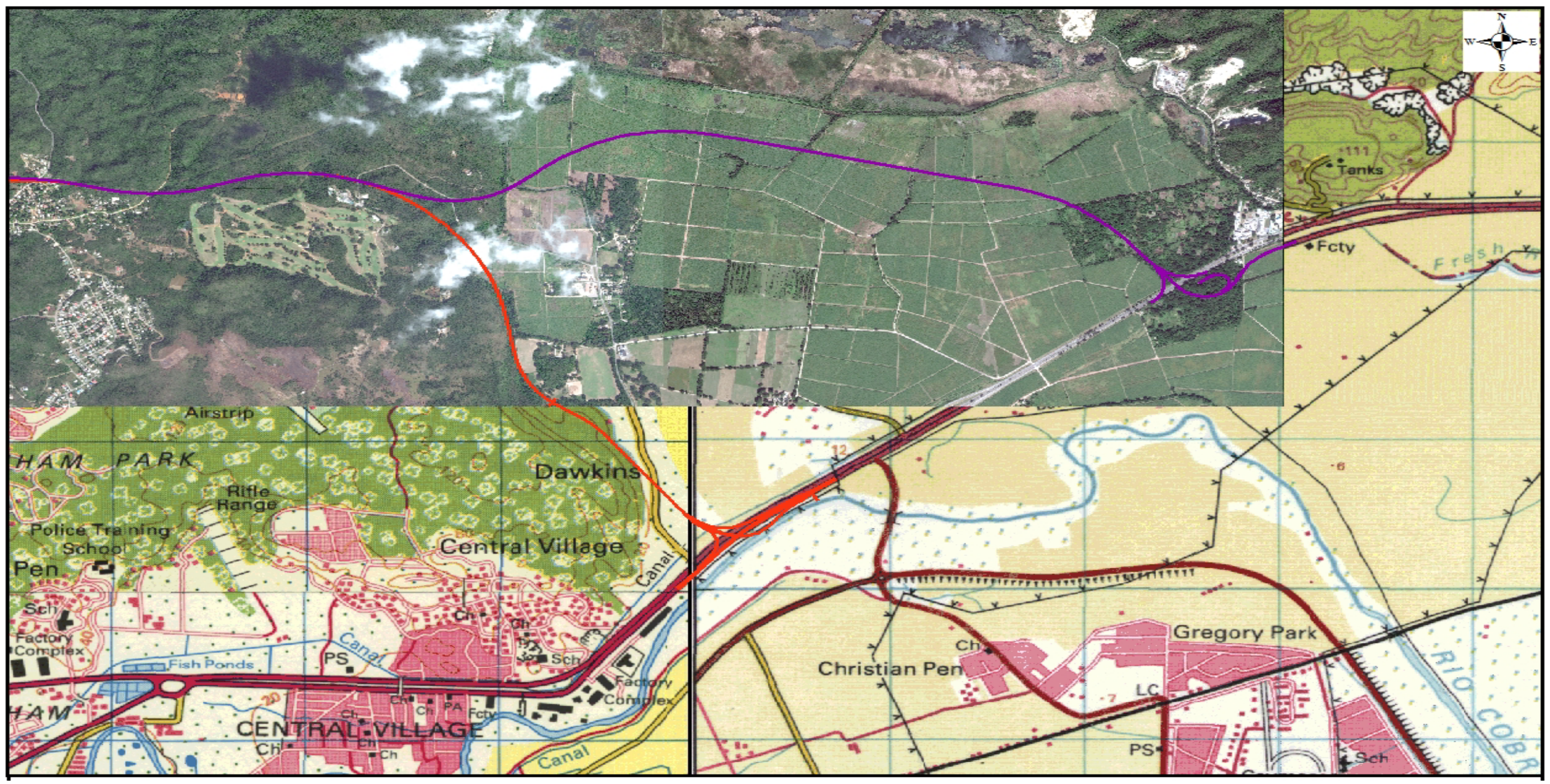
ENGINEERING GEOLOGICAL SURVEY REPORT (ABRIDGED VERSION)

JAMAICA NORTH SOUTH HIGHWAY PROJECT SECTION 1A

CAYMANAS TO LINSTEAD REALIGNMENT

(CAYMANAS INTERCHANGE)



2014 DECEMBER 18

CONTENT

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Total Legends

Q_4^{me}	Artificial Filling Layer
$Q_4^{al\ pl\ el\ dl\ c}$	Quaternary Holocene series alluvium proluvium, eluvium, deluvium, and colluvium
E	Tertiary
Etc Mn	Tertiary rock group (Etc、Mn)
Owb Mm Mp	Tertiary rock group (Owb、Mm、Mp)
K	Cretaceous
	Calcareous rock
	Andesite
	Artificial Accumulation
	Silty Clay
	Clay
	Gravel Soil
70° 70°	Inverse and normal fault occurrence
F	Unknown fault occurrence
42°	Rock occurrence (for plan view)
36°	Joint occurrence
138°∠38°	Rock occurrence (profile view)
	Stratigraphic boundary (for plan view)
	Stratigraphic boundary (section drawing)
	Regolith boundary
	Great sinkhole
	Fault fracture zone or tectonic fracture zone
652	Water level
TK1	Pit and number
BH01	Borehole and number
D1 D1'	Geophysical electrical survey line
ZS1 ZS1'	Geophysical seismic exploration line
	Weathered signs

Jamaican North-South Highway Project	Legends	Prepared by		Checked by		Verified by		Approved by		DWG No.	S-0	Page 1 of 1

General Information of Preliminary Survey in Engineering Geology of Jamaica South-North Highway

1 Preface

1.1 Project Overview

The proposed Jamaica South-North Highway will be an important channel connecting the capital Kingston and tourist center Ocho Rios. It is divided into the south section, the middle section and the north section. The beginning point of the south section is Kingston, connecting with Mandela Avenue and passing Caymanas and Angels; it crosses Rio Cobre River to Dam head, crosses the railway and extends to Bog Walk; then it reaches Linstead and the terminal point is Treadways in Linstead, connecting with the beginning point of the middle section. The beginning point of the north section is Moneague, connecting the terminal point of the middle section; it extends basically along the original A1 Highway to the north; passes Golden Grove, Trafalgar, Davis Town, Steer Town; reaches Ocho Rios and connects with A3 Highway. See Fig. 1-1. The landforms along the route are sea-alluvial plains, hills, alluvial valleys, low mountains, and alluvial plains. The design document of the route is formulated according to the NROCC and the concession agreement signed with the Jamaica Highway Co., Ltd. Based on the *British Design Manual for Roads and Bridges* and in due consideration of the design criterion regulated in the franchise agreement and the revised contents of the No.127, No.129, No.132 Engineering Change Orders, the final major technical standards applied are determined, as shown in Table 1-1.

Illustration of the task basis and the exploration process: the fourth design branch of the CCCC Second Highway Consultant Co., Ltd. is responsible for the project design, and the CCCC Wuhan Geotechnical Engineering Co., Ltd. is responsible for the geological survey. After the international engineering department of the institute issued the survey mission, Jamaica South-North Highway project survey department was established in a short time and related geological data and other technical data were collected. The first-phase preparations of the project have been under way: a series of engineering guidance documents were formulated, such as *Survey Outline* and *Project Outline*; surveying and mapping was conducted in November and December in 2011; the drilling field work of advanced exploration and detailed exploration was conducted during the period from September 2012 to May 2013; and finally the preliminary survey report on the project was formulated.

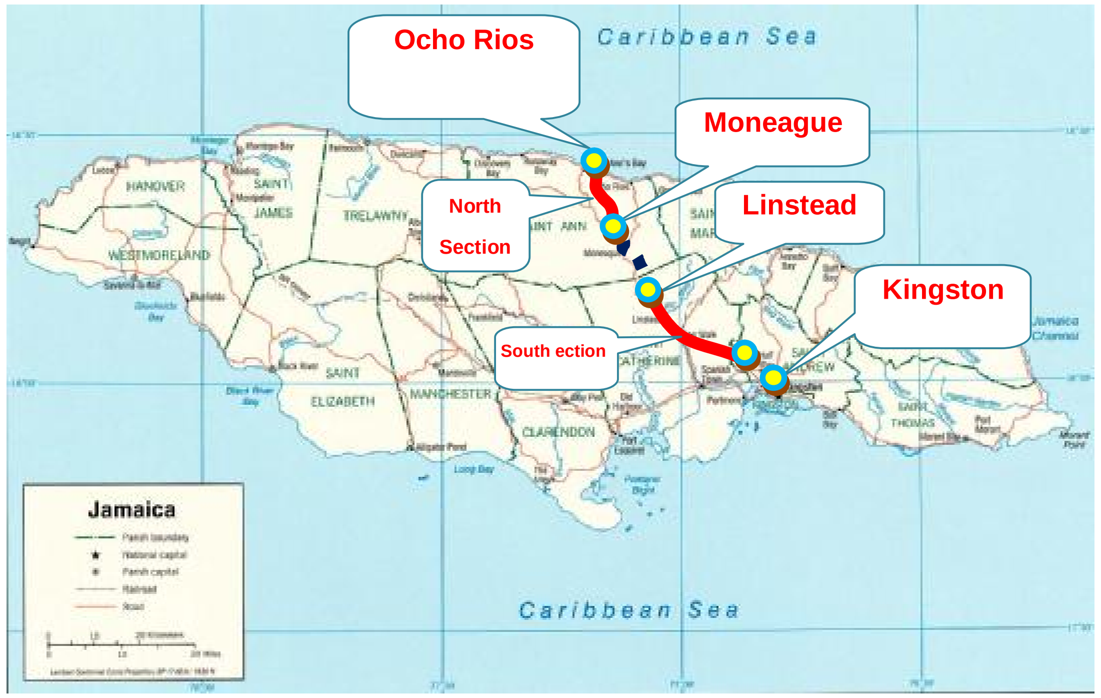


Fig. 1-1 Schematic Diagram of South-North Highway Route

Table 1-1 Technical Indicators of Jamaica South-North Highway Design

No.	Item	Technical indicator	Remarks
1	Design speed	80Km/hr	
2	Quantity of lanes	Two lanes in opposite direction (2+2)	
3	Absolute minimum stopping sight distance	110m (relaxing from 140m)	Extended to 110m in No. 127 Change Order
4	Absolute minimum radius of horizontal curve	450m	
5	Maximum high value	5%	
6	Maximum longitude slope	8%	Extended from 6% to 8% in No. 129 Change Order
7	Minimum K value of convex vertical curve	55	
8	Minimum K value of concave vertical curve	30	Extended from 55 to 30
9	Lane width	3.65m for both inner lane and outer lane	
10	Fill shoulder	2.5m hard shoulder+1.5m earth shoulder	

11	Excavation shoulder	2.5m hard shoulder+1.0m earth shoulder	
12	Width of middle strip	3 x 0.6m	
13	Nominal right-of-way scope	Within 10 meters from the slope toe of embankment or slope crest of excavation	

1.2 Purposes and Tasks of Engineering Geological Survey

1.2.1Survey Purposes

The purpose is to provide necessary engineering geological exploration and test data for the construction drawing design of the highway; find out preliminarily the engineering geological conditions and main engineering geological problems of the highway; and give an overall engineering geological evaluation for different sections of the highway.

1.2.2 Survey Tasks

(1) To find out preliminarily the engineering geological conditions of the highway construction site, and provide geological basis for the route plan and subgrade design;

(2) To find out preliminarily the geological structures of the proposed bridge, culvert channel and subgrade; the physical and mechanical characteristics of rock and soil mass; engineering geological and hydrogeological conditions; to provide geological data and design parameters needed by the project design and construction;

(3) To find out preliminarily the unfavorable geological bodies, special rock and soil and their distribution range and properties along the route; to provide geological data and design parameters needed by the prevention and control engineering design.

1.3 Implementation of Technical Standards

The survey is carried out mainly according to the *Soil and Foundation Manual* (2006 version) (prepared by the Communication and Transportation Office, Florida, America) and in reference with the regional geological map with a 1:50000 scale prepared by the Mines and Geology Division, Ministry of Mining and Resources, Jamaica.

2 Survey Methods and Completed Quantity

2.1 Survey Method

According to the topographic conditions, geological conditions, engineering layout and scale and the preliminary survey work of the project, we applied a comprehensive survey method combining engineering geological surveying and mapping, drilling, test pitting, in-situ test, physical prospecting and laboratory test. Engineering geological surveying and mapping refers to completing the surveying and mapping work based on the early successes; boreholes are located at the bridges, culverts, cuttings, high-fill embankment, gullies and depressions that possibly contain soft soil; in-situ test includes borehole standard penetration test and heavy dynamic penetration test; laboratory test studies the conventional physical and mechanical properties of rock and soil.

2.2 Quality Control and Completed Quantity

The boreholes along the route of the project are drilled by high-precision RTK-GPS instrument based on field measurement of design coordinate. After the drilling, closing point measurement is conducted for changed boreholes, so as to guarantee the accuracy and precision of boreholes. During the survey, the project department shall hold on to field quality management and formulate a series of field management system and specific measures for quality control. Drilling quality control group shall be set up specially and technician with survey experience shall be allocated for on-site inspection and supervision; quality inspection card shall be filled in for each borehole and unqualified ones shall be done again; rock core photos are taken for all the boreholes and written documents are provided for the field inspectors to approve and sign.

See Table 2-1 for the actual completed quantity in the survey.

Table 2-1 Table of Geological Survey Quantity of Jamaica South-North Highway

No.	Item	Work content	Unit	Completed quantity	Remarks
1	Engineering geologic surveying and mapping	1:10000 charting	km^2	50.0	
		1:2000 charting	km^2	20.4	
2	Drilling	Machine drilling	m/hole	2460.82/138	
		Excavation	m/hole	9.7/7	
3	In-situ test	Heavy dynamic penetration test (DPT)	Times	57	

No.	Item	Work content	Unit	Completed quantity	Remarks
		Standard penetration test (SPT)	Times	197	
4	Laboratory test	Undisturbed sample	Group	202	
		Disturbed sample	Group	55	
5	Physical prospecting	Electric method	km	13.149	
		Seismic method	km	2.811	

3 Physical Geographic and Engineering Geological Conditions

3.1 Geographic Position and Traffic Conditions

The south section of the route goes basically along the A1 Highway, and it passes plains, hills, low mountains and basins. The overall traffic conditions are good except in Section K13-K17+500 and Section K18+800-K19+400, where there are only paths which are far from the route and the farthest point is about 1km away. The construction is of great difficulty. The north section extends basically along the original A1 Highway to the north and the road network is developed well in the project area. The road grade is low but the traffic conditions are good.

3.2 Meteorology and Hydrology

The island of Jamaica has a tropical rainy climate and the temperature differences in four seasons and between day and night are small. The annual average air temperature is 26℃; the maximum annual average air temperature is 31℃; the minimum annual average air temperature is 21.7℃. From July to September, it is high temperature season and the air temperature is 30-34.5℃ with the maximum up to 36-37℃; the full year can be divided into two dry seasons (from June to July and from November to April in the following year) and two rainy seasons (in May and from August to October); the annual average rainfall capacity is about 2,000mm.

The river that has a close correlation with the South-North Highway route is Rio Cobre River, whose overall length is 50.9km. The river has many sources which converge at BOG WALK; then it passes the gorge between BOG WALK and Spain Town and runs to the Caribbean Sea in northwest of Kingston Harbor. The river intersects with the south section of the South-North Highway. The surface rivers develop poor in the north of the route and only brooks are found among the mountains. Karst funnels are developed in the section from the starting point of this section to K62 and the atmospheric precipitation converges in the karst funnels through brooks. Most of the rainfalls run into underground rivers and small lakes are formed because of blockage in some of the funnels.

3.3 Topography Landform

Based on the topography characteristics and structural framework, the route is divided into the following five landform areas: sea-alluvial plain (Area ①), tectonic corrosion and denudation hilly area (Area ②), alluvial plain (Area ③), tectonic corrosion and denudation low mountain area (Area ④) and alluvial basin and tiny hillock area (Area⑤). The north section is totally in tectonic corrosion and denudation hilly area.

(1) Sea-alluvial plain (Area ①)

It mainly exists in the section from the starting point to K2+450, and there is about 100m around K3+700. This section has a smooth terrain and a low topography; the elevation is generally 7-10m; the underground water level is high. The strata of the route area are mainly sand layer and clay layer. The subgrade shall be strengthened since there is soft soil in the upper part of the clay layer. Seismic liquefaction occurs easily in the sand layer and it shall be handled properly also. The engineering geological conditions are poor in this area (see Fig. 3-1 for the landform).

(2) Tectonic corrosion and denudation hilly area (Area ②)

In the south section: It exists mainly in K2+450-K10+200 section, where the overall topographic relief is large and the terrain is smooth in some parts, the elevation is about 20m-150m. The overburden layer is about 1-5m and the lithological character is red brown clay or limestone gravelly soil. The lithological character of the underlayer is gray limestone group in the Tertiary. Scarps and deposits at the foot slope are developed. The bedrock is buried shallow and the surface corrosion is developed. Small karst funnels are developed on the right sides of section K4+900 and section K8+280. The engineering geological conditions in this area are relatively good and attention shall be paid to karst.

In the north section: the terrain is relatively smooth in the section from the starting point of the north section to K46+800 and Section K52+800-K59; the elevation from the starting point to Section K46+800 is about 340-360m and the surface is covered by the Quaternary alluvial layer; the Tertiary limestone exposes in some parts. The elevation in Section K52+800-K59 is about 400-480m and the surface is covered by the Quaternary which is thick in the low-lying parts; the slope overburden layer is thin, being about 0.5-1.0m; the Tertiary limestone exposes in some parts. In other sections, the terrain is relatively steep with an elevation of about 360-480m; the covering layer is thin, being about 0.5m; the Tertiary limestone exposes in some parts; the terrain generally decreases to the sea level from K61 to the terminal point. See Fig. 3-2 and 3-3.

(3) Alluvial plain (Area ③)

It mainly exists in Section K10+200-K12+000, the route goes along basically the Rio Cobre River at the edge of the alluvial plain; the right side is not far from hills. The terrain is smooth and the elevation is about 39-55m. The drilling exposes a thick overburden layer which is mainly alluvial clay soil and sand gravel; the clay layer is basically hard plastic and is in good conditions. The bedrock is buried shallow in some parts, which is gray limestone group in the Tertiary layer. The engineering geological conditions are relatively common (Fig. 3-4).

(4) Tectonic corrosion and denudation low mountain area (Area ④)

The route enters low mountain area gradually from K12+000 and extends to K21+200. The overall terrain is undulating and the topography is steep; the elevation near the route is about 60-500m with deep cutting. The overburden layer is thin and the lithological character is red-brown red clay. The lithological character of the underlayer is gray limestone group in the Tertiary layer. Scarps and deposits at the footslope are developed. The bedrock is buried shallow; the surface corrosion is developed greatly; the karst and peak cluster landform are developed. The terrain is smooth for some parts in Section K16+500-K18+700 and the overburden layer is relatively thick. There are karst funnels here; large karst funnels are formed near K16+680; small karst funnels are formed near K17+900. Affected by extrusion fault, the rock is fragmental in Section K18+300-K20+100; breccias limestone can be seen in the exposed side of the bedrock; the cementation is general and karst is developed weakly. The integrity and continuity of the bedrock is generally good and it is in favorable stability for excavation; but the excavation slope rate shall be controlled. There are many high fills and deep excavation parts in this section and the engineering geological conditions are good. Attention shall be paid to karst and excavation slope rate (Fig. 3-5).

(5) Alluvial basin and tiny hillock area (Area ⑤)

The line goes into basin and tiny hillock area from K21+200 to the terminal point of the south section. It is a basin surrounded by mountains and the topography is smooth; near Linstead town (Section K23+600-K25+600), it is rolling terrain and the terrain is undulating but smooth in general. The covering layer is thick in the basin; the overburden layer in the tiny hillock area varies greatly and the bedrock exposes in some parts. The overburden layer is alluvial clay formed long before and it is hard plastic and solid in general. The mechanical property of the clay in valley area of the river and in low-lying places is poor; the expansibility of the clay layer is at moderate and strong level; the exposed bedrock is gray limestone group in the Tertiary layer. The engineering geological conditions in this area are ordinary (Fig. 3-6).

Fig. 3-1 Sea-Alluvial Plain

Fig. 3-2 Tectonic Corrosion and Denudation Hilly Area A

Fig. 3-3 Tectonic Corrosion and Denudation Hilly Area B

Fig. 3-4 Alluvial Plain

Fig. 3-5 Tectonic Corrosion and Denudation Low Mountain Area

Fig. 3-6 Alluvial Basin and Rolling Terrain

3.4 Formation Lithology

The exposed bedrocks in the section are mainly gray limestone in the Tertiary and the surface part is covered by the Quaternary. It is explained in a sequence from old to new as follows:

In the south section:

(1) The Tertiary (E)

It is distributed all along the route; the color is gray, including pale yellow limestone in some parts; fossils are contained; the diagenetic degree is uneven and the strength is uneven; it is soft rock or relatively soft rock in general; karst is developed and dissolved pores and fissures are developed.

I. Etc

It is distributed mainly in Section K16+900-K18+300; the color is gray, including light red limestone in some parts; the crystallization is even and dolomite is included in some parts; the rock is hard and corrosion is developed.

II. Mn

It is distributed mainly from K18+300 to the terminal point of the south section; the color is gray, including pale yellow limestone in some parts; the diagenetic degree is uneven and the strength is uneven. It is relatively soft rock generally and impurities are included in some parts which are soft rocks; corrosion is developed and it is poorly developed in some parts.

(2) The Quaternary (Q)

The Quaternary is widely distributed in the route area. It is caused mainly by sea-alluvial, alluvial or eluvial deposits.

I. Sea-alluvial area

It is mainly distributed at the sea-alluvial plain at the beginning point; it is mainly clay layer and sand layer; the surface ground is plastic clay layer; 6m underneath is soft plastic peat soil with a thickness of 0-3m which changes greatly; the soil property is soft with large void ratio; there are underlying clay layer and sand layer. The engineering properties are poor.

II. Alluvial area

It is distributed mainly in the alluvial plain, basin and tiny hillock; it is generally thick and the thickness varies little in tiny hillock area. In Section K10+200-K12+000, it is yellowish-brown clay, including a bit of sand layer; the clay layer is generally hard plastic; it has no expansibility or the expansibility is weak; the mechanical properties are ordinary. In the Section from K21+200 to the terminal point of south section, it is mainly stripe clay soil in red-brown or gray or yellowish-brown clay; it is hard plastic and solid; and the conditions run poor in river valley and low-lying areas; the expansibility of the soil is at moderate or strong level; slope treatment is required for the excavation and it shall not be used as roadbed fill materials. Alluvial secondary red clay layers also exist in karst funnels and low-lying areas in limestone area; it is relatively thick and the red clay has a hard surface layer; the moisture content becomes high near the bedrock surface and the soil mass becomes soft. Treatment measures shall be taken when the route passes this section.

III. Eluvial area

It is distributed mainly at the foot of mountains. The project is in limestone area and the eluvial soil layers are mainly red clay; the thickness is generally small but it changes greatly. When the fill subgrade passes, uneven sedimentation may occur; it shall be eliminated before filling the roadbed.

In the north section:

(1) The Tertiary (E)

I. Owb

It is mainly distributed in the section from the starting point of north section to K60+300; it is white limestone group and the color is white, including impurities; the diagenetic degree is uneven; it is product by cementation of calcium powder and limestone gravels (concretion form); the cementation degree is poor. The rock cores in the boreholes is fragmental with limestone gravels; it is soft rock or relatively soft rock generally; corrosion is developed and dissolved pores and fissures are developed in rock cores; there are karst caves in some parts and there are karst funnels in the surface ground.

II. Mm

It is mainly distributed in Section K60+300-K65+650; it is white limestone group; it is gray marl and the rock cementation is poor; the consolidation is also poor and it softens when meeting with water. It belongs to extremely soft rock and soft rock; corrosion is poorly developed; the dissolved pores and fissures are rare and there are no karst funnels developed in the surface ground.

III. Mp

It is mainly distributed in the section from K65+650 to the terminal point of the north section, it is gray coastal limestone; the lithology is pure and the crystallization and consolidation degree is good; the diagenetic degree is uneven in some parts. The rock cores in boreholes are stumpy and fragmental with scraps; the lithology is relatively soft rock or relatively hard rock. Corrosion is developed, and dissolved pores and fissures are developed in rock cores. There are karst caves in some parts.

(2) The Quaternary (Q)

The Quaternary is widely distributed in the route area. It is mainly alluvial and eluvial red clay.

I. Alluvial area

There are alluvial secondary red clay layer in the karst funnels and low-lying areas in the limestone mountains area. It is relatively thick and the surface layer of red clay is hard; when the drainage conditions are poor, the moisture content near the surface of bedrock becomes high and the soil mass softens. Treatment measures shall be taken when the route passes.

II. Eluvial area

It is mainly distributed at the foot of mountains. It is in limestone mountain area, and the eluvial soil layers are mainly red clay; the thickness is small and it changes greatly; when the fill subgrade passes, uneven sedimentation may occur and it shall be eliminated before filling the roadbed.

3.5 Regional Tectonics

The tectonic landform characteristics are formed by the intersection between the east-west fault in sinistral direction and the northwest-southeast trend plate. The series of plates contribute to three non-slip tectonic landform units, namely, the Blue Mountain, Clarence and Hanover block, which are formed through the coverage of limestone in the Tertiary period and volcanic derivatives in the cretaceous period.

In the project, there are two faults that have great influence on the south section, namely, F13 and F14. F13 is reverse fault pressed by extrusion; the rock mass is gravel limestone in Section K18+300-K20+100; the cementation is ordinary and the karst is developed poorly. The integrity and continuity in the bedrock is good and it is stable for excavation; but the excavation slope rate shall be controlled. F14 is normal fault; the formation of the basin in front of the mountain is related to the fault.

Faults are developed in the north section. Affected by the faults, large quantity of tectonic fissures are formed in the limestone; large quantity of karst funnels are formed affected by a long time of corrosion and base level of erosion; underground rivers connect the karst funnels and discharge the water flow to the northern Caribbean Sea.

3.6 Hydrogeological Conditions

The surface waters are developed in the south section, including Rio Cobre River and its branches. The route goes basically along the Rio Cobre River. The Rio Cobre River runs all the year round; since it is mountain stream, the flow is greatly affected by the precipitation; the flow is large in rainy season and it reduces greatly in dry season. However, since the karst water converges constantly from the limestone mountains and the catchment area is large, the river keeps running all the year round.

The surface water in the north section is developed poorly. Only some seasonal brooks are found in the valley and some lakes are formed by the blockage of water penetration channels in several karst funnels. There are no other waters that keep running all the year round.

3.6.1 Groundwater Type

Based on the differences of occurrence conditions and hydrodynamic characteristics of groundwater in different rock groups, the groundwater in the route area is divided into pore water in the Quaternary loose rocks and karst water in carbonate rocks. The water characteristics are as follows:

(1) Pore water in the Quaternary loose rock

It has three subclasses. The first subclass is distributed in the Quaternary loose rocks in the gully and at the foot of slope zone, most of which are pore water; the water-content rock formation is sand

and gravel layer and eluvial gravel soil; it is mainly dependent on the atmospheric precipitation recharge and the buried depth of groundwater is shallow; it is affected greatly by the topographic conditions; the water yield is small and it has great seasonal fluctuations. The second subclass is pore water in the Quaternary loose rocks distributed on both sides of the river valleys; it is supplied by karst water and affected by Rio Cobre River. The third subclass is the pore water in the Quaternary loose rocks; its underground water level is higher than the sea level and it is affected by the recharge of karst waters from surrounding limestone rock mass.

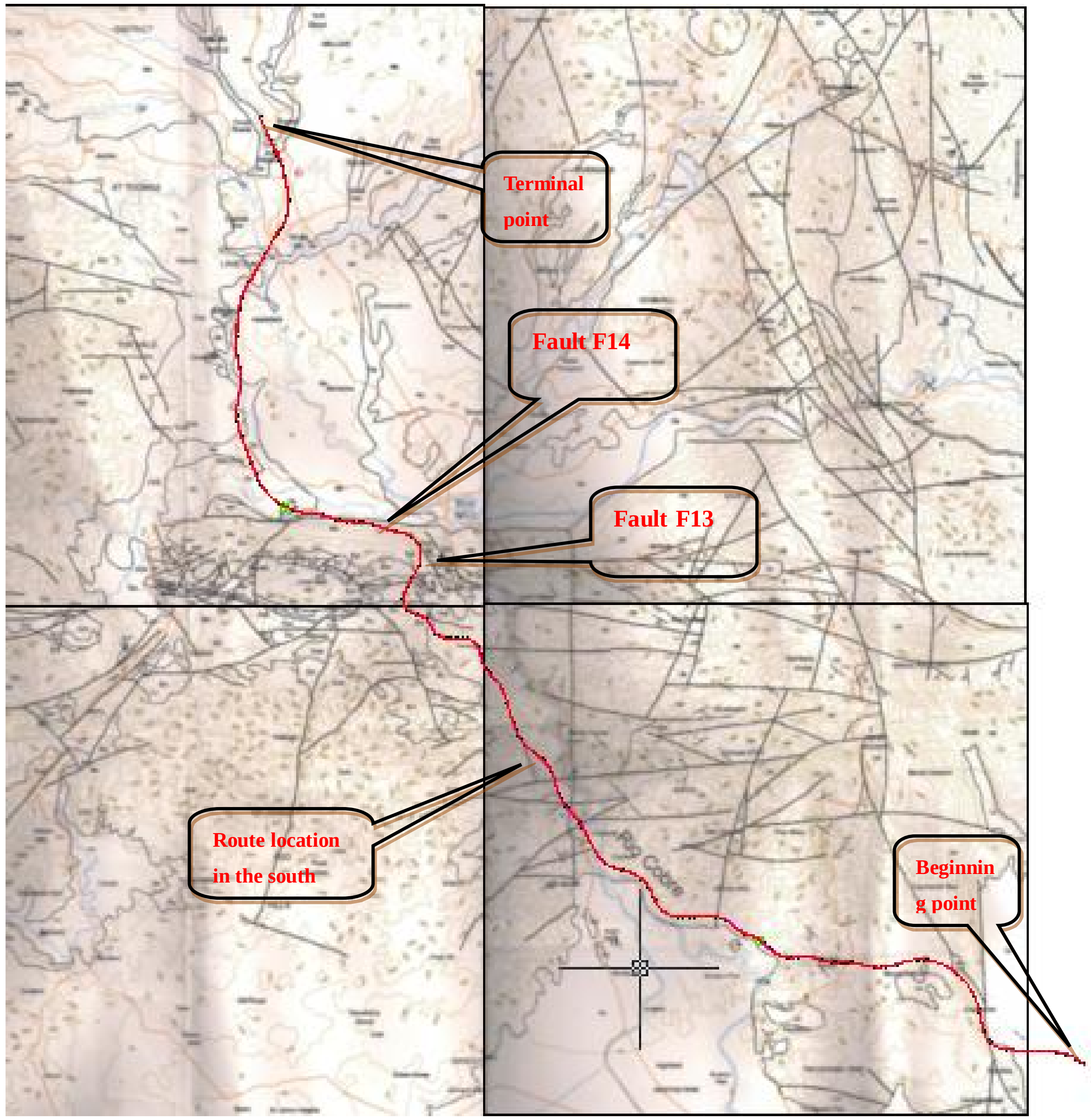


Fig. 3-7 Tectonic Map of the South Section of Jamaica South-North Highway

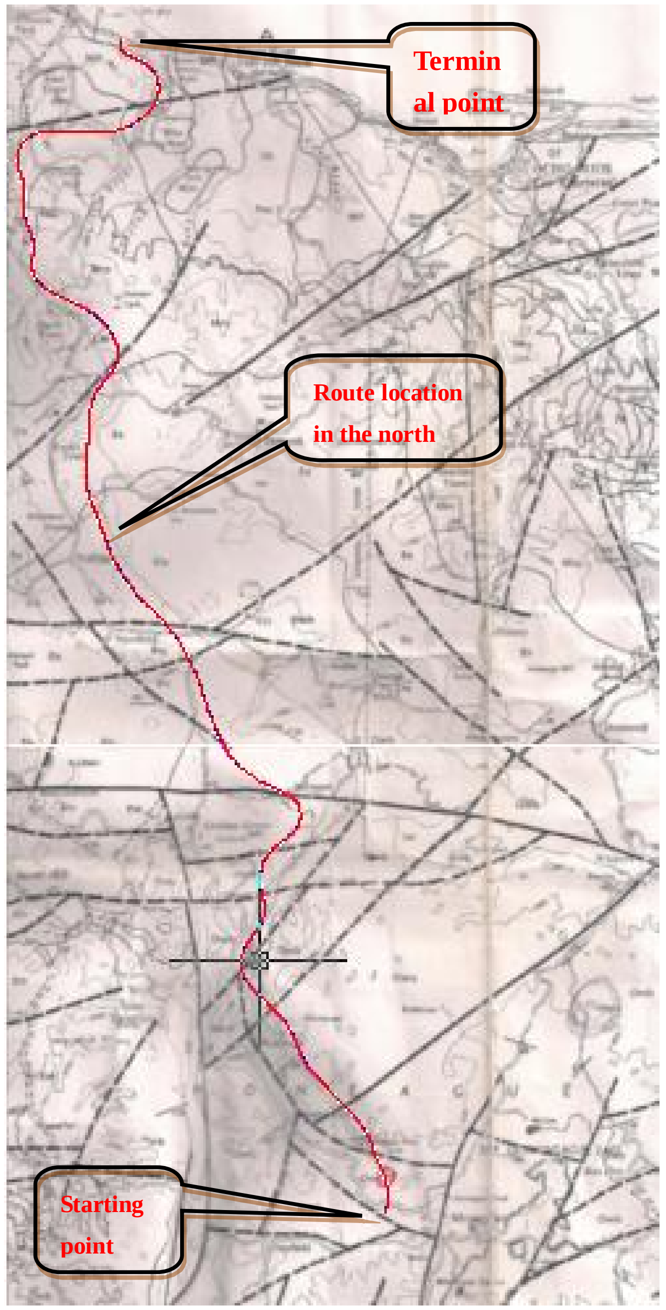


Fig. 3-8 Tectonic map of the north section of the Jamaica South-North Highway

(2) Karst water in carbonate rocks.

Since carbonate rocks layer are distributed widely in the area. Affected by the tectonic characteristics, the rock masses are fragmental and corrosion is developed. Most of the surface waters converge in the karren, karst trough or karst funnels after atmospheric precipitation and transform into groundwater. The water yield property is moderate. The groundwater is in vertical circulation zone and there are corrosion phenomena in different degrees along the joint plane. When the corrosion is strong, fissures and karst caves are formed; then irregular karst fissures are formed as “channels”; the groundwater flow enjoys a broad channel.

3.6.2 Groundwater Recharge, Runoff and Discharge

The groundwater in the south section mainly comes from atmospheric precipitation recharge; the runoff is mainly vertical movement; the main discharge method is that the spring water flows to the river valley and then to the ocean. The karst water in carbonate rocks is supplied by the atmospheric precipitation and moves in vertical direction; the runoff has a long way to go. The runoff of pore water in loose rocks has a short way to go and it is discharged mainly into the valleys and rivers nearby. The route passes two wells. One is 1# well, which is about 10m away from K25+725 on the right and 700 feet deep, with a pump output of 2,626 gallon/minute; it draws water all the day and has a history of 30 years. The other is 2# well, which is 35m away from K25+910 on the left and 660 feet deep, with a pump output of 2,626 gallon/minute; it draws water all the day and has a history of 30 years.

The groundwater of the north section mainly comes from the atmospheric precipitation; the main discharge method is that the karst waters converge into the underground rivers and run to the northern Caribbean Sea.

3.7 Unfavorable Geology and Special Rock and Soil

The unfavorable geology and special rock and soil in the route including karst, collapsed accumulation body and seismic liquefaction; the special rock and soil is expansive soil, soft soil and red clay.

(1) Karst

Limestone is widely distributed along the route; the water yield property is moderate or strong and karst is developed in general. The surface corrosion phenomena in the south section mainly include karrens, karst troughs and karst buds; there are karst funnels in K4+900, K8+280, K16+680 and K17+900; there are mainly karst caves underground; there are no underground rivers developed according to the survey. The foundation bearing stratum of the structures shall has a thick enough roof; attention shall be paid to the underground hollows for the fill subgrade. The surface corrosion phenomena in the north section mainly include karrens, karst troughs, karst buds and karst funnels; karst funnels are developed in the section from the starting point to K62; mainly karst caves and underground rivers are underground karst. The foundation bearing stratum of the structures shall has a thick enough roof; attention shall be paid to the underground hollows for the fill subgrade.


Fig. 3-9 Karst Funnels at K8+280


Fig. 3-10 Karst Funnels at K16+680

(2)Collapsed accumulation body

A collapsed accumulation body is developed in Section K20+700-K21+100. The route passes this period by excavation, and the maximum excavation height on the left side is 22m. According to field survey and borehole data, the overburden layer of the accumulation body is thin, being about 1-8m; it is mainly colluvial silty clay and gravelly soil; there is no groundwater in the boreholes. Gray limestone in the Tertiary underlies; corrosion is developed; but there are no karst caves. The accumulation body is stable at present, and the route passes in form of cutting; the maximum excavation height is 22m; it is excavated to the bedrock and is focused on the upper part of the body. The collapsed excavation body has no impact on the stability of the excavation.

(3) Seismic liquefaction

The starting part of the south section is sea-alluvial plain; there are silty soil and sandy soil in the layer, which are in saturated state. Under seismic oscillation conditions, liquefaction phenomenon may occur. However, since the route passes the edge of the sea-alluvial plain where the sandy soil is distributed unevenly, the seismic liquefaction degree is weak and is unevenly distributed. See Table 3-1 for the seismic liquefaction characteristics of the boreholes in the section from the starting point to K3+800.

Table 3-1 Seismic Liquefaction Judgment of Boreholes in the Section from the Starting Point of South Section to K3+800 (Seismic acceleration is considered to be 0.20g)

Borehole	Layer for liquefaction judgment	Seismic liquefaction judgment
BH98	③fine sand; ④gravelly sand; ⑧coarse sand	Liquefaction

BH99	②fine sand; ③gravelly sand; ⑥fine sand;⑧coarse sand	Liquefaction
BH100	②fine sand; ③gravelly sand; ⑥fine sand; ⑧medium sand	No liquefaction
BH103	①silty soil; ②medium sand	Liquefaction

There is no seismic liquefaction in other sections.

(4)Expansive soil

Expansive soil exists in three areas. One is the section from the starting point of the south section to K2+400; the hard plastic clay underlying the sandy soil layer has strong expansibility; but there is no condition for alteration of wetting and drying and swell-shrink deformation since the underground water level is high. The expansibility of the hard plastic clay has no impact on the sedimentation deformation and stability of the bedrock since this part of the route is fill. The second one is the clay layer at the interflow of Angels (silty soil has no expansibility); it has weak or moderate expansibility; there is no groundwater exposed in the survey and the subgrade is fill. There is no condition for alteration of wetting and drying for the clay layer if the drainage is well done, so the clay layer needs no treatment. The third one is the section from K21+200 (in the front of broken chainage) to the terminal point of the south section; it is alluvial basin and tiny hillock; brown clay and stripe clay in fuchsia mingled with gray are widely distributed; the viscosity of the clay is strong; thick liquid is produced in the boreholes. The test result shows that it is high liquid limit clay and the expansibility is moderate or strong. The underground water level varies greatly and floods may occur in rainy season; there are conditions for alteration of wetting and drying and swell-shrink deformation may occur. It is required that the clay layer shall be mixed with ashes or gravels before compacting and filling, and drainage protection shall be conducted; vegetation protection is also required for clay layer surface and a smooth slope is required for the excavation section of the road. See Table 3-2 for the expansibility of the clay layer in this section.

Table 3-2 Statistical Table of the Expansibility of Clay Layer in the Section from Section K21+200 (in front of broken chainage) to the Terminal Point of South Section

Soil layer	Statistical classification	Free swelling ratio δef (%)	Conclusion of expansibility
①Clay (stripe of fuchsia mingled with gray)	Number of samples	35	Moderate-Strong
	Maximum	115	
	Minimum	44	
	Mean	74.8	
	Standard deviation	18.2	
	Correction factor	1.07	
	Standard value	80.1	
②Clay (brown)	Number of samples	34	Moderate-Strong
	Maximum	115	
	Minimum	46	
	Mean	76.2	
	Standard deviation	17.2	
	Correction factor	1.07	
	Standard value	81.3	

There are only sporadic expansibilities in the clay layer in other sections and the expansibility is weak. It needs no treatment on the subgrade clay layer if the drainage is well done.

(5)Soft soil

The starting section is sea-alluvial plain. There is a layer of brown clay above the grayish-green clay layer. It is soft plastic and in some parts it is plastic; but the moisture content and compression coefficient are both low and they reach the soft soil standard basically. The boreholes show that the burial depth scope are respectively 3.8-5.9m in BH98; 4.6-6.0m in BH99; 3.0-4.0m in BH103; the layer wedges out in BH100. The bearing capacity norm of this layer is low and strengthening treatment is required before subgrade filling.

(6) Red clay

Since the project area is in a hot and humid climate, red clays are formed easily by laterization in the limestone distribution area. This type of clay soil is developed in tectonic corrosion and denudation hilly landform and tectonic corrosion and denudation low mountain landform. The thickness of red clay distributed on the surface of bedrock or weathering front is determined by the bedrock relief or the thickness of weathering layer; when the karrens, karst troughs and karst buds are developed in underlying bedrock, there is a great variation of thickness of the overlying red clay and the distribution is uneven. If the drainage conditions are poor, the moisture content in the red clay close to the bedrock becomes high and the mechanical property becomes poor.

3.8 Seismic Resistance Design Parameter and Seismic Effect

Located at Greater Antilles archipelago, Jamaica Island is a curved seismic zone with frequent seismic activities in Caribbean Sea. According to the Jamaica OAS distribution figure of seismic dangerous degrees, in any cycle of 50 years, the probability of Magnitude VII earthquake is over 10%. According to history, Magnitude VIII earthquakes have happened for many times during the past 350 years since 1667, which has brought about large losses (Table 3-3). According to the Jamaica seismic parameters, the basic seismic intensity is Degree IX; the seismic motion peak acceleration of the south section is 0.275g-0.3g, and that of the north section is 0.25g~0.275g.

Table 3-3 Seismic Influence in the History of Jamaica

Year	Date	The largest intensity	Local influences	Consequent losses
1667	--	VIII	--	Landslide
1688	March 1	VII	Port Royal	Ships and houses damages
1692	July 7	XX	Port Royal, Kingston	3,000 deaths; collapse of buildings; liquefaction, subsidence and landslide of sand
1771	September 3	VII、	Port Royal, Kingston	Ships and houses damages
1812	November 11	VIII	Kingston	Several deaths; fence down, damages to buildings
1824	April 10	VII	Kingston, Spanish town, Catherine Morgan, Old Harbor	Down of some houses
1839	November 5	VII	Montego Bay, St. James	Damages to government buildings
1907	January 14	IX	Kingston, Port Royal	1000 deaths, most of the buildings collapse; water pipe broke, landslides and falling; local tsunami
1914	August 3	VII	Eastern Jamaica	Buildings damages
1943	July 15	VII	Elizabeth St.	landslides
1957	March 1	VIII	Montego Bay, St.James	Four deaths, landslide; damages to bridges, break of poles and wires
1993	January 13	VII	Kingston, St. Andrew	Two deaths; structure damages
2005	June 12	VII	Center Jamaica	Damages to a large amount of structures

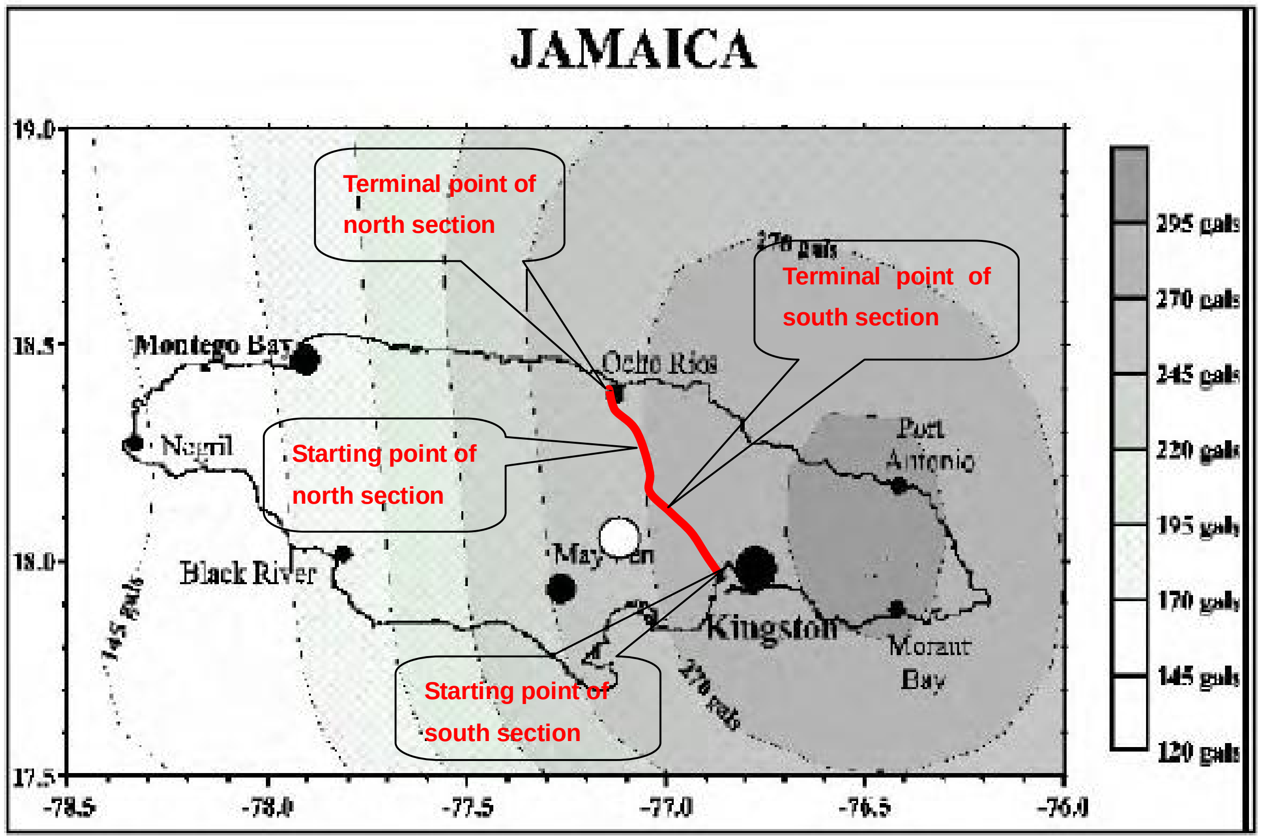


Figure 4-48 - Horizontal ground acceleration with 10% probability of exceedence in fifty years (Shepherd et al. 1999 in CDMP 2001), Contour interval is 25 gals (2.5%g). Modified from CDMP 2001. White spot is location of the Rio Cobre Gorge bypass

Fig. 3-11 Jamaica Seismic Parameters

4 Engineering Geological Rock Group

According to such factors as geological structure within the area, lithology characteristics and physical mechanics properties, the project area can be divided into two engineering geological rock groups: semi-rigid carbonate engineering geological rock group and loose rock engineering geological rock group.

(1) Semi-rigid carbonate engineering geological rock group

Rock group at the south section is mainly the Tertiary formation; its lithology is mainly gray white limestone, interbedded with pale yellow limestone locally. The rock mass is uneven in diagenetic degree and strength. Besides, corresponding rocks are generally soft rocks or relatively soft rocks. On the contrary, with relatively even diagenetic degree and crystallization degree, limestone of Etc rock group belongs to relatively hard rocks. Karst landform is developed; it is developed weakly only in brecciated limestone in Section K18+300-K20+100. Rock groups at the north section are mainly the Tertiary limestone formations with the following main lithologies: ① Owb white limestone group, gray white, containing impurities, uneven diagenetic degree, overall soft-relatively soft; ② Mm white limestone group, marls, gray white, relatively weak cementation and consolidation, easy to be softened by water, belonging to extremely soft rock-soft rock; ③ Mp coastal limestone group, gray white, relatively pure, relatively good crystallization and consolidation degree, uneven in diagenetic degree partially. Most of Karst develops and karst landform is developed. Karst corrosion is developed weakly only in Section K60+300-K65+650. There is hidden karst.

(2) Loose rock engineering geological rock group

It can be divided into three subgroups. The first subgroup is formed because of sea alluviation, and it is mainly distributed in the sea alluvial plain at the starting point. Layers here are relatively even, being mainly clay layer and sand layer. The surface is plastic clay layer. The soft plastic peat soil layer lies 6m beneath the surface with a thickness of 0-3m, characterized by relatively large changes, soft oil and large void ratio. Clay layer and sand layer lie beneath the above soft plastic peat soil layer. The above subgroup is of weak engineering properties. The second subgroup is formed because of flood alluvial, and it is mainly distributed in alluvial plains and tiny hillocks. The subgroup is generally thick, and the thickness changes largely in tiny hillock area. In Section K10+200-K12+000, it is mainly yellowish-brown clay layer, interbedded with a few sand layers. The clay layer is generally hard plastic, and it has nearly no expansibility or common mechanical properties. The section from K21+200 to the terminal point of the south section is dominated by clay of red brown interbedded with gray white stripes color and yellowish-brown color. The above clay is hard plastic or hard and its condition becomes weak in low-lying places. The expansibility of The soil mass is medium to strong. The secondary alluvial red clay also exists in karst funnel or local low-lying places at limestone mountain area. The red clay layer is relatively thick, and it is of hard surface layer. When approaching the surface of bedrock, moisture becomes high, and soil mass becomes soft. The last subgroup is formed because of eluviation, and it is mainly distributed in foothills. The project is limestone mountain area. The eluvial soil layer is dominated by red clay, which is of relatively small thickness wholly but changes largely in The thickness.

5 Engineering Geological Evaluation

The engineering geological conditions at the south route can be evaluated in sections as follows：

(1) From the starting point of the south section to K2+450

The section belongs to sea alluvial plain area in terms of landform. The terrain is gentle and the stratum is covered by the Quaternary sea alluvial overburden layer. There is a layer of yellowish-brown clay lying above the gray green clay in the stratum. The yellowish-brown clay is in the state of soft plastic, and it is plastic locally. However, with relatively low coefficient of moisture and compression, it basically meets the standard of soft soil. Besides, sand layer is universally exposed by The yellowish-brown clay. Underground water and surface water are developed in the section; seasonal small rivers can be seen here. The route is fill embankment, which has a largest height of 8.5 meters in the center fill. With several culvert channels, the route does not have such structural matter as bridge. Corresponding treatment shall be conducted for strata facing such issues as soft soil layer and vibration liquefaction in sand before filling the subgrade. Overall, the section is low in subgrade bearing capacity and weak in engineering geological properties.

(2) Section K2+450-K10+200

Landform of the section belongs to tectonic corrosion and denudation hilly area. With an overall steep terrain, the section is relatively gentle in local low-lying places. The overburden layer is the Quaternary eluvial red clay layer, characterized by overall thin layer, largely-changed thickness and large-amount exposed bedrock. There is clay layer in low-lying places, which is relatively thick. The overburden layer is of general mechanical properties. The underlying bedrock is the Tertiary limestone group (E). The diagenetic degree and strength of limestone is uneven, and its overall strength is relatively soft in overall strength, owing to which, it can serve as foundation bearing stratum. Limestone corrosion is developed strongly in the section; karst corrosion landform is also developed. Dissolved fissures and pores are common in rock cores, but karst caves are seldom. The geological survey reveals that relatively large karst caves have been developed near K8+280, and small type karst funnels have been found near K4+900. There are no bridges but several highly-filled and deeply-excavated road sections in the section. With relatively good integrity, the bedrock has relatively good excavation stability on the premise that slope rate can be controlled. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure is not influenced by settling differences resulting from the poor compaction of the soil layer.

The micro landform in Section K2+450-K2+750 and Section K3+600-K3+800 belong to sea alluvial plain, but since above sections are near mountain foot, their soft soil layers and sand layers may become thin. The subgrade of The section belongs to fill, and corresponding treatment method may refer to that from the starting point to K2+450.

(3) Section K10+200-K12+000

Landform of this section belongs to flood alluvial plain, and the route is basically along Rio Cobre River, which is located at the border of the alluvial plain. Terrain here is relatively gentle, and the corresponding elevation is generally 39-55m. The overburden layer exposed by drilling is relatively thick, which is mainly clay layer and sand and gravel stratum. However, the clay layer here is hard plastic with relatively good condition, which is of relatively high silt content, and little or weak expansibility; the sand stratum here is likely to produce seismic motion liquefaction, which shall be properly handled; the overburden layer of the section crossing over Rio Cobre River along the route is relatively thin; the bedrock belongs to the Tertiary limestone group (E) with relatively soft rock wholly, which has developed karst corrosion and karst caves. A large bridge crosses over Rio Cobre River at K11+605, and it is planned to adopt bored cast-in-place pile. Weathered limestone can be chosen for pile foundation bearing stratum, attention shall be paid to the thickness of limestone roof of the pile end bearing stratum; besides, there are two bridges linked to each other at Angles, namely, Angels mainline bridge at K10+270 and Angels A ramp bridge at AK0+945. The bridge foundation program for the above bridges is the same as that for the bridge crossing over Rio Cobre River. Filling shall be conducted for other sections, added with little excavation. Conventional treatment shall be conducted for subgrade filling and excavation, without the need for special treatment.

(4) Section K12+000-K16+900

Landform of this section belongs to tectonic corrosion and denudation low mountain area, characterized by steep terrain, relatively steep cutting and large-amount exposed bedrock. The overburden layer is the Quaternary eluvial red clay layer, which is relatively thin generally but changes largely in thickness. The bedrock belongs to the Tertiary limestone group (E); the diagenetic degree and strength of limestone is uneven, and its overall strength is relatively soft, owing to which, it can serve as foundation bearing stratum. Limestone corrosion is developed strongly in this section, with developed karst corrosion landform. Dissolved fissures and pores are common in rock cores, and karst caves exist in some places. Besides, there are small type karst funnels near K16+700. Crescent Railway

Bridge crosses over the railroad at K12+843 along the route, and it is planned to adopt bored cast-in-place pile. Weathered limestone can be chosen for pile foundation bearing stratum, but attention shall be paid to the thickness of limestone roof of the pile end bearing stratum. There are many highly-filled and deeply-excavated road sections; with relatively good integrity, the bedrock has relatively good excavation stability on the premise that slope rate can be controlled. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure is not influenced by settling differences resulting from the poor compaction of the soil layer.

(5) Section K16+900-K18+300

Landform of this section belongs to tectonic corrosion and denudation low mountain area, characterized by steep terrain, relatively steep cutting and exposed bedrock in large amount. The overburden layer is the Quaternary eluvial red clay layer, which is relatively thin generally but has large changes in thickness. The bedrock belongs to the Tertiary limestone group (Etc). The limestone is of the following characteristics: gray white, interbedded with pale red limestone locally, relatively even crystallization, containing dolomite locally, relatively hard rock, developed karst and leaking porehole. Besides, dissolved fissures and pores are common in rock cores, and karst caves exist in some places. There are small type karst funnels near K16+700.There are several highly-filled and deeply-excavated road sections; with good integrity in the whole, the bedrock has relatively good excavation stability on the premise that slope rate can be controlled. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure not be influenced by settling differences resulting from the poor compaction of the soil layer.

(6) Section K18+300-K20+650

Landform of this section belongs to tectonic corrosion and denudation low mountain area, characterized by steep terrain, relatively steep cutting and large-amount exposed bedrock. The overburden layer is the Quaternary eluvial red clay layer, which is relatively thin generally but changes largely in thickness. The bedrock is the Tertiary limestone group (Mn). Influenced by compression structure, most strata are brecciated limestone with general cementation. The above limestone is gray white, interbedded with pale yellow limestone locally, and it is mainly composed of relatively soft rock with a lot of impurities locally, namely, it belongs to soft rock-relatively soft rock; the karst corrosion is developed weakly on the whole; there are no karst caves but only a few dissolved pores and fissures in rock cores. For some sections (see through Poreholes BH54, BH56, BH57 and BH58), the brecciated limestone is interbedded with massive limestone; rock cores are mainly in the form of short column, but a few ones are in the form of chunky. Karst is developed; there are no karst caves but a lot of dissolved fissures and pores. Rocks are relatively hard, and they give crisp sound after being hammered. The section has several highly-filled and deeply-excavated road sections. With general cementation and good integrity, the brecciated limestone is of relatively good excavation stability on the premise that the slope rate is seriously controlled and the protective drainage is properly arranged.

(7) Section K20+650-K21+200

Landform of this section belongs to tectonic corrosion and denudation low mountain area, characterized by steep terrain, relatively steep cutting and large-amount exposed bedrock. The overburden layer is the Quaternary eluvial red clay layer, which is relatively thin generally but changes largely in thickness. The bedrock belongs to the Tertiary limestone group (Mn). The above limestone is gray white, interbedded with pale yellow limestone locally; it is mainly composed of relatively soft rock with a lot of impurities locally, namely, it belongs to soft rock; the karst corrosion is developed wholly; there are a lot of dissolved fissures and pores in rock cores and karst caves exist locally. There are several highly-filled and deeply-excavated road sections; with relatively good integrity, the limestone has relatively good excavation stability on the premise that slope rate can be controlled. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure not be influenced by settling differences resulting from the poor compaction of the soil layer. In particular, there is a collapsed accumulation mass in Section K20+700-K21+100.

(8) Section K21+200-K23+600

Landform of the section belongs to flood alluvial basin, and the terrain is gentle. The basin has relatively thick overburden layer, which is composed of alluvial clay with a long formation age. The overburden layer is in the form of hard plastic-hard wholly, and it is of weak clay mechanical properties at low-lying places; the expansibility of soil mass is medium-strong. The bedrock is deeply buried, belonging to the Tertiary limestone group (Mn). The limestone is gray white, interbedded with pale yellow limestone locally; it is mainly composed of relatively soft rock with a lot of impurities locally, namely, it belongs to soft rock; the karst corrosion develops wholly; there are a lot of dissolved fissures and pores in rock cores and karst caves exist locally. Fill subgrade is conducted for the line. The fill road bed shall not be filled before being compacted, and the underground drainage measures shall be improved to avoid the alternation of wetting and drying, which may make the soil mass experience expansion and contraction, thus influencing the structure of subgrade. The structure is a bridge crossing over the Black River at K21+427, and it is planned to adopt bored cast-in-place pile. Weathered limestone can be chosen for pile foundation bearing stratum, but attention shall be paid to the thickness of limestone roof of the pile end bearing stratum.

(9) Section K23+600-K25+600

Landform of the section belongs to flood alluvial tiny hillock and terrain here is relatively gentle. The overburden layer of tiny hillock changes largely in thickness and the bedrock is exposed locally. The basin has relatively thick overburden layer, which is formed by alluvial clay with a long formation age. The overburden layer is in the form of hard plastic-hard wholly, and it is of weak clay mechanical properties at low-lying places; the expansibility of soil mass is medium-strong. Belonging to the Tertiary limestone group (Mn), the bedrock here undulates largely in surface, and it is exposed locally. The above limestone is gray white, interbedded with pale yellow limestone locally, and it is mainly composed of relatively soft rock with a lot of impurities locally; namely, it belongs to soft rock; the karst corrosion here develops wholly; there are many dissolved fissures and pores in rock cores and karst caves exist in some parts. Fill subgrade is conducted for the line. The fill road bed shall not be filled before being compacted, and the underground drainage measures shall be improved to avoid the alternation of wetting and drying, which may make the soil mass experience expansion and contraction, thus influencing the structure of subgrade. The cutting is shallowly excavated in some places. The excavation face is mainly composed of bedrock and the slope stability is relatively good. Structures are the bridge crossing over the Black River at K26+085 and Vanity Fair Railway Bridge at K26+287, and it is planned to adopt bored cast-in-place pile. Weathered limestone can be chosen for pile foundation bearing stratum, but attention shall be paid to the thickness of limestone roof of the pile end bearing stratum.

(10) From Section K25+600 to the terminal point of south section

Landform of the section belongs to flood alluvial basin and terrain here is gentle. The basin has relatively thick overburden layer, which is formed by alluvial clay with a long formation age. The overburden layer is in the form of hard plastic-hard wholly, and it is of weak clay mechanical properties at valley regions and low-lying places; the expansibility of soil mass is medium-strong. Buried deeply, the bedrock here belongs to the Tertiary limestone group (Mn). The above limestone is gray white, interbedded with pale yellow limestone locally, and it is mainly composed of relatively soft rock wholly with a lot of impurities locally, namely, it belongs to soft rock; the karst corrosion is developed wholly; there are a lot of dissolved fissures and pores in rock cores and karst caves exist locally. Fill subgrade is conducted for the line. The fill road bed shall not be filled before being compacted, and the underground drainage measures shall be improved to avoid the alternation of wetting and drying, which may make the soil mass experience expansion and contraction, thus influencing the structure of subgrade. Structures are the Linstead and Linstead A ramp bridge at AK0+501.711, which are linked to each other, and it is planned to adopt bored cast-in-place pile. Weathered limestone can be chosen for pile foundation bearing stratum, but attention shall be paid to the thickness of limestone roof of the pile end bearing stratum.

The engineering geological conditions at the north route can be evaluated in sections as follows：

(1) From the starting point of north section to K46+800

Landform of the section belongs to structural corrosional hilly area, and the terrain here is smooth in the whole. The overburden layer is the Quaternary flood alluvial red clay layer. It is relatively thick in the whole and its thickness changes largely; the red clay is in the state of hard plastic, with general mechanical properties; the soil mass near the surface of bedrock is in the state of hard plastic, but the underlying soil layer is of weak expansibility locally. The underlying bedrock is the Tertiary limestone group (Qwb). The diagenetic degree and strength of limestone is uneven, and its overall strength is relatively soft in overall strength, owing to which, it can serve as foundation bearing stratum. Limestone corrosion is developed strongly in this section, and dissolved fissures and pores are common in rock cores. Without any bridges, shallow fill and excavation is conducted. The excavation road is of relatively good excavation stability on the premise that the slope rate is controlled. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure is not influenced by settling differences resulting from the poor compaction of the soil layer.

(2) Section K46+800-K52+800

Landform of this section belongs to tectonic corrosion and denudation hilly area. Terrain here is relatively steep wholly, and it is relatively gentle in intermountain depressions. The overburden layer is the Quaternary eluvial red clay layer, characterized by overall thin layer, largely-changed thickness and locally-exposed bedrock. There is clay layer in intermountain depressions, which is relatively thick. The overburden layer is of general mechanical properties. The underlying bedrock is the Tertiary limestone group (Owb). The diagenetic degree and strength of limestone is uneven, and its overall strength is relatively soft in overall strength, owing to which, it can serve as foundation bearing stratum. Limestone corrosion is developed strongly in this section, with developed karst corrosion landform. Dissolved fissures and pores are common in rock cores, but karst caves are seldom. Besides, most of karst caves are filled, and karst funnels are common near the route. There are several small bridges and culverts and highly-filled and deeply-excavated road sections at the section. Weathered limestone can be chosen as foundation bearing stratum, but attention shall be paid to the thickness of limestone roof of the pile end bearing stratum. With relatively good integrity, the bedrock has relatively good excavation stability on the premise that slope rate can be controlled. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure is not influenced by settling differences resulting from the poor compaction of the soil layer; corresponding measures shall be taken when the route approaches some karst funnels.

(3) Section K52+800-K59+000

Landform of the section belongs to tectonic corrosion and denudation hilly area, and terrain here is relatively gentle wholly. The overburden layer is the Quaternary eluvial red clay layer, characterized by overall thin layer, largely-changed thickness and locally-exposed bedrock. There is clay layer in intermountain depressions. The clay layer is in the state of plastic and hard plastic, with general mechanical properties. The moisture of the soil mass near the bedrock surface becomes high, but the underlying soil layer is of weak expansibility. The underlying bedrock is the Tertiary limestone group (Owb). The diagenetic degree and strength of limestone is uneven, and its overall strength is relatively soft in overall strength, owing to which, it can serve as foundation bearing stratum. Limestone corrosion is developed strongly in this section, with developed karst corrosion landform. Dissolved fissures and pores are common in rock cores, but karst caves are seldom. Besides, the karst caves are mostly filled, and karst funnels are common near the route. There are several bridges and culverts and 2 highly-filled road sections in the section. Weathered limestone can be chosen as bridge foundation bearing stratum, but attention shall be paid to the limestone roof thickness of the foundation bearing stratum. With relatively good integrity, the bedrock has relatively good excavation stability on the premise that slope rate can be controlled. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure not be influenced by settling differences resulting from the poor compaction of the soil layer; corresponding measures shall be taken when the route approaches some karst funnels.

(4) Section K59+000-K60+300

Landform of the section belongs to tectonic corrosion and denudation hilly area. Terrain here is relatively steep wholly, and it is relatively gentle in intermountain depressions. The overburden layer is the Quaternary eluvial red clay layer, characterized by overall thin layer, largely-changed thickness and locally-exposed bedrock. There is clay layer in intermountain depressions. The clay layer is in the state of plastic and hard plastic, with general mechanical properties. The underlying bedrock is the Tertiary limestone group (Owb). The diagenetic degree and strength of limestone is uneven, and its overall strength is relatively soft in overall strength, owing to which, it can serve as foundation bearing stratum. Limestone corrosion is developed strongly in this section, with developed karst corrosion landform. . Dissolved fissures and pores are common in rock cores; but karst caves are seldom. Besides, the karst caves are mostly filled, and karst funnels are common near the route. There are several bridges and culverts and 2 highly-filled road sections at the section. Weathered limestone can be chosen for bridge pile foundation bearing stratum, but attention shall be paid to the thickness of limestone roof of the pile end bearing stratum. With relatively good integrity, the bedrock has relatively good excavation stability on the premise that slope rate can be controlled. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure is not influenced by settling differences resulting from the poor compaction of the soil layer; corresponding measures shall be taken when the route approaches some karst funnel.

(5) Section K60+300-K65+650

Landform of the section belongs to tectonic corrosion and denudation hilly area. Terrain here is relatively steep wholly. The overburden layer is the Quaternary eluvial red clay layer, characterized by overall thin layer, largely-changed thickness and locally-exposed bedrock, with general mechanical properties. The underlying bedrock is the Tertiary limestone group (Mm), which belongs to white limestone group., The bedrock is marl with the following characteristics: gray white, relatively weak cementation and consolidation, easy to be softened by water, belonging to extremely soft rock-soft rock; karst corrosion is developed weakly in this section , and dissolved fissures and pores seldom; besides, the development of karst funnel is also seldom in the earth’s surface. There are no bridges but several highly-filled and deeply-excavated road sections at the section. The bedrock here has relatively good integrity, but it is soft and easy to be softened by water. Therefore, when conducting deep cutting excavation, the excavation slope rate shall be seriously controlled within 1:1 and the protective drainage for slope surface shall be arranged timely. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure is not influenced by settling differences resulting from the poor compaction of the soil layer.

(6) From K65+650 to the terminal point of north section

Landform of this section belongs to tectonic corrosion and denudation hilly area. Terrain here is relatively steep wholly, but it is gradually gentle after K66+700. The overburden layer is the Quaternary eluvial red clay layer, characterized by overall thin layer, largely-changed thickness and locally-exposed bedrock, with general mechanical properties. The underlying bedrock is the Tertiary limestone group (Mp), and it belongs to coastal limestone group. With the color of gray white, the limestone is mostly pure, and it is of relatively good crystallization and consolation degree, but the corresponding diagenetic degree is uneven partially. Rock cores of poreholes are mostly in the form of short column or chunky interbedded with scraps, and they belong to relatively soft rock-relatively hard rock. Karst corrosion is developed in this section, with developed dissolved fissures and pores in rock cores, and karst caves exist in some places. There are neither bridges nor highly-filled and deeply-excavated road sections.

6 Conclusions and Suggestions

(1) The engineering geological conditions, hydrogeological conditions and engineering geological characteristics of the route program for the project have been ascertained through the geological survey work conducted in this stage, which has provided necessary and sufficient geological bases for the choice of route program and laid foundations for the design of construction map.

(2) Landforms of the project area can be divided into five landform areas: sea alluvial plain area (Area ①), tectonic corrosion and denudation hilly area (Area ②), alluvial plain area (Area ③), tectonic corrosion and denudation low mountain area (Area ④) and alluvial basin and tiny hillock area (Area ⑤). The stratum of the project area is the Tertiary gray white limestone, and the surface is the Quaternary overburden layer. The project area is divided into two engineering geological rock groups: semi-rigid carbonate engineering geological rock group and loose rock engineering geological group.

(3) Defective geological phenomena in the road section are as follows: karst corrosion (development of karst funnels), collapsed accumulation mass and seismic liquefaction. Special rock and soil include expansive soil, soft soil and red clay.

(4) The underground water is divided into two types: loose rock pore water and carbonate rock karst water.

(5) According to the Jamaica seismic parameters, the basic seismic intensity within the project area is Degree IX; the seismic motion acceleration of the south section is 0.275g-0.3g, and that of the north section is 0.25g-0.275g.

(6) There are two faults with relatively large influence on south section, namely, Fault F13 and F14, among which, the Fault F13 is a reverse fault, influenced by compression, and the rock mass of Section K18+300-K20+100 is brecciated limestone. Fault F14 is a normal fault, which is related to the formation of piedmont basin. Faults are developed in the north section under the influence of structure, and a large amount of karst funnels are developed in the limestone area under the influence of fault.

(7) The structure forms of route include fill subgrade, excavation cutting and bridges and culverts. As for fill subgrade, special attention shall be paid to the section of karst funnel, and corresponding measures shall be taken to avoid the collapse of subgrade; besides, corresponding measures shall be taken to treat the soft soil and subgrade of sand liquefaction at the starting section. The excavation of cutting is basically the excavation of the bedrock of limestone, the stability of which can be basically maintained on the premise that the excavation slope rate is controlled. With general cementation but relatively good integrity, the brecciated limestone has relatively good excavation stability on the premise that the slope rate is seriously controlled and the protective drainage is properly arranged. As strongly-weathered marl rock is easy to be softened by water, the excavation slope rate of corresponding cutting excavation shall be controlled within 1:1, and drainage protective measures shall be properly taken. When choosing the bedrock of limestone as foundation bearing stratum for bridge pile foundation, and special attention shall be paid to the corrosion situation of pile limestone, so as to form a thick enough roof.

Engineering Geological Investigation Report for Caymanas Interchange Ramp A crossing Mandela Bridge Project

1 Introduction

1.1 Project Overview

Caymanas interchange ramp A crossing Mandela Bridge is the bridge proposed to be constructed crossing Mandela Road on Caymanas interchange ramp A at the starting point of the north section of Jamaica South-north Highway with basic orientation of bridge alignment being SN. Central chainage No. of the bridge is AK0+487; beginning and ending chainage No. is AK0+459-AK0+515; length of the bridge is 56.0m and the bridge span is 2×28 (hole ×m). Pre-stressed concrete cast-in-situ box girder is adopted in the superstructure, column pier and pile foundation are used in pier of the substructure, while U abutment and pile foundation are applied in the abutment.

1.2 Investigation Method and Workload Completed

Comprehensive investigation method combining geological surveying and mapping, drilling, in-situ test and laboratory test is applied at this investigation stage. Two boreholes are arranged. Field investigation duration is from July 25th to August 4th of 2013. Physical workload completed refers to Table 1-1.

Table 1-1 List of Completed Workload

Item		Unit	Qty	Remarks
Measurement	Coordinate measurement of exploration point	Point /time	2/4	Once for each of the borehole starting and ending points
Engineering geological surveying and mapping	Scale 1:2000	km^2	0.04	
Exploration	Drilling	m/pcs	75.3/2	Mechanical drilling, mud protection, full coring
Sampling and test of rock and soil	Undisturbed sample	pcs	17	
	Disturbed sample	pcs	8	
	Rock sample	pcs	-	
In-situ test	Standard penetration test (SPT)	time	17	
	Dynamic penetration test (DPT)	time	-	
Hydrogeological observation	Ground water level observation	time/hole	4/2	

2 Engineering and Geological Condition

2.1 Topographical & Geological and Traffic Condition

This road section belongs to costal alluvial plain area with flat terrain, favorable highway.

2.2 Stratum Lithology and Characteristics

Known from investigation data, the area is mainly Quaternary costal alluvial overburden layer, which is relatively thick, over the underlying Tertiary limestone. Stratum lithology and characteristics are as follows:

Layer ① silty clay ($Q_4{}^{al+m}$): gray black with russet brown interlayer, wet, soft plastic-malleable, contains organic materials, breccia, shell and etc. The maximum exposed thickness is 1.5m.

Layer ② medium sand ($Q_4{}^{al+m}$): grayish yellow, a little wet, loose-slightly dense, mainly medium sand, filled with coarse sand with thin layer of silty clay. Maximum exposed thickness of borehole is 3.3m.

Layer ③ silty clay ($Q_4{}^{al+m}$): russet brown, soft plastic, can be rubbed into stripe manually, contains thin layer of silt and siltstone. Maximum exposed thickness of borehole is 2.2m and locally thin-out.

Layer ④ clay ($Q_4{}^{al+m}$): grayish green with russet brown interlayer, hard plastic, can be easily rubbed into stripe manually, high dry strength, with thin sandy soil, locally contains relatively high content of silt particles, facies changes to silty clay. Maximum exposed thickness of borehole is 3.5m.

Layer ⑤ medium sand (Q_4 $^{al+m}$): grayish yellow, saturated, loose-slightly dense, mainly medium sand, with coarse sand and a small amount of roundstone filled, mixed with thin layer of silty clay. Locally facies changes to coarse sand. Maximum exposed thickness of borehole is 1.8m.

Layer ⑥ clay (Q_4 $^{al+m}$): grayish green with russet brown interlayer, hard plastic, can be easily rubbed into stripe manually, relatively high dry strength, mixed with thin layer of sandy soil. Maximum exposed thickness of borehole is 2.3m.

Lay ⑦ silty clay (Q_4 $^{al+m}$): russet brown mixed with fine stripe of light grey, hard plastic, smooth section, can be easily rubbed into stripe manually, relatively high dry strength, mixed with thin sand and a small amount of roundstone. Maximum exposed thickness of borehole is 21.6m.

Layer ⑧ medium sand (Q_4 $^{al+m}$): grayish yellow, saturated, dense, mainly medium sand, filled with coarse sand and a small amount of roundstone, mixed with thin layer of silty clay. It is not exposed in BH115 and js locally thinning-out.

Layer ⑨ medium weathered limestone (E): only exposed in borehole BH113, offwhite, microcrystalline texture, massive structure. Fissures develop relatively well. The rock cores are relatively fragmental and stumpy and are of fragmental structure with small amount of columnar ones. Corrosion develops well with small dissolving pores and no exposed karst cave. When hammering the rock, it makes a crispy sound. Thickness of the layer is 2.9m.

Layer ⑩ karst cave: only exposed in borehole BH113, fully filled, with no drill dropping. The filling is russet brown cohesive soil mixed with limestone gravel.

Layer ⑾ medium weathered limestone (E): only exposed in borehole BH113, offwhite, microcrystalline texture, diagenetic degree of the rock is uneven, strength is uneven, general lithology is soft. Fissures develop well, and the rock cores are most fragmentized and fragmental and rubbly. Corrosion and small dissolving pores develop well with no karst cave exposed. When hammering the rock, it makes a hollow sound. Thickness of the layer is 4.4m and it is not exposed.

2.3 Geological Structure

The area is Quaternary costal alluvial overburden layer with no obvious structural phenomenon.

2.4 Hydrogeological Condition

Development of surface water in the area is poor with small rivers and channels. By combining the topographical and geological conditions along the alignment and basing on data of this investigation and regional hydrogeological data, comprehensive analysis and judgment can be made that, groundwater of the overburden layer in this road section develop, which is infiltrated water found in all of the boreholes and fed by infiltration of atmospheric precipitation and karst fissure water from the nearby mountains.

2.5 Seismic Design Parameter

Referring to seismic parameter map of Jamaica, the basic seismic intensity is Scale IX and the peak ground acceleration is 0.275g ~0.3g.

2.6 Unfavorable Geology and Particular Rock and Soil

The unfavorable geology of the area is mainly seismic-induced liquefaction and karst. Considering the ground motion acceleration of 0.30g, the liquefaction judgment results are as follows: medium sand seismic-induced liquefaction occurs in Layer ② and Layer ⑤ of borehole BH98 and BH99, no medium sand liquefaction occurs in Layer ⑧. Underlying Tertiary limestone corrosion develops well; fully filled karst cave is exposed in borehole BH113. Particular rock and soil in the area is mainly soft soil, silty clay of Layer ① and ③ is soft plastic with poor mechanical properties.

3 Mechanical Index of the Stratum and Engineering Geological Assessment

Table 3-1 Suggested Value of Stratum Mechanical Index

Stratum sequence	Name of stratum	Status	Allowable bearing capacity of foundation [fao]（kPa）	Recommended frictional resistant qik（kPa）
①	Silty clay	Soft plastic - malleable	Omitted	Omitted
②	Medium sand	Loose- slightly dense	150	10
③	Silty clay	Soft plastic	Omitted	Omitted
④	Clay	Hard plastic	350-400	65-70
⑤	Medium sand	Loose- slightly dense	150	15
⑥	Clay	Hard plastic	390	70
⑦	Silty clay	Hard plastic	350	65
⑧	Medium sand	Dense	410	65
⑨	Medium weathered limestone	Relatively fragmental	2000	400
⑩	karst cave	Fully filled	Omitted	Omitted
⑾	Medium weathered limestone	Most fragmental	600	120

Note: empirical values are provided for gravelly soil and trial values for other soil.

4. Engineering Geological Assessment of Bridge Site, Pier and Abutment

4.1 Geological Environmental Stability and Suitability Assessment of the Bridge Site

The bridge site is stable with karst and is suitable for bridge construction.

4.2 Engineering Geological Assessment of Pier and Abutment

(1) Abutment

Strata at abutments of the two banks are mainly cohesive soil mixed with sand layer, cohesive soil of the surface layer is of soft plastic-malleable status with poor mechanical properties; cohesive soil of the lower layer is of hard plastic-hard status with common mechanical properties. Friction pile foundation and using hard plastic- hard cohesive soil as bearing stratum are suggested to be applied in abutment foundation.

(2) Pier

It is concluded that strata at pier are the same of that at abutment, so friction pile foundation is recommended to be adopted in the foundation with hard plastic- hard cohesive soil being used as bearing stratum.

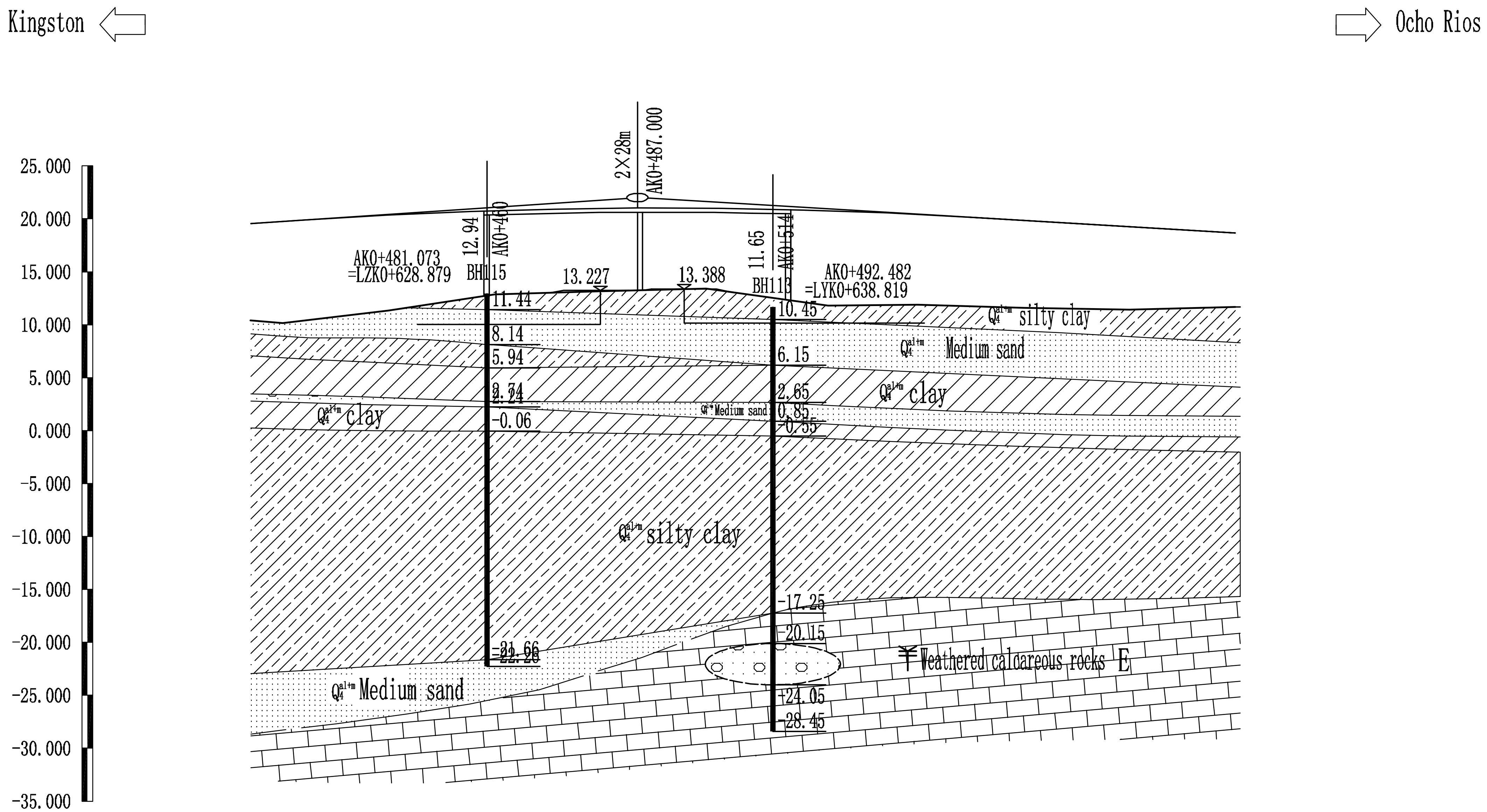
5. Conclusion and Suggestion

(1) Geological condition in the bridge site is stable with no fault or collapse being observed.

(2) Overburden layer in the bridge site is relatively thick with surface soil layer of poor mechanical properties; mechanical properties of the lower soil layer are relatively good. Underlying limestone karst develops well.

(3) Abutment foundation is suggested to adopt pile foundation and use hard plastic-hard cohesive soil as bearing stratum.

1
1



垂直比例尺 1:500
水平比例尺 1:1000

Ground elevation	10.16	11.35	12.86	13.17	13.40	11.82	11.90	11.57	11.41	11.67
Mileage stake number	AK0+420.000	AK0+440.000	AK0+460.000	AK0+480.000	AK0+500.000	AK0+520.000	AK0+540.000	AK0+560.000	AK0+580.000	AK0+600.000

Jamaica North-South Highway Project	Caymanas Interconnected Mandela Bridge Vertical Sectional View of Engineering Geology	Prepared by	李攀	Checked by	[signature]	Verified by	[signature]	Approved by	[signature]	DWG No.	S-2	Page 1 of 1

Project Name Caymanas Interconnected Mandela bridge **Position of Borehole** AK0+514 **Date of Commence** 2013.07.25

No. of Borehole BH113 **Orifice Elevation** 11.65 **Date of Completion** 2013.07.29

Coordinates of Borehole X=650663.693 Y=760308.189

Scale of Columnar Section 1:300

Depth of Layer (m) from	Depth of Layer (m) to	Thickness of Layer (m)	Elevation of Layer Bottom (m)	Cause & Age of Formation	Description of Rock (Soil) Layer	Groundwater Level Elevation (m)	Status or Density	Water Content or Humidity	Basic allowable value	Recommended friction
0.00	1.20	1.20	10.45	Q_4^{al+m}	Silty clay:gray black with yellow brown,wet,soft plastic,containing iron-manganese and breccia shells.		soft plastic			
1.20	5.50	4.30	6.15		Medium sand: gray yellow,loose, slightly wet - saturated,mainly medium sands, containing little fine sands with thin silty clay.	6.85	loose	slightly wet ~saturated	150	10
5.50	9.00	3.50	2.65		Clay:gray blue with yellow brown,hard plastic, can be shaped into bars with hands,with high dry strength,and thin sand soil.		hard plastic	21.3%	350	65
9.00	10.80	1.80	0.85		Medium sand: gray yellow,loose, saturated, mainly medium sands, containing gravels and pebbles with thin silty clay.		loose	saturated	150	15
10.80	12.20	1.40	-0.55		Clay:gray blue with yellow brown,hard plastic,can be shaped into bars with hands,with high dry strength,and thin sand soil.		hard plastic	19.8%	400	70
12.20	28.90	16.70	-17.25		Silty clay:yellow brown,hard plastic,with smooth sections;can be shaped into bars with hands,with high dry strength,and thin sand soil.		hard plastic	22.3%	350	65
28.90	31.80	2.90	-20.15	E	calcareous rocks: gray white with microcrystalline texture and block formation.Fissure is developed slightly, and rock cores are broken, like column and crushed stones .Corrosion is developed , with small holes and fissures，without karst caves.The sound is clear when they are hammered. RQD=55% and the recovery rate is approx. 80%.		broken slightly		2000	400
31.80	35.70	3.90	-24.05		Karst cave: Fully filled without omission of drilling. Filled with yellow brown clay, calcareous pebbles and cobbles.		karst cave		略	略
35.70	40.10	4.40	-28.45	E	calcareous rocks: gray white with microcrystalline texture The diagenesis degree and strength are not even. Rocks are generally soft.Fissure is developed and rock cores are broken, like crushed stones and clastic scraps.Corrosion is developed , with small holes and fissures，without karst caves. The sound is stuffy when they are hammered. RQD=0% and the recovery rate is approx. 75%.		extremely broken		600	120

Sampling No.	Depth of Bore
1	1.3~1.5
2	4.8~5
3	6.5~6.7
4	9~9.2
5	12~12.2
6	14.4~14.6
7	16.4~16.6
8	19.9~20.1
9	23.6~23.8
10	25.7~25.9
11	27.5~27.7

SPT / DPT	Depth of Bore
4	1.50
4	5.00
13	6.70
8	9.20
19	12.20
18	16.60
32	23.80
31	27.70

Project Name Caymanas Interconnected Mandela bridge **Position of Borehole** AK0+460 **Date of Commence** 2013.08.02

No. of Borehole BH115 **Orifice Elevation** 12.94 **Date of Completion** 2013.08.04

Coordinates of Borehole X=650661.779 Y=760361.995

Scale of Columnar Section 1:200

Depth of Layer (m) from	Depth of Layer (m) to	Thickness of Layer (m)	Elevation of Layer Bottom (m)	Cause & Age of Formation	Description of Rock (Soil) Layer	Groundwater Level Elevation (m)	Status or Density	Water Content or Humidity	Basic allowable value	Recommended friction
0.00	1.50	1.50	11.44	Q_4^{al+m}	Silty clay:yellow brown with gray black, wet, plastic,containing organic matter and fine sand.		plastic			
1.50	4.80	3.30	8.14		Medium sand: gray yellow,loose-slightly dense, slightly wet,mainly medium sands, containing coarse sand with thin silty clay.		loose~ slightly sense	slightly wet	200	20
4.80	7.00	2.20	5.94		Silty clay:yellow brown,soft plastic,can be shaped into bars with hands,containing thin silty sand and soil.	7.44	soft plastic	27.0%	150	35
7.00	10.20	3.20	2.74		Clay:yellow brown with gray blue ,hard plastic,can be shaped into bars with hands,with high dry strength,and thin sand soil.		hard plastic	18.5%	400	70
10.20	10.70	0.50	2.24		Medium sand: gray yellow,slightly dense, saturated,mainly medium sands, containing gravels and pebbles with thin silty clay.		slightly dense	saturated	330	35
10.70	13.00	2.30	-0.06		Clay:yellow brown with gray blue ,hard plastic, can be shaped into bars with hands,with high dry strength,and thin sand soil.		hard plastic	25.0%	390	75
13.00	34.60	21.60	-21.66		Silty clay:yellow brown with gray blue ,hard plastic,with smooth sections;can be shaped into bars with hands,with high dry strength,and thin sand soil and little cobble.		hard plastic	24.6%	350	65
34.60	35.20	0.60	-22.26		Medium sand: gray yellow,dense, saturated, mainly medium sands, containing gravels and pebbles with thin silty clay.		dense	saturated	410	65

Sampling No.	Depth of Bore
1	1.5~1.7
2	5.2~5.4
3	7.2~7.4
4	9.7~9.9
5	12.6~12.8
6	15~15.2
7	17.3~17.5
8	19.8~20
9	22~22.2
10	24.5~24.7
11	26.5~26.7
12	29~29.2
13	32.6~32.8
14	34.7~34.9

SPT / DPT	Depth of Bore
12	1.70
11	5.40
12	7.40
14	9.90
21	12.80
29	17.50
19	24.70
32	32.80
50	34.90

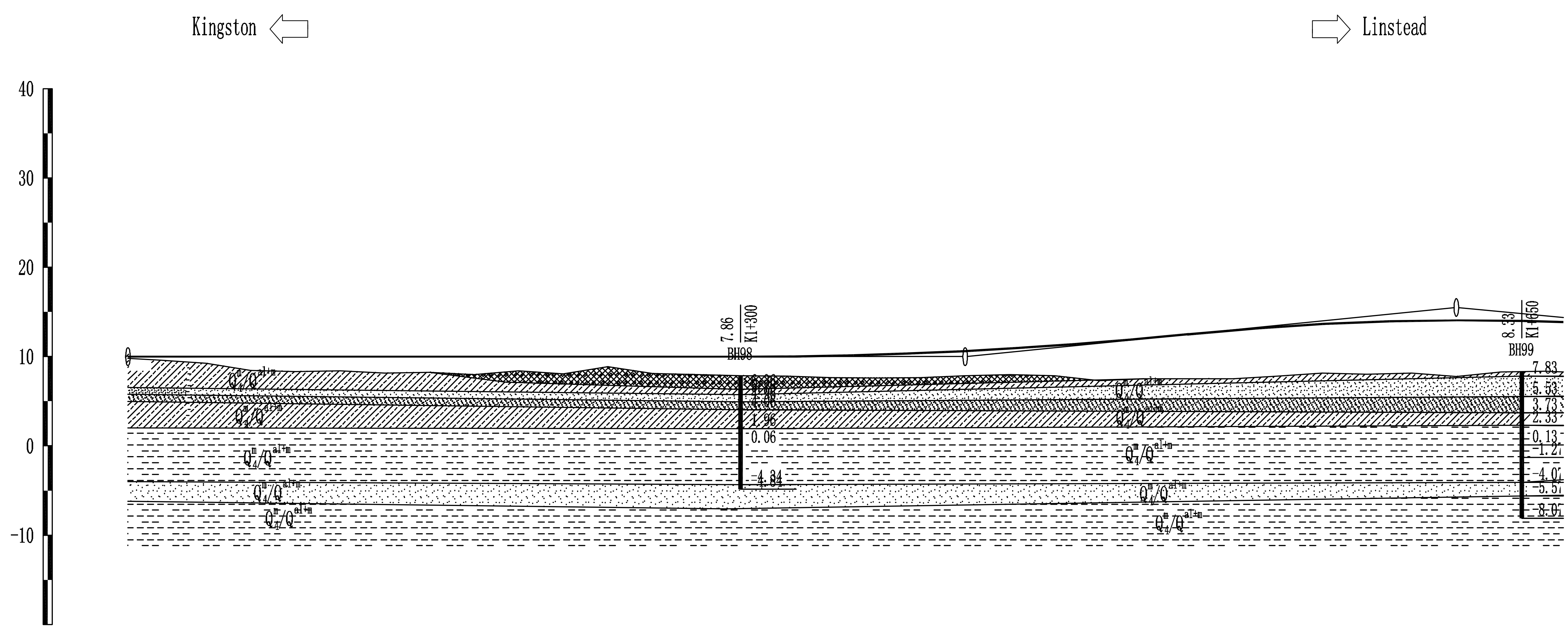
Jamaica North-South Highway Project	Borehole Histogram	Prepared by	李攀	Checked by	[signature]	Verified by	[signature]	Approved by	[signature]	DWG No.	C-3	Page 1 of 1

Borehole No.	Sample No.	Sampling Depth	Station No.	Grain Composition % (mm) 200~20.0	20~2.0	2.0~0.5	0.5~0.25	0.25~0.075	<0.075	2.0~0.075	0.075~0.002	<0.002	Natural Water Content % w	Natural Mass Density g/cm3 ρ	Dry Density g/cm3 ρd	Specific Gravity of Soil Partical G	Natural Void Ratio e	Saturation % Sr	Liquid Limit % LL	Plastic Limit % PL	Plasticity Index PI	Liquidity Index LI	Compressibility Coefficient MPa-1 α0.1-0.2	Compression Modulus MPa Es 0.1-0.2	Quick Shear Test Cohesion KPa C	Quick Shear Test Angle of Internal Friction ° φ	Soaking Quick Shear Cohesion KPa C	Soaking Quick Shear Angle of Internal Friction ° φ	Swelling Test Free Swelling Rate δef %	Swelling Test Load-free Swelling Rate δe %	Denomination of Soil Sample	Notes
BH113	1	1.30~1.50	AK0+514		2.6	11.5	30.3	46.6	9.0																						Fine sand	
	2	4.80~5.00			4.0	38.7	29.9	24.6	2.8																						Medium sand	
	3	6.50~6.70											21.3	1.98	1.63	2.74	0.68	86	37.3	18.7	18.6	0.14	0.16	10.5							Clay	
	4	9.00~9.20				11.7	41.6	36.4	10.3				23.3	1.93	1.57	2.66	0.70	89					0.23	7.3							Medium sand	
	5	12.00~12.20											19.8	2.05	1.71	2.74	0.60	90	38.8	17.5	21.3	0.11	0.12	13.3	124.8	5.4					Clay	
	6	14.40~14.60											25.1	1.92	1.53	2.71	0.77	89	39.1	22.9	16.2	0.14	0.27	6.5	74.7	16.2					Silty clay	
	7	16.40~16.60											24.9	1.91	1.53	2.71	0.77	87	34.2	19.9	14.3	0.35	0.23	7.6	55.7	18.6					Silty clay	
	8	19.90~20.10											22.1	1.95	1.60	2.71	0.70	86	34.5	19.8	14.7	0.16	0.21	8.1	69.7	20.5					Silty clay	
	9	23.60~23.80											23.3	1.95	1.58	2.71	0.71	88	33.6	20.4	13.2	0.22	0.20	8.3	59.5	23.0					Silty clay	
	10	25.70~25.90											17.4	2.11	1.80	2.71	0.51	93	33.0	17.9	15.1	-0.03	0.10	14.9	171.6	16.2					Silty clay	
	11	27.50~27.70											20.8	2.00	1.66	2.71	0.64	89	29.7	18.7	11.0	0.19	0.30	5.3	56.4	13.9					Silty clay	

CCCC Second Highway Consultants Co., Ltd.	**Jamaica H2K Highway Project**	**Summary of Soil Tests for sky bridge**	**Prepared by**		**Checked by**		**Verified by**		**Approved by**		**DWG No.**	**S-4**	**Page 1 of 1**

Borehole No.	Sample No.	Sampling Depth	Station No.	Grain Composition %（mm） 200~20.0	20~2.0	2.0~0.5	0.5~0.25	0.25~0.075	<0.075	2.0~0.075	0.075~0.002	<0.002	Natural Water Content % w	Natural Mass Density g/cm3 ρ	Dry Density g/cm3 ρd	Specific Gravity of Soil Particle G	Natural Void Ratio e	Saturation % Sr	Liquid Limit % LL	Plastic Limit % PL	Plasticity Index PI	Liquidity Index LI	Compressibility Coefficient MPa-1 α0.1-0.2	Compression Modulus MPa Es 0.1-0.2	Quick Shear Test Cohesion KPa C	Quick Shear Test Angle of Internal Friction ° φ	Soaking Quick Shear Cohesion KPa C	Soaking Quick Shear Angle of Internal Friction ° φ	Swelling Test Free Swelling Rate δef %	Swelling Test Load-free Swelling Rate δe %	Denomination of Soil Sample	Notes
BH115	1	1.50~1.70	AK0+460	6.8	12.3	41.4	29.0	9.2	1.3																						Coarse sand	
	2	5.20~5.40											27.0	1.88	1.48	2.71	0.83	88	27.9	17.6	10.3	0.91	0.45	3.9	1.9	12.5					Silty clay	
	3	7.20~7.40											18.5	2.04	1.72	2.74	0.59	86	36.0	18.1	17.9	0.02	0.22	7.0	76.6	17.6					Clay	
	4	9.70~9.90				4.5	20.7	52.7	22.1				26.5	1.92	1.52	2.66	0.75	94					0.26	6.7							Fine sand	
	5	12.60~12.80											25.0	1.97	1.58	2.74	0.74	93	50.0	27.3	22.7	-0.10	0.15	11.7	135.5	20.8					Clay	
	6	15.00~15.20											28.5	2.03	1.58	2.71	0.72	100	33.5	20.0	13.5	0.63	0.29	5.9	68.4	16.6					Silty clay	
	7	17.30~17.50			14.3	54.0	17.6	9.5	4.6																						Coarse sand	
	8	19.80~20.00											20.7	2.02	1.67	2.71	0.62	91	29.0	17.7	11.3	0.27	0.19	8.6	69.0	10.1					Silty clay	
	9	22.00~22.20											26.0	1.94	1.54	2.74	0.78	91	45.6	28.0	17.6	-0.11	0.29	6.1	72.8	17.6					Clay	
	10	24.50~24.70											21.5	1.99	1.64	2.74	0.67	88	46.6	26.4	20.2	-0.24	0.16	10.2	147.6	11.8					Clay	
	11	26.50~26.70											26.1	1.94	1.54	2.71	0.76	93	33.9	21.8	12.1	0.36	0.19	9.0	65.2	20.8					Silty clay	
	12	29.00~29.20			8.9	12.0	16.0	45.4	17.7				22.8	1.91	1.56	2.66	0.71	85													Fine sand	
	13	32.60~32.80											26.7	1.92	1.52	2.74	0.81	91	44.7	26.7	18.0	0.00	0.20	8.7	46.9	8.3					Clay	
	14	34.70~34.90			1.6	18.0	34.8	30.5	15.1				20.6	1.97	1.63	2.66	0.63	87					0.26	6.1							Medium sand	

CCCC Second Highway Consultants Co., Ltd.	**Jamaica H2K Highway Project**	**Summary of Soil Tests for lower bridge**	**Prepared by**		**Checked by**		**Verified by**		**Approved by**		**DWG No.**	**S-4**	**Page 1 of 1**



Vertical scale 1:500

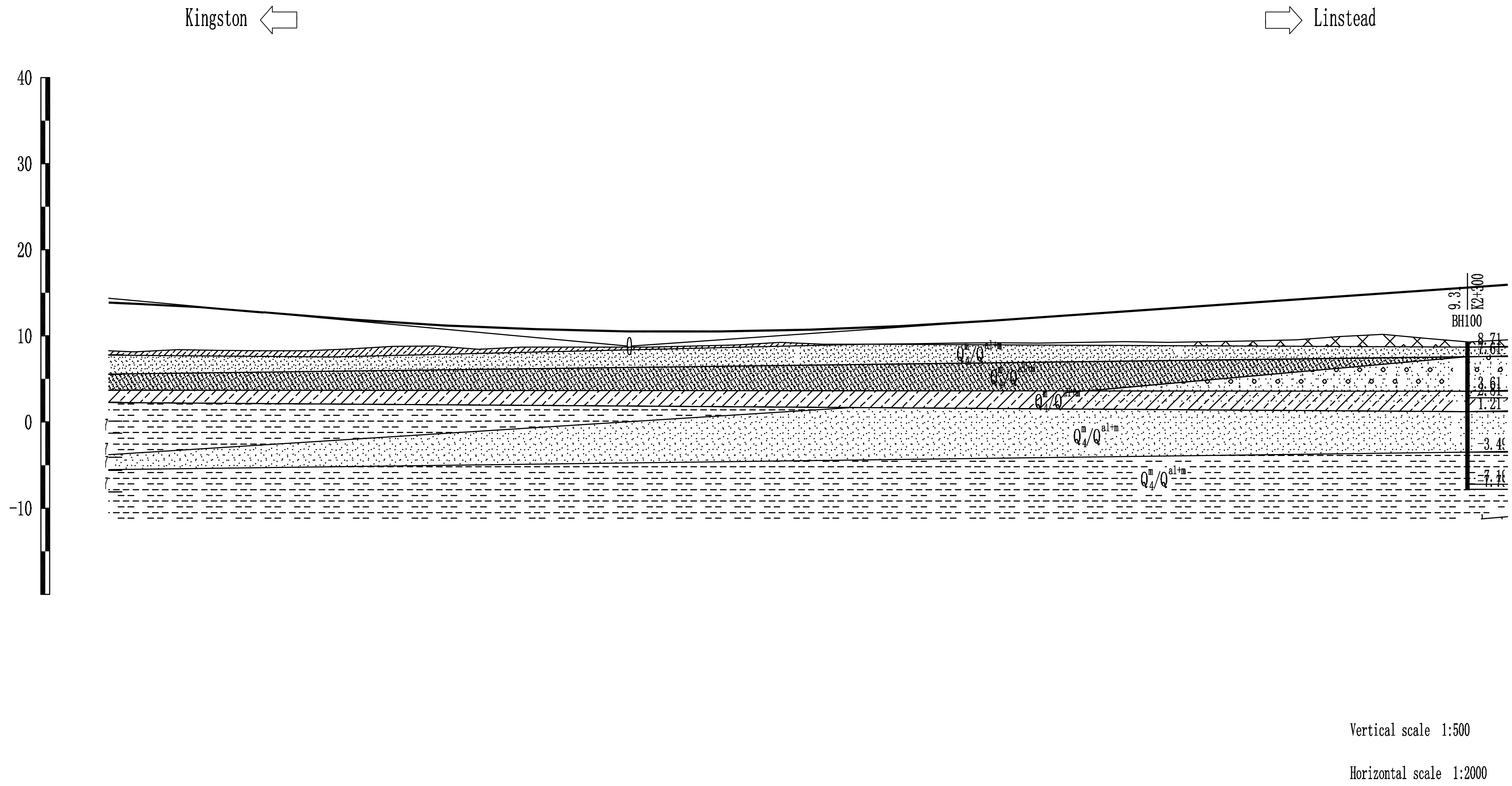
Horizontal scale 1:2000

Ground elevation	9.81	9.58	9.27	8.46	8.34	8.42	8.18	8.26	8.01	8.39	8.06	8.88	8.11	8.01	7.86	7.81	7.64	7.63	7.65	7.86	7.97	7.87	7.30	7.54	7.52	7.51	7.80	8.16	8.01	8.18	7.79	8.29	8.37
Mileage stake number	+024.966	+040.000	+060.000	+080.000	+100.000	+120.000	+140.000	+160.000	+180.000	+200.000	+220.000	+240.000	+260.000	+280.000	+300.000	+320.000	+340.000	+360.000	+380.000	+400.000	+420.000	+440.000	+460.000	+480.000	+500.000	+520.000	+540.000	+560.000	+580.000	+600.000	+620.000	+640.000	+660.000

engineering geological evaluation

The section belongs to sea alluvial plain area in terms of landform. The terrain is gentle and the stratum is covered by the Quaternary sea alluvial overburden layer. There is a layer of yellowish-brown clay lying above the gray green clay in the stratum. The yellowish-brown clay is in the state of soft plastic, and it is plastic locally. However, with relatively low coefficient of moisture and compression, it basically meets the standard of soft soil. Besides, sand layer is universally exposed by The yellowish-brown clay. Underground water and surface water are developed in the section; seasonal small rivers can be seen here. The route is fill embankment, which has a largest height of 8.5 meters in the center fill. With several culvert channels, the route does not have such structural matter as bridge. Corresponding treatment shall be conducted for strata facing such issues as soft soil layer and vibration liquefaction in sand before filling the subgrade. Overall, the section is low in subgrade bearing capacity and weak in engineering geological properties.

Jamaican North-South Highway Project	Engineering geological profile of whole line	Prepared by	李攀	Checked by	禹志呈	Verified by	[illegible]	Approved by	[illegible]	DWG No.	S-2	Page 1 of 76



Ground elevation	8.14	8.43	8.34	8.29	8.27	8.50	8.80	8.83	8.47	8.69	8.71	8.70	8.72	8.84	8.95	9.27	9.04	9.03	9.08	9.17	9.21	9.16	9.26	9.35	9.27	9.36	9.43	9.57	9.95	10.17	9.74	9.31	9.60
Mileage stake number	+680.000	+700.000	+720.000	+740.000	+760.000	+780.000	+800.000	+820.000	+840.000	+860.000	+880.000	+900.000	+920.000	+940.000	+960.000	+980.000	K2	+020.000	+040.000	+060.000	+080.000	+100.000	+120.000	+140.000	+160.000	+180.000	+200.000	+220.000	+240.000	+260.000	+280.000	+300.000	+320.000

engineering geological evaluation	The section belongs to sea alluvial plain area in terms of landform. The terrain is gentle and the stratum is covered by the Quaternary sea alluvial overburden layer. There is a layer of yellowish-brown clay lying above the gray green clay in the stratum. The yellowish-brown clay is in the state of soft plastic, and it is plastic locally. However, with relatively low coefficient of moisture and compression, it basically meets the standard of soft soil. Besides, sand layer is universally exposed by The yellowish-brown clay. Underground water and surface water are developed in the section; seasonal small rivers can be seen here. The route is fill embankment, which has a largest height of 8.5 meters in the center fill. With several culvert channels, the route does not have such structural matter as bridge. Corresponding treatment shall be conducted for strata facing such issues as soft soil layer and vibration liquefaction in sand before filling the subgrade. Overall, the section is low in subgrade bearing capacity and weak in engineering geological properties.

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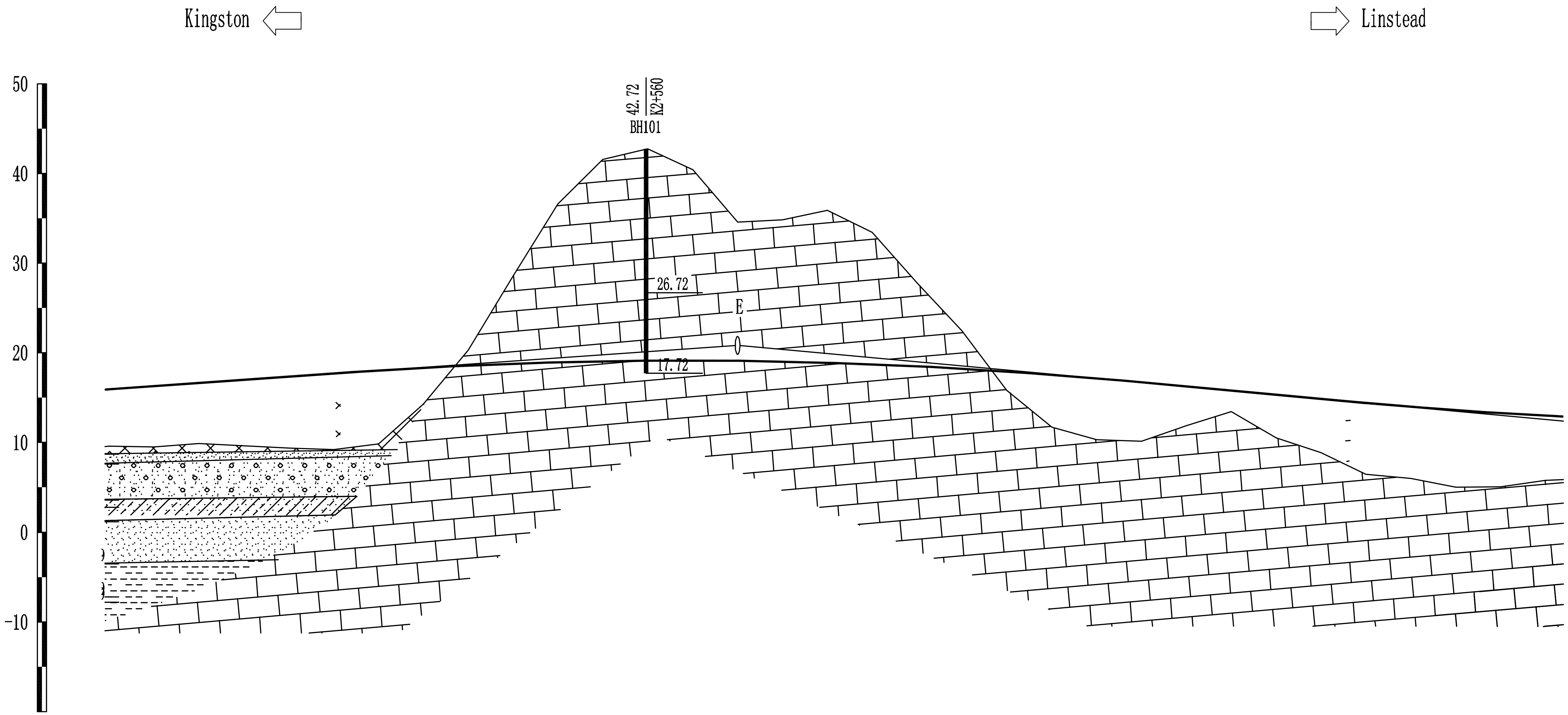

Ground elevation	9.51	9.89	9.67	9.39	9.24	9.86	14.31	20.30	28.58	36.62	41.54	42.72	40.40	34.57	34.82	35.90	33.44	27.81	22.46	15.85	11.70	10.33	10.15	11.88	13.48	10.54	8.88	6.49	6.00	5.03	5.09	5.81
Mileage stake number	+340.000	+360.000	+380.000	+400.000	+420.000	+440.000	+460.000	+480.000	+500.000	+520.000	+540.000	+560.000	+580.000	+600.000	+620.000	+640.000	+660.000	+680.000	+700.000	+720.000	+740.000	+760.000	+780.000	+800.000	+820.000	+840.000	+860.000	+880.000	+900.000	+920.000	+940.000	+960.000

engineering geological evaluation

The section of K2+330～K2+450 and K2+750～K3+000 belong to sea alluvial plain area in terms of landform. The terrain is gentle and the stratum is covered by the Quaternary sea alluvial overburden layer. Underground water and surface water are developed in the section; The route is fill embankment, With several culvert channels, the route does not have such structural matter as bridge. Corresponding treatment shall be conducted for strata facing such issues as soft soil layer and vibration liquefaction in sand before filling the subgrade. Overall, the section is low in subgrade bearing capacity and weak in engineering geological properties.The section of K2+450～K2+750 belong to tectonic corrosion and denudation hilly area. locally-exposed bedrock，The underlying bedrock is the Tertiary limestone group (E). The diagenetic degree and strength of limestone is uneven, and its overall strength is relatively soft in overall strength.With relatively good integrity, the bedrock has relatively good excavation stability on the premise that slope rate can be controlled.

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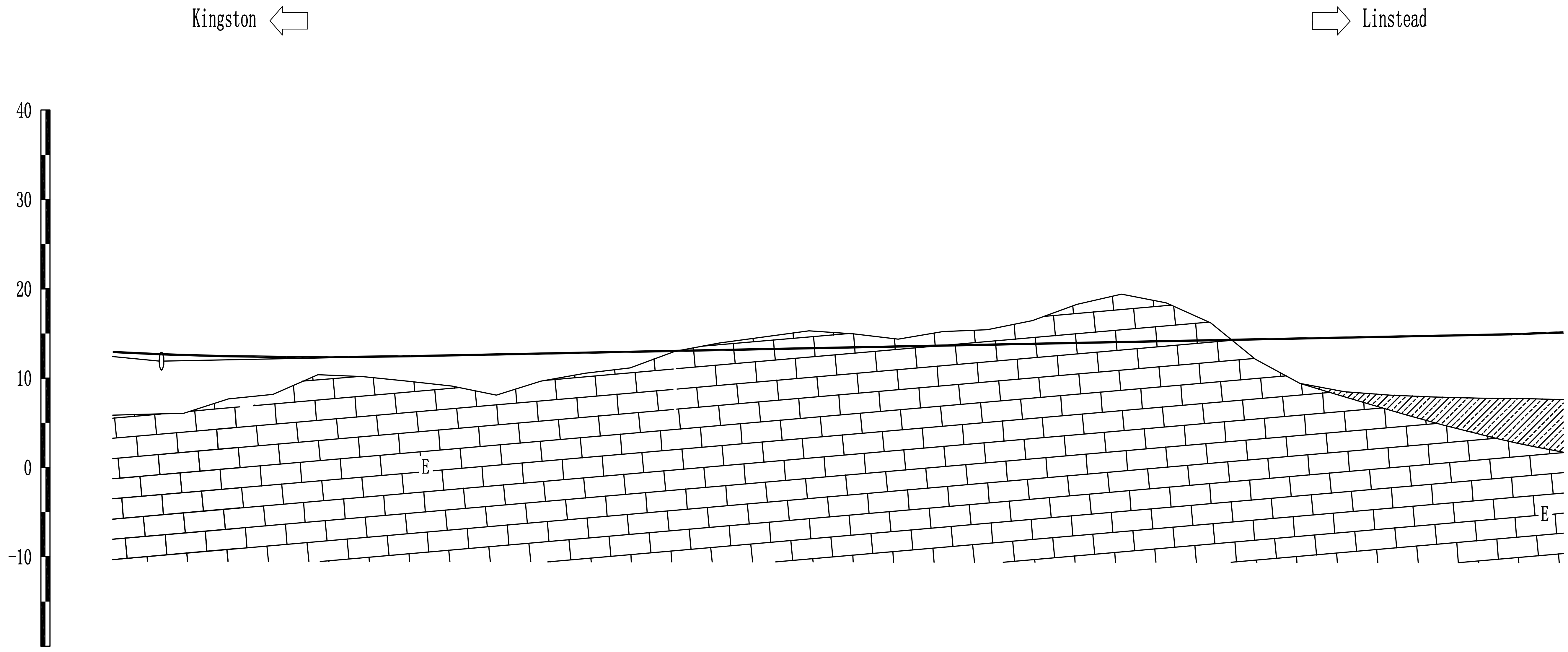

Vertical scale 1:500

Horizontal scale 1:2000

Mileage stake number	+980.000	K3	+020.000	+040.000	+060.000	+080.000	+100.000	+120.000	+140.000	+160.000	+180.000	+200.000	+220.000
Ground elevation	5.95	6.07	7.68	8.19	10.41	10.17	9.69	9.11	8.11	9.69	10.54	11.15	13.03

Mileage stake number	+240.000	+260.000	+280.000	+300.000	+320.000	+340.000	+360.000	+380.000	+400.000	+420.000	+440.000	+460.000	+480.000	+500.000	+520.000	+540.000	+560.000	+580.000	+600.000	+620.000
Ground elevation	13.94	14.61	15.31	14.98	14.35	15.22	15.42	16.46	18.26	19.39	18.42	16.19	12.13	9.41	8.47	8.12	7.91	7.76	7.74	7.57

engineering geological evaluation

The section belongs to sea alluvial plain area in terms of landform. The terrain is gentle and the stratum is covered by the Quaternary sea alluvial overburden layer. There is a layer of yellowish-brown clay lying above the gray green clay in the stratum. The yellowish-brown clay is in the state of soft plastic, and it is plastic locally. However, with relatively low coefficient of moisture and compression, it basically meets the standard of soft soil. Besides, sand layer is universally exposed by The yellowish-brown clay. Underground water and surface water are developed in the section; seasonal small rivers can be seen here. With several culvert channels, the route does not have such structural matter as bridge. Corresponding treatment shall be conducted for strata facing such issues as soft soil layer and vibration liquefaction in sand before filling the subgrade. Overall, the section is low in subgrade bearing capacity and weak in engineering geological properties.

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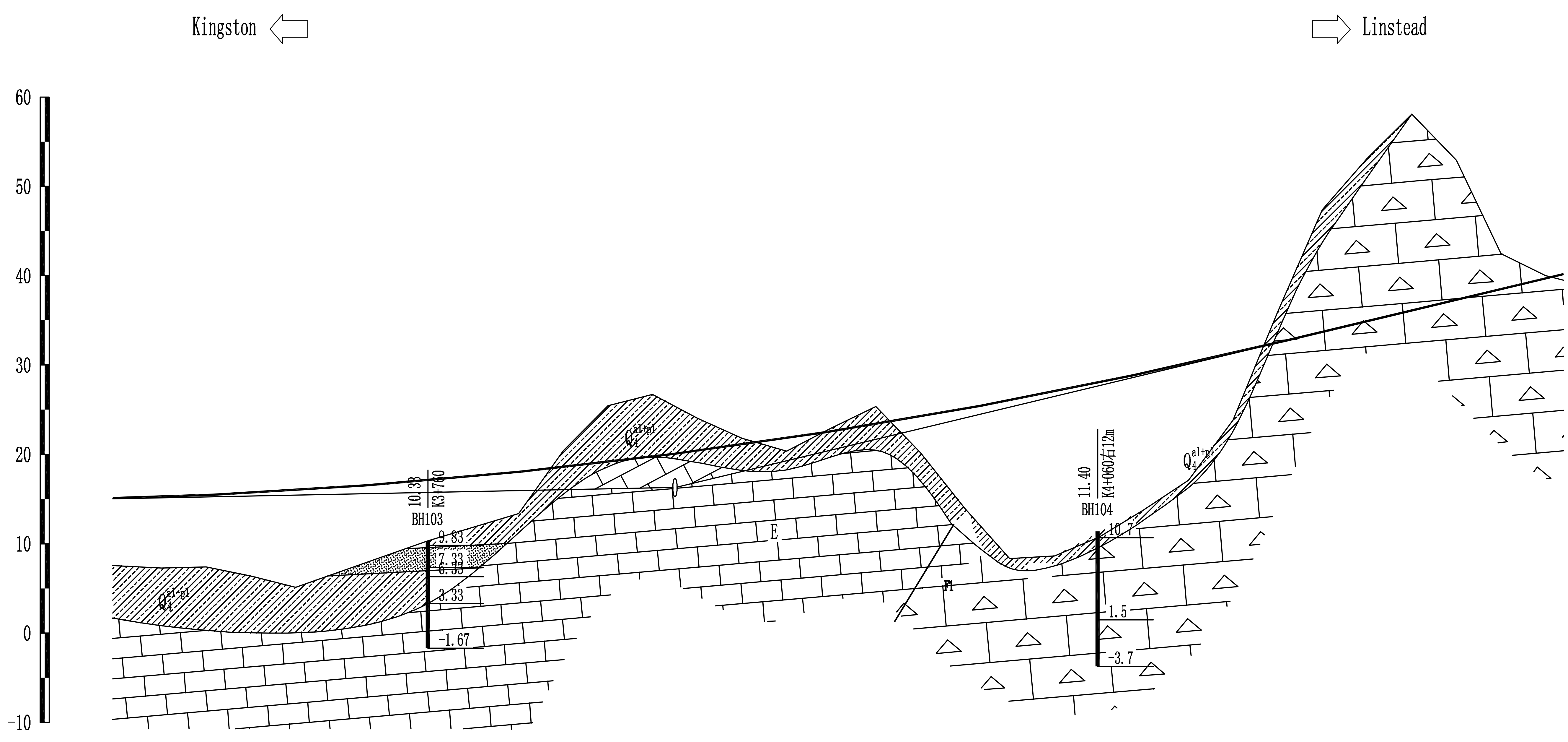

Vertical scale 1:500

Horizontal scale 1:2000

Ground elevation	7.31	7.41	6.40	5.15	5.37	6.96	6.83	7.34	13.39	20.42	25.47	26.72	24.08	21.81	20.39	22.96	25.36	20.20	13.96	8.35	8.68	10.77	13.81	17.14	23.86	35.97	47.35	53.10	58.06
Mileage stake number	+640.000	+660.000	+680.000	+700.000	+720.000	+740.000	+760.000	+780.000	+800.000	+820.000	+840.000	+860.000	+880.000	+900.000	+920.000	+940.000	+960.000	+980.000	K4	+020.000	+040.000	+060.000	+080.000	+100.000	+120.000	+140.000	+160.000	+180.000	+200.000

Ground elevation	52.93	42.48	40.03
Mileage stake number	+220.000	+240.000	+260.000

engineering geological evaluation

The section of K3+680～K3+800 belongs to sea alluvial plain area in terms of landform. The terrain is gentle and the stratum is covered by the Quaternary sea alluvial overburden layer. Underground water and surface water are developed in the section; seasonal small rivers can be seen here. Line fill subgrade, with several culvert channels, the route does not have such structural matter as bridge. Corresponding treatment shall be conducted for strata facing such issues as soft soil layer and vibration liquefaction in sand before filling the subgrade. Overall, the section is low in subgrade bearing capacity and weak in engineering geological properties. The section of K2+450～K2+750 belong to tectonic corrosion and denudation hilly area. locally-exposed bedrock，The underlying bedrock is the Tertiary limestone group (E). The diagenetic degree and strength of limestone is uneven, and its overall strength is relatively soft in overall strength.With relatively good integrity, the bedrock has relatively good excavation stability on the premise that slope rate can be controlled.

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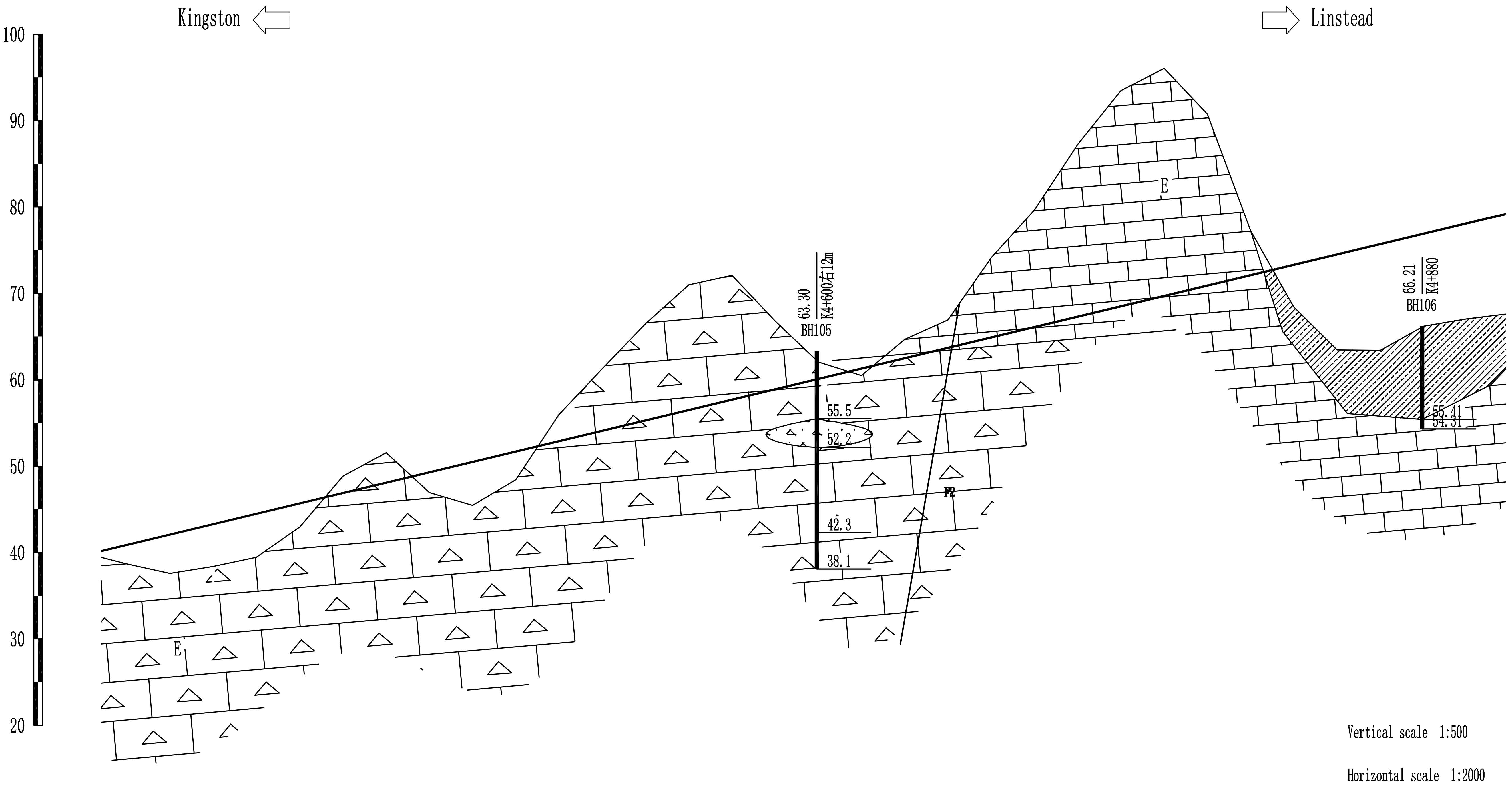

Ground elevation	Mileage stake number
38.69	+280.000
37.60	+300.000
38.44	+320.000
39.46	+340.000
43.00	+360.000
48.85	+380.000
51.56	+400.000
46.95	+420.000
45.46	+440.000
48.43	+460.000
55.97	+480.000
61.26	+500.000
66.52	+520.000
70.99	+540.000
72.08	+560.000
66.82	+580.000
62.07	+600.000
60.50	+620.000
64.71	+640.000
66.93	+660.000
74.16	+680.000
79.66	+700.000
87.23	+720.000
93.45	+740.000
96.05	+760.000
90.77	+780.000
77.31	+800.000
68.44	+820.000
63.47	+840.000
63.41	+860.000
66.21	+880.000
67.07	+900.000
67.65	+920.000

engineering geological evaluation

Landform of the section belongs to tectonic corrosion and denudation hilly area. With an overall steep terrain, the section is relatively gentle in local low-lying places. The overburden layer is the Quaternary eluvial red clay layer, characterized by overall thin layer, largely-changed thickness and large-amount exposed bedrock. There is clay layer in low-lying places, which is relatively thick. The overburden layer is of general mechanical properties. The underlying bedrock is the Tertiary limestone group (E). The diagenetic degree and strength of limestone is uneven, and its overall strength is relatively soft in overall strength, owing to which, it can serve as foundation bearing stratum. Limestone corrosion is developed strongly in the section; karst corrosion landform is also developed. Dissolved fissures and pores are common in rock cores, but karst caves are seldom. small type karst funnels have been found near K4+900. There are no bridges but several highly-filled and deeply-excavated road sections in the section. With relatively good integrity, the bedrock has relatively good excavation stability on the premise that slope rate can be controlled. The fill sections shall not be filled before compacting original overburden layer, so as to ensure that subgrade structure is not influenced by settling differences resulting from the poor compaction of the soil layer.

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