5.0 Barney Creek Diversion

5.1 Purpose

As discussed in earlier sections of this report, the design of the Barney Creek diversion has been modified since the preparation of the Draft EIS (URS, 2005a) to reflect optimisations in the proposed Open Cut Project and to incorporate recommendations that were provided as part of the EIS review. The purpose of this section is to address the requirements of the PER guidelines with respect to the Barney Creek diversion. Specifically it includes:

- An updated assessment of the geomorphology of Barney Creek following a recent site survey of critical reaches and the incorporation of the results of visual assessments of the channel geometry in the revised design of the diversion channel (Section 5.3)
- Characterisation of the existing aquatic habitats along the reach of Barney Creek that is to be diverted based on the results of a recent survey (Section 5.4)
- Development of a HEC-RAS model for the existing Barney and Surprise Creeks with the assumption of no concurrent flooding (backwater) in the Barney Creek catchment or in the McArthur River (Section 5.6.3)
- Modelling of the original (EIS) diversion design for Barney Creek to include no concurrent flooding from McArthur River (Section 5.6.6)
- Modification of the design of the Barney Creek diversion to address the risks identified by the modelling of the original diversion design (Section 5.6.7)
- Modelling of the modified Barney Creek diversion design to confirm acceptable performance in the case of no concurrent flooding from McArthur River Section (5.6.8)
- Assessment of the stream power and erosion potential in the various reaches of the proposed diversion channel (Section 5.6.9).
- Development of a rehabilitation strategy for the diversion channel (Section 5.7)

5.2 Summary

Table 5.1 provides a summary of the geomorphological, hydraulic, and ecological assessment undertaken of the revised design of the proposed diversion channel.

Table 5.1
Summary of Methodologies, Results and Conclusions

Item	Methodology	Results	Conclusion
Geomorphology for Barney Creek	Desk top analysis of aerial photographs, maps, orthophotos, and HEC-RAS model outputs. Ground surveys and aerial reconnaissance conducted during site visit in May 2006. Joint meetings and fieldwork with EPA and Professor Erskine in May 2006.	Barney Creek catchment has been divided into the following sub-catchments: • Buffalo Creek which is NNW of the mine and drops steeply over its first 3 km before forming a more gently sloping creek • Barney Creek upstream of the mine has well-grassed banks with no evidence of bank erosion. It is not an active stream system with numerous swamps providing attenuation of storm flows • Surprise Creek has well-defined vertical banks of weathered alluvial sands and gravels with numerous bedrock bars across the bed. Some high flows are diverted to the adjacent catchment of Emu Creek. Surprise Creek is the most active in the catchment • The reach of Barney Creek to be diverted is sinuous with steep banks. Its upstream end has gravely bed material and bedrock outcrops. Downstream of its confluence with Surprise Creek it passes through floodplain alluvium and the riparian vegetation reflects that of the McArthur River Design of the diversion will seek to replicate the form and function of the present channel of Barney Creek. Where required by subsurface conditions or revegetation needs, the design will differ from the natural channel, but will be consistent with conditions in the reaches to be diverted.	Barney Creek is an active channel that has adjusted to carry significant peak flows from Surprise Creek. The diverted section of the creek is slightly unstable with eroded banks and lag deposits of larger gravel in the channel bed In the lower 500 m of Barney Creek there is a backwater effect from the McArthur River as evidenced by finer sediments and vegetation similar to the river's riverine species

Item	Methodology	Results	Conclusion
Model hydraulic performance of diversion channel.	The HEC-RAS model was used to determine acceptable velocities, shear stress and stream powers as follows: • Use detailed hydraulic analysis of the existing creek system to define 'natural' levels of velocity, shear stress and stream power for stable creek sections where bed and bank materials are similar • Model velocity, shear stress and stream power of the diversion and compare to existing creek values and guidelines for diversions through similar geology • Modify the design of the diversion by varying geometric parameters and the inclusion of rock riffles and large woody debris to achieve acceptable hydraulic parameters.	The model results for the revised diversion design when there is no concurrent flooding in the McArthur River were as follows: Slightly Weathered Rock Sections • Design to include stepped riffle section to dissipate energy of flood flows • The maximum stream power results are less than the calculated threshold erodibility values using the Annandale methodology. Extremely Weathered Rock Sections • The velocity, shear stress and stream power are generally similar to that of the existing mine reach of Barney Creek • The velocity, shear stress and stream power values through the downstream reach of the diversion through extremely weathered rock are within those recommended in the ACARP guidelines • The maximum stream power results are less than the calculated threshold erodibility values using the Annandale methodology.	The model results for the revised diversion design indicate that: • The diversion channel will have a similar hydraulic performance to the existing creek and will convey similarly sized bank-full flood flows • The diversion channel will be stable over the mine life and beyond including for local flood events with no concurrent flooding in the McArthur River • The channel diversion will not be subject to significant erosion or sediment deposition • The diversion channel will not result in detrimental impacts to the existing Barney Creek upstream of the diversion.
Rehabilitation Strategy	Existing aquatic, riverine and riparian habitats were characterised following further field surveys conducted in May 2006. Specialist advice was sought on technical aspects of species selection, seed collection and vegetation establishment.	A rehabilitation strategy was developed for the diversion which included the following: • The inclusion of large woody debris in along the channel bed to provide micro-habitats for fish. • Revegetation of the channel banks including: – use of seeds and seedlings from local species already growing along the river bank – planting in topsoil that has been placed within rock-lined banks along the diversion channel to prevent the topsoil being washed away	Revegetation of the banks of the diversion channel will enable a functioning riverine ecosystem to be established.

Item	Methodology	Results	Conclusion
		– implementation of an effective maintenance program including fertilising, watering and weed control – implementation of an effective monitoring and replacement program.	

5.3 Barney Creek Geomorphology

The geomorphology of Barney Creek is described in order to provide a basis for assessing the impact of its diversion around the open cut on channel and floodplain landforms, sediment transport and hydrological systems.

The assessment has been carried out using the maps and aerial photographs described in Section 4.3.1 above for the McArthur River diversion.

The creek was inspected in May 2006 for ground-based field work, and a helicopter survey of the catchment was also undertaken.

These field observations have been used in the HEC-RAS modelling, and in developing engineering and biological design specifications for the proposed diversion channel.

5.1.1 Barney Creek Catchment

Barney Creek is a small true left bank tributary of the McArthur River that comprises about 6 % of the river catchment upstream of the mine. It occupies an area of hills, tablelands and plains to the north-west and west of the mine. It rises in a belt of hills that run east towards the Bukalara Range. The furthest parts of the catchment are more than 35 km west of the mine, and the closer parts are ~10 km to the north-west. The hills and tablelands are predominantly formed in McArthur Group dolomitic siltstone, with higher parts in the Stretton Sandstone. They mostly rise no more than 200 m above sea level, although in the far west they are over 270 m high. Valleys are incised around 60 m below the hills and tablelands, and the plains are about 30 m lower again.

The total area of the Barney Creek catchment is 660 km^2, and there are three main tributaries which from west to north-west are Barney Creek, Buffalo Creek and Surprise Creek.

5.1.2 Barney Creek Sub-catchment

The Barney Creek sub-catchment is the largest, draining some 390 km^2 of the far western hill country. Here the streams flow south for about 15 km out of the hills in relatively steep courses that drop up to 200 m. They join to form Barney Creek proper which then flows east for more than 30 km across the plains in a sinuous low-gradient course that falls only 40 m in this distance. The creek passes through many swamps and billabongs across these plains, with the largest swamp covering more than 6 km^2. For some 5 km downstream of this swamp, the stream course becomes very indistinct and is reduced to a chain of shallow dry ponds that occupy a 500 m wide floodplain. However, about 6 km north-west of the mine a single main channel forms and this continues in a shallow swale-like channel that is about 20 m across and 1 to 1.5 m deep.

5.1.3 Buffalo Creek Sub-catchment

The Buffalo Creek subcatchment drains from hills west-north-west of the mine, and covers 170 km^2. The hills and tablelands in its headwaters vary from 160 to 200 m above sea level, and the small tributaries drop steeply 50 to 100 m in their first 3 km, before forming the much more gently sloping creek which flows across the northern margin of the McArthur River plains. The channel is shallow and not well defined, and 5.5 km west of the mine it disappears for several hundred metres.

5.1.4 Barney Creek Upstream of the Mine

Once joined by Buffalo Creek, Barney Creek flows east for about 5.5 km around the northern side of the mine site. It has formed an irregular floodplain up to 200 m wide and 5 m below the general level of the McArthur River plain here. A typical cross section from chainage 6517 in the Barney Creek HEC-RAS model is shown in Chart 5.1 and Plate 5.1 shows the channel at about this location.

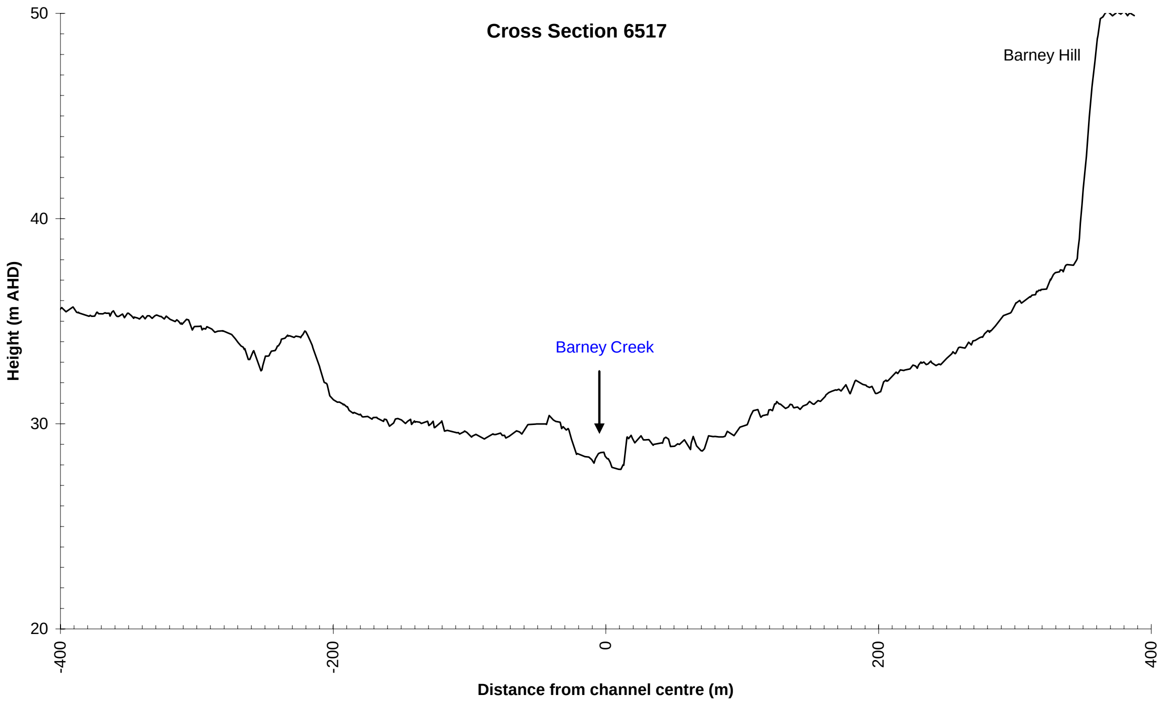


Chart 5.1

Barney Creek Cross Section at Chainage 7043

Plate 5.1

Barney Creek Channel Near Chainage 6517 (Jan 2006)

The location shown in Plate 5.1 is just upstream of the Surprise Creek junction. The channel is 1 to 2 m deep below the adjacent floodplain, and 20 to 50 m wide. The channel banks are well grassed and slope down to the bed without evidence of bank erosion. Bed material comprises a lag deposit of subangular cobbles up to 15 cm across. From this it is interpreted that while flows here are capable of transporting all of the sand and gravel-sized material supplied to the stream, they do erode enough to form well-defined channel banks. This indicates that the Barney Creek and Buffalo Creek sub-catchments are not very active stream systems. As noted above, there are numerous swamps and billabongs on the upper Barney Creek floodplain, suggesting there would be significant attenuation of peak storm flows through the catchment, and this is consistent with the lack of well-formed channel banks in the lower catchment.

5.1.5 Surprise Creek Sub-catchment

The Surprise Creek sub-catchment contrasts with the Buffalo Creek and Barney Creek sub-catchments. It is the smallest of the sub-catchments at 100 km^2, and about 80 % of it comprises hills and tablelands rising to 195 m above sea level. It leaves the hills about 7 km north-west of the mine and flows in a sinuous course to the north of the mine, joining Barney Creek 0.5 km north of the mine.

Surprise Creek has a channel with well-defined banks 2 to 5 m high along its entire course across the plains. Plate 5.2 shows an example, about 6 km north-west of the mine. Material exposed in the banks is red weathered sand and subrounded gravels up to 5 cm across interpreted as alluvium. The eroded channel bank is vertical, and is interpreted as a terrace feature. Bed material in the channel here is also subrounded gravel up to 5 cm in diameter, and there are numerous bedrock bars across the channel.

Plate 5.2

Surprise Creek about 5 km NW of Mine (May 2006)

The section of Surprise Creek shown in Chart 5.2 flows in front of the Bald Hills, and on the north bank, between the creek and the hills, the floodplain slopes away to the north. There is a shallow drainage line between the hills and Surprise Creek, and this feeds south and east into a chain of billabongs that in turn drain east into Emu Creek. During a major flood in 2001 water from this area flowed across the Carpentaria Highway damaging several hundred metres of the road. The Bald Hills catchment area for the drainage line and billabongs is only approximately 5 km^2, and is considered to be too small to have generated the flows that caused the highway damage. It is likely that floodwaters from Surprise Creek may have contributed to flow into this area. This is significant, as it suggests Surprise Creek may lose some water during higher magnitude events resulting in less than predicted flows in the Barney Creek diversion.

Chart 5.2 shows a typical cross section of Surprise Creek at chainage 2900, which is about 500 m south-east of the Carpentaria Highway. The channel is about 100 m wide at the top, and has very steep banks incised 5 m below the floodplain. This well formed channel feature is in marked contrast to the smaller Barney Creek channel shown above (Chart 5.1).

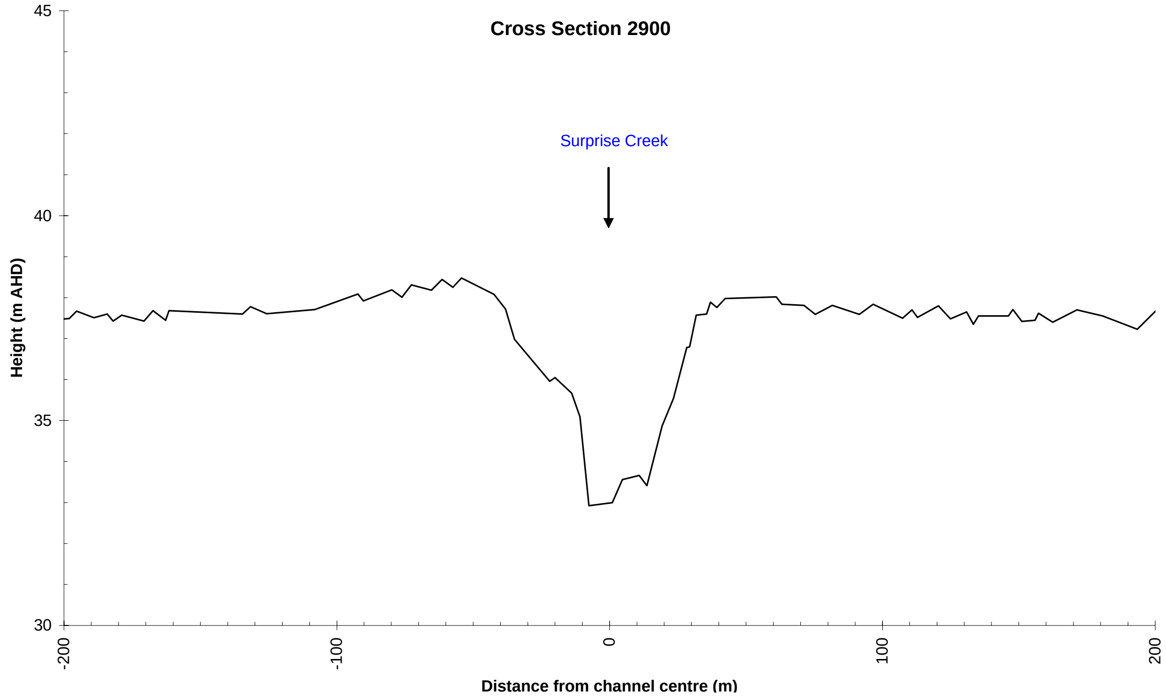


Chart 5.2

Surprise Creek Cross Section at Chainage 2900

From the channel features described above, it is interpreted that Surprise Creek is hydrologically the most active of the three Barney Creek sub-catchments. This has ramifications for the design of the Barney Creek diversion as discussed in the sections below.

5.1.6 Diverted Reaches of Barney/Surprise Creeks

The proposed Barney Creek diversion will divert flow in the lower 2,500 m of Barney Creek, and the lower 500 m of Surprise Creek. This section briefly describes these reaches that will be lost.

The lower 500 m of Surprise Creek retains the general form described above, and occupies a 4 to 5 m deep channel incised in steep banks below the flood plain. The top width of the channel banks is approximately 40 m. The Barney Creek diversion will intersect Surprise Creek at about chainage 500, and a drop structure will be required to lower Surprise Creek to the bed level of the diversion.

The diversion will leave Barney Creek at about chainage 6520. From here to the McArthur River, Barney Creek drops 9.5 m over a channel distance of 2,500 m at a slope of 1in 265. The first section of the creek has a very gentle slope, as it is upstream of Surprise Creek confluence. This 350 m reach has been described and illustrated above in Chart 5.1 and Plate 5.1. At the junction of Surprise Creek, Barney Creek changes character, and takes on the form of the much more active Surprise Creek. At the junction, Surprise Creek turns sharply to the north-east, however, there is a high level cut-off channel that takes Surprise Creek flood water in a direct path through an east trending channel for about 400 m to rejoin the main Barney Creek at about chainage 5700.

The combined Barney/Surprise Creeks channel is illustrated Chart 5.3 and Plate 5.3. This is at chainage 5930, about 200 m downstream of the Surprise Creek junction. Here the main channel sweeps around to the south, and the outside of the bend shows a typical cut bank some 3 m high. The channel is formed in fine gravel alluvium, and retains the overall features of the Surprise Creek channel system, although it is somewhat smaller. This difference in size is due to the cut-off channel described above.

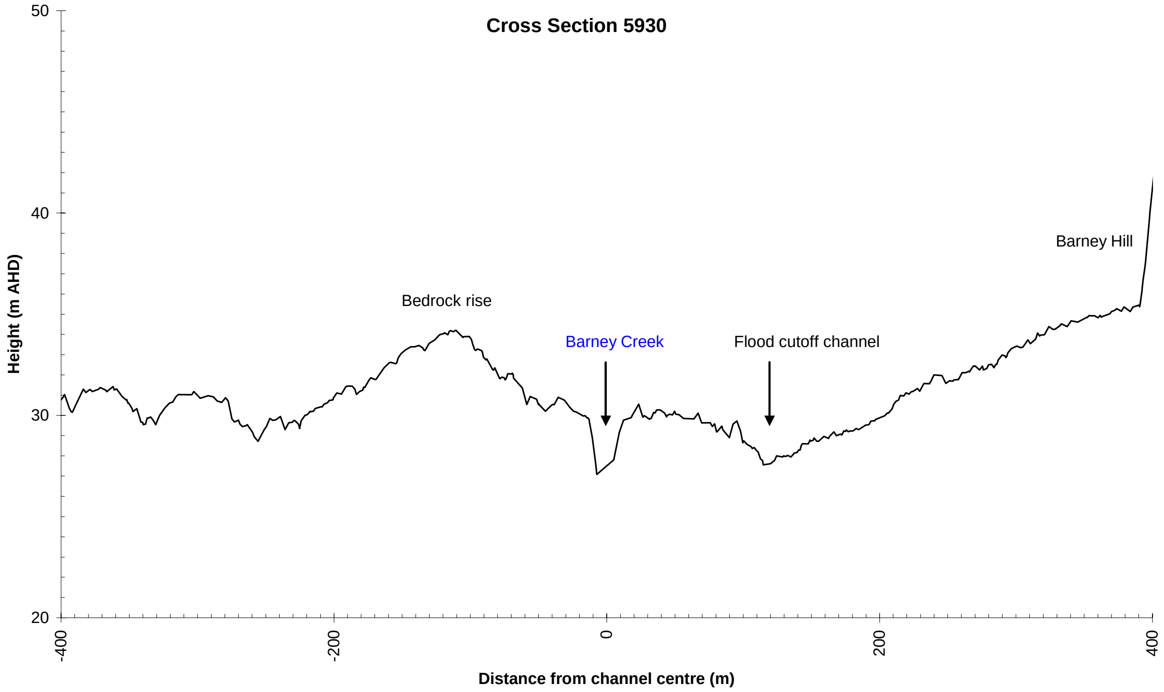


Chart 5.3

Barney Creek at Chainage 5930

Plate 5.3

Cut Bank in Barney Creek at Chainage 5930 (Jan 2006)

The diverted reach of Barney Creek has a sinuosity of 1.8 due to two large meander bends in the central parts of the reach.

Chart 5.4 and Plate 5.4 illustrate a typical cross section through the upstream meander bend at chainage 5606. Here the channel bed is about 10 m across, and the banks are 3.5 to 4 m high. The bed material is gravel up to 10 cm in diameter, and nearby are sub-rounded boulders up to 0.5 m in diameter. These are interpreted as lag deposits from bedrock outcrops that are common through the upper part of the diverted reach. In Plate 5.4 it can be seen that the channel banks were not as steeply sloping as elsewhere, suggesting this reach had not experienced erosive discharges for some time.

Just downstream of this cross section the creek swings in a sharp bend to the north, entering the second of the large meander bends. At this point a cut-off channel carries flood flows directly east for about 200 m to rejoin Barney Creek at chainage 4750, cutting off some 840 m of the main channel.

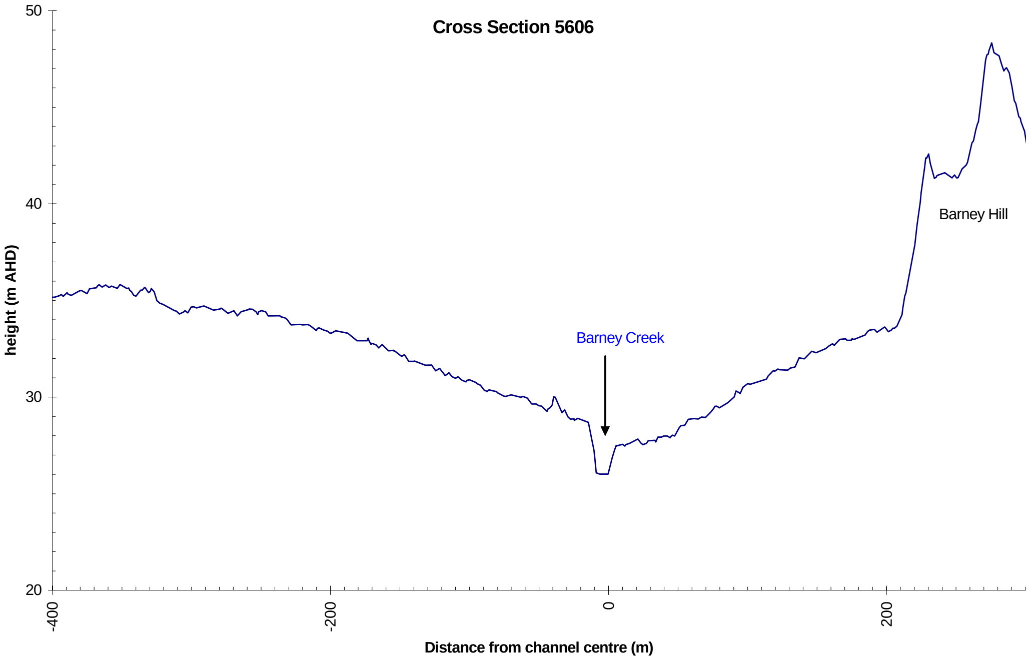


Chart 5.4

Barney Creek Cross Section at Chainage 5606

Plate 5.4
Barney Creek Channel at Chainage 5606 (Jan 2006)

In its lower 700 m, Barney Creek deepens it valley as it cuts down to the level of the McArthur River through some rock sections and floodplain alluvium. At chainage 4600 the channel bifurcates at a bedrock bar, to rejoin about 100 m downstream. At about 500 m from the McArthur River the bed and channel bank materials become much finer and the riparian vegetation corridor becomes denser and for the first time includes species found along the main McArthur River channel. This is interpreted as marking the upstream limit of the typical backwater effect of the McArthur River in the lower reach of Barney Creek. Channel slope reduces here to about 1 in 600, and a typical cross section is shown in Chart 5.5 and illustrated in Plate 5.5.

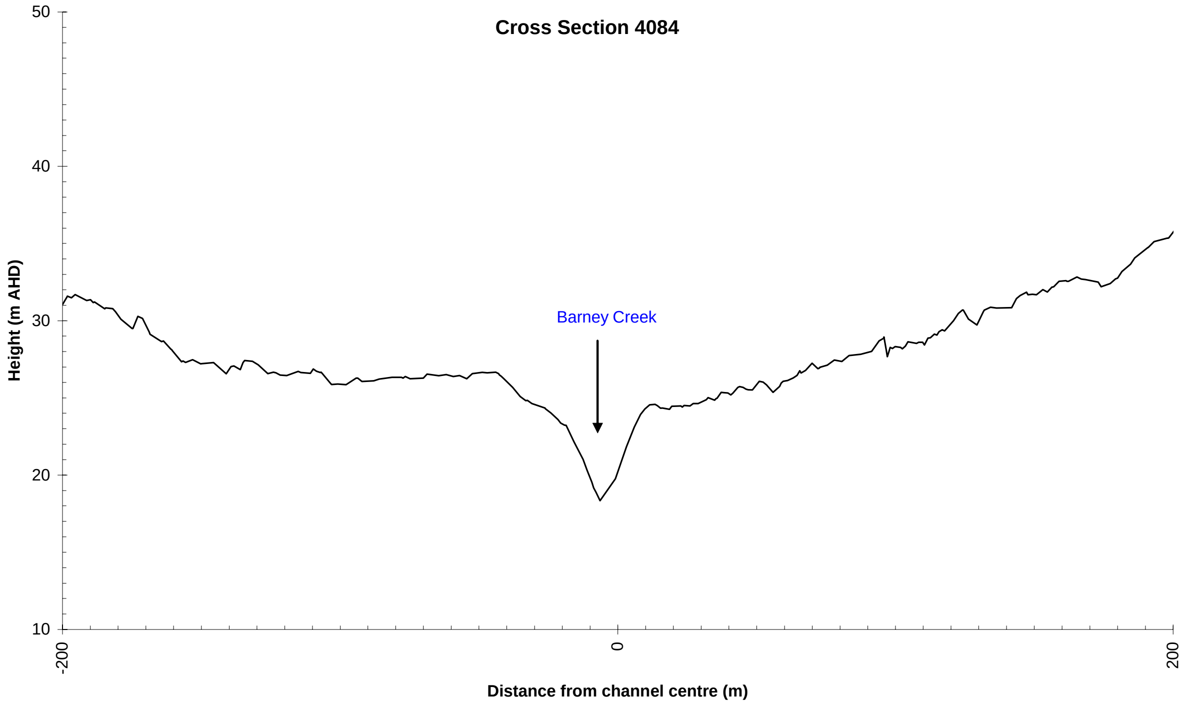


Chart 5.5

Barney Creek Cross Section just Upstream of the McArthur River Confluence

Chart 5.5 and Plate 5.5 show the channel banks are distinctively v-shaped, up to 8 m deep and 55 m wide at the top. The banks are coated with fine sand and silt deposits, and the channel bed is very narrow, consistent with the backwater effect of the McArthur River. The bed of Barney Creek does not grade to the bed of the McArthur River, and is 'hanging' about 1.5 m higher. This indicates that when Barney Creek is flowing, the McArthur River is also carrying water, and the backwater effect here does not allow Barney Creek to cut its bed down to the level of the McArthur River bed.

Plate 5.5

Upstream View into Barney Creek at the McArthur River confluence (Jan 2006)

5.1.7 Conclusions

This geomorphology assessment has described the environmental conditions in the Barney Creek system in order to provide a context for development of the design of the Barney Creek diversion. It can be seen that the Barney Creek mine reach is an active channel that has adjusted to carry significant peak flow events derived from the Surprise Creek sub-catchment. These are able to erode the banks of the channel, and have left lag deposits of larger gravels in the channel bed. This suggests that the mine reach is potentially slightly unstable in its present form. There are numerous bed rock outcrops in the channel bed, and these have probably contributed to the creek being unable to form a more stable channel system.

There is a backwater effect as the creek joins the McArthur River, and this appears to occur whenever Barney Creek is flowing, as the bed of the creek has not been able to down-cut to the grade of the McArthur River.

5.4 Aquatic Habitats

This sub-section describes the aquatic and riverine habitats occurring along the existing Barney Creek channel within the reach proposed for diversion. Data were obtained through field surveys conducted in May 2006. The data have been used to inform the engineering and biological design specifications for the proposed diversion channel so that key habitat types and management strategies can be included.

Data on aquatic habitat characteristics were collected using the AUSRIVAS Physical Assessment Protocol (Parsons, Thoms and Norris, 2002). This system is used Australia-wide for characterisation of aquatic habitats and enables detailed assessments to be made of conditions at each sample site. While procedures within the protocol are comprehensive, they are designed for use over a range of conditions Australia-wide. Some variables were not relevant to the Barney Creek and hence were either not recorded or noted only in a general context. Some additional parameters not included in the AUSRIVAS protocols were recorded because they were considered relevant to the project.

Sampling was conducted at two sites along the Barney Creek channel within the area to be diverted. The locations of the survey sites are shown on Figure 4.1. The parameters recorded at each site were grouped into the following major categories:

- General site data
- Water quality
- Riparian zone vegetation
- Channel form
- Bed-form features
- Channel cross section
- USEPA habitat assessment
- In-stream habitats.

A planform sketch of each 100 m reach was made and site photographs were taken at each cross section site. Copies are provided in Appendix E.

General water quality parameters in Barney Creek were similar at both monitoring sites. Water temperatures ranged between 25.7°C and 26.3°C. Conductivity varied between 261 and 326 µS/cm, dissolved oxygen levels were 5.55 and 5.73 mg/L, and pH ranged from 7.19 to 7.51. No sediment oils, water oils or odours were noted at any sites. Turbidity was estimated to be slight or turbid due to suspended materials.

The vegetation along Barney Creek is mapped in the Draft EIS (URS, 2005a) as Map Unit No. 8 – Riverine Woodland, dominated by *Casuarina cunninghamiana* and *Lophostemon grandiflorus*. This is a highly variable community including narrow linear bands of riverbank species on smaller tributary creeks and a broader vegetation community on diffuse drainage ways and overflow channels. Dominant upper stratum species include *Casuarina cunninghamiana* and *Eucalyptus microtheca* to 8 to10 m high, while *Terminalia bursarina, Excoecaria parvifolia* and *Lophostemon grandiflorus* are common along the banks.

While tall trees provide up to 50 to 60% shading of the McArthur River channel, Barney Creek is much less shaded, with vegetation shading only about 10 to 20%.

The bed of Barney Creek is generally stable, with sub-angular sediments and moderate to low compaction. Rock bars are prevalent and bank materials generally consisted of a variety of materials including gravel, pebbles, boulders and bedrock.

The USEPA “HABSCORE” index is a rapid assessment protocol focussing on biological and physical stream parameters to indicate relative stream conditions. Physical parameters only are considered in the AUSRIVAS habitat protocol (Parsons, Thoms and Norris, 2000). Each parameter is scored separately and an overall comparative result is obtained by applying the total score as a percentage of the possible total. For Barney Creek, the highest scores were assigned for epifaunal colonisation, lack of channel alteration, and pool substrate characterisation. The sites scored lowest for parameters such as bank stability, vegetative cover and riparian zone width. Both Barney Creek sites scored 41% in the analysis indicating that overall, the area has a below average rating for in-stream fauna colonisation.

Unlike McArthur River, Barney Creek does not provide an ecological role as a migratory corridor for aquatic or riparian fauna. Fish diversity in Barney Creek is much lower than in the McArthur River due to its highly dynamic nature and the lack of permanent pools. Only eight species are known from Barney Creek (Hanley, 1993; Hollingsworth Dames & Moore, 1992) compared to 31 species in the adjacent McArthur River (Section 11.2.1). All of the fishes found in Barney Creek are small species and typical of those known to invade ephemeral habitats in the Gulf region. The creek is used as a temporary wet season habitat for these species, and as the dry season progresses, fishes living in this area become trapped and die as the pools dry up, thus providing a food source for fauna groups such as birds.

5.5 Flood Hydrology for Barney and Surprise Creeks

5.5.1 Flood Flows

Floods in Barney Creek and Surprise Creek are highly variable. Floods can occur as a result of isolated rainfall events (thunderstorms, cyclone) over the Barney and Surprise Creek catchments, or as a result of concurrent flooding in the McArthur River (cyclone and monsoonal).

The Barney Creek catchment upstream of the confluence with Surprise Creek generally consists of steeper hills in the upper-third of the catchment and is relatively flat for the remaining two-thirds. Anecdotal evidence from mine site personnel suggests that Barney Creek has significant flood retention areas, including billabongs and depression areas, upstream of its confluence with Surprise Creek where flows are attenuated before reaching the mine site.

The Surprise Creek catchment is approximately one-third the size of Barney Creek’s, but has a more actively eroding channel which is primarily due to the alluvial geology in the creek channel and the steeper longitudinal grade. The Surprise Creek floodplain to the east is relatively flat, and during large flooding events, the banks of Surprise Creek overtop into the floodplain and enter into tributaries of Emu Creek. One such break out occurred in 2001, when a flood overtopped the Surprise Creek banks and floodplain, entered into a small tributary of Emu Creek and damaged a 2 km reach of the Carpenteria Highway.

Design flood hydrology estimates of peak flood flows in Barney and Surprise Creeks have recently been updated by KBR (2006) utilising empirical relationships to estimate peak flood flows at select locations in the Barney Creek catchment. Design peak flood estimates for Barney and Surprise Creek are presented in Table 5.2. A flood frequency plot of the design peak flood estimates is presented in Appendix F.2.

Table 5.2

Barney and Surprise Creek – Design Peak Flow Estimates

Catchment Location	**Catchment Area (km^2)**	**Peak Flood Flows (m^3/s)**					
		Average Recurrence Interval (ARI) (years)					
		2	**5**	**10**	**20**	**50**	**100**
Barney Creek upstream of confluence with Surprise Creek	360	330	535	690	780	850	975
Barney Creek at confluence with McArthur River	660	450	680	930	1,220	1,400	1,650
Surprise Creek	100	120	145	240	440	550	675

Source: adapted from KBR (2006).

5.5.2 Extreme Flooding

Since the diversion of Barney Creek will be a permanent feature of the landscape after closure of the mine, the diversion channel should be designed to be stable for a range of flooding events, including extreme floods. One example of an extreme rainfall event which resulted in significant flooding and erosion occurred over a catchment near Jabiru in 1980. The storm cell was approximately 100 km^2 in size and resulted in high rainfall intensities of approximately 350 mm in 6 hours.

Surprise Creek is considered a more active stream than Barney Creek, therefore the simulation of an extreme flooding event over Surprise Creek would likely result in a larger peak than a similar storm cell over Barney Creek. Additionally, the flow retention within the Barney Creek catchment would likely result in a lower peak discharge than for Surprise Creek and a longer hydrograph. For a rainfall intensity of 350 mm in 6 hours over the entire Surprise Creek catchment, a peak flow of approximately 1,400 m^3/s could be expected. This event would be significantly greater than a 100-year ARI storm event in Surprise Creek, or approximately a 50 year ARI flood event in Barney Creek. It is recognised that overflow into Emu Creek would occur for this magnitude of flood event, but to be conservative, it was assumed that all of the peak discharge of 1,400 m^3/s would enter into Barney Creek.

5.6 Hydraulic Modelling of Barney and Surprise Creeks

5.6.1 Introduction

Modelling (HEC-RAS) for the existing Barney and Surprise Creek system has been undertaken to assess their hydraulic characteristics and how they relate to the McArthur River. The modelling tasks undertaken include the following:

- Estimation of the roughness coefficients using Cowan's method
- Development of a HEC-RAS model for the existing Barney and Surprise Creeks with the assumption of no concurrent flooding (backwater) in the Barney Creek catchment or in the McArthur River
- Modelling of the original (EIS) diversion design for Barney Creek to include no concurrent flooding from McArthur River
- Modification of the design of the Barney Creek diversion to address the risks identified by the modelling of the original diversion design
- Re-modelling of the modified Barney Creek diversion design to confirm acceptable performance in the case of no concurrent flooding from McArthur River

A discussion of each of the above tasks is given below.

5.6.2 Estimation of Roughness Coefficients Using Cowan's method

Since there is not a stream gauge located on either Barney Creek or Surprise Creek, calibration of HEC-RAS roughness coefficients to recorded flood data could not be performed. Therefore an estimation of the roughness coefficients was undertaken that utilised the Cowan's method for estimating channel and flood plain roughness coefficients as described in Section 4.5.5.

Cowan's method utilises the following equation and six factors in order estimate a composite channel roughness coefficient:

$$n_{total} = (n_b + n_1 + n_2 + n_3 + n_4)m$$

Where:

n_b = a base value of n for a straight, uniform, smooth channel in natural materials

n_1 = a correction factor for the effect of surface irregularities

n_2 = a value for variations in shape and size of the channel cross-section

n_3 = a value for obstructions

n_4 = a value for vegetation and flow conditions

m = a correction factor for meandering of the channel.

A more detailed discussion of each parameter is provided in Section 4.5.5.

Barney Creek

The Barney Creek channel generally consists of the following different types of cross-sections:

- Cobble and rock-lined channel base with varying densities of vegetation (typically located upstream of the confluence with Surprise Creek and the first 500 m downstream of the confluence) – refer to Plate 5.1
- Smooth, rock-lined channel base with little vegetation in the main channel and higher density vegetation on the channel banks (typically located in the horseshoe meander and upstream of the meander) – refer to Plate 5.6
- Isolated rock bars or large rock outcroppings in the channel base and banks with little vegetation (rock diameters > 1m) – refer to Plate 5.7
- Alluvial deposits on the channel base and banks with high density vegetation in the channel base and banks (located near the confluence with the McArthur River) – refer to Plate 5.5
- Rock outcroppings in the anabranch channel at the horseshoe meander – refer to Plate 5.8.

Plate 5.6

Reach of Barney Creek which Shows Relatively Smooth Bedrock-Lined Channel Bed

Plate 5.7

Reach of Barney Creek which Shows Rock Outcroppings in Channel Bed

Plate 5.8

Reach of Anabranch in Barney Creek which Shows Rock Outcroppings in Channel Bed

The Cowan's method roughness coefficients were selected for each cross-section type, as presented above, based on the criteria outlined in Section 4.5.5, and a total roughness coefficient, n, was calculated. A summary of the adopted values for the Barney Creek Manning's roughness coefficient using Cowan's method together with the coefficients derived by the model calibration method is provided in Table 5.3. A range of adopted values is also presented because of the variability in roughness that was modelled at each channel cross section.

Table 5.3

Summary of Cowan's Method Roughness Coefficients for the Barney Creek main channel

Cross-section Type	n_b	n_1	n_2	n_3	n_4	m	Total n (Cowan's Method)	Adopted Range
Cobble and rock-lined	0.04	0.001	0.001	0.0	0.001	1.0	0.043	0.04 – 0.05
Smooth, rock-lined channel (little veg.)	0.03	0.0	0.001	0.0	0.001	1.0	0.032	0.032 – 0.035
Isolated large rocks and rock outcroppings (>1 m dia.)	0.045	0.003	0.001	0.005	0.002	1.0	0.056	0.055 - 0.06
Alluvial deposits in channel and high density vegetation	0.025	0.0	0.001	0.01	0.01	1.0	0.046	0.04 – 0.05
Anabranch through rock outcroppings	0.05	0.01	0.005	0.01	0.005	1.0	0.08	0.08

Surprise Creek

Similarly, Cowan's method was applied to estimate Manning's roughness coefficient for the Surprise Creek main channel. Plate 5.2 shows a typical reach of Surprise Creek, and Table 5.4 shows the estimated roughness parameters and total Cowan's method roughness coefficient.

Table 5.4

Summary of Cowan's Method Roughness Coefficients for the Surprise Creek main channel

Cross-section Type	n_b	n_1	n_2	n_3	n_4	m	Total n (Cowan's Method)	Adopted Range
Alluvial bed and active erosion	0.03	0.0	0.001	0.002	0.002	1.0	0.036	0.035 – 0.04

A floodplain roughness coefficient of 0.079 was adopted for the Barney Creek and Surprise Creek floodplains based on relative density of vegetation from the aerial photography. This is similar to the typical roughness coefficient adopted for the McArthur River floodplain.

5.6.3 Modelling of Existing Creek Conditions

Barney and Surprise Creeks were modelled (HEC-RAS) in their existing condition to establish baseline hydraulic parameters for a range of flood events and to compare the model results to the qualitative geomorphologic assessment. The model setup included the following:

- Barney Creek reach from the Carpentaria Highway to the confluence with McArthur River
- Surprise Creek reach which extends from upstream of the Carpentaria Highway to the confluence with Barney Creek
- The anabranch at the downstream reach of Barney Creek was modelled as a separate branch by using the split-flow routine in the HEC-RAS program
- Downstream boundary condition in the McArthur River utilised a rating curve for two scenarios; (1) no concurrent flooding in McArthur River and (2) concurrent flooding in McArthur River
- Roughness coefficients for Barney and Surprise Creeks as listed in Table 5.3 and Table 5.4 respectively
- Assume all flood flow from Surprise Creek is conveyed to Barney Creek.

Two separate rating curves were developed for the downstream boundary rating curve in the McArthur River by assuming no concurrent (backwater) flooding and concurrent flooding. For the scenario of no concurrent flooding, the existing-conditions McArthur River model (Section 4.5.7) was modified to reflect a single inflow to the river from Barney Creek (the McArthur River model previously included inflow from the Glyde River). The elevation-discharge rating curve at McArthur River cross-section 16935 was then input as the downstream boundary condition. Table 5.5 shows the elevation-discharge relationship for Barney Creek for both cases of concurrent and non-concurrent flooding in the McArthur River.

Table 5.5

Elevation-Discharge Table for Barney Creek Existing Conditions

ARI (years)	Discharge (m^3/s)	Elevation Assuming No Concurrent Flooding in McArthur River (mAHD)	Elevation Assuming Concurrent Flooding in McArthur River (mAHD)
2	450	26.32	26.93
5	680	27.74	30.18
10	930	28.73	31.50
20	1,220	29.63	35.20
50 (also Surprise Creek Extreme Flood Event)	1,400	30.20	36.98
100	1,650	30.66	39.40

Additionally, it was conservatively assumed for the existing-conditions model simulations for Barney and Surprise Creeks that all of the floodwaters from Surprise Creek were conveyed to Barney Creek.

The hydraulic parameters used to characterise the river hydraulics were flow velocity, shear stress and stream power. These are described as follows:

- Flow velocity (the speed of flow along the river) is commonly used for initial assessments of the potential for erosion
- The bed shear stress represents the force between the river flow and resistance to flow provided by the bed and banks of the river channel. Shear stress is commonly used to determine the potential for sediment movement.
- Stream power provides the most reliable indicator of the potential for the river channel to erode based on the energy dissipation rate of flow along the river. It is a measure of the rate of work done by the river flow and is calculated as the product of shear stress and velocity.

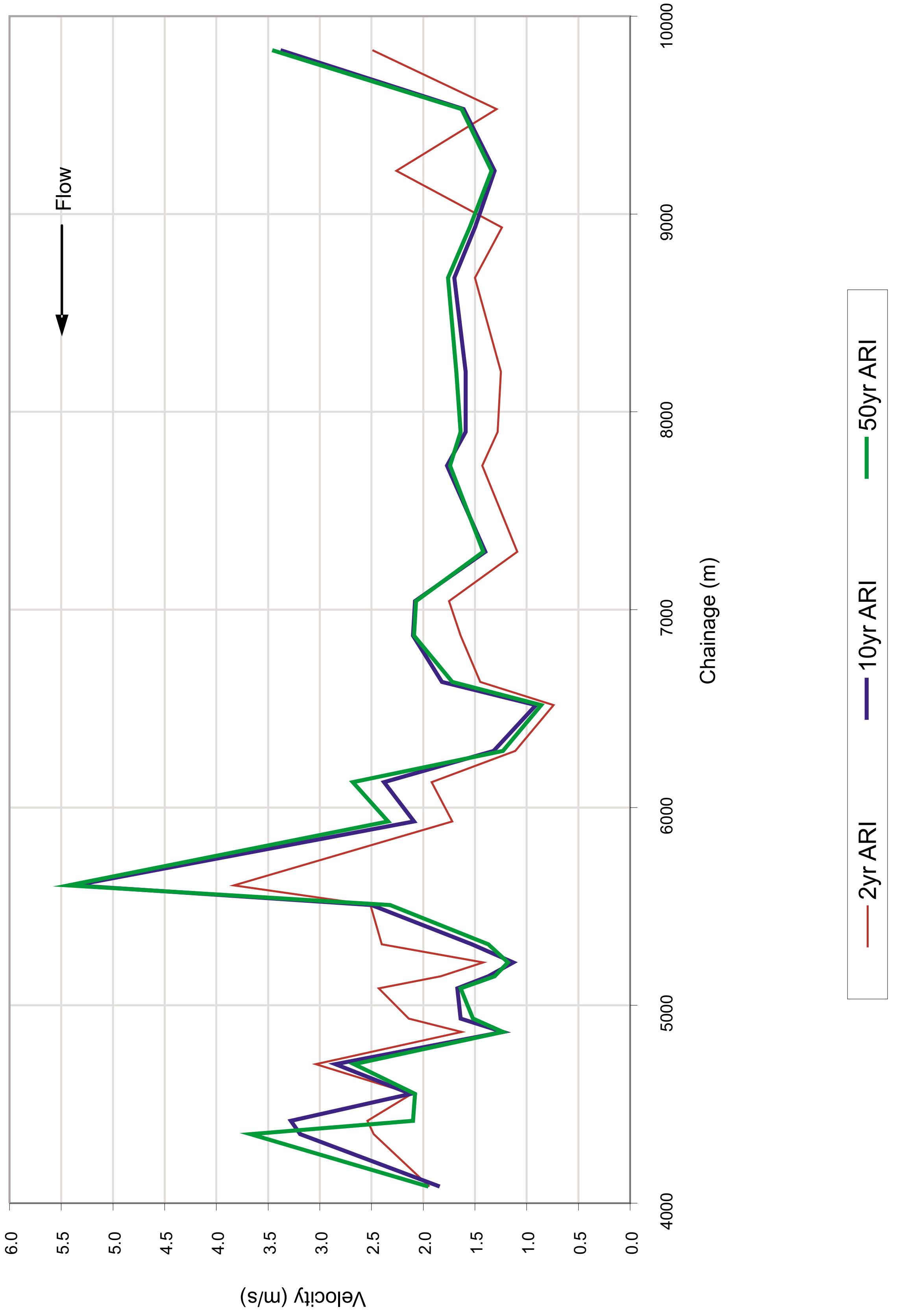
Longitudinal profiles of the existing river flow velocity and stream power for the 2, 5, 50 and 100-year ARI floods are presented in Figures 5.1 and 5.2 and are summarised in Tables 5.6 and 5.7 for the no concurrent flooding and concurrent flooding scenarios, respectively. The longitudinal profiles display the results for the Barney Creek reach that extends from its confluence with the McArthur River to immediately upstream of its confluence with Surprise Creek, and the Surprise Creek reach from approximately the southern end of the TSF to its confluence with Barney Creek. Additional hydraulic profile plots for the entire Barney and Surprise Creek reaches for all parameters and flow cases analysed are presented in Appendix F.2.

Table 5.6

Summary of Key Hydraulic Parameters for Existing Barney and Surprise Creeks Assuming No Concurrent Flooding

Hydraulic Parameter (Main Channel Flow)	Flood Event ARI	Barney Creek Upstream of Surprise Creek Confluence	Surprise Creek	Barney Creek Downstream of Surprise Creek Confluence
Velocity (m/s)	2-year	0.7 – 2.3	1.0 – 2.6	0.5 – 3.0
	5-year	0.9 – 3.2	0.7 – 2.8	0.5 – 3.7
	50-year	0.8 – 3.4	1.4 – 3.8	0.8 – 4.6*
	100-year	1.0 – 2.1	1.4 – 3.2	1.6 – 4.7
Shear Stress (N/m^2)	2-year	20 - 70	10 - 50	10 -200
	5-year	15 - 100	10 - 80	11 - 170
	50-year	12 - 120	17 - 130	30 - 150*
	100-year	15 - 65	20 - 100	20 - 150
Stream Power (W/m^2)	2-year	10 - 170	10 -100	5 - 600
	5-year	15 - 350	10 - 240	7 - 500
	50-year	10 - 400	40 - 470	10 - 700*
	100-year	10 - 140	30 - 350	20 - 700

* Results are also utilised for Surprise Creek extreme flood event analysis



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PROFILE OF VELOCITIES IN EXISTING BARNEY CREEK

Drawn: VH	Approved: CMP	Date: 27-06-2006
Job No.: **42625552**	File No. 42625552-g-212.cdr	

Figure: **5.1**

Rev. A

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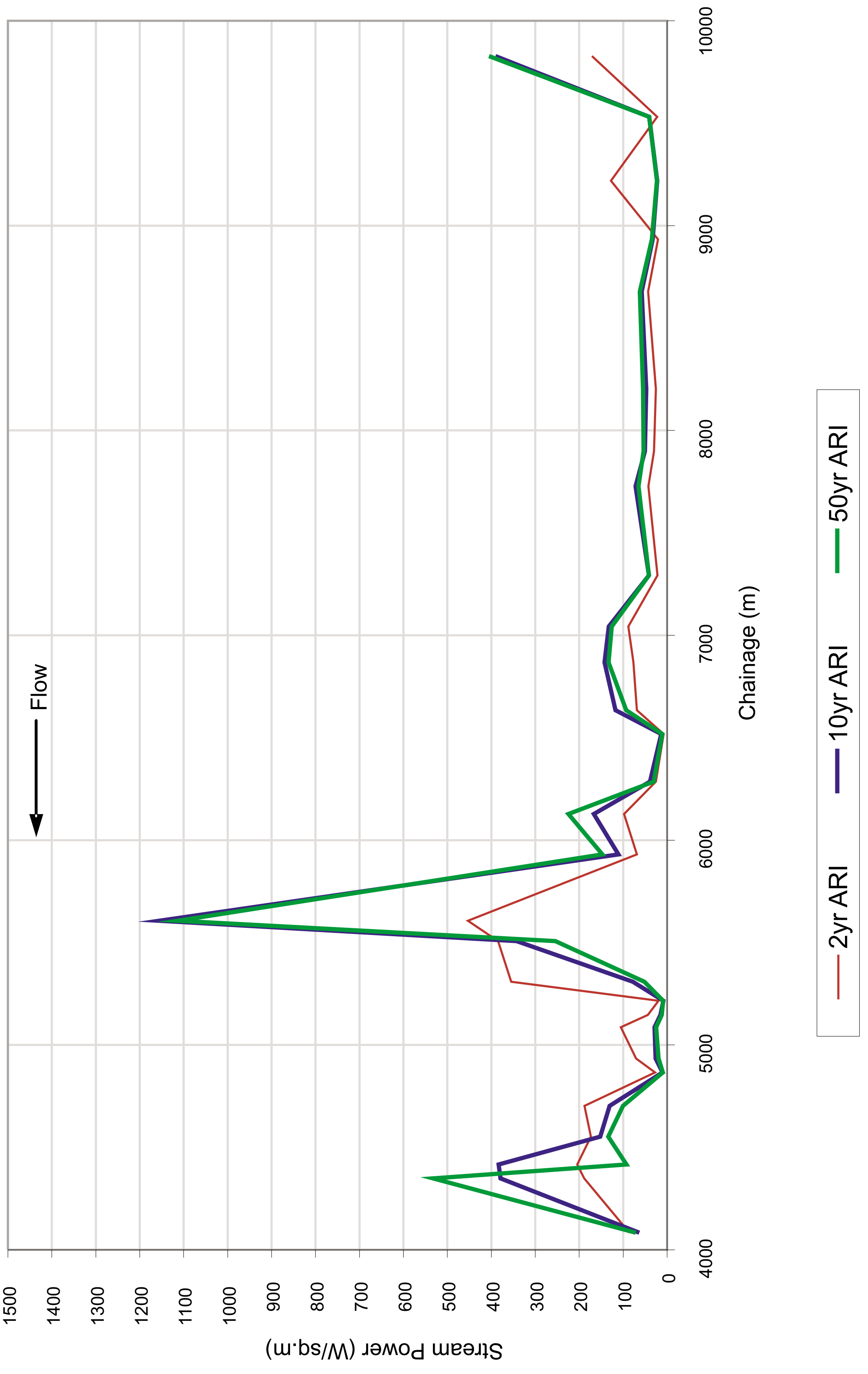

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PUBLIC ENVIRONMENTAL REPORT

PROFILE OF STREAM POWER IN EXISTING BARNEY CREEK

Drawn: VH	Approved: CMP	Date: 27-06-2006	Figure: **5.2**	Rev. A
Job No.: **42625552**	File No. 42625552-g-213.cdr			A4

Table 5.7

Summary of Key Hydraulic Parameters for Existing Barney and Surprise Creeks Assuming Concurrent Flooding

Hydraulic Parameter (Main Channel Flow)	Flood Event ARI	Barney Creek Upstream of Surprise Creek Confluence	Surprise Creek	Barney Creek Downstream of Surprise Creek Confluence
Velocity (m/s)	2-year	0.7 – 2.3	1.0 – 2.6	0.5 – 3.0
	5-year	0.9 – 3.2	0.7 – 2.8	0.4 – 3.6
	50-year	0.5 – 1.1	0.5 – 3.8	0.2 – 1.2*
	100-year	0.4 – 0.7	0.2 – 3.2	0.2 – 1.0
Shear Stress (N/m^2)	2-year	20 - 70	10 - 50	10 - 200
	5-year	15 - 100	10 - 80	6 - 90
	50-year	3 - 11	2 - 150	2 - 9*
	100-year	1 - 4	1 - 100	0.9 - 5
Stream Power (W/m^2)	2-year	10 - 170	10 -100	5 - 600
	5-year	15 - 350	10 - 240	2 -330
	50-year	1 -11	1 - 470	1 - 11*
	100-year	0.7 -3.0	0.4 -350	0.1 -4.3

* Results are also utilised for Surprise Creek extreme flood event analysis

In general, the model results show that the existing Barney Creek and Surprise Creek system exhibits higher localised velocities, shear stresses, and stream powers in Barney Creek, primarily as a result of the rock-lined reaches and rock outcroppings. The HEC-RAS model outputs for the existing creeks were checked for consistency where high values of any of the parameters (shear stress, velocity or stream power) occurred. These were checked by using ground-based or aerial photographs. In those situations, the high values generally occurred where bedrock or rock outcroppings were exposed in the channel or some other flow restriction was present. In all cases the creek channel was considered stable. The results also show that the fresh rock geology is relatively durable and can withstand larger velocities, shear stresses and stream powers.

5.6.4 Flood Capacity of Surprise Creek

A separate hydraulic model of the existing Barney and Surprise Creek system was developed in order to estimate the existing flood capacity of Surprise Creek. During a flood event in 2001, floodwater overtopped the Surprise Creek main channel and floodplain, damaged a 2 km stretch of the Carpenteria Highway, and conveyed water into Emu Creek. Two separate locations have been identified where floodwaters would likely overtop in large flooding events. The first is located in the 2 km reach of Surprise Creek, located immediately upstream of the TSF. At this location, floodwater would overtop the floodplain and enter a small drainage channel that becomes progressively wider as it approaches the Carpenteria Highway. The second is located immediately downstream of the Carpenteria Highway where the Surprise Creek floodplain extends approximately 1 km to the north-east.

To estimate the flood capacity of Surprise Creek and its floodplain at these two locations, various discharges were iteratively modelled through Surprise Creek until the floodwaters overtopped the highest elevation locations in the floodplain. The results show that the first location has a maximum capacity of approximately 500 m^3/s (approximately 20-year to 50-year ARI) before spilling to Emu Creek. The results also show that the second location has a maximum capacity of approximately 1,400 m^3/s, or approximately the peak discharge from the calculated extreme flooding event.

5.6.5 Design Requirements from PER and Follow-on Discussions

The following three design requirements were identified from the PER guidelines and follow-on discussions for the Barney Creek diversion.

1. The stability and integrity of the Barney Creek diversion should not be compromised for all modelled flood events including extreme flooding.

The Barney Creek diversion channel is designed to be a permanent feature of the landscape, and as such should have the means of conveying not only the design floods flows (2 year to 100 year ARI floods), but also the extreme flood events without compromising the stability of the diversion channel. The Barney Creek diversion channel should be designed to be stable for localised flooding in the Barney and Surprise Creek catchments (i.e. assuming no concurrent flooding in the McArthur River) because it is recognised that local storm events, including extreme flooding events, can occur over these catchments.

2. Design for vegetation establishment of the Barney Creek diversion channel through the downstream extremely weathered rock/alluvial section for flood events less than or equal to the 50 year ARI for the life of mine.

Similar to the McArthur River diversion channel design, the diversion channel for Barney Creek should be designed to allow for newly-planted vegetation in the extremely weathered rock/alluvial section reach to be able to resist flow velocities and stream powers for flood events less than or equal to the 50-year ARI. This will be achieved by limiting stream powers through the alluvial section to less than or equal to 65 W/m^2. MRM would accept the risks associated with floods larger than a 50 year ARI during the life of the mine. Potential risks would include the loss of non-established vegetation and rock and topsoil mixtures. In such an event, MRM would reinstate the vegetation and the rock and topsoil mixture as per the vegetation management plan.

3. Fish passage along Barney Creek and Surprise Creek.

It is recognised that fish passage along the existing Barney and Surprise Creeks is limited and of significantly less importance than the McArthur River. There are no permanent pools in Barney Creek and it only flows for relatively short periods following rain events. Fish can only move up Barney Creek when both it and the McArthur River are flowing. Furthermore, the existing rocky outcrops along the creek bed pose obstructions to fish passage except in periods of high flow. The diversion design will allow for fish movement for periods of high concurrent flows in both Barney Creek and the McArthur River.

5.6.6 Modelling of Original (EIS) Diversion Design

The design parameters for the Barney Creek diversion, as presented in the Draft EIS, were as follows:

- Assume concurrent flooding in Barney Creek and McArthur River (i.e. backwater from McArthur River) for all ARIs (2-year to 100-year)
- Minimise earthworks for diversion excavation (tie into unnamed creek at downstream end)
- Upstream 600 m of diversion channel partially through competent rock
- Diversion channel to be excavated through mostly alluvium
- Utilise rock lining where necessary to reduce potential for erosion (D_{50} = 600 mm) in diversion channel and limit velocities to less than 4.5 m/s
- Vary cross-section width (15 m to 40 m) to reduce velocities in channel
- Design haul road crossing bridge with piers.

Table 5.8 summarises the maximum velocities and stream powers for the original (EIS) diversion channel assuming concurrent flooding in the McArthur River.

Table 5.8

Key Hydraulic Parameters for Original (EIS) Barney Creek Diversion Channel assuming Concurrent Flooding

ARI	Upstream of Haul Road Bridge		Downstream of Haul Road Bridge	
	Max. Velocity (m/s)	Max. Stream Power (W/m^2)	Max. Velocity (m/s)	Max. Stream Power (W/m^2)
2-year to 5-year	2.3	70	3.0	400
50-year to 100-year	2.6	200	4.5	600

This design for the Barney Creek diversion channel would enable it to remain a relatively stable channel because of the large diameter rock lining proposed and the high tailwater elevations from the assumed concurrent flooding in the McArthur River. However, the stream powers for all events were generally greater than 65 W/m^2 and would threaten the stability of newly-planted vegetation.

The case of no concurrent flooding of the McArthur River was also modelled for the original diversion design. The results are presented in Table 5.9.

Table 5.9

Key Hydraulic Parameters for Original (EIS) Barney Creek Diversion Channel Assuming No Concurrent Flooding

ARI	Upstream of Haul Road Bridge		Downstream of Haul Road Bridge	
	Max. Velocity (m/s)	Max. Stream Power (W/m^2)	Max. Velocity (m/s)	Max. Stream Power (W/m^2)
2-year to 5-year	2.2	150	4.5	800
50-year to 100-year	2.8	400	6.5	2,000

The above model results shows that the velocities will exceed 4.5 m/s for all flood events at the downstream end of the diversion channel as it flows into the unnamed creek. This exceeds the threshold velocity for 600 mm diameter rock and would create significant scour and erosion. Additionally, the stream powers for all modelled flood events would exceed 65 W/m^2, threatening the establishment of vegetation.

5.6.7 Design Modifications to Diversion Channel

Due to the risks to channel stability associated with the high velocities and stream powers associated with the original design, particularly for the case of no concurrent flooding in the McArthur River, the original Barney Creek diversion design has been modified. The basis of the design modifications is outlined in this sub-section.

Figure 4.4 shows the proposed layout of the modified diversion channel and the flood protection bund. The longitudinal section of the modified creek diversion is shown in Figure 5.3 while Figure 5.4 shows the typical cross sections.

Hydraulic Design Objective

The objective of the modified hydraulic design of the Barney Creek diversion is to establish hydraulic behaviour that is similar to that of the existing creek system, to ensure that the diverted channel is stable and supportive of revegetation, and to protect the upstream and downstream reaches from any detrimental changes in creek hydraulics. As described in Section 5.6.2, the existing Barney Creek channel is sinuous downstream of its confluence with Surprise Creek with rock outcropping through the first 500 m. The remainder of the reach consists generally of alluvial deposits from backwater as a result of flooding in the McArthur River. This combination of creek sinuosity and high roughness locations as a result of the exposed rock, allows for energy dissipation in the creek before flows join the McArthur River. Therefore a similar energy dissipation system has been incorporated into the design of the Barney Creek diversion.

The diversion alignment as described in the Draft EIS was determined by the constraints provided by the local topography, the existing channel geometry, the location of the flood protection bund, and the location of the Overburden Emplacement Facility (OEF). This alignment has largely remained unchanged. However minor alignment changes have occurred based on further consideration of the

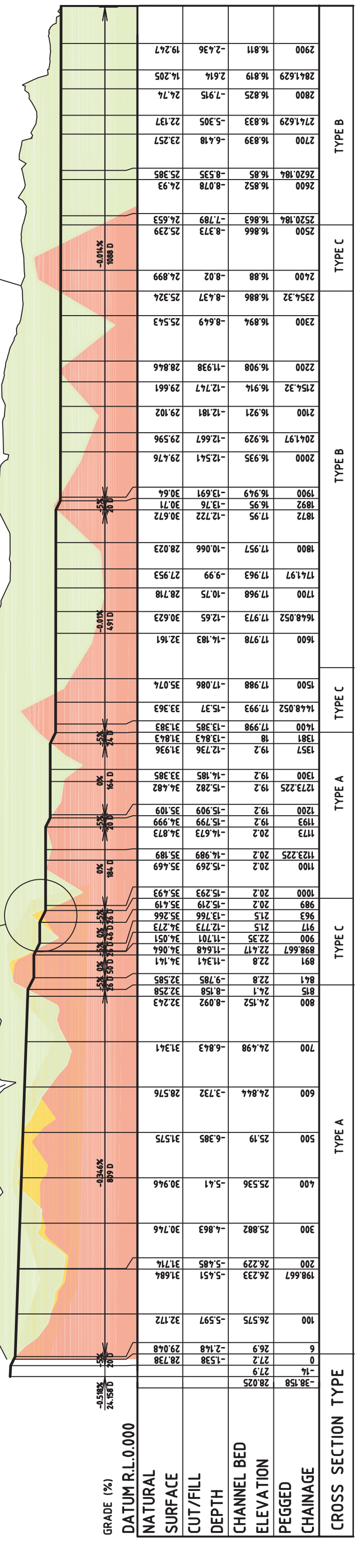
BARNEY CREEK DIVERSION CHANNEL MATERIAL LEGEND

- 🟩 ALLUVIUM
- 🟨 EXTREMELY WEATHERED ROCK
- 🟥 SLIGHTLY WEATHERED ROCK

ARI	MAX. VELOCITY (m/s)	MAX. STREAM POWER (W/m²)
2yr	1.1	19
5yr	1.4	38
10yr	1.6	55
50yr	1.9	65

ARI	MAX. VELOCITY (m/s)	MAX. STREAM POWER (W/m²)
2yr	5.3	1,800
5yr	5.8	1,830
10yr	6.1	1,830
50yr	6.4	1,930

ARI	MAX. VELOCITY (m/s)	MAX. STREAM POWER (W/m²)
2yr	2.8	190
5yr	3.2	320
10yr	2.4	105
50yr	2.1	60



PEGGED CHAINAGE	CHANNEL BED ELEVATION	CUT/FILL DEPTH	NATURAL SURFACE
-38.158	28.025		
-14	27.9		
0	27.2	-1.538	28.738
6	26.9	-2.148	29.048
100	26.575	-5.597	32.172
198.667	26.233	-5.451	31.684
200	26.229	-5.485	31.714
300	25.882	-4.863	30.746
400	25.536	-5.41	30.946
500	25.19	-6.385	31.575
600	24.844	-3.732	28.576
700	24.498	-6.843	31.341
800	24.152	-8.092	32.243
815	24.1	-8.158	32.258
841	22.8	-9.785	32.585
891	22.8	-11.341	34.141
898.667	22.417	-11.648	34.064
900	22.35	-11.701	34.051
917	21.5	-12.773	34.273
963	21.5	-13.766	35.266
989	20.2	-15.219	35.419
1000	20.2	-15.293	35.493
1100	20.2	-15.269	35.469
1123.225	20.2	-14.989	35.189
1173	20.2	-14.673	34.873
1193	19.2	-15.799	34.999
1200	19.2	-15.909	35.109
1273.225	19.2	-15.282	34.482
1300	19.2	-14.185	33.385
1357	19.2	-12.736	31.936
1381	18	-13.843	31.843
1400	17.998	-13.385	31.383
1448.052	17.993	-15.37	33.363
1500	17.988	-17.086	35.074
1600	17.978	-14.183	32.161
1648.052	17.973	-12.65	30.623
1700	17.968	-10.75	28.718
1741.97	17.963	-9.99	27.953
1800	17.957	-10.066	28.023
1872	17.95	-12.722	30.672
1892	16.95	-13.76	30.71
1900	16.949	-13.691	30.64
2000	16.935	-12.541	29.476
2041.97	16.929	-12.667	29.596
2100	16.921	-12.181	29.102
2154.32	16.914	-12.747	29.661
2200	16.908	-11.938	28.846
2300	16.894	-8.649	25.543
2354.32	16.886	-8.437	25.324
2400	16.88	-8.02	24.899
2500	16.866	-8.373	25.239
2520.184	16.863	-7.789	24.653
2600	16.852	-8.078	24.93
2620.184	16.85	-8.535	25.385
2700	16.839	-6.418	23.257
2741.629	16.833	-5.305	22.137
2800	16.825	-7.915	24.74
2841.629	16.819	2.614	14.205
2900	16.811	-2.436	19.247

CROSS SECTION TYPE

BARNEY CREEK DIVERSION CHANNEL

NOT TO SCALE

Source: Kellogg Brown & Root Pty Ltd, Drawing No. BEE508-C-DWG-202, Date 30.06.2006

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LONGITUDINAL PROFILE OF BARNEY CREEK DIVERSION

Drawn: VH
Approved: CMP
Date: 29-06-2006
Job No.: **42625552**
File No. 42625552-g-208b.cdr
Figure: **5.3**
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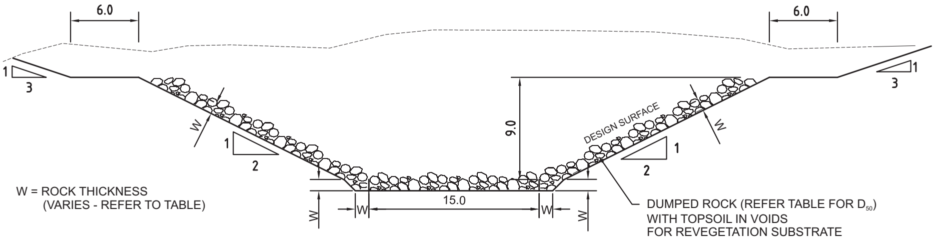
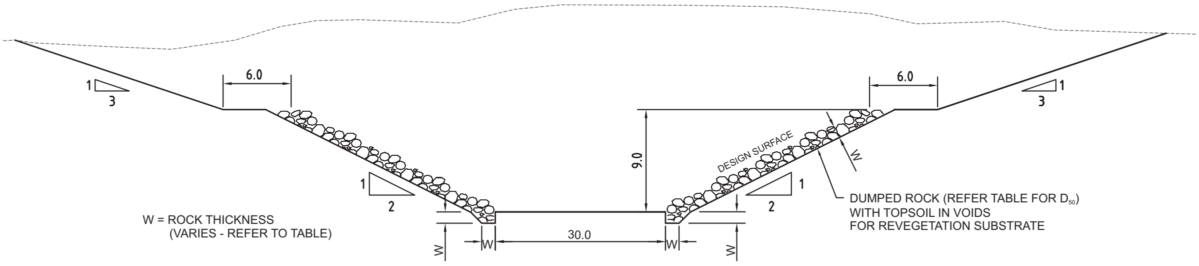


W = ROCK THICKNESS
(VARIES - REFER TO TABLE)

DUMPED ROCK (REFER TABLE FOR D_{50})
WITH TOPSOIL IN VOIDS
FOR REVEGETATION SUBSTRATE

BARNEY CREEK DIVERSION CHANNEL
TYPE A

NOT TO SCALE

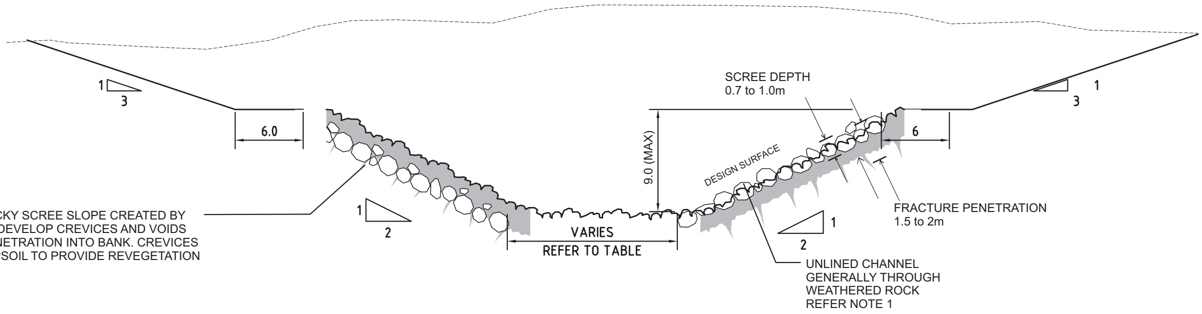


W = ROCK THICKNESS
(VARIES - REFER TO TABLE)

DUMPED ROCK (REFER TABLE FOR D_{50})
WITH TOPSOIL IN VOIDS
FOR REVEGETATION SUBSTRATE

BARNEY CREEK DIVERSION CHANNEL
TYPE B

NOT TO SCALE



NOTE 1
FRACTURED ROCKY SCREE SLOPE CREATED BY OVER BLAST TO DEVELOP CREVICES AND VOIDS 1.5m TO 2.0m PENETRATION INTO BANK. CREVICES FILLED WITH TOPSOIL TO PROVIDE REVEGETATION SUBSTRATE.

SCREE DEPTH
0.7 to 1.0m

FRACTURE PENETRATION
1.5 to 2m

UNLINED CHANNEL
GENERALLY THROUGH
WEATHERED ROCK
REFER NOTE 1

BARNEY CREEK DIVERSION CHANNEL
TYPE C

NOT TO SCALE

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TYPICAL CROSS SECTIONS OF BARNEY CREEK DIVERSION

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File No. 42625552-g-209b.cdr

Figure: **5.4**

Rev. B
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underlying geology, the modified channel geometry, bed slope and bank conditions, and the re-modelled flow parameters to ensure that the design objectives can be achieved.

Bank-Full Flow

For Barney Creek, flood flows in excess of the 2-year ARI generally break the creek banks and spread out over the floodplain. Therefore, a key design condition for the diversion is for the channel flow capacity to replicate the natural river channel ‘bank-full’ flow capacity. In this instance the ‘bank-full’ flow is approximately equivalent to the peak flows of a 2-year ARI flood event. For larger flood events, flows in the diversion channel will flow across the floodplain as is the case with the existing creek system.

Diversion Channel Geology

A geotechnical investigation (boreholes) was undertaken as part of the Draft EIS along the previously proposed Barney Creek diversion channel alignment to determine the geology that the diversion channel would be constructed through and for laboratory testing. More recently, a percussion probe survey was conducted along the revised alignment to supplement the borehole data and refine the approximate depths and extent of the geological strata, in particular the high strength, slightly-weathered rock. No laboratory testing was performed for this investigation. The percussion drilling was spaced at intervals varying from 50 to 100 m along the Barney Creek diversion channel alignment.

Three types of geology were identified: slightly-weathered rock (high strength); extremely-weathered rock (low strength); and alluvial material. The location of these geological materials along the diversion’s longitudinal section is shown in Figure 5.3. The occurrence of the higher strength slightly-weathered rock is also evidenced by the presence of rock outcroppings and rock bars in the existing Barney Creek channel at and near its confluence with Surprise Creek.

Modified Diversion Design

Modifications have been made to the Barney Creek diversion design to ensure that it is stable under all design flow conditions and to reduce the potential for impacts to both the Barney and Surprise Creek systems upstream of the diversion and to the McArthur River downstream of the diversion. Changes to the design presented in the Draft EIS (URS, 2005a) include the following:

- The longitudinal grade of the upstream reach of the diversion channel (first 890 m) which is generally through extremely-weathered rock/alluvial material will consist of one stepped rock riffle (similar geometry to those proposed for the McArthur River diversion) at chainage 30. The reach of diversion channel after the rock riffle will have a longitudinal grade of approximately 0.34% and have a structure to transition the flows from Surprise Creek to the diversion channel.
- Rock riffle steps will be located from chainage 890 to 1550 through the slightly-weathered rock reaches and are spaced between 45 and 200 m. Large diameter rock riprap (D_{50} = 750 mm to 1,000 mm) will be placed on the banks and bed where the slightly-weathered rock (higher strength) is not encountered.

- The longitudinal grade of the downstream reach of the diversion channel (remaining 1,400 m) which is through mainly extremely-weathered rock/alluvial materials will be approximately 1V:5,000H, and includes one riffle through an small section of slightly-weathered rock
- The flood protection bund around the open cut has been moved slightly to provide additional floodplain width for less frequent flood events
- An energy dissipation chute structure is proposed at the confluence of Surprise Creek and the Barney Creek diversion channel. A conceptual design of the proposed structure is given in Drawing BEE508-C-DWG-204 in Appendix B.
- The diversion channel design includes the following geometry and parameters:
  - 15 m channel base width; 2H:1V side slopes from chainage 0 to 1550
  - 30 m channel base width; 2H:1V side slopes from chainage 1550 to 2980
  - Compound trapezoidal cross section for excavation depths > 9 m
  - In the upstream reach of the diversion where the channel will be excavated in extremely-weathered rock, coarse rock lining (D_{50} = 300 mm) will be placed on the channel bed and banks to a minimum thickness of 1 m. Voids in the coarse rock lining on channel banks will be filled with topsoil.
  - In the downstream reach of the diversion where the channel banks are in extremely-weathered rock, coarse rock lining (D_{50} = 200 mm) will be placed on the banks to a minimum thickness of 1 m. Voids in the coarse rock lining will be filled with topsoil. The rock lining is primarily intended to provide a stable substrate for the re-establishment of riverine vegetation. The rock lining will retain the topsoil on the channel banks to enable the vegetation to establish. In addition, the rock lining will provide erosion protection for the channel banks.
  - Large woody debris (LWD) will be placed in the bed of the channel to assist in rehabilitation, to provide localised habitat, and to encourage sediment trapping
  - Shallow pools (approximately 0.5m in depth) will be formed upstream of each riffle
  - The haul road will cross the diversion channel over a bridge (rather than culvert as originally proposed).

The seven riffles in the diversion channel have been designed so that the energy from the floodwaters would be dissipated by the impact of the water on the riffles By utilising the strength of the underlying slightly-weathered rock and the large diameter rock riprap, the stability of the structure can be assured. The riffles have been designed in accordance with the criteria established by Newbury and Gaboury (1994). The provision of the rock riffles will mimic the function of the existing bedrock outcrops in Barney Creek. Key design features of the riffles include the following:

- The riffle would have a maximum height of approximately 1.9 m at the edges and tapering to a U-shaped minimum height of approximately 1.4 m in the centre. An over-excavated pool, approximately 500 mm in depth will be located between adjacent riffles. This design will create a series of upstream riffle pools as slower velocity areas for fish resting.

- The downstream slope of each riffle step will be approximately 1V:20H with the upstream slope approximately 1V:5H

Fish passage across the stepped energy dissipation structure on Surprise Creek will be possible only during periods of high concurrent flows in both Barney and Surprise Creeks and the McArthur River. At such times, the stepped structure will tend to be “drowned out” by backwater from the high flows in Barney Creek and the McArthur River. However, the fish habitat value of Surprise Creek is low because there are no permanent pools, it only flows for relatively short periods following rain events, and the existing rocky outcrops along the creek bed pose obstructions to fish passage.

A summary of the realignment geometry and foundation conditions is presented in Table 5.10.

Table 5.10

Diversion Channel Realignment

Design Chainage (m)[1]	Bed Slope	Channel Bed Width (m)	Channel Side Slopes (V:H)	Foundation Conditions and General Features
0 to 890	1 : 300	15	1:2	One riffle at chainage 30 through slightly weathered rock. Base and banks of channel from chainage 50 to 870 through extremely-weathered rock/alluvium Bed and banks downstream of riffle will be rock lined (D_{50} = 300mm).
890 to 1550	Varies (5 riffles)	15	1:2	Base of diversion channel through slightly-weathered rock, except between chainages 1050 and 1150 and between 1250 and 1420 where the channel base and banks will be lined with large diameter rock (D_{50} = 750 to 1,000 mm) Bed and banks (up to 4 m above bed) in slightly weathered rock between chainage 870 and 1000 The channel banks will be lined with the large diameter rock where the slightly-weathered rock is not encountered 6 m wide benches 9 m above the channel bed, both sides of channel, with bank slope above terraces at 1 in 3.
1550 to 2980	1 : 5,000	30	1:2	Bed and banks in extremely-weathered rock/alluvium with slightly weathered rock at chainages 1950 to 2250 and 2450 to 2550 One riffle at chainage 1950 through slightly weathered rock. 6 m wide benches 9 m above the channel bed, both sides of channel, with bank slope above terraces at 1 in 3.

[1] See Figure 5.3

5.6.8 Modelling the Modified Diversion Channel

Modelling of the modified diversion channel design was undertaken using the HEC-RAS program to evaluate its hydraulic performance. The model results for the existing creek channel, as discussed in Section 5.6.3, provide a baseline for comparison with the results for the diversion.

Two separate rating curves were developed for the downstream boundary rating curve in the McArthur River by assuming no concurrent (backwater) flooding and concurrent flooding. For the scenario of no concurrent flooding, the existing-conditions McArthur River model (Section 4.5.7) was modified to reflect a single inflow to the river from Barney Creek (the McArthur River model previously included inflow from the Glyde River). The elevation-discharge rating curve at McArthur River cross section 15502 was then input as the downstream boundary condition. Table 5.11 shows the elevation-discharge relationship for the Barney Creek diversion for both cases of concurrent and non-concurrent McArthur River flooding. The 500-year ARI flood was only modelled for the no concurrent flooding scenario, because for concurrent flooding in the McArthur River, the flood levels are controlled by backwater levels from the Bukalara Range. The 500-year ARI flood was simulated in order to estimate the freeboard depth between peak flood levels and the crest of the flood protection bund.

Table 5.11

Elevation-Discharge Table for Barney Creek Diversion

ARI (years)	Barney Creek Discharge (m^3/s)	Elevation Assuming No Concurrent Flooding in McArthur River (m AHD)	Elevation Assuming Concurrent Flooding in McArthur River (m AHD)
2	450	25.46	26.12
5	680	26.67	29.08
10	930	27.61	30.50
20	1,220	28.40	34.8
50 (also Surprise Creek Extreme Flood Event)	1,400	28.83	36.9
100	1,650	29.39	39.34
500	1,740	29.75	-*

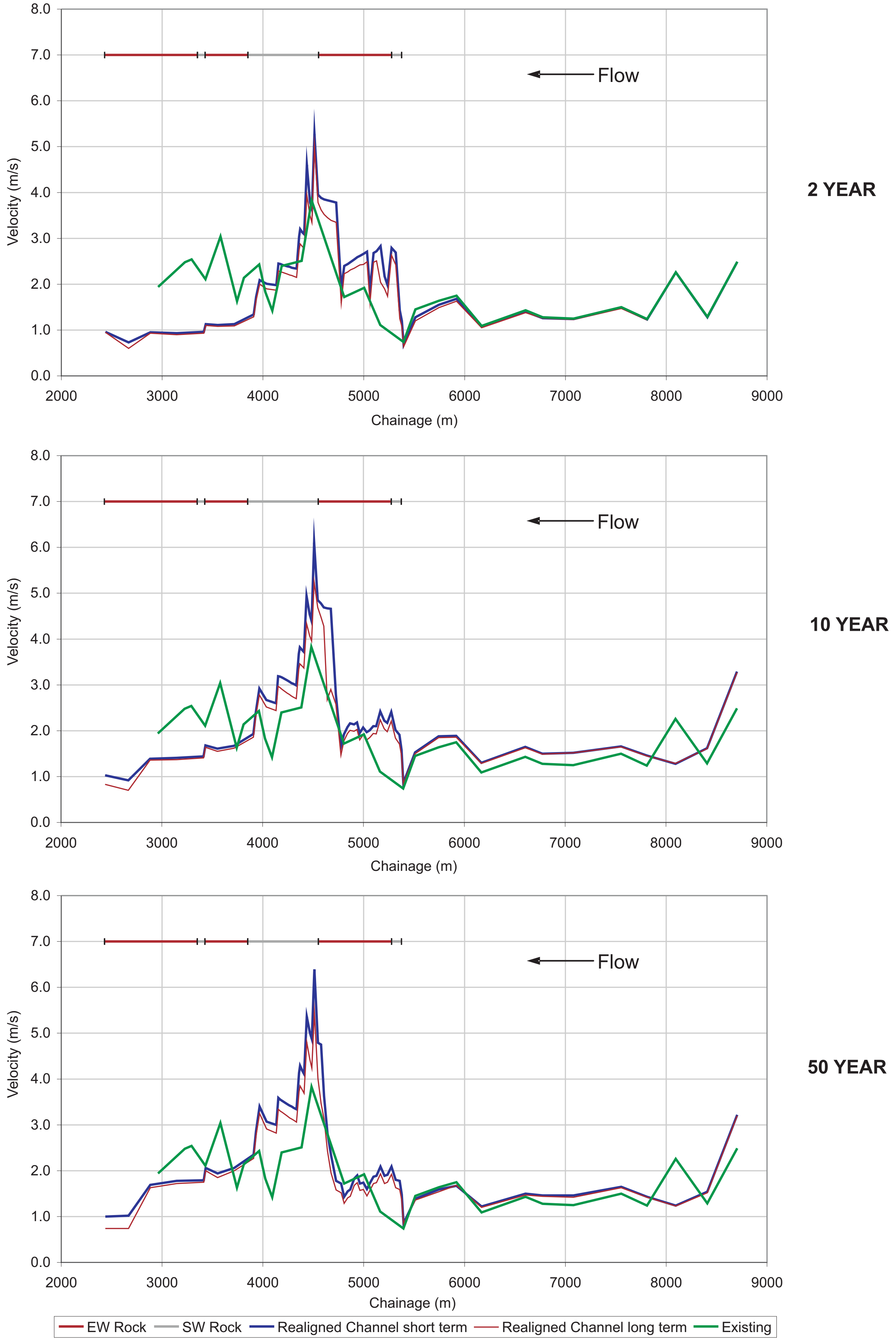
* Concurrent flooding not modelled for 500-year ARI because of flooding extents from McArthur River floodplain.

The HEC-RAS model assumed the same roughness coefficients as described in Section 5.6.2 for the undiverted reaches of Barney Creek and Surprise Creek. The estimated roughness coefficients for the diverted Barney Creek channel, for short-term vegetation conditions (i.e. immediately after opening the diversion channel) and for long-term vegetation conditions, are presented in Table 5.12.

Table 5.12

Roughness Coefficients for Barney Creek Diversion

Diversion Reach	Short-term Vegetation Conditions		Long-term Vegetation Conditions	
	Channel	Floodplain	Channel	Floodplain
Rock excavated steps	0.035	0.079	0.04	0.079
Rock lined through alluvium	0.035	0.079	0.04 – 0.06	0.079



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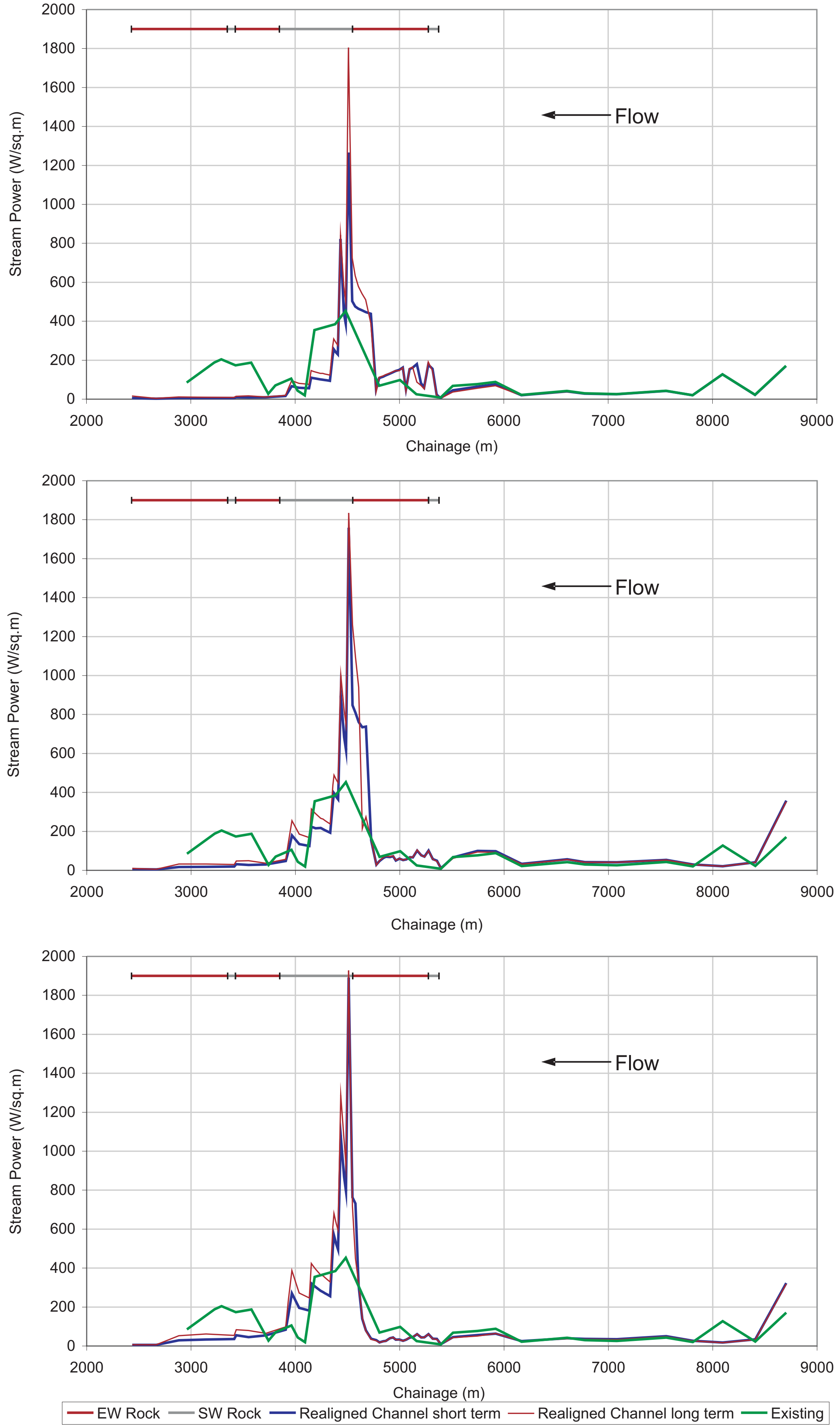
McARTHUR RIVER MINE
OPEN CUT PROJECT
PUBLIC ENVIRONMENTAL REPORT

PROFILE OF VELOCITY IN DIVERTED BARNEY CREEK ASSUMING NO CONCURRENT FLOODING IN McARTHUR RIVER

Drawn: VH	Approved: CMP	Date: 27-06-2006	Figure: **5.5**
Job No.: **42625552**	File No. 42625552-g-210b.cdr		Rev. B A4



2 YEAR

10 YEAR

50 YEAR

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McARTHUR RIVER MINE
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PROFILE OF STREAM POWER IN DIVERTED BARNEY CREEK ASSUMING NO CONCURRENT FLOODING IN McARTHUR RIVER

Drawn: VH	Approved: CMP	Date: 27-06-2006
Job No.: **42625552**	File No. 42625552-g-211b.cdr	

Figure: **5.6**

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In order to assess the potential for erosion, the predicted flow velocities and shear stresses for diversion channel design were also compared to the ACARP (2002) guidelines. These guidelines suggest maximum stream powers for stable channels for a range of geological conditions and flow events.

Summaries of the velocity, shear stress and stream power results are presented in Tables 5.13 – 5.15 and selected plots are presented in Figures 5.5 and 5.6. These plots show the results for the short-term condition before revegetation has established and for the long term after vegetation is established, both without concurrent flooding in the McArthur River. All plots for water level, velocity, shear stress and stream power are presented in Appendix F.2. The 500-year water level plot, assuming no concurrent flooding in McArthur River, shows that the maximum flood level will not reach the crest of the flood protection bund.

Table 5.13

Summary of Predicted Flow Velocities (m/s)

ARI	Existing Creek	Upstream Reach through Extremely-Weathered Rock/Alluvium Section of Diversion (Ch 50-890)		Slightly-Weathered Rock Section of Diversion (Ch 890-1,550)		Downstream Reach through Extremely-Weathered Rock/Alluvium Section of Diversion (Ch 1,550-2,980)	
		Model Result	ACARP Guideline	Model result	ACARP Guideline	Model Result	ACARP Guideline
2-year	0.7 – 2.2 Max 3.0	1.6 – 2.5 Max. 2.8	1 - 1.5	2.5 – 3.5 Max. 5.3	1.3 - 1.8	0.9 – 1.1 Max. 1.1	1 - 1.5
5-year	1.0 – 2.5 Max 3.7	1.8 – 2.5 Max. 3.2	Not defined	2.2 – 4.0 Max. 5.8	Not defined	1.0 – 1.4 Max. 1.4	Not defined
10-year	1.4 – 2.5 Max 4.5	1.8 – 2.1 Max. 2.4	Not defined	2.0 – 4.5 Max. 6.1	Not defined	0.9 – 1.5 Max. 1.6	Not defined
20-year	1.4 – 3.0 Max 4.6	1.5 – 1.8 Max 2.1	Not defined	2.0 – 5.0 Max. 6.3	Not defined	1.0 – 1.9 Max 1.9	Not defined
50-year	1.4 – 2.5 Max. 4.6	1.3 – 1.8 Max. 2.1	1.5 - 2.5	2.0 – 4.5 Max. 6.4	2.0 - 3.0	1.2 – 1.9 Max. 1.9	1.5 - 2.5
100-year	1.7 – 2.6 Max. 4.7	1.5 – 1.7 Max. 2.0	Not defined	2.0 – 5.0 Max. 6.3	Not defined	1.5 – 2.0 Max. 2.2	Not defined

Table 5.14

Summary of Predicted Shear Stresses (N/m^2)

ARI	Existing Creek	Upstream Reach through Extremely-Weathered Rock/Alluvium Section of Diversion (Ch 50-890)		Slightly-Weathered Rock Section of Diversion (Ch 890-1,550)		Downstream Reach through Extremely-Weathered Rock/Alluvium Section of Diversion (Ch 1,550-2,980)	
		Model Result	ACARP Guideline	Model result	ACARP Guideline	Model Result	ACARP Guideline
2-year	20 - 50 Max 200	30 - 50 Max. 73	<40	50 - 125 Max. 360	<55	6 - 10 Max. 10	<40

ARI	Existing Creek	Upstream Reach through Extremely-Weathered Rock/Alluvium Section of Diversion (Ch 50-890)		Slightly-Weathered Rock Section of Diversion (Ch 890-1,550)		Downstream Reach through Extremely-Weathered Rock/Alluvium Section of Diversion (Ch 1,550-2,980)	
		Model Result	**ACARP Guideline**	**Model result**	**ACARP Guideline**	**Model Result**	**ACARP Guideline**
5-year	30 - 70 Max 170	30 – 50 Max. 100	Not defined	50 - 150 Max. 360	Not defined	8 - 14 Max. 14	Not defined
10-year	30 - 80 Max 140	20 – 40 Max. 47	Not defined	50 - 150 Max. 350	Not defined	12 - 20 Max. 20	Not defined
20-year	30 - 70 Max 150	20 – 30 Max. 35	Not defined	50 - 250 Max. 360	Not defined	8 - 20 Max. 20	Not defined
50-year	30 - 60 Max. 150	18 - 30 Max. 30	<80	30 - 200 Max. 350	<120	10 - 30 Max. 30	<80
100-year	30 - 60 Max. 150	12 -32 Max. 32	Not defined	50 - 200 Max. 340	Not defined	10 -30 Max. 30	Not defined

Table 5.15

Summary of Predicted Stream Powers (W/m^2)

ARI	Existing Creek	Upstream Reach through Extremely-Weathered Rock/Alluvium Section of Diversion (Ch 50-890)		Slightly-Weathered Rock Section of Diversion (Ch 890-1,550)		Downstream Reach through Extremely-Weathered Rock/Alluvium Section of Diversion (Ch 1,550-2,980)	
		Model Result	**ACARP Guideline**	**Model result**	**ACARP Guideline**	**Model Result**	**ACARP Guideline**
2-year	10 -80 Max 600	50 – 150 Max. 190	20 - 60	100 - 600 Max. 1,800	50 - 110	3 – 19 Max. 19	20 - 60
5-year	40 - 100 Max 470	60 -150 Max. 320	Not defined	100 - 600 Max. 1,830	Not defined	5 -38 Max. 38	Not defined
10-year	70 - 200 Max 640	30 - 50 Max. 105	Not defined	100 - 800 Max. 1,830	Not defined	10 - 55 Max. 55	Not defined
20-year	50 - 200 Max. 680	30 - 50 Max. 70	Not defined	100 - 800 Max. 1,970	Not defined	5 - 65 Max. 65	Not defined
50-year	30 - 60 Max. 700	20 - 50 Max. 60	100 - 150	100 -1,000 Max. 1,930	100 - 350	5 - 65 Max. 65	100 - 150
100-year	60 -100 Max. 700	30 - 60 Max. 60	Not defined	100 – 1,000 Max. 1,810	Not defined	5 - 70 Max. 100	Not defined

The above model results show that:

- The predicted hydraulic parameters (velocity, shear stress and stream power) for the extremely-weathered rock section of the diversion channel are generally less than those for the existing Barney Creek channel for the range of floods modelled. The long-term risk of instability for the diversion channel is therefore low.

- The predicted hydraulic parameters for the extremely-weathered rock areas of the diversion channel are less than the ACARP guidelines for limited capacity channels. The long-term risk of instability for the diversion channel is therefore low.
- Not withstanding the low risk of channel instability, large woody debris will be strategically placed in the bed of the extremely-weathered rock section of the diversion to artificially increase the hydraulic roughness, to further lower channel velocities and stream powers, to assist in sediment deposition, and to provide microhabitat for fish.
- The predicted hydraulic parameters for the slightly-weathered rock section of the diversion channel are shown to exceed the ACARP guidelines. For this reason a further analysis of its stability using the Annandale method has been undertaken (Section 5.6.9).
- The reach upstream of the diversion channel shows similar velocities and stream powers for the scenarios with concurrent flooding and no concurrent flooding and no changes are expected to existing erosion or sedimentation patterns in these areas.

5.6.9 Annandale Analysis of Stream Power and Erosion Potential of Barney Creek Diversion

Analytical Method

As discussed in Section 4.5.10, the Annandale (1995) method is considered best practice for estimating the erodibility of various geologic materials. This method utilises quantifiable geotechnical data to evaluate an Erodibility Index, K, that has been calibrated to extensive field observations and research of a wide range of materials from loose sand, cohesive clay, jointed weathered rock, to hard rock. This method has been applied to further assess the stability of the Barney Creek diversion in the same way it was used in to assess the stability of the McArthur River diversion (Section 4.5.1).

The geotechnical investigations indicated that the diversion will be based either within extremely weathered rock of low strength or slightly weathered rock of high strength. Hence an Annandale analysis was utilised for both rock types.

Extremely-Weathered Rock

An Annandale analysis was performed for the extremely-weathered rock that exists in the downstream section of the diversion based on borehole data for that area (BHB2, BHB3 and BHB4). The results of this analysis are shown in Table 5.16.

Table 5.16

Annandale Analysis Results for Extremely-Weathered Rock

Borehole	Material description at base	RQD	Jn	Jr	Ja	Ms	Kb	Kd	Js	K	Max. Stream Power (W/m^2)
BHB2	Extremely Weathered Sandstone	1	5	1	1	0.87	0.2	1	0.4	7.0E-02	140
BHB3	Extremely Weathered Shale	1	5	1	1	0.87	0.2	1	0.4	7.0E-02	140
BHB4	Extremely Weathered Sandstone	1	5	1	1	0.87	0.2	1	0.4	7.0E-02	140

Note: (1) Weathered sandstone in BHB4 comprised of extremely-weathered and distinctly-weathered sandstone and has been assessed as extremely-weathered. (2) A minimum RQD of 1 has been assigned to the extremely-weathered rock

Table 5.16 shows that the extremely-weathered sandstone and shale materials will resist erosion for a maximum stream power of 140 W/m^2.

Table 5.17 compares the modelled stream powers (no concurrent flooding in the McArthur River) in the extremely-weathered rock in the downstream section of the diversion with the results from the Annandale analysis as well as the ACARP guidelines.

Table 5.17

Comparison of Modelled and Guideline Stream Powers (W/m^2) through Downstream 1,400 m of Barney Creek Diversion through Extremely-Weathered Rock Section

ARI	Modelled Stream Power in Diversion with no Concurrent Flooding	Modelled Stream Power in Existing Creek Channel	Annandale Analysis	ACARP Guidelines for Limited Capacity Channel	Annandale Analysis for D_{50}=200 mm Rock on Channel Banks
2-year	19	600	140	<60	250
5-year	38	470		Not Defined	
10-year	55	640		Not Defined	
20-year	65	680		Not Defined	
50-year	65	700		<100	
100-year	100	700		Not Defined	

Table 5.16 shows that the diversion channel through the extremely weathered rock would resist erosion for the following reasons:

- The stream powers in the diversion channel would be less than those in the existing creek channel
- The Annandale analysis results show that the extremely weathered rock has a threshold stream power of approximately 140 W/m^2, which is greater than the maximum stream power in the diversion of 65 W/m^2 for flood events up to the 50-year ARI event (for the conservative case of no concurrent flooding)

- The predicted stream powers in the downstream 1,400 m of the diversion for both the 2-year and 50-year ARI events are within the range given in the ACARP guidelines
- The maximum stream powers in the downstream reach through the extremely weathered rock for storm events greater than the 50-year ARI would result in stream powers of up to 80 W/m^2. However, the diverted stream banks through the downstream 1,400 m will be lined with rock (D_{50} = 200 mm) that will resist erosion for stream powers up to 250 W/m^2.
- The upstream 890 m of the Barney Creek diversion channel, downstream of the first riffle, will be lined with rock riprap (D_{50} = 300 mm) on the channel bed and banks to protect the diversion channel from erosion. Table 5.19 shows that rock with a median diameter of 300 mm will resist stream powers of 630 W/m^2.
- Parts of the bed and banks of the upstream stepped reach will encounter areas of extremely-weathered rock. In these area the maximum stream powers could reach 1,900 W/m^2 and hence large diameter rock riprap (D_{50} = 750 to 1,000 mm) will be placed in the channel bed and banks to protect the diversion channel from erosion. Table 5.19 shows that large diameter rock with median diameters between 750 mm and 1,000 mm will resist stream powers of 5,000 W/m^2 and 10,000 W/m^2 respectively.

The channel bed in the downstream 1,400 m of the diversion through the extremely weathered rock/alluvium materials will be unlined because, due to the low stream powers, it would not be subject to significant erosion. Any erosion of the channel bed which did occur would be limited by the upstream slightly weathered rock and bank controls. The depth and upstream migration of any erosion of the channel bed would be limited by the presence of slightly weathered rock in the upper reach of the diversion channel. Any lateral erosion would be limited by the erosion resistant rock lining of the channel banks. The potentially erodible, but erosion constrained, channel bed will allow the creek to regenerate a natural meandering pattern for low flows in the channel without generating excessive sediment and without causing unsustainable or destructive erosion.

Based on the above results, the downstream section of the proposed diversion channel through the extremely-weathered rock would be stable in both the short-term and long-term.

Slightly-Weathered Rock

An Annandale analysis was performed for the slightly-weathered rock that would be excavated as part of the diversion based on borehole data for that area (BHC14, BHC15, and BHC31). The results of this analysis are shown in Table 5.18.

Table 5.18

Annandale Analysis Results for Slightly-Weathered Rock Section of Diversion Channel

Borehole	Material description at base	RQD	Jn	Jr	Ja	Ms	Kb	Kd	Js	K	Max. Stream Power (W/m^2)
BHC31	Slightly Weathered Shale	25	5	1	1	17.7	5.0	1	0.4	3.5E+01	14,500
BHC15	Slightly Weathered Sandstone	85	5	1	1	35	17.0	1	0.4	2.4E+02	60,600
BHC14	SW Shale	40	5	1	1	35	8.0	1	0.4	1.1E+02	34,400

Table 5.18 shows that the slightly-weathered rock strata in the diversion will resist erosion for stream powers greater than 14,500 W/m^2.

Table 5.19 compares the modelled stream powers (no concurrent flooding in the McArthur River) in the slightly-weathered rock in the upstream section of the diversion with the results from the Annandale analysis as well as the ACARP guidelines.

The Annandale analysis results, as presented in Table 5.18, show that the slightly-weathered rock strata has a threshold stream power of approximately 14,500 W/m^2, which is significantly greater than the maximum predicted stream power in the upstream section of the diversion of 1,900 W/m^2. Based on the above results, the slightly-weathered rock in the proposed diversion channel would be stable in both the short term and long term.

Table 5.19

Comparison of Modelled and Guideline Stream Powers (W/m^2) through Slightly-Weathered Rock Section

ARI	Modelled Stream Power in Diversion with no Concurrent Flooding	Modelled Stream Power in Existing River Channel	Annandale Analysis	ACARP Guidelines for Bedrock Controlled Channel	Annandale Analysis for Rock Riprap on Channel Bed and Banks
2-year	1,800	600	>14,500	50-110	630 (D_{50} = 300 mm); 5,000 (D_{50} = 7500 mm); 10,000 (D_{50} = 1,000 mm)
5-year	1,830	470		Not Defined	
10-year	1,830	640		Not Defined	
20-year	1,970	680		Not Defined	
50-year	1,930	700		100-350	
100-year	1,810	700		Not Defined	

5.7 Rehabilitation of the Proposed Diversion Channel

As discussed in Section 5.4, Barney Creek has limited value as a fish habitat when compared with that of the McArthur River. There are no permanent pools in Barney Creek and it only flows for relatively short periods following rain events. Fish can only move up Barney Creek when both it and the McArthur River are flowing. Furthermore, the existing rocky outcrops along the creek bed pose obstructions to fish passage except in periods of high flow.

Realignment of Barney Creek will create an altered riverine environment which will require effective, long-term and sustainable revegetation, consistent with existing vegetation communities along the lower reaches of the existing creek. Revegetation of the proposed diversion channel will be undertaken to help recreate the existing aquatic and riparian ecosystem function.

Along the alluvial sections of the diversion, instability of topsoil placed on the channel banks can result in young plants being scoured out. Even though soft when wet, the banks can also be compacted during construction thus restricting initial root establishment. Rapid and deep root development must be encouraged. To overcome this problem, adequate soil depth will be created by adding rock cover to at least 1 m depth and infilling with weed free, non-dispersive soil.

Using the same methods as described in Section 4.6.3 for the McArthur River, the rehabilitation strategy to be used for Barney Creek will include the following:

- Site clearing
- Topsoil and vegetation recovery
- Site preparation
- Topsoil infilling of the rock lined batter slopes
- Placement of large woody debris
- Planting of seeds and tube stock of a selection of local species
- Fertiliser application
- Maintenance activities
- Monitoring.

The existing vegetation along Barney Creek is a riverine woodland. The closed riparian corridor vegetation type found along the McArthur River is not present along Barney Creek. As discussed in Section 5.4, while vegetation provides up to 50-60% shading of the McArthur River channel, Barney Creek is much less shaded, with vegetation shading only about 10-20%.

While the banks of the Barney Creek diversion will be revegetated using the same techniques described in Section 4.6.3 for the McArthur River, there will be a slight difference in the species planted. For Barney Creek, emphasis will be on planting existing riverine woodland dominant species such as *Casuarina cunninghamiana* and *Lophostemon grandiflorus*, rather than riparian corridor species dominant along the McArthur River, such as *Barringtonia acutangula* and *Melaleuca argentea*.