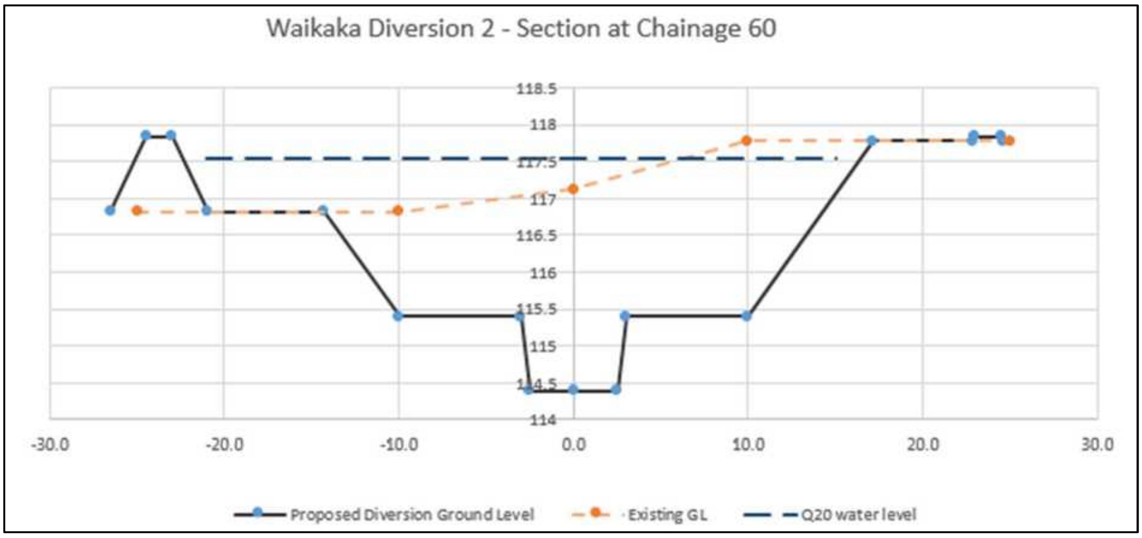

Figure 3 - Indicative Diversion Cross Section (Diversion 2, Chainage 60)

3 FLOOD HAZARD ASSESSMENT

A 2D flood hazard model was evaluated to assess flood mitigation locations and to reduce the potential for flooding of proposed works areas during the mining operation. The generalised flood conditions used within the flood model were as follows:

- 2D terrain – Surface LiDAR 1x1m grid, Manning's n=0.035, no additional structures (bridges/culverts);
- Model boundary conditions:
    - Inflow hydrograph (Q_{20} = 116 cumecs, 3 hours duration);
    - Outflow – normal depth condition;
- Model analysis: Full momentum;
- NB: external stormwater sources from rain on wider floodplain were not incorporated in model with flooding source from the Waikaka River above the bridge;

The flood model results are presented in Figure 4, with the generalised proposed flood banks locations overlaid (Bank 1 to Bank 9)

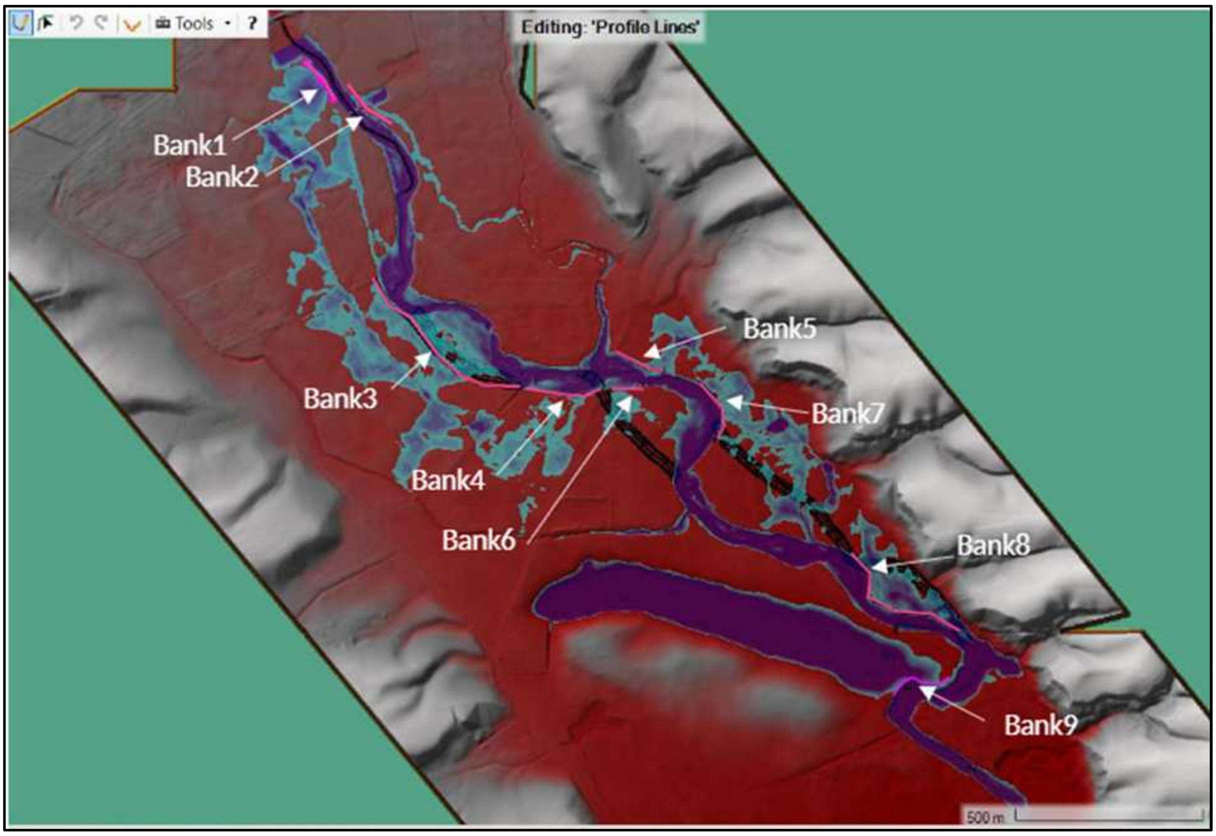

Figure 4 - Waikaka Stream 20 year Flood Model and Proposed Embankment Locations

Full flood plain was modelled on a 1mx1m grid. Input of water was applied immediately downstream of the road bridge (north of the site) as a hydrograph.

There was no addition of culverts of bridges within the model area, where existing crossings are located some adjustment of conveyance may be required if significant influence from bridge crossings are anticipated to be confirmed on site.

4 FLOOD MITIGATION

The application of flood mitigation embankments is proposed along the river's edge with the general extents presented in Figure 4.

The flood bunding is to be applied with a finished embankment height approximately 0.3m above the Q20 flood level for this initial proposal. A summary of maximum embankment heights and embankment lengths for each of the sites is presented in Table 1. Long sections for the proposed embankments are appended to this document (Appendix B).

Table 1 Q20 Flood Embankment Summary

Embankment	Embankment Length (m)	Maximum Bank Height (m)	Comment
Bank 1	115m	1.4m	Embankment crest generally level along section approximately RL 121.5m
Bank 2	125m	1.8m	Embankment crest grades down 0.24% over length
Bank 3	390m	0.9m	Embankment crest grades down 0.23% over length
Bank 4	160m	1.0m	Embankment crest generally level along section approximately RL 117.7m
Bank 5	130m	0.9m	Embankment crest grades down 0.22% over length, downstream end left open to return water from side stream into main Waikaka River
Bank 6	70m	<0.6m	Embankment crest generally level along section approximately RL 117.45m
Bank 7	170m	0.9m	Chainage 0 – 40 bank RL 116.7m embankment level, then grades down at 0.08%.
Bank 8	400m	1.5m	Chainage 0 – 125 bank RL 114.8m embankment level, then grades down at 0.25%. Downstream of embankment truncated to allow surface water to flow back to Waikaka Stream
Bank 9	180m	1.45m	Embankment crest generally level along section approximately RL 117.45m

5 CONCLUSIONS

RJHall and Associates Ltd have been engaged to prepare and updated summary report for the proposed temporary river diversion of the Waikaka Stream, and the addition of flood mitigation to reduce the risk of flooding of mining works area.

The updated long sections are provided to break up the effects and overall diversion timeframe presented in the original report. The diversions works are designed to cater for 20 year recurrence interval flood (discussed in previous reporting).

In addition to the diversion works, a proposal for flood mitigation works is presented, this work involves placement of embankments to prevent breakout of the river into the wider floodplain, to lower the risk of inundation of the work site, during the mining process.

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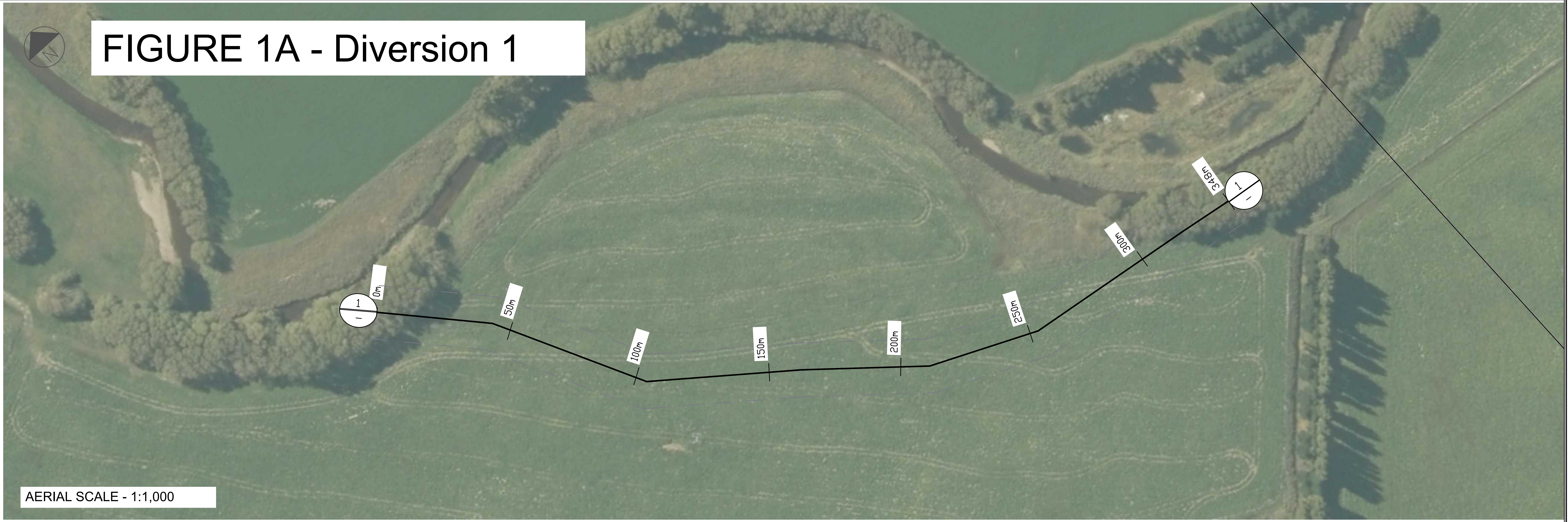
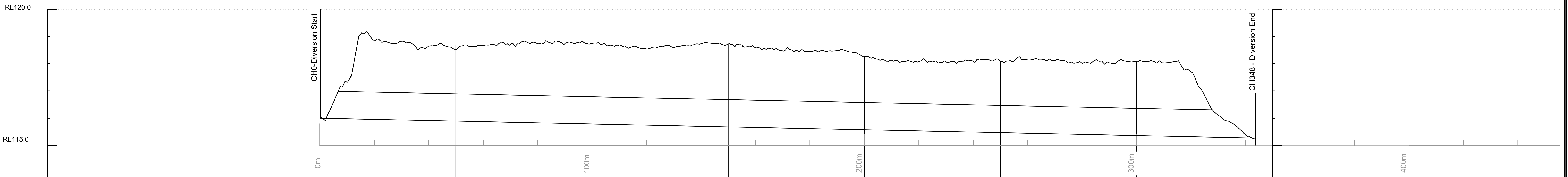
CMEngNZ, BE (Civil) Hons, Dip (Civil)

Appendix A – Diversion Layout Plan

FIGURE 1A - Diversion 1





Existing GL (m)	116.04	118.52	118.75	118.73	118.27	118.09	118.07	
Berm Invert (m)	117.00	116.90	116.79	116.69	116.59	116.48	116.38	116.28
Low Flow Invert (m)	116.00	115.90	115.79	115.69	115.59	115.48	115.38	115.28
Chainage (m)	0.00	50.00	100.00	150.00	200.00	250.00	300.00	350.00

LONGSECTION 1 SCALE- Hoz: 1:1,000, Vert: 1:100 (at A3)

AMENDMENTS:

REV:	DESCRIPTION:	BY:	DATE:
A	Initial Sections	CH	17.04.24

SITE: Waikaka Gold	DRAWING NO. H01-1	PROJECT NO. RIV-021-056	DATE. 17.04.2023
TITLE: Proposed Channel Layout and Long Section (1 of 4)	SCALE AT A2. As Shown / DRAWN. CH	CHECKED. CH	REVISION. B

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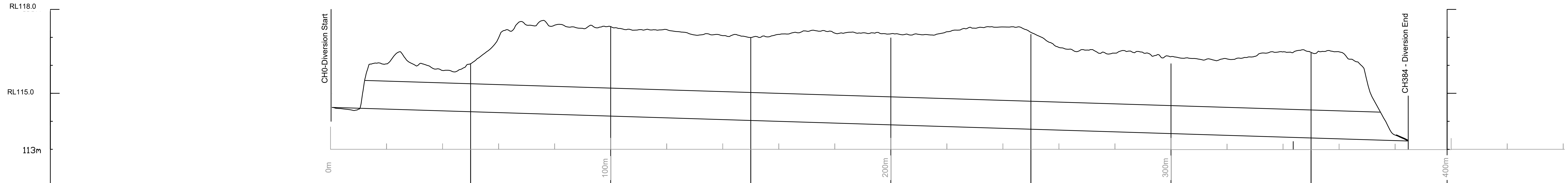
FIGURE 1B



Existing GL (m)	114.50	116.09	117.36	117.01	117.14	117.15	116.32	116.44
Berm Invert (m)	115.51	115.42	115.32	115.23	115.14	115.04	114.95	114.85
Low Flow Invert (m)	114.51	114.42	114.32	114.23	114.14	114.04	113.95	113.85
Chainage (m)	0.00	50.00	100.00	150.00	200.00	250.00	300.00	350.00

LONGSECTION 2 SCALE- Hoz: 1:1,000, Vert: 1:100 (at A3)

REV:	DESCRIPTION:	BY:	DATE:
A	Initial Sections	CH	17.04.24

AMENDMENTS:

SITE: Waikaka Gold

TITLE: Proposed Channel Layout and Long Section (2 of 4)

DRAWING NO. H02-1

PROJECT NO. RIV-021-056

DATE. 17.04.2024

SCALE AT A2. As Shown

DRAWN. CH

CHECKED. CH

REVISION. B

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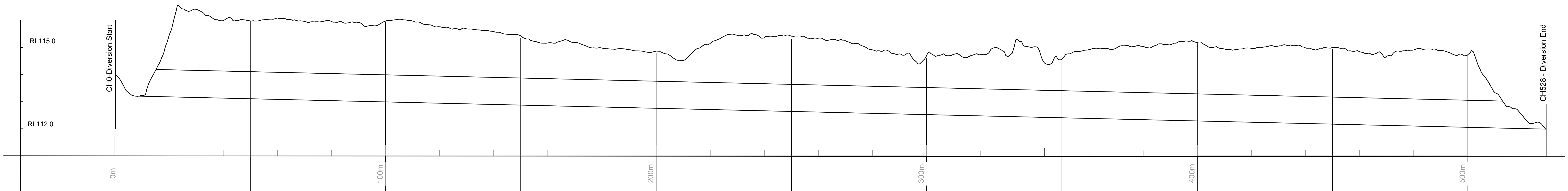

Existing GL (m)	114.00	115.98	115.98	115.42	114.84	115.42	114.75	114.59	115.18	115.01	114.76
Berm Invert (m)	114.20	114.05	113.90	113.75	113.60	113.45	113.30	113.15	113.00	112.84982	112.6998
Low Flow Invert (m)	113.20	113.20	113.20	113.20	113.20	113.20	113.20	113.20	113.20	113.20	113.20
Chainage (m)	0.00	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00	500.00

LONGSECTION 3 SCALE- Hoz: 1:1,000, Vert: 1:100 (at A3)

REV:	DESCRIPTION:	BY:	DATE:
A	Initial Sections	CH	17.04.24

AMENDMENTS:

SITE: Waikaka Gold	DRAWING NO.: H03	PROJECT NO.: RIV-021-056	DATE: 17.04.2024
TITLE: Proposed Channel Layout and Long Section (3 of 4)	SCALE AT A2.: As Shown; DRAWN.: CH	CHECKED.: CH	REVISION.: A

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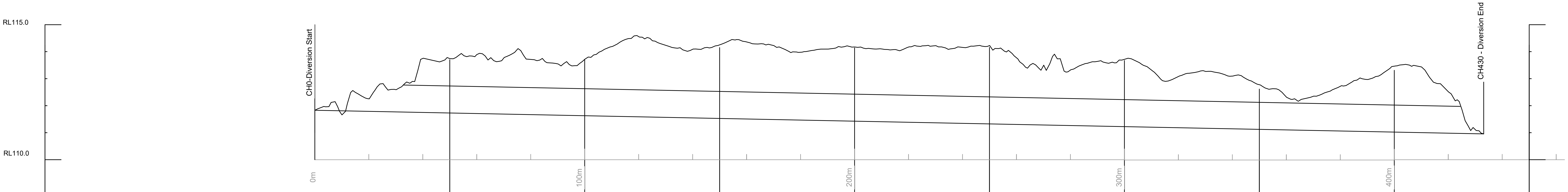

Existing GL (m)	111.83	113.75	113.72	114.25	114.18	114.23	113.71	112.79	113.49
Berm Invert (m)	112.81	112.71	112.61	112.52	112.42	112.32	112.22	112.12	112.02
Low Flow Invert (m)	111.81	111.71	111.61	111.52	111.42	111.32	111.22	111.12	111.02
Chainage (m)	0.00	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00

LONGSECTION 4 SCALE- Hoz: 1:1,000, Vert: 1:100 (at A3)

REV:	DESCRIPTION:	BY:	DATE:
A	Initial Sections	CH	17.04.24

AMENDMENTS:

SITE: Waikaka Gold

TITLE: Proposed Channel Layout and Long Section (4 of 4)

DRAWING NO.: H04

PROJECT NO.: RIV-021-056

DATE: 17.04.2024

SCALE AT A2.: As Shown

DRAWN.: CH

CHECKED.: CH

REVISION.: A

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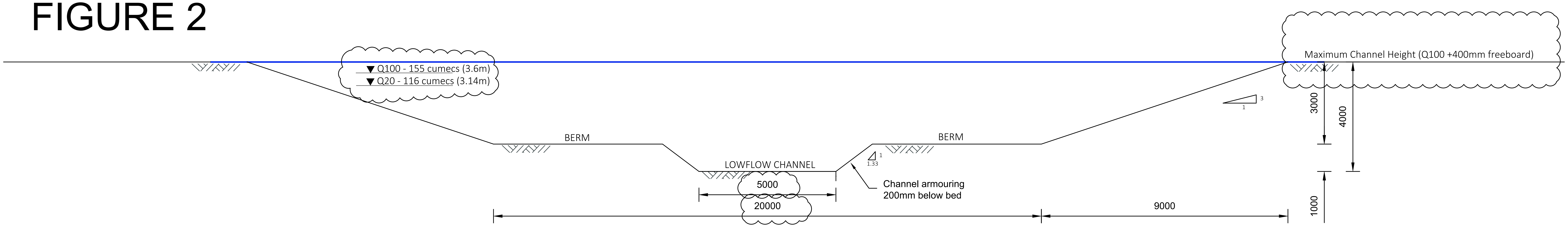
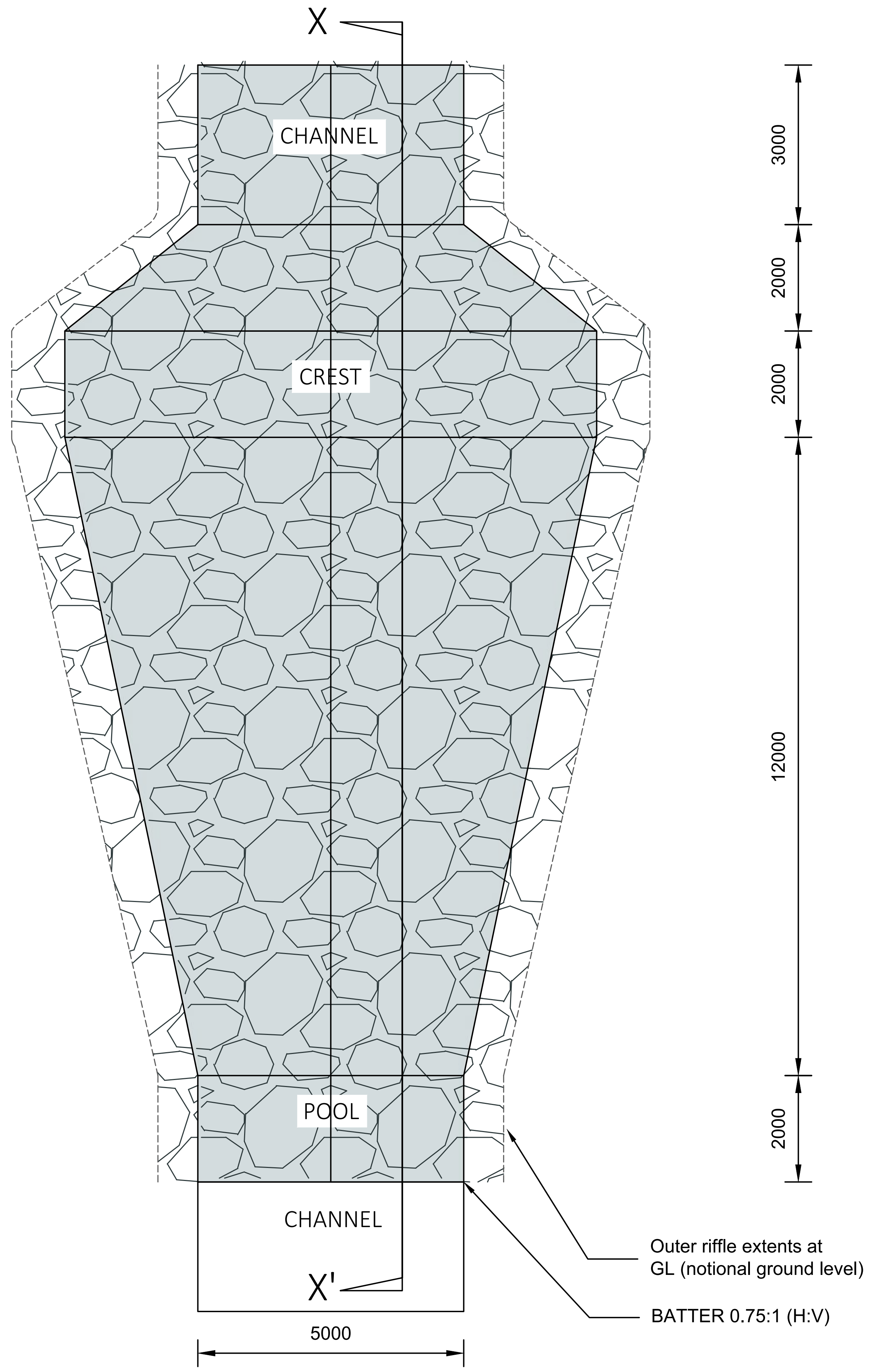
FIGURE 2



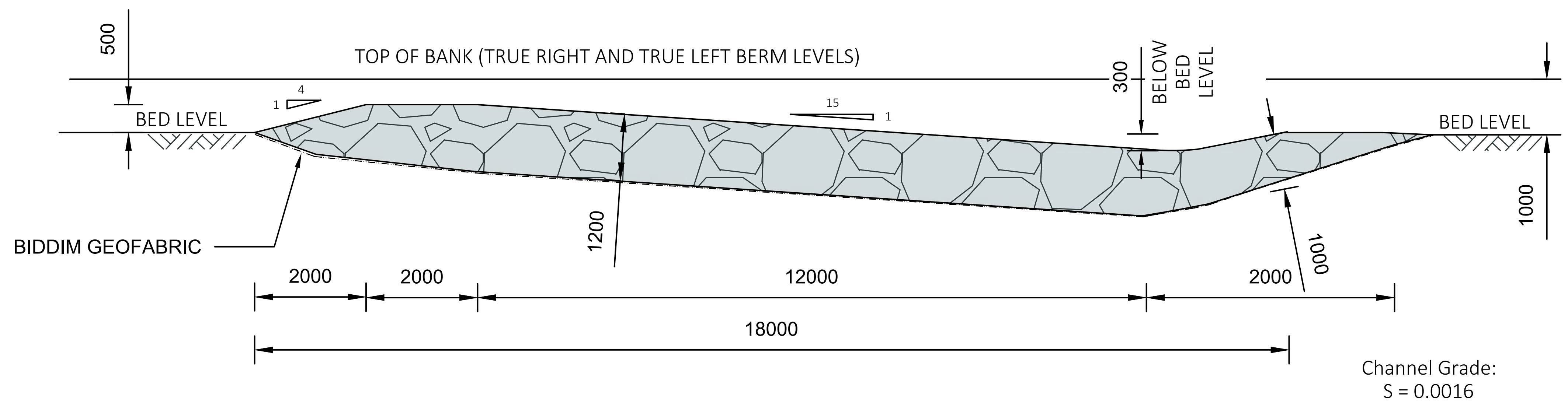
Typical Proposed Cross Section
(Scale 1:100)

NOTE:
The low flow channel is shown centered on the middle of the wider channel profile. The actual low flow channel will be constructed with a sinuosity of 1.5 and accordingly will deviate from this location across the floor of the of the flood channel. The low flow channels location will approach no closer than 1m from the base of the outer batter.



Detail 1 Pool / Riffle Invert Dimension
(Scale 1:100)

GRADING FOR RIFFLE / POOL LINING	
% Smaller	Diam (mm)
100	220
95	190
75	100
50	70
10	40



Section X - X' Pool / Riffle Invert Dimension
(Scale 1:100)

REV:	DESCRIPTION:	BY:	DATE:
C	Minor Updates	CH	13.04.22
B	Section Updates	CH	12.04.22
A	Initial Sections	CH	17.03.22

AMENDMENTS:

SITE: Waikaka Gold

TITLE: Proposed Channel Typcial Details (1 of 1)

DRAWING NO. D01		PROJECT NO. RIV-021-056	DATE. 13.04.22
SCALE AT A2. 1:100	DRAWN. CH	CHECKED. CH	REVISION. C

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Appendix B – Flood Model – Proposed Berm Long Sections

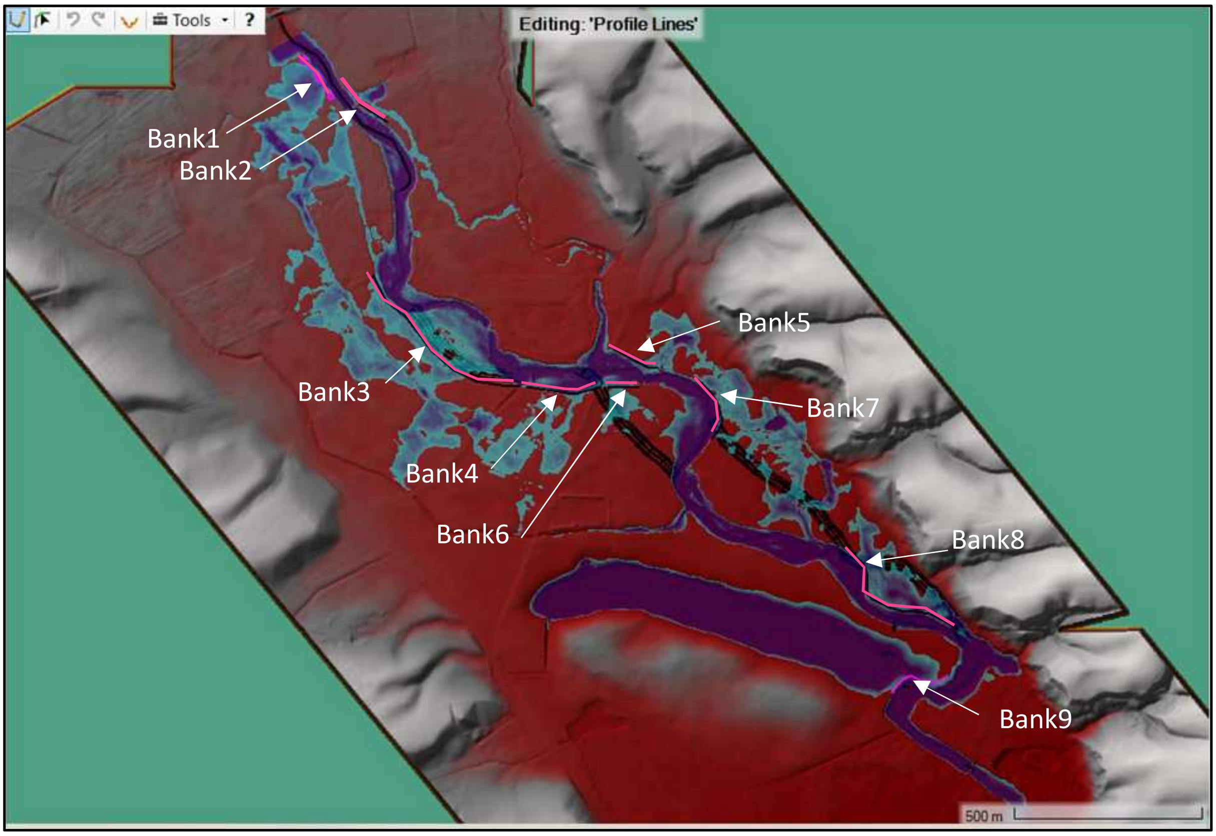

Figure 1: Flood Mitigation Embankment Layout

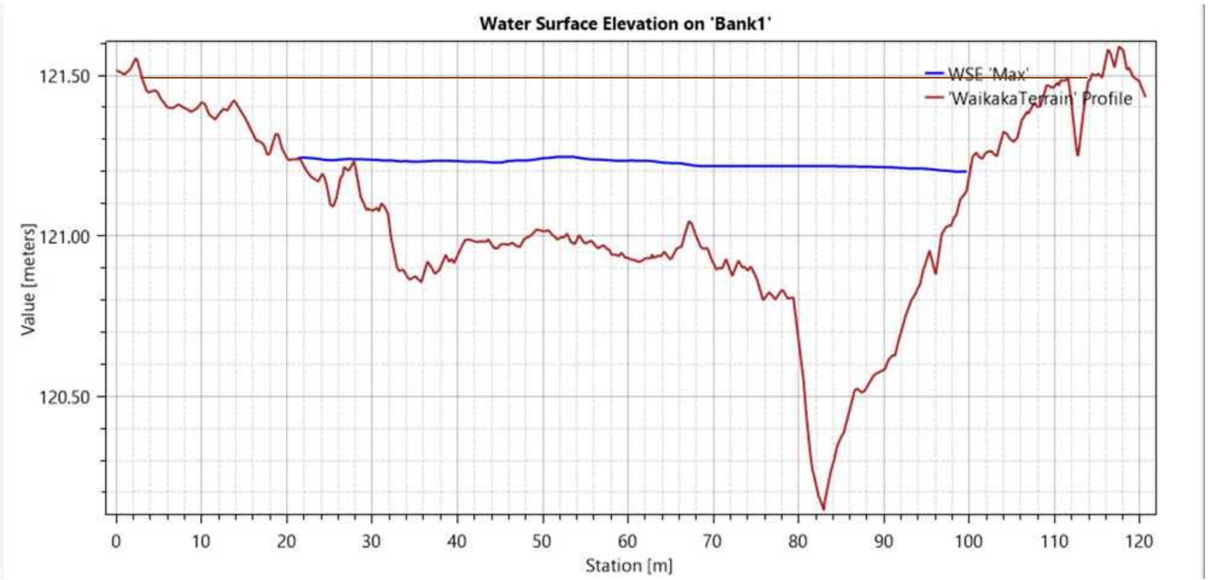

Figure 2: Bank 1 Long Section with estimated flood bank profile (brown line)

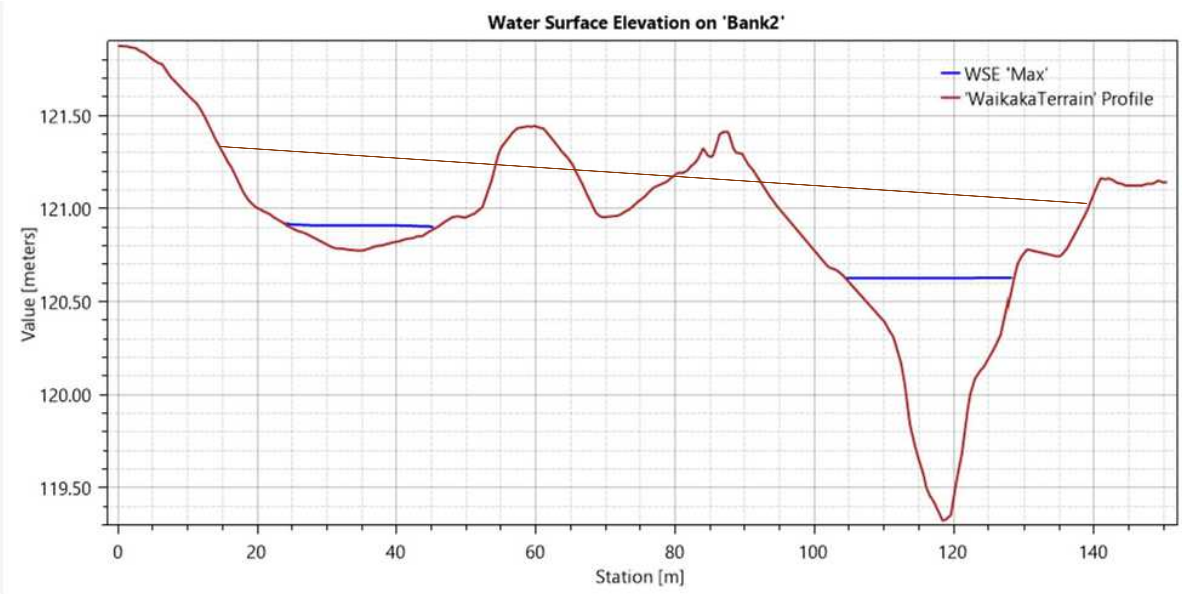

Figure 3: Bank 2 Long Section with estimated flood bank profile (brown line)

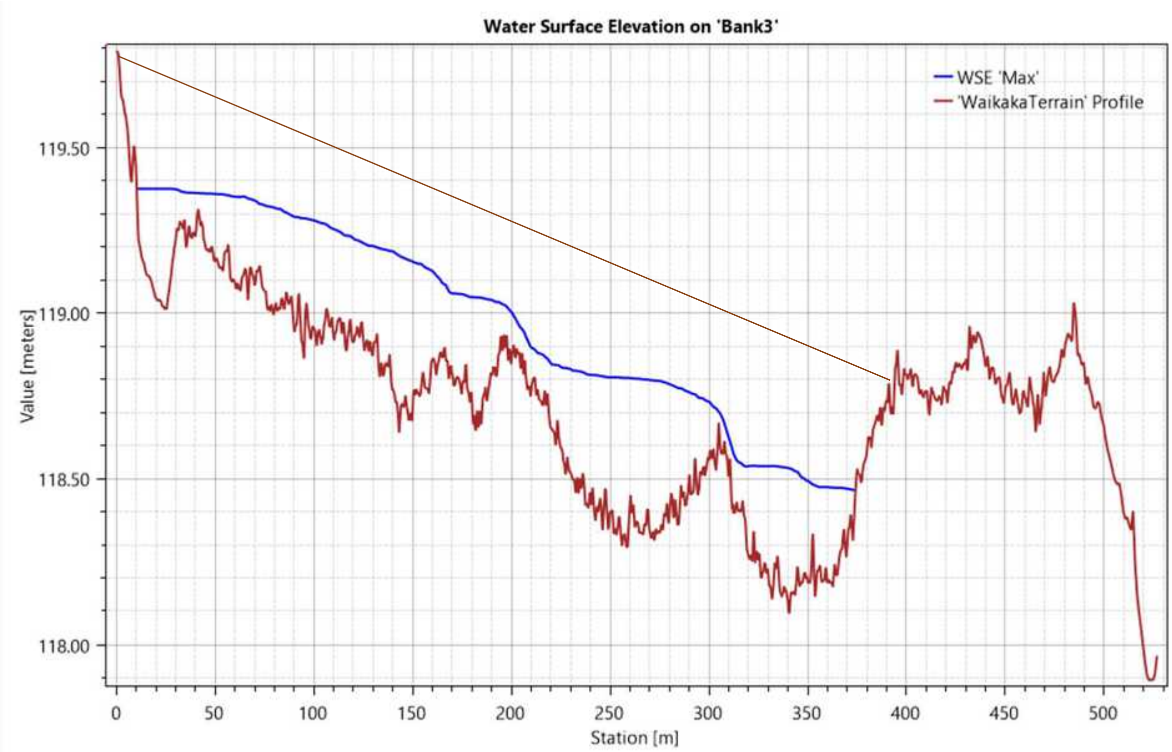

Figure 4: Bank 3 Long Section with estimated flood bank profile (brown line)

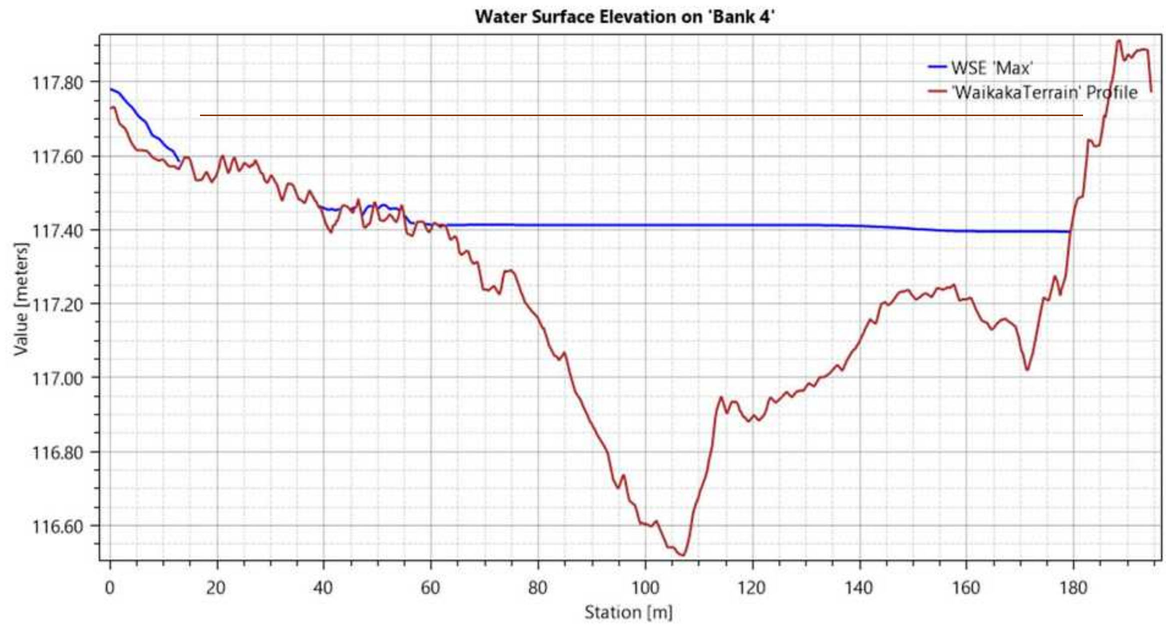

Figure 5: Bank 4 Long Section with estimated flood bank profile (brown line)

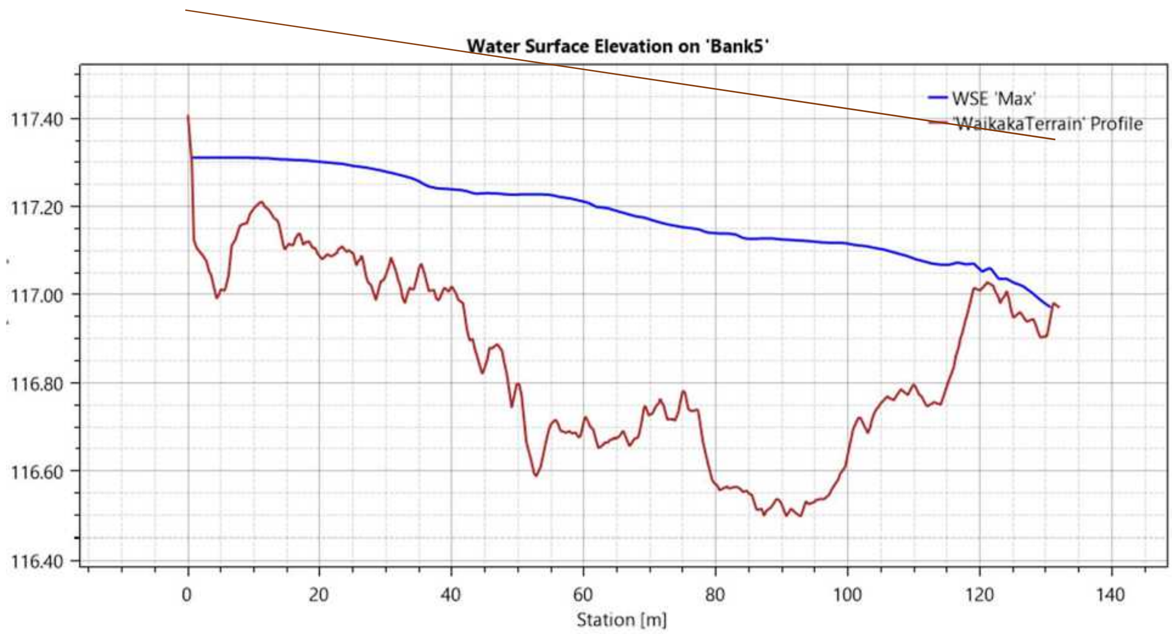

Figure 6: Bank 5 Long Section with estimated flood bank profile (brown line)

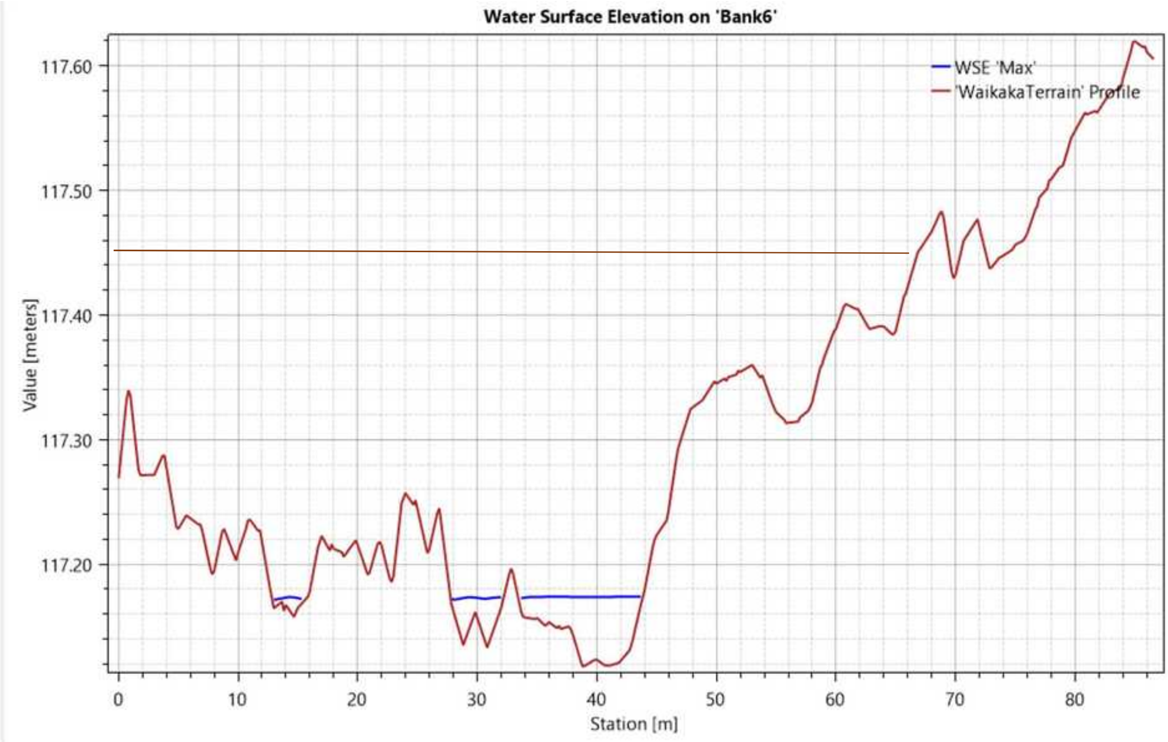

Figure 7: Bank 6 Long Section with estimated flood bank profile (brown line)

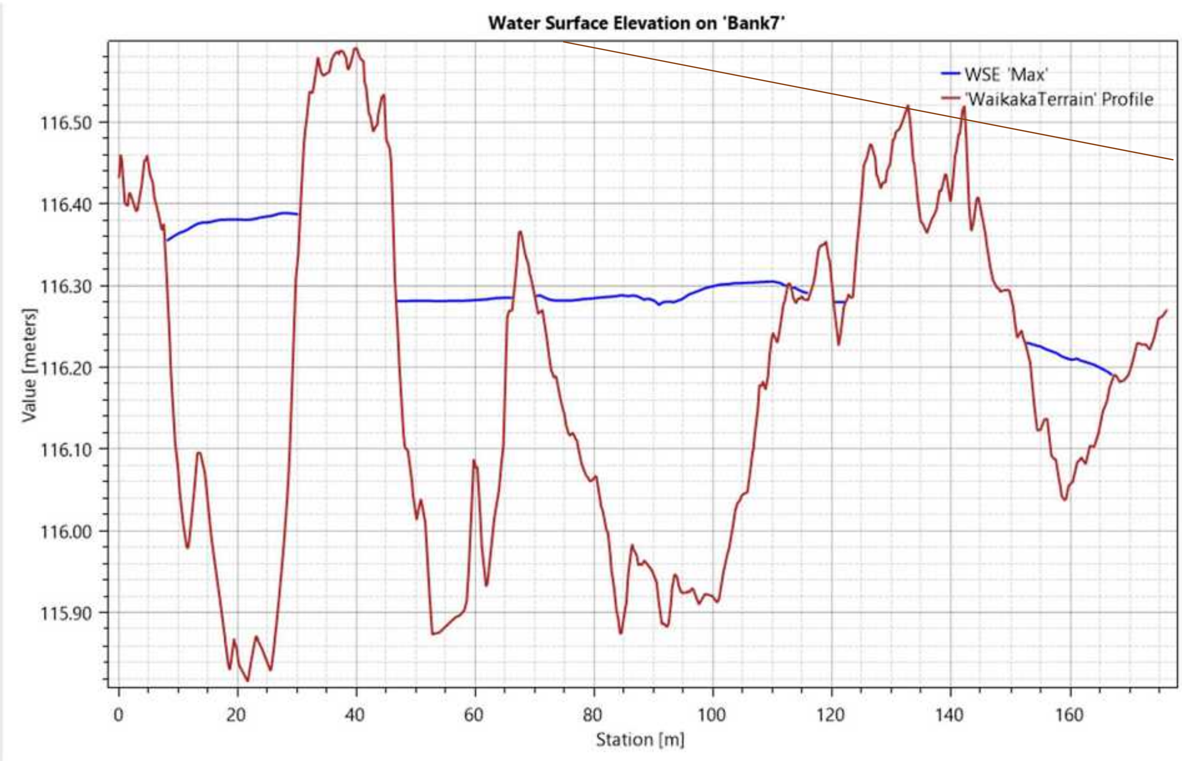

Figure 8: Bank 7 Long Section with estimated flood bank profile (brown line)

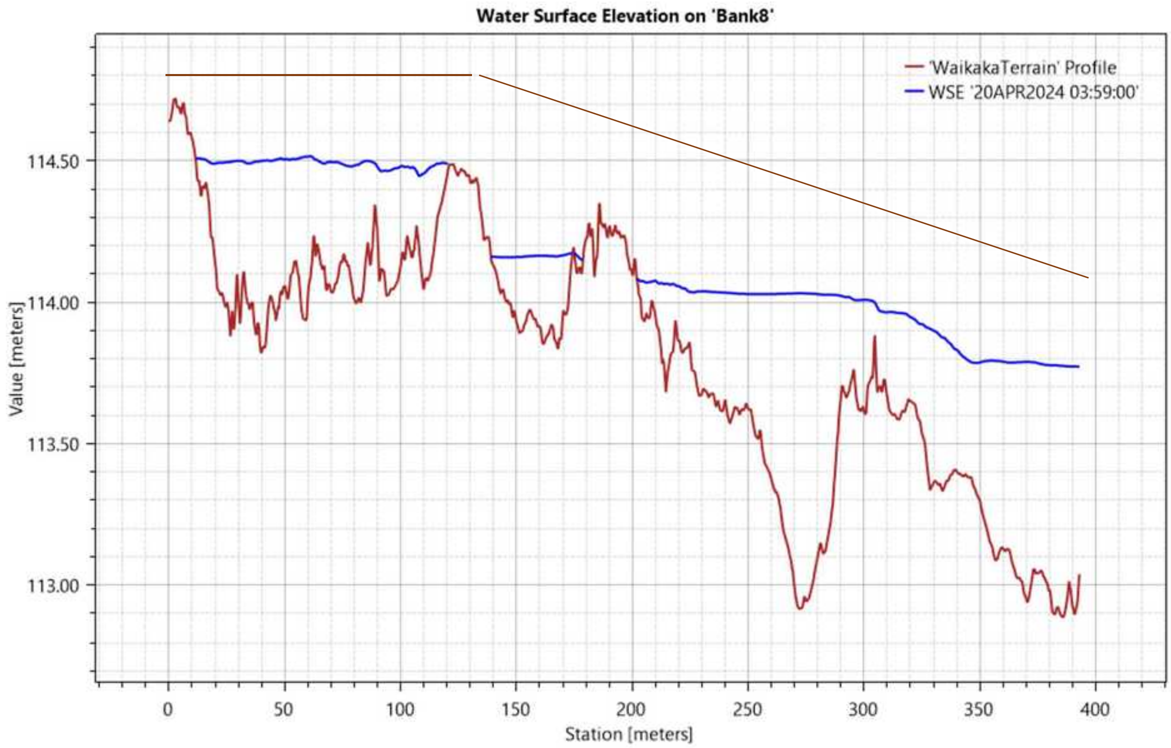

Figure 9: Bank 8 Long Section with estimated flood bank profile (brown line)

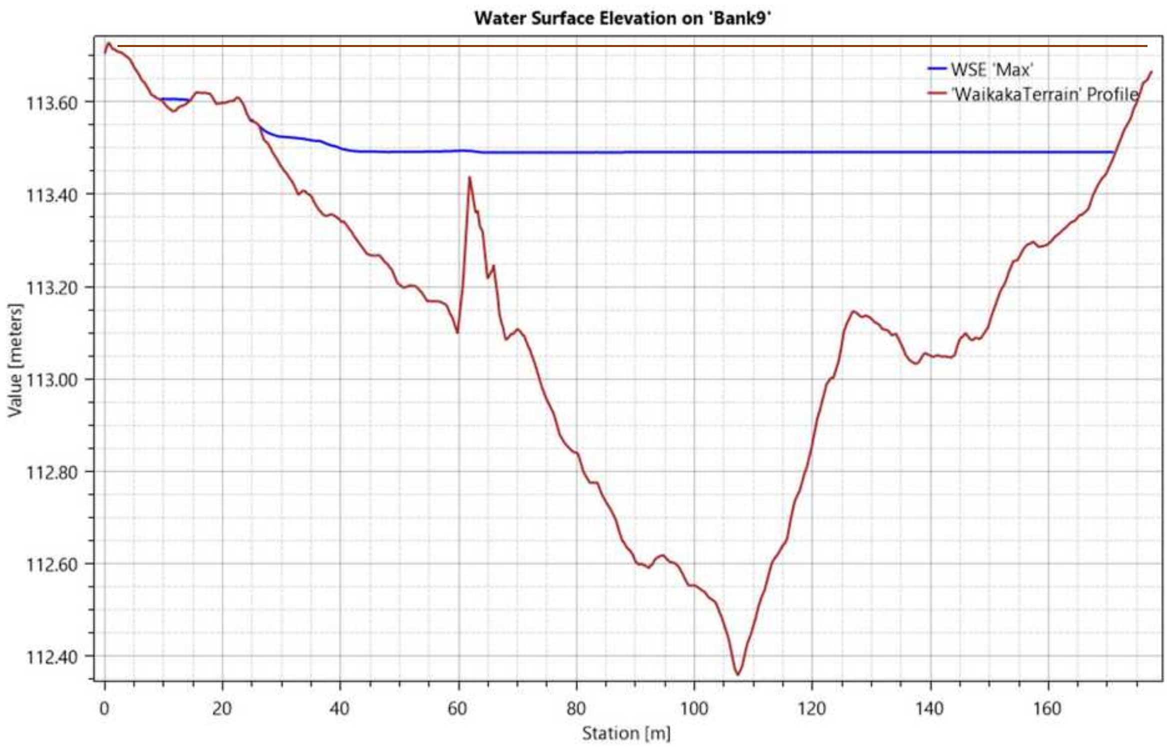

Figure 10: Bank 9 Long Section with estimated flood bank profile – settlement pond outlet (brown line)

Waikaka River Diversion

Dr. Henry R. Hudson

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L & M Mining Limited

Report 99-18
December 1999

Environmental Management Associates Ltd

Executive Summary

L&M Mining Ltd will apply to the Southland Regional Council for resource consent to divert the Waikaka River. It is proposed that a permanent river diversion will be constructed in two phases:

- In the initial stages of mining a ~1,000 m lower diversion channel will be constructed along the left (east) bank terrace edge; and
- After a few years of mining a ~1,400 m upper diversion channel will be constructed along left side of the valley.

A short temporary channel (~200 m) will link the lower diversion with the Waikaka River.

A self-sustaining, compound, or two-stage, channel design is proposed:

- A sinuous floodway channel to pass the design discharge ($\geq$ the 20 year return period flood); with
- An active low flow stream channel within this floodway.

Engineering objectives include:

- Containing the 20-year flood within the floodway;
- Allowing larger floods to spill over into the river valley;
- Controlling floodway channel stability (bank erosion, and long term aggradation or degradation); and
- Providing habitat diversity in the low flow channel and floodway.

Habitats accommodated in the design include:

1. A highly sinuous, pool-riffle, low flow channel, with minimum pool depths of 0.8 m, pool lengths of ~50 to ~90m, and diverse flow velocities;
2. An extensive wetland floodplain containing backwaters, ponds and marshes, that is frequently inundated;
3. Riparian margins along the floodway wetlands; and
4. Off-channel pond-wetlands providing deep-water habitats (drought refugees), islands, shallow wading shelves, and water purification.

The diversion channels will be constructed in virgin ground, or in the historic mine spoil.

The net effect of the proposal is to construct a high quality channel, exceeding the habitat values of the current channelized reach. Significant adverse effects will be avoided, mitigated or remedied.

Acknowledgements

Very useful discussions were held with John Gardyne and Ken Gardyne (landowners), David Manhire (L&M Mining), Kevin Marshall (Southland Regional Council), Ian McCahon (Montgomery Watson), Tony McDougall (L&M Mining), Ken Murray (Department of Conservation), Mark Pizey (L&M Mining), Maurice Rodway (Southland Fish and Game Council), Michael Skerrett (Te Ao Marama), Stuart Sutherland (Southland Fish and Game Council) and Deanne White (Department of Conservation). Their insights and discussion of issues and options were greatly appreciated. Ross Pannell of Southland Regional Council provided the flood frequency and flow duration analysis for the Waikaka River at Craigie Road. Ian McCahon (Montgomery Watson) drafted the prototype reach figures. In his review of the draft proposal, Maurice Rodway provided many useful observations and comments. Thanks.

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Introduction

Open cast mining of placer gold deposits in the Waikaka River valley is proposed. The mining area would extend over about a 2 km length of river valley upstream of river km 23.6. The valley is ~1 km wide in this reach. In order to access the gold bearing deposits, which are at a depth of 20 to 40 m, the Waikaka River must be diverted.

This report proposes a design for the river diversion based on experience, site inspection, and discussion with affected parties. The report outline follows the technical steps required for planning a diversion (page 26).

"Natural" Conditions

Historic Mining

The Waikaka is a meandering gravel bed river. The river and valley has been extensively modified. The proposed mining reach was mined about 60 to 100 years ago. The upper few meters of the valley alluvium was excavated and replaced as dredge spoil. The spoil material has alluvial gravels in a fine matrix (Figure 1, page 14). There are unmodified alluvial and colluvial remnants along the valley edge. The remnant deposits are composed of partially consolidated silts and clays (Figure 2).

Previous Diversion and Channelization

During the course of the historic mining the natural river was diverted and highly modified. More recently (the late 1960s and 1970s), the river in the proposed mining reach was straightened to alleviate flooding. Property boundary surveys (largely from the 1870s) indicate that the natural river channel had a sinuosity of ~1.48 over the proposed mining reach (Figure 3). Over the lower ~1 km a secondary channel, with a sinuosity of ~1.15, flowed along the left valley wall. Aerial photographs and topographic maps indicate that the present river channel sinuosity is ~1.25.

Valley and Channel Slope

River cross section surveys by L&M Mining shows that the present <u>river</u> has a gradient of 1:300 to 1:330 in the proposed mine reach.[1] The river gradient is steeper above the mine site and flattens further downstream (Figure 4).

Spot heights show that the <u>valley</u> slope varies over the proposed mining reach. The east side of the valley has a slope of 1:230, the west side 1:250, and the middle of the valley 1:290.[1] A detailed survey will refine these slope estimates.

[1] Ian McCahon, Montgomery Watson, pers. comm.

Bedrock exposures control the overall river channel gradient. Bedrock exposures do not occur in the proposed mine reach – the valley has alluvium to a depth of 20 to 40 m. Bedrock exposures occur 8 to 10 km downstream of the proposed mine reach and in the gorge about 4 km upstream.[2]

Disturbed Channel River Stability

Following channelization in the 1960s and 1970s the river was highly unstable. Extensive edge protection was undertaken. Although some larger rocks were used for bank protection, rock rubble blisters ("spurs" or "groynes"), with rocks up to 400 mm, have provided effective bank protection. Over the last several years, the river has achieved a reasonable degree of stability.[2]

Undisturbed River Channel Features

About 600 m upstream of the proposed mining area the flood control works stopped (at topographic map river km 27.25). The unchanneled reach of the river irregularly meanders upstream to the bedrock-controlled gorge reach (river km 31 to 35.3). Sinuosity varies along the reach up to the gorge. The tortuously meandering reach has a topographic map derived sinuosity of 1.4 and 1:10,000 aerial photograph derived sinuosity of 1.5.

Although the reach was not straightened, bank protection has been undertaken (largely willow fascines and stake plantings), which confined the river and reduced sinuosity. On the property boundary map (from the 1870s) the tortuous meander reach had a sinuosity of ~1.7 (Figure 3).

The unchanneled reach channel dimensions are highly variable. Limited observations suggest that bank heights are 1.5 to 2.5 m and are typically steep sided (1:1 to vertical, Figure 5). The deepest scour hole observed was ~1 m deep at low flow (Figure 6). The active channel width was approximately 5 to 6 m. The channel is typically bordered by a low-lying floodway about three times as wide as the active channel (Figure 7).

The unchanneled reach has a lower flow than the mine reach. Shepherd's Creek is a significant tributary (~15 km^2) that enters below the Waikaka bridge (Table 1).

Bed Material Characteristics

The river flows through dredge spoil in the proposed mining reach. Gravels and some boulders are contained in a matrix of clays and silts (Figure 8). Downstream sections of bed are erosion resistant clay.[3]

Riffles/rapids are composed of a few boulders, cobbles and gravel. The largest fluvially derived boulder (as opposed to displace riprap) had axial dimensions of 450 x 210 x 90 mm. Limited sampling shows that s

[2] Kevin Marshall, Southland Regional Council, pers. comm.
[3] Maurice Rodway, Southland Fish and Game Council, pers. comm.

surficial materials of the riffles/rapids are composed of cobbles and gravel (D_{95} 125 mm; D_{75} 70 mm; and D_{50} 45 mm) (Figure 9). Surface materials of active bar deposits in the undisturbed upper reach were relatively coarse: (D_{95} 60 to 115 mm; D_{75} 35 to 75 mm; and D_{50} 20 to 70 mm) (Figure 10). Observations suggest that the composition of the bed is reasonably consistent downstream through the proposed mine reach.

Underlying materials were considerably finer. Disturbance of the bed resulted in a sediment plume in the streamflow.

Bedload Transport

There are no measurements of bedload transport, but three lines of evidence suggest that bedload transport is small. Sections of bed are clay [3], replenishment of gravel extraction sites is relatively slow [2] and the old mine ponds in the lower mine reach have only partially infilled over the last 60 years.[1]

Streamflow

Southland Regional Council provided flow frequency estimates for the Waikaka River at Craigie Road (318 km^2). Montgomery Watson estimated streamflow for the mine site based on area (155 km^2) and rainfall weighting (Table 1):

Table 1. Flood frequency estimates for the Waikaka River (m^3/s).

Return Period (years)	Waikaka at Craigie Road	Upper Mine Reach	Shepherds Creek	Middle Mine Reach
MAF	115	55	10	65
5	170	80	15	95
10	225	105	20	125
20	280	135	25	160
50	370	175	35	210
100	440	210	40	250

Shepherds Creek is a significant tributary (~15 km^2) that enters the mining reach below Waikaka bridge. Shepherd's Creek normally peaks before the Waikaka River because of the shorter travel distance from the headwaters.[4]

Flow duration values for the mine site were prorated from the extended Craigie Road record provided by Southland Regional Council. The percentage of time streamflows are exceeded are summarized for the reach below Shepherds Creek in Table 2.

Presently Shepherds Creek flows into the Waikaka River near the mid point of the proposed mine site. The confluence may be relocated hence the engineering design is based on inclusion of runoff from Shepherds Creek.

[4] John Gardyne, pers. comm.

Table 2. Flow duration estimates for the Waikaka River below Shepherds Creek (mine reach) (m^3/s).

	0	1	2	3	4	5	6	7	8	9
0	175.0	16.5	10.6	8.26	6.86	5.86	5.18	4.67	4.26	3.91
10	3.63	3.39	3.18	3.00	2.84	2.69	2.57	2.46	2.36	2.27
20	2.19	2.11	2.04	1.97	1.91	1.85	1.80	1.74	1.69	1.64
30	1.60	1.56	1.52	1.48	1.45	1.41	1.37	1.34	1.31	1.28
40	1.25	1.22	1.20	1.17	1.14	1.11	1.09	1.06	1.04	1.02
50	1.00	0.98	0.96	0.93	0.91	0.89	0.87	0.85	0.83	0.82
60	0.80	0.79	0.77	0.76	0.74	0.72	0.71	0.69	0.68	0.66
70	0.64	0.63	0.61	0.59	0.57	0.56	0.54	0.53	0.51	0.50
80	0.48	0.47	0.45	0.44	0.42	0.41	0.39	0.37	0.36	0.34
90	0.33	0.31	0.29	0.28	0.26	0.24	0.23	0.21	0.19	0.17

Diversion Plans

Temporary or Permanent Diversion

The design requirements for a temporary channel are similar to a permanent channel with respect to channel dimensions, and bed and bank stability requirements. For example, erosion producing a sustained sediment plume would be unacceptable.

The preferred approach is to move the channel once. Advantages include:

- Less disruption to flora and fauna; and
- Lower cost to construct one channel rather than a temporary channel then a permanent diversion channel.

As discussed below, approximately 2,600 m of diversion is proposed, of which 2,400 m will be permanent. A ~200 m temporary channel is required to link the Waikaka River to the lower diversion. This temporary channel is in the proposed mine path, hence will be removed. The upper diversion will join the lower diversion near the terrace edge (about 1,000 m up the lower diversion) (Figure 11).

Timing and Location of Diversions

The following development scenario is proposed, with the approximate position of the diversions indicated in Figure 11. (The exact channel position relative to the terrace edge will be determined when the detailed topographic mapping is completed):

⇒ Commence operations on the western side of the valley at the lower end of the reach;

⇒ Construct a ~1,000 m lower permanent diversion channel along the eastern side of the valley along the terrace edge;

⇒ Construct a temporary channel, about 200 m long, from the lower diversion to the Waikaka River;

⇒ Establish vegetation in the lower permanent diversion channel (refer to the rehabilitation plan);

⇒ Complete diversion of the Waikaka River into the new channels;

⇒ Mine up one side of the valley to the end point of the mine area;

⇒ Construct a ~1,400 m upper permanent diversion channel along the eastern side of the valley;

⇒ Establish vegetation in the upper diversion channel;

⇒ Complete diversion of the Waikaka River, Shepherds Creeks and other ephemeral streams/drains into the upper channel;

⇒ Mine the remainder of the valley (which includes the 200 m temporary channel);

⇒ Progressively rehabilitate the river valley to pasture; and

⇒ Monitor and maintain the diversion as required.

Phased Construction

Discussions suggest it would be acceptable to affected parties (landowners, iwi, Fish and Game Council and Department of Conservation) to phase construction. The lower diversion channel is required in the initial phase of mining (Figure 11). The upper diversion channel would be constructed later in the project.

A 200 m temporary link from the Waikaka River to the permanent lower diversion is required. The temporary channel is in the proposed mined path, so will be excavated and rehabilitated to pasture.

A phased approach has several advantages:

- Lower initial cost;
- Vegetation can become established prior to significant streamflow;
- Performance of the lower diversion design can be evaluated over a period of years before the upper diversion is completed; and
- Any required remedial work on the lower diversion can be undertaken while equipment and materials are on site.

Channel Configuration

A compound, or two-stage, channel design is proposed to accommodate the engineering and environmental requirements:

1. A sinuous floodway channel to pass the design discharge ($\geq$ the 20 year return period flood); and
2. An active low flow stream channel within this floodway.

Features of the proposed diversion are illustrated in the following figures: Figure 7 illustrates an example of channel cross sectional form from the natural two-stage reach upstream; Figure 12 illustrates the two-stage floodway concept; Figure 11 shows the channel alignment and planform; Figure 13 illustrates details of the proposed planform; and Figure 14 illustrates the vegetation rehabilitation. (See the accompanying rehabilitation plan for details of the latter – Petrie 1999).

Floodway Channel

Design Discharge

Southland Regional Council require that the diversion channel provide at least an equal level of flood protection as the existing channel. The existing channel has an estimated 20-year return-period design capacity, but in reality has reaches that flood during lesser events. The proposed floodway will convey at least a 1-in-20-year flood.

Flood Risk

A 1-in-20-year flood is a flood that is expected to occur, on average, once in every 20 years. The average length of time between two such floods is called the return period. The 1-in-20 year flood has a probability of 0.05 or 5% of being equalled or exceeded in any one year. The probability only indicates how likely a flood is – but not when the flood will occur. Thus, a 20-year event may occur this year, next year, perhaps several times or not at all, over the next few decades.

For the recommended design dimensions the initial floodway capacity will be in excess of a 100-year flood. As the vegetation grows over several years, the floodway capacity will reduce to the design flood (i.e. the 1-in-20-year flood of 160 m^3/s).

Valley and Channel Slopes

As discussed earlier, the east side of the valley has an average overall slope of 1:230. With a sinuous floodway pattern (Figure 11; Figure 15), (average sinuosity of 1.12) the probable floodway channel slope will be around 1:260. The low flow channel will have an irregular meander pattern with an average sinuosity of ~1.5, hence a probable average low flow channel slope of 1:350.

Bed and Bank Cover

Channel dimensions are largely determined by the resistance to flow caused by the roughness of the channel and vegetation. There will be no instream plantings, but the low flow channel banks will be planted.

As discussed in the accompanying rehabilitation plan, three areas of planting are proposed (Petrie 1999; Figure 14). The "wet" zone around the low flow channel, ponds and backwaters, will be planted in a native grasses and multi-stemmed shrubs. Selected species include narrow leafed toetoe, red tussock, Carex spp, and mountain flax, koromiko and mingimingi.

The remainder of the floodway channel and the floodway berms will be planted in a mixture of native shrubs and small trees with an inter-planting of shrub willow to provide scour protection. Groupings will include a mixture of lowland ribbonwoods, narrow leafed Oleraia, manuka, koromiko, cabbage tree, southern kowhai and "scrubby" Coprosma. The floodplain meander bends will be planted in short rotational and long-term tree species. Selected species include Tasman poplar, black and gray alders, Douglar fir and Holm oaks.

The floodway will be fenced. The plants will be locally sourced.

The floodway side slopes will provide limited flow conveyance capacity. High flow resistance is anticipated from the proposed vegetation.

Moderate to high roughness values (Manning's "n") are used in the hydraulic calculations: 0.038 for the floodway bottom and 0.075 for the floodway side slopes. These are conservative values that account for substrate, channel sinuosity, bed configuration, obstructions and vegetation effects (Cowan 1956 and Jarrett 1985 in Gordon and others 1992). The roughness values are consistent with observed roughness in New Zealand rivers (Hicks and Mason 1991).

The low flow channel has a limited conveyance capacity (2 to 3 m^3/s, depending on roughness), but this can be retrospectively adjusted to increase or decrease the frequency and duration of floodway inundation. At 2 m^3/s capacity the low flow channel is overtopped 23% of the time and the 3m^3/s capacity is exceeded 13% of the time (Table 2). (The bed of the floodway would be inundated ~50 to 80 days per year on average; and depressions in the floodway would have permanent water).

Floodway Channel Dimensions

Various combinations of channel widths and depths can accommodate the design flood, but the intention is to construct a self-sustaining "natural" channel with a sufficiently wide zone for the low flow channel to freely migrate.

Steep sided banks, as observed upstream (Figure 5), are unsuitable for establishment of a stable riparian margin. Slopes of 1:3 are in the middle of the optimal range for soil bioengineering (Figure 16). Batter slopes will vary from 1:3 to 1:5 (Figure 13).

In summary, the following dimensions are proposed:

- ⇒ Hydraulic radius (~depth): 2.25 m (subject to detailed survey)
- ⇒ Side slopes: 1:3 to 1:5
- ⇒ Floodway bottom width: 22 m (with 1:5 side slopes) to 25 m (1:3 side slopes)
- ⇒ Floodway top width: 38m (with 1:3 side slopes) to 45 m (with 1:5 side slopes)

The corridor bounding the active channel may be set aside as marginal strip, an esplanade reserve, or land with some other designation.

Channel Stability

The objective is to achieve a non-structural, self-sustaining, channel. This can only be achieved if the river is dynamically stable (i.e. the river is not generally degrading or aggrading, both of which can cause significant lateral erosion, but cut and fill occurs from flood to flood). The proposed diversion is entirely within virgin ground or old mine spoil. Grade control will be achieved with the riffles and grade control structures.

Grade Control

Grade control structures, composed of quarry rock rubble, will be placed at the upper and lower end of the diversion and in the mid point of the diversion. These grade control structures will extend across the floodway and will be tied-in to riprap along the banks (Figure 11).

At design bankfull discharge (Q_{20}), with a sinuosity of 1.12 and an assumed slope of 1:260, the shear stress exerted on the bed will be ~86 N/m^2. In terms of stable bed material size, particle packing is critical. The stable size ranges from a D_{50} of 53 mm (closely packed bed) to 235 mm (average "loose" bed). Oversized boulders (450 mm) will be placed on the bed to ensure stability and provide opportunities for fish passage.

Secondary grade control will be achieved at riffles throughout the system. Gravels, cobbles and boulders exposed in the mining operation will be screened and placed in the bed across the floodway to form the riffles. Details are provided in the following section.

Low rates of bedload transport will limit the natural development of a streambed armour layer. Therefore, the bed of the floodway will be lined with a 0.5 m layer of screened fine material, gravel, cobbles and boulders. This layer will be compacted to emulate a naturally embedded (closely packed) condition. The mine spoil will be screened to remove excessive fines (i.e. the equivalent to natural winnowing of the interstitial fine materials).

The low flow channel will flow over the compacted gravel-cobble-boulder bed. The margins of the low flow channel (the floodway bed) will be formed by a one meter layer of compacted "stoney soil" spoil that will be planted with native wetland grasses (e.g. Figure 1, Figure 8; and Figure 17).

Bank Protection

Rock protection requirements of the floodway are minimised by maintaining low batter slope (<1:3) rather than steep streambanks (Figure 16). Batters will be planted immediately following construction. Extensive rock protection should <u>not</u> be required if the riparian vegetation cover is established prior to major flooding.

The following is proposed:

1. Floodways batters will be constructed at a low angle (1:5 to 1:3 slopes) using compacted mine spoil;

2. Floodway batters will be planted immediately with mixed vegetation for bank protection and environmental benefit;
3. Rip rap will be placed on the batters at the primary grade controls, and plantings will be incorporated;
4. Rock blisters (spurs or groynes) will be are placed in major bends and plantings will be incorporated; and
5. Further rock blisters and vegetation will be placed in response to channel evolution. (This is the current approach to river control in the Waikaka).

Low Flow Channel

In a compound or two-stage floodway design, the active channel occupies a portion of the floodway. There are several objectives to the design including:

1. Provision of a dynamically stable low flow channel;
2. Provision of space for the low flow channel to migrate;
3. Provision of instream habitat; and
4. Provision of floodplain wetland (frequently inundated) habitat.

There are several approaches to the design of a low flow channel in a floodway (Table 3). A carbon copy - reference reach hybrid approach is taken here. The objectives are:

- To copy the tortuous meandering pattern of the pre-mining channel evident in the 1870 property boundaries; and
- To emulate the cross sectional and longitudinal form of the unchanneled reach upstream.

The overall objective is to construct a dynamically stable river channel. A relatively narrow, highly sinuous, low flow channel will be allowed to meander within a relatively broad floodway without adversely affecting floodway bank stability.

Low Flow Channel

To emulate the cross section of the low flow unchannelized reach upstream, a channel width of 6 m is proposed. The unchannelized reach upstream has scour pockets up to 1 m deep on the outside of bends where bank erosion is constrained. Much of the channel has a relatively uniform bed with maximum depths of ~50 cm during low flows. These "runs" extend over several or more channel widths. As discussed previously, this reach has a gravel-cobble bed with clay exposures.

Downstream the channelized reach has pools up to 1.5 m deep at low flows. These deep pools occur in tight bends with resistant banks [3]. This reach has sections of clay bed with a silt overlay.

Meander Geometry

For a design channel width of 6 m, a stable meander length is 67 m ±20 m and stable radius of curvature is 15.5 m ±4.5 m (Leopold 1994). The radius of curvature, meander length and amplitude of the meanders are varied within the stable range to achieve the desired sinuosity of 1.48 and natural irregularity of channel pattern (Figure 11).

Natural channels have variable widths. Typically, pool reaches are up to 25% narrower than riffle sections. Point bars will be constructed into the channel as discussed below.

Pools and Riffles

In natural rivers riffles occur at a spacing of three to ten channel widths depending on channel slope. At higher slopes, there is a shorter spacing between riffles (NRA 1994 in Brookes and Sear 1996). The Waikaka has a very low slope for a gravel pool-riffle river, hence riffles will be place on average approximately ten channel widths apart at the cross-over between successive pools. The spacing will vary with the meander length.

Two types of riffles will be constructed: water level control riffles, alternating with cross-overs. The proposed sequence of features is:

> *LB Pool ⇒ Riffle⇒ RB Pool ⇒ Cross-over ⇒ LB Pool ⇒ Riffle⇒ RB Pool ⇒ Cross-over ⇒ LB Pool ...*

Pools will be constructed downstream of the riffles (Haltiner and others (1996). The bed will undulate from riffles (0.5 m above the general bed invert) to pools (0.3 m below the general bed invert). At zero flow over the riffle, the water depth in the pools will be 0.8 m. For the conditions illustrated in Figure 9, the pool depth would be ~1.2 m, which provides ideal adult trout depths and velocities (citations in Hudson 1999). Bankfull pool depth of the low flow channel is 1.3 m.

Cross-overs occur as the thalweg (deepest part of the channel) alternatives from the left bank to the right bank. Cross-overs have a relatively uniform depth and are often described as "runs" or "glides". The "runs" will be a similar depth to the pools, but their cross section will be symmetrical.

Pools will generally range from ~50 to ~90 m in length (the stable meander wavelength).

Riffles will extend in an arc across the floodway. The objective is to push the flow toward a mid channel course. As such the riffles will have the appearance of a diagonal bar (e.g. Figure 9).

The crest of the riffle will be ~0.5 m above the general bed invert (Haltiner and others 1996). The crest of the riffle will be notched to provide fish passage at extreme low flow. The riffles will incorporate oversized boulders to provide additional roughness, stream aeration and fish passage opportunities.

Following Newbury and Gaboury (1993), the riffles will have an upstream slope of 1:4 and a downstream slope of 1:15. This approximates the dimensions of the natural channel riffles in the unchanneled reach upstream (Figure 9).

As discussed in the section on stability, secondary grade control will be achieved at riffles throughout the system. The riffles will be constructed from compacted gravel, cobbles and boulders exposed in the mining operation. (Some rock rubble may also be added if required). The material will be screened, but will not be entirely free of silt and clay. A matrix of fine material is required in order to provide suitable spawning habitat. Embededness of up to 25% is required to provide stability and excellent habitat quality (McCabe and Sandretto 1985 in Hudson 1999). Point bars will be constructed with similar material (Figure 17).

Wetland Inundation

Channel and bank edge roughness is expected to be in the range of 0.03 (clean, sinuous channel) to 0.05 (clean streambed and brushy vegetated banks). Overtopping of the low flow channel will occur at a flow of ~2 to 3 m^3/s, respectively. Referring to Table 2, page 3, the median flow (1.0 m^3/s, which is exceeded half the time) is contained within the low flow channel. Overtopping of the low flow channel is expected to occur on average 47 to 84 times per year.

Off-Channel Habitats

Dredge ponds will be removed in the mining. These will be replaced with at least an equal area of more diverse pond-wetland habitats adjacent to the floodway. The objective is to emulate oxbow ponds. These ponds will serve several purposes:

- Provide deep water habitats (more than 2 m depth at low flow);
- Provide shallow mud wading shelves for waterfowl;
- Provide island habitats for resting and roosting; and
- Act as a filter purifying farm and drain runoff.

Deep ponds are expected to have a relatively long life, as has been the case for the dredge ponds. The locations of these ponds will be negotiated with affected parties as the land rehabilitation is planned. Some of these ponds will not be connected to the Waikaka River via a low flow channel. The objective is to replace existing isolated ponds that contain galaxiides. Ponds will be stocked with fish recovered from the existing dredge ponds.

Wetlands will be constructed at the mouths of the major drains. These wetlands will have deep water (~2m depth) and shallow areas. The locations of these ponds will be negotiated with affected parties as the land rehabilitation is planned. The drainage naturalisation principles described in the development of the Southland Sustainable Drainage Management Strategy will be applied to the land drainage system (Hudson 1998).

Monitoring and Assessment

Monitoring and assessment requirements will be specified in the resource consents. Ongoing evaluation of the hydraulic, morphologic and biological performance of the diversion should be undertaken to:

- Identify and fix problems as they occur;
- Document the hydraulic and morphological performance of the diversion and effects on the adjacent channel;
- Document the biological performance of the diversion; and
- Report the lessons learned from the first diversion so the experience can be applied to subsequent diversions.

Conclusions

A compound, or two-stage, channel design is proposed for the diversion of the Waikaka River. The design can accommodate a 20-year flood before flow across the valley floor occurs.

The current river channel provides variable quality aquatic and riparian habitats. Habitats will be improved with the diversion. Specifically, the following will be constructed:

1. A highly sinuous, pool-riffle, low flow channel, with minimum pool depths of 0.8 m, pool lengths of ~50 to ~90m, and diverse flow velocities;
2. An extensive wetland floodplain containing backwaters, ponds and marshes, that is frequently inundated;
3. Riparian margins along the floodway wetlands; and
4. Off-channel pond-wetlands providing deep-water habitats (drought refugees), islands, shallow wading shelves, and water purification.

A riparian and wetland rehabilitation plan accompanies this proposal (Petrie 1999).

Channel stability will be achieved with rock rubble grade control structures that extend across the floodway, and gravel/boulder riffles that extend across the floodway.

The low flow channel will migrate across the floodway, but will be constrained by vegetated batters and rock where required. The floodway channel will be underlain with compacted, screened, gravel and boulders. The low flow channel will have a pool-riffle-run gravel-boulder bed and point bars emulating natural channels.

The diversion will be undertaken in two stages. The lower ~1,000 m will be constructed in the initial stages of the project. The upper diversion (~1,400 m) will be undertaken later. A short (< 200 m) temporary channel will link the lower diversion to the Waikaka River.

The diversion along the eastern terrace will be constructed in virgin ground or on old mine spoil.

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Figures

Figure 1. Waikaka Valley dredge spoil material from the test pit (the notebook is 185 by 115 mm).

Figure 2. Waikaka valley undisturbed alluvial and colluvial deposits, west bank, upper mine site.

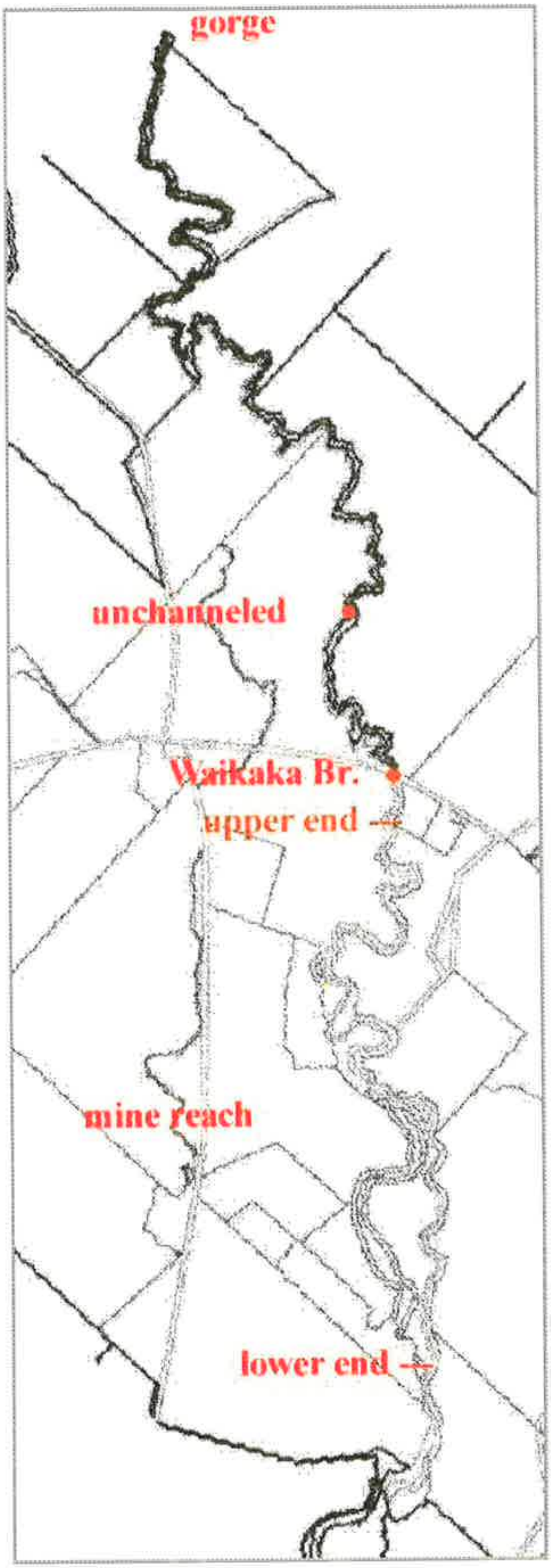


Figure 3. Property boundary map (~1870, with some more recent adjustments).

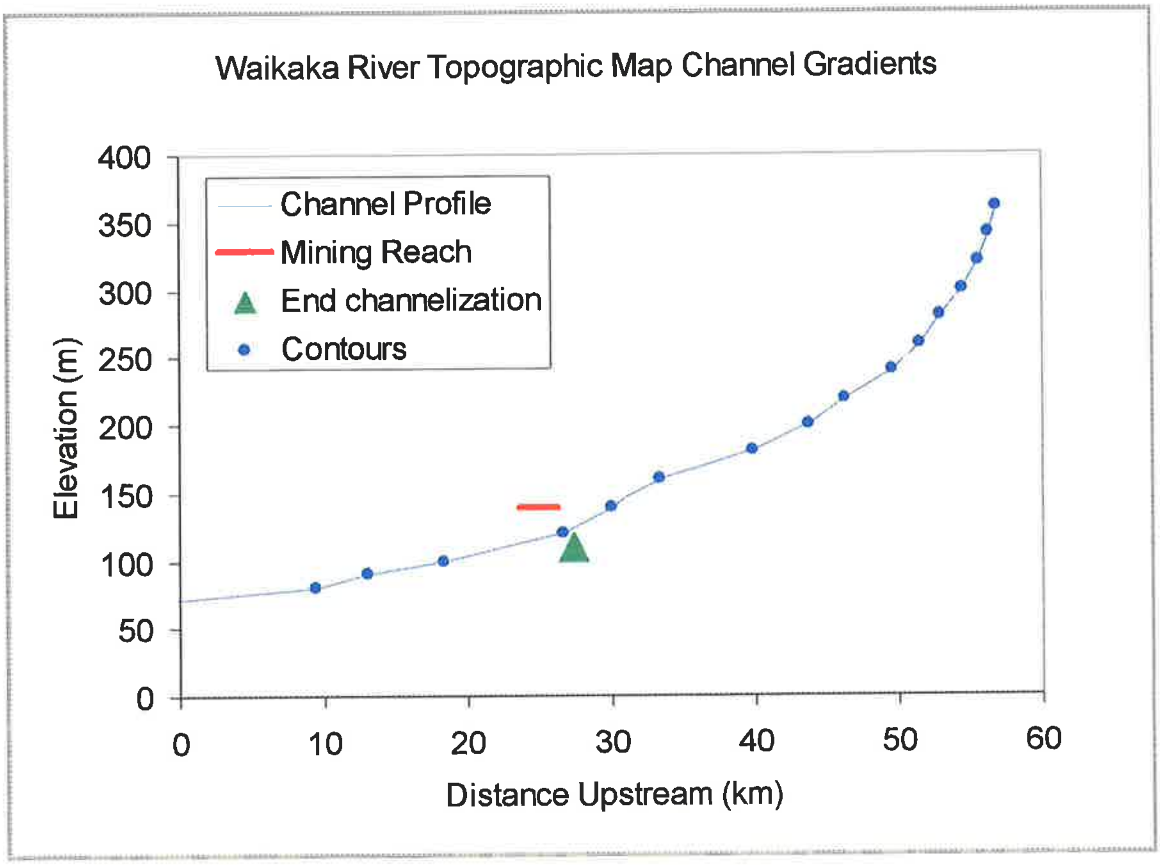


Figure 4. Waikaka River long profile from 1:50,000 topographical maps.

Figure 5. Unchannelized reach above the proposed mine site. View upstream showing typical bank heights of ~2.5 m.

Figure 6. Unchannelized reach upstream. The deepest observed scour hole was ~1 m at low flow.

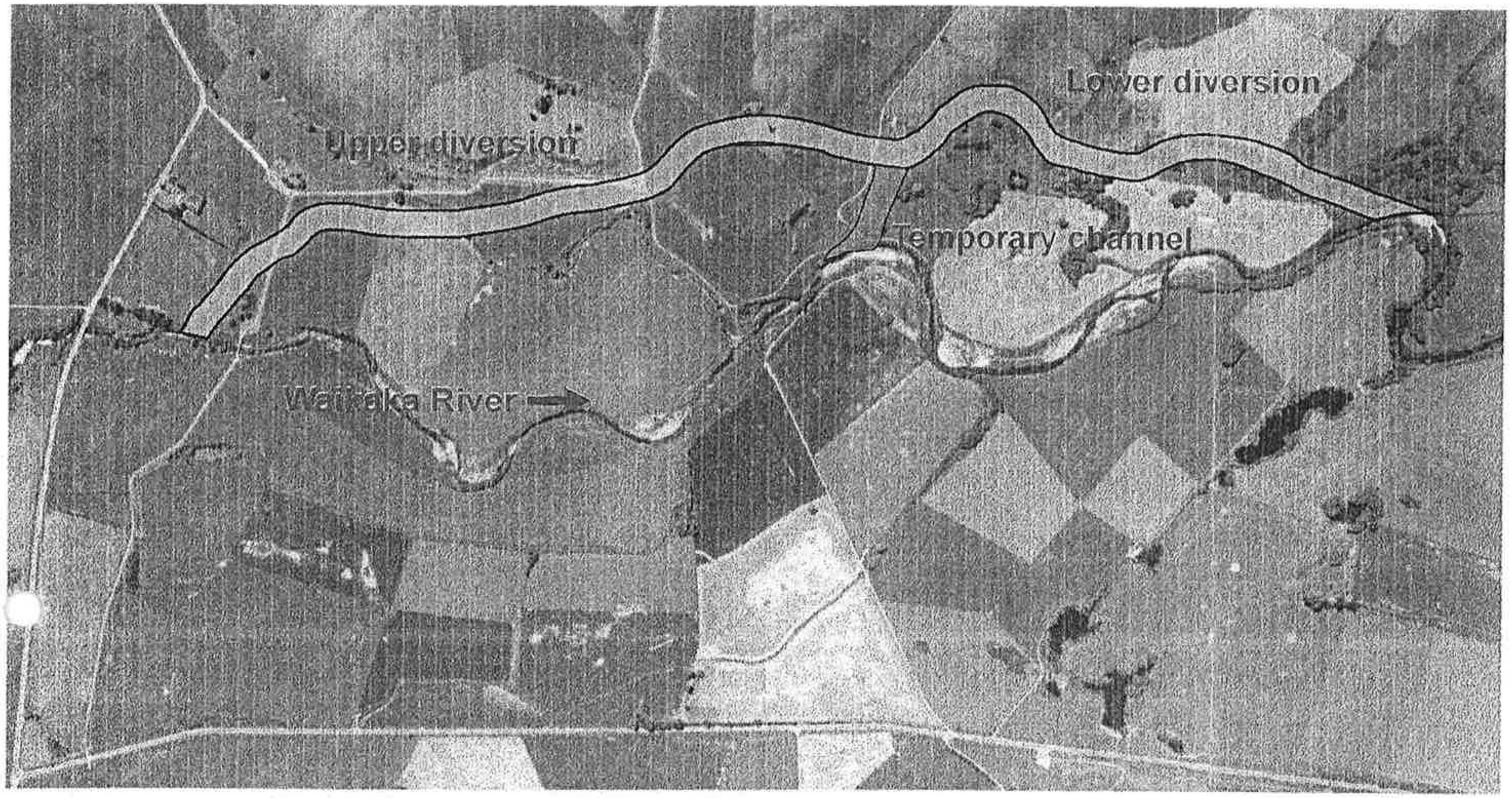
Figure 7. Unchannelized reach upstream. The low flow channel flows within a broader floodway.

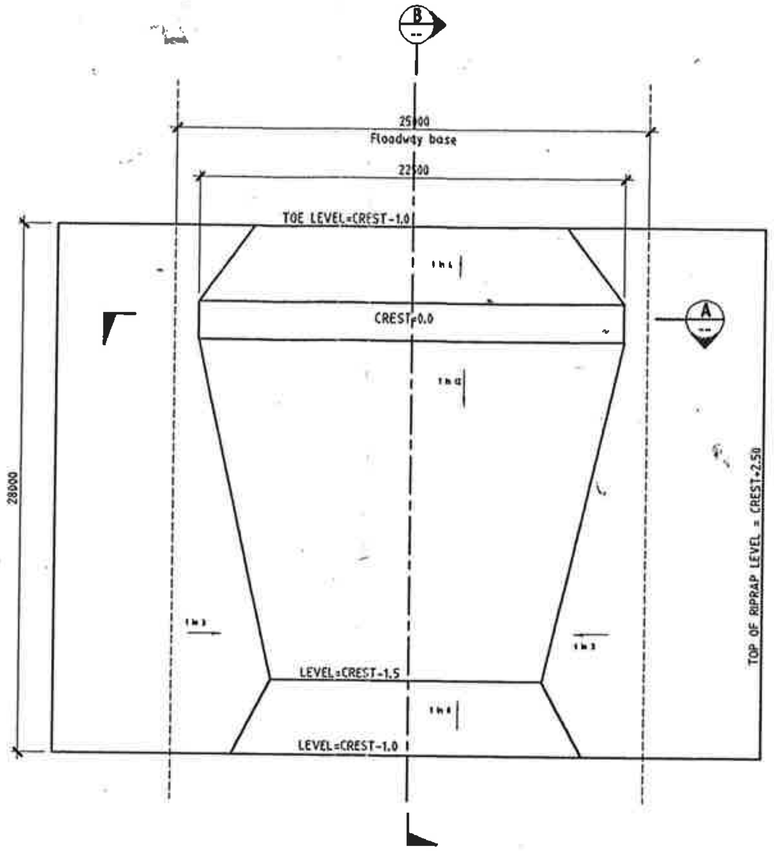
Figure 8. The river flows through old dredge spoil which is composed of gravels and some boulders contained in a silt/clay matrix. (The notebook is 185 by 115 mm).

Figure 9. Riffles are composed of gravels and boulders (D_{50} ~45 mm).

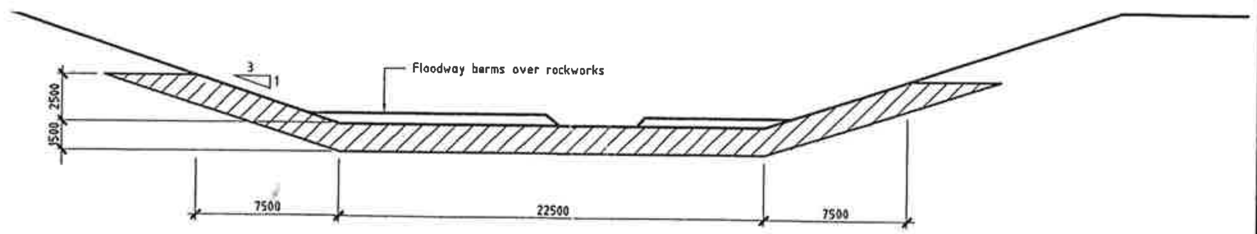
Figure 10. Bar surface materials in the undisturbed reach are relatively coarse (D_{50} ~ 20 mm). This armour layer overlays much finer material. (The grid lines on board are 50 mm).

Figure 11. Proposed alignment and grade control structure design of the Waikaka River diversion.

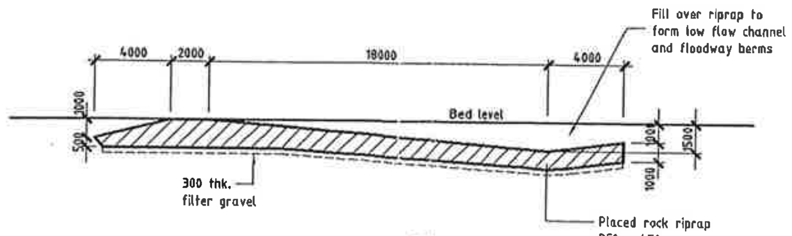




GRADE CONTROL STRUCTURE
1:200 (3 No. ON DIVERSION)



SECTION A
1 : 200



SECTION B
1 : 200

IMPORTANT NOTE:

Final location and alignment of diversion is subject to finalisation of mine pit design and scheduling, and to detail design with topographic data.
Location shown is illustrative only to show relative positions of grade control structures.

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1

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MONTGOMERY WATSON

L & M MINING LTD
WAIKAKA PROJECT

WAIKAKA STREAM DIVERSION
CONCEPTUAL PLAN & GRADE CONTROL STRUCTURE

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SCALES : AS SHOWN
Job No. 47422.01 | Sheet No. P1 | Rev.

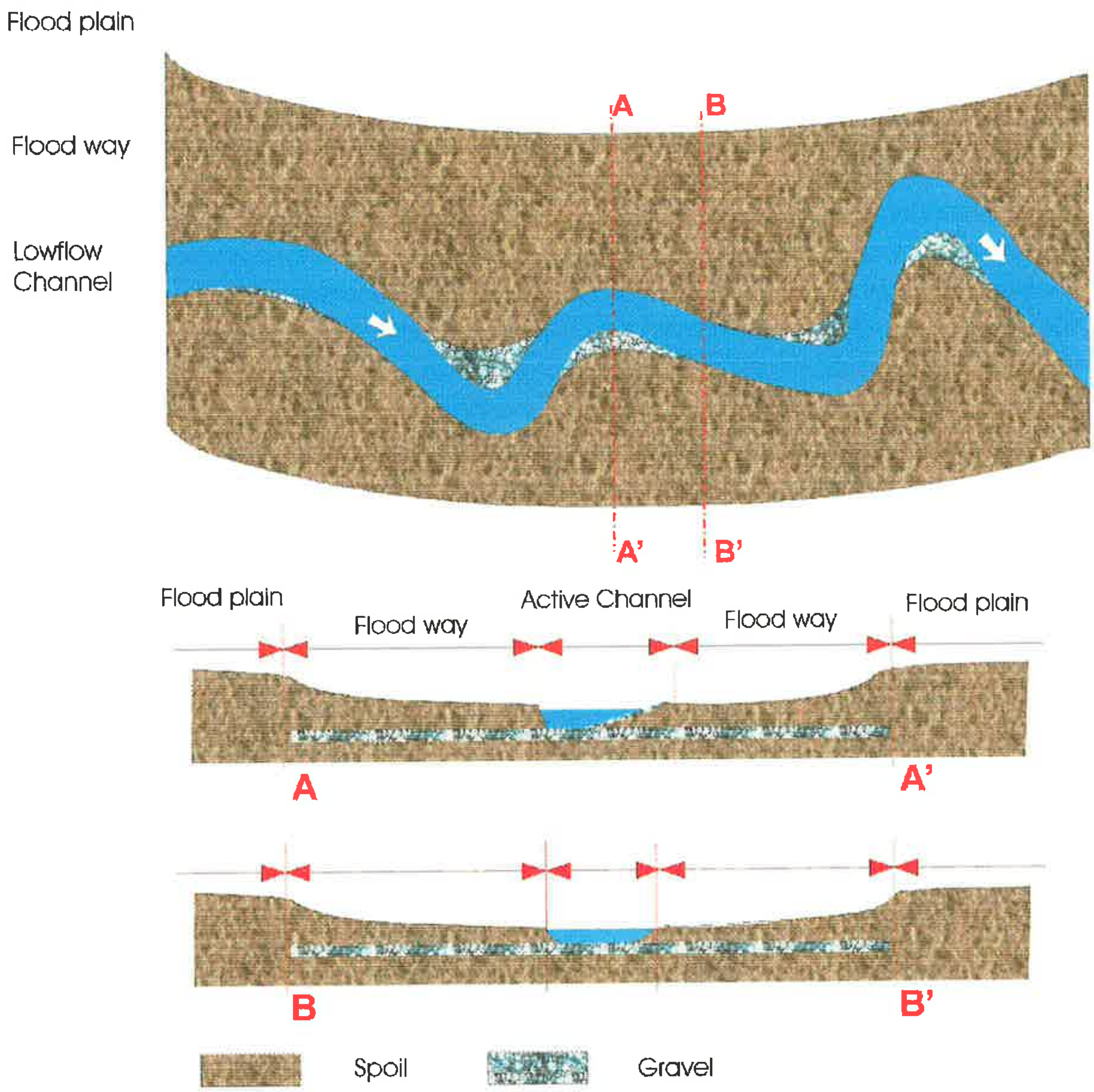


Figure 12. Conceptual plan of a two-stage floodway for the Waikaka River diversion.

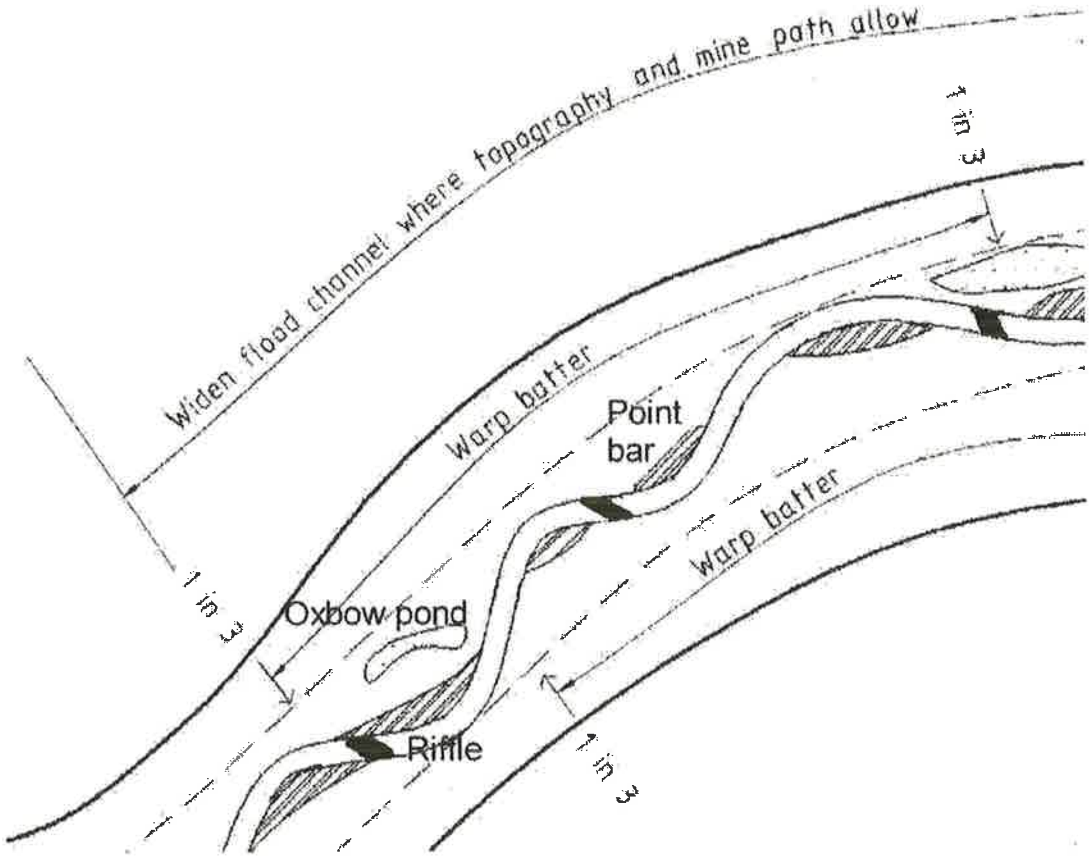
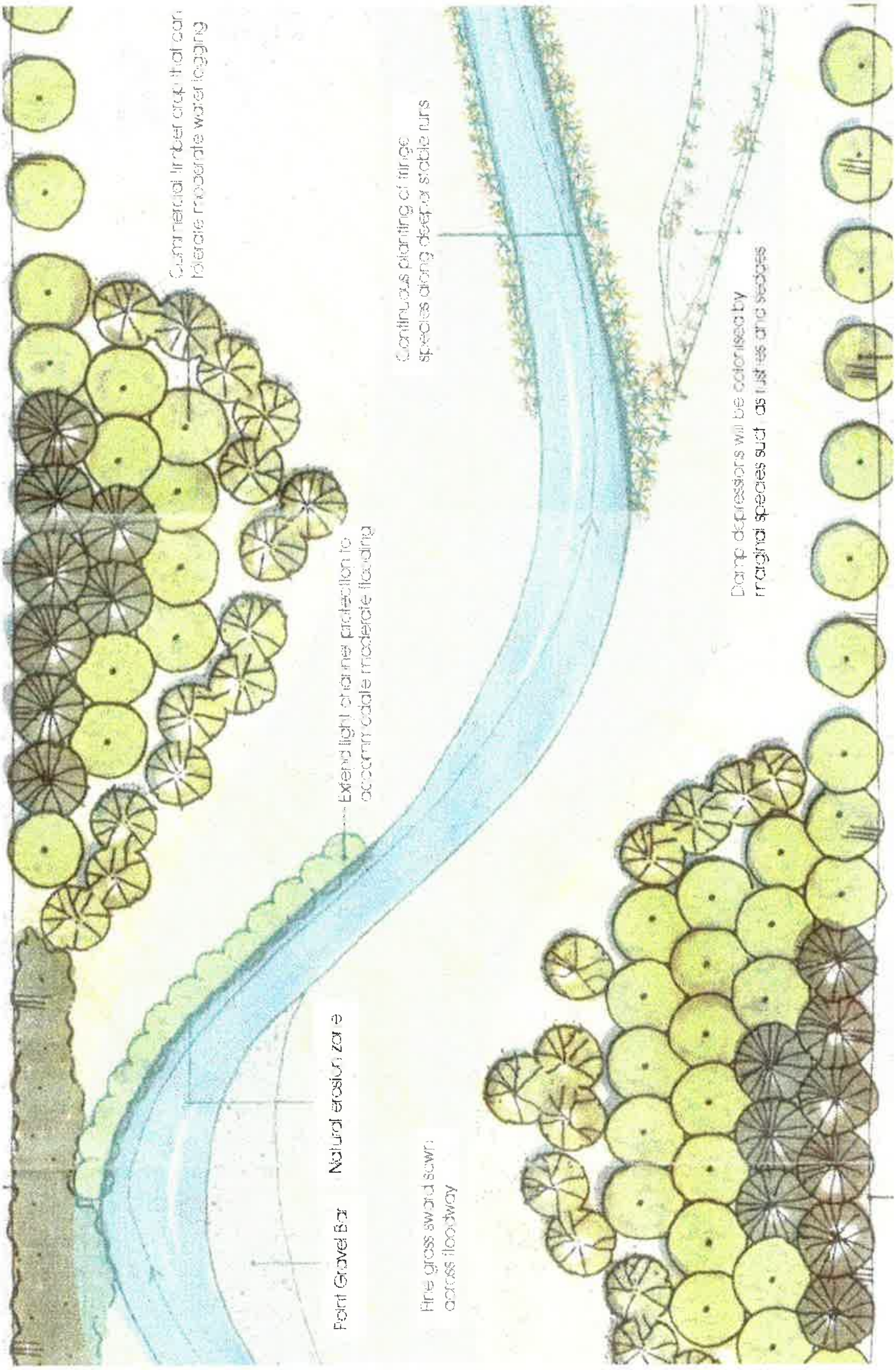


Figure 13. A prototype reach of the Waikaka diversion channel.

Figure 14. Typical section for rehabilitation of the Waikaka diversion.



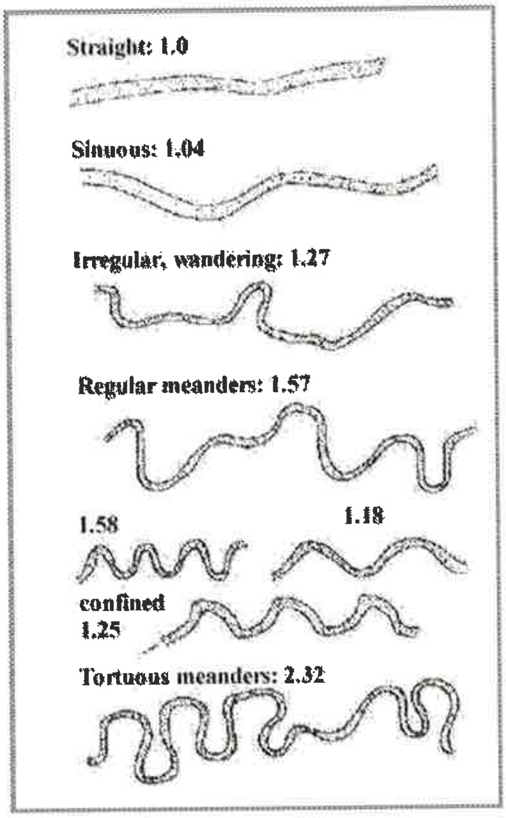


Figure 15. Channel patterns and sinuosity (based on Kellerhals and Church 1989).

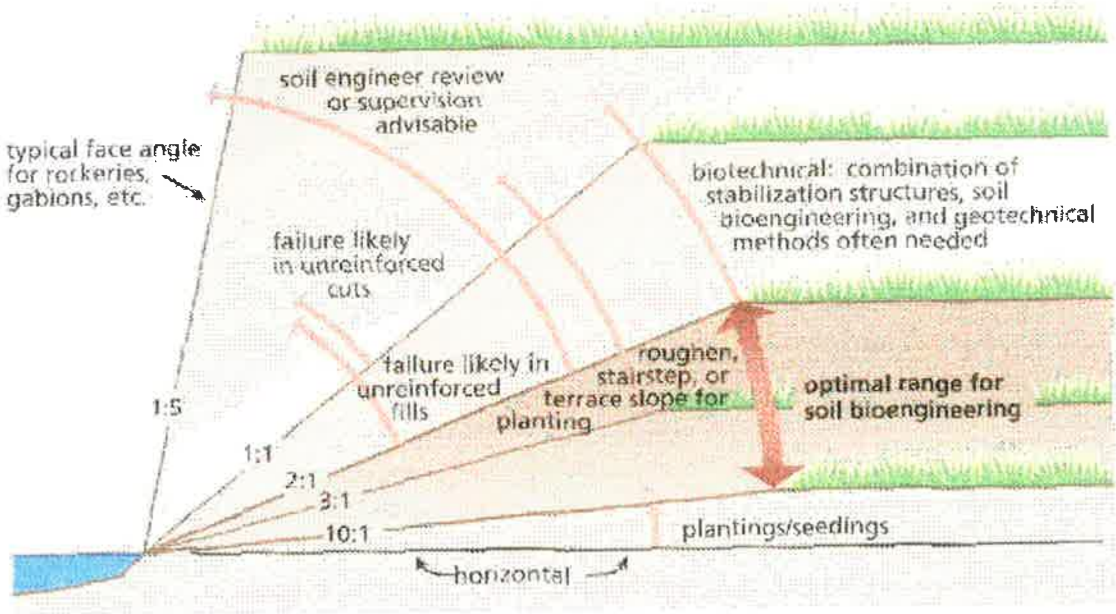


Figure 16. Side slope stability (source: FIASRWG 1998).

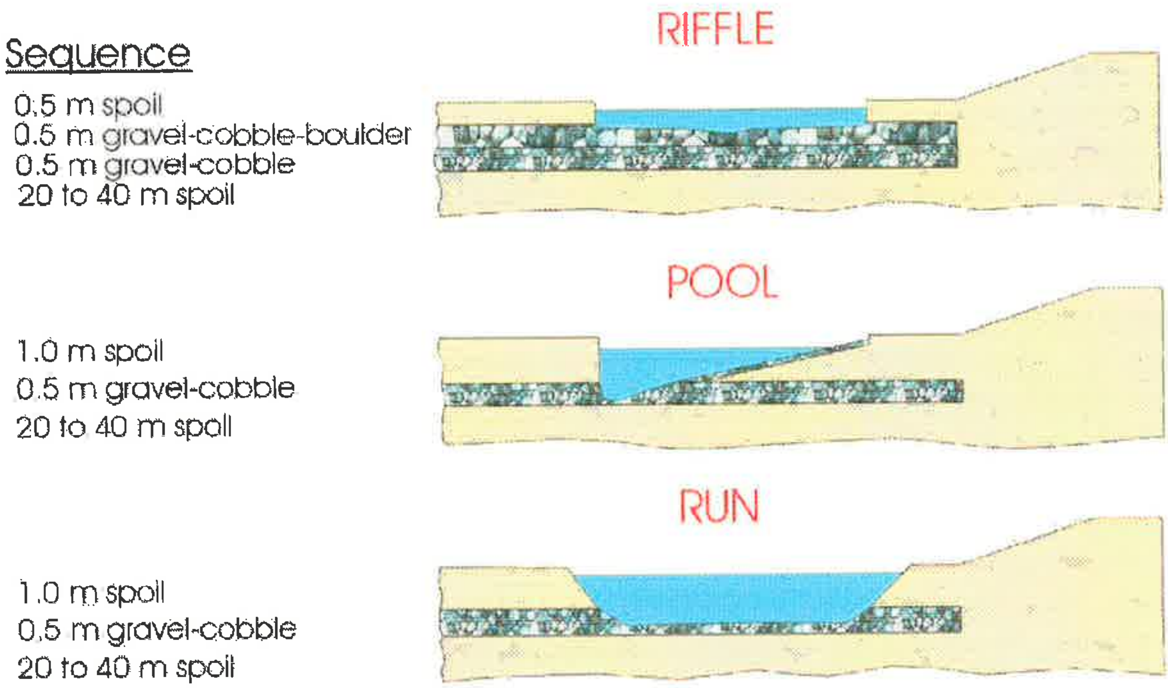


Figure 17. Pool, riffle and run cross section details.

Table 3. Technical steps in river diversion planning.

1. Describe catchment characteristics, river type, and hydrological response, including:
   ⇒ Gradient controls;
   ⇒ Bedload transport;
   ⇒ Channel characteristics of target and reference reaches; and
   ⇒ Streamflow characteristics.

2. Considering reach and other constraints, select a preliminary right of way for the restored stream corridor.

3. Determine the bed material size distribution:
   ⇒ Surficial materials in the active channel bed and banks;
   ⇒ Material at the design channel location and depth; and
   ⇒ Predict the size of armour layer development....

4. Determine the design discharge or range of discharges. (Conventional design is based on hydraulic conveyance for a specified flood flow whereas restoration design is based on emulating natural conditions):
   ⇒ Determine formative discharges (which may include determining sediment loads for calculation of the formative discharge);
   ⇒ Determine low and high flow habitat requirements; and
   ⇒ Determine flood inundation frequencies for corridor wetlands-floodway habitat.

5. Determine grade control requirements:
   ⇒ Determine grade control structure suitability for the particular river type (e.g. C4 river type, poor performance of wing deflectors);
   ⇒ Determine habitat requirements (fish passage, shelter ...).

6. Design a dynamically stable river channel planform and cross section (combining a selection of approaches including carbon copy, regime relations, analytical relations, reference reach...):
   ⇒ Determine habitat requirements for target species;
   ⇒ Determine bed material transport requirements;
   ⇒ Determine meander geometry (sinuosity, channel length and slope) and channel alignment;
   ⇒ Compute mean flow, width and depth at design discharge;
   ⇒ Compute riffle spacing; and
   ⇒ Check channel stability and reiterate as required.

7. Frequent inspection of work is required.

8. Monitor morphological and biological effects and maintain as required.

Tasks are not always executed sequentially. Iteration is invariably required.

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Facsimile Message

To: Peter York
Organisation: Gore District Council
Fax No: 03 2088875 0 3 2089 087
From: Kevin O'Sullivan , Consents Officer
Date: Friday, 28 January 2000
Subject: *Draft Conditions - L&M Mining (File Ref: L002-018)*
No. of Pages (including this cover sheet) 7

Message:

Peter

Draft conditions as discussed.

In response to your letter to John about a joint hearing – we expect that a hearing will not be necessary and that the application will be dealt with by the Southland Regional Council Consents Committee, probably at their March meeting.

Regards

Kevin O'Sullivan
Consents Officer