CLIFF FACE STABILISATION WORKS ROCKS ROAD NELSON

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SUMMARY

State Highway 6, Rocks Road, Nelson traverses the base of a 40 m high sea cliff. Sections of this cliff face have been subject to ongoing local failures that have caused temporary closure of the state highway. The stability issues have been three fold:

(a) Creep movement of fill at the top of the cliff.
(b) Potential failure of a rock block on unfavourably oriented discontinuities.
(c) Ravelling of the rock surface.

To address these issues a reinforced concrete pile palisade wall, dowels, inclined drains and **rockfall** protection netting have been provided. This paper discusses the design and construction of the stabilising works.

1. INTRODUCTION

State Highway 6, Rocks Road, follows the foreshore southwest of Port Nelson. A cliff face rises from the road edge at an angle of typically 50º to the horizontal to a height of 40 m. A section of this cliff face has been subject to ongoing local failures that have caused temporary closures of Rocks Road. A slope failure in August 1990 comprising 500 m^3 and closing Rocks Road for several days was one such event.

Traffic disruption and the risk of injury or damage to vehicles led Transit New Zealand (TNZ) to engage Beca Carter Hollings & Ferner Ltd (BCHF) to undertake detailed investigation and design and construction monitoring of cliff face stabilisation works. Royds Garden Ltd (now Montgomery Watson New Zealand Limited (MW)) were engaged as a subconsultant (the engineer's representative to the contract) to assist with engineering geological investigations and construction monitoring. This paper discusses the design and construction of the stabilisation works.

2. GEOLOGY

The geologic structure of the cliff face is summarised on Figure 2. Sandstone, siltstone and mudstone of the Magazine Point Formation dips into the cliff at 60º with a strike subparallel to the cliff face. In the Nelson area the total thickness of this unit probably exceeds 1500 m and was deposited by turbidity currents and submarine debris flows in an early Tertiary sea. It is predominantly a moderately well indurated competent sandstone, well exposed on the foreshore in front of the cliff at low tide. However, at the project site, higher up the stratigraphic column the unit is more deeply weathered, less competent and dominated by siltstone which has given rise to rockfalls and slumping. Bedding ranges from 50 mm to 1 m thick. Joint defects include a dominant set sub-parallel to the cliff face and daylighting from the cliff face. This joint set is identified as joint set 1 on Figure 2. The cliff is 40 metres high having been formed by erosion and undercutting of the sea during the post glacial **period** over the past 6000 years. Erosion and subsequent oversteepening **of** this old sea bluff continued until construction of State Highway 6 in 1893.

3. MECHANISMS OF INSTABILITY

Three mechanisms of past and/or potential instability had been identified. These were; (a) creep movement of fill at the crest of the cliff, (b) block failures of rock on the joint set sub-paralleling the cliff face, and (c) ravelling of the rock face. Respective techniques employed to remedy these mechanisms of instability were; (a) a palisade of reinforced concrete piles, (b) dowels and inclined drains, and (c) scaling and rockfall protection netting. Figures 1 and 2 show the areas of potential instability in plan and section.

4. PALISADE OF BORED PILES

Some 4 m thickness of fill and "The Cliffs" road had been constructed at the crest of the cliff during residential and subdivisional development in the 1970's. The fill comprises soft silty clay with its outer surface stand**ing** at 40º to the horizontal. Creep type movement of this fill is evidenced by cracking in The Cliffs road surface.

Options considered to stabilise this fill included: excavation and replacement with geogrid reinforced fill, excavation and construction of a crib retaining wall, and construction of a palisades reinforced concrete piles. The palisade of piles was selected because it was assessed to be the most cost effective option and had the added benefit of causing minimum disturbance during construction. The stabilising works could be constructed without disturbing the road and underground services. 500 mm diameter reinforced concrete piles at 1.5 m centres embedding 3 m into the colluvium and rock underlying the fill were constructed to form a 30 m length of pile palisade.

5. DOWELS AND INCLINED DRAINS

Increased shearing resistance along the potential failure planes of joint set 1 (refer Figure 2) was provided by installing steel dowels and inclined drains. The steel dowels comprised HD40 reinforcing bars of 6 m length grouted into 75 mm diameter holes drilled perpendicular to the joint set. These steel dowels were provided on a grid of 3 m spacing downslope and 3 m spacing across slope. The dowels are to act as "shear pins" and were sized to increase the factor of safety against shear failure for both the static and the earthquake design case.

It was noted that past instability of this section of rock face has coincided with heavy rain fall events. It is probable that build-up of water pressure in the rock joints during and following rain contributes to cause the instability. Inclined drains extending beyond the daylighted joint sets were installed on a grid of 3 m spacing downslope and 3 m spacing across slope. The drains comprise 7 m long 50 mm diameter slotted PVC pipe installed in 75 mm diameter drilled holes.

The section of rock face identified as requiring dowel and inclined drain stabilising works measured 15 m across slope and 30 m downslope.

6. ROCKFALL PROTECTION NETTING

A 60 m long section of the 40 m high cliff face was identified as presenting a high potential hazard of rockfall and thus was treated with rockfall protection netting.

Galvanised and PVC coated double twisted mesh was used. The mesh was hung from an anchorage system, at the crest of the cliff, comprising a steel rope catenary spanning between anchors at 1 m spacings. The anchorage system was designed to have a greater holding capacity than the mesh it supports. At the base of the cliff a similar anchorage system comprising steel rope, strops and anchors, allows the netting to lift 300 mm to expel debris. It can also be disconnected for periodic removal of any collected debris.

With this rockfall protection netting in place any rock dislodged from the face is able to fall in a controlled manner beneath the netting to collect at the base. Prior to permanently placing the netting loose rock was scaled from the cliff face.

7. CONSTRUCTION

The site works were started in mid April 1994 by Hampton Construction of Paraparaumu using a small, and slow but effective, 2 man crew. Once vegetation was cleared an engineering geologic inspection was undertaken to confirm joint set orientation and set out the extent and location of construction works. For reasons of safety, control and cost effectiveness the cliff face was inspected by abseiling. Introductory abseil training was provided through the local caving group and rope anchors were installed, tested and approved for the "white knuckle" geotechnical inspection. Owing to the slope steepness (50° to near vertical), the height above the highway (40m) and the heavy vehicle traffic below special techniques were employed whenever personnel were moving around on the cliff face. These included:

- double line rope access (a working rope and a safety tie off)
- positioning 'spotters' in radio contact on the highway below (to control traffic when material became dislodged)
- securing all loose equipment with rope/rubber cord (ie rock hammer, Brunton compass, cans of spray paint etc)
- continuous, regular radio contact with backup personnel at the top when beyond line-of-sight.

The design work was undertaken by BCHF in Wellington with the Nelson office of Montgomery Watson handling implementation of the geotechnical investigation and the day to day construction monitoring. As a consequence a well co-ordinated, transparent flow of communication between the two partners was critical to the success of the project.

Modifications to the original construction work set out and extent were confirmed early on and the completed stabilisation works consisted of:

- 23 bored piles to 6 m (30 m of pile palisade)
- 48 grouted rock dowels
- 19 inclined drains
- **59** top net anchors (to 3 m)
- 19 detachable bottom net anchors (to 1.5 m)
- 2700 m^2 rockfall protection netting (60 m length)
- **280** m^3 scaling
- 45 metres of 1.8 m high security fence at the top
- 60 m^3 additional scaling outside of the project site

A total of 5 variations were approved and implemented during the extended construction period including:

- an extension of the depth (and number) of top anchors due to unfavourable ground conditions. A reinforced concrete strip was added at the head of the anchors
- removal of loose materials (deep soil cracks) elsewhere along the cliff top identified during a 400m **inspection** traverse (Royds Consulting, 1994)
- an extension of the netting 18m to the south.

On completion of the initially proposed rockfall protection netting a slump of approximately 120 m^3 occurred at the southern limits of the works. That portion of the slump beneath the netting was contained resulting in a controlled release of rock and soil some 40 m below. As a consequence of the excellent performance **of the netting** and **the** potential for further rockfall to the south it was decided to extend the netting 18 m south.

Rock blasting and shotcrete work allowed for in the original contract was found to be unnecessary with extension of the netting and additional scaling selected as the most cost effective way of safely reducing risk to the highway. The construction period for the work was extended well beyond the original 12 week period by an additional 32 weeks owing to the construction technique and difficult access to the project work face. Five separate time extensions, were approved. Four weeks of liquidation damage were assessed to the contactor and additional construction supervision fees were allowed due to the extended work duration.

8. CONCLUSION

This project employed traditional rock slope stabilising and protection techniques which are not commonly used in New Zealand. The stabilising and protection works proved successful with there being no rock block failures or debris falling onto this section of the state highway since the construction of the works in 1994. While issues of instability remain to be addressed elsewhere along portions of SH-6 to the north, this work has been very successful in effectively addressing the most immediate stability issue. A total of 60 m length of cliff face was treated at a cost of approximately $250,000 (1994).

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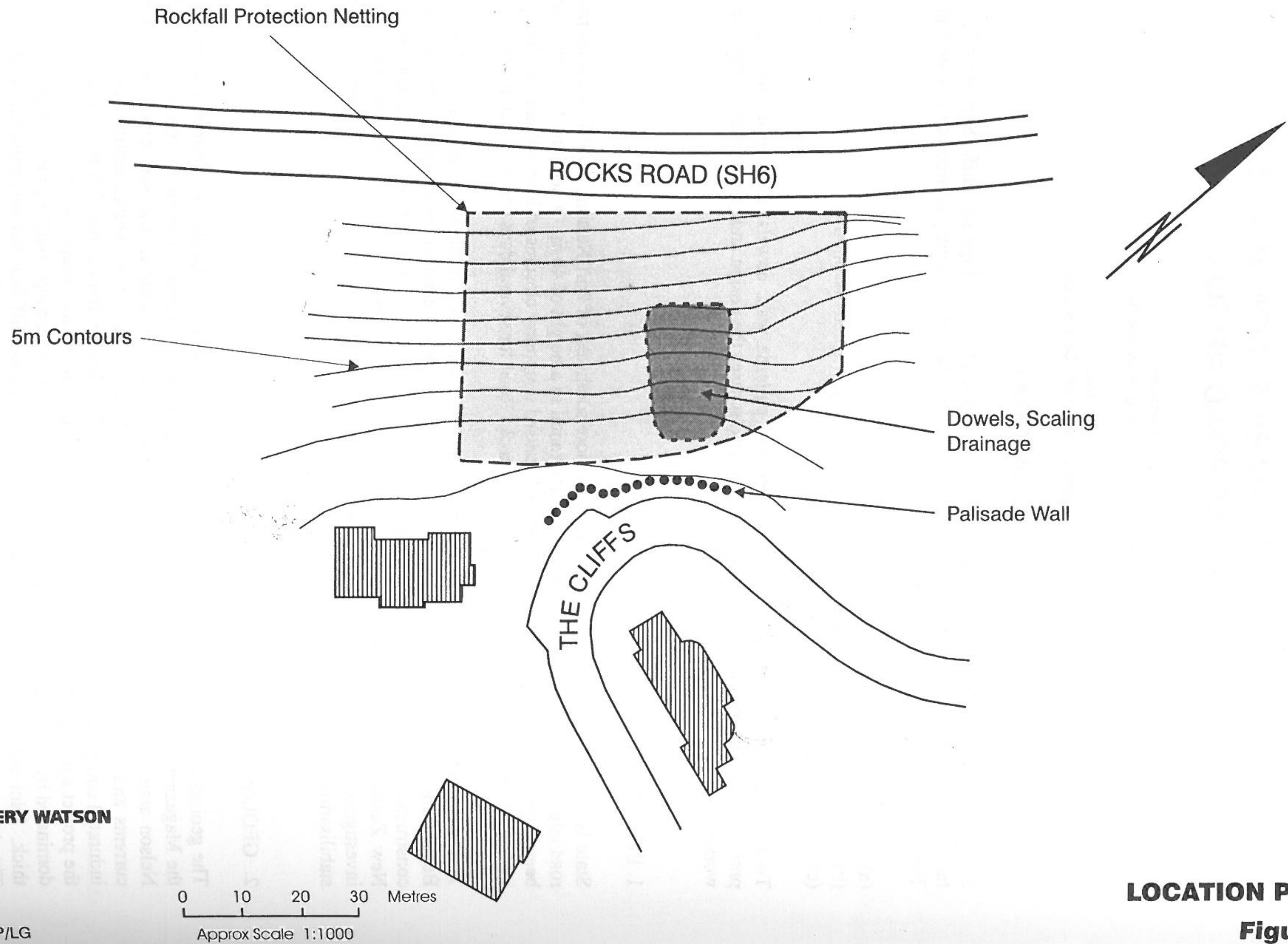

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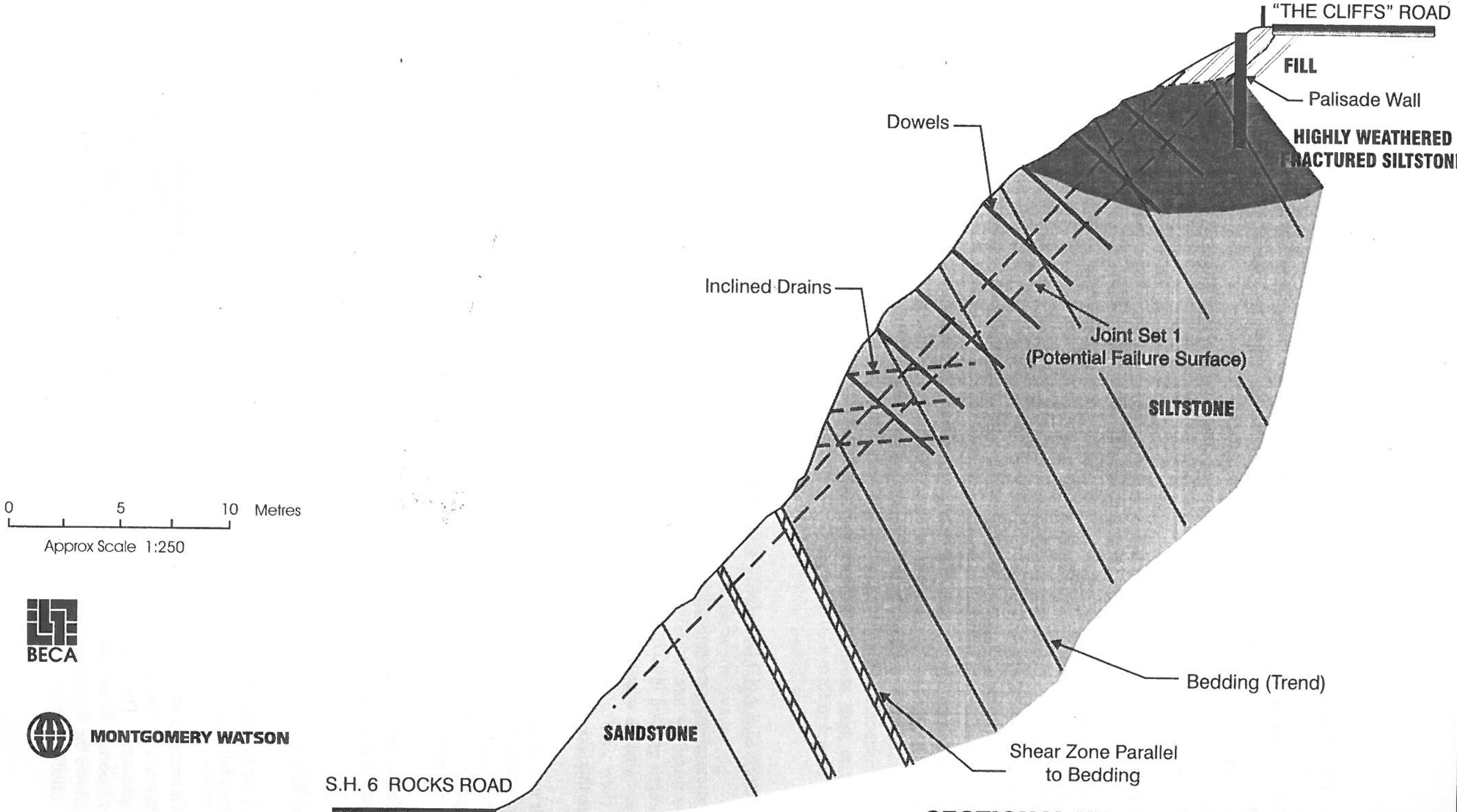
LOCATION PLAN

Figure 1



SECTIONAL VIEW LOOKING NORTH EAST

Figure 2

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