Appendix A6-2 Engineering Geological Investigation for Feasibility Study

A6-2.1 Quantity of Works

Table A6-2.1 Quantity of the Work

Work			Unit	Site-1 Region CAR Kennon (232 km)	Site-2 Region CAR Lagawe – Banaue (301 km)	Site-3 Region II Dalton Pass (211 km)	Site-4 Region VII Ginalitan - Alegria (172 km)	Site-5 Region VIII Wright-Taft (846 km)	Total
1. Preparation work			site	1	1	1	1	1	5
2. Topographic Surveying	(1) Planimetric and counter map	S=1 : 500	ha	4.735	11.460	1.24	1.273	2.012	20.720
2. Topographic Surveying	(1) Planimetric and counter map	S=1:5,000	ha	0.000	0.000	0.000	0.000	0.000	0.000
2. Topographic Surveying	(2) Cross section	S=1 : 500	m	160	470	60	50	75	815
3. Engineering Geological Mapping/Profiling	(1) Engineering geological map	S=1:500	ha	4.735	11.460	1.24	1.273	2.012	20.720
3. Engineering Geological Mapping/Profiling	(1) Engineering geological map	S=1:5,000	ha	0.0	0.0	100.0	0.0	0.0	100.0
3. Engineering Geological Mapping/Profiling	(1) Engineering geological map	S=1:50,000	ha	5,000	5,000	5,000	5,000	5,000	25,000
3. Engineering Geological Mapping/Profiling	(2) Engineering geological Profile	S=1:500	m	160	470	60	40	75	815
3. Engineering Geological Mapping/Profiling	(2) Engineering geological Profile	S=1:5,000	m	0	0	2,000	0	0	2,000
3. Engineering Geological Mapping/Profiling	(2) Engineering geological Profile	V=1:20,000 H=1:50,000	m	10,000	10,000	10,000	10,000	10,000	50,000
4. Drilling, In-situ Test and Monitoring	(1) Drilling: Transportation of drilling machine	Region CAR, or Region II	Site*nos	0	1	1	0	0	2
4. Drilling, In-situ Test and Monitoring	(1) Drilling: Transportation of drilling machine	Region VII, VIII	Site*nos	0	0	0	1	1	2
4. Drilling, In-situ Test and Monitoring	(1) Drilling: Mobilization and demobilization of drilling machine	slope gradient is gentler than 15 degree	point	0	1	1	1	1	4
4. Drilling, In-situ Test and Monitoring	(1) Drilling: Mobilization and demobilization of drilling machine	slope gradient is equal to steeper than 15 degree	point	0	1	0	1	1	3
4. Drilling, In-situ Test and Monitoring	(1) Drilling: All-core 66 mm diameter		m	0	55	15	13	51	134
4. Drilling, In-situ Test and Monitoring	(1) Drilling: Non-core 66 mm diameter		m	0	67	0	0	36.5	103.5
4. Drilling, In-situ Test and Monitoring	(2) Standard Penetration Test (SPT)		test	0	36	16	13	36	101
4. Drilling, In-situ Test and Monitoring	(3) Field permeability test		test	0	7	3	3	10	23
4. Drilling, In-situ Test and Monitoring	(4) Dynamic cone penetration test		m	0	0	0	9	0	9
4. Drilling, In-situ Test and Monitoring	(5) Sounding of soil depth and strength		point	8	16	9	8	16	58
4. Drilling, In-situ Test and Monitoring	(6) Installation of perforated pipe		m	0	45	15	13	36.5	109.5
4. Drilling, In-situ Test and Monitoring	(7) Installation of perforated pipe with strain gauge		m	0	60	0	0	55	115
4. Drilling, In-situ Test and Monitoring	(8) Groundwater monitoring		site*time	0	12	4	7	10	33
4. Drilling, In-situ Test and Monitoring	(9) Pipe strain gauge monitoring		site*time	0	11	0	0	10	21
4. Drilling, In-situ Test and Monitoring	(10) Movable stake installation		site*time	3	8	3	0	6	20
4. Drilling, In-situ Test and Monitoring	(11) Ground water prospecting		m	0	45	0	13	10	68
4. Drilling, In-situ Test and Monitoring	(12) Test pitting		site	0	0	0	0	0	0
5. Reporting			site	1	1	1	1	1	5

A6-2.2 Kennon Road Km 232 (Region CAR)

(1) General

(a) Objectives of the Geotechnical Investigation

The geotechnical investigation was conducted in order to obtain the mechanism of Road Slip (RS) and to gather the geological/geotechnical information for countermeasure design. Figure A6-2.1 shows the location plan of the geotechnical investigation.

(b) Scope of Works

The scope of geotechnical investigation is tabulated in Table A6-2.2.

Table A6-2.2 Scope of Geotechnical Investigation

Item		Unit	Quantity	Remarks
Planimetric and contour mapping, S = 1:500		ha	4.735	
Cross Section, S = 1:500		m	160	
Engineering geological mapping	S = 1:500	ha	4.735	surrounding area
Engineering geological profiling	V = 1:20,000, H = 1:50,000	m	10,000	surrounding area
	S = 1:500	m	160	
Sounding of soil depth and strength		nos.	8	
Movable stake installation		nos.	3	

(2) Geological Distribution

Andesite is distributed as bedrock in this site. Talus deposit and terrace deposits is distributed at the base of cut slope and beside the road way, respectably.

Talus deposit, terrace deposit and andesite are distributed in chorological order. Table A-6.2.3 shows facies of each stratum.

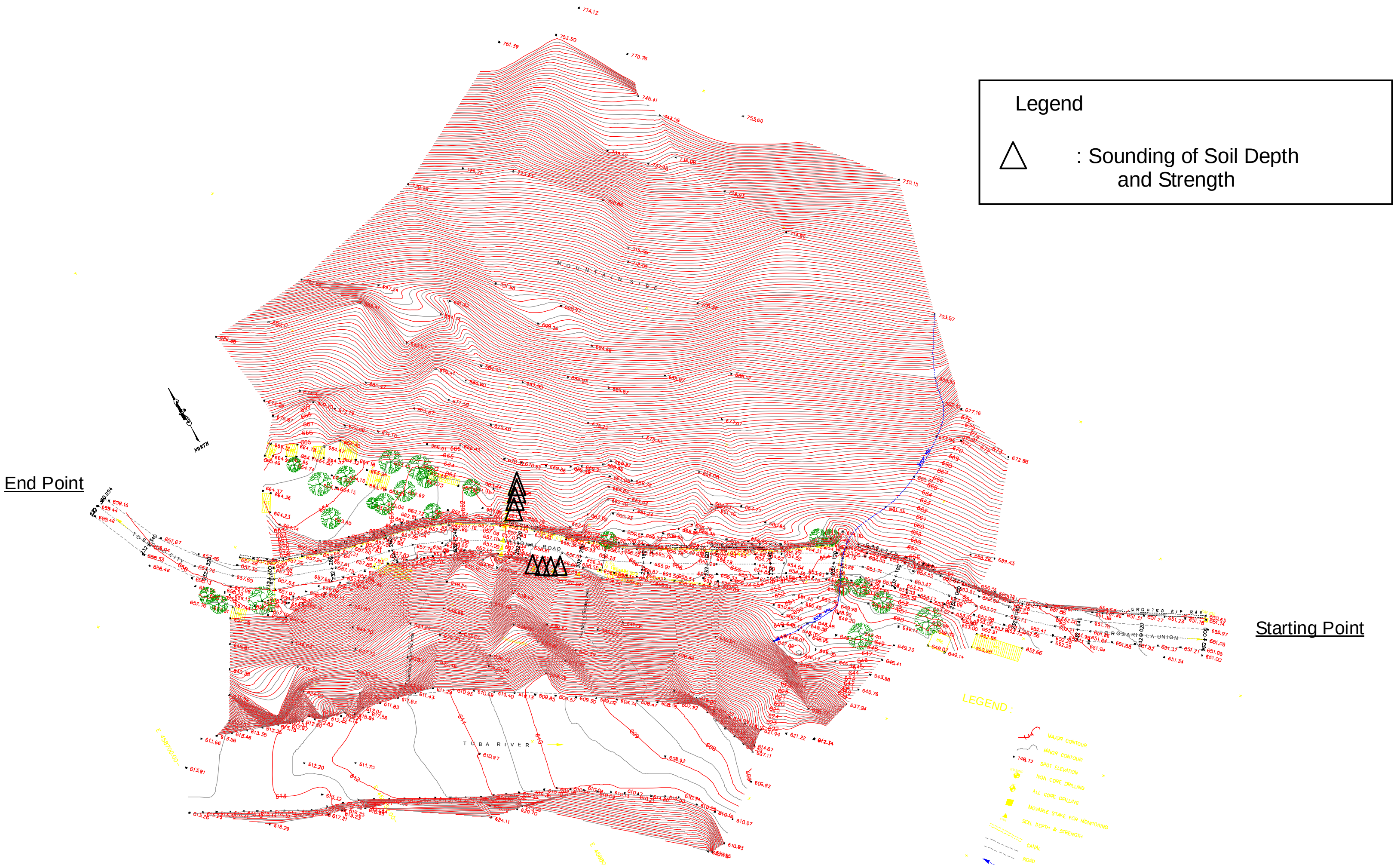


Figure A6-2.1 Location of the Geotechnical Investigation

Table A6-2.3 Facies of Each Stratum

Geological Stratum		Facies
Talus deposit		The talus deposit consists of sandy soil with gravel. The matrix is loose sandy soil. The shape of the gravel is mainly angular to sub-angular.
Terrace deposit		The terrace deposit consists of sandy soil with gravel. The matrix is dense sandy soil. The shape of the gravel is mainly rounded to sub-rounded.
Andesite		The andesite was affected by hydrothermal alteration. The brownish-color was formed. The rock by oxidation and cracks are recognized at the outcrop.

Figure A6-2.2 shows the engineering geological cross section at the site.

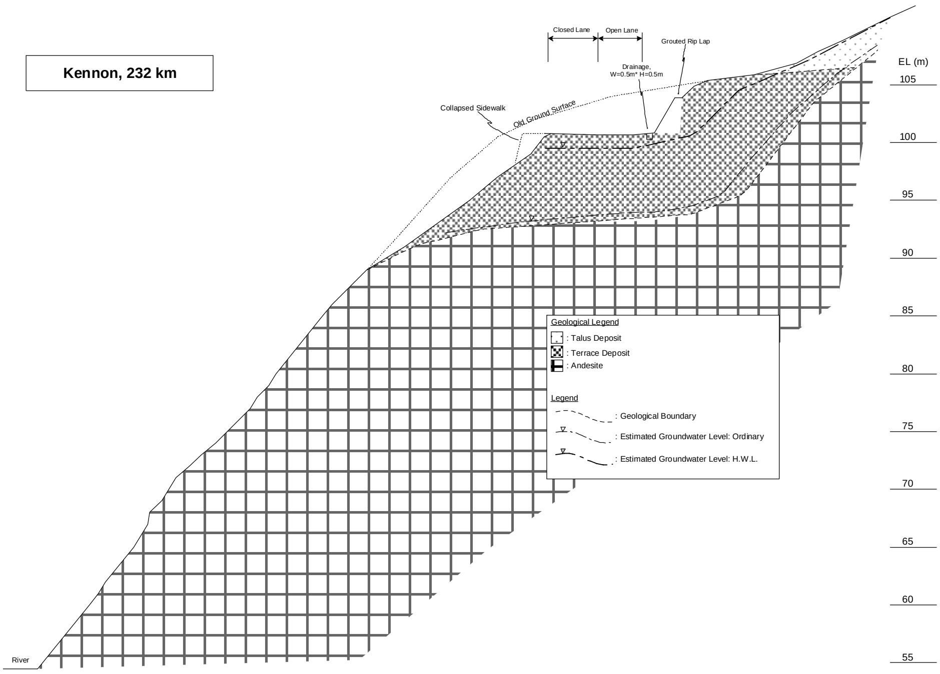


Figure A6-2.2 Engineering Geological Profiling

(3) Geotechnical Properties

Geotechnical properties for each stratum are tabulated in Table A6-2.4.

Table A6-2.4 Geotechnical Properties

Geological Stratum	Unit weight γ (kN/m³)	Shear strength for calculation of earth pressure: Cohesion c (kN/m²)	Shear strength for calculation of earth pressure: Internal friction angle φ (degrees)	Allowable bearing capacity q_a (kN/m²)
Talus deposit	18	-	30	200
Terrace deposit	20	-	40	450
Andesite	22	-*	-*	600

*: Earth pressure does not generate in the andesite which is moderate and slightly weathered rock, consequently, shear strength is not shown in the above table.

(a) Unit Weight and Shear Strength

Unit weight and shear strength are determined by using the "Japan Highway Public Corporation, Design Guideline" (see Table A6-2.5) and rock classification by Ortiz (hereinafter referred to as "the Ortiz classification", see Table A6-2.6).

Table A6-2.5 Unit Weight by Soil Type

	Soil Type	Conditions		Wet Density (t/m³)	Internal Friction Angle (degree)	Cohesion (kN/m²)	Soil Classification by JGS*
Fill	Gravel / Sand with gravel	Compacted fill		2.0	40	0	{G}
Fill	Sand	Compacted fill	wide range of grain size distribution	2.0	35	0	{S}
Fill	Sand	Compacted fill	sorted sand	1.9	30	0	{S}
Fill	Sandy soil	Compacted fill		1.9	25	≥ 30	{SF}
Fill	Clayey Soil	Compacted fill		1.8	15	≥ 50	{M}, {C}
Fill	Kanto loam	Compacted fill		1.4	20	≥ 10	{V}
Natural Ground	Gravel	Dense / wide range of grain size distribution		2.0	40	0	{G}
Natural Ground	Gravel	Loose / sorted gravel		1.8	35	0	{G}
Natural Ground	Sand with gravel	Dense		2.1	40	0	{G}
Natural Ground	Sand with gravel	Loose		1.9	35	0	{G}
Natural Ground	Sand	Dense / wide range of grain size distribution		2.0	35	0	{S}
Natural Ground	Sand	Loose / sorted gravel		1.8	30	0	{S}
Natural Ground	Sandy soil	Dense		1.9	30	≥ 30	{SF}
Natural Ground	Sandy soil	Loose		1.7	25	0	{SF}
Natural Ground	Clayey soil	Stiff (slightly yield by strong finger pressure)		1.8	25	≥ 50	{M}, {C}
Natural Ground	Clayey soil	Slightly soft (proceed by moderate finger pressure)		1.7	20	≥ 30	{M}, {C}
Natural Ground	Clayey soil	Soft (easily proceed by finger pressure)		1.6	15	≥ 15	{M}, {C}
Natural Ground	Clay / Silt	Stiff (slightly yield by strong finger pressure)		1.7	20	≥ 50	{M}, {C}
Natural Ground	Clay / Silt	Slightly soft (proceed by moderate finger pressure)		1.6	15	≥ 30	{M}, {C}
Natural Ground	Clay / Silt	Soft (easily proceed by finger pressure)		1.4	10	≥ 15	{M}, {C}
Natural Ground	Kanto loam	-		1.4	5 (ϕ_u)	≥ 30	{V}

*JGS: The Japanese Geotechnical Society

Table A6-2.6 Unit Weight by Rock Classification tabulated by Ortiz

Type	Remarks	Typical Rock / Soil	Classification Parameter: RQD	Classification Parameter: V_L (m/s)	Classification Parameter: Q	Classification Parameter: RSR	Geotechnical Properties: Unit Weight γ (t/m³)	Shear Strength Peak: c (kN/m²)	Shear Strength Peak: ϕ (°)	Shear Strength Residual: c_r (kN/m²)	Shear Strength Residual: ϕ_r (°)
A	Massive, hard	Granite, Silicastone, Limestone, Siliceous Sandstone, Hard Conglomerate, Basalt, Consolidated Volcanic Rock, Gneiss	100 - 95	>5,000	>100	100 - 80	3.0 - 2.6	400,000 - 50,000	60 - 50	2,000 - 500	35 - 30
B	Schistose or re-consolidated	Phyllite, Slate, Schist, Breccia, Consolidated Mylonite, Alternation Silicastone	90 - 70	5,000 - 3,500	80 - 30	80 - 60	2.8 - 2.2	200,000 - 30,000	45 - 30	1,000 - 100	35 - 30
	Moderate crack / weathering of Type A										
C	Consolidated bedded rock	Marine Marl, Molasse, Weathering Limestone, Weaken Conglomerate, Shale, Mudstone, Sandstone, Gypsum	80 - 70	4,000 - 2,500	50 - 20	70 - 50	2.6 - 2.1	70,000 - 5,000	45 - 30	500 - 0	30 - 15
	Disadvantageous strike and dip of Type B										
	Calcareous Karst										
D	Consolidated Deposit	Younger Red Sandstone / Bunter Series, Marine Clay, Tillite, Tuff, Chalk, Loess, Shale, Loam, Residual Soil of Arkose Sandstone	100 - 60	4,000 - 800	10 - 2	60 - 40	2.6 - 2.2	2,000 - 100	30 - 22	200 - 0	25 - 10
	Gypsum Karst										
E	Many cracks, fractures / block-wise of rock or soil	Mylonite, Fault Zone, Volcanic Product, Clastic Rock, Easily Fractured Marl, Dense Granular Soil	60 - 25	3,000 - 1,500	2 - 0.05	50 - 35	2.4 - 2.2	500 - 0	45 - 30	-	30 - 25
F	Hardly compacted clayey soil / soft rock	Residual Soil, Laterite, Varve Clay, Clayey Till, Flysh	N/A	3,000 - 1,000	0.10 - 0.01	40 - 30	2.2 - 1.7	200 - 0	28 - 22	-	20 - 8
G	Loose soft Quaternary deposit	Loose Alluvial Sand and Gravel / Mud / Soft Clay / Silt / Peat / Colluvial Soil	N/A	3,000 - 800	<0.05	35 - 25	2.0 - 1.5	-	38 - 30	-	30

Table A6-2.7 shows relationship between geological stratum distributed in the site and ground/soil type.

Table A6-2.7 Geological Stratum in the Site and Ground Type of Table A6-2.4 and Table A6-2.5

Geological Stratum in the Site	Ground / Soil Type in Table A6-2.5 and Table A6-2.6	Remarks
Talus Deposit	Natural Ground Sand: Loose	It is inferred that the thickness of the talus deposit on the slope is around 2 to 3 m and the deposit is loose.
Terrace Deposit	Natural Ground Gravel: Dense and wide grain size distribution	The terrace deposit is distributed backward of the grouted riprap of mountain side. Gradient of the outcrop is nearly vertical around 1.5 m in height. The matrix is dense and moderately cemented.
Andesite	Hard, moderate crack / weathering	The outcrop is brownish by alteration.

(b) Allowable bearing capacity (q_a)

Allowable bearing capacity is determined using “Highway Earthwork Series - Manual for Slope Protection, Japan Road Association, 1999” (hereinafter referred to as “the Manual in Japan”, see Table A6-2.8).

Table A6-2.8 Allowable Bearing Capacity by Ground Type (Ordinary Condition)

Ground Type		Allowable bearing capacity q_a (kN/m^2)	Remarks	
			Unconfined compression strength q_u (kN/m^2)	N-value
Rock	Uniformly hard rock with less cracks	1,000	≥ 10,000	-
	Hard rock with many cracks	600	≥ 10,000	-
	Soft rock / mudstone	300	≥ 1,000	-
Gravelly Soil	Dense	600	-	-
	Loose	300	-	-
Sandy Soil	Dense	300	-	30 to 50
	Moderate	200	-	20 to 30
Clayey Soil	Very stiff	200	200 to 400	15 to 30
	Stiff	100	100 to 200	10 to 15

Table A6-2.9 shows the relationship between geological stratum distributed in the site and ground/soil type described in Table A6-2.7.

Table A6-2.9 Geological Stratum in the Site and Ground Type of Table A6-2.7

Geological Stratum in the Site	Ground Type in Table A6-2.7	Remarks
Talus Deposit	Sandy Soil Loose	The deposit is loose.
Terrace Deposit	Gravelly Soil Dense	The deposit is dense. In case of heavy rains, bearing capacity may be reduced due to increased saturation.
Andesite	Rock: Hard rock with many cracks	The outcrop shows many cracks; however, the rock itself is hard.

(4) Groundwater Level

Usually, groundwater level is distributed at the boundary between the terrace deposit and andesite, and increases during heavy rains.

A6-2.3 Lagawe-Banaue Road, Km 301 (Region CAR)

(1) General

(a) Objectives of the Geotechnical Investigation

The geotechnical investigation was conducted in order to determine the mechanism of Landslide (LS) and to obtain the geological/geotechnical information for design of countermeasures. Figure 6A-2.3 shows location plan of the geotechnical investigation.

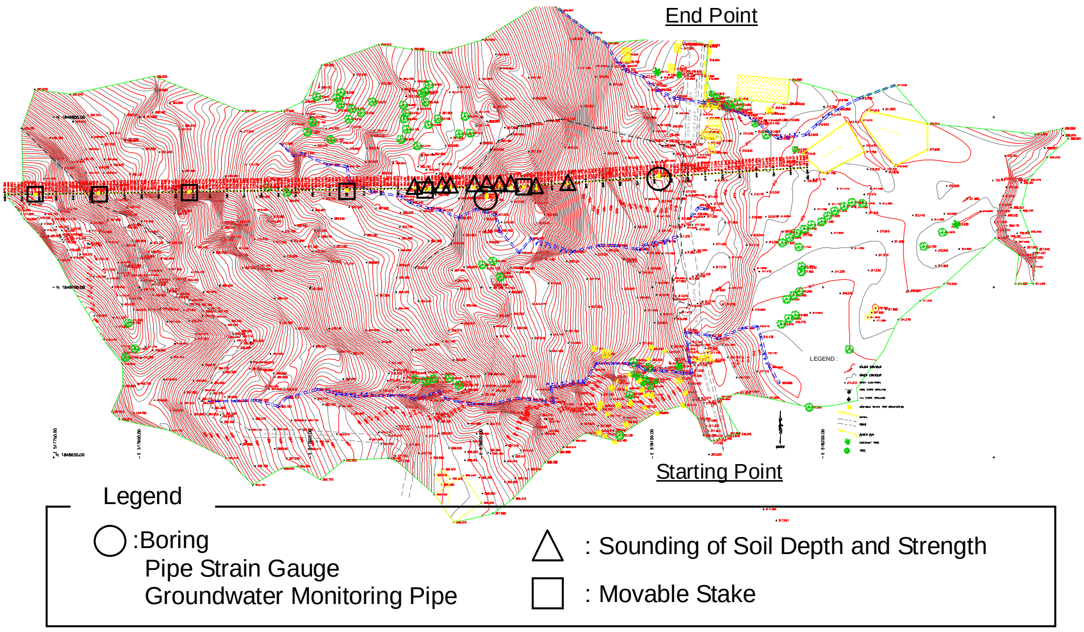


Figure A6-2.3 Location of the Geotechnical Investigation

(b) Scope of Works

The scope of geotechnical investigation is tabulated in Table A6-2.10.

Table A6-2.10 Scope of Geotechnical Investigation

Item		Unit	Quantity	Remarks
Planimetric and contour mapping, S = 1:500		ha	11.460	the site area
Cross Section, S = 1:500		m	470	
Engineering geological mapping	S = 1:50,000	ha	5,000	surrounding of the site
	S = 1:500	ha	11.460	the site area
Engineering geological profiling	V = 1:20,000, H = 1:50,000	m	10,000	surrounding of the site
	S = 1:500	m	470	the site area
Boring	Core, 66 mm	m	55	2 boreholes
	None-core, 66 mm	m	67	2 boreholes
Standard Penetration Test		time	36	2 boreholes
Field permeability test		test	7	2 boreholes
Sounding of soil depth and strength		nos.	16	
Installation of perforated pipe		m	45	2 monitoring wells
Groundwater monitoring		time	12	
Installation of perforated pipe strain gauge		m	60	2 monitoring pipes
Pipe strain gauge monitoring		time	11	
Movable stake installation		nos.	8	
Groundwater prospecting		m	45	2 monitoring wells

(2) Geological Distribution

Conglomerates are distributed at the landslide area towards the end section of Lagawe-Banaue road. Outcrop of sandstone and mudstone are distributed at some areas along the road.

(3) Conditions of Geological Stratum at the Site

Conglomerate 1, and conglomerate 2 and sandstone are distributed in chronological order. Table A6-2.11 shows facies of each stratum.

Table A6-2.11 Description of Each Stratum

Geological Stratum		Remarks
Conglomerate 1		The matrix is not cemented. It consists of rounded cobble, boulder with sand and some fines.
Conglomerate 2		It is polymictic conglomerate and gradually lithified in comparison with conglomerate 1. It consists of rounded cobble/boulder with some fines.
Sandstone		It is a weathered rock.

Figure A6-2.4 shows the engineering geological cross section at the site.

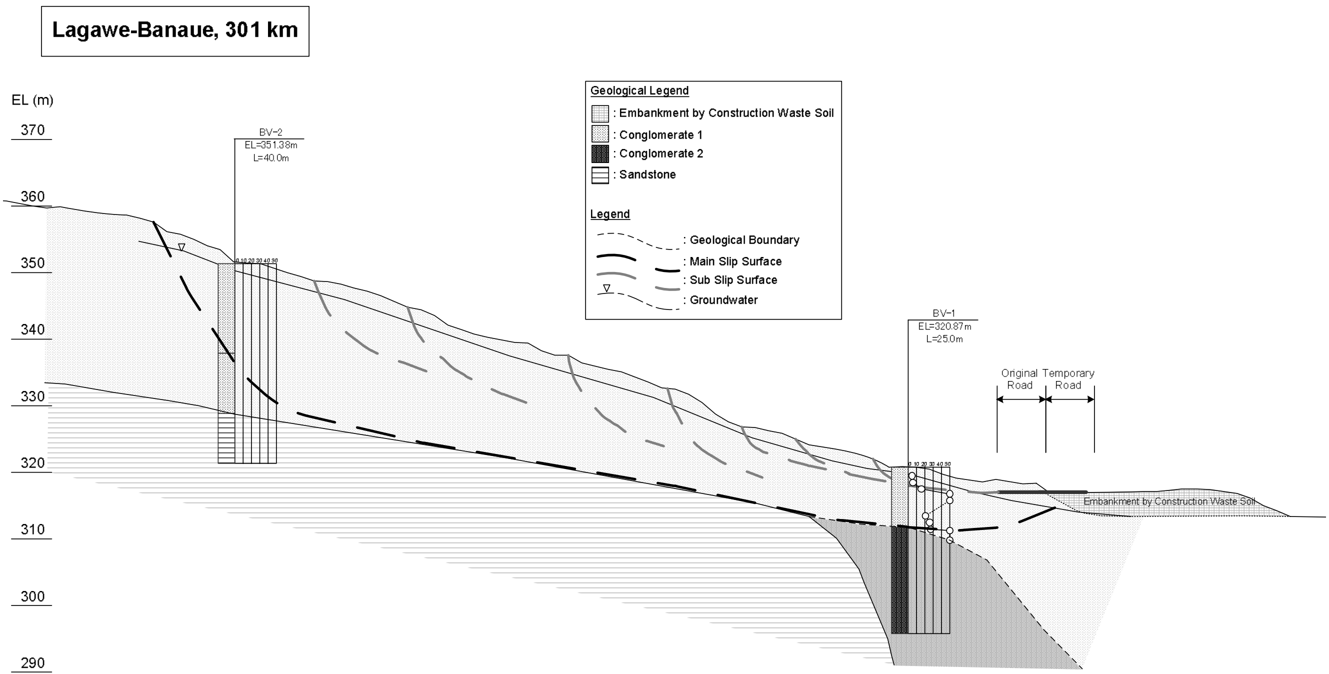


Figure A6-2.4 Engineering Geological Profiling

(4) Geotechnical Properties

Geotechnical properties for each stratum are tabulated in Table A6-2.12.

Table A6-2.12 Geotechnical Properties

Geological Stratum	Average N-value	Unit weight γ (kN/m^3)	Shear strength for calculation of stability analysis		Coefficient of permeability k (cm/sec)	Allowable bearing capacity q_a (kN/m^2)
			Cohesion c (kN/m^2)	Internal friction angle ϕ (degrees)		
Conglomerate 1		19	(obtained by stability analysis)		2.7E -04	100
Conglomerate 2		21	-*	-*	2.4E -04	300
Sandstone	-	21	-*	-*	-	600

*Not required for the stability analysis.

(a) Unit Weight (γ)

Unit weight is determined using the “Highway Earthwork Series - Manual for Slope Protection, Japan Road Association, 1999” (hereinafter referred to as “the Manual in Japan”, see Table A6-2.13) and the Ortiz classification (see Table A6-2.14).

Table A6-2.13 Unit Weight by Soil Type

Ground Type	Soil Type	Unit Weight (kN/m^3)	
		Loose	Dense
Natural Ground	Sand or Gravelly Sand	18	20
	Sandy Soil	17	19
	Clayey Soil	14	18
Fill	Sand or Gravelly Sand	20	
	Sandy Soil	19	
	Clayey Soil (w_L*<50 %)	18	

* w_L: Liquid limit

Table A6-2.14 Unit Weight by Rock Classification Tabulated by Ortiz

Type	Remarks	Typical Rock / Soil	Classification Parameter				Geotechnical Properties				
							Unit Weight	Shear Strength			
								Peak		Residual	
			RQD	V_L (m/s)	Q	RSR	γ (t/m³)	c (kN/m²)	ϕ (°)	c_r (kN/m²)	ϕ_r (°)
A	Massive, hard	Granite, Silicastone, Limestone, Siliceous Sandstone, Hard Conglomerate, Basalt, Consolidated Volcanic Rock, Gneiss	100 - 95	>5,000	>100	100 - 80	3.0 - 2.6	400,000 - 50,000	60 - 50	2,000 - 500	35 - 30
B	Schistose or re-consolidated	Phyllite, Slate, Schist, Breccia, Consolidated Mylonite, Alternation Silicastone	90 - 70	5,000 - 3,500	80 - 30	80 - 60	2.8 - 2.2	200,000 - 30,000	45 - 30	1,000 - 100	35 - 30
	Moderate crack / weathering of Type A										
C	Consolidated bedded rock	Marine Marl, Molasse, Weathering Limestone, Weaken Conglomerate, Shale, Mudstone, Sandstone, Gypsum	80 - 70	4,000 - 2,500	50 - 20	70 - 50	2.6 - 2.1	70,000 - 5,000	45 - 30	500 - 0	30 - 15
	Disadvantageous strike and dip of Type B										
	Calcareous Karst										
D	Consolidated Deposit	Younger Red Sandstone / Bunter Series, Marine Clay, Tillite, Tuff, Chalk, Loess, Shale, Loam, Residual Soil of Arkose Sandstone	100 - 60	4,000 - 800	10 - 2	60 - 40	2.6 - 2.2	2,000 - 100	30 - 22	200 - 0	25 - 10
	Gypsum Karst										
E	Many cracks, fractures / block-wise of rock or soil	Mylonite, Fault Zone, Volcanic Product, Clastic Rock, Easily Fractured Marl, Dense Granular Soil	60 - 25	3,000 - 1,500	2 - 0.05	50 - 35	2.4 - 2.2	500 - 0	45 - 30	-	30 - 25
F	Hardly compacted clayey soil / soft rock	Residual Soil, Laterite, Varve Clay, Clayey Till, Flysh	N/A	3,000 - 1,000	0.10 - 0.01	40 - 30	2.2 - 1.7	200 - 0	28 - 22	-	20 - 8
G	Loose soft Quaternary deposit	Loose Alluvial Sand and Gravel / Mud / Soft Clay / Silt / Peat / Colluvial Soil	N/A	3,000 - 800	<0.05	35 - 25	2.0 - 1.5	-	38 - 30	-	30

Table A6-2.15 shows relationship between geological stratum distributed in the site and ground / soil type described in Table A6-2.13 and Table A6-2.14.

Table A6-2.15 Geological Stratum in the Site and Ground Type of Table A6-2.13 and Table A6-2.14

Geological Stratum in the Site	Ground / Soil Type in Table 6.12 and Table 6.13	Remarks
Conglomerate 1	Natural ground Gravelly Sand	Amount of gravel and matrix is almost same.
Conglomerate 2	Hardly compacted clayey soil /soft rock	Lithified grade is moderately high. The conglomerate 2 corresponds to soft rock.
Sandstone	Soft rock	RQD (Rock Quality Designation) of the boring core is low.

(b) Coefficient of Permeability (k)

Coefficient of permeability is determined by the results of borehole permeability test. Table A6-2.16 shows the summary of results of the borehole permeability test.

Table A6-2.16 Results of the Borehole Permeability Test

	BV-1		BV-2		Average (logarithmic) k (cm/sec)
	Depth (GL-m)	k (cm/sec)	Depth (GL-m)	k (cm/sec)	
Conglomerate 1	5	1.4E-04	5	6.4.E-04	2.7E-04
			10	3.3.E-04	
			15	1.4.E-04	
			20	3.7.E-04	
Conglomerate 2	10	1.2E-04			2.4E-04
	15	4.8E-04			

(c) Allowable bearing capacity (q_a)

Allowable bearing capacity is determined using the Manual in Japan (see Table A6-2.17).

Table A6-2.17 Allowable Bearing Capacity by Ground Type (Ordinary Condition)

Ground Type		Allowable bearing capacity q_a (kN/m^2)	Remarks	
			Unconfined compression strength q_u (kN/m^2)	N-value
Rock	Uniformly hard rock with less cracks	1,000	≥ 10,000	-
	Hard rock with many cracks	600	≥ 10,000	-
	Soft rock / mudstone	300	≥ 1,000	-
Gravelly Soil	Dense	600	-	-
	Loose	300	-	-
Sandy Soil	Dense	300	-	30 to 50
	Moderately Dense	200	-	20 to 30
Clayey Soil	Very stiff	200	200 to 400	15 to 30
	Stiff	100	100 to 200	10 to 15

Source: Guideline on Earthwork for Road

Table A6-2.18 shows relationship between geological stratum distributed at the site and ground/soil type described in Table A6-2.17.

Table A6-2.18 Geological Stratum in the Site and Ground Type of Table A6-2.17

Geological Stratum in the Site	Ground / Soil Type in Table 6.16	Remarks
Conglomerate 1	Clayey Soil: Stiff	Subsurface is particularly soft (the average N-value was less than 10 from ground level to -3 m. It is originally moderately cemented/consolidated gravely soil, but cementation is decomposed due to landslide displacement and weathering.
Conglomerate 2	Rock: Soft rock	It is moderately cemented/consolidated gravely soil.
Sandstone	Rock: Hard rock with many cracks	The hard rock with many cracks is applied because of the low RQD.

(4) Groundwater Level

Groundwater level was recorded at about 1 m below the ground surface during boring at BV-1. It was raining during the duration of the boring. Consequently, the groundwater level for the stability analysis was set up at 1 m below the ground surface.

(5) Mechanism of Landslide (LS)

Mechanism of the Landslide (LS) at the site is estimated as follows.

- The damaged site (altitude of the road is around 317 m) is part of the tongue of a large-scale landslide. The landslide is located at an altitude of about 410 m.
- Tension crack/secondary scarp in the slope, which is about 360 m in altitude

or below, has existed from the past due to continuous creep-like sliding activity caused by heavy rains.

- The soil embankment from construction waste, which was dumped at the side of the road, seems to prevent/mitigate the landslide activity and serves as a counterweight fill work.
- A cut slope was excavated beside the road as part of the road improvement project. The cutting induced slope instability. In addition, heavy rains saturated the slope, and caused further destabilization. It is recognized as a retrogressive slide.
- Consequently, the old landslide block where the crown located at an altitude of about 357 m, and has a width and length of about 130 m and 140 m, respectively, was activated.
- Currently, several cracks and sub-scarps have appeared at the right side of the landslide block, which means that the sliding activity is relatively high in comparison at the left side.

A6-2.3. Dalton Pass Km 211 (Region II)

(1) General

(a) Objectives of the Geotechnical Investigation

The geotechnical investigation was conducted in order to determine the mechanism of Road Slip (RS) and to obtain geological/geotechnical information for design of countermeasure. Figure A6-2.5 shows location plan of the geotechnical investigation.

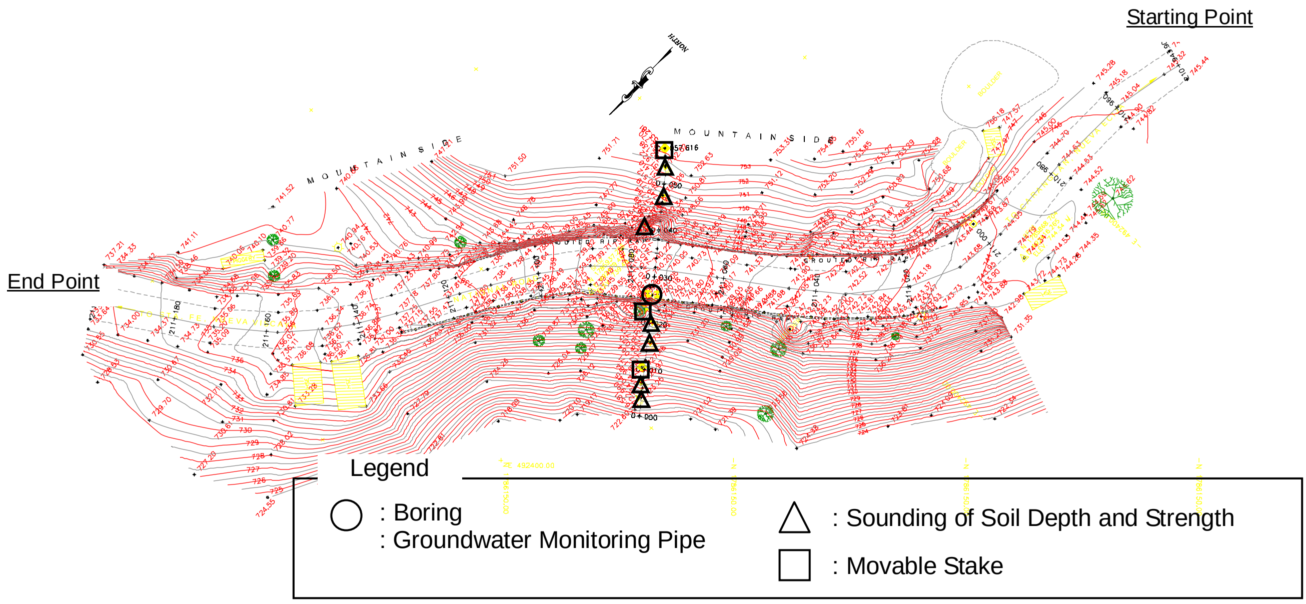


Figure A6-2.5 Location of the Geotechnical Investigation

(b) Scope of Work

The scope of geotechnical investigation is tabulated in Table A6-2.19.

Table A6-2.19 Scope of Geotechnical Investigation

Item		Unit	Amount	Remarks
Planimetric and contour mapping, S = 1:500		ha	1.24	the site area
Cross Section, S = 1:500		m	60	
Engineering geological mapping	S = 1:50,000	ha	5,000	surrounding of the site
	S = 1:5,000		100.0	
	S = 1:500	ha	1.24	the site area
Engineering geological profiling	V = 1:20,000, H = 1:50,000	m	10,000	surrounding of the site
	S = 1:2,000	m	2,000	
	S = 1:500	m	60	the site area
Boring	Core, 66 mm	m	15.0	1 borehole
Standard penetration test		time	16	1 borehole
Sounding of soil depth and strength		nos.	9	
Installation of perforated pipe		m	15.0	1 monitoring well
Groundwater monitoring		time	4	
Movable stake installation		nos.	3	

(2) Geological Distribution

Weathered and porous limestone is distributed in the site and its environment.

(3) Conditions of Geological Stratum at the Site

Fill, talus deposit, highly weathered limestone and weathered limestone are distributed in chorological order. Table A6-2.20 shows facies of each stratum.

Table A6-2.20 Description of Each Stratum

Geological Stratum		Facies
Fill		Fill material is sandy soil with gravel and consists of a wide range of grain sizes.
Talus deposit		The talus deposit is gravelly sand. The gravel is mainly sub-angular limestone.
Limestone		About one (1) m of the uppermost part is highly weathered (soft rock and some portion is gravelly soil).
		Weathered (soft rock) and porous conditions. Small-sized cavities were encountered during boring.

Figure A6-2.6 shows engineering geological cross section at the site.

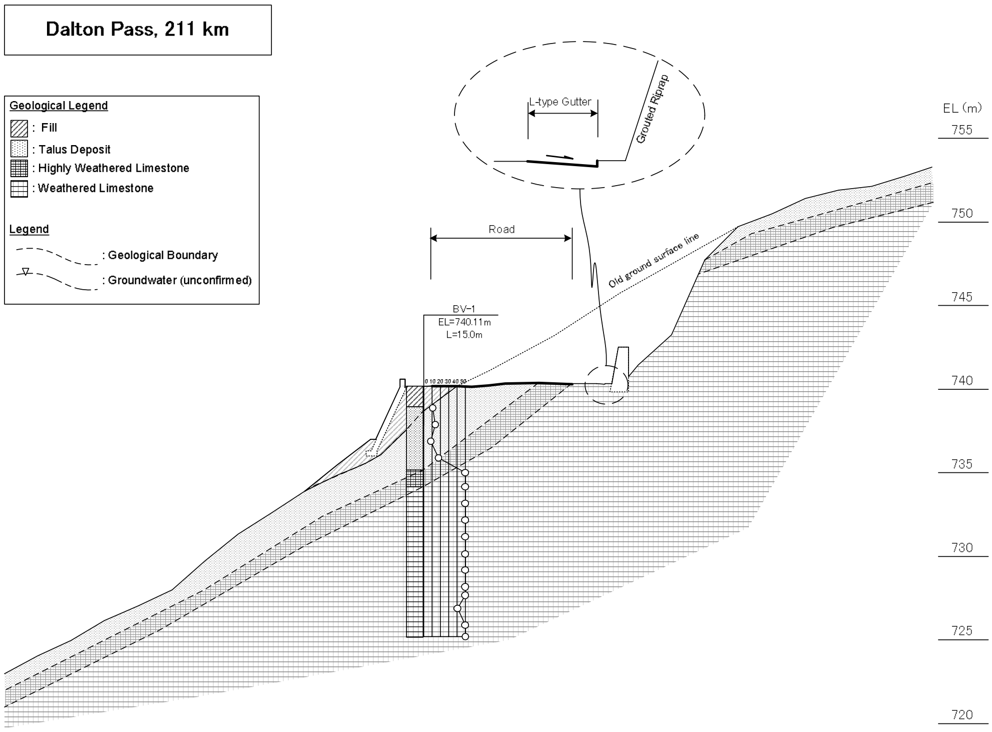


Figure A6-2.6 Engineering Geological Profiling

(4) Geotechnical Properties

Geotechnical properties for each stratum are tabulated in Table A6-2.21.

Table A6-2.21 Geotechnical Properties

Geological Stratum	Average N-value	Unit weight γ (kN/m^3)	Shear strength for calculation of earth pressure		Coefficient of permeability k (cm/sec)	Allowable bearing capacity q_a (kN/m^2)
			Cohesion c (kN/m^2)	Internal friction angle ϕ (degrees)		
Fill	-	19	-	27	-*	200
Talus deposit	13	18	-	31	-*	200
Highly weathered limestone	> 50	20	180	-	-*	300
Weathered limestone	> 50	21	5,000	30	-*	600

*: Groundwater was unconfirmed during boring .

(a) Average N-value

Average N-value is determined by arithmetic mean using the results of SPT (Standard Penetration Test). When there is some singular N-value, the value should be ignored at the calculation.

Figure A6-2.7 shows N-value distribution by each geological stratum.

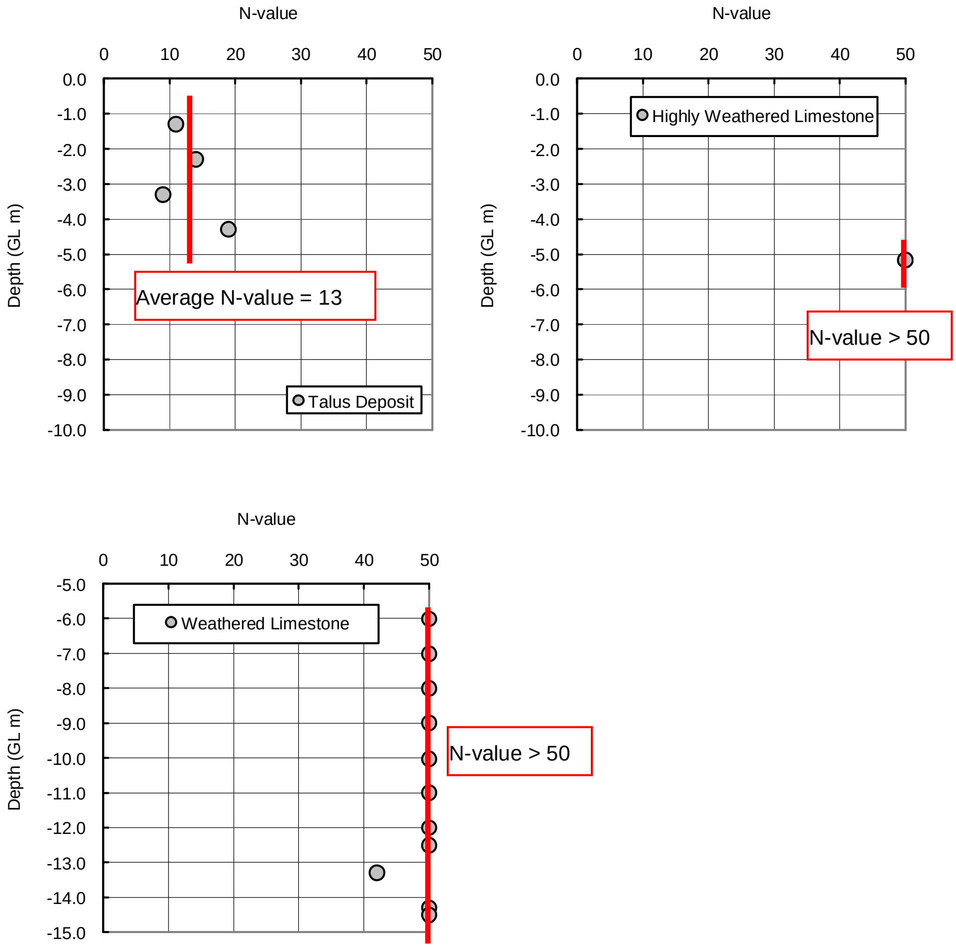


Figure A6-2.7 N-value by Each Geological Stratum

(b) Unit Weight (γ)

Unit weight is determined using the Manual in Japan (see Table A6-2.22) and the Ortiz classification (see Table A6-2.23).

Table A6-2.22 Unit Weight by Soil Type

Ground Type	Soil Type	Unit Weight (kN/m^3) Loose	Unit Weight (kN/m^3) Dense
Natural Ground	Sand or Gravelly Sand	18	20
	Sandy Soil	17	19
	Clayey Soil	14	18
Fill	Sand or Gravelly Sand	20	
	Sandy Soil	19	
	Clayey Soil (w_L*<50 %)	18	

* w_L: Liquid limit

Table A6-2.23 Unit Weight by Rock Classification Tabulated by Ortiz

Type	Remarks	Typical Rock / Soil	Classification Parameter: RQD	Classification Parameter: V_L (m/s)	Classification Parameter: Q	Classification Parameter: RSR	Geotechnical Properties: Unit Weight γ (t/m^3)	Shear Strength Peak: c (kN/m^2)	Shear Strength Peak: φ (°)	Shear Strength Residual: c_r (kN/m^2)	Shear Strength Residual: $φ_r$ (°)
A	Massive, hard	Granite, Silicastone, Limestone, Siliceous Sandstone, Hard Conglomerate, Basalt, Consolidated Volcanic Rock, Gneiss	100 - 95	>5,000	>100	100 - 80	3.0 - 2.6	400,000 - 50,000	60 - 50	2,000 - 500	35 - 30
B	Schistose or re-consolidated	Phyllite, Slate, Schist, Breccia, Consolidated Mylonite, Alternation Silicastone	90 - 70	5,000 - 3,500	80 - 30	80 - 60	2.8 - 2.2	200,000 - 30,000	45 - 30	1,000 - 100	35 - 30
	Moderate crack / weathering of Type A										
C	Consolidated bedded rock	Marine Marl, Molasse, Weathering Limestone, Weaken Conglomerate, Shale, Mudstone, Sandstone, Gypsum	80 - 70	4,000 - 2,500	50 - 20	70 - 50	2.6 - 2.1	70,000 - 5,000	45 - 30	500 - 0	30 - 15
	Disadvantageous strike and dip of Type B										
	Calcareous Karst										
D	Consolidated Deposit	Younger Red Sandstone / Bunter Series, Marine Clay, Tillite, Tuff, Chalk, Loess, Shale, Loam, Residual Soil of Arkose Sandstone	100 - 60	4,000 - 800	10 - 2	60 - 40	2.6 - 2.2	2,000 - 100	30 - 22	200 - 0	25 - 10
	Gypsum Karst										
E	Many cracks, fractures / block-wise of rock or soil	Mylonite, Fault Zone, Volcanic Product, Clastic Rock, Easily Fractured Marl, Dense Granular Soil	60 - 25	3,000 - 1,500	2 - 0.05	50 - 35	2.4 - 2.2	500 - 0	45 - 30	-	30 - 25
F	Hardly compacted clayey soil / soft rock	Residual Soil, Laterite, Varve Clay, Clayey Till, Flysh	N/A	3,000 - 1,000	0.10 - 0.01	40 - 30	2.2 - 1.7	200 - 0	28 - 22	-	20 - 8
G	Loose soft Quaternary deposit	Loose Alluvial Sand and Gravel / Mud / Soft Clay / Silt / Peat / Colluvial Soil	N/A	3,000 - 800	<0.05	35 - 25	2.0 - 1.5	-	38 - 30	-	30

Table A6-2.24 shows relationship between geological stratum distributed in the site and ground/soil type described in Table A6-2.22 and Table A6-2.23.

Table A6-2.24 Geological Stratum in the Site and Ground Type of Table A6-2.22 and Table A6-2.23

Geological Stratum in the Site	Ground / Soil Type in Table A6-.22 and Table 6.23	Commentary
Fill	Fill: Sandy soil	Fill material is sandy soil with gravel, and wide range of grain sizes.
Talus deposit	Natural ground Gravelly sand: Loose	The talus deposit is gravelly sand, average N-value shows 13. It corresponds to the loose conditions.
Highly weathered limestone	Consolidated bedded rock	Slightly lower value than the minimum value of the 'consolidated bedded rock' of Table A6-2.23 is applied due to highly weathered and porous conditions.
Weathered limestone	Consolidated bedded rock	The minimum value of the 'consolidated bedded rock' of Table A6-2.23 is applied due to porous conditions.

(c) Cohesion (c) (for calculation of earth pressure)

In case a geological stratum consists of clayey soil or highly weathered rock (clay-like material), cohesion is calculated by the following equation, referring to the Manual in Japan for shear strength of soil.

$c = 6\text{ N to }10\text{ N (kN/m}^2\text{)}$

where;

c = Cohesion (kN/m^2)

N =N-value

(Note: In this Study, 6 N and 10 N are applied for soil and highly weathered rock, respectively.)

The highly weathered limestone is like a clayey soil; hence, cohesion is calculated by the above equation.

(d) Internal Friction Angle (ϕ) (for calculation of earth pressure)

In case that a geological stratum consists of sandy soil, internal friction angle is calculated by the following equation, referring to the Manual in Japan for shear strength of soil.

$$\phi = 15 + \sqrt{15 \cdot N} \leq 45^\circ, \quad N > 5$$

where,

ϕ: Internal friction angle (degrees)

N: N-value

The fill and talus deposit are judged as sandy soil; hence, internal friction angle is calculated by the above equation.

(e) Coefficient of Permeability (k)

Coefficient of permeability is determined by the results of borehole permeability test. However, the coefficient was not obtained by the test because groundwater was not encountered during boring.

(f) Allowable bearing capacity (q_a)

Allowable bearing capacity is determined using the Manual in Japan (see Table A6-2.25).

Table A6-2.25 Allowable Bearing Capacity by Ground Type (Ordinary Condition)

Ground Type		Allowable bearing capacity q_a (kN/m^2)	Remarks	
			Unconfined compression strength q_u (kN/m^2)	N-value
Rock	Uniformly hard rock with less cracks	1,000	≥ 10,000	-
	Hard rock with many cracks	600	≥ 10,000	-
	Soft rock / mudstone	300	≥ 1,000	-
Gravelly Soil	Dense	600	-	-
	Loose	300	-	-
Sandy Soil	Dense	300	-	30 to 50
	Moderately Dense	200	-	20 to 30
Clayey Soil	Very stiff	200	200 to 400	15 to 30
	Stiff	100	100 to 200	10 to 15

Table A6-2.26 shows relationship between geological stratum distributed at the site and ground / soil type described in Table A6-2.25.

Table A6-2.26 Geological Stratum in the Site and Ground Type of Table A6-2.25

Geological Stratum in the Site	Ground Type in Table A6-2.25	Commentary
Fill	Sandy soil: Moderately Dense	It is inferred that N-value of the fill is not so high (less than 30).
Talus deposit	Sandy soil: Moderately Dense	The talus deposit is gravelly sand; however, average N-value shows 13. Consequently, the value is downgraded from 'Gravelly soil: Dense' of Table A6-2.25. As a result, it corresponds with the 'Sandy Soil: Moderately Dense' of Table A6-2.25.
Highly weathered limestone	Soft rock	It corresponds with soft rock, since it is highly weathered and porous.
Weathered limestone	Hard rock with many cracks	It corresponds with hard rock with many cracks due to the existence of small-sized cavities.

(5) Groundwater Level

Groundwater was not encountered during boring work at BV-1.

(6) Mechanism of Road Slip (RS)

Mechanism of Road Slip (RS) at the site is as follows.

- The fill materials consist of sandy soil with gravel and have wide range of grain sizes. The materials are good for earthen works.
- The grouted riprap located at the valley side of the road serves a counterweight fill and support for the road. However, the fill materials which serve as foundation are unable to support the slope since it is not dense (N-value is 13).
- It is also inferred that continuous deformation is progressing (like a creep phenomenon) since the grouted riprap is unstable to support the unstable slope.

A6-2.4 Ginatilan-Alegria Road Km 171 (Region VII)

(1) General

(a) Objectives of the Geotechnical Investigation

The geotechnical investigation was conducted in order to determine the mechanism of the Coastal Erosion (CE) and to obtain the geological/geotechnical information for the design of countermeasures. Figure A6-2.8 shows the location plan of the geotechnical investigation.

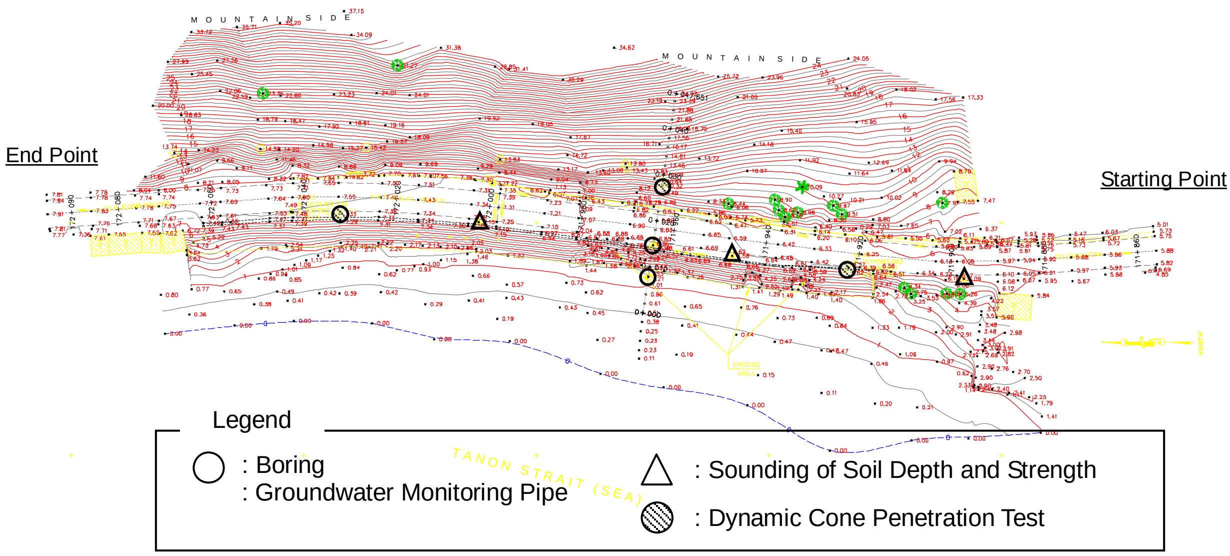


Figure A6-2.8 Location of the Geotechnical Investigation

(b) Scope of Work

Scope of geotechnical investigation is tabulated in Table A6-2.27.

Table A6-2.27 Scope of the Geotechnical Investigation

Item		Unit	Quantity	Remarks
Planimetric and contour mapping, S = 1:500		ha	1.273	the site
Cross Section, S = 1:500		m	50	
Engineering geological mapping	S = 1:50,000	ha	5,000	surrounding of the site
	S = 1:500	ha	1.273	the site
Engineering geological profiling	V = 1:20,000, H = 1:50,000	m	40	surrounding of the site
	S = 1:500	m	0	the site
Boring	All-core, 66 mm	m	13.0	2 boreholes
Standard penetration test		time	13	2 boreholes
Field permeability test		test	3	1 boreholes
Sounding of soil depth and strength		nos.	8	
Dynamic cone penetration test		nos.	9	
Installation of perforated pipe		m	13.0	2 monitoring wells
Groundwater monitoring		time	7	
Groundwater prospecting		m	13	1 monitoring wells

(2) Geological Distribution

Shale and limestone occur as bedrock in this site. Outcrops of shale were weathered and factual.

(3) Conditions of Geological Stratum at the Site

Highly weathered shale and weathered limestone are distributed in chronological order. Table A6-2.28 shows description of each stratum.

Table A6-2.28 Description of Each Stratum

Geological Stratum		Remarks
Weathered shale		The outcrop is classified as soft rock due to intense weathering and fractures due to the presence of small scale faults.
Weathered limestone		The core from boring was broken (like a soil sample).

Figure A6-2.9 shows engineering geological cross section at the site.

Ginatilan-Alegria,171 km

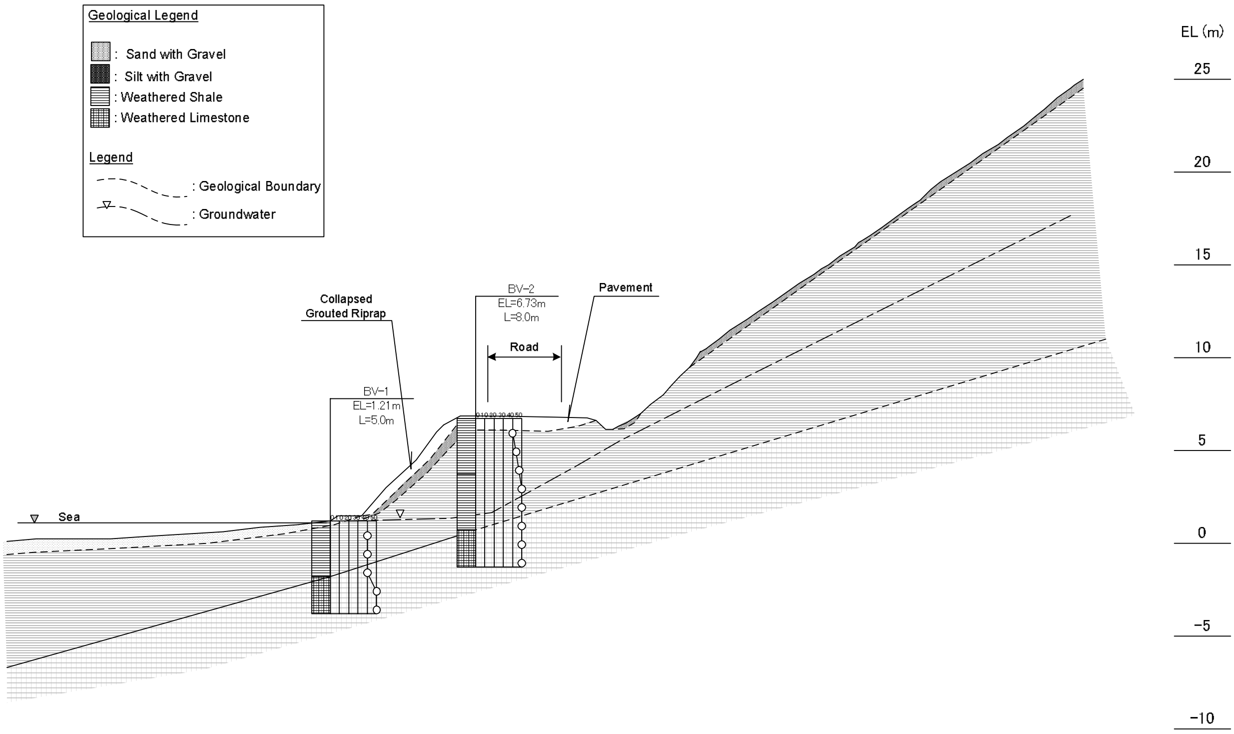


Figure A6-2.9 Engineering Geological Profiling

(4) Geotechnical Properties

Geotechnical properties for each stratum are tabulated in Table A6-2.29.

Table A6-2.29 Geotechnical Properties

Geological Stratum	Average N-value	Unit weight γ (kN/m^3)	Coefficient of permeability k (cm/sec)	Allowable bearing capacity q_a (kN/m^2)
Weathered shale	46	19	-*	300
Weathered limestone	> 50	21	-**	600

*: Groundwater was unconfirmed in highly weathered shale layer.

**: One permeable test was conducted. However, the result was not adequate for the stratum.

(a) Average N-value

Average N-value is determined by arithmetic mean using the results of SPT (Standard Penetration Test).

Figure A6-2.10 shows N-value distribution of each geological Stratum.

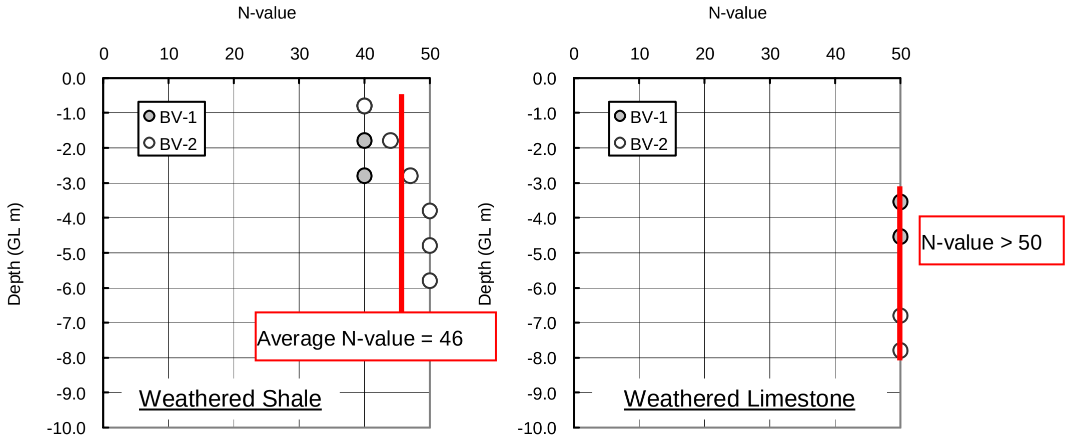


Figure A6-2.10 N-value of Each Geological Stratum

(a) Unit Weight

Unit weight is determined using the Ortiz classification (see Table A6-2.30).

Table A6-2.30 Unit Weight by Rock Classification Tabulated by Ortiz

Type	Remarks	Typical Rock / Soil	Classification Parameter				Geotechnical Properties				
							Unit Weight γ (t/m^3)	Shear Strength			
								Peak		Residual	
			RQD	V_L (m/s)	Q	RSR		c (kN/m^2)	ϕ (°)	c_r (kN/m^2)	ϕ_r (°)
A	Massive, hard	Granite, Silicastone, Limestone, Siliceous Sandstone, Hard Conglomerate, Basalt, Consolidated Volcanic Rock, Gneiss	100 - 95	>5,000	>100	100 - 80	3.0 - 2.6	400,000 - 50,000	60 - 50	2,000 - 500	35 - 30
B	Schistose or re-consolidated	Phyllite, Slate, Schist, Breccia, Consolidated Mylonite, Alternation Silicastone	90 - 70	5,000 - 3,500	80 - 30	80 - 60	2.8 - 2.2	200,000 - 30,000	45 - 30	1,000 - 100	35 - 30
	Moderate crack / weathering of Type A										
C	Consolidated bedded rock	Marine Marl, Molasse, Weathering Limestone, Weaken Conglomerate, Shale, Mudstone, Sandstone, Gypsum	80 - 70	4,000 - 2,500	50 - 20	70 - 50	2.6 - 2.1	70,000 - 5,000	45 - 30	500 - 0	30 - 15
	Disadvantageous strike and dip of Type B										
	Calcareous Karst										
D	Consolidated Deposit	Younger Red Sandstone / Bunter Series, Marine Clay, Tillite, Tuff, Chalk, Loess, Shale, Loam, Residual Soil of Arkose Sandstone	100 - 60	4,000 - 800	10 - 2	60 - 40	2.6 - 2.2	2,000 - 100	30 - 22	200 - 0	25 - 10
	Gypsum Karst										
E	Many cracks, fractures / block-wise of rock or soil	Mylonite, Fault Zone, Volcanic Product, Clastic Rock, Easily Fractured Marl, Dense Granular Soil	60 - 25	3,000 - 1,500	2 - 0.05	50 - 35	2.4 - 2.2	500 - 0	45 - 30	-	30 - 25
F	Hardly compacted clayey soil / soft rock	Residual Soil, Laterite, Varve Clay, Clayey Till, Flysh	N/A	3,000 - 1,000	0.10 - 0.01	40 - 30	2.2 - 1.7	200 - 0	28 - 22	-	20 - 8
G	Loose soft Quaternary deposit	Loose Alluvial Sand and Gravel / Mud / Soft Clay / Silt / Peat / Colluvial Soil	N/A	3,000 - 800	<0.05	35 - 25	2.0 - 1.5	-	38 - 30	-	30

Table A6-2.31 shows relationship between geological stratum distributed in the site and ground / soil type described in Table A6-2.30.

Table A6-2.31 Geological Stratum in the Site and Ground Type of Table A6-2.30

Geological Stratum in the Site	Ground / Soil Type in Table 6.29	Commentary
Weathered shale	Hardly compacted clayey soil / soft rock	The outcrop shows soft rock and N value is around 40.
Weathered limestone	Consolidated, bedded rock	N value is bigger than 50.

(c) Coefficient of Permeability (k)

Coefficient of permeability is determined by the results of borehole permeability test. The borehole permeability test was conducted three (3) times. Test 1 and Test 2 were conducted in the highly weathered shale. This layer does not have groundwater and seems to be impermeable materials. However, the result shows good permeability coefficient. Test 3 was conducted in the weathered shale. This layer also seems to be impermeable materials; however, the results show medium-good permeability.

(d) Allowable bearing capacity (qa)

Allowable bearing capacity is determined using the Manual in Japan (see Table A6-2.32).

Table A6-2.32 Allowable Bearing Capacity by Ground Type (Ordinary Condition)

Ground Type		Allowable bearing capacity q_a (kN/m^2)	Remarks	
			Unconfined compression strength q_u (kN/m^2)	N-value
Rock	Uniformly hard rock with less cracks	1,000	≥ 10,000	-
	Hard rock with many cracks	600	≥ 10,000	-
	Soft rock / mudstone	300	≥ 1,000	-
Gravelly Soil	Dense	600	-	-
	Loose	300	-	-
Sandy Soil	Dense	300	-	30 to 50
	Moderately Dense	200	-	20 to 30
Clayey Soil	Very stiff	200	200 to 400	15 to 30
	Stiff	100	100 to 200	10 to 15

Table A6-2.33 shows the relationship between geological stratum distributed in the site and ground / soil type described in Table A6-2.32.

Table A6-2.33 Geological Stratum in the Site and Ground Type of Table A6-2.32

Geological Stratum in the Site	Ground Type In Table A 6-2.32	Commentary
Weathered shale	Rock: Soft rock / mudstone	The outcrop shows soft rock and SPT is around 40.
Weathered limestone	Rock: Hard rock with many cracks	N value is bigger than 50.

(5) Groundwater Level

Groundwater level is influenced by the sea tide level.

(6) Mechanism of Coastal Erosion (CE)

Mechanism of Coastal Erosion (CE) at the site is as follows.

- Fractured shale due to presence of small-scale faults is distributed/exposed at the site and was found behind the existing (collapsed) grouted riprap. The matrix of the shale is also weak.
- The damaged/collapsed grouted riprap was poorly constructed (i.e. lack of concrete, and etc.).
- Infiltration of runoff, raised groundwater level due to heavy rains and wave action caused erosion of fine grained soil from the backfill, thus forming cavities behind the riprap. Also, the strength of riprap itself was not sufficient. According to the results, the riprap collapsed due to wave action on some occasions.

6.3.5 Wright-Taft Road Km 846 (Region VIII)

(1) General

(a) Objectives of the Geotechnical Investigation

The geotechnical investigation was conducted in order to determine the mechanism of the Road Slip (RS) and to obtain the geological/geotechnical information for design of countermeasures. Figure A6-2.20 shows the location of the geotechnical investigation.

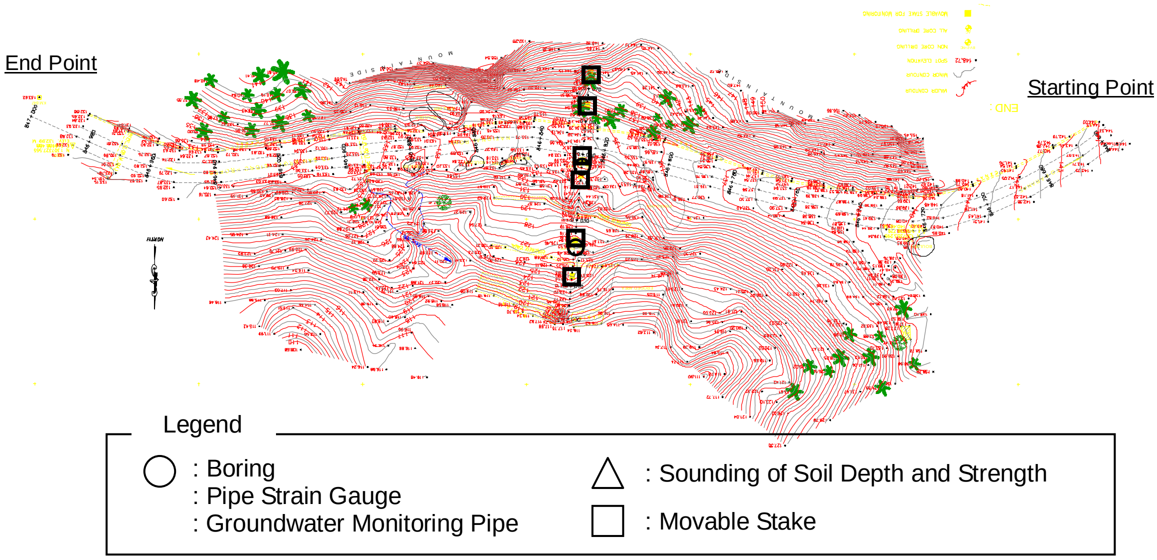


Figure A6-2.20 Location of the Geotechnical Investigation

(b) Scope of Work

Scope of geotechnical investigation is tabulated in Table A6-2.34.

Table A6-2.34 Scope of Geotechnical Investigation

Item		Unit	Amount	Remarks
Planimetric and contour mapping, S = 1:500		ha	2.012	the site
Cross Section, S = 1:500		m	75	
Engineering geological mapping	S = 1:50,000	ha	5,000	surrounding of the site
	S = 1:500	ha	2.012	the site
Engineering geological profiling	V = 1:20,000, H = 1:50,000	m	10,000	surrounding of the site
	S = 1:500	m	75	the site
Boring	Core, 66 mm	m	51	2 boreholes
	Non-core, 66 mm	m	36.5	2 boreholes
Standard penetration test		time	36	2 boreholes
Field permeability test		test	10	2 boreholes
Sounding of soil depth and strength		nos.	16	
Installation of perforated pipe		m	36.5	2 monitoring wells
Groundwater monitoring		time	10	
Installation of perforated pipe with strain gauge		m	55	2 monitoring pipes
Pipe strain gauge monitoring		time	10	
Movable stake installation		nos.	6	
Groundwater prospecting		m	10	2 monitoring wells

(2) Geological Distribution

Geology at the site and the surrounding areas consist of limestone, and alternating layers of sandstone/mudstone/shale beneath the limestone. The toe of the subsurface slope is covered by talus deposit.

(3) Conditions of Geological Strata at the Site

Embankment fill, old surface soil, talus deposit, highly weathered rock of alternating layer consisted of sandstone/mudstone/shale), moderately weathered rock, and slightly weathered rock are distributed in chronological or descending order. Table A6-2.35 shows the description of each stratum.

Table A6-2.35 Description of Each Stratum

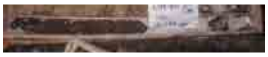
Geological Stratum		Remarks
Embankment fill		Fill materials consist of soil from construction waste and sandy gravel (limestone).
Old surface soil		The old surface soil includes organic materials (dark brown color).
Talus deposit		Talus deposit is sandy soil with sub-angular gravel.
Highly weathered rock		The strata consist of alternating layers of sandstone, mudstone and shale. The core is almost like clayey/sandy soil with gravel depending on the weathering conditions.
Moderately weathered rock		
Slightly weathered rock		

Figure A6-2.21 shows the engineering geological cross section at the site.

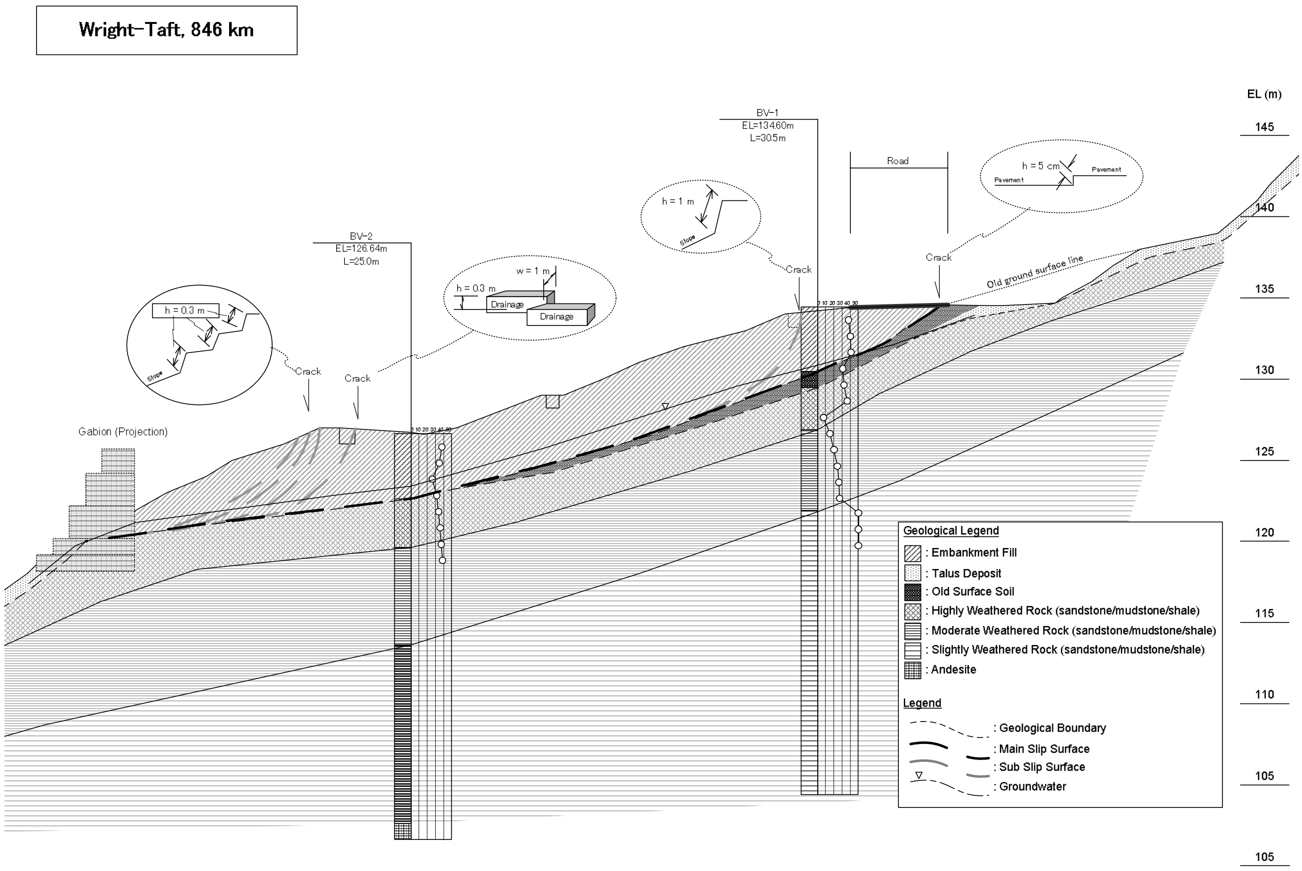


Figure A6-2.21 Engineering Geological Profiling

(4) Geotechnical Properties

Geotechnical properties for each stratum are tabulated in Table A6-2.36.

Table A6-2.36 Geotechnical Properties

Geological Stratum	Average N-value	Unit weight γ (kN/m^3)	Shear strength for calculation of earth pressure		Coefficient of permeability k (cm/sec)	Allowable bearing capacity q_a (kN/m^2)
			Cohesion c (kN/m^2)	Internal friction angle ϕ (degrees)		
Embankment fill	35	18	210	-	3.3×10^{-4}**	200
Old surface soil	32*	14	186	-	1.9×10^{-4}	100
Highly weathered rock	35	20	350	-	3.3×10^{-4}	300
Moderate weathered rock	25	21	-	-	9.8×10^{-5}	400
Slightly weathered rock	> 50	22	-	-	-	600

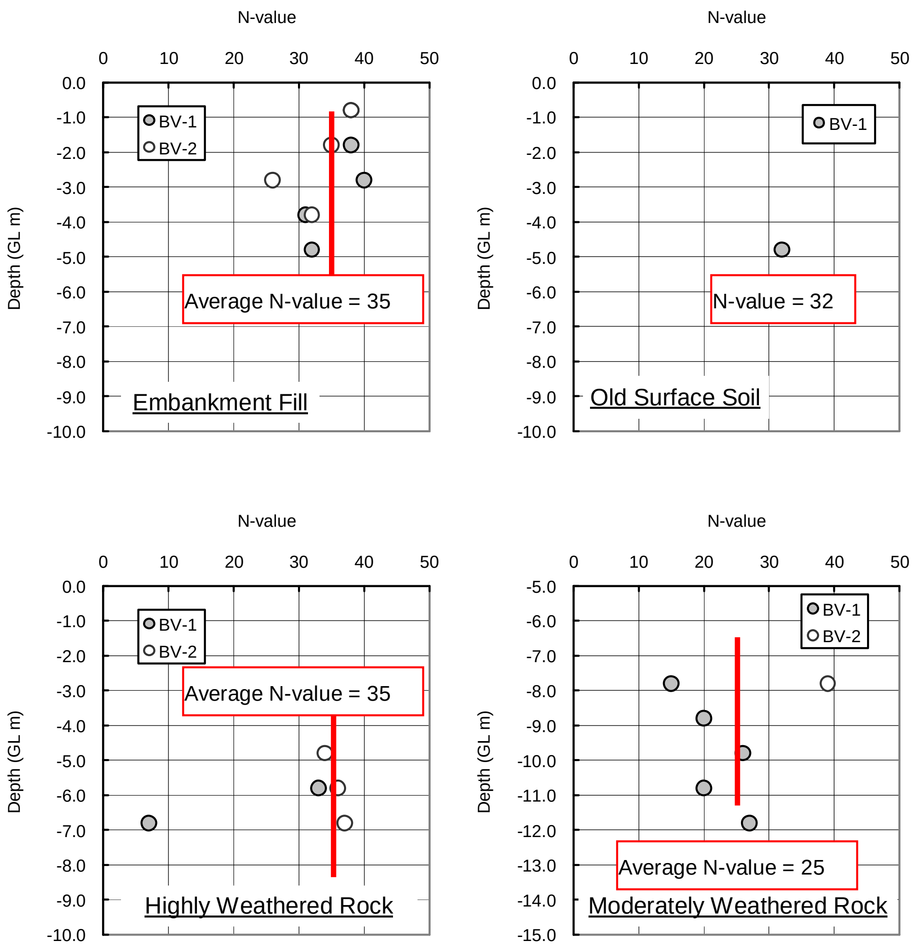
*: Thickness of old surface soil is thin and standard penetration test was conducted 1 time only. Also, the soil layer is not continuous along the slope. Consequently, the abovementioned properties are treated as a guide.

**: Permeability test was conducted above the natural groundwater level. Consequently, this value can be used as a reference.

(a) Average N-value

Average N-value is determined by arithmetic mean using the results of SPT (standard penetration test).

Figure A6-2.22 shows N-value distribution by each geological stratum.



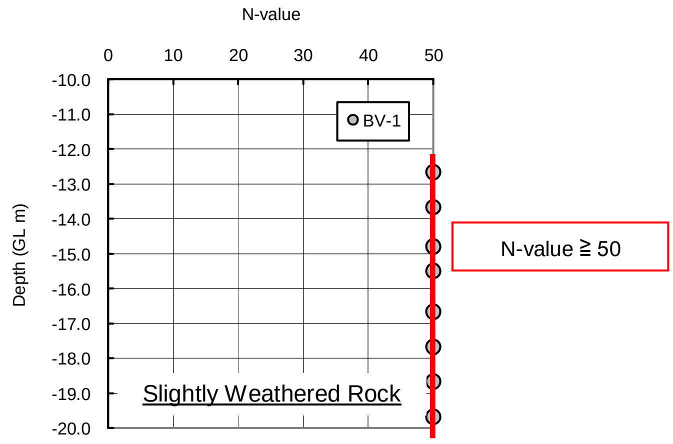


Figure A6-2.22 N-value of Each Geological Stratum

(b) Unit Weight (γ)

Unit weight was determined using the Manual in Japan (see Table A6-2.37) and the Ortiz classification (see Table A6-2.38).

Table A6-2.37 Unit Weight by Soil Type

Ground Type	Soil Type	Unit Weight (kN/m^3)	
		Loose	Dense
Natural Ground	Sand or Gravelly Sand	18	20
	Sandy Soil	17	19
	Clayey Soil	14	18
Fill	Sand or Gravelly Sand	20	
	Sandy Soil	19	
	Clayey Soil (w_L*<50 %)	18	

* w_L: Liquid limit

Table A6-2.38 Unit Weight by Rock Classification Tabulated by Ortiz

Type	Remarks	Typical Rock / Soil	Classification Parameter: RQD	Classification Parameter: V_L (m/s)	Classification Parameter: Q	Classification Parameter: RSR	Geotechnical Properties: Unit Weight γ (t/m³)	Shear Strength, Peak: c (kN/m²)	Shear Strength, Peak: φ (°)	Shear Strength, Residual: c_r (kN/m²)	Shear Strength, Residual: $φ_r$ (°)
A	Massive, hard	Granite, Silicastone, Limestone, Siliceous Sandstone, Hard Conglomerate, Basalt, Consolidated Volcanic Rock, Gneiss	100 - 95	>5,000	>100	100 - 80	3.0 - 2.6	400,000 - 50,000	60 - 50	2,000 - 500	35 - 30
B	Schistose or re-consolidated	Phyllite, Slate, Schist, Breccia, Consolidated Mylonite, Alternation Silicastone	90 - 70	5,000 - 3,500	80 - 30	80 - 60	2.8 - 2.2	200,000 - 30,000	45 - 30	1,000 - 100	35 - 30
	Moderate crack / weathering of Type A										
C	Consolidated bedded rock	Marine Marl, Molasse, Weathering Limestone, Weaken Conglomerate, Shale, Mudstone, Sandstone, Gypsum	80 - 70	4,000 - 2,500	50 - 20	70 - 50	2.6 - 2.1	70,000 - 5,000	45 - 30	500 - 0	30 - 15
	Disadvantageous strike and dip of Type B										
	Calcareous Karst										
D	Consolidated Deposit	Younger Red Sandstone / Bunter Series, Marine Clay, Tillite, Tuff, Chalk, Loess, Shale, Loam, Residual Soil of Arkose Sandstone	100 - 60	4,000 - 800	10 - 2	60 - 40	2.6 - 2.2	2,000 - 100	30 - 22	200 - 0	25 - 10
	Gypsum Karst										
E	Many cracks, fractures / block-wise of rock or soil	Mylonite, Fault Zone, Volcanic Product, Clastic Rock, Easily Fractured Marl, Dense Granular Soil	60 - 25	3,000 - 1,500	2 - 0.05	50 - 35	2.4 - 2.2	500 - 0	45 - 30	-	30 - 25
F	Hardly compacted clayey soil / soft rock	Residual Soil, Laterite, Varve Clay, Clayey Till, Flysh	N/A	3,000 - 1,000	0.10 - 0.01	40 - 30	2.2 - 1.7	200 - 0	28 - 22	-	20 - 8
G	Loose soft Quaternary deposit	Loose Alluvial Sand and Gravel / Mud / Soft Clay / Silt / Peat / Colluvial Soil	N/A	3,000 - 800	<0.05	35 - 25	2.0 - 1.5	-	38 - 30	-	30

Table A6-2.39 shows relationship between geological strata distributed in the site and ground/soil type described in Table A6-2.37 and Table A6-2.38.

Table A6-2.39 Geological Stratum in the Site and Ground Type of Table A6-2.37 and Table A6-2.38

Geological Stratum in the Site	Ground / Soil Type in Table A6-2.37 and Table 6.38	Commentary
Embankment fill	Fill / Sandy Soil	The core from boring is clay with gravel. It is assumed that embankment fill material was not properly and adequately compacted
Old surface soil	Natural Ground / Clayey Soil: Loose	Organic materials are included.
Highly weathered rock	Hardly compacted clayey soil / soft rock	The core is almost clay with limestone fragment.
Moderate weathered rock	Consolidated bedded rock	The core from boring is almost sand
Slightly weathered rock	Consolidated bedded rock	The core from boring consists of sand and sandstone.

(c) Cohesion (c) (for calculation of earth pressure)

In case a geological stratum corresponds with clayey soil or highly weathered rock (clay-like material), cohesion is calculated by the following equation, referring to the Manual in Japan for shear strength of soil.

$c = 6N$ to $10N$

where,

c: Cohesion (kN/m^2)

N: N-value

(Note: In this Study, 6N and 10N are applied for soil and highly weathered rock, respectively.)

Embankment fill, the old surface soil, and the matrix of highly weathered rock are clayey soil, and like a clayey soil. Cohesion is calculated by the above equation.

(d) Coefficient of Permeability (k)

Coefficient of permeability is determined by the results of borehole permeability test.

Table A6-2.40 shows summary of results of the borehole permeability test.

Table A6-2.40 Results of the Borehole Permeability Test

	BV-1		BV-2		Average (logarithmic)
	Depth (GL-m)	k (cm/sec)	Depth (GL-m)	k (cm/sec)	k (cm/sec)
Embankment Fill	2	4.6E-04	2	2.3E-04	(3.3E-04)
Old surface soil	5	1.9E-04			1.9E-04
Highly weathered rock	7	7.2E-04	5 7	1.0E-04 6.0E-05	3.3E-04
Moderately weathered rock	10	1.6E-04	10	6.0E-05	9.8E-05

The permeability test in the embankment fill was conducted above the natural groundwater level (around GL-3 m). Consequently, this value is used as a reference.

(e) Allowable bearing capacity (qa)

Allowable bearing capacity is determined using the Manual in Japan (see Table A6-2.41).

Table A6-2.41 Allowable Bearing Capacity by Ground Type (Ordinary Condition)

Ground Type		Allowable bearing capacity q_a (kN/m^2)	Remarks	
			Unconfined compression strength q_u (kN/m^2)	N-value
Rock	Uniformly hard rock with few cracks	1,000	≥ 10,000	-
	Hard rock with many cracks	600	≥ 10,000	-
	Soft rock / mudstone	300	≥ 1,000	-
Gravelly Soil	Dense	600	-	-
	Loose	300	-	-
Sandy Soil	Dense	300	-	30 to 50
	Moderately Dense	200	-	20 to 30
Clayey Soil	Very stiff	200	200 to 400	15 to 30
	Stiff	100	100 to 200	10 to 15

Table A6-2.42 shows the relationship between geological strata distributed in the site and ground / soil type described in Table A6-2.41.

Table A6-2.42 Geological Stratum in the Site and Ground Type of Table A6-2.41

Geological Stratum in the Site	Ground Type in Table A6-2.41	Commentary
Embankment fill	Clayey Soil: Very stiff	Average N-value shows 35; however, this value is affected by gravel. Matrix of the core is clayey soil.
Old surface soil	Clayey Soil: Stiff	Organic materials are included.
Highly weathered rock	Rock: Soft rock	The boring core is almost clay with limestone fragment.
Moderately weathered rock	Rock: Soft rock to hard rock with many cracks	The core is almost sand and is easy to break by finger pressure.
Slightly weathered rock	Rock: Hard rock with many cracks	The core is a mixture of sand and sandstone.

(5) Groundwater Level

Groundwater level was observed at about 3 m below ground surface during boring at BV-1 and BV-2.

(6) Mechanism of Road Slip (RS)

Mechanism of the Road Slip (RS) at the site is as follows.

- Surface water/runoff and groundwater infiltrated the embankment fill due to inadequate surface water drainage work and no-countermeasure (drain) at the boundary between the original ground surface and the embankment fill.
- The embankment fill materials became oversaturated, and hence, became unstable.
- Meanwhile, a slope failure occurred at the edge of the embankment fill.
- The gabion at the edge the embankment fill also moved and partially collapsed (overturning), thus causing the embankment fill to be unstable.
- Creep movement of the embankment fill has continued, and crack/ settlement has occurred at the boundary between the original ground and embankment fill materials at the valley/ravine side.