Review of Engineering Geological Aspects of Hong Kong West Drainage Tunnel

GEO Report No. 372

K.L.H. Lo

Geotechnical Engineering Office
Civil Engineering and Development Department
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Preface

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (http://www.cedd.gov.hk) on the Internet.

Raymond W M Cheung
Head, Geotechnical Engineering Office
February 2024

Foreword

This report presents the findings from the review of engineering geological aspects of Hong Kong West Drainage Tunnel. The objective of the study is to compare and contrast the pre-construction and post-construction engineering geological models of the tunnel.

This study was carried out by Mr Kevin L.H. Lo of the Hong Kong Geological Survey of the Planning Division. It has been reviewed by Dr Denise L.K. Tang.

Jeffrey C F Wong
Chief Geotechnical Engineer/Planning

Abstract

Tunnel mapping records are invaluable resources for geotechnical practitioners as these records provide a factual account of the subsurface ground conditions along the tunnels. Hong Kong West Drainage Tunnel traverses from Tai Hang to Cyberport, crossing crosses different rock formations, eight major faults as well as subsidiary faults, shear zones and contact zones in the western part of Hong Kong Island. The consultants' design models and the contractor's as-built tunnel mapping records of the project have been reviewed to evaluate the ground model along the tunnel alignment in detail. Review of geological conditions, including lithology, major faults, minor faults, photolineaments, joints as well as the rock mass quality and groundwater conditions of the main tunnel were conducted.

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1 Introduction

1.1 Objectives of this Study

Tunnelling works form an integral part of infrastructure development in Hong Kong. Prior to construction, sufficient site investigations, adequate characterisation of ground conditions and timely recognition of adverse geological features are indispensable in managing geotechnical risk of a tunnelling project. During construction, subsurface ground conditions encountered along the tunnel are carefully mapped and recorded. These tunnel mapping records provide a factual account of the ground conditions which will serve as an invaluable resource for geotechnical practitioners for future infrastructure development.

The objective of this review study is to compare and contrast the pre-construction and post-construction engineering geological models of the main tunnel of Hong Kong West Drainage Tunnel (HKWDT; Figure 1.1). The drainage tunnel traverses from Tai Hang to Cyberport, crossing different rock formations, eight major faults as well as subsidiary faults, shear zones and contact zones in the western part of Hong Kong Island. The consultants' design models and the contractor's as-built tunnel mapping records of the project have been reviewed to evaluate the ground model along the tunnel alignment in detail.

1.2 Project Background

Hong Kong West Drainage Tunnel (HKWDT) consists of a 10.7-km main drainage tunnel (hereafter main tunnel) traversing from Tai Hang to Cyberport, 34 intakes and around 8-km long adits connecting the intakes with the drainage tunnel. The drainage tunnel intercepts stormwater collected from the upper catchment at the Mid-Levels area and discharge into the sea directly. The invert levels of the tunnel ranges from +3.44 mPD near Cyberport to +47.97 mPD near Tai Hang. The HKWDT project was commenced in November 2009 and completed in August 2012. The Drainage Services Department (DSD) was the Client for the project. Ove Arup and Partners Hong Kong Limited and Dragages-Nishimatsu Joint Venture (DNJV) were the design consultants and contractor for the project, respectively.

Under Agreement No. CE 17/2005 (DS) – "Design and Construction of Hong Kong West Drainage Tunnel", a Geotechnical Interpretation Report (Arup, 2007) was prepared by Project's design consultant. This report presented a detailed pre-construction geological/engineering geological model for the tunnel project, based on desk study data and site-specific ground investigation data (i.e. 57 vertical drillholes, 16 inclined drillholes, 1 horizontal drillhole and associated field/laboratory tests). At the subsequent construction stage, tunnel face mapping at varying intervals ranging from 5-90 m were conducted by the contractor. The geological data was then summarized into as-built geological long sections (DNJV, 2011) of the tunnel alignment.

The main tunnel was constructed by two hard rock Tunnel Boring Machines (TBM) with excavation diameters of 7.2 m for the eastern TBM and 8.2 m for the western TBM. The horizontal adits connected to the main tunnel were excavated by drill and blast method. The 34 intake structures that were used to collect and convey stormwater were constructed in the form of dropshafts primarily by raise boring method (23 nos.) as well as reverse circulation drilling and mechanical excavation for the remaining intakes.

1.3 Site Geology

According to the 1:20,000-scale geological map Sheet 11 (GCO, 1986; GEO, 2012), the main tunnel traverses from fine-grained granite and fine- to medium-grained granite of the Mount Butler Granite at around CH 0 – 3300, medium-grained granite of the Kowloon Granite at around CH 3300 – 3750, fine ash vitric tuff of the Ap Lei Chau Formation at around CH 3750 – 7900, coarse ash crystal tuff of the Mount Davis Formation at around CH 7900 – 8800, fine ash vitric tuff and eutaxitic fine ash vitric tuff of the Ap Lei Chau Formation at CH 8800 – 9800, fine-grained granite of the Mount Butler Granite at around CH 9800 – 10000, and to coarse ash crystal tuff and eutaxitic crystal-bearing fine ash vitric tuff at around CH 10000 – 10700 (Figure 1.2). A band of tuffaceous sedimentary rock of the Mount Davis Formation was mapped at approximately CH 8700. The tuffs at approximately CH 6550 – CH 7500 are inferred to have been affected by contact metamorphism, based on earlier studies by Strange & Shaw (1986).

The major structural features along the main tunnel are dominated by faults, photolineaments, and a series of folds. Five persistent faults, two of which trend northwest, two of which trend northeast and one of which trends north, intersect the main tunnel at different orientations. A northeast-trending fault is in close proximity to the main tunnel alignment at around CH 8450 – 8950. Four photolineaments, of varying orientations, intercept the main tunnel at different locations (i.e. CH 1850, CH 3300, CH 5700 and CH 6300). The volcanic strata beneath High West and Victoria Peak were folded into a series of anticlines and synclines, but the fold axes do not intercept with the main tunnel alignment as shown in the published geological maps.

The Quaternary superficial deposits cover the low-lying areas. Colluvium commonly occurs along valleys, drainage lines as well as the Mid-levels Area (at around CH 7750 – 8500). However, with the exception of the portal areas, the main tunnel was largely situated within rock at depths well below the soil/rock interface with a rock cover of 100 m or greater (Arup, 2007).

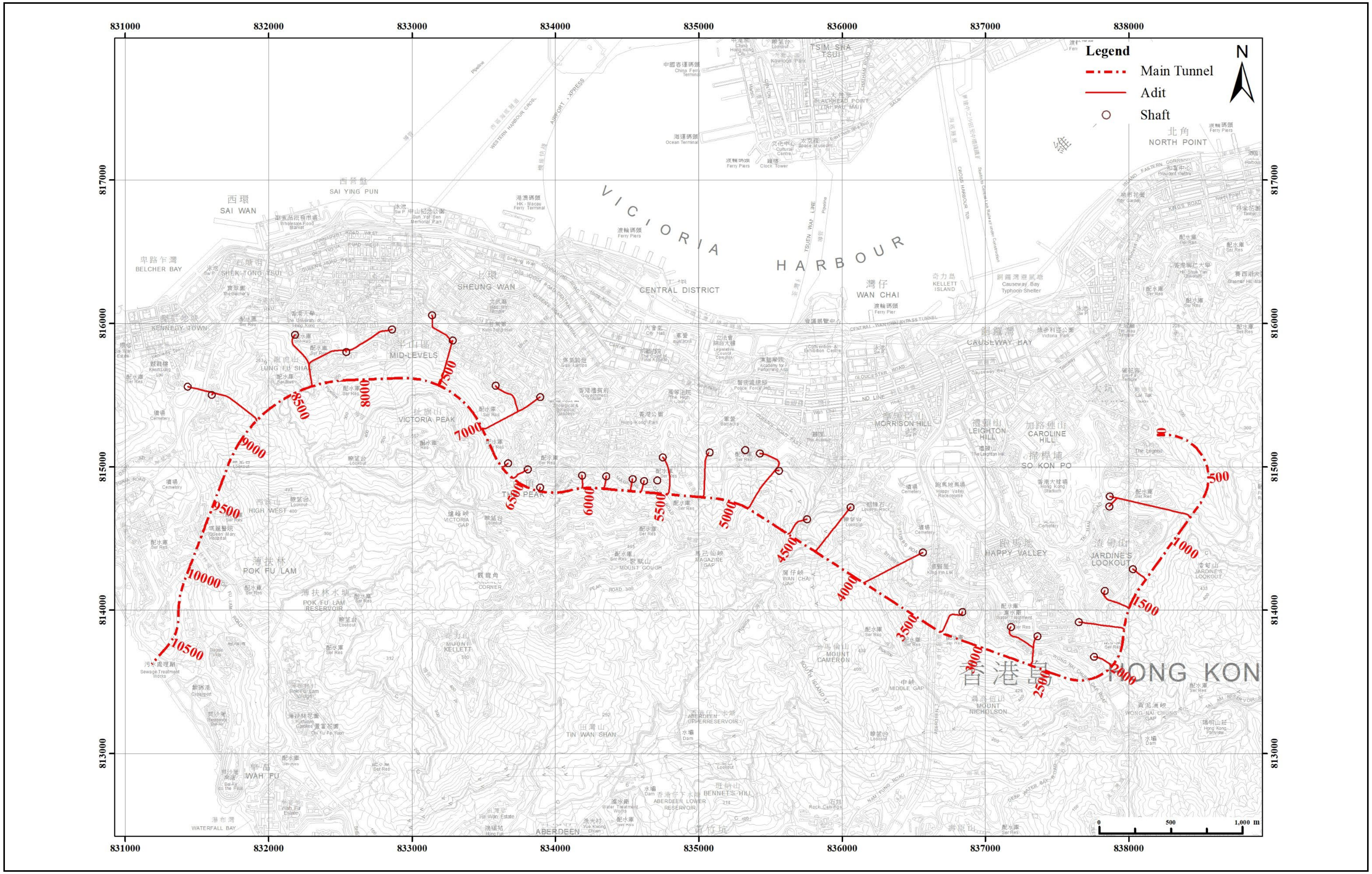


Figure 1.1 General Layout of Hong Kong West Drainage Tunnel

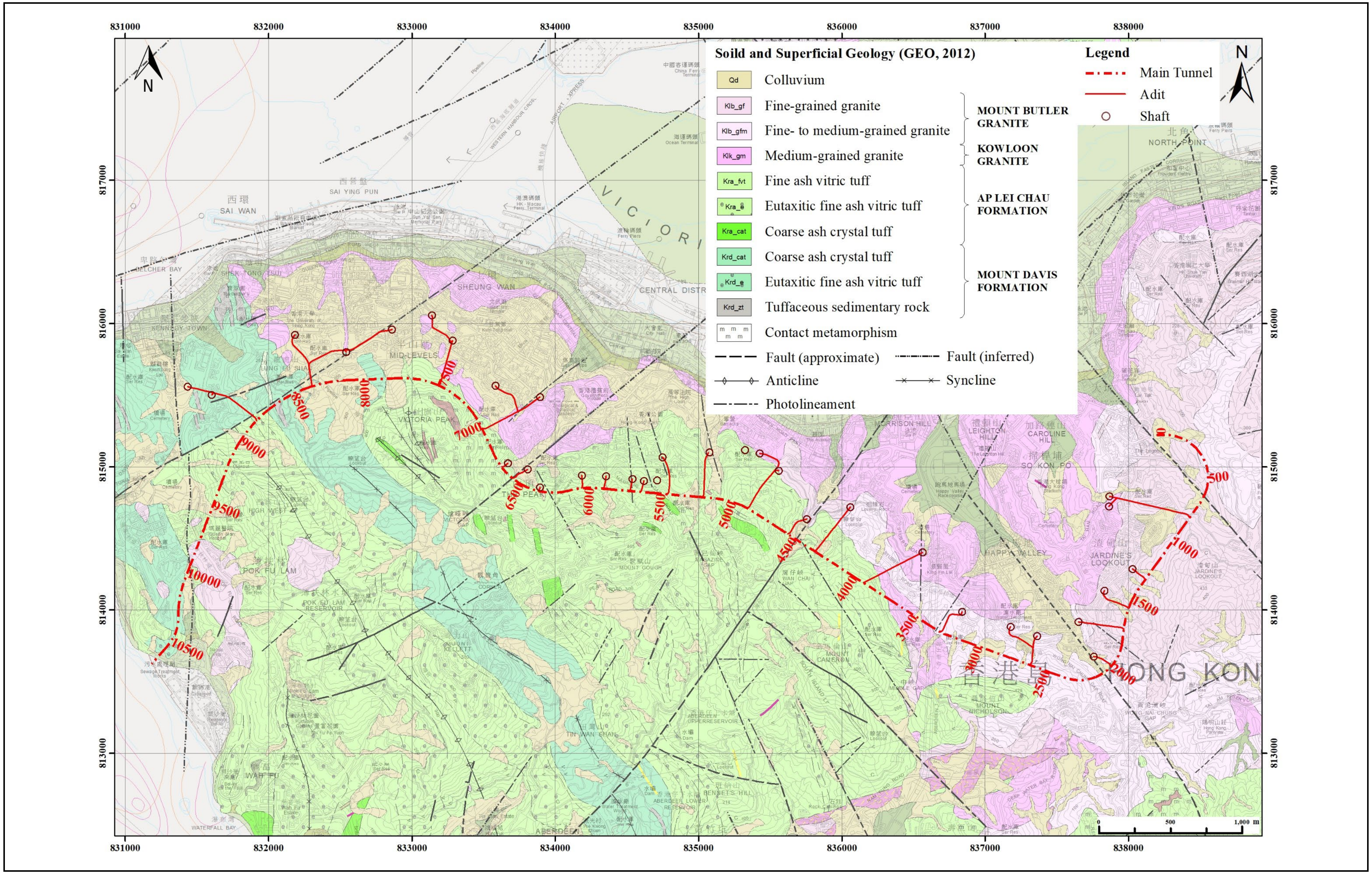


Figure 1.2 Geological Map of Hong Kong West Drainage Tunnel (after GEO, 2012)

2 Pre-Construction and Post-Construction Geological Model

2.1 Overview

The aim of this section is to present the pre-construction and post-construction geological models of the HKWDT project, based on the information presented in the Geotechnical Interpretation Report (Arup, 2007) prepared by Project's design consultant and the contractor's as-built geological long sections (DNJV, 2011) of the tunnel alignment submitted by the Project's contractor. The geological conditions, including lithology, major faults, minor faults, photolineaments, joints as well as the rock mass quality and groundwater conditions of the main tunnel will be discussed.

2.2 Lithology

The geological conditions along the main tunnel are discussed in seven portions, based on distribution of rock types. Tables 2.1 and 2.2 summarise the predicted and actual lithologies along the main tunnel, respectively. The distribution of predicted and actual lithologies along the main tunnel are shown in Figures 2.1 and 2.2. No mapping records were retrieved at CH 10583 – 10700 of the main tunnel.

Table 2.1 Summary of Predicted Lithologies along the Main Tunnel (after Arup, 2007)

Chainage (m)	Predicted Rock Type to be Encountered along Main Tunnel
CH 0 – 130	Fine-grained granite
CH 130 – 830	Fine- to medium-grained granite
CH 830 – 4100	Medium-grained granite
CH 4100 – 6350	Fine ash vitric tuff
CH 6350 – 6700	Fine ash vitric tuff with lenses of coarse ash tuff and metamorphosed tuff at geological contacts
CH 6700 – 6900	Fine-grained granite
CH 6900 – 7100	Fine- to medium-grained granite
CH 7100 – 7150	Medium-grained granite
CH 7150 – 7450	Fine- to medium-grained granite
CH 7450 – 7770	Fine-grained granite
CH 7770 – 8050	Metamorphosed coarse ash tuff
CH 8050 – 8450	Fine ash vitric tuff
CH 8450 – 8900	Coarse ash tuff
CH 8900 – 9300	Fine ash vitric tuff
CH 9300 – 9600	Metamorphosed fine ash tuff
CH 9600 – 10100	Fine-grained granite
CH 10100 – 10450	Metamorphosed fine ash tuff
CH 10450 – 10700	Coarse ash tuff

Table 2.2 Summary of Actual Lithologies along the Main Tunnel (after DNJV, 2011)

Portion No.	Chainage (m)	Actual Rock Type along Main Tunnel	Rock Unit(s)
1	CH 0 – 1600	Fine- to medium-grained granite	Mount Butler Granite
	CH 1600 – 1800	Medium- to coarse-grained granite	
	CH 1800 – 4000	Medium-grained granite	
2	CH 4000 – 6725	Fine ash tuff	Ap Lei Chau Formation
	CH 6725 – 6860	Coarse ash tuff	
3	CH 6860 – 7000	Granite	Kowloon Granite
	CH 7000 – 7400	Medium-grained granite	
	CH 7400 – 7550	Fine- to medium-grained granite	
4	CH 7550 – 7800	Coarse ash tuff	Mount Davis Formation
	CH 7800 – 9058	Fine ash tuff and coarse ash tuff (occasionally lapilli-bearing)	
5	CH 9058 – 10013	Fine-grained granite (locally medium-grained granite)	Kowloon Granite
6	CH 10013 – 10187	Granite and tuff (contact zone)	Kowloon Granite and Mount Davis Formation
7	CH 10187 – 10400	Fine ash tuff	Mount Davis Formation
	CH 10400 – 10583	Coarse ash tuff	

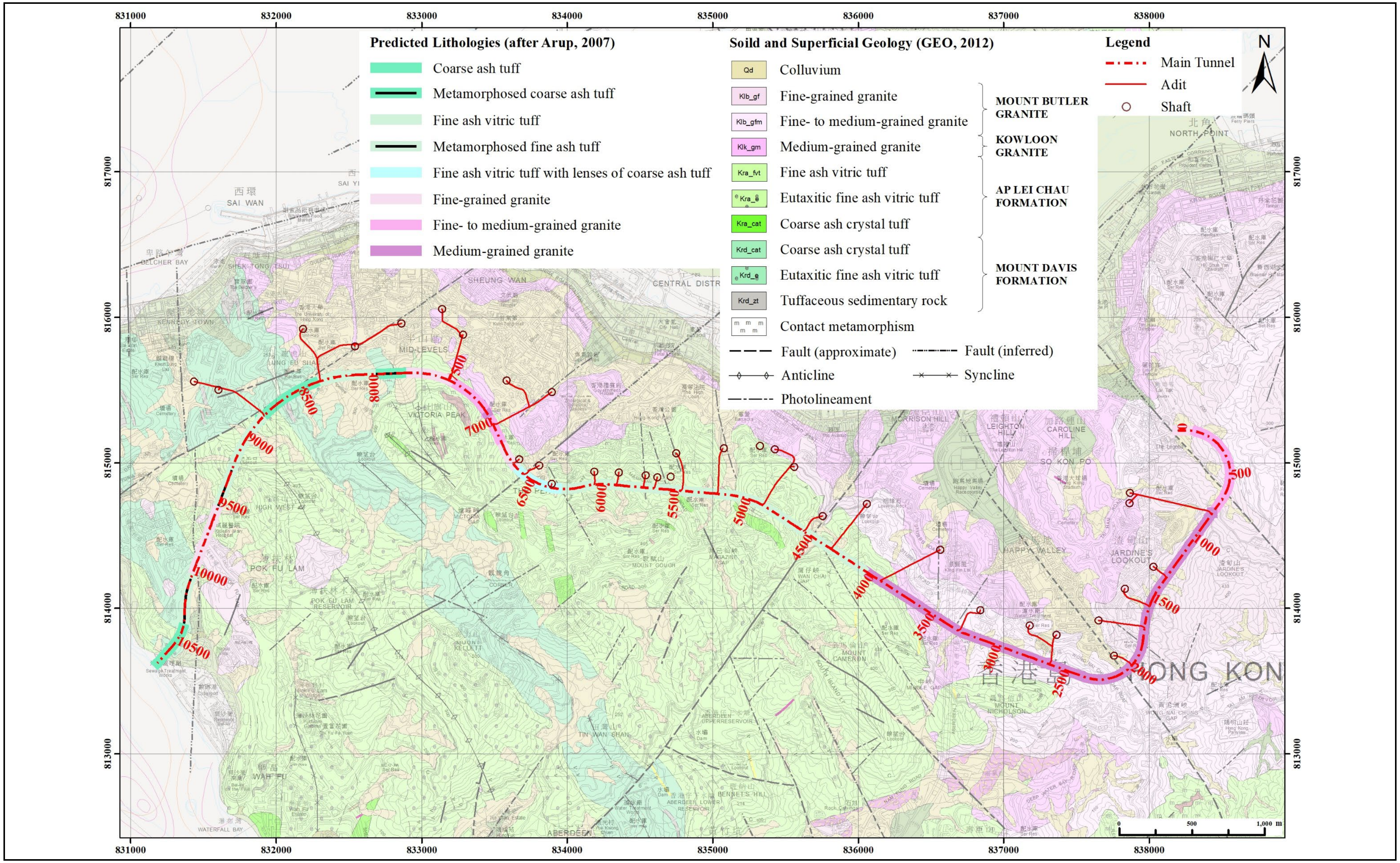


Figure 2.1 Predicted Lithologies along the Main Tunnel (after Arup, 2007; GEO, 2012)

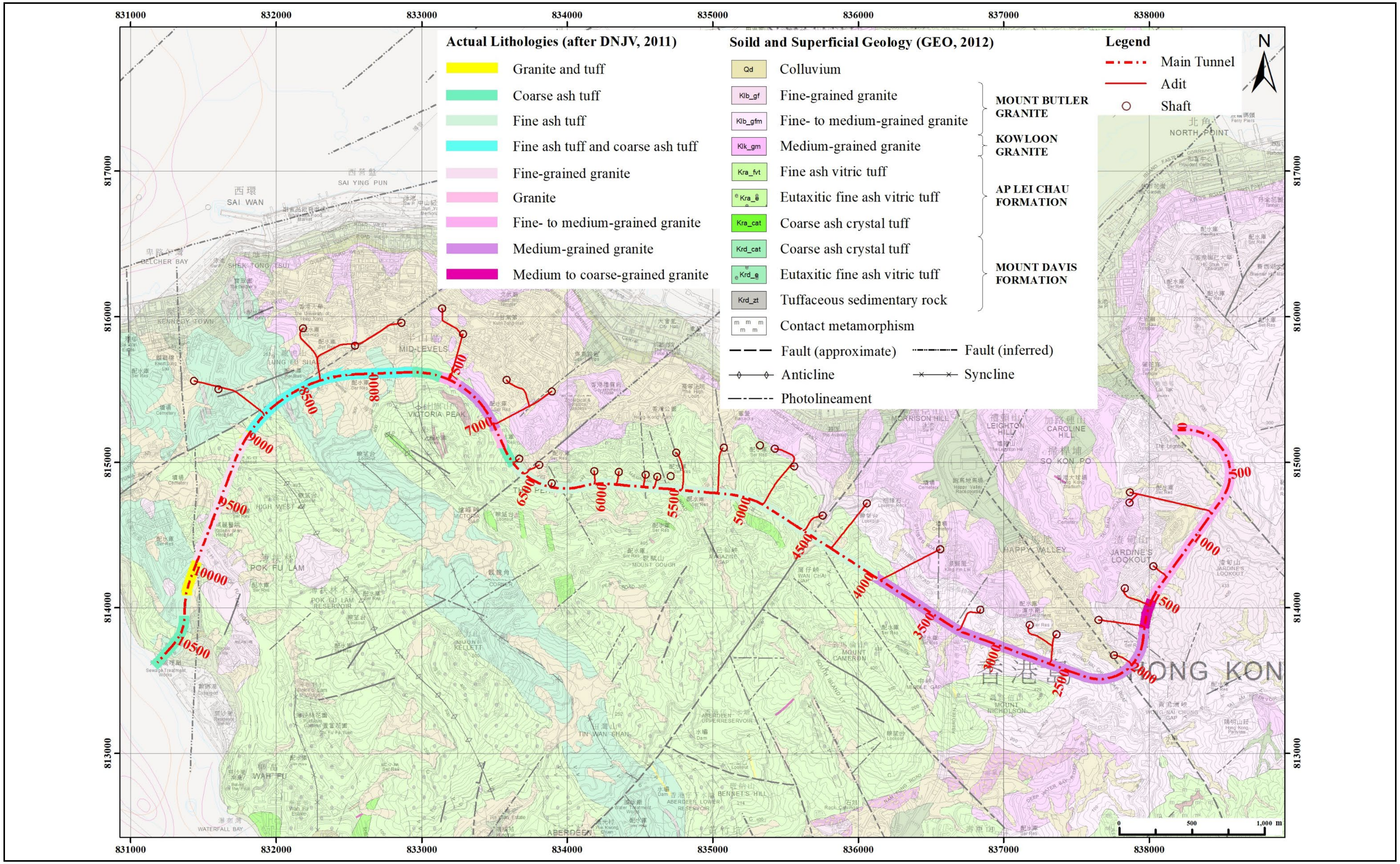


Figure 2.2 Actual Lithologies along the Main Tunnel as Shown in the As-built Records (after DNJV, 2011; GEO, 2012)

In addition, the contractor recorded the rock weathering grades, which is summarised in Figure 2.3. Grade I/II rocks were encountered in nearly half of the length of the main tunnel, followed by approximately 37% of length of main tunnel in Grade I.

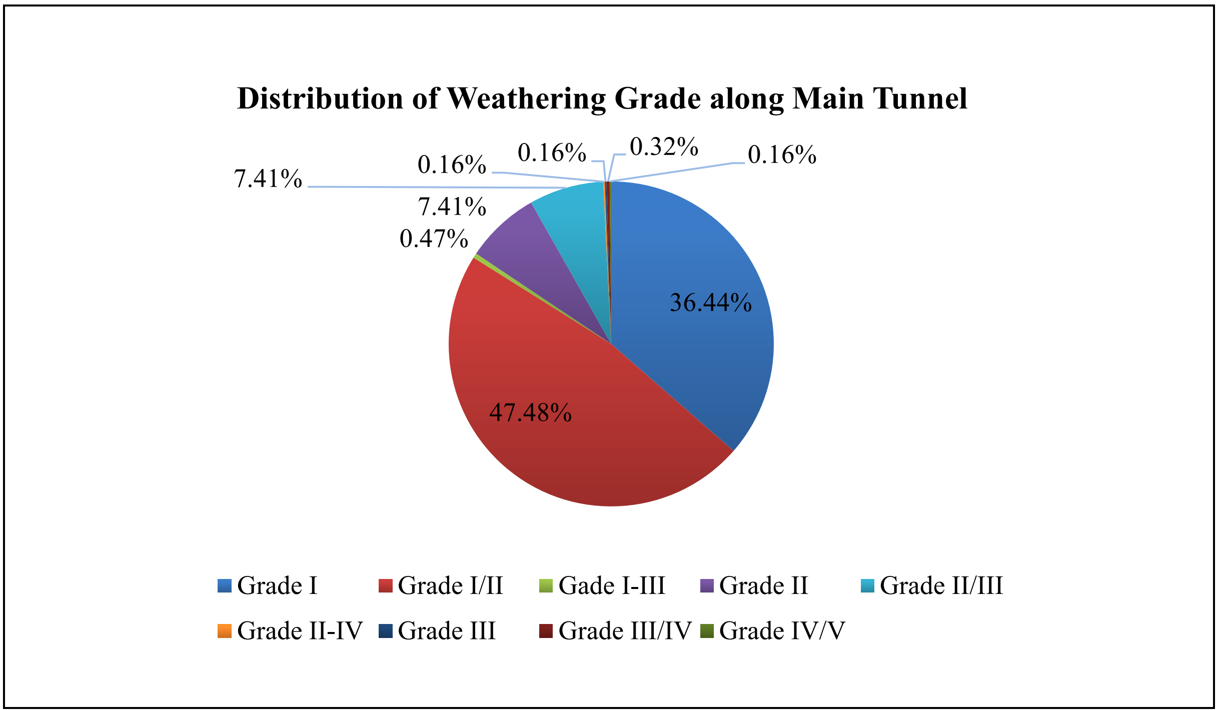


Figure 2.3 Distribution of Rock Weathering Grade along the Main Tunnel (after DNJV, 2011)

2.2.1 Portion 1 (CH 0 – 4000)

Granites were firstly encountered in the eastern portion of the main tunnel from Tai Hang to Mount Cameron. Arup (2007) predicted that granites would be encountered at CH 0 – 4100. The grain sizes of granite varied from fine-grained (CH 0 – 130), to fine- to medium-grained (CH 130 – 830) and to medium-grained (CH 830 – 4100). The boundaries between granite of different grain sizes were inferred based on site-specific ground investigation data. Pegmatite veins/dykes that were anticipated along the main tunnel. The colour of granites was not described in the consultant's geotechnical report.

During construction stage, fine- to medium-grained granite (CH 0 – 1600), medium- to coarse-grained granite (CH 1600 – 1800) and medium-grained granite (CH 1800 – 4000) were encountered in the first 4000 metres of the main tunnel as documented in the as-built geological sections by DNJV (2011). The color of granites was described as light grey to pinkish grey, spotted black and occasionally pinkish orange. Pegmatite veins and mafic dykes were observed at approximately CH 601 – 792. However, their exact location, extent and orientation were not recorded. The contractor assigned the granites at CH 0 – 4000 as the Mount Butler Granite (Klb) of the Lion Rock Suite.

2.2.2 Portion 2 (CH 4000 – 6860)

Portion 2 of the main tunnel passed through volcanic rocks from Mount Cameron to Victoria Gap. Arup (2007) predicted that volcanic rocks, predominantly fine ash vitric tuff would be encountered at CH 4100 – 6700. Bands of coarse ash crystal tuff and eutaxite might occasionally present at CH 6350 – 6700. It was expected that the first contact between granite and tuff would be encountered beneath Mount Cameron at around CH 4100, where the tuffs were inferred to have been metamorphosed. In addition, granite intrusions, described as "pervasive stringers of granite", and minor quartzphyric rhyolite might be encountered in the central portion of the main tunnel.

A sharp geological contact between medium-grained granite and volcanic rocks intersected the main tunnel at CH 4000, but the orientation was not recorded (DNJV, 2011). The location of the first geological contact encountered along the main tunnel was approximately 100 m to the east, compared to the pre-construction geological model presented by Arup (2007). The contractor gave a more detailed description on the rock type along the main tunnel. Fine ash tuff was encountered at CH 4015 – 6725, while coarse ash tuff was encountered at CH 6725 – 6860. The volcanic rocks were assigned to the Ap Lei Chau Formation (Kra) of the Repulse Bay Volcanic Group. The contractor did not record any sign of metamorphism in the volcanic rocks. Several fine-grained granite intrusions were encountered at CH 6632, CH 6643, CH 6704 and CH 6761. A pegmatite intrusion was encountered at CH 6856. However, owing to the simplicity of the contractor's geological sections, most of the extent/orientation of the intrusions were not recorded. No quartzphyric rhyolite dyke was encountered in this area, as opposed to the pre-construction geological model.

2.2.3 Portion 3 (CH 6860 – 7550)

The western portion of the main tunnel passed through granites and volcanic rocks from Victoria Gap to Cyberport, where the geology was more complex comparing to the eastern and central portions of the main tunnel. Arup (2007) anticipated that the second lithological contact between granite and tuff, of similar conditions described at CH 4000, would be encountered in the vicinity of Victoria Gap at around CH 6700. Based on existing GI records and the information collected from Mid-levels Study (GCO, 1982), the geological contact was inferred to be complex, irregular in shape and include stringers and zones of inter-fingering of granite and tuff (Figure 2.4). In terms of grain size, Arup (2007) assumed the granites beneath Victoria Peak were folded in the form of an antiform, where grain size gradually increases towards the core of the fold. Alternating "layers" of fine-grained granite, fine- to medium-grained granite and medium-grained granite were inferred at CH 6700 – 7770.

The geological contact between granite and tuff was encountered at around CH 6860 (orientation not specified) where a pegmatite intrusion was also recorded. The actual location of the second geological contact was approximately 160 m to the west, compared to the pre-construction geological model presented by Arup (2007). Granite (grain size not specified) was encountered at CH 6860 – 7000, followed by medium-grained granite at CH 7000 – 7400 and fine- to medium-grained granite at CH 7400 – 7550, in which the variation in grain size in granite was different from the predictions by Arup (2007). The granitic rocks were assigned to the Kowloon Granite (Klk) of the Lion Rock Suite.

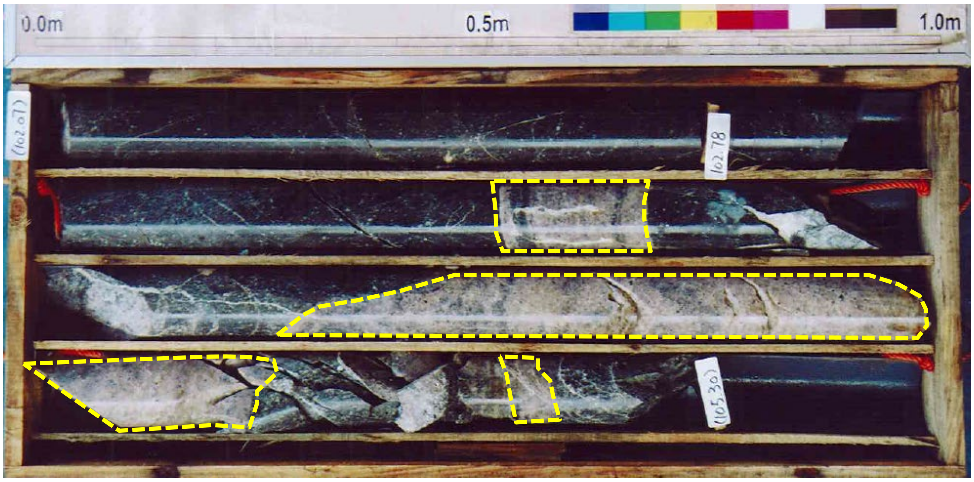


Figure 2.4 Granite Stringers (in Yellow Polygons) Close to the Contact between Granite and Tuff near Victoria Gap, Hong Kong (Drillhole No. 43775/TP4, Box 31)

2.2.4 Portion 4 (CH 7550 – 9058)

Arup (2007) anticipated that the main tunnel would encounter the third geological contact between granite and tuff beneath Victoria Peak at around CH 7770, and eventually passed into fine ash vitric tuff. The tuffs between CH 7770 and CH 9960 were inferred to have been altered by thermal metamorphism and hornfels might be encountered for several hundred metres away from the geological contact between granite and tuff (Figure 2.5). Fine ash vitric tuff was expected at CH 8050 – 8450 and at CH 8900 – 9300. Coarse ash tuff was expected between CH 8450 and CH 8900.

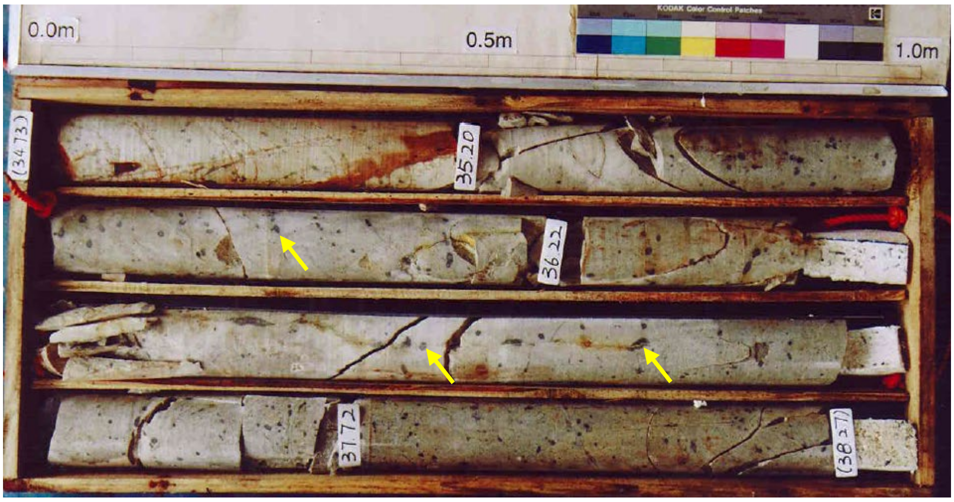


Figure 2.5 Hornfels (with spots) Close to the Contact between Granite and Tuff near Victoria Peak, Hong Kong (Drillhole No. 43774/MA14, Box 7)

An approximately 50 m-wide contact zone, was encountered at CH 7550 (DNJV, 2011), which was around 220 m to the east, compared to the pre-construction geological model presented by Arup (2007). Coarse ash tuff, fine- to medium-grained granite and an aplite vein were recorded within the contact zone. Four more aplite veins (CH 7655, CH 7698, CH 7731 and CH 7753) and one coarse-grained granite intrusion (CH 7718) were encountered within 150 m of the contact zone. The volcanic rocks were described as coarse ash tuff at CH 7600 – 7800, and as fine and coarse ash tuff with occasional lapilli lithic clasts at CH 7800 – 9058. No sign of metamorphism was recorded in the volcanic rocks.

2.2.5 Portion 5 (CH 9058 – 10013)

Arup (2007) predicted that the fourth geological contact between granite and tuff in between Pok Fu Lam and High West at approximately CH 9600. Based on available ground investigation data, the contact was unlikely to be sharp and numerous stringers of granite could be expected within the volcanic rocks (Arup, 2007). It was anticipated that fine-grained granite would be encountered at CH 9600 – 10100. Subordinate quartzphyric rhyolite dykes might be encountered along the main tunnel alignment.

According to the as-built records, the geological contact was displaced approximately 500 m to the east at CH 9058 compared with the pre-construction model (DNJV, 2011). Fine-grained granite was encountered at CH 9058 – 10013. Subordinate medium-grained granite was locally observed between CH 9200 and CH 9400. Quartz and pegmatite veins were observed between CH 9400 and CH 9600. "Dark grey plutonic dykes", possibly mafic dykes, were encountered at CH 9830 to CH 9760.

2.2.6 Portion 6 (CH 10013 – 10187)

Arup (2007) suggested that the main tunnel would encounter the geological contact between granite and tuff in Pok Fu Lam at around CH 10100. They assumed that fine ash tuff would be encountered at CH 10100 – 10450, followed by coarse ash tuff at CH 10450 – 10700. Fine ash tuff adjacent to the contact was inferred to have been metamorphosed and numerous stringers of granite could be expected within the tuff. Based on contractor's as-built geological sections (DNJV, 2011), the lithological contact was not clearly defined such that the contact zone was about 174 m wide, given both fine-grained granite and fine to coarse ash tuff were encountered between CH 10013 and CH 10187.

2.2.7 Portion 7 (CH 10187 – 10583)

Fine ash tuff was encountered at CH 10187 – 10400, whereas coarse ash tuff was encountered at CH 10400 – 10583 of the main tunnel. The contractor did not record any sign of metamorphism in the volcanic rocks. Granite and/or pegmatite veins were observed between CH 10200 and CH 10583, which was similar to the pre-construction geological model by Arup (2007).

2.3 Structural Geology

2.3.1 Overview

In the consultant's geotechnical interpretation report (Arup, 2007), eight major faults, three minor faults and seventeen photolineaments were inferred based on desk study, API and site-specific ground investigation data (Table 2.3). Arup (2007) attempted to estimate the extent of different structural geological features, in which the terminologies "Fault Transition Zone" and "Main Fault Zone" were used in their report. To avoid confusion, the above terminologies were modified to "Transition Zone" and "Main Influence Zone", respectively in this report (Table 2.4).

In the contractor's as-built geological sections (DNJV, 2011), "shear zone", "fault zone", "fault breccia", "fault gouge", "highly fractured rock mass", "shear zone with highly fractured rock mass" were the terminologies used qualitatively for describing the major weakness zones encountered along the main tunnel. The extent, orientation and nature of the geological structures were not recorded. Table 2.5 summarises the weakness zones encountered along main tunnel. The distribution of weakness zones, together with the inferred geological structures by Arup (2007) are shown in Figure 2.6.

2.3.2 Faults

Detailed assessment of eight major faults was conducted by Arup (2007) such that their predicted position, orientation, nature and extent (i.e. main influence zone and disturbed zone) were documented in the consultant's report. The right major faults are shown in Figure 2.6.

The NW-trending Tai Tam Fault was characterised by fractured zones, fault breccia with slickensided joint surfaces (Arup, 2007). The fault strikes at 135-140° and dips at 80-85°. The fault was anticipated to be 2-5 m wide, with an influence zone of 70-85 m wide at CH 645 (Arup, 2007). According to the as-built record (DNJV, 2011), weakness zone was not mapped, but the contractor recorded a significant drop in Q-value (i.e. from 15.83-0.56) at CH 651.

The NW-trending Wong Nai Chung Gap Fault was characterised by two distinct fault bands comprised fault breccia, chlorite-coated and kaolin-infilled slickensided joints (Arup, 2007). The two fault bands had a similar strike (140-145°) and dip angle (80-85°). It was anticipated the fault zone was 1-6 m in width and the thickness of the disturbed zone ranged from 35-52 m at CH 2130 (Arup, 2007). During tunnel construction, localised highly-decomposed granite and fault breccia were encountered in between CH 2090 and CH 2130 (DNJV, 2011).

The NE-trending Middle Gap Fault was characterised by minor brittle fault features, chlorite-coated and kaolin-infilled joints (Arup, 2007). The fault strikes at 010-030° and dips at 70° to 80°. It was anticipated that the fault was 1-4 m in width and the thickness of the disturbed zone ranged from 130-135 m at CH 3270 (Arup, 2007). No weakness zones, which might be associated with the Middle Gap Fault, were recorded in the contractor's geological sections (DNJV, 2011).

Table 2.3 Summary of Anticipated Geological Structures along the Main Tunnel (after Arup, 2007)

Predicted Chainage (m)	Geological Structure	Trend (Relation to the tunnel)
CH 215	Photolineament	E (Oblique)
CH 645	Tai Tam Fault	NW (Oblique)
CH 1850	Photolineament	NW (Perpendicular)
CH 2130	Wong Nai Chung Gap Fault	NW (Perpendicular)
CH 2420	Photolineament	N (Perpendicular)
CH 2690	Photolineament	N (Oblique)
CH 3130	Photolineament	NE (Perpendicular)
CH 3220	Photolineament	N (Oblique)
CH 3270	Middle Gap Fault	NE (Perpendicular)
CH 3540	Minor Fault	N (Oblique)
CH 4540	Wanchai Gap Fault	NE (Perpendicular)
CH 5080	Magazine Gap Fault	NW (Oblique)
CH 5215	Photolineament	N (Perpendicular)
CH 5260	Photolineament	NW (Oblique)
CH 5590	Photolineament	NW (Oblique)
CH 5730	Photolineament	NW (Oblique)
CH 5920	Photolineament	N (Perpendicular)
CH 6420	Minor Fault	NW (Oblique)
CH 6570	Victoria Gap Fault	NE (Perpendicular)
CH 6730	Photolineament	NE (Perpendicular)
CH 7050	Photolineament	NE (Perpendicular)
CH 7530	Photolineament	NW (Oblique)
CH 7810	Photolineament	N (Perpendicular)
CH 8360	Sandy Bay Fault	NE (Sub-parallel)
CH 8960	Sandy Bay Fault	NE (Sub-parallel)
CH 9800	Photolineament	N (Oblique)
CH 9950	Photolineament	N (Oblique)
CH 10160	Telegraph Bay Fault	N (Oblique)
CH 10360	Minor Fault	N (Oblique)

Table 2.4 Extent of Different Geological Structures along the Main Tunnel (after Arup, 2007)

Type of Structure	Width of Main Influence Zone[(1)] (m)	Width of Transition Zone[(2)] (m)
Major Fault	5 - 30	10 - 150
Minor Fault	1 - 5	5 - 50
Photolineament	0.5 - 3	2 - 10

Notes: (1) Renamed from "Main Fault Zone".
(2) Renamed from "Fault Transition Zone".

Table 2.5 Summary of Adverse Geological Features Encountered along the Main Tunnel (after DNJV, 2011)

Chainage (m)	Adverse Geological Feature	Width (m)
CH 946	Shear zone	Not recorded
CH 982	Fault zone	Not recorded
CH 2092 – 2127	Fault breccia	35 m
CH 2220	Shear zone	Not recorded
CH 4364	Highly fractured rock mass	Not recorded
CH 5254 – 5873	Highly fractured rock mass	619 m
CH 6523	Highly fractured rock mass	Not recorded
CH 6633 – 6644	Highly fractured rock mass	11 m
CH 8319	Shear zone	Not recorded
CH 8834	Shear zone	Not recorded
CH 8994	Fault breccia, fault gouge	Not recorded
CH 9000 – 9071	Shear zone	71 m
CH 9343 – 9487	Shear zone	144 m
CH 9508	Fault gouge	Not recorded
CH 9511	Fault zone	Not recorded
CH 9514 – 9580	Shear zone	66 m
CH 9550	Fault zone	Not recorded
CH 9616 – 10583	Shear zone with highly fractured rock mass	967 m

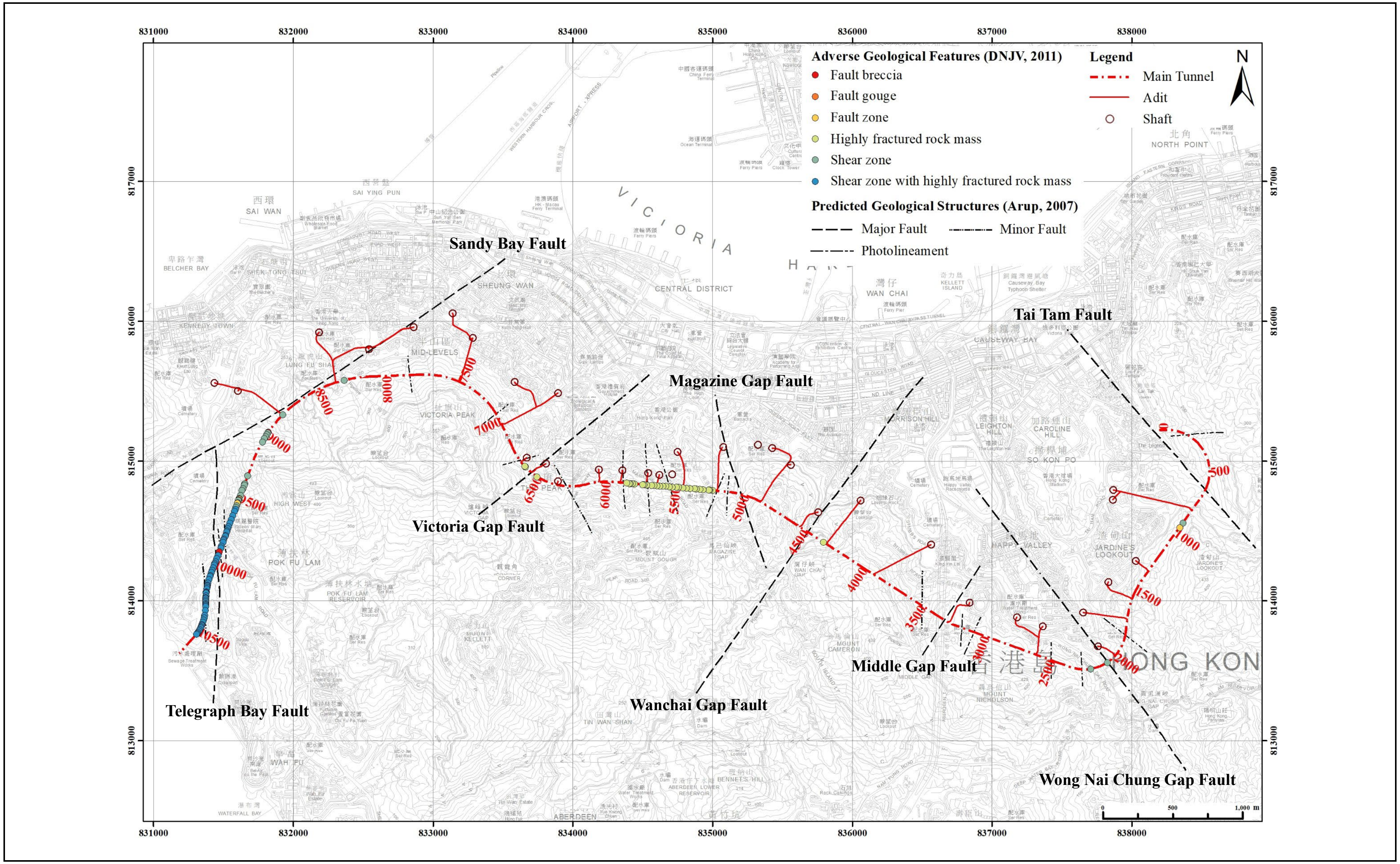


Figure 2.6 Geological Structures and Features as Predicted in the Pre-Construction Model and as Shown in the As-built Records along the Main Tunnel (after Arup, 2007; DNJV, 2011)

The NE-trending Wanchai Gap Fault was categorised as an extensive and regional fault, which comprised discrete zones of fault breccia and mafic dykes with microfractures, slickensided and chlorite-coated joints (Arup, 2007). The fault strikes at 028-032° and dips at 65-75°. It was anticipated that the fault was 25-35 m in width and the thickness of the disturbed zone ranged from 120-140 m at CH 4540 (Arup, 2007). However, no weakness zones nor significant drop in Q-value, which might be indicative of the Wanchai Gap Fault were recorded in the contractor's geological sections (DNJV, 2011).

The NW-trending Magazine Gap Fault was characterised by a number of discrete fault zones, shear zones and fault breccia (Arup, 2007). Narrow bands of fault gouge and foliated tuff were inferred, based on ground investigation data (Arup, 2007). The fault strikes at 150-160° and dips at 80-90°. It was anticipated that the fault was 5-15 m in width and the thickness of the disturbed zone ranged from 90-110 m at CH 5080 (Arup, 2007). However, no weakness zones nor significant drop in Q-value, which might be indicative of the Magazine Gap Fault, were recorded in the contractor's geological sections (DNJV, 2011).

The NE-trending Victoria Gap Fault was characterised by brittle features including fault breccia and slickensided joints (Arup, 2007). The fault strikes at 045-055° and dips at 75-90°. It was anticipated that the fault was 1-5 m in width and the thickness of the disturbed zone ranged from 115-135 m at CH 6570 (Arup, 2007). No weakness zones nor significant drop in Q-value were recorded in the contractor's geological sections (DNJV, 2011).

The NE-trending Sandy Bay Fault was categorised as a persistent, regional geological structure, which comprised variable geological conditions ranging from closely-spaced slickensided joints to shear zones of intense chlorite and kaolin-coated joints, hydrothermally altered rocks, fault gouge and fault breccia (Arup, 2007). Despite the fault did not intersect the main tunnel, it posed a significant risk as it ran sub-parallel to the main tunnel alignment. The fault strikes at 235-245° and dips at 70-80°. It was anticipated that the fault was 1-2 m in width and the thickness of the disturbed zone ranged from 130-135 m (Arup, 2007). It was estimated that the main tunnel at CH 8360 and CH 8960 would be closer to the fault in comparison to the other parts of the tunnel. During tunnel construction, no weakness zones nor significant drop in Q-value were recorded near CH 8360. However, poor rock mass conditions, including fault breccia, fault gouge, and shear zones were encountered at CH 8994 – CH 9071 (DNJV, 2011). The calculated Q-value dropped to 0.03 the lowest at CH 9000 and with groundwater inflow of 100L/min at CH 9083 prior to pre-excavation grouting.

The N-S-trending Telegraph Bay Fault was characterised by both ductile and brittle features, which comprised mylonite and fault breccia, slickensided joints (Arup, 2007). Quartz veins and chloritised granites were also recorded. The fault strikes at 173-179° and dips at 70-75°. It was anticipated that the fault was 2-6 m in width and the thickness of the disturbed zone ranged from 95-105 m at CH 10160 (Arup, 2007). The main tunnel encountered poor rock mass conditions from CH 9343 to CH 10583 (DNJV, 2011). Shear zone with highly-fractured rock mass were recorded in the contractor's geological long sections. The average Q-value for this region was 1.58 and it dropped to 0.03 the lowest at CH 10135.

Three minor faults were anticipated at CH 3540, CH 6420 and CH 10360, respectively (Figure 2.6; Arup, 2007). The first two faults were shown in the published 1:20,000-scale geological map (GCO, 1986), while the latter fault was inferred by Arup (2007), based on aerial photograph interpretation. The degree of disturbance of the minor faults on the main tunnel were inferred to be less extensive in comparison to the Major Faults. In reality, no weakness zones nor significant drop in Q-value were recorded near CH 3540 and CH 6420 (DNJV, 2011). On the other hand, poor rock mass conditions were encountered near CH 10360, in which "shear zone with highly fractured rock mass" were recorded in the contractor's geological long sections, which might relate to the Telegraph Bay Fault.

2.3.3 Photolineaments

Seventeen photolineaments were identified based on desk study and API by Arup (2007) (Figure 2.6). Eleven out of the 17 photolineaments at CH 215, CH 1850, CH 2420, CH 2690, CH 3130, CH 3220, CH 5920, CH 6730, CH 7050, CH 7530, and CH 7810 had minimal effect on the rock mass quality along the main tunnel.

Four photolineaments were inferred at CH 5215, CH 5260, CH 5590 and CH 5730 (Figure 2.6; Arup, 2007). Highly-fractured rock mass was recorded at CH 5254 to CH 5873 with a total length of 619 m (DNJV, 2011), where the four photolineaments were anticipated. Significant groundwater inflow (i.e. up to 150L/min) was recorded at CH 5602. The average Q-value for this region was 2.19 and it dropped to 0.89 the lowest at CH 5509.

The two remaining photolineaments were inferred at CH 9800 and CH 9950 (Figure 2.6; Arup, 2007). "Shear zone with highly fractured rock mass" was recorded in the contractor's geological long sections, which might be related to the Telegraph Bay Fault (DNJV, 2011).

2.3.4 Joints

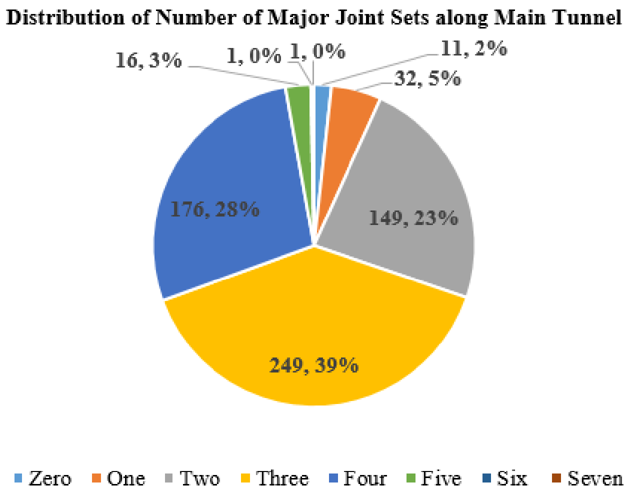
Arup (2007) carried out rock joint assessment based on acoustic televiewer surveys from the project-specific drillholes as well as mapping of surface exposures at rock slopes in close proximity to the main tunnel alignment. The rock joint data is shown in five location plans with stereoplots and a summary table in Appendix B. Arup (2007) attempted to summarise the rock joint data by lithologies, which are divided into six portions as shown in Table 2.6.

The contractor recorded the rock discontinuity data during construction by mapping at either cutter head or telescopic opening. In the as-built geological long sections, the number of joint sets was recorded at each individual mapping record. The orientation of discontinuities (each with a given range) was summarised at 100-m intervals, whereas description of rock joint properties, including joint spacing, aperture, waviness and nature of infilling were summarised at 200-m intervals.

The number of joint sets for each round of mapping along main tunnel is summarised in Figure 2.7. In most cases, two to four major joint sets (574 nos.) were recorded during the excavation, which account for 90% of the records. Rock masses with zero set (11 nos.) and one set (32 nos.) of joint were also encountered along main tunnel and in very few extreme cases, up to six to seven major joint sets were recorded in the contractor's geological long sections (DNJV, 2011).

Table 2.6 Summary of Major Discontinuity Sets for Hong Kong West Drainage Tunnel (after Arup, 2007)

Chainage (m)	Rock Type	Dip/Dip Direction (°)
CH 0 – 4100	Granite	82/041
		72/056
		72/204
		73/352
		4/053
CH 4100 – 6700	Tuff	67/214
		71/280
		79/314
		24/021
CH 6700 – 7700	Granite	61/229
		89/347
		47/301
		16/072
		30/302
CH 7700 – 9600	Tuff	70/060
		59/189
		38/243
		40/301
		62/307
		12/360
CH 9600 – 10100	Granite	78/178
		78/267
		32/251
		32/331
CH 10100 – 10700	Tuff	54/026
		74/244
		74/313



No. of Major Joint Sets	Quantity
Zero	11
One	32
Two	149
Three	249
Four	176
Five	16
Six	1
Seven	1
	635

Figure 2.7 Distribution of Numbers of Major Joint Sets along the Main Tunnel (after DNJV, 2011)

Based on the distribution of lithologies and weakness zones as stated in the above, the relationship between the number of major joint sets, rock type and/or weakness zones is evaluated as shown in Figure 2.8. It is evident that the number of major joint sets observed within the volcanic rocks were higher than those within the granitic rocks, which may imply that the volcanic rocks were more fractured than the granite along the main tunnel. In addition, it is noted that the number of major joint sets were relatively higher along weakness zones. However, the relationship was not conclusive and did not tie in with all weakness zones.

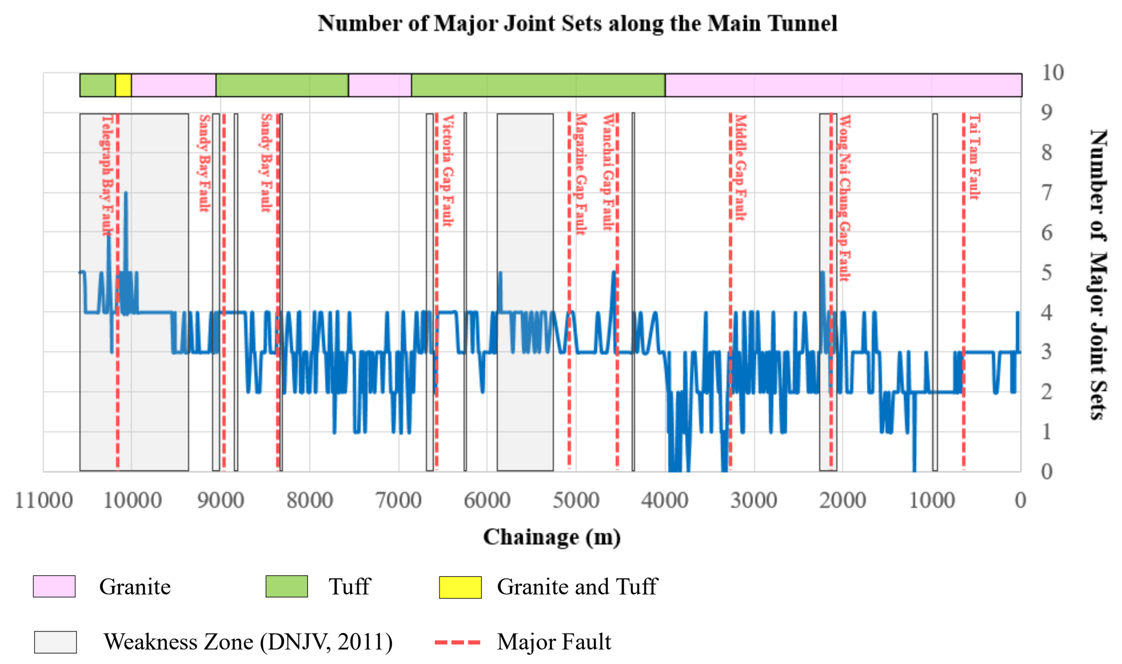


Figure 2.8 Number of Major Joint Sets along the Main Tunnel (after DNJV, 2011)

Joint infilling in the granitic rocks comprised a wide variety of materials. Three groups namely “clay”, “non-clay” and “staining” were defined in the analysis of the joint data. “Clay” minerals include kaolin and chlorite. “Non-clay” minerals include quartz and calcite. “Staining” includes iron oxide and manganese oxide stained. The rock joint data is subsequently plotted on stereonets by using the computer software “DIPS” as shown in Figure 2.9. Table 2.7 summarises the interpreted major joint sets encountered at the seven portions of the main tunnel.

2.3.4.1 Portion 1 (CH 0 – 4000)

Arup (2007) predicted four sub-vertical joint sets and one sub-horizontal joint set at CH 0 – 4100. In reality, four sub-vertical joint sets (J1-J4) were interpreted at Portion 1 (Figure 2.9). Major joint sets J1 (ESE-WNW trending) and J3 (NNE-SSW trending) were more prominent within the portion and they formed an orthogonal pair at a dihedral angle of around 90°. Joint spacing was generally described as “closely to widely spaced”. Aperture of joints were mostly described as “tight to extremely narrow”. In terms of nature of infilling, rock joints in 50% of the length of portion were stained, 45% with “non-clay” infilling and 5% with “clay” infilling.

2.3.4.2 Portion 2 (CH 4000 – 6860)

Arup (2007) predicted three sub-vertical joint sets and one sub-horizontal joint set at CH 4100 – 6700. In reality, four sub-vertical joint sets (J1-J4) and one sub-horizontal joint set (J5) were interpreted at Portion 2 (Figure 2.9). Major joint sets J3 (NE-SW trending) and J4 (ENE-SWS trending) were more prominent within the portion and they formed a conjugate pair at a dihedral angle of 30°. Within the portion, the spacing and aperture of the joints were described as “closely to medium spaced” and “tight to extremely narrow”, respectively. In terms of nature of infilling, rock joints in 71% of the length of portion were stained, 12% with "non-clay" infilling and 17% with "clay" infilling.

2.3.4.3 Portion 3 (CH 6860 – 7550)

Arup (2007) predicted three sub-vertical joint sets and two sub-horizontal joint sets at CH 6860 – 7550. In reality, five sub-vertical joint sets (J1-J5), one gently-dipping joint set (J7) and one sub-horizontal joint (J6) set were interpreted (Figure 2.9). Major joint sets J1 (ESE-SWS trending) and J2 (NW-SE trending) were more prominent among other joint sets within the portion and they formed a conjugate pair at dihedral angle of around 30°. Joint spacing was described as either “closely to medium spaced” or “medium to widely spaced” within the portion, each accounted for 50% of the length of the portion. Joint aperture was described as “tight to extremely narrow”. Rock joints within the portion were stained, but no infilling was recorded.

Table 2.7 Summary of Rock Joint Data recorded along the Main Tunnel (after DNJV, 2011)

Portion No.	Chainage (m)	Rock Type	Major Joint Set	Dip/Dip Direction (°)
1	CH 0 – 4000	Granite	J1a; J1b	83/202; 82/020
			J2a; J2b	82/257; 83/069
			J3a; J3b	75/294; 87/109
			J4	82/326
2	CH 4000 – 6860	Tuff	J1a; J1b	82/206; 80/019
			J2a; J2b	82/261; 82/079
			J3a; J3b	82/311; 81/168
			J4a; J4b	83/342; 82/172
			J5	19/208
3	CH 6860 – 7550	Granite	J1a; J1b	83/208; 86/026
			J2a; J2b	77/234; 86/055
			J3a; J3b	83/323; 83/144
			J4	66/355
			J5	82/113
			J6	19/202
			J7	36/039
4	CH 7550 – 9058	Tuff	J1a; J1b	82/216; 81/042
			J2a; J2b	75/253; 85/073
			J3a; J3b	82/307; 80/132
			J4a; J4b	83/334; 80/158
			J5	19/051
			J6	19/121
5	CH 9058 – 10013	Granite	J1	82/185
			J2	82/216
			J3	82/251
			J4	82/149
			J5	19/064
6	CH 10013 – 10187	Granite and Tuff(1)	J1a; J1b	75/237; 75/063
			J2a; J2b	83/285; 75/093
			J3	18/199
7	CH 10187 – 10583	Tuff	J1	83/225
			J2	59/263
			J3a; J3b	82/312; 83/135
			J4a; J4b	82/342; 83/165

Note:
(1) Along geological contact where both rock types were encountered.

2.3.4.4 Portion 4 (CH 7550 – 9058)

Arup (2007) predicted five sub-vertical joint sets and one sub-horizontal joint set at CH 7700 – 9600. In reality, four sub-vertical joint sets (J1-J4) and two sub-horizontal joint sets (J5-J6) were interpreted at Portion 4 (Figure 2.9). Major joint sets J2 and J3 (both NE-SW trending) were more prominent among other joint sets within the portion and they formed a conjugate pair at dihedral of around 30°. Joint spacing was described as “closely to medium spaced” or “extremely closely to closely spaced”, which accounted for 75% and 25% of the length of the portion, respectively. Joint aperture was described as “tight to extremely narrow”. In terms of nature of infilling, rock joints in 50% of the length of the portion were stained and 50% with clay infilling.

2.3.4.5 Portion 5 (CH 9058 – 10013)

Arup (2007) predicted two sub-vertical joint sets and two sub-horizontal joint sets at CH 9600 – 10100. In reality, four sub-vertical joint sets (J1-J4) and one sub-horizontal joint set (J5) were interpreted at Portion 5 (Figure 2.9). Major joint sets J1 and J2 (both NW-SE trending) were more prominent among other joint sets within the portion and they formed a conjugate pair at a dihedral angle of around 30°. Joint spacing was described as “very closely to medium spaced”, “very closely to closely spaced” and “extremely closely to closely spaced” in 60%, 20%, and 20% of the length of the portion, respectively. Joint aperture was described as “tight to extremely narrow”. In terms of nature of infilling, rock joints in 40% of the length of the portion were stained and 60% with "non-clay" infilling.

2.3.4.6 Portion 6 (CH 10013 – 10187)

At Portion 6, two sub-vertical joint sets (J1-J2) and one sub-horizontal joint set (J3) were interpreted (Figure 2.9). Major joint set J3 (NW-SE trending) was more prominent among other joint sets within the portion. Joint spacing was described as “very closely to medium spaced”. Joint aperture was described as “tight to narrow”. “Clay” infilling was recorded in rock joints in the portion. The rock joint patterns were not compared with the pre-construction geological model as both granite and tuff were encountered at Portion 6.

2.3.4.7 Portion 7 (CH 10187 – 10583)

Arup (2007) predicted three sub-vertical joint sets at CH 10100 – 10700. In reality, four sub-vertical joint sets (J1-J4) were interpreted, of which J3 and J4 formed a conjugate pair at Portion 7 (Figure 2.9). Some sub-horizontal random joints were also recorded. Joint spacing was described as "very closely to medium spaced". Joint aperture was described as "tight to narrow". Both "clay" and "non-clay" infilling were recorded within the portion.

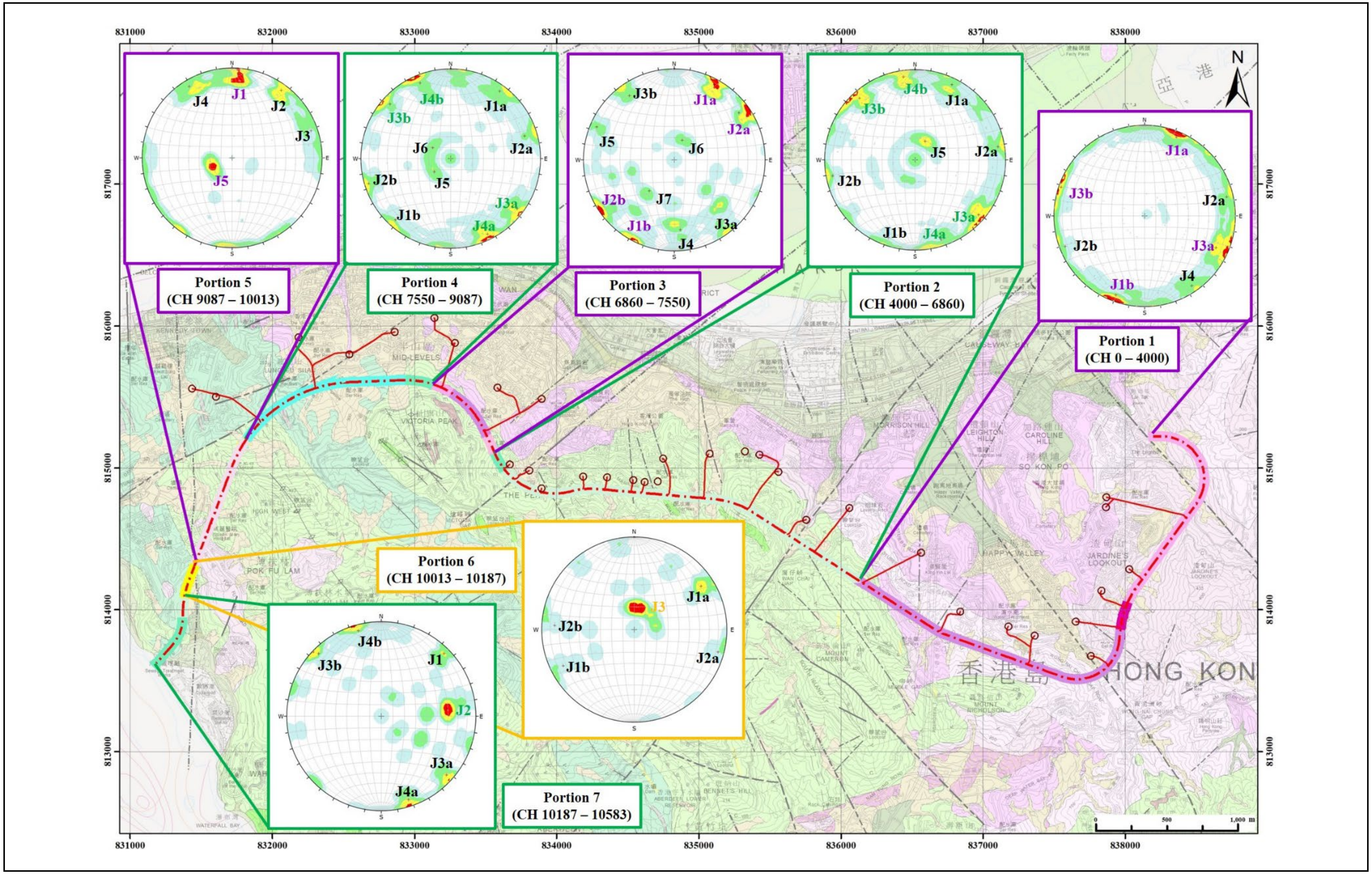


Figure 2.9 Stereoplots Based on the Rock Joint Data from the As-built Records of the Main Tunnel

2.4 Engineering Geological Properties

2.4.1 Rock Mass Quality

Arup (2007) assessed the rock mass quality by using the Q-system with the following equation as defined by Barton et al (1974):

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF} \quad \text{...} \quad (2.1)$$

Based on the above scheme, the rock mass quality could be sub-divided into a number of Rock Rating Classes as shown in Table 2.8. The consultant also conducted a statistical assessment of the anticipated Q-values into six portions by distribution of rock types. The rock rating classes are simplified as shown in Table 2.9.

Table 2.8 Classification of Rock Rating Classes Based on Q-value (after Barton et al, 1974; Arup, 2007)

Q-value	Rock Rating Class
< 0.1	Extremely Poor
0.1 - 1	Very Poor
1 - 4	Poor
4 - 10	Fair
10 - 40	Good
> 40	Very Good

Table 2.9 Summary of Distribution of Predicted Q-value of the Main Tunnel (after Arup, 2007)

Chainage (m)	Rock Type	Estimated Percentage in Rock Rating Class					
		Ext. Poor	Very Poor	Poor	Fair	Good	Very Good
CH 0 – 4100	Granite	0%	1%	5%	21%	41%	32%
CH 4100 – 6700	Tuff	1%	5%	24%	35%	33%	3%
CH 6700 – 7700	Granite	0%	0%	5%	18%	43%	33%
CH 7700 – 9600	Tuff	0%	2%	14%	20%	51%	12%
CH 9600 – 10100	Granite	0%	2%	15%	21%	51%	10%
CH 10100 – 10700	Tuff	2%	8%	28%	38%	24%	0%

During construction, the contractor also assessed the rock mass quality by using the Q-system. However, the six individual parameters were not recorded in the contractor's geological long section (DNJV, 2011). A statistical assessment of the actual Q-values was conducted and grouped into the simplified rock rating classes and by distribution of rock types. A total number of seven portions are grouped and the results are shown in Table 2.10.

The anticipated ranges of Q-value and actual Q-value are subsequently plotted in Figure 2.10. The rock mass quality recorded in various segments of the main tunnel is discussed in Section 2.4.1.1 to 2.4.1.7.

2.4.1.1 Portion 1 (CH 0 – 4000)

At Portion 1, the as-mapped Q-value ranged from 0.25 to 400.00. Over 70% of the rock mass was classified as "Good" or better in the rock rating class, which was consistent with the predictions made by Arup (2007). Rock mass quality increased readily from CH 2000 to CH 4000, such that a maximum Q-value of 400.0 was recorded at CH 3313 and CH 3736, which was significant higher than the anticipated Q-value. The rock mass was inferred to be massive with no major joint sets, based on the contractor's as-built records. There was one exception that the Q-value dropped from 15.83 to 0.56 at CH 652, which was thought to be related to the Tai Tam Fault as inferred by Arup (2007). A significant drop in Q-value (i.e. from 15.00 to 0.44) was recorded within the weakness zone at CH 2100, which was in the vicinity of the Wong Nai Chung Gap Fault as inferred by Arup (2007).

Table 2.10 Summary of Distribution of Actual Q-value of the Main Tunnel (after DNJV, 2011)

Chainage (m)	Rock Type	Actual Percentage in Rock Rating Class					
		Ext. Poor	Very Poor	Poor	Fair	Good	Very Good
CH 0 – 4000	Granite	0%	5%	9%	14%	40%	32%
CH 4000 – 6860	Tuff	0%	7%	57%	30%	6%	0%
CH 6860 – 7550	Granite	0%	0%	2%	34%	43%	21%
CH 7550 – 9058	Tuff	3%	5%	21%	28%	32%	11%
CH 9085 – 10013	Granite	0%	17%	43%	17%	23%	0%
CH 10013 – 10187	Granite & Tuff	54%	38%	8%	0%	0%	0%
CH 10187 – 10583	Tuff	27%	52%	21%	0%	0%	0%

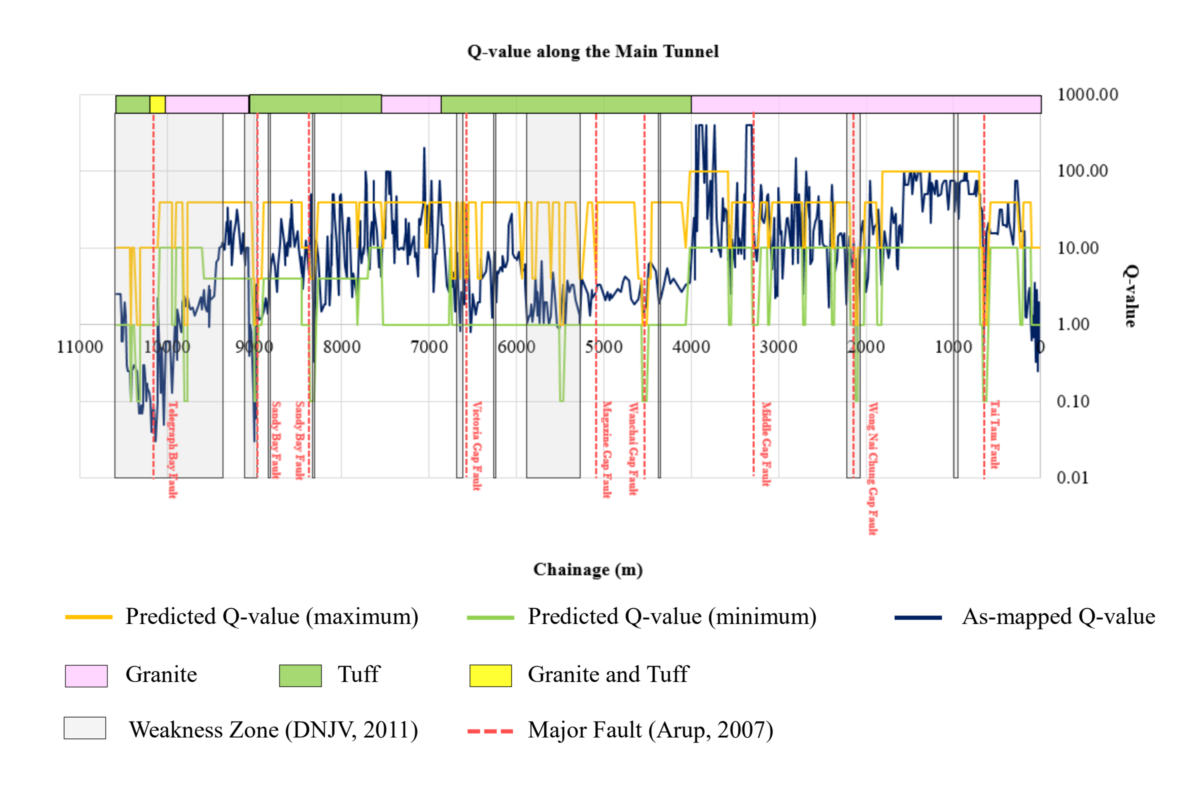


Figure 2.10 Distribution of Predicted and Actual Q-values along the Main Tunnel (after Arup, 2007; DNJV, 2011)

2.4.1.2 Portion 2 (CH 4000 – 6860)

At Portion 2, the as-mapped Q-value ranged from 0.80 to 35.00. Over 50% of the rock mass fell within the "Poor" category in the rock rating class, while Arup (2007) predicted that there should be less than 25% of "Poor" rock mass. Poor rock mass with Q-values ranging from 1.00 to 4.00 was primarily located at CH 5253 – 5873 where a prominent weakness zone was described in the contractor's geological long sections, which was in the vicinity of four photolineaments as inferred by Arup (2007).

2.4.1.3 Portion 3 (CH 6860 – 7550)

At Portion 3, the as-mapped Q-value ranged from 2.67 to 200.00. Over 90% of the rock mass was classified as "Fair" or better in the rock rating class, which was consistent with the predictions made by Arup (2007). The maximum Q-value recorded in Portion 3 was at CH 7055. Three photolineaments were inferred by Arup (2007) in Portion 3 but they seemed not to carry any implications on the rock mass quality.

2.4.1.4 Portion 4 (CH 7550 – 9058)

At Portion 4, the as-mapped Q-value ranged from 0.03 to 100.00. Around 40% of the rock mass was classified as "Good" or better in the rock rating class, which was lower than the anticipated rock mass conditions (i.e. over 60% of "Good" or better rock mass). Extremely poor rock mass conditions were recorded at CH 8319 (i.e. Q-value of 0.03) and at CH 8990 – 9000 (i.e. Q-value ranged from 0.03 to 0.07), which were interpreted to be related to the Sandy Bay Fault.

2.4.1.5 Portion 5 (CH 9058 – 10013)

At Portion 5, the as-mapped Q-value ranged from 0.13 to 33.33. Over 40% of the rock mass was classified as "Poor" in the rock rating class. "Very Poor" rock mass accounted for 17% of Portion 5, which were interpreted to be mostly related to Sandy Bay Fault, and Telegraph Bay Fault running sub-parallel to the main tunnel alignment. The rock mass conditions at Portion 5 were poorer than expected, such that Arup (2007) originally predicted that there should be around 50% of "Good" rock mass.

2.4.1.6 Portion 6 (CH 10013 – 10187)

At Portion 6, the as-mapped Q-value ranged from 0.03 to 2.20. Over 50% of the rock mass was classified as "Extremely Poor" in the rock rating class. Portion 6 had the worst rock mass conditions among other portions, which was thought to be related to the deeply-weathered zones along the geological contact between granite and tuff.

2.4.1.7 Portion 7 (CH 10187 – 10583)

At Portion 7, the observed Q-value ranged from 0.07 to 2.52. Arup (2007) anticipated that near 60% of rock mass would belong to "Fair" or better category in the rock rating class. In reality, over 50% of the rock mass was classified as "Very Poor", which was thought to be related to the Telegraph Graph Bay Fault. Adverse rock mass conditions were recorded within the whole portion in the contractor's geological long section (DNJV, 2011).

2.4.2 Groundwater Conditions

Hong Kong West Drainage Tunnel (HKWDT) constituted a deep hard rock tunnel such that the consultant treated the rock mass as a homogeneous medium with respect to its hydrogeological behavior. The nature of groundwater inflow was assumed to be dictated primarily by hydraulic conductivity of the rock mass. Due to the crystalline nature of both the granitic and volcanic rock mass, the predominant factor controlling groundwater inflow towards the tunnel would be the presence of discontinuities, weakness zones, faults, etc. (Arup, 2007). HKWDT was designed as a drained tunnel dependent on pre-excavation grouting to reduce water inflow. The following contractual requirements for allowable inflow limit were imposed for the Project:

(a) 0.2 litre/minute per metre of probe hole ahead of the excavation face;

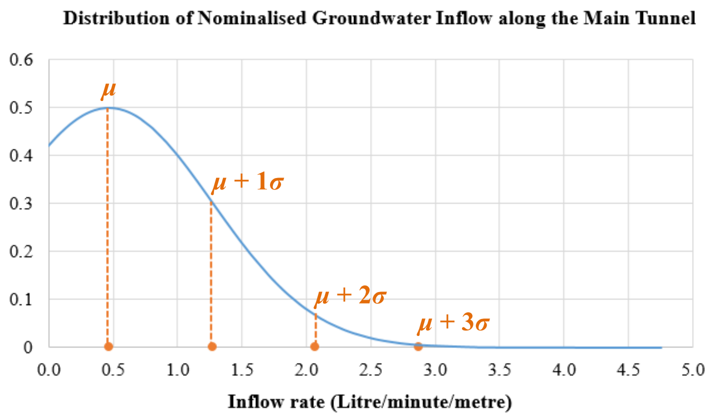
(b) 10 litres/minute per 100 metres of tunnel;

(c) 2 litres/minute through excavation face(s); and

(d) 300 litres/minute at tunnel portal(s).

Probing ahead of the excavation face was carried out by the contractor and actual rates of groundwater inflow were measured to determine the need for pre-excavation grouting. The groundwater inflow rate, together with the length of probe hole and volume of grout being used were summarised in the contractor's geological long sections (DNJV, 2011). The raw data is compiled in Appendix C of this report.

Given the lengths of each round probe hole were different, the unit for groundwater inflow was nominalised (L/min to L/min per metre). The data is illustrated in the form of a distribution curve as shown in Figure 2.11. The maximum inflow experienced in the main tunnel was 4.75 L/min/m at around CH 9834. Over 70% of the probing records indicated that the inflow rates were lower than 0.47 L/min/m (i.e. the mean value as shown in Figure 2.11).



Mean (μ):	0.47 L/min/m
Standard Deviation (σ):	0.80 L/min/m
$\mu + 1\sigma$:	1.27 L/min/m
$\mu + 2\sigma$:	2.07 L/min/m
$\mu + 3\sigma$:	2.87 L/min/m

Inflow (L/min/m)	Quantity	Percentage
< 0.47	227	73%
0.47-1.27	35	11%
1.27-2.07	30	10%
2.07-2.87	12	4%
> 2.87	7	2%

Figure 2.11 Distribution of Groundwater Inflow along the Main Tunnel (after DNJV, 2011)

The results, together with the distribution of rock type and locations of weakness zones are presented in Figure 2.12. The groundwater conditions along the main tunnel are discussed in Sections 2.4.2.1 to 2.4.2.7.

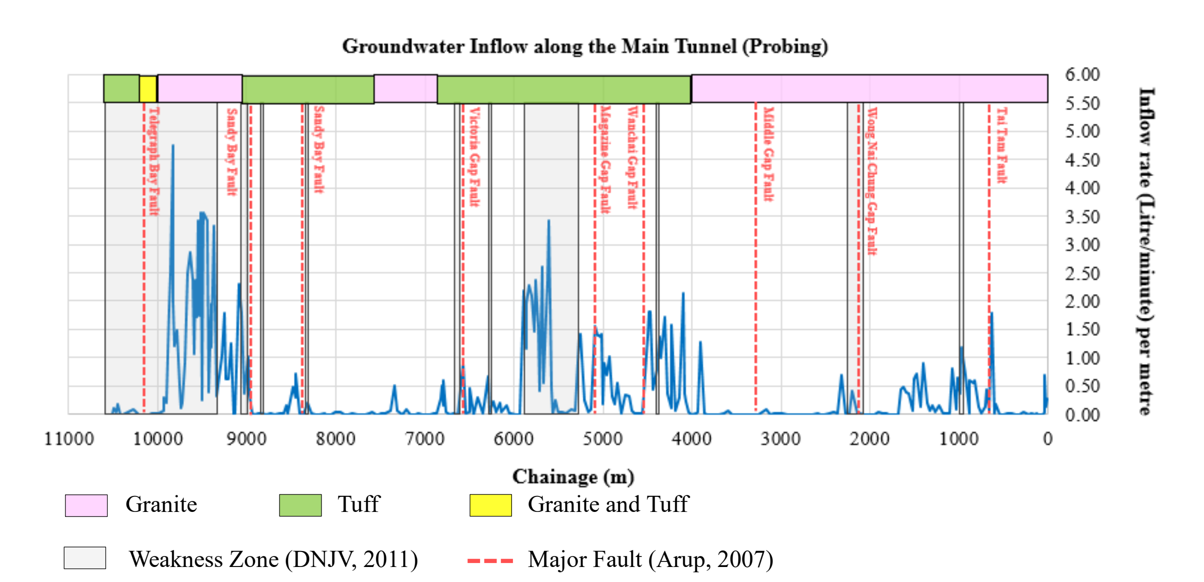


Figure 2.12 Groundwater Inflow from Probing along the Main Tunnel (after DNJV, 2011)

2.4.2.1 Portion 1 (CH 0 – 4000)

The groundwater inflow in probe holes within Portion 1 ranged from dry to 1.78 L/min/m with an average inflow of 0.16 L/min/m. The highest inflow rate was recorded at CH 627 and was associated with Tai Tam Fault as inferred by Arup (2007). Insignificant groundwater inflow was recorded in the vicinity of Wong Nai Chung Gap Fault and Middle Gap Fault.

2.4.2.2 Portion 2 (CH 4000 – 6860)

The groundwater inflow in probe holes within Portion 2 ranged from dry to 3.42 L/min/m with an average inflow of 0.68 L/min/m. The highest inflow rate was recorded at CH 5602 and was within an extensive weakness zone at CH 5254 – 5873 as indicated by the contractor (DNJV, 2011). Groundwater inflow was recorded in the vicinity of Wanchai Gap Fault (i.e. up to 1.81 L/min/m), Magazine Gap Fault (i.e. up to 1.39 L/min/m) and Victoria Gap Fault (i.e. up to 0.91 L/min/m).

2.4.2.3 Portion 3 (CH 6860 – 7550)

The groundwater inflow in probe holes within Portion 3 ranged from dry to 0.51 L/min/m with an average inflow of 0.05 L/min/m. The highest inflow rate was recorded at CH 7340 and was not associated with any known geological structures.

2.4.2.4 Portion 4 (CH 7550 – 9058)

The groundwater inflow in probe holes within Portion 4 ranged from dry to

1.78 L/min/m with an average of 0.15 L/min/m. The highest inflow rate was recorded at CH 9065 and within a weakness zone at CH 9000 – 9071 as indicated by the contractor (DNJV, 2011).

2.4.2.5 Portion 5 (CH 9058 – 10013)

The groundwater inflow in probe holes within Portion 5 ranged from dry to 4.75 L/min/m with an average inflow of 1.54 L/min/m, which was the highest among other portions of the main tunnel. The highest inflow rate was recorded at CH 9833 and within an extensive weakness zone at CH 9616 – 10583 as indicated by the contractor (DNJV, 2011).

2.4.2.6 Portion 6 (CH 10013 – 10187)

The groundwater inflow in probe holes within Portion 6 ranged from dry to 0.01 L/min/m and was considered as minimal in this portion.

2.4.2.7 Portion 7 (CH 10187 – 10583)

The groundwater inflow in probe holes within Portion 7 ranged from dry to 0.17 L/min/m with an average of 0.03 L/min/m.

3 Discussion

3.1 Summary of Findings

In terms of the distribution of rock type, the pre-construction geological model proved to be quite accurate in the majority of the main tunnel. Some deviations on the distribution of grain sizes of granites were noted in the consultant's report (Arup, 2007) and the contractor's as-built geological long sections (DNJV, 2011). However, these textural variations in granites had a relatively minor engineering implications to the tunnelling project.

For volcanic rocks, either fine ash tuff or coarse ash tuff were recorded during the construction stage, and their distribution generally concurs with the predictions given by Arup (2007). The consultant also attempted to indicate the locations where metamorphosed tuffs would be anticipated (Arup, 2007), given that it might carry engineering implications on TBM excavation as their physical properties could be different from non-metamorphosed tuff. Nevertheless, the contractor did not record any metamorphosed tuffs throughout their geological section (DNJV, 2011).

The main tunnel encountered the intrusive contact between granite and volcanic rocks at five locations, as predicted by Arup (2007) and confirmed by DNJV (2011), which is summarised in Table 3.1. Intrusive contacts are usually irregular in shape and the underground conditions are highly variable. The fourth geological contact, which was originally anticipated between Pok Fu Lam and High West at CH 9600. In reality, the contact was encountered between Lung Fu Shan and High West at CH 9058.

Table 3.1 Summary of Geological Contacts between Granite and Tuff along the Main Tunnel (after Arup, 2007; DNJV, 2011)

Contact No.	Predicted Chainage (m)	Actual Chainage (m)	Remarks
1	CH 4100	CH 4000	Sharp geological contact, 100 m to the east
2	CH 6700	CH 6860	Sharp geological contact, 160 m to the west
3	CH 7770	CH 7550	Sharp geological contact, 220 m to the east
4	CH 9600	CH 9058	Sharp geological contact, 542 m to the east
5	CH 10100	CH 10013 – 10187	Contact zone that is not clearly defined

In terms of structural geology, three types of geological structures, namely “Major Fault”, “Minor Fault” and “Photolineament”, of different extent of influence zone and transition zone, were inferred by Arup (2007) along the main tunnel. On the other hand, the terminologies “shear zone”, “fault zone”, “fault breccia”, “fault gouge” and “shear zone with highly fractured rock mass” were used qualitatively for describing weakness zones by the contractor (DNJV, 2011). The locations of weakness zones overlap with four out of eight major faults, including the Wong Nai Chung Gap Fault, Victoria Gap Fault, Sandy Bay Fault and Telegraph Bay Fault. An extensive weakness zone that overlapped with four photolineaments was located at CH 5254 – 5873. No record of weakness zones, which might be indicative of the Tai Tam Fault, Middle Gap Fault, Wanchai Gap Fault and Magazine Gap Fault were shown in the contractor’s geological long section (DNJV, 2011).

In terms of rock joints, a wealth of rock joint data was collected by the contractor during tunnel mapping and was plotted on stereonets. The volcanic rocks have a relatively higher number of joint sets in comparison to granitic rocks along the main tunnel.

In terms of Q-value and rock mass rating class, the predictions made by Arup (2007) for Portions 1 to 4 of the main tunnel generally concurred with the actual rock mass quality as recorded by the contractor (DNJV, 2011). As for Portions 5 to 7 of the main tunnel, the rock mass quality was poorer than expected and was thought to be related to the influence by the Sandy Bay Fault and the Telegraph Bay Fault.

In terms of groundwater, areas of significant groundwater were mainly within Portions 2 and 5 of the main tunnel and were associated with Sandy Bay Fault, Telegraph Bay Fault and weakness zones.

3.2 Limitations of this Study

The present study was largely based on the consultant’s geotechnical interpretation report and the contractor’s as-built geological long section. Original tunnel mapping records and operational information of TBM (e.g. advancement rate) of the project were unavailable for review and study. In the contractor’s as-built geological long section, the descriptions for adverse geological features were very general, making it difficult to correlate with the inferred faults as described in the consultant's report. The data scarcity might also due to the fact that tunnel mapping could only be conducted at cutter head or telescopic opening of the TBM tunnel. The above limitations were acknowledged.

4 Conclusions

A review study has been conducted on the engineering geological aspects of Hong Kong West Drainage Tunnel. The useful engineering geological data, including the lithology, geological structures, rock mass quality and groundwater conditions were extracted from the contractor's as-built geological long section. The comparisons between the pre-construction and post-construction geological models were documented in this report. The similarities and differences between the two models, including the distribution of lithology, locations of intrusive contacts, rock joint orientations and adverse rock mass conditions were discussed. The data will be used in setting up a tunnel database for future use.

5 References

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Appendix A

Summary of Engineering Geological Data

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 1 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
7.00	III/IV	Klb	gfm	-	Damp	3	0.44	-	
22.00	II/III	Klb	gfm	-	Dry	3	0.44	-	
23.00	II/III	Klb	gfm	-	Damp	3	1.94	-	
27.00	II/III	Klb	gfm	-	Dry	3	1.94	-	
29.00	II/III	Klb	gfm	-	Damp	3	0.83	-	
30.00	II/III	Klb	gfm	-	Damp	4	0.25	-	
32.00	II/III	Klb	gfm	-	Wet	4	0.75	-	
35.00	II/III	Klb	gfm	-	Damp	3+R	0.41	-	
47.00	I	Klb	gfm	-	Damp	3+R	2.87	-	
54.00	I/II	Klb	gfm	-	Dry	3	2.27	-	
60.00	III	Klb	gfm	-	Dry	3	0.33	-	
63.00	IV/V	Klb	gfm	-	Dry	3	2.00	-	
66.00	I/III	Klb	gfm	-	Dry	2	1.00	-	
68.00	I/II/III	Klb	gfm	-	Dry	3	3.50	-	
84.00	II/III	Klb	gfm	-	Damp	3	0.69	-	
94.00	II/III	Klb	gfm	-	Dry	2+R	1.30	-	
98.00	II/III	Klb	gfm	-	Damp	3	0.63	-	
120.00	II/III	Klb	gfm	-	Dry	3	1.25	-	
123.00	I/II	Klb	gfm	-	Dry	3	3.00	-	
137.00	I/II	Klb	gfm	-	Dry	3	2.63	-	
163.00	I/II	Klb	gfm	-	Dry	3	1.25	-	
180.00	I/II	Klb	gfm	-	Dry	3	1.29	-	
183.00	I/II	Klb	gfm	PW90/100	Dry	3	16.67	ET001	
192.97	I/II	Klb	gfm	PW90/100	Dry	3	16.67	ET002	
214.70	I/II	Klb	gfm	UW to PW90/100	Dry	3	16.67	ET003	
231.16	I/II	Klb	gfm	UW to PW90/100	Dry	3	16.67	ET004	
264.16	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET005	
290.00	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET006	
304.76	I	Klb	gfm	UW to PW90/100	Dry	3	20.00	ET007	
310.76	I	Klb	gfm	UW to PW90/100	Dry	3	11.10	ET008	
357.20	I/II	Klb	gfm	UW to PW90/100	Dry	3	22.20	ET009	
376.53	I/II	Klb	gfm	UW to PW90/100	Dry	3	40.00	ET010	
388.79	I/II	Klb	gfm	UW to PW90/100	Dry	3	18.90	ET011	
405.09	I/II	Klb	gfm	UW to PW90/100	Dry	3	20.00	ET012	
424.04	I/II	Klb	gfm	UW to PW90/100	Dry	3	20.00	ET013	
434.41	I/II	Klb	gfm	UW to PW90/100	Dry	3	20.00	ET014	
445.84	I/II	Klb	gfm	UW to PW90/100	Dry	3	31.67	ET015	
470.06	I/II	Klb	gfm	UW to PW90/100	Dry	3	31.67	ET016	
487.85	I/II	Klb	gfm	UW to PW90/100	Dry	3	15.00	ET017	
504.12	I/II	Klb	gfm	UW to PW90/100	Dry	3	15.83	ET018	
529.90	I/II	Klb	gfm	UW to PW90/100	Dry	3	15.83	ET019	
552.05	I/II	Klb	gfm	UW to PW90/100	Dry	3	15.83	ET020	

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 2 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
574.92	I/II	Klb	gfm	UW to PW90/100	Dry	3	15.83	ET021	
601.93	I/II	Klb	gfm	UW to PW90/100	Dry	3	21.10	ET022	pegmatite veins and basalt dykes observed
621.53	I/II	Klb	gfm	UW to PW90/100	Dry	3	15.83	ET023	pegmatite veins and basalt dykes observed
651.52	I/II	Klb	gfm	UW to PW90/100	Minor Inflow	3	0.56	ET024	<5L/min, pegmatite veins and basalt dykes observed
652.96	III-IV	Klb	gfm	UW to PW90/100	Minor Inflow	3	7.50	ET025	<5L/min, pegmatite veins and basalt dykes observed
672.25	I/II	Klb	gfm	UW to PW90/100	Dry	2	30.00	ET026	pegmatite veins and basalt dykes observed
682.96	I/II	Klb	gfm	UW to PW90/100	Dry	3	33.33	ET027	pegmatite veins and basalt dykes observed
688.96	I/II	Klb	gfm	UW to PW90/100	Dry	3	33.33	ET028	pegmatite veins and basalt dykes observed
690.54	I	Klb	gfm	UW to PW90/100	Dry	3	50.00	ET029	pegmatite veins and basalt dykes observed
702.55	I	Klb	gfm	UW to PW90/100	Dry	2	50.00	ET030	pegmatite veins and basalt dykes observed
721.41	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET031	pegmatite veins and basalt dykes observed
735.37	I	Klb	gfm	UW to PW90/100	Dry	3	47.50	ET032	pegmatite veins and basalt dykes observed
739.24	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET033	pegmatite veins and basalt dykes observed
758.24	I/II	Klb	gfm	UW to PW90/100	Dry	2	50.00	ET034	pegmatite veins and basalt dykes observed
779.08	I	Klb	gfm	UW to PW90/100	Dry	2	50.00	ET035	pegmatite veins and basalt dykes observed
792.58	I/II	Klb	gfm	UW to PW90/100	Dry	2	50.00	ET036	pegmatite veins and basalt dykes observed
804.31	I/II	Klb	gfm	UW to PW90/100	Dry	2	50.00	ET037	
810.31	I/II	Klb	gfm	UW to PW90/100	Dry	2	50.00	ET038	
818.11	I/II	Klb	gfm	UW to PW90/100	Dry	2	50.00	ET039	
828.43	I/II	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET040	
842.07	I/II	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET041	
842.17	I/II	Klb	gfm	UW to PW90/100	Dry	2	100.00	ET042	
856.94	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET043	
867.67	I	Klb	gfm	UW to PW90/100	Dry	2	100.00	ET044	
879.62	I	Klb	gfm	UW to PW90/100	Minor Inflow	2	75.00	ET045	<5L/min
909.69	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET046	
924.61	I	Klb	gfm	UW to PW90/100	Dry	2	71.25	ET047	
945.74	I/II	Klb	gfm	UW to PW90/100	Dry	2	23.80	ET048	Shear zone, manganese coating, surface staining and chloride coating
960.67	I/II	Klb	gfm	UW to PW90/100	Dry	2	71.25	ET049	
981.65	I/II	Klb	gfm	UW to PW90/100	Dry	2	30.00	ET050	Fault zone, 85/350, 150mm wide grade iv infill
989.24	I/II	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET051	
1008.71	I	Klb	gfm	UW to PW90/100	Minor Inflow	2	75.00	ET052	<5L/min
1031.23	I	Klb	gfm	UW to PW90/100	Minor Inflow	2	75.00	ET053	<5L/min
1059.93	I/II	Klb	gfm	UW to PW90/100	Minor Inflow	3	31.67	ET054	<5L/min
1062.72	I	Klb	gfm	UW to PW90/100	Dry	3	33.33	ET055	
1070.30	I/II	Klb	gfm	UW to PW90/100	Dry	2	47.50	ET056	
1083.80	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET057	
1092.79	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET058	
1107.82	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET059	
1131.78	I	Klb	gfm	UW to PW90/100	Dry	2	66.70	ET060	
1144.38	I	Klb	gfm	UW to PW90/100	Dry	2	50.00	ET061	
1170.74	I	Klb	gfm	UW to PW90/100	Dry	2	47.00	ET062	

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 3 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
1182.89	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET063	
1193.36	I	Klb	gfm	UW to PW90/100	-	-	-	ET064	
1199.36	I	Klb	gfm	UW to PW90/100	Dry	2	75.00	ET065	
1215.89	I	Klb	gfm	UW	Dry	2	50.00	ET066	
1245.99	I	Klb	gfm	UW	Dry	2	71.25	ET067	
1259.38	I/II	Klb	gfm	UW	Dry	3	21.25	ET068	
1269.92	I	Klb	gfm	UW	Dry	1	100.00	ET069	
1298.29	I	Klb	gfm	UW	Dry	2	50.00	ET070	
1309.79	I	Klb	gfm	UW	Dry	2	50.00	ET071	
1325.32	I	Klb	gfm	UW	Dry	2	50.00	ET072	
1356.93	I/II	Klb	gfm	UW	Dry	3	30.00	ET073	
1376.50	I	Klb	gfm	UW	Dry	2	100.00	ET074	
1386.99	I	Klb	gfm	UW	Dry	2	100.00	ET075	
1400.37	I	Klb	gfm	UW	Dry	2	100.00	ET076	
1427.33	I	Klb	gfm	UW	Dry	2	75.00	ET077	
1451.47	I	Klb	gfm	UW	Dry	1	100.00	ET078	
1471.01	I	Klb	gfm	UW	Dry	1	50.00	ET079	
1481.55	I	Klb	gfm	UW	Dry	2	100.00	ET080	
1498.15	I	Klb	gfm	UW	Dry	1	100.00	ET081	
1520.45	I	Klb	gfm	UW	Minor Inflow	2	66.00	ET082	<5L/min
1555.10	I	Klb	gfm	UW	Dry	1	66.67	ET083	
1564.02	I	Klb	gfm	UW	Dry	1	100.00	ET084	
1586.44	I	Klb	gfm	UW	Minor Inflow	3	11.88	ET085	<5L/min
1608.68	I	Klb	gmc	UW	Dry	3	20.00	ET086	
1618.07	I	Klb	gmc	UW	Dry	3	18.89	ET087	
1636.05	I	Klb	gmc	UW	Dry	4	5.30	ET088	
1649.54	I	Klb	gmc	UW	Dry	4	6.00	ET089	
1664.43	I	Klb	gmc	UW	Minor Inflow	2	28.30	ET090	<5L/min
1681.09	I	Klb	gmc	UW	Minor Inflow	2	21.30	ET091	<5L/min
1703.41	I	Klb	gmc	UW	Dry	2	33.33	ET092	
1712.62	I	Klb	gmc	UW	Dry	3	18.89	ET093	
1729.34	I/II	Klb	gmc	UW	Dry	3	8.90	ET094	
1742.72	I/II	Klb	gmc	UW	Dry	3	7.50	ET095	
1757.76	I	Klb	gmc	UW	Dry	4	9.00	ET096	
1775.71	I/II	Klb	gmc	UW	Dry	3	13.30	ET097	
1790.75	I/II	Klb	gmc	UW	Dry	3	16.69	ET098	
1808.79	I/II	Klb	gm	UW	Dry	3	5.00	ET099	
1822.27	I/II	Klb	gm	UW	Dry	3	3.33	ET100	
1838.75	II	Klb	gm	UW	Damp	3	8.80	ET101	
1853.67	I/II	Klb	gm	UW	Dry	3	31.67	ET102	
1867.34	I/II	Klb	gm	UW	Minor Inflow	3	21.25	ET103	<5L/min

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 4 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
1886.78	I/II	Klb	gm	UW	Dry	3	20.00	ET104	
1901.82	I/II	Klb	gm	UW	Damp	2	18.70	ET105	
1922.76	I/II	Klb	gm	UW	Dry	2	15.00	ET106	
1942.25	I/II	Klb	gm	UW	Dry	2	31.40	ET107	
1951.25	I/II	Klb	gm	UW	Dry	2	75.00	ET108	
1963.24	I/II	Klb	gm	UW	Dry	3	10.56	ET109	
1981.33	I/II	Klb	gm	UW	Dry	4	4.00	ET110	
2000.84	I/II	Klb	gm	UW to PW90/100	Dry	4	2.67	ET111	
2006.92	I/II	Klb	gm	UW to PW90/100	Dry	4	6.67	ET112	
2024.76	I/II	Klb	gm	UW to PW90/100	Dry	2	15.00	ET113	
2039.83	I/II	Klb	gm	UW to PW90/100	Dry	2	22.50	ET114	
2056.40	I/II	Klb	gm	UW to PW90/100	Dry	3	15.00	ET115	
2092.24	II-IV	Klb	gm	UW to PW90/100	Dry	4	1.83	ET116	Locally HDG
2099.92	II/III	Klb	gm	UW to PW90/100	Dry	3	0.44	ET117	Locally HDG, Fault Breccia
2118.12	I/II	Klb	gm	UW to PW90/100	Dry	3	7.22	ET118	
2126.95	II/III	Klb	gm	UW to PW90/100	Minor Inflow	3	7.22	ET119	<5L/min, Fault Breccia
2137.49	II/III	Klb	gm	UW to PW90/100	Dry	2	12.50	ET120	
2154.09	I/II	Klb	gm	UW to PW90/100	Minor Inflow	4	5.67	ET121	<5L/min
2181.19	I/II	Klb	gm	UW to PW90/100	Dry	3	7.50	ET122	
2193.09	II	Klb	gm	UW to PW90/100	Dry	3	14.20	ET123	
2209.56	I/II	Klb	gm	UW	Dry	4	5.66	ET124	
2220.05	I/II	Klb	gm	UW	Dry	5	1.86	ET125	Shear zone
2235.20	I/II	Klb	gm	UW	Dry	5	5.33	ET126	
2248.09	I/II	Klb	gm	UW	Dry	3	15.80	ET127	
2256.14	I/II	Klb	gm	UW	Dry	3	10.00	ET128	
2269.64	I/II	Klb	gm	UW	Dry	3	14.16	ET129	
2282.99	I	Klb	gm	UW	Dry	2	15.83	ET130	
2299.62	I	Klb	gm	UW	Dry	2	15.83	ET131	
2314.58	I/II	Klb	gm	UW	Dry	2	14.20	ET132	
2329.49	II	Klb	gm	UW	Dry	3	7.10	ET133	
2349.07	I/II	Klb	gm	UW	Minor Inflow	3	5.00	ET134	<5L/min
2352.09	I/II	Klb	gm	UW	Minor Inflow	2	9.00	ET135	<5L/min
2371.45	I/II	Klb	gm	UW	Dry	3	11.25	ET136	
2385.08	I	Klb	gm	UW	Dry	2	67.50	ET137	
2401.45	I/II	Klb	gm	-	Dry	3	28.33	ET138	
2428.48	I/II	Klb	gm	-	Dry	4	1.67	ET139	
2452.44	I/II	Klb	gm	-	Dry	3	10.55	ET140	
2476.51	I	Klb	gm	-	Dry	3	10.55	ET141	
2489.99	I/II	Klb	gm	-	Dry	3	11.30	ET142	
2501.92	I/II	Klb	gm	-	Dry	2	22.50	ET143	
2524.62	I/II	Klb	gm	-	Dry	2	22.50	ET144	

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 5 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
2531.92	I/II	Klb	gm	-	Dry	4	11.25	ET145	
2546.98	I	Klb	gm	-	Dry	2	47.50	ET146	
2555.99	I	Klb	gm	-	Dry	2	31.67	ET147	
2567.94	I	Klb	gm	-	Dry	2	23.75	ET148	
2581.48	I/II	Klb	gm	-	Dry	2	22.50	ET149	
2598.00	I/II	Klb	gm	-	Dry	2	16.70	ET150	
2617.51	II	Klb	gm	UW	Dry	3	7.08	ET151	
2635.55	I/II	Klb	gm	UW	Dry	3	6.25	ET152	
2647.70	I/II	Klb	gm	UW	Dry	1	63.30	ET153	
2652.22	I/II	Klb	gm	UW	Dry	3	25.00	ET154	
2670.12	I	Klb	gm	UW	Dry	1	50.00	ET155	
2685.04	I	Klb	gm	UW	Dry	1	100.00	ET156	
2700.08	I/II	Klb	gm	UW	Dry	2	35.62	ET157	
2716.63	I/II/III	Klb	gm	UW	Dry	3	2.50	ET158	
2734.58	II	Klb	gm	UW	Dry	3	30.00	ET159	
2748.10	I/II	Klb	gm	UW	Dry	3	10.60	ET160	
2764.61	I/II	Klb	gm	UW	Dry	2	50.00	ET161	
2781.11	I/II	Klb	gm	UW	Dry	4	6.33	ET162	
2806.86	I	Klb	gm	UW	Dry	1	150.00	ET163	
2820.13	I/II	Klb	gm	UW	Dry	3	16.70	ET164	
2833.70	I	Klb	gm	UW	Dry	3	6.25	ET165	
2844.28	I	Klb	gm	UW	Dry	2	37.50	ET166	
2858.68	I	Klb	gm	UW	Dry	3	10.60	ET167	
2890.68	I	Klb	gm	UW	Dry	2	25.00	ET168	
2904.27	I/II	Klb	gm	UW	Dry	3	24.00	ET169	
2928.23	I/II	Klb	gm	UW	Minor Inflow	2	12.00	ET170	<5L/min
2928.34	I/II	Klb	gm	UW	Minor Inflow	2	12.00	ET171	<5L/min
2955.40	I	Klb	gm	UW	Dry	4	4.00	ET172	
2964.95	I	Klb	gm	UW	Dry	3	16.70	ET173	
2976.33	I	Klb	gm	UW	Dry	3	15.00	ET174	
2990.17	I	Klb	gm	UW	Dry	3	28.30	ET175	
3006.52	I	Klb	gm	UW	Dry	2	60.00	ET176	
3015.55	I/II	Klb	gm	UW	Dry	4	2.37	ET177	
3026.07	I/II	Klb	gm	UW	Dry	3	3.12	ET178	
3036.38	I/II	Klb	gm	UW	Dry	4	2.25	ET179	
3052.87	I/II	Klb	gm	UW	Dry	2	25.00	ET180	
3075.47	I	Klb	gm	UW	Dry	2	5.33	ET181	
3111.52	I	Klb	gm	UW	Dry	4	25.00	ET182	
3117.52	I	Klb	gm	UW	Dry	1	50.00	ET183	
3132.34	I	Klb	gm	UW	Dry	1	47.50	ET184	
3147.26	I	Klb	gm	UW	Dry	2	31.70	ET185	

Table A   Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 6 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
3147.54	I	Klb	gm	UW	Dry	2	31.70	ET186	
3164.03	I	Klb	gm	UW	Dry	3	21.10	ET187	
3189.51	I	Klb	gm	UW	Dry	2	23.80	ET188	
3192.46	I	Klb	gm	UW	Dry	2	50.00	ET189	
3202.99	I	Klb	gm	UW	Dry	4	67.00	ET190	
3235.96	I	Klb	gm	UW	Dry	2	10.00	ET191	
3243.50	I	Klb	gm	UW	Dry	3	6.70	ET192	
3252.46	I	Klb	gm	UW	Dry	3	6.70	ET193	
3269.10	I	Klb	gm	UW	Dry	3	11.10	ET194	
3278.00	I	Klb	gm	UW	Dry	3	11.10	ET195	
3291.51	I	Klb	gm	UW	Dry	2	25.00	ET196	
3295.97	I	Klb	gm	UW	Dry	2	33.75	ET197	
3312.63	I	Klb	gm	UW	Dry	0	400.00	ET198	
3317.22	I/II	Klb	gm	UW	Dry	1	400.00	ET199	
3338.10	I	Klb	gm	UW	Dry	1	400.00	ET200	
3345.64	I	Klb	gm	UW	Dry	0	400.00	ET201	
3359.09	I	Klb	gm	UW	Dry	1	400.00	ET202	
3366.68	I	Klb	gm	UW	Dry	1	400.00	ET203	
3389.98	I/II	Klb	gm	UW	Dry	3	7.20	ET204	
3395.20	I	Klb	gm	UW	Dry	2	50.00	ET205	
3422.39	I/II	Klb	gm	UW	Dry	3	8.33	ET206	
3431.17	I/II	Klb	gm	UW	Dry	3	8.30	ET207	
3444.69	I/II	Klb	gm	UW	Dry	3	13.30	ET208	
3465.69	I/II	Klb	gm	UW	Dry	3	8.30	ET209	
3477.96	I/II	Klb	gm	UW	Dry	1	71.25	ET210	
3491.27	I/II	Klb	gm	UW	Dry	3	10.56	ET211	
3494.24	I/II	Klb	gm	UW	Dry	3	5.67	ET212	
3531.75	II	Klb	gm	UW	Dry	2	13.10	ET213	
3539.19	II	Klb	gm	UW	Minor Inflow	4	2.50	ET214	<5L/min
3569.30	I/II	Klb	gm	UW	Seepage	2	20.00	ET215	
3582.83	I/II	Klb	gm	UW	Minor Inflow	2	7.08	ET216	<5L/min
3588.82	I/II	Klb	gm	UW	Dry	1	30.00	ET217	
3612.79	I	Klb	gm	UW	Minor Inflow	2	33.00	ET218	<5L/min
3629.86	I	Klb	gm	UW	Dry	2	22.50	ET219	
3638.31	I/II	Klb	gm	UW	Dry	2	45.00	ET220	
3662.36	II	Klb	gm	UW	Dry	3	7.78	ET221	
3675.86	II	Klb	gm	UW	Dry	3	8.89	ET222	
3684.86	I	Klb	gm	UW	Dry	3	9.40	ET223	
3687.99	I	Klb	gm	UW	Dry	3	10.60	ET224	
3706.00	I	Klb	gm	UW	Dry	2	23.80	ET225	
3716.50	I	Klb	gm	UW	Minor Inflow	1	100.00	ET226	<5L/min

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 7 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
3735.87	I	Klb	gm	UW	Dry	0	400.00	ET227	
3736.00	I	Klb	gm	UW	Dry	0	400.00	ET228	
3753.99	I	Klb	gm	UW	Dry	1	71.30	ET229	
3773.53	I/II	Klb	gm	UW	Dry	3	8.89	ET230	
3781.05	I	Klb	gm	UW	Dry	1	75.00	ET231	
3812.53	I	Klb	gm	UW	Dry	2	23.75	ET232	
3830.53	I	Klb	gm	UW	Dry	0	400.00	ET233	
3852.95	I	Klb	gm	UW	Dry	2	71.25	ET234	
3872.47	I	Klb	gm	UW	Dry	0	400.00	ET235	
3887.92	I	Klb	gm	UW	Dry	0	400.00	ET236	
3905.49	I	Klb	gm	UW	Dry	0	400.00	ET237	
3931.12	I	Klb	gm	UW	Dry	2	16.70	ET238	
3941.62	I	Klb	gm	UW	Dry	0	400.00	ET239	
3943.10	I	Klb	gm	UW	Dry	0	400.00	ET240	
3944.60	I	Klb	gm	UW	Dry	2	75.00	ET241	
3946.11	I	Klb	gm	UW	Dry	2	150.00	ET242	
3947.61	I	Klb	gm	UW	Dry	2	150.00	ET243	
3949.11	I	Klb	gm	UW	Minor Inflow	1	150.00	ET244	<5L/min
3950.60	I/II	Klb	gm	UW	Wet	2	10.00	ET245	
3952.08	I/II	Klb	gm	UW	Minor Inflow	3	3.93	ET246	<5L/min
3953.60	I/II	Klb	gm	UW	Damp	2	11.90	ET249	
3955.41	I/II	Klb	gm	UW	Minor Inflow	2	6.67	ET251	<5L/min
3956.66	I/II	Klb	gm	UW	Minor Inflow	2	15.80	ET253	<5L/min
3958.07	I/II	Klb	gm	UW	Minor Inflow	2	15.00	ET255	<5L/min
3958.08	I/II	Klb	gm	UW	Damp	2	11.25	ET247	
3959.60	I	Klb	gm	UW	Damp	1	23.30	ET248	
3961.41	I	Klb	gm	UW	Dry	2	17.80	ET250	
3962.66	I	Klb	gm	UW	Damp	2	25.00	ET252	
3964.07	I	Klb	gm	UW	Damp	2	25.00	ET254	
4013.13	I/II	Klb/Kra	gm/fat	UW	Dry	3+R	3.54	WT356	
4067.51	I/II	Kra	fat	UW	Dry	3+R	3.33	WT355	
4109.34	I/II	Kra	fat	UW	Minor Inflow	4	2.66	WT354	<5L/min
4198.12	I/II	Kra	fat	UW	Dry	3+R	4.01	WT353	
4243.15	I/II	Kra	fat	UW	Dry	3+R	3.44	WT352	
4274.00	I/II	Kra	fat	UW	Minor Inflow	4	5.50	WT351	<5L/min
4313.67	I/II	Kra	fat	UW	Dry	3+R	3.44	WT350	
4348.16	I/II	Kra	fat	UW	Dry	4	2.33	WT349	
4363.87	I/II	Kra	fat	UW	Dry	3+R	1.89	WT348	highly fractured rock mass
4401.85	I/II	Kra	fat	UW	Dry	3+R	5.00	WT347	
4445.89	I/II	Kra	fat	UW	Dry	3+R	6.25	WT346	
4468.58	I/II	Kra	fat	UW	Dry	3+R	6.67	WT345	

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 8 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
4483.46	I/II	Kra	fat	UW	Dry	3+R	6.25	WT344	
4509.14	I/II	Kra	fat	UW	Dry	3+R	1.89	WT343	
4558.51	I/II	Kra	fat	UW	Dry	3+R	1.33	WT342	
4573.50	I/II	Kra	fat	UW	Dry	5	3.75	WT341	
4606.78	I/II	Kra	fat	UW	Dry	4	2.19	WT340	
4653.18	I/II	Kra	fat	UW	Dry	3+R	1.88	WT339	
4683.18	I/II	Kra	fat	UW	Dry	3+R	2.19	WT338	
4713.54	I/II	Kra	fat	UW	Dry	3+R	3.75	WT337	
4754.07	I/II	Kra	fat	UW	Damp	4	4.33	WT336	
4783.81	I/II	Kra	fat	UW	Minor Inflow	3	3.61	WT335	<5L/min
4803.39	I/II	Kra	fat	UW	Dry	3+R	2.70	WT334	
4842.59	I/II	Kra	fat	UW	Dry	3+R	2.92	WT333	
4908.50	I/II	Kra	fat	UW	Dry	3+R	2.25	WT332	
4926.20	I/II	Kra	fat	UW	Minor Inflow	3+R	2.50	WT331	
4937.03	I/II	Kra	fat	UW	Damp	3+R	2.08	WT330	
4955.90	II	Kra	fat	UW	Damp	3	2.70	WT329	
4985.02	I/II	Kra	fat	UW	Damp	3+R	2.08	WT328	
5034.67	I	Kra	fat	UW	Minor Inflow	4	3.33	WT327	<5L/min
5070.00	I	Kra	fat	UW	Dry	4	3.33	WT326	
5088.75	I	Kra	fat	UW	Dry	4	2.70	WT325	
5133.77	I	Kra	fat	UW	Dry	3	2.22	WT324	
5140.25	I	Kra	fat	UW	Dry	3+R	2.81	WT323	
5160.79	I/II	Kra	fat	UW	Dry	3+R	1.33	WT322	
5177.00	I	Kra	fat	UW	Damp	3	2.50	WT321	
5253.91	I	Kra	fat	UW	Damp	4	4.00	WT320	highly fractured rock mass
5271.89	I	Kra	fat	UW	Damp	4	1.00	WT319	highly fractured rock mass
5276.34	I	Kra	fat	UW	Damp	4	1.33	WT318	highly fractured rock mass
5321.45	I	Kra	fat	UW	Minor Inflow	3+R	2.08	WT317	<5L/min, highly fractured rock mass
5346.87	I	Kra	fat	UW	Damp	4	3.33	WT316	highly fractured rock mass
5366.71	I	Kra	fat	UW	Damp	4	3.33	WT315	highly fractured rock mass
5390.63	I	Kra	fat	UW	Damp	4	2.66	WT314	highly fractured rock mass
5416.15	I	Kra	fat	UW	Dry	3+R	3.75	WT313	highly fractured rock mass
5442.52	I	Kra	fat	UW	Minor Inflow	4	1.00	WT312	<5L/min, highly fractured rock mass
5465.81	I	Kra	fat	UW	Dry	3+R	3.30	WT311	highly fractured rock mass
5497.19	I/II	Kra	fat	UW	Minor Inflow	4	1.00	WT310	<5L/min, highly fractured rock mass
5509.35	I	Kra	fat	UW	Minor Inflow	4	0.89	WT309	<5L/min, highly fractured rock mass
5540.69	I	Kra	fat	UW	Damp	3	0.97	WT308	highly fractured rock mass
5563.34	I	Kra	fat	UW	Minor Inflow	4	2.33	WT307	<5L/min, highly fractured rock mass
5585.77	II	Kra	fat	UW	Minor Inflow	3	4.90	WT306	<5L/min, highly fractured rock mass
5608.30	II	Kra	fat	UW	Minor Inflow	4	1.32	WT305	highly fractured rock mass
5630.80	I	Kra	fat	UW	Damp	4	1.00	WT304	gm intrusion, highly fractured rock mass

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 9 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
5653.17	I	Kra	fat	UW	Minor Inflow	4	2.00	WT303	<5L/min, highly fractured rock mass
5674.56	I	Kra	fat	UW	Damp	4	2.00	WT302	gm intrusion, highly fractured rock mass
5693.67	I	Kra	fat	UW	Minor Inflow	4	1.07	WT301	pegmatite veins, highly fractured rock mass
5711.71	II	Kra	fat	UW	Dry	3	6.70	WT300	gm intrusion
5734.45	I	Kra	fat	UW	Dry	4	1.07	WT299	gm intrusion, highly fractured rock mass
5753.99	I/II	Kra	fat	UW	Minor Inflow	4	2.67	WT298	<5L/min, gm intrusion, highly fractured rock mass
5762.66	I/II	Kra	fat	UW	Minor Inflow	4	1.33	WT297	<5L/min, highly fractured rock mass
5784.32	I/II	Kra	fat	UW	Minor Inflow	4	4.33	WT296	<5L/min
5794.64	II	Kra	fat	UW	Minor Inflow	4	1.80	WT295	<5L/min
5811.92	I/II	Kra	fat	UW	Medium Inflow	4	1.10	WT294	10L/min, highly fractured rock mass
5829.36	I/II	Kra	fat	UW	Minor Inflow	4	1.83	WT293	<5L/min, highly fractured rock mass
5843.76	I/II	Kra	fat	UW	Minor Inflow	4	1.33	WT292	<5L/min, highly fractured rock mass
5852.18	I/II	Kra	fat	UW	Minor Inflow	5	1.33	WT291	<5L/min, highly fractured rock mass
5873.10	I/II	Kra	fat	UW	Dry	4	1.06	WT290	highly fractured rock mass
5894.83	I/II	Kra	fat	UW	Dry	4	3.33	WT289	
5900.70	I	Kra	fat	UW	Dry	3	6.25	WT288	
5904.63	I	Kra	fat	UW	Dry	3	5.42	WT287	
5930.15	I	Kra	fat	UW	Minor Inflow	3	5.00	WT286	<5L/min
5938.43	I/II	Kra	fat	UW	Dry	4	4.32	WT285	
5965.80	I/II	Kra	fat	UW	Dry	3	8.90	WT284	
5989.04	I	Kra	fat	UW	Dry	3+R	7.08	WT283	
5994.61	I	Kra	fat	UW	Dry	3	7.50	WT282	
6013.53	I	Kra	fat	UW	Dry	3	7.50	WT281	
6036.91	I	Kra	fat	UW	Dry	3	8.30	WT280	
6051.59	I/II	Kra	fat	UW	Dry	2	28.30	WT279	
6088.68	I/II	Kra	fat	UW	Dry	3+R	20.00	WT278	
6097.89	I/II	Kra	fat	UW	Minor Inflow	3	7.08	WT277	<5L/min
6118.43	I/II	Kra	fat	UW	Damp	4	5.67	WT276	
6137.17	I/II	Kra	fat	UW	Damp	4	5.67	WT275	
6154.70	I	Kra	fat	UW	Dry	4	8.00	WT274	
6164.05	I	Kra	fat	UW	Dry	3+R	5.00	WT273	
6180.22	I/II	Kra	fat	UW	Damp	4	5.67	WT272	
6204.79	I/II	Kra	fat	UW	Dry	4	4.67	WT271	
6218.20	I/II	Kra	fat	UW	Damp	4	5.00	WT270	
6231.97	I/II	Kra	fat	UW	Dry	4	2.00	WT269	
6249.35	I/II	Kra	fat	UW	Dry	3	8.90	WT268	
6281.22	I/II	Kra	fat	UW	Dry	3+R	1.25	WT267	
6302.32	I	Kra	fat	UW	Dry	3	6.67	WT266	
6323.20	I	Kra	fat	UW	Dry	3	8.90	WT265	
6352.01	I/II	Kra	fat	UW	Minor Inflow	4	5.00	WT264	<5L/min
6395.05	I/II	Kra	fat	UW	Minor Inflow	4	4.00	WT262	<5L/min

Table A   Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 10 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
6411.58	I/II	Kra	fat	UW	Minor Inflow	4	7.30	WT261	<5L/min
6421.27	I	Kra	fat	UW	Minor Inflow	4	2.00	WT260	<5L/min
6438.64	I	Kra	fat	UW	Minor Inflow	4	1.96	WT259	<5L/min
6461.58	I/II	Kra	fat	UW	Dry	4	1.37	WT258	
6499.09	I/II	Kra	fat	UW	Dry	4	2.50	WT257	
6502.15	I/II	Kra	fat	UW	Dry	4	2.00	WT256	
6524.71	I/II	Kra	fat	UW	Dry	4	0.80	WT255	highly fractured rock mass
6548.70	I/II	Kra	fat	UW	Dry	4	6.00	WT254	
6559.08	I/II	Kra	fat	UW	Dry	4	11.30	WT253	
6583.10	I/II	Kra	fat	UW	Dry	2	35.00	WT252	
6595.42	I/II	Kra	fat	UW	Dry	3	1.87	WT251	
6632.54	I	Kra	fat	UW	Dry	3	2.67	WT250	gf intrusion, highly fractured rock mass
6643.58	I/II	Kra	fat	UW	Dry	4	0.83	WT249	gf intrusion, highly fractured rock mass
6667.75	I/II	Kra	fat	UW	Minor Inflow	4	3.00	WT248	<5L/min
6675.88	I/II	Kra	fat	UW	Dry	4	8.67	WT247	
6691.09	I	Kra	fat	UW	Minor Inflow	3	3.06	WT246	<5L/min
6704.39	I	Kra	fat	UW	Minor Inflow	4	1.50	WT245	gf intrusion, <5L/min
6726.87	I/II	Kra	cat	UW	Dry	4	4.90	WT244	
6736.21	I/II	Kra	cat	UW	Minor Inflow	3+R	3.09	WT243	<5L/min
6761.93	I/II	Kra	cat	UW	Dry	3	7.80	WT242	gf intrusion
6771.05	I/II	Kra	cat	UW	Minor Inflow	3	2.68	WT241	<5L/min
6792.01	I	Kra	cat	UW	Minor Inflow	4	3.25	WT240	<5L/min
6798.01	I	Kra	cat	UW	Dry	4	3.25	WT239	
6817.49	I	Kra	cat	UW	Dry	3	8.30	WT238	
6831.00	I	Kra	cat	UW	Dry	2	13.30	WT237	
6842.50	I	Kra	cat	UW	Dry	3	20.00	WT236	
6856.29	I	Kra	cat	UW	Dry	3	20.00	WT235	pegmatite intrusion
6876.10	I	Klk	gm	UW	Dry	1	75.00	WT234	
6896.92	I	Klk	gm	UW	Dry	2	15.83	WT233	
6914.09	I	Klk	gm	UW	Dry	3	8.33	WT232	
6926.22	I	Klk	gm	UW	Dry	3	8.33	WT231	
6946.88	I	Klk	gm	UW	Dry	4	2.67	WT230	
6962.19	I	Klk	gm	UW	Dry	2	18.75	WT229	
6970.81	I	Klk	gm	UW	Dry	1	75.00	WT228	
6990.37	I	Klk	gm	UW	Dry	3+R	10.00	WT227	
6995.08	I	Klk	gm	UW	Dry	3	14.16	WT226	
7015.47	I	Klk	gm	UW	Dry	3	15.80	WT225	
7021.47	I	Klk	gm	UW	Dry	2	35.63	WT224	
7039.12	I	Klk	gm	UW	Dry	2	21.30	WT223	
7039.74	I	Klk	gm	UW	Dry	2	45.00	WT222	
7054.57	I	Klk	gm	UW	Dry	1	200.00	WT221	

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Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
7069.67	I	Klk	gm	UW	Dry	2	35.63	WT220	
7084.84	I/II	Klk	gm	UW	Dry	2	23.75	WT219	
7098.71	I	Klk	gm	UW	Dry	3	20.00	WT218	
7109.91	I/II	Klk	gm	UW	Dry	3+R	23.75	WT217	
7126.19	I/II	Klk	gm	UW	Dry	4	4.33	WT216	
7144.29	I/II	Klk	gm	UW	Dry	3	8.69	WT215	
7159.96	I/II	Klk	gm	UW	Dry	3	7.78	WT214	
7176.57	I/II	Klk	gm	UW	Dry	2+R	14.20	WT213	
7192.44	I/II	Klk	gm	UW	Dry	3	11.11	WT212	
7215.69	II	Klk	gm	UW	Minor Inflow	3	8.25	WT211	
7228.75	I	Klk	gm	UW	Dry	3	21.10	WT210	
7244.71	I/II	Klk	gm	UW	Dry	3+R	6.25	WT209	
7265.11	I	Klk	gm	UW	Dry	2+R	23.80	WT208	
7270.11	I	Klk	gm	UW	Dry	2	16.66	WT207	
7292.63	I	Klk	gm	UW	Dry	3	9.44	WT206	
7314.84	I/II	Klk	gm	UW	Dry	2+R	10.00	WT205	
7317.47	I/II	Klk	gm	UW	Minor Inflow	3	10.00	WT204	
7346.42	I/II	Klk	gm	UW	Dry	3	9.44	WT203	
7355.79	I/II	Klk	gm	UW	Dry	3	10.00	WT202	
7375.38	I	Klk	gm	UW	Dry	1+R	47.50	WT201	
7395.59	I/II	Klk	gm	UW	Dry	3	6.30	WT200	
7404.92	I/II	Klk	gfm	UW	Dry	2+R	22.50	WT199	
7422.01	I/II	Klk	gfm	UW	Dry	3	15.80	WT198	
7445.38	I	Klk	gfm	UW	Dry	1+R	100.00	WT197	
7456.72	I	Klk	gfm	UW	Dry	1+R	50.00	WT196	
7471.68	I/II	Klk	gfm	UW	Dry	1+R	100.00	WT195	
7488.80	I	Klk	gfm	UW	Dry	1+R	100.00	WT194	
7498.94	I	Klk	gfm	UW	Dry	3+R	13.30	WT193	
7531.29	I/II	Klk	gfm	UW	Dry	3+R	18.80	WT192	
7550.51	I/II	Krd/Klk	cat/gfm	UW	Dry	4	4.30	WT191	
7564.27	I	Krd/Klk	cat/gfm	UW	Dry	3	10.00	WT190	
7576.87	I/II	Krd/Klk	cat/gfm	UW	Dry	3+R	5.60	WT189	
7599.94	I	Krd/Klk	cat/gfm	UW	Dry	2+R	16.67	WT188	aplite vein
7628.51	I	Krd	cat	UW	Dry	3	33.30	WT187	
7629.56	I	Krd	cat	UW	Dry	2	74.50	WT186	
7635.64	I	Krd	cat	UW	Dry	2	11.25	WT185	
7655.01	I	Krd	cat	UW	Dry	3	22.20	WT184	aplite vein
7672.62	I	Krd	cat	UW	Dry	2+R	15.83	WT183	
7683.71	I	Krd	cat	UW	Dry	4	5.33	WT182	
7698.60	I	Krd	cat	UW	Dry	3	10.00	WT181	aplite vein
7718.80	I	Krd	cat	UW	Dry	1+R	66.67	WT180	gc intrusion

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 12 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
7722.12	I	Krd	cat	UW	Dry	2	100.00	WT179	
7731.51	I	Krd	cat	UW	Dry	2	75.00	WT178	aplite vein
7739.14	I	Krd	cat	UW	Dry	2	11.11	WT177	
7744.45	I	Krd	cat	UW	Dry	3	8.33	WT176	
7753.27	I	Krd	cat	UW	Dry	3	10.00	WT175	aplite vein
7768.36	I/II	Krd	cat	UW	Dry	4	6.33	WT174	
7779.71	I/II	Krd	cat	UW	Dry	3	9.44	WT173	
7786.12	I	Krd	cat	UW	Dry	2	22.50	WT172	
7791.01	I	Krd	cat	UW	Dry	2+R	14.20	WT171	
7799.02	I/II	Krd	cat	UW	Dry	2+R	14.20	WT170	
7817.87	I/II	Krd	fat & cat	UW	Dry	3+R	2.29	WT169	
7833.25	I/II	Krd	fat & cat	UW	Dry	3+R	2.71	WT168	
7864.06	I/II	Krd	fat & cat	UW	Dry	4	4.67	WT167	
7874.25	I/II	Krd	fat & cat	UW	Damp	4	2.33	WT166	
7882.31	I/II	Krd	fat & cat	UW	Damp	4	2.33	WT165	
7913.71	I	Krd	fat & cat	UW	Dry	2+R	25.00	WT164	
7918.71	I	Krd	fat & cat	UW	Dry	3	16.67	WT163	
7928.32	I	Krd	fat & cat	UW	Dry	2	25.00	WT162	
7935.36	I	Krd	fat & cat	UW	Dry	2+2R	16.70	WT161	
7942.14	I	Krd	fat & cat	UW	Dry	4	4.00	WT160	
7961.38	I/II	Krd	fat & cat	UW	Dry	3+R	5.72	WT159	
7976.89	I	Krd	fat & cat	UW	Dry	3	10.00	WT158	
7997.71	I	Krd	fat & cat	UW	Dry	2+R	30.00	WT157	
8011.37	I	Krd	fat & cat	UW	Dry	2+R	50.00	WT156	
8018.45	I	Krd	fat & cat	UW	Dry	2+R	47.50	WT155	
8031.74	I/II	Krd	fat & cat	UW	Dry	3	2.41	WT154	
8061.14	I/II	Krd	fat & cat	UW	Dry	3	8.89	WT153	
8061.86	I/II	Krd	fat & cat	UW	Dry	3	11.10	WT152	
8076.84	I	Krd	fat & cat	UW	Dry	2	25.00	WT151	
8095.37	I	Krd	fat & cat	UW	Dry	2	50.00	WT150	
8099.87	I	Krd	fat & cat	UW	Dry	2	50.00	WT149	
8110.56	I	Krd	fat & cat	UW	Dry	4	6.00	WT148	
8112.87	I	Krd	fat & cat	UW	Dry	3+R	15.00	WT147	
8123.04	I	Krd	fat & cat	UW	Dry	4	3.16	WT146	
8137.51	I/II	Krd	fat & cat	UW	Dry	3+R	1.81	WT145	
8147.30	I/II	Krd	fat & cat	UW	Dry	3	5.83	WT144	
8163.53	I	Krd	fat & cat	UW	Dry	2+R	14.20	WT143	
8187.02	I/II	Krd	fat & cat	UW	Dry	3+R	1.88	WT142	
8198.36	I/II	Krd	fat & cat	UW	Dry	3+R	1.83	WT141	
8236.51	I	Krd	fat & cat	UW	Dry	4	1.50	WT140	
8265.91	I/II	Krd	fat & cat	UW	Dry	3	7.78	WT139	

Table A   Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 13 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
8286.20	I	Krd	fat & cat	UW	Dry	2+R	12.50	WT138	
8319.36	I/II	Krd	fat & cat	UW	Damp	4	0.33	WT137	Shear zone
8350.73	I/II	Krd	fat & cat	UW	Dry	4	50.00	WT136	
8364.10	I/II	Krd	fat & cat	UW	Dry	4	15.00	WT135	
8376.17	I/II	Krd	fat & cat	UW	Minor Inflow	3+R	4.70	WT134	<5L/min
8413.60	I/II	Krd	fat & cat	UW	Minor Inflow	3+R	12.50	WT133	
8439.59	I/II	Krd	fat & cat	UW	Minor Inflow	3+R	2.92	WT132	
8456.86	I/II	Krd	fat & cat	UW	Minor Inflow	4	7.56	WT131	
8460.99	I/II	Krd	fat & cat	UW	Minor Inflow	4	4.67	WT130	
8489.82	I/II	Krd	fat & cat	UW	Minor Inflow	4	10.00	WT129	
8502.21	I/II	Krd	fat & cat	UW	Minor Inflow	3	16.67	WT128	
8539.76	I/II	Krd	fat & cat	UW	Minor Inflow	3	10.56	WT127	
8560.31	I/II	Krd	fat & cat	UW	Dry	2+R	21.10	WT126	
8570.47	I/II	Krd	fat & cat	UW	Dry	2+R	42.22	WT125	
8589.54	I/II	Krd	fat & cat	UW	Dry	2+R	10.60	WT124	
8591.61	I/II	Krd	fat & cat	UW	Dry	2+R	23.80	WT123	
8616.25	I/II	Krd	fat & cat	UW	Minor Inflow	3+R	7.90	WT122	
8624.35	I/II	Krd	fat & cat	UW	Dry	3+R	11.90	WT121	
8640.50	I/II	Krd	fat & cat	UW	Dry	4	9.50	WT120	
8649.93	I/II	Krd	fat & cat	UW	Dry	4	6.00	WT119	
8662.73	I/II	Krd	fat & cat	UW	Dry	3+R	11.90	WT118	
8689.73	I/II	Krd	fat & cat	UW	Dry	2+R	23.80	WT117	
8707.57	I/II	Krd	fat & cat	UW	Dry	3+R	11.30	WT116	
8724.04	I/II	Krd	fat & cat	UW	Dry	4	6.00	WT115	
8740.96	I/II	Krd	fat & cat	UW	Dry	4	2.67	WT114	
8761.83	I/II	Krd	fat & cat	UW	Dry	4	5.67	WT113	
8786.16	I/II	Krd	fat & cat	UW	Dry	4	8.50	WT112	
8805.01	I/II	Krd	fat & cat	UW	Dry	4	6.00	WT111	
8832.65	I/II	Krd	fat & cat	UW	Dry	4	2.40	WT110	Shear plane
8842.43	II	Krd	fat & cat	UW	Damp	4	1.42	WT109	
8868.61	I/II	Krd	fat & cat	UW	Damp	4	2.25	WT108	
8895.28	I/II	Krd	fat & cat	UW	Dry	4	1.50	WT107	
8919.69	I/II	Krd	fat & cat	UW	Dry	4	1.25	WT106	granite vein
8952.53	I/II	Krd	fat & cat	UW	Minor Inflow	4	1.17	WT105	<5L/min
8974.96	II	Krd	fat & cat	UW	Wet	4	3.30	WT104	>5L/min
8989.83	II	Krd	fat & cat	UW	Wet	4	0.06	WT103	>5L/min
8994.22	II	Krd	fat & cat	UW	Damp	4	0.07	WT102	fault breccia, fault gouge (50/140-170)
9000.22	II	Krd	fat & cat	UW	Minor Inflow	4	0.03	WT101	Shear zone, <5L/min
9011.04	II	Krd	fat & cat	UW	Wet	4	0.13	WT100	Shear zone, >5L/min
9028.78	II	Krd	fat & cat	UW	Minor Inflow	4	0.80	WT099	Shear zone, <5L/min
9041.32	II	Krd	fat & cat	UW	Minor Inflow	3+R	1.00	WT098	Shear zone, <5L/min

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 14 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
9057.56	II/III	Krd/Klk	fat & cat/gf	UW	Minor Inflow	4	0.40	WT097	Contact zone, <5L/min
9071.16	I/II	Klk	gf	UW	Minor Inflow	3+R	10.00	WT096	Shear zone, <5L/min
9089.29	I/II	Klk	gf	UW	Dry	3	10.00	WT095	
9104.03	I/II	Klk	gf	UW	Damp	4	6.00	WT094	
9130.84	I/II	Klk	gf	UW	Minor Inflow	3+R	15.83	WT093	<5L/min
9140.36	I/II	Klk	gf	UW	Minor Inflow	3	9.44	WT092	<5L/min
9153.71	I/II	Klk	gf	UW	Damp	3+R	8.33	WT091	
9185.26	I/II	Klk	gf	UW	Minor Inflow	3+R	25.00	WT090	<5L/min
9196.77	I/II	Klk	gf	UW	Minor Inflow	3	31.70	WT089	<5L/min
9216.71	I/II	Klk	gf	UW	Minor Inflow	3	22.22	WT088	<5L/min
9237.88	I/II	Klk	gf	UW	Damp	3+R	15.00	WT087	
9261.31	I/II	Klk	gf	UW	Damp	4	6.00	WT086	
9264.65	I/II	Klk	gf	UW	Damp	3+R	22.50	WT085	
9276.03	I/II	Klk	gf	UW	Minor Inflow	3+R	12.50	WT084	<5L/min
9293.26	I/II	Klk	gf	UW	Minor Inflow	3+R	11.25	WT083	<5L/min
9302.35	I	Klk	gf	UW	Minor Inflow	3+R	33.33	WT082	<5L/min
9309.15	I/II	Klk	gf	UW	Minor Inflow	3	16.70	WT081	<5L/min
9315.17	I/II	Klk	gf	UW	Minor Inflow	3	22.22	WT080	<5L/min
9342.77	I/II	Klk	gf	UW	Damp	4	9.60	WT079	Shear zone
9359.70	I/II	Klk	gf	UW	Minor Inflow	3+R	12.00	WT078	<5L/min
9369.94	I/II	Klk	gf	UW	Minor Inflow	3	10.56	WT077	<5L/min
9400.00	I/II	Klk	gf	UW to PW90/100	Damp	3+R	10.00	WT076	Minor shear zone
9409.00	I/II	Klk	gf	UW to PW90/100	Dry	4	7.20	WT075	Minor shear zone
9439.03	I/II	Klk	gf	UW to PW90/100	Damp	3+R	6.67	WT074	Minor shear zone
9453.10	I/II	Klk	gf	UW to PW90/100	Damp	3+R	2.38	WT073	Minor shear zone
9487.15	II	Klk	gf	UW to PW90/100	Minor Inflow	3	2.25	WT072	Shear zone, <5L/min
9507.92	II	Klk	gf	UW to PW90/100	Minor Inflow	3	2.07	WT071	Fault gouge, <5L/min
9510.88	II	Klk	gf	UW to PW90/100	Minor Inflow	3	2.83	WT070	Minor fault zone, <5L/min
9513.92	II	Klk	gf	UW to PW90/100	Minor Inflow	4	0.93	WT069	Shear zone, <5L/min
9516.89	II	Klk	gf	UW to PW90/100	Minor Inflow	3+R	3.20	WT068	Shear zone, <5L/min
9534.90	II	Klk	gf	UW to PW90/100	Minor Inflow	3+R	1.50	WT067	Shear zone, <5L/min
9550.23	II/III	Klk	gf	UW to PW90/100	Minor Inflow	4	1.60	WT066	Minor fault zone, shear zone, <5L/min
9568.20	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.80	WT065	Shear zone, <5L/min
9580.28	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	2.83	WT064	Shear zone, <5L/min
9600.98	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.60	WT063	Shear zone with highly fractured rock mass, <5L/min
9616.24	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	2.27	WT062	Shear zone with highly fractured rock mass, <5L/min
9646.10	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.70	WT061	Shear zone with highly fractured rock mass, <5L/min
9676.92	I/II	Klk	gf	UW to PW90/100	Dry	4	1.33	WT060	Shear zone with highly fractured rock mass
9706.51	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.70	WT059	Shear zone with highly fractured rock mass, <5L/min
9731.90	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.60	WT058	Shear zone with highly fractured rock mass, <5L/min
9745.34	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.70	WT057	Shear zone with highly fractured rock mass, <5L/min

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 15 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
9761.40	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	2.27	WT056	Shear zone with highly fractured rock mass, <5L/min
9767.40	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	2.40	WT055	Shear zone with highly fractured rock mass, <5L/min
9789.80	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.73	WT054	Shear zone with highly fractured rock mass, <5L/min
9795.80	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	2.40	WT053	Shear zone with highly fractured rock mass, <5L/min
9819.32	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	2.00	WT052	Shear zone with highly fractured rock mass, <5L/min
9825.32	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.04	WT051	Shear zone with highly fractured rock mass, <5L/min
9839.84	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	0.80	WT050	Shear zone with highly fractured rock mass, <5L/min
9886.75	I/II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.60	WT049	Shear zone with highly fractured rock mass, <5L/min
9881.58	I/II	Klk	gf	UW to PW90/100	Dry	4	0.35	WT048	Shear zone with highly fractured rock mass
9896.20	II	Klk	gf	UW to PW90/100	Dry	4	0.80	WT047	Shear zone with highly fractured rock mass
9907.42	II	Klk	gf	UW to PW90/100	Minor Inflow	4	1.20	WT046	Shear zone with highly fractured rock mass, <5L/min
9937.86	II/III	Klk	gf	UW to PW90/100	Minor Inflow	4	0.13	WT045	Fault breccia, <5L/min
9945.92	II	Klk	gf	UW to PW90/100	Minor Inflow	5	0.13	WT044	Shear zone with highly fractured rock mass, <5L/min
9964.11	II	Klk	gf	UW to PW90/100	Minor Inflow	4	0.60	WT043	Shear zone with highly fractured rock mass, <5L/min
9991.15	II	Klk	gf	UW to PW90/100	Minor Inflow	4	0.60	WT042	Shear zone with highly fractured rock mass, <5L/min
9991.26	II	Klk	gf	UW to PW90/100	Minor Inflow	4	0.60	WT041	Shear zone with highly fractured rock mass, <5L/min
10013.60	II	Klk	gf	UW to PW90/100	Minor Inflow	5	0.60	WT040	Shear zone with highly fractured rock mass, <5L/min
10028.60	II	Krd/Klk	fat & cat/gf	UW to PW90/100	Minor Inflow	4	0.20	WT039	Shear zone with highly fractured rock mass, <5L/min
10034.60	II/III	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	5	0.05	WT038	Shear zone with highly fractured rock mass
10054.20	II/III	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	4	0.50	WT037	Shear zone with highly fractured rock mass
10066.60	II/III	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	7	0.13	WT036	Shear zone with highly fractured rock mass
10083.90	II	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	4	0.33	WT035	Shear zone with highly fractured rock mass
10106.40	II	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	5	2.20	WT034	Shear zone with highly fractured rock mass
10108.70	II	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	4	0.10	WT033	Shear zone with highly fractured rock mass
10135.00	II	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	5	0.03	WT032	Shear zone with highly fractured rock mass
10158.90	II	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	5	0.09	WT031	Shear zone with highly fractured rock mass
10174.40	II/III	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	4	0.05	WT030	Shear zone with highly fractured rock mass
10180.30	II/III	Krd/Klk	fat & cat/gf	UW to PW90/100	Dry	4	0.04	WT029	Shear zone with highly fractured rock mass
10187.50	II/III	Krd/Klk	fat & cat/gf	UW to PW90/100	Minor Inflow	4	0.10	WT028	Shear zone with highly fractured rock mass, <5L/min
10199.00	II/III	Krd	fat & cat	UW to PW90/100	Minor Inflow	4	0.13	WT027	Shear zone with highly fractured rock mass, <5L/min
10224.40	II/III	Krd	fat	UW to PW90/100	Dry	4	0.15	WT026	Shear zone with highly fractured rock mass, g & p intrusions
10225.40	II/III	Krd	fat	UW to PW90/100	Minor Inflow	3	0.17	WT025	Shear zone with highly fractured rock mass, g & p intrusions
10231.10	II/III	Krd	fat	UW to PW90/100	Minor Inflow	4	0.10	WT024	Shear zone with highly fractured rock mass, g & p intrusions
10249.60	II/III	Krd	fat	UW to PW90/100	Minor Inflow	5	0.20	WT023	Shear zone with highly fractured rock mass, g & p intrusions
10259.80	II	Krd	fat	UW to PW90/100	Minor Inflow	6	0.30	WT022	Shear zone with highly fractured rock mass, g & p intrusions
10265.60	II/III	Krd	fat	UW to PW90/100	Minor Inflow	5	0.30	WT021	Shear zone with highly fractured rock mass, g & p intrusions
10276.20	II/III	Krd	fat	UW to PW90/100	Minor Inflow	4	0.09	WT020	Shear zone with highly fractured rock mass, g & p intrusions
10283.70	II/III	Krd	fat	UW to PW90/100	Minor Inflow	4	0.07	WT019	Shear zone with highly fractured rock mass, g & p intrusions
10295.50	II/III	Krd	fat	UW to PW90/100	Minor Inflow	4	0.09	WT018	Shear zone with highly fractured rock mass, g & p intrusions
10302.20	II/III	Krd	fat	UW to PW90/100	Minor Inflow	4	0.07	WT017	Shear zone with highly fractured rock mass, g & p intrusions
10307.60	II/III	Krd	fat	UW to PW90/100	Minor Inflow	4	0.07	WT016	Shear zone with highly fractured rock mass, g & p intrusions

Table A Summary of Engineering Geological Data (after DNJV, 2011) (Sheet 16 of 16)

Chainage	Rock grade	Rock formation	Rock type	Rock mass	Water Inflow	Discontinuity Sets	Q value	Mapping Record No.	Remarks
10312.50	II/III	Krd	fat	UW to PW90/100	Minor Inflow	4	0.07	WT015	Shear zone with highly fractured rock mass, g & p intrusions
10342.20	II/III	Krd	fat	UW to PW90/100	Minor Inflow	5	0.25	WT014	Shear zone with highly fractured rock mass, g & p intrusions
10375.50	II	Krd	fat	UW to PW90/100	Dry	4	0.30	WT013	Shear zone with highly fractured rock mass, g & p intrusions
10395.00	II/III	Krd	fat	UW to PW90/100	Dry	4	0.25	WT012	Shear zone with highly fractured rock mass, g & p intrusions
10409.60	II/III	Krd	cat	UW to PW90/100	Dry	4	0.10	WT011	Shear zone with highly fractured rock mass, g intrusions
10428.20	II	Krd	cat	UW to PW90/100	Minor Inflow	4	0.25	WT010	Shear zone with highly fractured rock mass, g intrusions
10448.70	II/III	Krd	cat	UW to PW90/100	Dry	4	0.25	WT009	Shear zone with highly fractured rock mass, g intrusions
10452.30	II	Krd	cat	UW to PW90/100	Dry	4	0.25	WT008	Shear zone with highly fractured rock mass, g intrusions
10462.10	II/III	Krd	cat	UW to PW90/100	Dry	4	0.30	WT007	Shear zone with highly fractured rock mass, g intrusions
10470.10	II	Krd	cat	UW to PW90/100	Dry	4	1.30	WT006	Shear zone with highly fractured rock mass, g intrusions
10481.80	II/III	Krd	cat	UW to PW90/100	Dry	4	2.00	WT005	Shear zone with highly fractured rock mass, g intrusions
10493.80	II/III	Krd	cat	UW to PW90/100	Dry	4	1.20	WT004	Shear zone with highly fractured rock mass, g intrusions
10506.40	II/III	Krd	cat	UW to PW90/100	Dry	4	0.60	WT003	Shear zone with highly fractured rock mass, g intrusions
10516.40	II/III	Krd	cat	UW to PW90/100	Dry	4	0.60	WT002	Shear zone with highly fractured rock mass, g intrusions
10520.62	II/III	Krd	cat	UW to PW90/100	Dry	4	1.20	WT001	Shear zone with highly fractured rock mass, g intrusions
10535.00	II/III	Krd	cat	-	Dry	5	2.52	-	Shear zone with highly fractured rock mass, g intrusions
10583.00	II/III	Krd	cat	-	Dry	5	2.52	-	Shear zone with highly fractured rock mass, g intrusions

Appendix B

Summary of Rock Discontinuity Data

Table B Summary Rock Discontinuity Data (Sheet 1 of 9)

Starting Chainage (m)	Ending Chainage (m)	Rock Type	Dip (◦)	Dip Direction (◦)	Spacing	Aperture	Infilling
CH 180	CH 290	Granite	45-90	325-355	Very closely to widely spaced	Tight to extremely narrow	Staining
			75-90	175-205			
			0-20	295-325			
CH 290	CH 400	Granite	75-90	330-000			
			60-75	010-040			
			20-40	295-325			
CH 400	CH 500	Granite	70-85	300-330	Very closely to medium spaced	Tight to extremely narrow	Non-clay
			70-85	210-240			
			70-90	010-040			
CH 500	CH 600	Granite	75-90	300-330			
			85-90	200-260			
			20-45	280-310			
CH 600	CH 620	Granite	70-83	320-330	Very closely to medium spaced	Tight to extremely narrow	Staining
			70-83	230-250			
			70-90	030-070			
CH 620	CH 720	Granite	85	290-320			
			85-90	210-240			
			75-80	000-030			
CH 720	CH 800	Granite	75-85	340-010			
			70-90	260-290			
			85-90	220-250			
CH 800	CH 900	Granite	75-90	260-290	Very closely to medium spaced	Tight to extremely narrow	Non-clay
			75-90	335-005			
			73-90	005-035			
CH 900	CH 1000	Granite	75-90	305-335			
			75-90	245-270			
			75-90	155-195			
CH 1000	CH 1090	Granite	75-90	260-290	Closely to widely spaced	Tight	Non-clay
			75-90	255-285			
			75-90	350-020			
CH 1090	CH 1200	Granite	75-90	260-290			
			75-90	350-020			
			75-90	005-035			
CH 1200	CH 1295	Granite	75-90	260-290	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	065-095			
			60-75	335-005			
CH 1295	CH 1400	Granite	75-90	200-230			
			75-90	265-290			
			75-90	295-305			
CH 1400	CH 1490	Granite	75-90	020-050	Closely to widely spaced	Tight to extremely narrow	Staining
			75-90	290-320			
			75-90	050-080			
CH 1490	CH 1600	Granite	75-90	195-225			
			75-90	030-040			
			75-90	290-300			
CH 1600	CH 1695	Granite	75-90	240-270	Closely to widely spaced	Tight to extremely narrow	Non-clay
			75-90	300-330			
			75-90	150-180			
CH 1695	CH 1800	Granite	75-90	290-320			
			60-75	110-140			
			75-90	260-290			
			75-90	230-250			

Table B Summary Rock Discontinuity Data (Sheet 2 of 9)

Starting Chainage (m)	Ending Chainage (m)	Rock Type	Dip (◦)	Dip Direction (◦)	Spacing	Aperture	Infilling
CH 1800	CH 1895	Granite	75-90	180-210	Very closely to widely spaced	Tight to extremely narrow	Staining
			70-90	270-300			
			60-75	120-150			
CH 1895	CH 2000	Granite	40-85	270-300			
			75-90	200-230			
CH 2000	CH 2095	Granite	60-85	030-060	Closely to medium spaced	Tight to extremely narrow	Clay
			60-90	120-130			
			60-90	290-320			
			75-90	200-230			
			75-90	020-050			
			40-75	350-350			
CH 2095	CH 2200	Granite	60-90	103-135			
			60-90	312-345			
			60-75	160-190			
			75-90	210-280			
			75-90	230-260			
CH 2200	CH 2290	Granite	60-90	260-290	Very closely to medium spaced	Tight to extremely narrow	Non-clay
			75-90	220-250			
			75-90	040-070			
			75-90	140-170			
			75-90	300-330			
			20-40	080-110			
CH 2290	CH 2400	Granite	75-90	345-015			
			75-90	270-300			
			75-90	200-300			
CH 2400	CH 2495	Granite	75-90	235-265	Closely to widely spaced	Tight to extremely narrow	Non-clay
			75-90	160-190			
			20-40	040-070			
CH 2495	CH 2600	Granite	75-90	250-280			
			75-90	040-100			
			60-85	180-210			
			60-90	220-250			
			60-90	040-070			
			40-75	320-330			
CH 2600	CH 2695	Granite	75-90	280-310	Closely to widely spaced	Tight to extremely narrow	Non-clay
			60-90	020-050			
			60-75	220-250			
CH 2695	CH 2800	Granite	75-90	005, 185			
			75-90	095, 275			
			75-90	020, 200			
			20-40	020-050			
CH 2800	CH 2895	Granite	20-60	185-215	Closely to medium spaced	Tight to extremely narrow	Non-clay
			20-40	245-275			
			45-90	320-350			
			45-90	140-170			
CH 2895	CH 3000	Granite	50-75	340-010			
			10-30	220-250			
			70-90	280-310			
			70-90	045-095			

Table B Summary Rock Discontinuity Data (Sheet 3 of 9)

Starting Chainage (m)	Ending Chainage (m)	Rock Type	Dip (◦)	Dip Direction (◦)	Spacing	Aperture	Infilling
CH 3000	CH 3100	Granite	75-90	005-035	Closely to widely spaced	Tight to extremely narrow	Staining
			75-90	185-215			
			75-90	275-305			
			60-75	305-335			
			0-20	185-215			
CH 3100	CH 3200	Granite	75-90	005-035			
			75-90	200-230			
			75-90	065-095			
CH 3200	CH 3300	Granite	60-90	335-005	Medium to very widely spaced	Tight to extremely narrow	Staining
			60-90	155-185			
			75-90	245-275			
			60-75	125-155			
CH 3300	CH 3400	Granite	75-90	160-190			
			90	350-020			
			40-60	245-275			
CH 3400	CH 3500	Granite	75-90	040-070	Closely to widely spaced	Tight to extremely narrow	Non-clay
			75-90	230-260			
			20-40	260-290			
CH 3500	CH 3600	Granite	75-90	020-030			
			75-90	200-230			
			75-90	110-140			
			75-90	290-320			
CH 3600	CH 3700	Granite	75-90	075-105	Medium to widely spaced	Tight to extremely narrow	Staining
			75-90	320-350			
			75-90	040-070			
			20-40	225-255			
CH 3700	CH 3800	Granite	75-90	170-200			
			75-90	350-020			
			0-20	230-260			
CH 3800	CH 3940	Granite	75-90	065-095	Medium to extremely wide spaced	Tight to extremely narrow	Staining
			75-90	245-275			
			75-90	350-020			
			75-90	290-320			
CH 3940	CH 3985	Granite	75-90	170-200	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	280-300			
			75-90	290-320			
CH 3985	CH 4000	Granite	75-90	170-200			
			75-90	280-300			
			75-90	290-320			
CH 4000	CH 4100	Volcanic	60-75	306-336	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	096-126			
			75-90	176-206			
			60-75	100-130			
CH 4100	CH 4200	Volcanic	0-20	006-036			
			40-60	186-216			
			75-90	096-126			
			75-90	306-336			
CH 4200	CH 4300	Volcanic	0-20	036-066	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	306-336			
			40-60	306-006			
			40-60	066-096			
CH 4300	CH 4400	Volcanic	0-20	126-156			
			60-75	216-246			
			60-75	351-021			
			75-90	141-171			

Table B Summary Rock Discontinuity Data (Sheet 4 of 9)

Starting Chainage (m)	Ending Chainage (m)	Rock Type	Dip (◦)	Dip Direction (◦)	Spacing	Aperture	Infilling
CH 4400	CH 4500	Volcanic	0-20	156-216	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	156-186			
			75-90	246-306			
CH 4500	CH 4600	Volcanic	75-90	306-336			
			75-90	246-276			
			40-60	066-096			
			0-20	096-126			
CH 4600	CH 4700	Volcanic	75-90	306-336	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	156-186			
			0-20	194-224			
CH 4700	CH 4800	Volcanic	75-90	194-254			
			75-90	254-314			
			75-90	314-014			
			0-20	194-224			
CH 4800	CH 4900	Volcanic	0-20	186-216	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	111-141			
			75-90	186-216			
CH 4900	CH 5000	Volcanic	75-90	203-233			
			75-90	263-293			
			75-90	143-173			
			0-20	323-023			
CH 5000	CH 5100	Volcanic	75-90	173-203	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	143-203			
			20-40	083-113			
			20-60	263-293			
CH 5100	CH 5200	Volcanic	75-90	143-173			
			60-90	203-233			
			0-20	248-278			
CH 5200	CH 5300	Volcanic	75-90	321-351	Closely to medium spaced	Tight to extremely narrow	Staining
			40-75	171-201			
			40-60	261-291			
			75-90	051-081			
CH 5300	CH 5400	Volcanic	75-90	021-051			
			60-90	306-336			
			0-20	351-021			
CH 5400	CH 5500	Volcanic	60-75	201-231	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	231-261			
			60-75	081-111			
			0-40	261-291			
CH 5500	CH 5600	Volcanic	75-90	186-216			
			75-90	261-291			
			0-20	141-171			
			60-75	111-141			
CH 5600	CH 5700	Volcanic	75-90	321-351	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	231-261			
			40-60	171-201			
			0-20	081-111			
CH 5700	CH 5800	Volcanic	75-90	319-349			
			75-90	049-079			
			60-75	110-140			
			20-40	049-079			
			0-20	350-020			

Table B Summary Rock Discontinuity Data (Sheet 5 of 9)

Starting Chainage (m)	Ending Chainage (m)	Rock Type	Dip (◦)	Dip Direction (◦)	Spacing	Aperture	Infilling
CH 5800	CH 5900	Volcanic	75-90	077-107	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	137-167			
			75-90	200-230			
			40-60	257-287			
			0-20	350-020			
CH 5900	CH 6000	Volcanic	75-90	285-315			
			75-90	141-171			
			75-90	345-015			
			0-20	165-195			
CH 6000	CH 6100	Volcanic	75-90	173-203	Closely to medium spaced	Tight to extremely narrow	Staining
			60-90	133-163			
			60-75	203-233			
			20-40	213-345			
CH 6100	CH 6200	Volcanic	75-90	140-170			
			75-90	245-275			
			0-20	232-262			
CH 6200	CH 6300	Volcanic	75-90	261-291	Closely to medium spaced	Tight to extremely narrow	Staining
			40-90	081-111			
			40-60	321-351			
			0-20	171-201			
CH 6300	CH 6400	Volcanic	75-90	173-203			
			75-90	265-295			
			60-75	310-340			
			60-75	025-055			
			0-40	055-085			
CH 6400	CH 6500	Volcanic	75-90	283-313	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	193-223			
			75-90	107-137			
			40-60	043-073			
			60-75	137-167			
			0-20	193-223			
CH 6500	CH 6600	Volcanic	75-90	175-209			
			75-90	269-299			
			60-75	359-029			
			0-20	205-235			
CH 6600	CH 6700	Volcanic	75-90	229-259	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	309-339			
			75-90	048-078			
			40-60	120-150			
			20-40	019-049			
CH 6700	CH 6800	Volcanic	75-90	276-306			
			75-90	186-216			
			60-75	141-171			
			0-20	186-216			
CH 6800	CH 6900	Volcanic and Granite	75-90	306-336	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	210-240			
			60-75	216.246			
			40-60	351-021			
			0-20	229-259			
CH 6900	CH 7000	Granite	75-90	320-350			
			75-90	020-050			
			40-60	050-080			
			40-60	310-350			
			0-20	110-140			

Table B Summary Rock Discontinuity Data (Sheet 6 of 9)

Starting Chainage (m)	Ending Chainage (m)	Rock Type	Dip (◦)	Dip Direction (◦)	Spacing	Aperture	Infilling
CH 7000	CH 7100	Granite	75-90	109-139	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	049-079			
			75-90	179-209			
			60-75	019-099			
			0-20	332-002			
CH 7100	CH 7200	Granite	75-90	194-224			
			75-90	056-089			
			60-75	314-344			
CH 7200	CH 7300	Granite	75-90	210-240	Medium to widely spaced	Tight to extremely narrow	Staining
			40-60	075-105			
			40-60	285-315			
			40-60	005-035			
CH 7300	CH 7400	Granite	75-90	209-239			
			75-90	149-179			
			60-75	329-359			
			40-60	040-070			
			0-20	180-210			
CH 7400	CH 7500	Granite	75-90	115-145	Medium to widely spaced	Tight to extremely narrow	Staining
			75-90	209-239			
			40-60	005-035			
CH 7500	CH 7600	Granite & Volcanic	75-90	115-145	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	209-239			
			60-75	329-359			
			40-60	285-315			
			0-20	180-210			
CH 7600	CH 7700	Volcanic	75-90	298-328	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	223-253			
			75-90	343-013			
			40-60	223-253			
			0-20	029-049			
CH 7700	CH 7800	Volcanic	75-90	283-313			
			75-90	043-073			
			75-90	208-238			
			40-60	223-253			
			0-20	253-283			
CH 7800	CH 7900	Volcanic	75-90	298-328	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	043-073			
			60-75	208-238			
			40-60	339-009			
			40-60	163-223			
			0-20	253-283			
			0-20	073-103			
CH 7900	CH 8000	Volcanic	75-90	014-044			
			75-90	073-103			
			40-60	163-193			
			65-75	158-188			
			0-20	193-223			

Table B Summary Rock Discontinuity Data (Sheet 7 of 9)

Starting Chainage (m)	Ending Chainage (m)	Rock Type	Dip (◦)	Dip Direction (◦)	Spacing	Aperture	Infilling
CH 8000	CH 8100	Volcanic	75-90	026-056	Closely to medium spaced	Tight to extremely narrow	Staining
			75-90	149-179			
			75-90	314-344			
			60-75	315-345			
			40-60	056-086			
			0-20	060-090			
CH 8100	CH 8200	Volcanic	75-90	226-256			
			75-90	304-334			
			75-90	135-165			
			60-75	046-076			
			60-75	135-165			
			0-20	175-205			
CH 8200	CH 8300	Volcanic	60-90	323-353	Closely to medium spaced	Tight to extremely narrow	Clay
			75-90	068-088			
			60-75	002-032			
			0-20	123-153			
CH 8300	CH 8400	Volcanic	75-90	356-026			
			75-90	261-311			
			60-75	206-236			
			40-60	119-149			
CH 8400	CH 8500	Volcanic	75-90	156-186	Closely to medium spaced	Tight to extremely narrow	Clay
			75-90	336-006			
			75-90	198-228			
			40-75	078-108			
			20-60	258-288			
			0-20	051-081			
CH 8500	CH 8600	Volcanic	75-90	193-223			
			75-90	323-333			
			75-90	130-160			
			75-90	310-340			
			45-60	166-196			
			0-20	104-134			
			0-20	017-047			
CH 8600	CH 8700	Volcanic	75-90	185-215	Extremely closely to closely spaced	Tight to extremely narrow	Clay
			75-90	250-310			
			40-60	325-355			
			0-20	140-170			
			0-20	310-340			
CH 8700	CH 8800	Volcanic	75-90	104-134			
			75-90	179-209			
			75-90	260-290			
			75-90	333-006			
			40-60	261-291			
			0-20	004-034			
CH 8800	CH 8900	Volcanic	60-75	098-128	Extremely closely to closely spaced	Tight to extremely narrow	Clay
			75-90	218-248			
			0-20	114-144			
CH 8900	CH 9000	Volcanic	20-40	047-077			
			60-90	306-336			
			60-75	171-201			
			75-90	272-302			

Table B Summary Rock Discontinuity Data (Sheet 8 of 9)

Starting Chainage (m)	Ending Chainage (m)	Rock Type	Dip (◦)	Dip Direction (◦)	Spacing	Aperture	Infilling
CH 9000	CH 9100	Volcanic & Granite	75-90	216-246	Very closely to medium spaced	Tight to extremely narrow	Staining
			75-90	306-336			
			75-90	186-216			
			0-20	096-126			
			60-75	126-156			
CH 9100	CH 9200	Granite	75-90	156-186			
			75-90	246-276			
			0-20	051-081			
			40-60	246-276			
			75-96	141-171			
CH 9200	CH 9300	Granite	75-90	147-171	Very closely to medium spaced	Tight to extremely narrow	Staining
			75-90	066-096			
			75-90	201-231			
			75-90	086-156			
			20	051-081			
CH 9300	CH 9400	Granite	75-90	186-216			
			75-90	261-281			
			75-90	141-171			
			40-60	351-021			
			20-40	031-086			
			0-20	051-081			
CH 9400	CH 9500	Granite	75-90	186-216	Very closely to medium spaced	Tight to extremely narrow	Non-clay
			75-90	231-261			
			75-90	141-171			
			40-60	351-021			
CH 9500	CH 9600	Granite	75-90	156-186			
			75-90	186-216			
			75-90	051-081			
			0-20	045-075			
CH 9600	CH 9700	Granite	75-90	230-260	Extremely closely to closely spaced	Tight to extremely narrow	Non-clay
			75-90	155-185			
			0-20	050-080			
CH 9700	CH 9800	Granite	75-90	185-215			
			75-90	215-245			
			40-75	155-195			
			0-20	275-305			
CH 9800	CH 9900	Granite	75-90	100-180	Very closely to closely spaced	Tight to extremely narrow	Non-clay
			75-90	215-245			
			75-90	300-330			
			0-20	280-310			
			60-75	125-155			
CH 9900	CH 10000	Granite	75-90	140-170			
			75-90	220-250			
			40-60	105-185			
			0-20	185-215			
CH 10000	CH 10095	Granite & Volcanic	75-90	240-270	Very closely to medium spaced	Tight to narrow	Clay
			75-90	065-095			
			60-75	210-240			
			20-40	160-190			
			0-20	245-275			
CH 10095	CH 10200	Granite & Volcanic	75-90	140-170			
			75-90	235-285			
			40-60	060-090			
			0-20	185-215			

Table B Summary Rock Discontinuity Data (Sheet 9 of 9)

Starting Chainage (m)	Ending Chainage (m)	Rock Type	Dip (◦)	Dip Direction (◦)	Spacing	Aperture	Infilling
CH 10200	CH 10300	Volcanic	75-90	195-225	Very closely to medium spaced	Tight to narrow	Clay
			75-90	135-165			
			75-90	315-345			
			0-20	195-225			
CH 10300	CH 10400	Volcanic	20-40	300-330			
			75-90	225-285			
			40-60	135-165			
			40-60	235-265			
CH 10400	CH 10535	Volcanic	75-90	080-110	Very closely to medium spaced	Tight to narrow	Non-clay
			75-90	150-180			
			75-90	310-340			
			40-60	270-300			
			60-75	255-265			

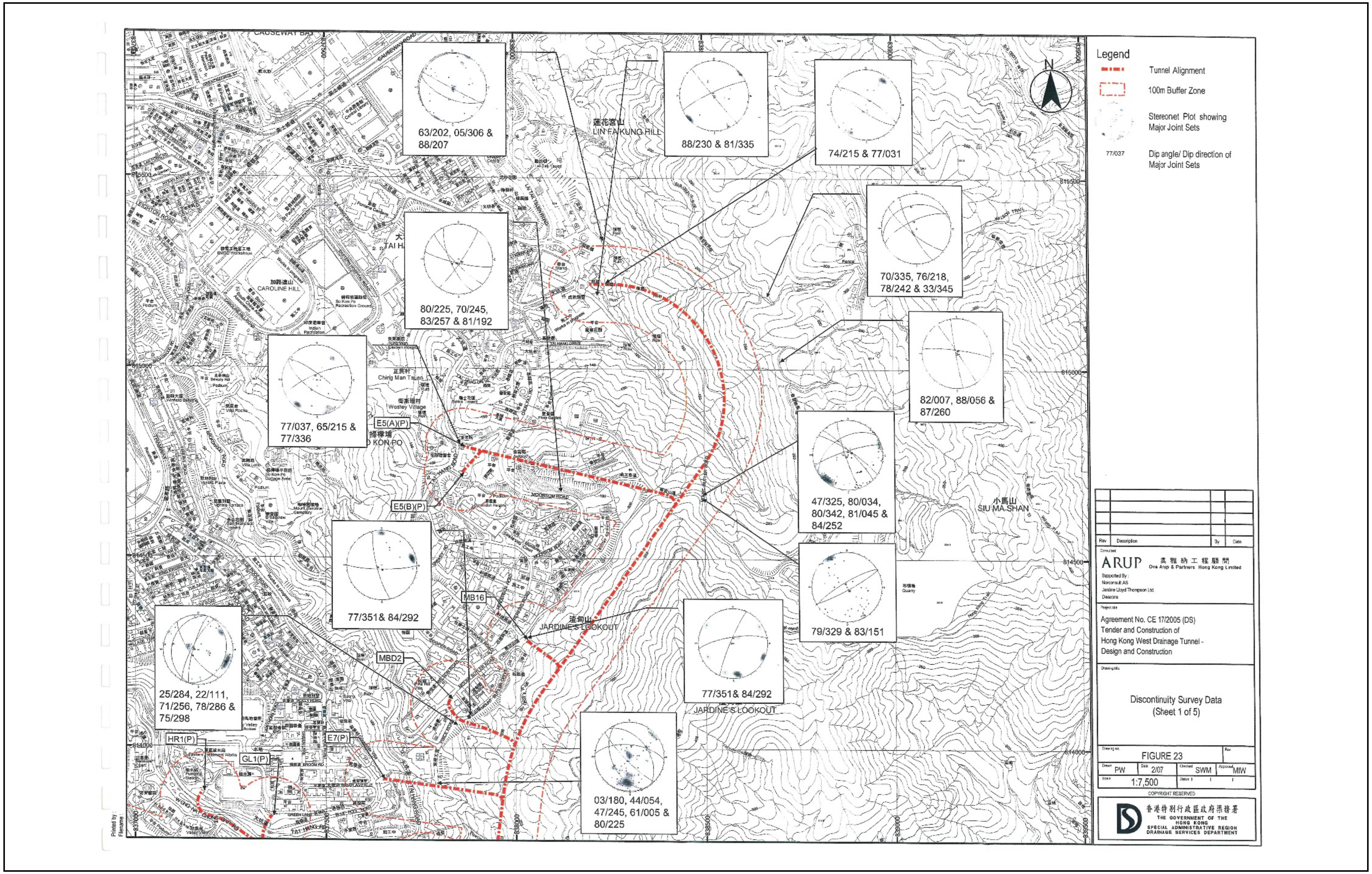


Figure B1 Discontinuity Survey Data of Hong Kong West Drainage Tunnel (Sheet 1 of 5) (from Arup, 2007)

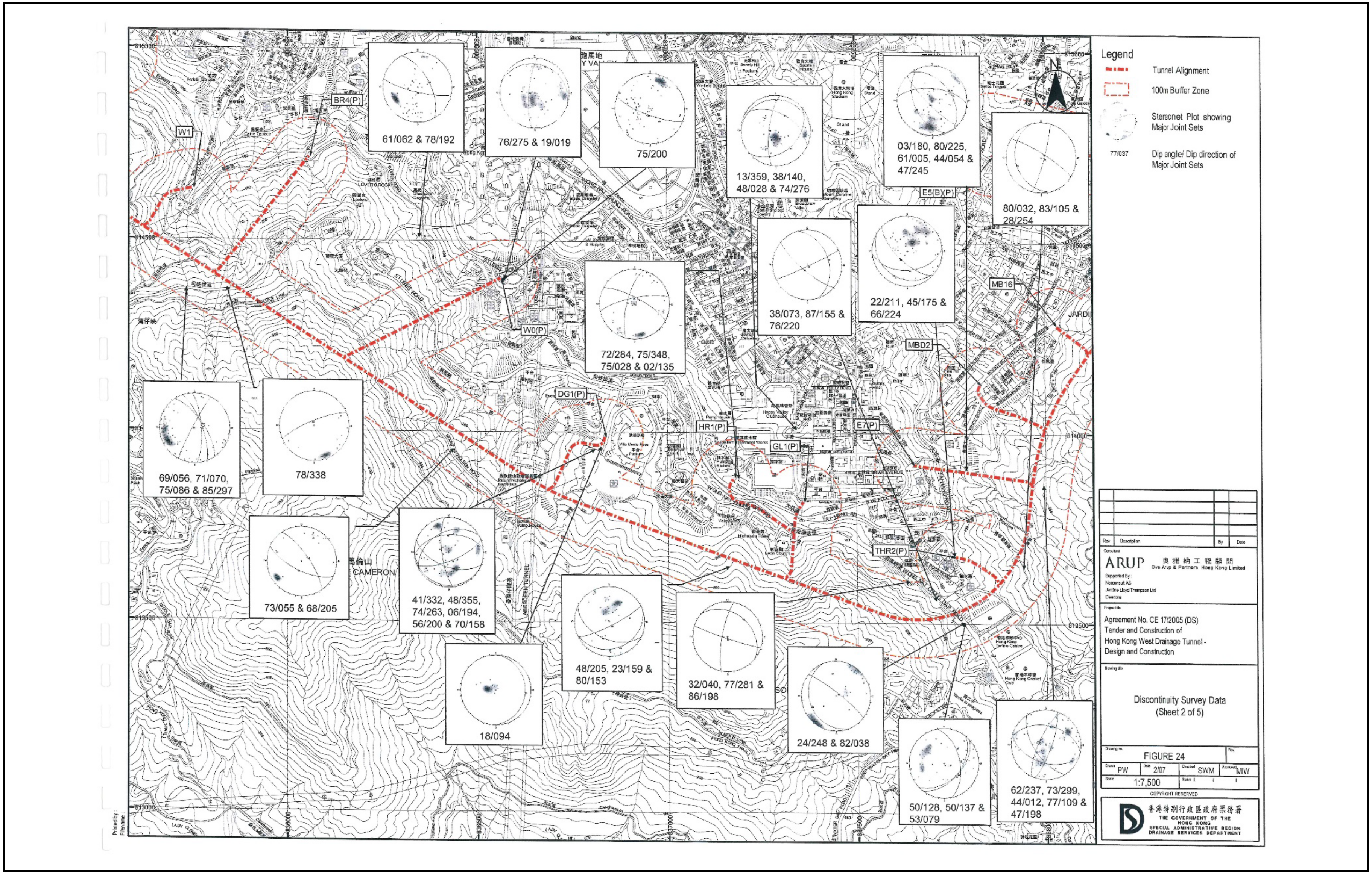


Figure B2 Discontinuity Survey Data of Hong Kong West Drainage Tunnel (Sheet 2 of 5) (from Arup, 2007)

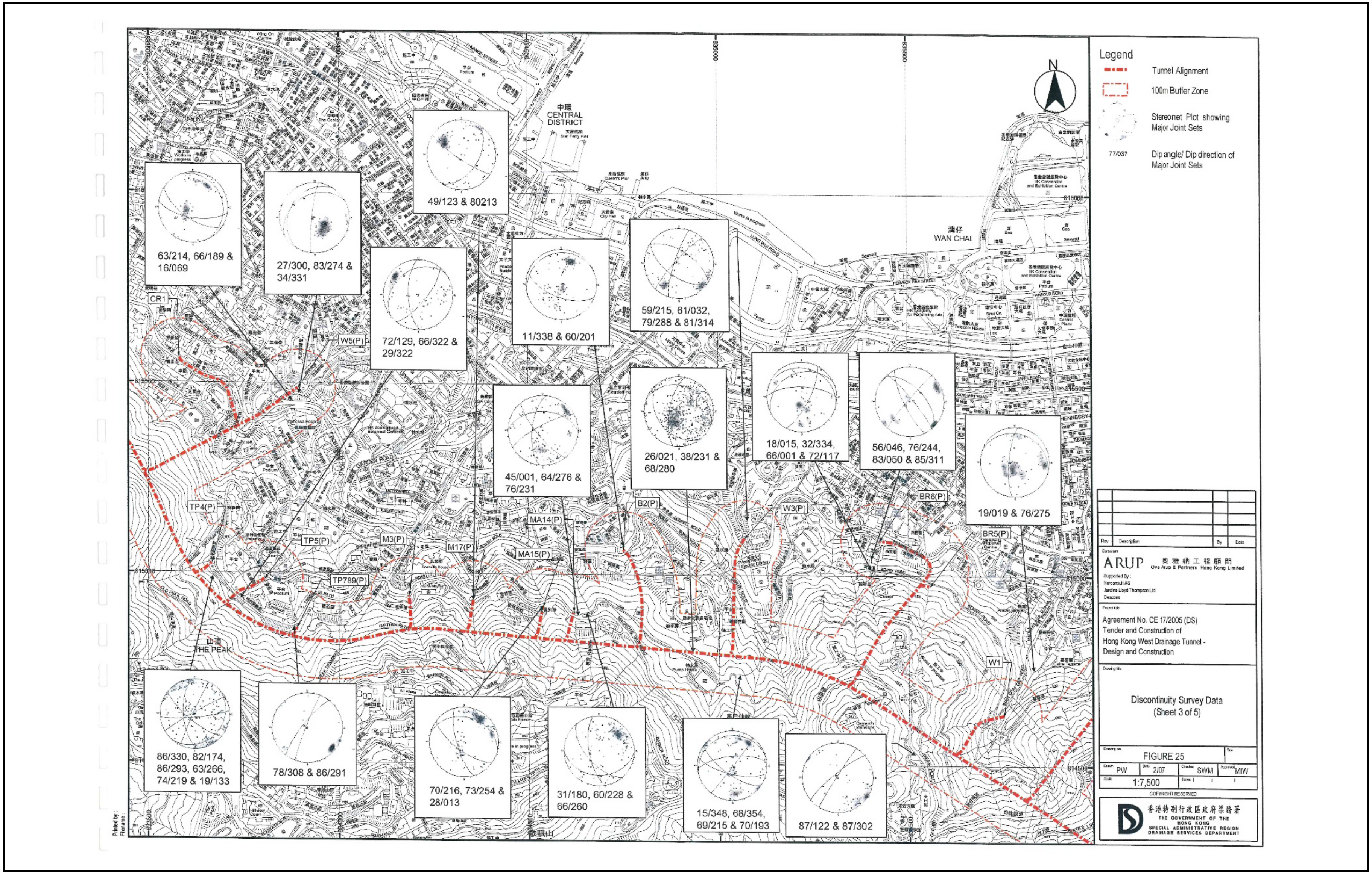


Figure B3 Discontinuity Survey Data of Hong Kong West Drainage Tunnel (Sheet 3 of 5) (from Arup, 2007)

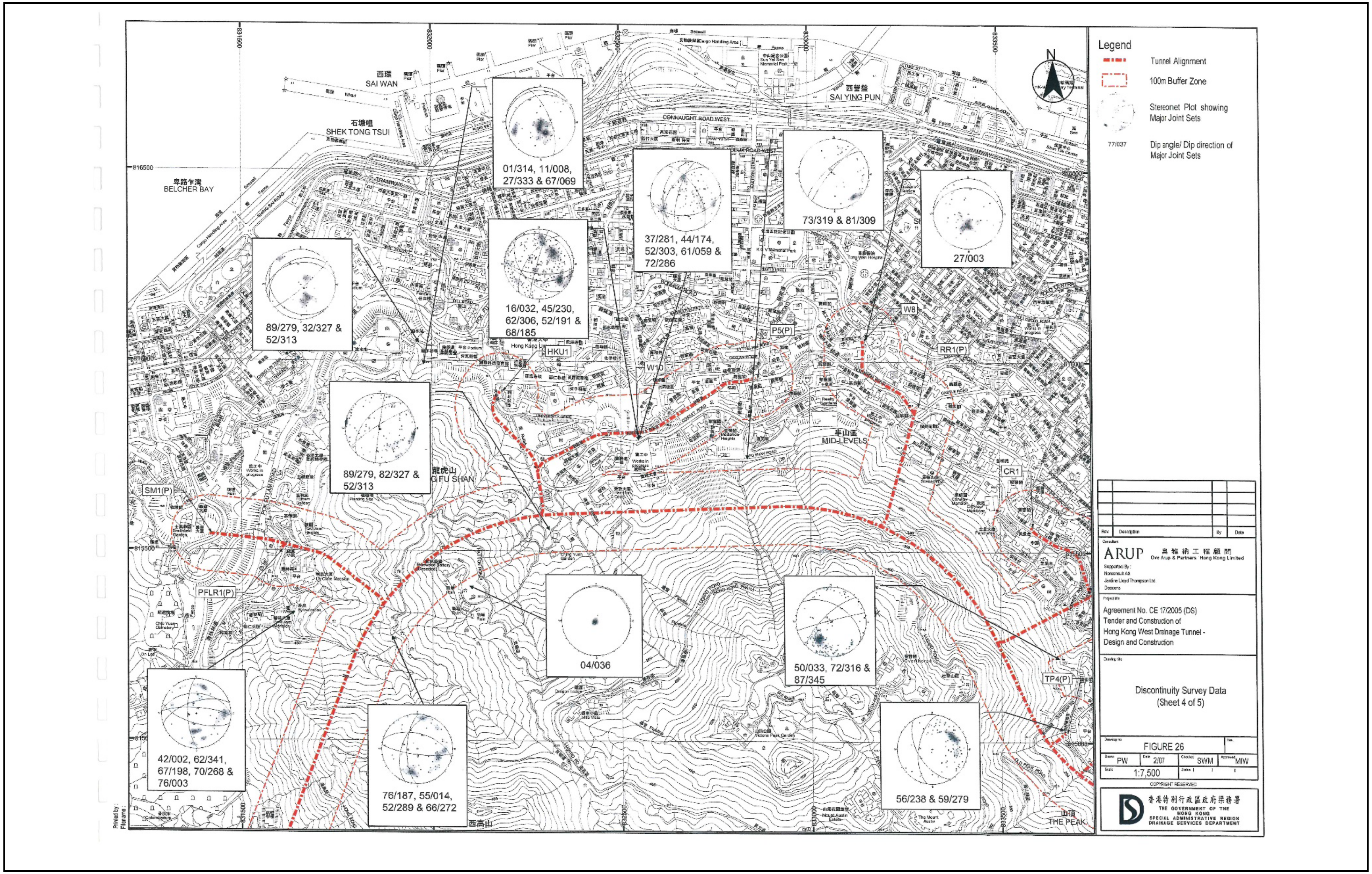


Figure B4 Discontinuity Survey Data of Hong Kong West Drainage Tunnel (Sheet 4 of 5) (from Arup, 2007)

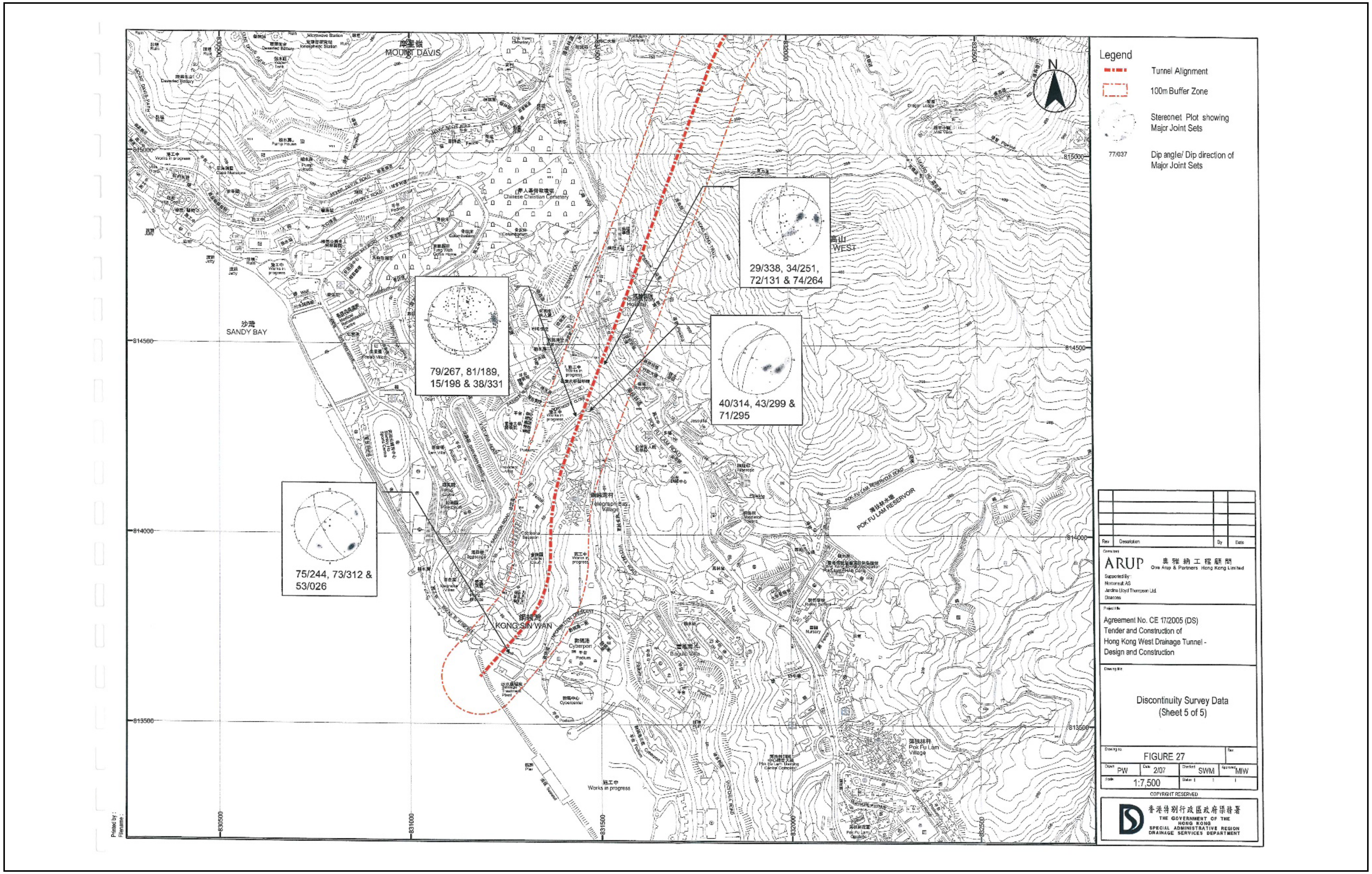


Figure B4 Discontinuity Survey Data of Hong Kong West Drainage Tunnel (Sheet 5 of 5) (from Arup, 2007)

Appendix C

Summary of Probing Records

Table C Summary of Probing Records (Sheet 1 of 8)

Starting Chainage	End Chainage	Probe length	Inflow (L/min)	Inflow (L/min/m)
15.00	35.00	20.00	5.40	0.27
27.00	47.00	20.00	2.50	0.13
35.00	55.00	20.00	13.95	0.70
44.00	64.00	20.00	0.60	0.03
60.00	85.00	25.00	0.00	0.00
80.00	106.00	26.00	0.00	0.00
97.00	122.00	25.00	0.00	0.00
114.80	139.80	25.00	0.00	0.00
130.00	155.40	25.40	0.40	0.02
146.70	176.70	30.00	0.00	0.00
189.00	229.30	40.30	0.75	0.02
220.70	281.10	60.40	0.00	0.00
270.16	326.86	56.70	1.80	0.03
316.75	374.45	57.70	0.10	0.00
363.20	423.60	60.40	0.00	0.00
411.07	465.97	54.90	0.50	0.01
451.84	506.74	54.90	0.30	0.01
496.84	546.24	49.40	0.20	0.00
535.94	590.84	54.90	0.20	0.00
580.92	621.22	40.30	7.50	0.19
607.93	651.83	43.90	1.10	0.03
627.53	669.63	42.10	75.00	1.78
657.52	712.42	54.90	3.60	0.07
696.53	751.43	54.90	24.00	0.44
708.55	763.45	54.90	7.20	0.13
746.11	795.51	49.40	1.30	0.03
785.08	839.98	54.90	7.80	0.14
824.11	868.01	43.90	25.95	0.59
842.07	896.97	54.90	30.00	0.55
885.62	927.71	42.09	25.00	0.59
885.62	940.52	54.90	0.90	0.02
930.61	980.02	49.41	34.00	0.69
966.67	1008.76	42.09	50.00	1.19
987.65	1029.74	42.09	15.00	0.36
1014.71	1069.61	54.90	35.00	0.64
1037.23	1079.32	42.09	4.00	0.10
1068.72	1108.98	40.26	33.00	0.82
1098.79	1153.69	54.90	0.50	0.01
1137.38	1192.68	55.30	0.60	0.01
1176.74	1231.64	54.90	0.90	0.02
1221.89	1276.79	54.90	8.00	0.15
1265.30	1320.20	54.90	2.30	0.04
1304.28	1346.37	42.09	6.80	0.16
1331.32	1373.41	42.09	2.80	0.07

Table C Summary of Probing Records (Sheet 2 of 8)

Starting Chainage	End Chainage	Probe length	Inflow (L/min)	Inflow (L/min/m)
1362.93	1425.15	62.22	12.00	0.19
1406.37	1450.29	43.92	40.00	0.91
1433.33	1488.23	54.90	7.00	0.13
1477.01	1519.10	42.09	30.00	0.71
1504.15	1546.24	42.09	26.00	0.62
1526.45	1581.35	54.90	3.00	0.05
1570.00	1612.09	42.09	15.00	0.36
1592.46	1634.55	42.09	16.70	0.40
1624.07	1666.16	42.09	20.00	0.48
1655.54	1697.63	42.09	18.40	0.44
1687.09	1747.48	60.39	0.10	0.00
1735.34	1795.53	60.19	0.00	0.00
1781.71	1825.63	43.92	0.00	0.00
1814.79	1869.69	54.90	0.50	0.01
1859.67	1920.08	60.41	0.50	0.01
1907.82	1968.21	60.39	1.80	0.03
1957.25	2017.84	60.59	0.00	0.00
2006.84	2047.10	40.26	0.00	0.00
2030.76	2074.68	43.92	0.00	0.00
2062.40	2122.79	60.39	0.00	0.00
2105.95	2166.31	60.36	0.50	0.01
2149.49	2209.88	60.39	0.50	0.01
2199.09	2241.18	42.09	17.10	0.41
2226.05	2286.44	60.39	0.50	0.01
2275.64	2336.03	60.39	0.50	0.01
2320.58	2369.99	49.41	34.50	0.70
2358.09	2418.48	60.39	1.50	0.02
2407.45	2467.84	60.39	2.00	0.03
2458.45	2518.84	60.39	0.40	0.01
2507.92	2568.31	60.39	0.00	0.00
2552.98	2613.37	60.39	0.20	0.00
2593.50	2653.89	60.39	0.50	0.01
2641.55	2701.94	60.39	0.00	0.00
2691.04	2751.43	60.39	0.00	0.00
2740.58	2800.97	60.39	0.20	0.00
2790.09	2850.48	60.39	0.20	0.00
2839.70	2900.09	60.39	0.00	0.00
2884.74	2945.13	60.39	0.00	0.00
2934.25	2994.64	60.39	0.30	0.00
2982.46	3042.85	60.39	0.40	0.01
3032.07	3092.46	60.39	0.50	0.01
3081.47	3141.86	60.39	0.70	0.01
3123.52	3183.91	60.39	0.00	0.00
3170.03	3224.93	54.90	4.40	0.08

Table C Summary of Probing Records (Sheet 3 of 8)

Starting Chainage	End Chainage	Probe length	Inflow (L/min)	Inflow (L/min/m)
3209.00	3269.39	60.39	2.00	0.03
3258.46	3313.36	54.90	0.10	0.00
3301.97	3362.36	60.39	0.00	0.00
3351.64	3412.03	60.39	0.00	0.00
3401.20	3461.59	60.39	0.00	0.00
3450.66	3511.05	60.39	0.00	0.00
3500.24	3560.63	60.39	0.00	0.00
3545.19	3605.58	60.39	0.00	0.00
3594.82	3655.21	60.39	4.00	0.07
3644.31	3704.70	60.39	0.80	0.01
3693.99	3764.38	70.39	0.00	0.00
3741.47	3801.86	60.39	0.00	0.00
3787.05	3847.44	60.39	0.00	0.00
3836.53	3869.47	32.94	0.00	0.00
3858.95	3919.34	60.39	1.60	0.03
3905.49	3947.58	42.09	54.00	1.28
3937.00	3975.44	38.44	1.20	0.03
3956.50	4016.50	60.00	0.50	0.01
4007.13	3956.50	50.63	0.00	0.00
4034.45	3996.11	38.34	1.50	0.04
4061.51	4015.76	45.75	10.00	0.22
4079.37	4024.47	54.90	20.00	0.36
4103.34	4061.25	42.09	90.00	2.14
4145.49	4085.10	60.39	18.00	0.30
4192.12	4131.73	60.39	4.20	0.07
4237.15	4194.80	42.35	66.60	1.57
4237.15	4176.76	60.39	6.00	0.10
4268.00	4207.61	60.39	22.00	0.36
4307.67	4263.75	43.92	75.00	1.71
4342.16	4281.77	60.39	60.00	0.99
4370.95	4327.03	43.92	60.00	1.37
4395.85	4351.93	43.92	35.00	0.80
4439.89	4379.50	60.39	27.00	0.45
4462.58	4418.33	44.25	80.00	1.81
4477.46	4433.54	43.92	80.00	1.82
4503.10	4459.18	43.92	60.00	1.37
4552.51	4492.12	60.39	1.00	0.02
4600.78	4540.39	60.39	1.20	0.02
4647.58	4586.79	60.79	1.00	0.02
4677.18	4622.28	54.90	3.00	0.05
4707.54	4656.30	51.24	16.60	0.32
4748.00	4687.68	60.32	20.00	0.33
4797.39	4740.66	56.73	1.50	0.03

Table C Summary of Probing Records (Sheet 4 of 8)

Starting Chainage	End Chainage	Probe length	Inflow (L/min)	Inflow (L/min/m)
4836.59	4792.67	43.92	24.00	0.55
4874.20	4813.81	60.39	10.80	0.18
4902.50	4847.60	54.90	17.50	0.32
4931.03	4887.11	43.92	45.00	1.02
4949.40	4905.48	43.92	30.00	0.68
4979.02	4929.61	49.41	45.00	0.91
4997.40	4955.30	42.10	7.50	0.18
5010.85	4968.79	42.06	60.00	1.43
5028.67	4984.75	43.92	60.00	1.37
5051.17	5007.87	43.30	60.00	1.39
5064.00	5020.80	43.20	60.00	1.39
5082.75	5044.32	38.43	60.00	1.56
5127.77	5067.36	60.41	5.00	0.08
5171.00	5110.61	60.39	2.50	0.04
5214.84	5153.95	60.89	15.00	0.25
5247.91	5205.82	42.09	60.00	1.43
5265.89	5210.99	54.90	75.00	1.37
5315.45	5255.06	60.39	4.00	0.07
5360.71	5300.32	60.39	5.00	0.08
5410.15	5349.76	60.39	1.00	0.02
5459.81	5399.42	60.39	2.20	0.04
5503.35	5448.45	54.90	1.80	0.03
5527.61	5489.18	38.43	10.00	0.26
5557.34	5502.44	54.90	0.00	0.00
5579.77	5537.68	42.09	20.00	0.48
5602.30	5558.38	43.92	150.00	3.42
5624.80	5586.37	38.43	90.00	2.34
5647.14	5608.71	38.43	44.90	1.17
5668.56	5624.64	43.92	24.00	0.55
5687.67	5649.24	38.43	100.00	2.60
5705.71	5661.79	43.92	18.00	0.41
5728.45	5690.02	38.43	60.00	1.56
5756.66	5714.57	42.09	100.00	2.38
5778.32	5736.23	42.09	62.00	1.47
5805.92	5763.80	42.12	88.00	2.09
5823.22	5779.30	43.92	100.00	2.28
5867.10	5828.67	38.43	75.00	1.95
5867.10	5806.71	60.39	70.00	1.16
5888.83	5861.38	27.45	60.00	2.19
5932.43	5872.04	60.39	0.30	0.00
5983.04	5922.65	60.39	0.30	0.00
6031.81	5971.53	60.28	0.80	0.01
6045.59	6012.62	32.97	0.50	0.02

Table C Summary of Probing Records (Sheet 5 of 8)

Starting Chainage	End Chainage	Probe length	Inflow (L/min)	Inflow (L/min/m)
6087.80	6032.70	55.10	8.00	0.15
6137.20	6076.81	60.39	3.00	0.05
6148.71	6106.62	42.09	8.50	0.20
6198.79	6138.40	60.39	2.70	0.04
6225.97	6182.05	43.92	10.00	0.23
6275.22	6214.83	60.39	1.80	0.03
6296.32	6256.06	40.26	27.00	0.67
6346.01	6285.62	60.39	1.50	0.02
6373.06	6329.14	43.92	7.00	0.16
6405.58	6356.17	49.41	14.50	0.29
6455.58	6395.19	60.39	0.00	0.00
6493.09	6449.17	43.92	20.00	0.46
6493.09	6443.68	49.41	1.80	0.04
6542.70	6482.31	60.39	1.20	0.02
6577.10	6522.20	54.90	50.00	0.91
6628.54	6566.15	62.39	0.00	0.00
6669.88	6609.49	60.39	0.50	0.01
6715.06	6654.67	60.39	0.00	0.00
6755.93	6695.54	60.39	2.50	0.04
6792.01	6749.92	42.09	25.00	0.59
6792.01	6731.62	60.39	10.00	0.17
6811.49	6769.40	42.09	21.40	0.51
6825.00	6764.61	60.39	17.10	0.28
6870.10	6809.71	60.39	0.80	0.01
6890.92	6847.00	43.92	0.30	0.01
6940.88	6880.49	60.39	0.00	0.00
6984.37	6923.98	60.39	0.00	0.00
7033.74	6973.35	60.39	0.00	0.00
7078.84	7018.45	60.39	0.40	0.01
7110.25	7059.10	51.15	0.00	0.00
7159.96	7099.57	60.39	0.20	0.00
7209.69	7149.30	60.39	5.00	0.08
7259.11	7198.72	60.39	0.00	0.00
7308.84	7248.45	60.39	4.50	0.07
7340.42	7291.01	49.41	25.00	0.51
7389.59	7329.20	60.39	3.80	0.06
7439.38	7478.99	39.61	0.20	0.01
7482.80	7422.41	60.39	0.40	0.01
7525.46	7464.90	60.56	0.20	0.00
7544.51	7511.57	32.94	0.00	0.00
7593.94	7531.72	62.22	3.00	0.05
7622.51	7562.12	60.39	0.50	0.01
7666.62	7606.23	60.39	0.20	0.00

Table C Summary of Probing Records (Sheet 6 of 8)

Starting Chainage	End Chainage	Probe length	Inflow (L/min)	Inflow (L/min/m)
7712.80	7652.41	60.39	0.00	0.00
7762.36	7701.97	60.39	0.00	0.00
7811.87	7751.48	60.39	0.50	0.01
7858.06	7797.67	60.39	0.30	0.00
7907.71	7547.32	360.39	1.50	0.00
7955.38	7894.99	60.39	2.00	0.03
8005.37	7944.98	60.39	2.40	0.04
8055.14	7999.75	55.39	0.00	0.00
8104.56	8042.34	62.22	0.00	0.00
8131.51	8071.12	60.39	1.00	0.02
8181.02	8118.80	62.22	0.20	0.00
8230.52	8168.30	62.22	0.00	0.00
8280.20	8219.81	60.39	0.50	0.01
8313.36	8269.44	43.92	8.60	0.20
8358.10	8297.71	60.39	0.20	0.00
8407.60	8345.38	62.22	0.80	0.01
8450.86	8408.77	42.09	30.00	0.71
8450.86	8390.47	60.39	18.00	0.30
8483.82	8443.11	40.71	20.00	0.49
8533.76	8473.37	60.39	0.80	0.01
8553.76	8491.67	62.09	9.00	0.14
8583.54	8521.32	62.22	0.40	0.01
8634.50	8572.28	62.22	0.60	0.01
8683.73	8621.51	62.22	0.20	0.00
8734.96	8672.74	62.22	0.80	0.01
8780.16	8717.94	62.22	0.30	0.00
8832.65	8770.43	62.22	0.50	0.01
8862.12	8799.00	63.12	0.70	0.01
8913.69	8851.47	62.22	0.00	0.00
8946.53	8902.61	43.92	1.20	0.03
8968.96	8926.67	42.29	15.00	0.35
8983.83	8941.74	42.09	43.00	1.02
9035.32	8993.23	42.09	15.00	0.36
9065.16	9023.07	42.09	75.00	1.78
9083.30	9035.72	47.58	110.00	2.31
9134.36	9072.14	62.22	1.20	0.02
9147.71	9114.77	32.94	0.00	0.00
9179.28	9139.00	40.28	50.00	1.24
9210.71	9166.79	43.92	27.00	0.61
9231.89	9191.63	40.26	25.00	0.62
9255.31	9213.22	42.09	75.00	1.78
9286.77	9244.68	42.09	43.00	1.02
9336.77	9276.38	60.39	20.00	0.33

Table C Summary of Probing Records (Sheet 7 of 8)

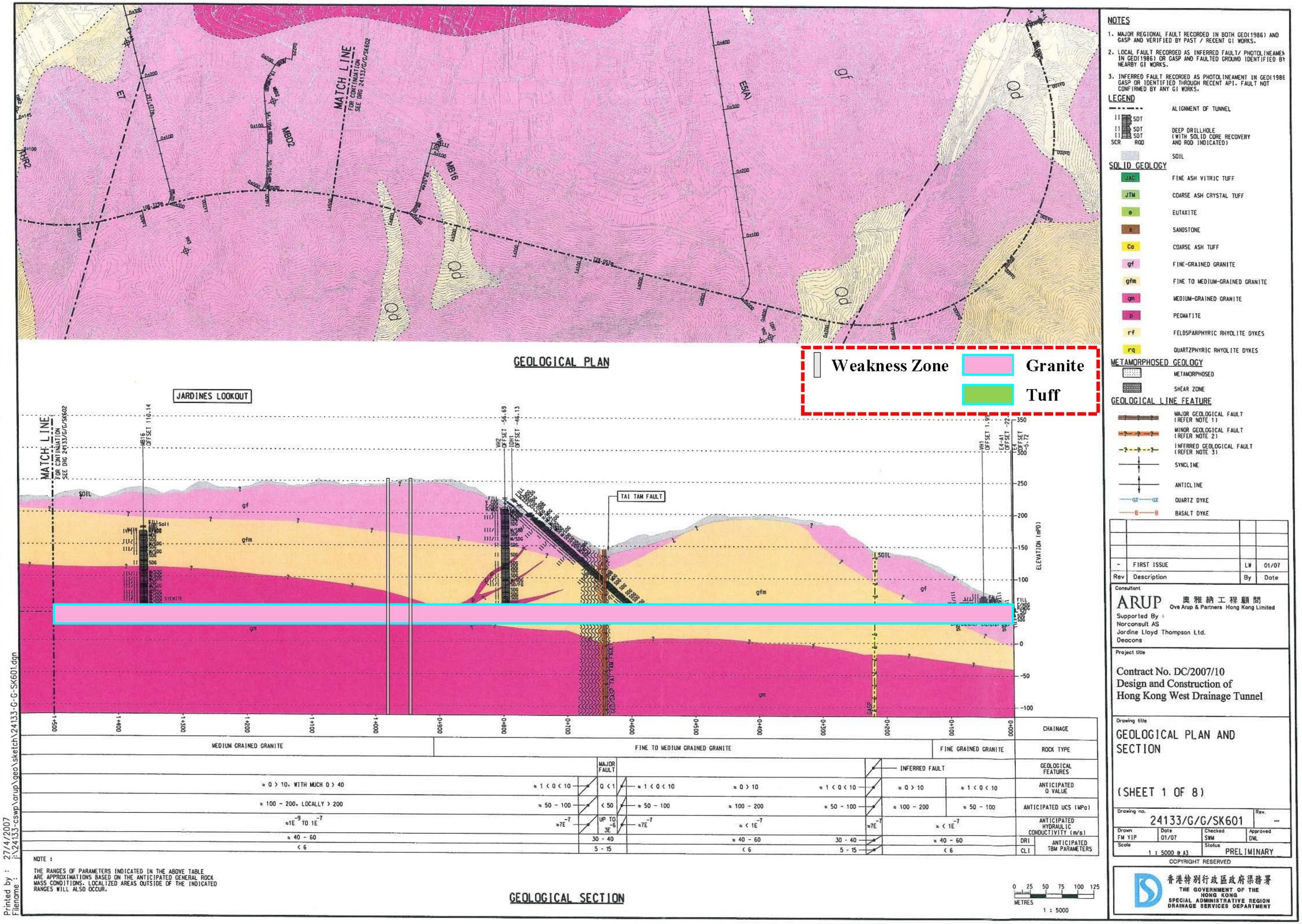
Starting Chainage	End Chainage	Probe length	Inflow (L/min)	Inflow (L/min/m)
9363.94	9321.85	42.09	140.00	3.33
9394.00	9351.91	42.09	50.00	1.19
9403.00	9364.57	38.43	75.00	1.95
9433.03	9392.77	40.26	16.00	0.40
9447.10	9403.18	43.92	150.00	3.42
9481.15	9439.06	42.09	150.00	3.56
9507.92	9474.98	32.94	8.00	0.24
9510.89	9468.80	42.09	150.00	3.56
9528.00	9490.47	37.53	65.00	1.73
9544.23	9500.31	43.92	150.00	3.42
9562.20	9518.28	43.92	75.00	1.71
9574.28	9532.19	42.09	100.00	2.38
9594.98	9532.19	62.79	67.50	1.08
9610.24	9568.15	42.09	100.00	2.38
9640.10	9598.01	42.09	120.00	2.85
9670.92	9630.66	40.26	100.00	2.48
9700.52	9645.62	54.90	50.00	0.91
9725.90	9683.81	42.09	8.60	0.20
9739.34	9697.25	42.09	4.60	0.11
9756.57	9717.48	39.09	20.00	0.51
9789.80	9749.54	40.26	60.00	1.49
9819.32	9769.91	49.41	60.00	1.21
9835.30	9820.20	15.10	30.00	1.99
9833.84	9791.75	42.09	200.00	4.75
9860.75	9820.49	40.26	100.00	2.48
9875.59	9835.33	40.26	75.00	1.86
9901.42	9859.33	42.09	9.00	0.21
9931.86	9889.77	42.09	12.50	0.30
9939.92	9897.83	42.09	2.70	0.06
9985.26	9934.02	51.24	0.55	0.01
10022.60	9965.87	56.73	0.70	0.01
10060.60	10003.87	56.73	0.60	0.01
10102.70	10045.97	56.73	0.00	0.00
10129.00	10081.42	47.58	0.00	0.00
10168.40	10113.50	54.90	0.00	0.00
10218.40	10163.50	54.90	0.00	0.00
10270.20	10214.04	56.16	5.00	0.09
10336.20	10299.60	36.60	1.20	0.03
10369.50	10325.58	43.92	0.30	0.01
10389.00	10356.06	32.94	0.00	0.00
10422.20	10381.84	40.36	0.10	0.00
10446.30	10405.13	41.17	7.00	0.17
10472.90	10432.64	40.26	1.25	0.03

Table C Summary of Probing Records (Sheet 8 of 8)

Starting Chainage	End Chainage	Probe length	Inflow (L/min)	Inflow (L/min/m)
10488.28	10448.15	40.13	4.60	0.11
10514.62	10465.82	48.80	0.00	0.00
10532.00	10512.00	20.00	0.00	0.00
10535.00	10515.00	20.00	0.00	0.00
10551.00	10531.00	20.00	0.00	0.00
10560.00	10539.00	21.00	0.00	0.00
10571.20	10551.20	20.00	0.00	0.00
10583.00	10563.00	20.00	0.00	0.00

Appendix D

Revised Geological Sections


GEOLOGICAL PLAN
Weakness Zone
Granite
Tuff
JARDINES LOOKOUT
MATCH LINE
FOR CONTINUATION SEE DRG 24133/G/G/SK602
TAI TAM FAULT
SOIL
ELEVATION (mPD)
CHAINAGE
ROCK TYPE
MEDIUM GRAINED GRANITE
FINE TO MEDIUM GRAINED GRANITE
FINE GRAINED GRANITE
GEOLOGICAL FEATURES
MAJOR FAULT
INFERRED FAULT
ANTICIPATED Q VALUE
ANTICIPATED UCS (MPa)
ANTICIPATED HYDRAULIC CONDUCTIVITY (m/s)
ANTICIPATED TBM PARAMETERS
NOTE :
THE RANGES OF PARAMETERS INDICATED IN THE ABOVE TABLE ARE APPROXIMATIONS BASED ON THE ANTICIPATED GENERAL ROCK MASS CONDITIONS. LOCALIZED AREAS OUTSIDE OF THE INDICATED RANGES WILL ALSO OCCUR.
GEOLOGICAL SECTION
METRES
1 : 5000
NOTES
1. MAJOR REGIONAL FAULT RECORDED IN BOTH GEO(1986) AND GASP AND VERIFIED BY PAST / RECENT GI WORKS.
2. LOCAL FAULT RECORDED AS INFERRED FAULT/ PHOTOLINEAMENT IN GEO(1986) OR GASP AND FAULTED GROUND IDENTIFIED BY NEARBY GI WORKS.
3. INFERRED FAULT RECORDED AS PHOTOLINEAMENT IN GEO(1986) GASP OR IDENTIFIED THROUGH RECENT API. FAULT NOT CONFIRMED BY ANY GI WORKS.
LEGEND
ALIGNMENT OF TUNNEL
DEEP DRILLHOLE (WITH SOLID CORE RECOVERY AND RQD INDICATED)
SOIL
SOLID GEOLOGY
FINE ASH VITRIC TUFF
COARSE ASH CRYSTAL TUFF
EUTAXITE
SANDSTONE
COARSE ASH TUFF
FINE-GRAINED GRANITE
FINE TO MEDIUM-GRAINED GRANITE
MEDIUM-GRAINED GRANITE
PEGMATITE
FELDSPARPHYRIC RHYOLITE DYKES
QUARTZPHYRIC RHYOLITE DYKES
METAMORPHOSED GEOLOGY
METAMORPHOSED
SHEAR ZONE
GEOLOGICAL LINE FEATURE
MAJOR GEOLOGICAL FAULT (REFER NOTE 1)
MINOR GEOLOGICAL FAULT (REFER NOTE 2)
INFERRED GEOLOGICAL FAULT (REFER NOTE 3)
SYNCLINE
ANTICLINE
QUARTZ DYKE
BASALT DYKE
FIRST ISSUE
Consultant
ARUP
奧雅納工程顧問
Ove Arup & Partners Hong Kong Limited
Supported By :
Norconsult AS
Jardine Lloyd Thompson Ltd.
Deacons
Project title
Contract No. DC/2007/10
Design and Construction of
Hong Kong West Drainage Tunnel
Drawing title
GEOLOGICAL PLAN AND SECTION
(SHEET 1 OF 8)
Drawing no.
24133/G/G/SK601
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THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION DRAINAGE SERVICES DEPARTMENT
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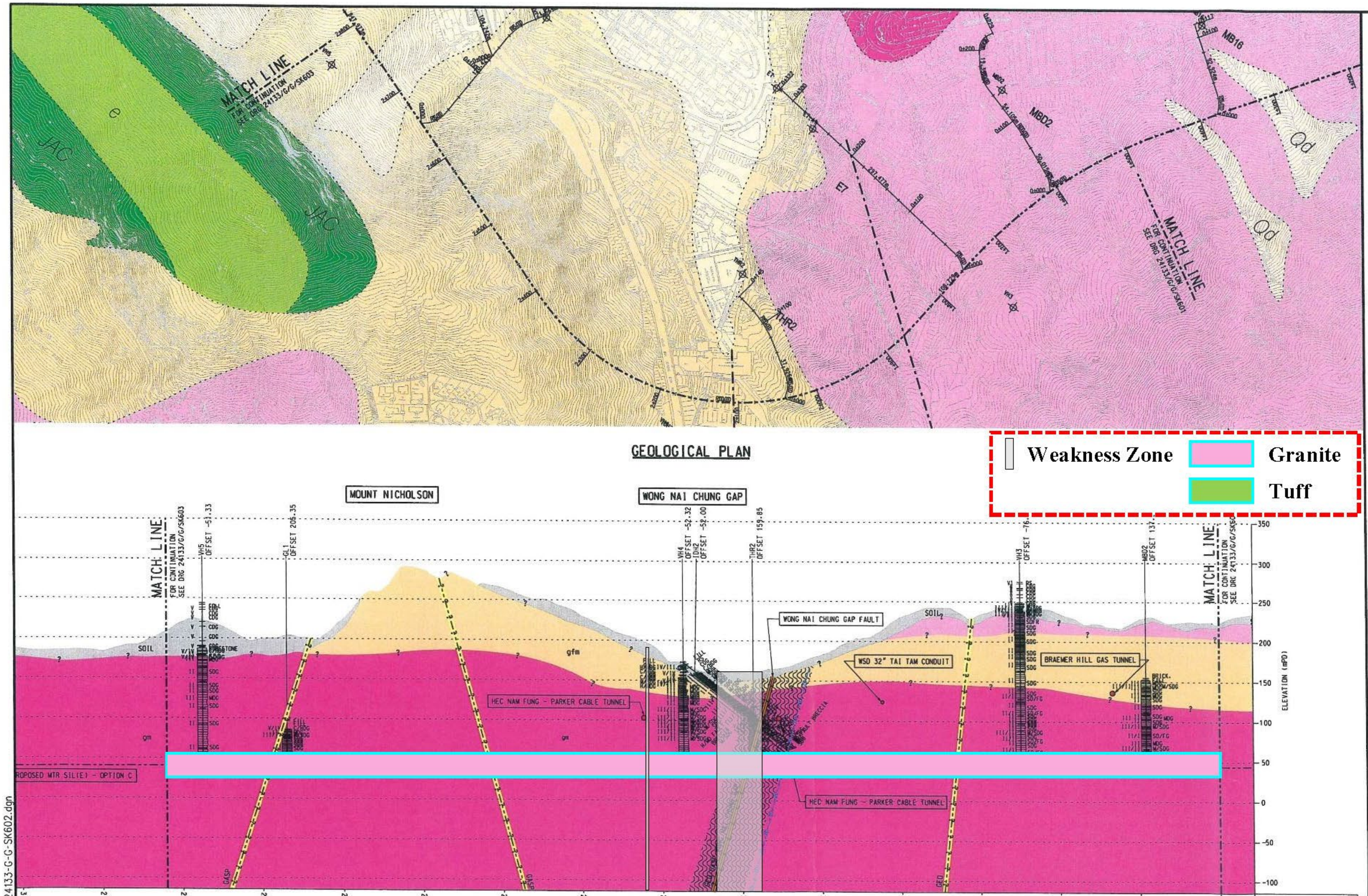

CHAINAGE	3+000 – 2+700		2+700 – 2+400		2+400 – 2+100				2+100 – 1+800		1+800 – 1+500
ROCK TYPE	MEDIUM GRAINED GRANITE										
GEOLOGICAL FEATURES		INFERRED FAULT		INFERRED FAULT		SHEAR ZONE	MAJOR FAULT	SHEAR ZONE		INFERRED FAULT	
ANTICIPATED Q VALUE	≈ Q > 10	1 < Q < 10	≈ Q > 10	1 < Q < 10	≈ Q > 10	1 < Q < 10	Q < 1	1 < Q < 10	≈ Q > 10	1 < Q < 10	≈ Q > 10, WITH MUCH Q > 40
ANTICIPATED UCS (MPa)	≈ 100 - 200, LOCALLY > 200	50 - 100	≈ 100 - 200	50 - 100	≈ 100 - 200	≈ 50 - 100	< 50	≈ 50 - 100	≈ 100 - 200	50 - 100	≈ 100 - 200, LOCALLY > 200
ANTICIPATED HYDRAULIC CONDUCTIVITY (m/s)	≈1E-9 TO 1E-7	7E-7	≈1E-9 TO 1E-7	7E-7	≈1E-9 TO 1E-7	≈7E-7	UP TO 3E-6	≈7E-7	≈1E-9 TO 1E-7	≈1E-7	≈1E-9 TO 1E-7
ANTICIPATED TBM PARAMETERS DRI	≈ 40 - 60	30 - 40	≈ 40 - 60	30 - 40	≈ 40 - 60	30 - 40			≈ 40 - 60	30 - 40	≈ 40 - 60
ANTICIPATED TBM PARAMETERS CLI	< 6	5 - 15	< 8	5 - 15	< 8	5 - 15			< 8	5 - 15	< 8

NOTE :

THE RANGES OF PARAMETERS INDICATED IN THE ABOVE TABLE ARE APPROXIMATIONS BASED ON THE ANTICIPATED GENERAL ROCK MASS CONDITIONS. LOCALIZED AREAS OUTSIDE OF THE INDICATED RANGES WILL ALSO OCCUR.

GEOLOGICAL SECTION

0 25 50 75 100 125 METRES 1 : 5000

NOTES

1. MAJOR REGIONAL FAULT RECORDED IN BOTH GEO(1986) AND GASP AND VERIFIED BY PAST / RECENT GI WORKS.
2. LOCAL FAULT RECORDED AS INFERRED FAULT/ PHOTOLINEAMENT IN GEO(1986) OR GASP AND FAULTED GROUND IDENTIFIED BY NEARBY GI WORKS.
3. INFERRED FAULT RECORDED AS PHOTOLINEAMENT IN GEO(1986) GASP OR IDENTIFIED THROUGH RECENT API. FAULT NOT CONFIRMED BY ANY GI WORKS.

LEGEND

ALIGNMENT OF TUNNEL
DEEP DRILLHOLE (WITH SOLID CORE RECOVERY AND RQD INDICATED)
SOIL

SOLID GEOLOGY

- JAC FINE ASH VITRIC TUFF
- JTM COARSE ASH CRYSTAL TUFF
- e EUTAXITE
- s SANDSTONE
- Ca COARSE ASH TUFF
- gf FINE-GRAINED GRANITE
- gfm FINE TO MEDIUM-GRAINED GRANITE
- gm MEDIUM-GRAINED GRANITE
- p PEGMATITE
- rf FELDSPARPHYRIC RHYOLITE DYKES
- rq QUARTZPHYRIC RHYOLITE DYKES

METAMORPHOSED GEOLOGY

- METAMORPHOSED
- SHEAR ZONE

GEOLOGICAL LINE FEATURE

- MAJOR GEOLOGICAL FAULT (REFER NOTE 1)
- MINOR GEOLOGICAL FAULT (REFER NOTE 2)
- INFERRED GEOLOGICAL FAULT (REFER NOTE 3)
- SYNCLINE
- ANTICLINE
- QUARTZ DYKE
- BASALT DYKE

Rev	Description	By	Date
-	FIRST ISSUE	LW	01/07

Consultant

ARUP 奧雅納工程顧問 Ove Arup & Partners Hong Kong Limited

Supported By : Norconsult AS, Jardine Lloyd Thompson Ltd., Deacons

Project title

Contract No. DC/2007/10
Design and Construction of
Hong Kong West Drainage Tunnel

Drawing title

GEOLOGICAL PLAN AND SECTION

(SHEET 2 OF 8)

Drawing no. 24133/G/G/SK602 Rev. -

Drawn	Date	Checked	Approved
FM YIP	01/07	SWM	DML

Scale 1 : 5000 @ A3 Status PRELIMINARY

香港特別行政區政府渠務署
THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION DRAINAGE SERVICES DEPARTMENT

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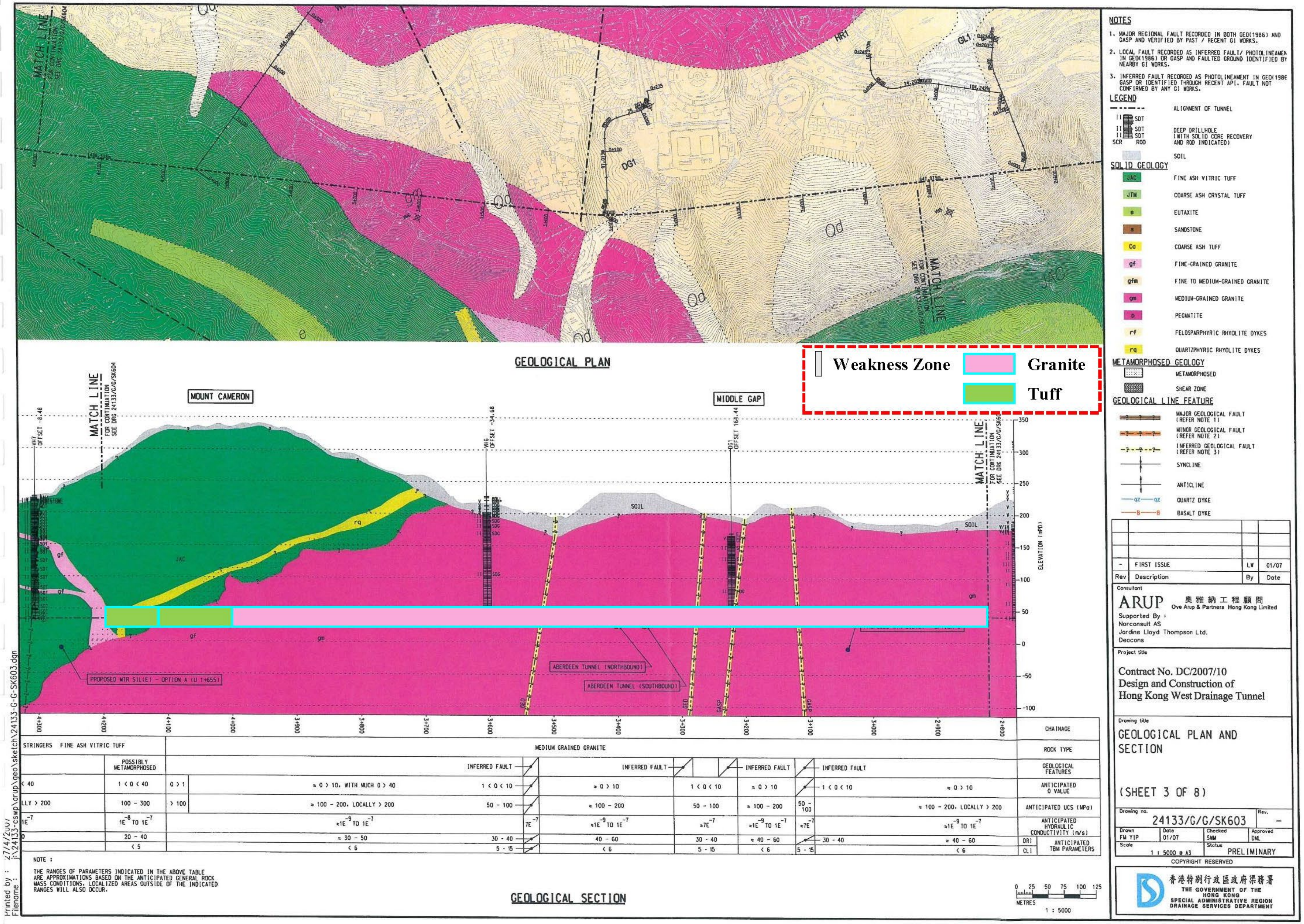
NOTES
1. MAJOR REGIONAL FAULT RECORDED IN BOTH GEO(1986) AND GASP AND VERIFIED BY PAST / RECENT GI WORKS.
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LEGEND
ALIGNMENT OF TUNNEL
DEEP DRILLHOLE (WITH SOLID CORE RECOVERY AND RQD INDICATED)
SOIL
SOLID GEOLOGY
JAC FINE ASH VITRIC TUFF
JTM COARSE ASH CRYSTAL TUFF
e EUTAXITE
s SANDSTONE
Ca COARSE ASH TUFF
gf FINE-GRAINED GRANITE
gfm FINE TO MEDIUM-GRAINED GRANITE
gm MEDIUM-GRAINED GRANITE
p PEGMATITE
rf FELDSPARPHYRIC RHYOLITE DYKES
rq QUARTZPHYRIC RHYOLITE DYKES
METAMORPHOSED GEOLOGY
METAMORPHOSED
SHEAR ZONE
GEOLOGICAL LINE FEATURE
MAJOR GEOLOGICAL FAULT (REFER NOTE 1)
MINOR GEOLOGICAL FAULT (REFER NOTE 2)
INFERRED GEOLOGICAL FAULT (REFER NOTE 3)
SYNCLINE
ANTICLINE
QUARTZ DYKE
BASALT DYKE
Weakness Zone
Granite
Tuff
GEOLOGICAL PLAN
MATCH LINE FOR CONTINUATION SEE DRG 24133/G/G/SK604
MOUNT CAMERON
MIDDLE GAP
MATCH LINE FOR CONTINUATION SEE DRG 24133/G/G/SK602
ELEVATION (mPD)
PROPOSED MIR SIL(E) - OPTION A (U 1+655)
ABERDEEN TUNNEL (NORTHBOUND)
ABERDEEN TUNNEL (SOUTHBOUND)
CHAINAGE
ROCK TYPE
GEOLOGICAL FEATURES
ANTICIPATED Q VALUE
ANTICIPATED UCS (MPa)
ANTICIPATED HYDRAULIC CONDUCTIVITY (m/s)
ANTICIPATED TBM PARAMETERS
STRINGERS FINE ASH VITRIC TUFF
MEDIUM GRAINED GRANITE
POSSIBLY METAMORPHOSED
INFERRED FAULT
NOTE :
THE RANGES OF PARAMETERS INDICATED IN THE ABOVE TABLE ARE APPROXIMATIONS BASED ON THE ANTICIPATED GENERAL ROCK MASS CONDITIONS. LOCALIZED AREAS OUTSIDE OF THE INDICATED RANGES WILL ALSO OCCUR.
GEOLOGICAL SECTION
METRES 1 : 5000
Rev Description By Date
- FIRST ISSUE LW 01/07
Consultant
ARUP 奧雅納工程顧問 Ove Arup & Partners Hong Kong Limited
Supported By :
Norconsult AS
Jardine Lloyd Thompson Ltd.
Deacons
Project title
Contract No. DC/2007/10
Design and Construction of
Hong Kong West Drainage Tunnel
Drawing title
GEOLOGICAL PLAN AND SECTION
(SHEET 3 OF 8)
Drawing no. 24133/G/G/SK603
Drawn FM YIP Date 01/07 Checked SMM Approved DML
Scale 1 : 5000 @ A3 Status PRELIMINARY
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THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION DRAINAGE SERVICES DEPARTMENT
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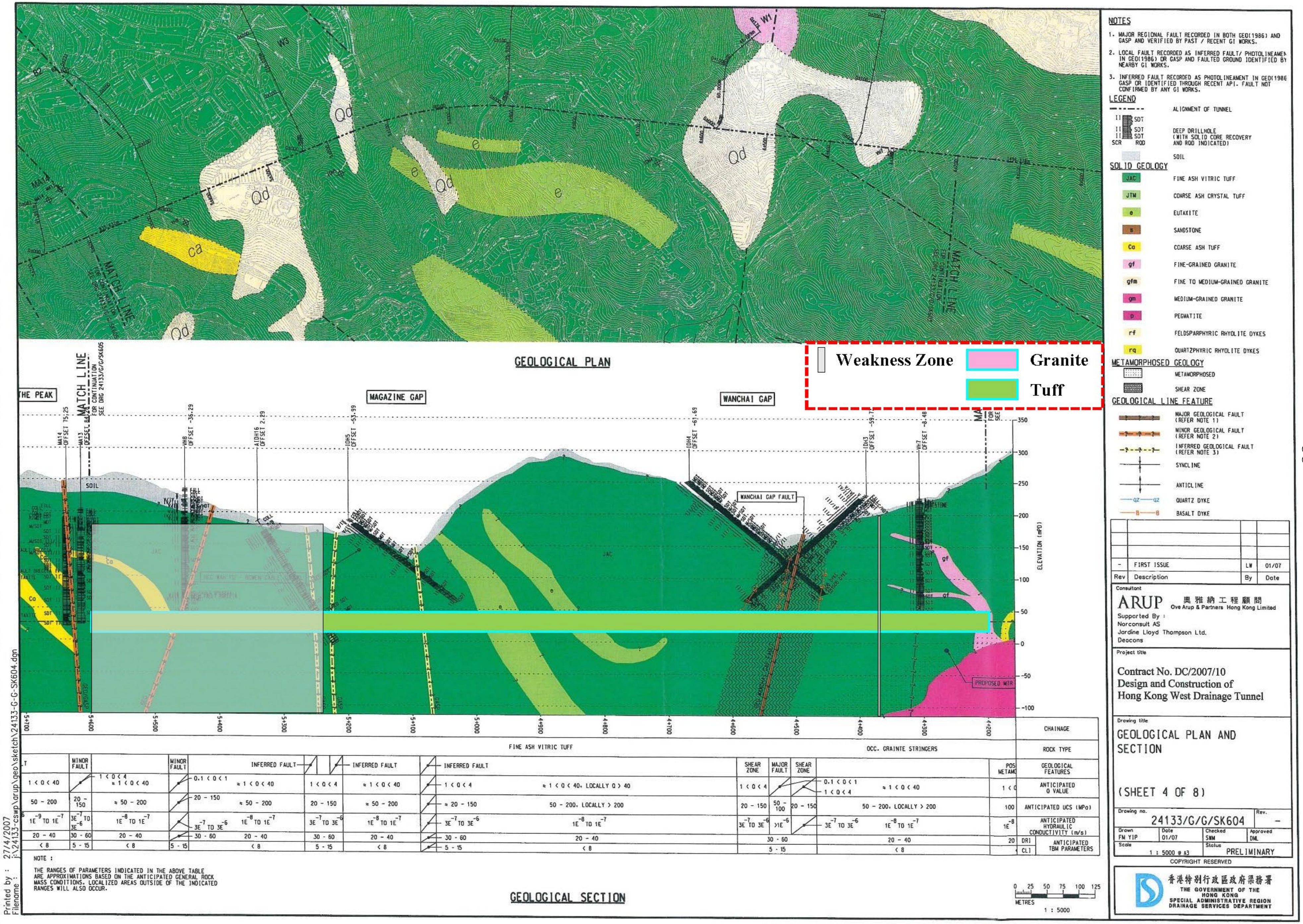
GEOLOGICAL PLAN
GEOLOGICAL SECTION
Weakness Zone
Granite
Tuff
THE PEAK
MAGAZINE GAP
WANCHAI GAP
WANCHAI GAP FAULT
MATCH LINE
FINE ASH VITRIC TUFF
OCC. GRAINITE STRINGERS
CHAINAGE
ROCK TYPE
GEOLOGICAL FEATURES
ANTICIPATED Q VALUE
ANTICIPATED UCS (MPa)
ANTICIPATED HYDRAULIC CONDUCTIVITY (m/s)
ANTICIPATED TBM PARAMETERS
ELEVATION (mPD)
NOTE :
THE RANGES OF PARAMETERS INDICATED IN THE ABOVE TABLE ARE APPROXIMATIONS BASED ON THE ANTICIPATED GENERAL ROCK MASS CONDITIONS. LOCALIZED AREAS OUTSIDE OF THE INDICATED RANGES WILL ALSO OCCUR.
NOTES
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LEGEND
ALIGNMENT OF TUNNEL
DEEP DRILLHOLE (WITH SOLID CORE RECOVERY AND RQD INDICATED)
SOIL
SOLID GEOLOGY
FINE ASH VITRIC TUFF
COARSE ASH CRYSTAL TUFF
EUTAXITE
SANDSTONE
COARSE ASH TUFF
FINE-GRAINED GRANITE
FINE TO MEDIUM-GRAINED GRANITE
MEDIUM-GRAINED GRANITE
PEGMATITE
FELDSPARPHYRIC RHYOLITE DYKES
QUARTZPHYRIC RHYOLITE DYKES
METAMORPHOSED GEOLOGY
METAMORPHOSED
SHEAR ZONE
GEOLOGICAL LINE FEATURE
MAJOR GEOLOGICAL FAULT (REFER NOTE 1)
MINOR GEOLOGICAL FAULT (REFER NOTE 2)
INFERRED GEOLOGICAL FAULT (REFER NOTE 3)
SYNCLINE
ANTICLINE
QUARTZ DYKE
BASALT DYKE
- FIRST ISSUE LW 01/07
Rev Description By Date
Consultant
ARUP 奧雅納工程顧問 Ove Arup & Partners Hong Kong Limited
Supported By : Norconsult AS Jardine Lloyd Thompson Ltd. Deacons
Project title
Contract No. DC/2007/10 Design and Construction of Hong Kong West Drainage Tunnel
Drawing title
GEOLOGICAL PLAN AND SECTION
(SHEET 4 OF 8)
Drawing no. 24133/G/G/SK604 Rev. -
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METRES 1 : 5000
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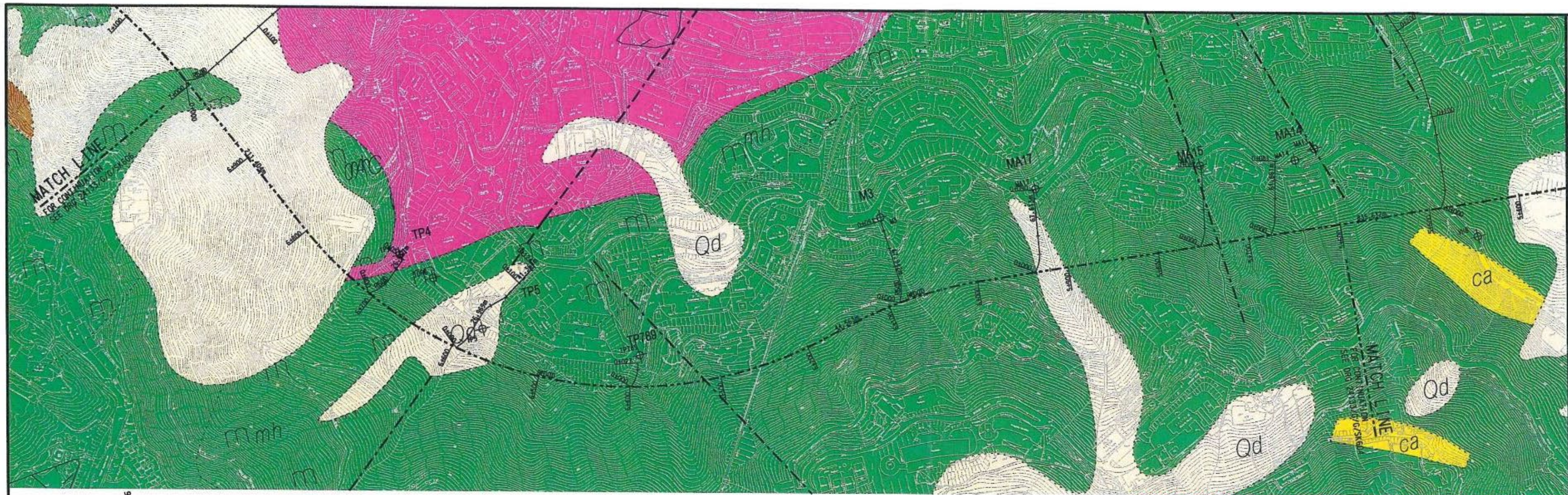
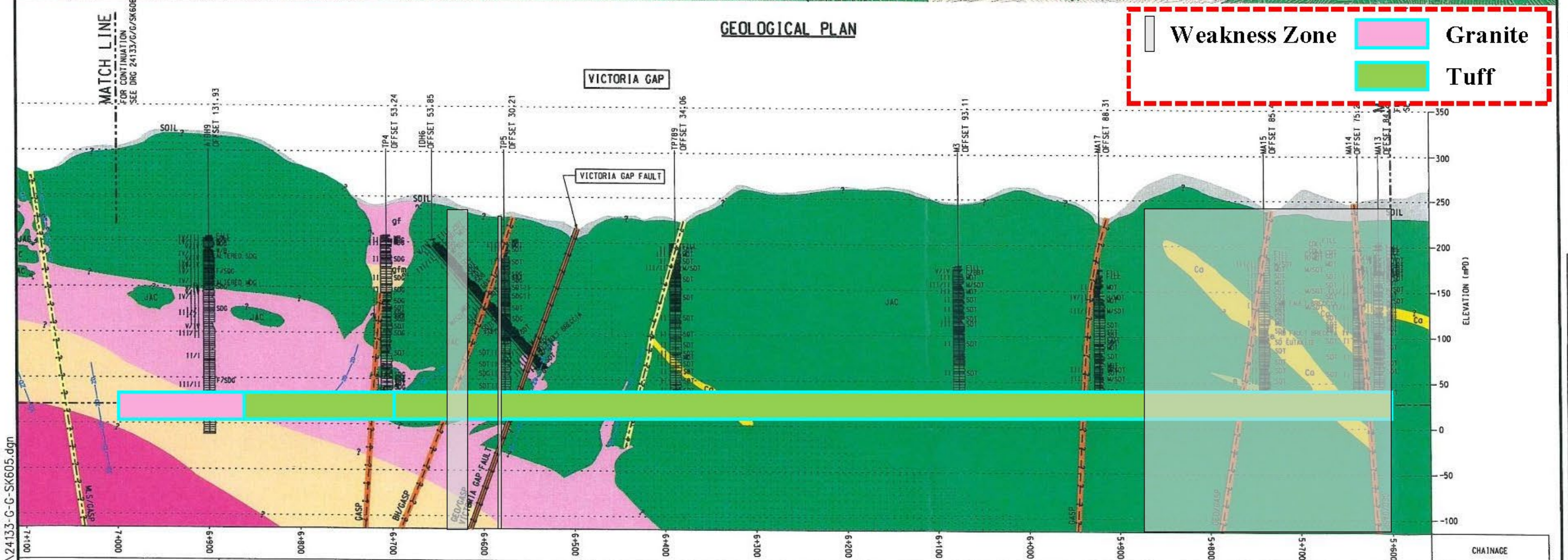


GEOLOGICAL PLAN



ROCK TYPE	FINE TO MEDIUM GRAINED GRANITE	FINE GRAINED GRANITE		FINE ASH VITRIC TUFF										
GEOLOGICAL FEATURES	INFERRED FAULT		MINOR FAULT	MINOR FAULT	MAJOR FAULT	POSSIBLY METAMORPHOSED AND WITH FREQUENT GRANITE STRINGER	INFERRED FAULT		MINOR FAULT		MINOR FAULT		MINOR FAULT	
ANTICIPATED Q VALUE	1 < Q < 10	≈ Q > 40, LOCALLY 1 < Q < 40		1 < Q < 40	1 < Q < 40	1 < Q < 40 1 < Q < 4	1 < Q < 4	≈ 1 < Q < 40, LOCALLY Q > 40	1 < Q < 4	1 < Q < 40	1 < Q < 4	1 < Q < 40	1 < Q	≈
ANTICIPATED UCS (MPa)	50 - 100	≈ 100 - 200		100 - 300	100 - 300	100 - 300 20 - 150	20 - 150	≈ 50 - 200, LOCALLY > 200	20 - 150	50 - 200	20 - 150	50 - 200	20 - 150	≈
ANTICIPATED HYDRAULIC CONDUCTIVITY (m/s)	$7E^{-7}$	≈$1E^{-9}$ TO $1E^{-7}$		$1E^{-9}$ TO $1E^{-7}$	$1E^{-9}$ TO $1E^{-7}$	$3E^{-7}$ TO $3E^{-6}$ $1E^{-9}$ TO $1E^{-7}$	$3E^{-7}$ TO $3E^{-6}$	≈$1E^{-9}$ TO $1E^{-7}$	$3E^{-7}$ TO $3E^{-6}$	≈ $1E^{-9}$ TO $1E^{-7}$	$3E^{-7}$ TO $3E^{-6}$	$1E^{-9}$ TO $1E^{-7}$	$3E^{-7}$ TO $3E^{-6}$	1
ANTICIPATED TBM PARAMETERS: DRI		40 - 70		20 - 30	20 - 30 30 - 60	20 - 30 30 - 60	20 - 30 30 - 60	20 - 40	30 - 60	20 - 40	30 - 60	20 - 40	30 - 60	
ANTICIPATED TBM PARAMETERS: CLI		5 - 15		< 5	< 5 5 - 15	< 5 5 - 15	< 5 5 - 15	< 6	5 - 15	< 6	5 - 15	< 8	5 - 15	

NOTE :

THE RANGES OF PARAMETERS INDICATED IN THE ABOVE TABLE ARE APPROXIMATIONS BASED ON THE ANTICIPATED GENERAL ROCK MASS CONDITIONS. LOCALIZED AREAS OUTSIDE OF THE INDICATED RANGES WILL ALSO OCCUR.

GEOLOGICAL SECTION

0 25 50 75 100 125 METRES 1 : 5000

NOTES

1. MAJOR REGIONAL FAULT RECORDED IN BOTH GEO(1986) AND GASP AND VERIFIED BY PAST / RECENT GI WORKS.
2. LOCAL FAULT RECORDED AS INFERRED FAULT/ PHOTOLINEAMENT IN GEO(1986) OR GASP AND FAULTED GROUND IDENTIFIED BY NEARBY GI WORKS.
3. INFERRED FAULT RECORDED AS PHOTOLINEAMENT IN GEO(1986) GASP OR IDENTIFIED THROUGH RECENT API. FAULT NOT CONFIRMED BY ANY GI WORKS.

LEGEND

- ALIGNMENT OF TUNNEL
- SDT / SCR / RQD — DEEP DRILLHOLE (WITH SOLID CORE RECOVERY AND RQD INDICATED)
- SOIL

SOLID GEOLOGY

- JAC — FINE ASH VITRIC TUFF
- JTM — COARSE ASH CRYSTAL TUFF
- e — EUTAXITE
- s — SANDSTONE
- Ca — COARSE ASH TUFF
- gf — FINE-GRAINED GRANITE
- gfm — FINE TO MEDIUM-GRAINED GRANITE
- gm — MEDIUM-GRAINED GRANITE
- p — PEGMATITE
- rf — FELDSPARPHYRIC RHYOLITE DYKES
- rq — QUARTZPHYRIC RHYOLITE DYKES

METAMORPHOSED GEOLOGY

- METAMORPHOSED
- SHEAR ZONE

GEOLOGICAL LINE FEATURE

- MAJOR GEOLOGICAL FAULT (REFER NOTE 1)
- MINOR GEOLOGICAL FAULT (REFER NOTE 2)
- INFERRED GEOLOGICAL FAULT (REFER NOTE 3)
- SYNCLINE
- ANTICLINE
- qz — QUARTZ DYKE
- B — BASALT DYKE

Rev	Description	By	Date
-	FIRST ISSUE	LW	01/07

Consultant

ARUP 奧雅納工程顧問 Ove Arup & Partners Hong Kong Limited

Supported By :
Norconsult AS
Jardine Lloyd Thompson Ltd.
Deacons

Project title

Contract No. DC/2007/10
Design and Construction of
Hong Kong West Drainage Tunnel

Drawing title

GEOLOGICAL PLAN AND SECTION

(SHEET 5 OF 8)

Drawing no.		Rev.	
24133/G/G/SK605		-	
Drawn: FM YIP	Date: 01/07	Checked: SWM	Approved: DML
Scale: 1 : 5000 @ A3		Status: PRELIMINARY	

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THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION DRAINAGE SERVICES DEPARTMENT

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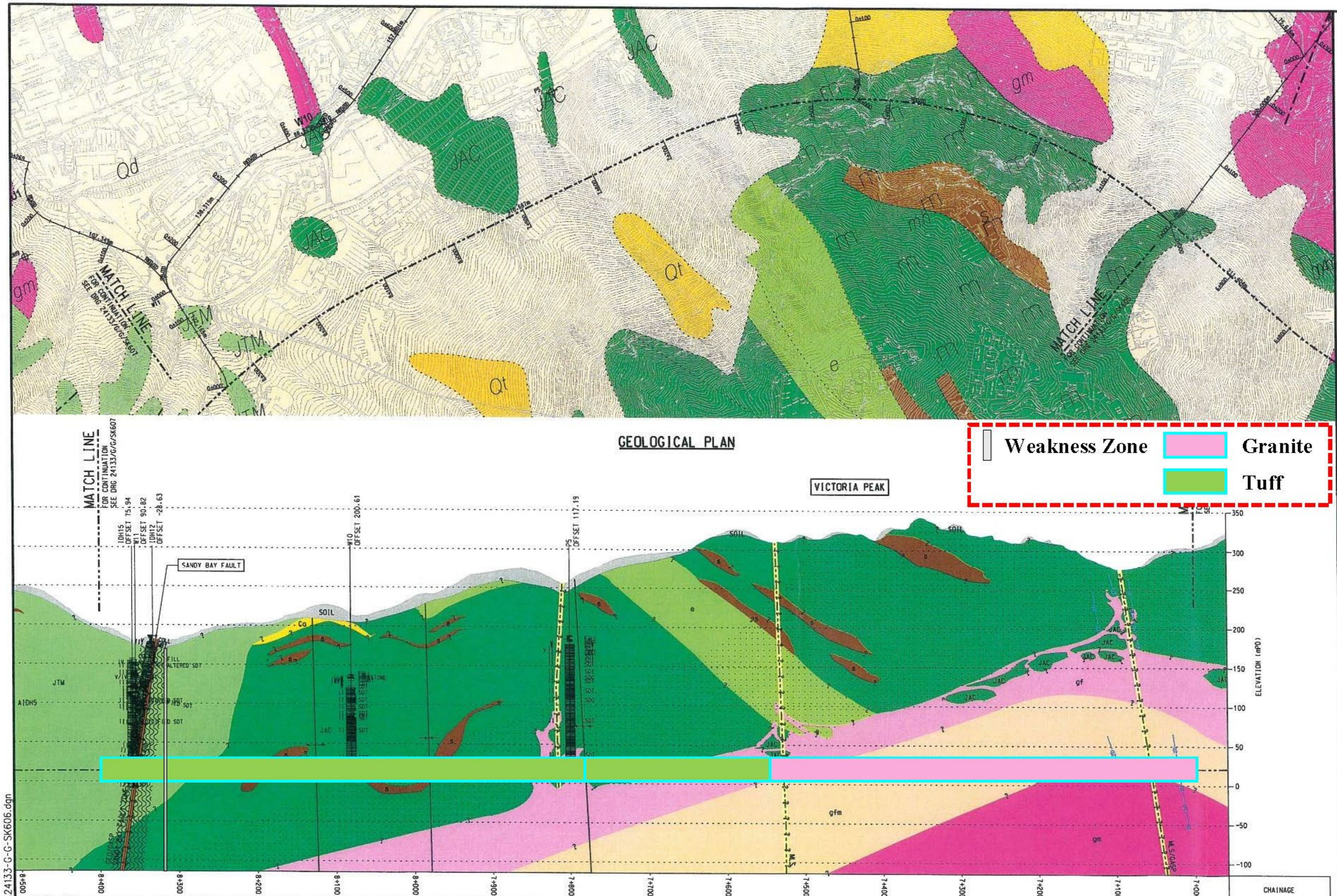

CHAINAGE	8+400 (shear zone)	8+400 (fault zone)	8+350 (shear zone)	8+300 – 7+900	7+900 – 7+810	Inferred fault	7+800 – 7+660	7+660 – 7+460	Inferred fault	7+460 – 7+040	Inferred fault
ROCK TYPE	COARSE ASH CRYSTAL TUFF			FINE ASH VITRIC TUFF				FINE GRAINED GRANITE		FINE TO MEDIUM GRAINED GRANITE	
GEOLOGICAL FEATURES	SHEAR ZONE	FAULT ZONE	SHEAR ZONE	ANTICLINE, SYNCLINE	POSSIBLY METAMORPHOSED WITH GRANITE STRINGERS	INFERRED FAULT	ANTICLINE		INFERRED FAULT		INFERRED FAULT
ANTICIPATED Q VALUE	1 < Q < 10	Q < 4	1 < Q < 10	4 < Q < 40		1 < Q < 10	4 < Q < 40	≈ Q > 10	1 < Q < 10	≈ Q > 40, LOCALLY 1 < Q < 40	1 < Q < 10
ANTICIPATED UCS (MPa)	50 - 150	50 - 100	50 - 150	50 - 200	100 - 300	50 - 100	100 - 300	100 - 200	50 - 100	100 - 200, LOCALLY > 200	50 - 100
ANTICIPATED HYDRAULIC CONDUCTIVITY (m/s)	$1E^{-7}$ TO $1E^{-6}$			$1E^{-9}$ TO $1E^{-7}$		$1E^{-7}$ TO $1E^{-6}$	$1E^{-9}$ TO $1E^{-7}$	$1E^{-9}$ TO $1E^{-7}$	$\approx 7E^{-7}$	$1E^{-9}$ TO $1E^{-7}$	$7E^{-7}$
ANTICIPATED TBM PARAMETERS – DRI	30 - 60			25 - 40	25 - 40	30 - 40	25 - 40	25 - 40	30 - 60		
ANTICIPATED TBM PARAMETERS – CLI	5 - 15			< 8	< 8	5 - 15	< 8	< 6	5 - 15		

NOTE :

THE RANGES OF PARAMETERS INDICATED IN THE ABOVE TABLE ARE APPROXIMATIONS BASED ON THE ANTICIPATED GENERAL ROCK MASS CONDITIONS. LOCALIZED AREAS OUTSIDE OF THE INDICATED RANGES WILL ALSO OCCUR.

0 25 50 75 100 125 METRES 1 : 5000

NOTES

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2. LOCAL FAULT RECORDED AS INFERRED FAULT/ PHOTOLINEAMENT IN GEO(1986) OR GASP AND FAULTED GROUND IDENTIFIED BY NEARBY GI WORKS.
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LEGEND

- ALIGNMENT OF TUNNEL
- DEEP DRILLHOLE (WITH SOLID CORE RECOVERY AND RQD INDICATED) — SDT, SCR, RQD
- SOIL

SOLID GEOLOGY

- JAC — FINE ASH VITRIC TUFF
- JTM — COARSE ASH CRYSTAL TUFF
- e — EUTAXITE
- s — SANDSTONE
- Co — COARSE ASH TUFF
- gf — FINE-GRAINED GRANITE
- gfm — FINE TO MEDIUM-GRAINED GRANITE
- gm — MEDIUM-GRAINED GRANITE
- p — PEGMATITE
- rf — FELDSPARPHYRIC RHYOLITE DYKES
- rq — QUARTZPHYRIC RHYOLITE DYKES

METAMORPHOSED GEOLOGY

- METAMORPHOSED
- SHEAR ZONE

GEOLOGICAL LINE FEATURE

- MAJOR GEOLOGICAL FAULT (REFER NOTE 1)
- MINOR GEOLOGICAL FAULT (REFER NOTE 2)
- INFERRED GEOLOGICAL FAULT (REFER NOTE 3)
- SYNCLINE
- ANTICLINE
- QUARTZ DYKE
- BASALT DYKE

Rev	Description	By	Date
-	FIRST ISSUE	LW	01/07

Consultant

ARUP 奧雅納工程顧問 Ove Arup & Partners Hong Kong Limited

Supported By : Norconsult AS, Jardine Lloyd Thompson Ltd., Deacons

Project title

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Design and Construction of
Hong Kong West Drainage Tunnel

Drawing title

GEOLOGICAL PLAN AND SECTION

(SHEET 6 OF 8)

Drawing no. 24133/G/G/SK606 Rev. -

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FM YIP	01/07	SWM	DML

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THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION DRAINAGE SERVICES DEPARTMENT

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GEOLOGICAL PLAN
GEOLOGICAL SECTION
Weakness Zone
Granite
Tuff
FU LAM
HIGH WEST
MATCH LINE FOR CONTINUATION SEE DRG 24133/G/G/SK608
SANDY BAY FAULT
PROPOSED HyD ROUTE 4 (ALIGNMENT P01) CH
ELEVATION (mPD)
NOTES
1. MAJOR REGIONAL FAULT RECORDED IN BOTH GEO(1986) AND GASP AND VERIFIED BY PAST / RECENT GI WORKS.
2. LOCAL FAULT RECORDED AS INFERRED FAULT/ PHOTOLINEAMENT IN GEO(1986) OR GASP AND FAULTED GROUND IDENTIFIED BY NEARBY GI WORKS.
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LEGEND
ALIGNMENT OF TUNNEL
DEEP DRILLHOLE (WITH SOLID CORE RECOVERY AND RQD INDICATED)
SOIL
SOLID GEOLOGY
JAC FINE ASH VITRIC TUFF
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e EUTAXITE
s SANDSTONE
Ca COARSE ASH TUFF
gf FINE-GRAINED GRANITE
gfm FINE TO MEDIUM-GRAINED GRANITE
gm MEDIUM-GRAINED GRANITE
p PEGMATITE
rf FELDSPARPHYRIC RHYOLITE DYKES
rq QUARTZPHYRIC RHYOLITE DYKES
METAMORPHOSED GEOLOGY
METAMORPHOSED
SHEAR ZONE
GEOLOGICAL LINE FEATURE
MAJOR GEOLOGICAL FAULT (REFER NOTE 1)
MINOR GEOLOGICAL FAULT (REFER NOTE 2)
INFERRED GEOLOGICAL FAULT (REFER NOTE 3)
SYNCLINE
ANTICLINE
QUARTZ DYKE
BASALT DYKE
FIRST ISSUE LW 01/07
Rev Description By Date
Consultant
ARUP 奧雅納工程顧問 Ove Arup & Partners Hong Kong Limited
Supported By : Norconsult AS Jardine Lloyd Thompson Ltd. Deacons
Project title
Contract No. DC/2007/10
Design and Construction of
Hong Kong West Drainage Tunnel
Drawing title
GEOLOGICAL PLAN AND SECTION
(SHEET 7 OF 8)
Drawing no. 24133/G/G/SK607
Drawn FM YIP Date 01/07 Checked SWM Approved DML
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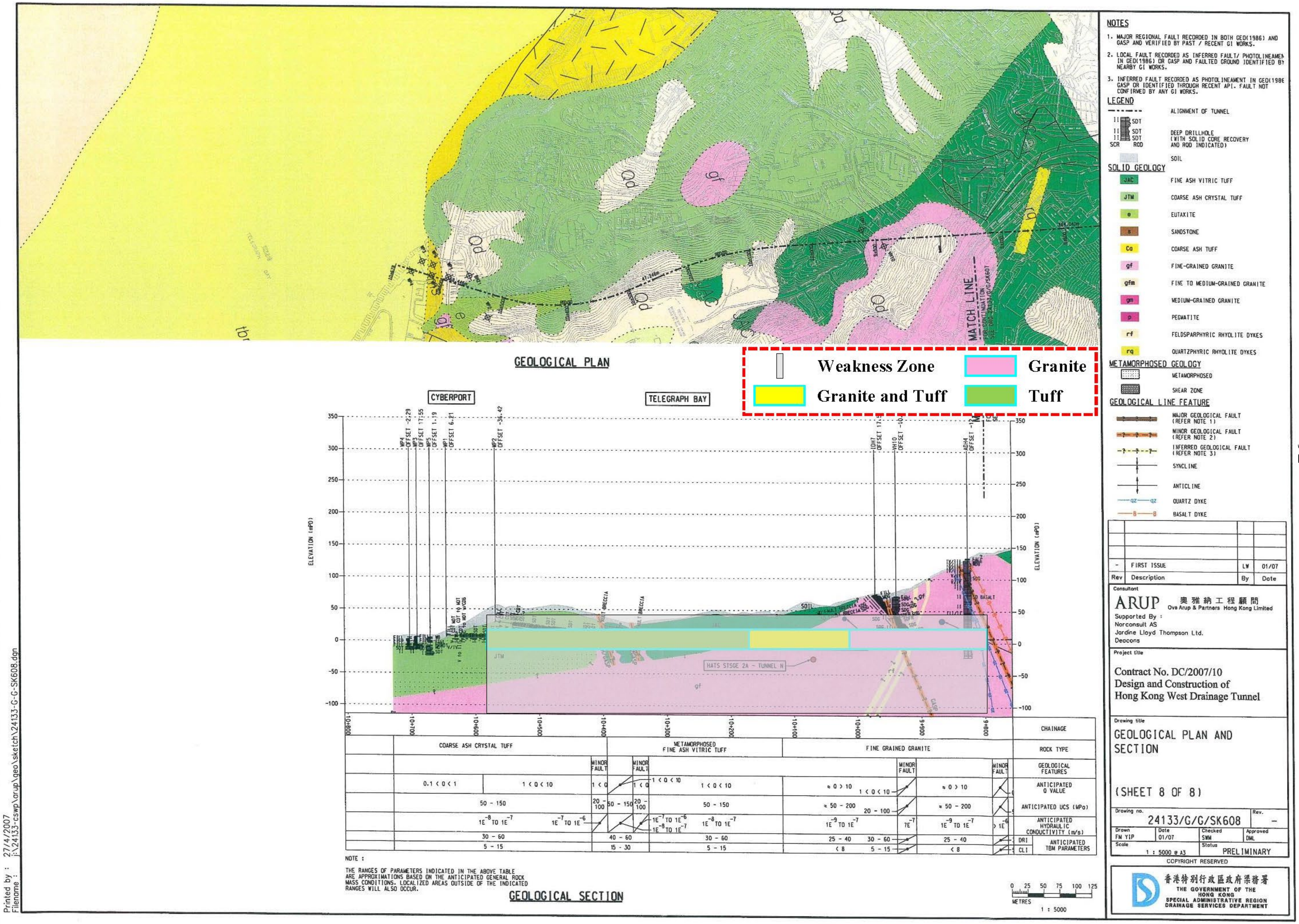
THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION DRAINAGE SERVICES DEPARTMENT
CHAINAGE
ROCK TYPE
GEOLOGICAL FEATURES
ANTICIPATED Q VALUE
ANTICIPATED UCS (MPa)
ANTICIPATED HYDRAULIC CONDUCTIVITY (m/s)
ANTICIPATED TBM PARAMETERS
FINE GRAINED GRANITE
FINE ASH VITRIC TUFF
COARSE ASH CRYSTAL TUFF
POSSIBLY METAMORPHOSED
SHEAR ZONE
MAJOR FAULT
MINOR FAULT
≈ 4 < Q < 40, LOCALLY HIGHER AND LOWER
≈ 50 - 200, LOCALLY > 200
NOTE :
THE RANGES OF PARAMETERS INDICATED IN THE ABOVE TABLE ARE APPROXIMATIONS BASED ON THE ANTICIPATED GENERAL ROCK MASS CONDITIONS. LOCALIZED AREAS OUTSIDE OF THE INDICATED RANGES WILL ALSO OCCUR.
METRES 1 : 5000
Printed by : 27/4/2007
Filename : j:\24133-cswp\arup\geo\sketch\24133-G-G-SK607.dgn



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