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THE GOVERNMENT OF MAURITIUS

THE STUDY ON
LANDSLIDE PROTECTION PROJECT
IN [illegible]

FINAL REPORT

EXECUTIVE SUMMARY

[illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY

THE GOVERNMENT OF MAURITIUS

THE STUDY ON LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

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NOVEMBER 1990

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1. INTRODUCTION

Active movements of the landslide at La Butte were recognized in the period from November 1986 to May 1987. The landslide covers an area of about 400 m x 700 m in size which includes a highly populated area in its lower half. Location of the study area is shown in Fig.1.1.

The Government of Mauritius designated the district of about 12.5 ha as a high risk area for landslide damages. In the restricted area, 327 houses are packed and 479 families are living. Anticipated potentially endanger area is assumed in the outside lower parts of the landslide area. Total population of the high risk area and the anticipated potentially endanger area is about 3700. More than 50 buildings or houses were demolished because of their serious damages by landslide movements. A mosque built more than 120 years ago and included in these demolished buildings. About 1 m differences in level, which cause traffic interference, were created on main roads in the landslide area.

A sizable number of houses in the landslide area are damaged by cracks but residents area still living in these houses. Residents in the area are anxious about safety of their houses, landslide movements, and repair of the houses. From these facts the landslide seems to be a large social problem in Mauritius. The Government of Mauritius decided to secure the landslide area by providing protective measures because residents in the area are unwilling to move to other places and it is difficult to find preferable lands to move to in the vicinity.

Preliminary studies on this landslide was made by a British expert in 1987 and a Japanese expert team in 1988. These preliminary studies established the necessity for future investigation. The government of Mauritius accordingly requested the government of Japan to undertake the present studies. The "Scope of Works" was signed in March 1989 and this study was initiated in April 1989.

Objectives of the investigations were:

1) to clarify movements and causes of the landslide in La Butte by observation and measurement

2) to prepare long term protective measures against the landslide movements
3) to undertake urgent protective measures for mitigation of the landslide movements, and
4) to transfer technology to Mauritian counterparts throughout the entire operation.

The study was divided into two stages; the first stage was from April 1989 to August 1989 and the second was from September 1989 to November 1990 when the study is scheduled to be completed.

The first stage investigation clarified the natural condition of the landslide area and movements of the landslide by topographic survey, geological investigation, and analysis of monitoring data. Before completion of the first stage investigation, planning for an experimental investigation was made, This mainly comprised construction of a drainage well with drilling of groundwater collection and other boreholes. An interim report was prepared on completion of the first stage study.

The experimental investigation, construction of the drainage and intermediate wells, drilling of groundwater collection boreholes and drainage boreholes, and installation of drainage facilities, were performed as an urgent protective measure against landslide movements during the second stage study.

Installation of surface water drainage channels, execution of soil removal, and operation of emergency counterweight embankments were done in parallel with execution of the experimental investigation.

For protective against landslide movements in the long term, planning and design of long term protective measures for the landslide were made on the basis of all results obtained from the investigation and the urgent protective works.

Planning and design of long term protective measures mainly consisting of construction of three drainage wells with drilling of 2100 m of groundwater collection boreholes and 8996 m of steel piling works are proposed as the conclusion of this study. The work required for construction of the long term protective measures is estimated to take 22 months.

Total project cost is estimated to be Rs.272.3 million for the long term protective measure on the price levels of January 1990. The total benefit is estimated to be Rs.438.09 million resulting in 1.96 CBR, Rs.214.11 million in NPV and 47.7 % IRR, which confirm the economic viability of the project.

2. FIELD INVESTIGATIONS

2.1 Installation of Monitoring Equipment

For investigation and observation of the landslide the following monitoring equipment was installed in and around the landslide area.

EQUIPMENT	No.
Rain gauge	1 unit
Tiltmeters	7 unit
Extensometers	16 unit
Borehole inclinometers	8 boreholes

The location of this equipment is shown in Fig.2.1.

2.2 Topographic Survey

Cross sectional surveys at 1:500 scale was made along five observation lines selected for stability analysis. A 1:1000 scale contour map was prepared for the area covering the landslide and surrounding areas.

More than 400 mm of subsidence of ground surface was measured along the leveling survey line-1 in the southwestern part of the landslide in May 1989. However, no further subsidence was measured in the following period which decreased rainfall. The location of leveling survey lines is indicated in Fig.2.2 and graphs of the subsidence is shown in Fig.2.3. Diminishing subsidence was believed to be due not only to decreasing rainfall but also to the effect of soil removal which was carried out as an urgent protective measure at the end of 1989.

2.3 Geological Investigations

Geological investigations consisted of 235 m (10 holes) of borehole drilling for measurement of groundwater levels and 195 m (8 holes) for measurement by borehole inclinometer. Borehole drilling was accompanied by recovery of core samples and field tests in the boreholes.

The landslide area is composed of up to 40 m of scree deposits, overlying basaltic bedrocks. The scree deposits are composed of clayey soil with basaltic gravel, underlain by an fat clayey layer of about 5 m thick in the toe portions of the landslide. Permeability coefficients of the scree deposits ranged mostly in the from $x10^{-2}$ cm/s to $x10^{-3}$ cm/s, indicating their relatively high permeability. A summary of the borehole drilling and permeability test results is given in Table 2.1.

The slide surfaces of the landslide are assumed be mostly among the scree deposits except for some parts where slide surfaces were estimated to touch the bedrock surfaces. The depth to the slide surfaces and the bedrock surfaces were assumed to be greatest in the central part of the landslide, and is assumed to be gradually decrease towards the outside. A contour map of the slide surface with the bedrock surface is shown in Fig.2.4, and geological profiles along the observation lines are given in Fig.2.5 to Fig.2.10.

Judging from the features of the slide surfaces and the bedrock surfaces and continuation of open tension cracks, the landslide movements are considered to be essentially the movement of just one single sliding mass.

2.4 Strength of Clayey Materials along Slide Surface

Landslide movements generally occur through shearing displacement of clayey soil materials along slide surfaces. It is important therefore to clarify the strength of the clayey materials along the slide surfaces for verifying the stability of landslides.

For clarifying the mechanical and physical properties, laboratory tests were conducted on samples of clayey soil materials collected from the site.

Undisturbed samples were collected for mechanical tests and disturbed samples were collected for physical tests. The results of these tests are summarized in Tables 2.2 and 2.3. The main mechanical properties obtained for the clayey soil materials are as follows:

MECHANICAL PROPERTY	VALUE
Cohesion	1.0 - 3.0 t/m^2
Internal friction angle	5.5 - 28.0 deg.

2.5 Analysis of Monitoring Data

Monitoring data were collected from one (1) rain gauge, seven (7) tiltmeters, sixteen (16) extensometers, and eight (8) boreholes for borehole inclinometer measurement.

The general pattern of rainfall as recorded in Port Louis is that the average annual rainfall for 36 years from 1951 to 1987 was as 960 mm of which about 80 % was recorded in the rainy season from November to April. The rain gauge installed at Ecole de la Montagne has revealed that rainfall of less than 1000 m is recorded in dry years (such as 1989-90) and more than 1300 mm in rainy years in these recent years. Rainfall data for the landslide area are shown in Figs.2.11 and 2.12.

As for landslide monitoring data, slight shearing displacements were interpreted in the records from boreholes in the eastern part of landslide but intensive shearing displacements were measured in the records of the borehole BV-X1 in the lower slopes of extensometer E-3. A small landslide, 60 m x 80 m, occurred along a secondarily developed slide surface in the lower slopes below E-3. This small landslide was believed to have been triggered by soil removal work. Records of the borehole inclinometer in borehole BV-X1 are shown in Fig.2.13.

Tilting movements of the ground surface had been measured by the seven tiltmeters installed in and around the landslide area. A relatively clear accumulating tendency to N-S movement was interpreted in the records from the tiltmeters T-4 and T-6 were installed in the eastern part of the landslide. Measurement records of tiltmeters T-4 and T-6 are shown in Figs.2.14 and 2.15.

Since recording large displacements in the 1988-9 rainy season, the extensometers have not indicated any significant movement except for records from extensometer E-3. Movements of the small secondary landslide had been recorded by E-3 since October 1989 during soil removal work which was undertaken as an urgent protective measure.

To stop the movement counterweight embankments were constructed both at the end of January 1990 and at the end of May 1990. Intensive displacement amounting to as much as 6.5 mm/day was halted by these counterweight treatments, but further movements expected after heavy continuous rainfall. For protective against future landslide movements, determent works composed of steel piling works are planned for long term protective. Displacement records from the extensometers are shown in Figs.2.16.

Measurement of groundwater levels in the landslide area has been made in the boreholes drilled in both this study and in the previous studies. Rising of groundwater levels after relatively heavy rainfall was observed mostly in boreholes drilled in the eastern part of the landslide. Therefore, installation of drainage wells, mainly for their peak cut-off function, will be more effective in the eastern part than the western part of the landslide. Results of groundwater level measurement are shown in Fig.2.17.

2.6 Landslide Mechanism

The landslide that happened in La Butte is a colluvial landslide according to a general classification of landslides types. In this landslide slickensides frequently develop implying that intensive sliding stress had been acting on the scree deposits.

Depths to the slide surfaces and the bedrock surfaces in the landslide area are maximum at the central part of the landslide. No tension crack, which would imply the possibility of the landslide dividing into several blocks, has been seen. The landslide movement is therefore considered to be that of a single sliding mass.

A large drawdown of groundwater was measured in the boreholes drilled in the central part of the landslide. A drawdown of about 20 m was measured in the boreholes drilled in the western part, but drawdowns for 5 - 20 m or less were measured in the that eastern part of the landslide. From these facts installation of drainage wells is likely to be more effective in the eastern part than the western part of the landslide.

The strengths of clayey materials were confirmed to be 1.0 - 3.0 t/m^2 of cohesion and 5.5 - 28.0 deg. of internal friction angle by laboratory tests. Therefore, the assumed values of 1.0 t/m^2 for cohesion and 9.0 - 9.7 deg. for internal friction angle for stability analysis for the landslide on the whole were confirmed to be reasonable.

3. URGENT PROTECTIVE MEASURES

3.1 Preparation of Urgent Protective Measures

Urgent protective measures for mitigation of landslide movement were taken during the study which included: installation of surface water drainage channels; construction of one drainage well with drilling of groundwater collection boreholes; and some soil removal work.

To prevent surface water from infiltrating into the landslide, surface drainage channels were planned and constructed around the upper parts of the landslide. The alignments of theses surface drainage channels are given in Fig.2.18.

As one of urgent protective measures against landslide movements, an experimental investigation was planned. This included construction of a drainage well and an intermediate well, and drilling of groundwater collection boreholes and drainage boreholes. The drainage well was sited in the central part of the landslide near W-line with a view of effective drainage of groundwater.

From a stability analysis along the observation W-line, the improvement of safety factor was expected for about 6 % on the assumption that groundwater levels would be decreased by about 2 m near W-line by providing the drainage well.

The main features of the drainage well works were as follows:

1) Depth of the drainage well is 20 m.
2) Diameter of the drainage well is 3.5 m.
3) Total length of groundwater collection boreholes is 1000 m (20 holes).
4) Depth of the intermediate well is 15 m.
5) Total length of groundwater drainage boreholes is 120 m (2 holes).

For mitigation of the landslide movement soil removal was planned and undertaken from the central upper slope of the landslide area for reducing the weight of the sliding earth masses.

3.2 Experimental Investigation

The 20 m deep experimented drainage well was designed to be protected by 2.7 mm thick steel liner plates and 125x125x6.5 mm steel stiffeners. The design was confirmed to be sufficiently strong against buckling pressure and compressive stress. The structure of drainage well is shown in Fig.3.1.

Examination of the strength of the intermediate well followed the same procedure as for the drainage well.

Construction of the experimental system composed as following: excavation and mucking; liner plate installation; further excavation and concreting; installation of boring machine and drilling of groundwater collection and drainage boreholes; drainage channel construction; masonry works and concrete placing; installation of cover and fencing; and observation of results.

The total working period for constructing the experimental drainage system and investigations was estimated to take 14 months but the actual work was completed within about 10 months. The main reason for shortening of the work period was the relatively low rainfall in the rainy season from 1989 to 1990.

The main cost components for the experimental investigation were the direct construction cost, indirect construction cost, and general supervision cost. The total construction cost was estimated at J.Yen 91.4 million for all the required works.

Construction of the drainage well and the intermediate well was performed by assembling and installing steel liner plates after every 0.5 m interval excavation. Drilling of groundwater collection boreholes for 1000 m (20 holes) were carried out after construction of the drainage well from inside of the drainage well. Drilling of drainage boreholes was made for 120 m, connecting the drainage well with the ground surface through the intermediate well. Installation of the drainage facility was made finally from the outlet of the drainage borehole.

After the rainy season from November 1988 to April 1989, in which more than 1300 mm of rainfall was recorded, there was no heavy rainfall through the study period. There was a large fall in the groundwater level as recorded in the boreholes drilled during this period. Groundwater levels near the drainage well are given in Fig.3.2 with comparison of groundwater levels measured in June 1989 and June 1990. As indicated in the figure, groundwater levels in June 1990 were much lower than the levels of the groundwater collection boreholes. Consequently there was no drainage of groundwater into the drainage well.

On account of the dry weather it was not possible to assess fully the value of the drainage well works. However, the difference in groundwater levels were considered to be recovered remarkably in the landslide during and after heavy rainfalls as recorded in June 1989. Taking the high permeability of the sliding earth masses into consideration also, the drainage well should function well during and after heavy continuous rainfall.

3.3 Soil Removal Work

For securing stable equilibrium of the sliding earth masses, excavation and removal of earth materials from the upper central part of the landslide was planned as an urgent protective measure. Design of the soil removal endeavored to take into account better matching of excavation slopes with surrounding mountain slopes. The excavated slopes were designed accordingly to be semicircular in form. The expected amount for earth excavation was about 50000 m^3. Design of the soil removal site is shown in Fig.3.3.

The expected improvement safety factors for the observation W-line and X-line after soil removal is 3.1 % and 7.6 % respectively. Total expected improvement of safety factor by the experimental investigation and the soil removal work is summarized as follows:

OBSERVATION LINE	BEFORE SOIL REMOVAL	AFTER SOIL REMOVAL	AFTER EXPERI. INVESTIGATION	TOTAL F.s
W	F.s=1.00	F.s=1.031	F.s=1.061	1.092
X	F.s=1.00	F.s=1.071		1.071

Effect of the soil removal on landslide movements is indicated in the leveling survey results. Remarkable subsidence had been recorded in the section along the leveling survey line-1 in the southwestern part of the landslide. Constant subsidence had been measured from the end of 1987 to the middle of 1989, but after the middle of 1989 subsidence was minimal even in the rainy season of 1989 - 90. The effect of the soil removal would therefore seem to have been beneficial. Survey results of ground surface subsidence are shown in Fig.2.3.

Despite remarkable displacement records on the extensometers in the rainy 1988-89 season, no remarkable displacement occurred in the landslide as a whole in the after April 1989. This have been mainly due to the completion of the soil removal works.

3.4 Emergency Counterweight

Monitoring records from extensometer E-3 indicated some intensive displacements possibly caused by a small secondary landslide in the slope below E-3. The small landslide was believed to have been triggered by the soil removal conducted in the period between the end of October 1989 and the middle of December 1989. Very large shearing displacements were interpreted by the borehole inclinometer in the borehole BV-X1 at depths of 5.0 m and 10.5 m. The records of borehole inclinometer are shown in Fig.2.13.

The displacement amount recorded by extensometer E-3 varied between 1mm/day and 3mm/day, and the total displacement amount reached 120 mm by the end of January 1990, with the displacement seeming to be continuing. Accordingly treatment by an emergency counterweight for mitigation of this small landslide was planned and executed at the end of January 1990. The movement of the landslide ceased instantly after completion of this counterweight.

However, the movement began again after relatively heavy rainfall in February. Displacements continued and was 200 mm between the middle of February and the beginning of March 1990. To check this movement, further counterweights were planned and implemented between the end of May and the beginning of June 1990. After providing these counterweights, movement gradually ceased in June 1990. The location and size of the counterweights are shown in Figs.3.4 and 3.5.

Before providing these counterweights, stability analysis was conducted to determine the appropriate size of counterweights needed and to estimate the probable effects of these counterweights. Improvement of the safety factor was expected of about 12 % for the secondary landslide as a result of providing these counterweights.

Movement of the small landslide diminished after completion of the counterweights. However, further movements may be expected in the future after continuous heavy rainfall. Determent works such as steel piling works will be required for stabilization of this small landslide in the long term.

4. LONG TERM PROTECTIVE MEASURES

Location of sites for the protective measures is shown in Fig.4.1.

4.1 Planning of Long Term Protective Measures

The target of this study was preparation of long term protective measures for the landslide at La Butte. These were planned as a combination of prevention works and determent works. The prevention works comprise drainage works and the determent works comprise steel piling works.

For planning of the long term protective measure, the basic nature of the landslide and function of the protective measures were identified as follows:

1) The landslide movements are considered to act as one single unit mass movement.

2) The planned safety factor should be PF.s=1.2.

3) The protective measures should be a combination of drainage works and steel piling works.

4) The groundwater level is assumed to be depressed by 2.0 m in the landslide area by the drainage works.

5) In design of the steel piling works, improvement of the safety factor by soil removal will be taken into consideration.

6) The designing of the steel piling works will be made for securing the planned safety factor of PF.s=1.2.

4.2 Stability Analysis for the Long Term Protective Measures

For design of the protective measures, stability analysis was made for each observation line on the assumption of 2 m depression of the water level by the drainage works over the whole landslide area.

Improvement of safety factors by the soil removal were taken into consideration in the stability analysis.

The strengths of clayey materials along slide surfaces were those calculated in planning of the experimental investigation and the soil removal.

For design of the steel pile works, stability analysis was made to confirm the adequacy of the works for prevention of the landslide. The procedure for designing of the steel pile work was as follows:

1) To find the improvement in safety factors (F.s) for each observation line after the soil removal on the assumption of 2 m drawdown by drainage works

2) To calculate the deficit in safety factor by deducting the safety factor (F.s) from the planned safety factor (PF.s)

3) To calculate required deterrent force (P) against the landslide movement by multiplying the calculated insufficiency in safety factor by force along the tangent line (T) of each slice of each observation line, that is, P = (PF.s - F.s)x T

4) To calculate the total required deterrent force by multiplying the required deterrent force (P) by section length between each observation line

5) To calculate required deterrent force for the unit section length by dividing the total required deterrent force by total section length of piling work alignment

Through these processes the total required deterrent force for the main landslide was calculated to be about 72000 tons, and the required deterrent force per the unit section length was obtained as 95.75 t/m. On the other hand, total required deterrent force and the required deterrent force per the unit section length for the small landslide are 3348 tons and 47.83 t/m.

4.3 Drainage Work

4.3.1 Horizontal borehole drilling from ground surface

For protective of the slope surface, especially for excavated slopes in the soil removal work site, drainage works by drilling of horizontal boreholes aim to drain shallow groundwater. The required total drilling length is 1670 m for the horizontal boreholes. Drilling of the horizontal boreholes is planned to be made from the berms created during soil removal. Effluent from these boreholes will discharge into the surface drains installed on the berms after soil removal work.

4.3.2 Drainage well work

For securing stability of the landslide by draining deeper groundwater, a further three drainage wells and an intermediate well are required in the upper part of the landslide. Total required quantity of drainage wells is 35 m (3 wells). Groundwater collection boreholes will amount to 2100 m in total. One intermediate well of 11 m deep will be constructed for conveyance of drainage water to the ground surface.

The main function of the drainage wells is expected to be for peak cut-off of suddenly increased groundwater levels after heavy rainfalls. For stability analysis on the landslide, about 2 m drawdown of groundwater levels below these observed in June 1989 was assumed in the whole landslide area by providing drainage wells.

4.4 Steel Piling Work

For securing stability of the landslide, steel pile work is proposed as a long term determent. Thickness, diameter, and interval of steel piles are decided on the basis of the required deterrent force, actual experience in Japan, relation to the diameter of steel piles, depth to slide surface and so on. Calculated values are summarized below for the main landslide and small landslide separately.

Item	Main Landslide	Small Landslide
Thickness of pile	17 mm	9 mm
Diameter of pile	300 mm	300 mm
Interval of pile	2.0 m	2.0 m

The alignment and cross sectional profiles of the steel piling works are shown in Figs.4.2 and 4.3.

Required quantities for the long term protective measure is given in Table 3.1 and the main work items and quantity may be summarized as follows:

PROTECTIVE MEASURES	QUANTITIES	DIMENSION
Drainage works:		
Horizontal boreholes	1670 m (30-50 m)	66 mm (dia)
Drainage well	35 m (3 wells)	3.5 m (dia)
Groundwater collection boreholes	2100 m (50-60 m)	66 mm (dia)
Intermediate well	11 m (1 well)	3.5 m (dia)
Drainage borehole	200 m (50 m)	116 mm (dia)
Piling Works:		
1) Main landslide		
Vertical boring	8800 m (13-37m,380 holes)	350 mm (dia)
Steel pile installation	8420 m (12-36m,380 piles)	300 mm (dia) 17 mm (thick)
2) Small landslide		
Vertical boring	576 m (16m,36holes)	350 mm (dia)
Steel pile installation	576 m (16m,36piles)	300 mm (dia) 9 mm (thick)

4.5 Construction Plan and Schedule

The schedule for construction of the long term protective measure assumes completion within about 22 months from the loan procedure to completion of the main construction works. The implementation time schedule is shown in Fig.4.4.

Construction of the drainage wells and the intermediate well is planned to be carried out by using two sets of equipment. Drilling of groundwater collection boreholes and the drainage boreholes is assumed to be made by two sets of drilling machines. Drilling of the horizontal boreholes for draining shallower groundwater is planned to be carried out by using the same drilling machines as for the groundwater collection boreholes. The steel piling work is planned on the basis of vertically drilled boreholes into which the steel pile will be placed before filling with cement mortar.

4.6 Cost Estimate

Total project cost is estimated to be Rs.272.3 million at January 1990 price levels, comprising a foreign currency portion of Rs.219.5 million and a local currency portion of Rs.52.8 million as shown below.

(unit: Rs.million)

ITEM	F/C	L/C	TOTAL
Construction cost	178.3	29.3	207.6
Administration expense	0.0	6.3	6.3
Price escalation	0.0	5.2	5.2
Physical contingency	17.8	4.1	21.9
Engineering service	16.5	2.4	18.9
Interest during construction	6.9	5.5	12.4
Total	219.5	52.8	272.3

4.7 Economic Evaluation

Project evaluation started from estimation of the potential area at risk from landslide damage as shown in Fig.4.5. Project evaluation was then made on the with-project and without-project principle: that is, project benefits evaluated as potential damage which would be caused by a landslide without the project. Project costs are those required measures to protect the area from landslide disasters.

For assessing the project benefit, cost of damage were calculated for facilities such as buildings and public services. The total damage cost was estimated at Rs.417.11 million as summarized in Table 4.1. By comparison, the project cost was estimated at Rs.272.3 million and is summarized in Table 4.2.

Economic viability of the project was assessed by applying three discounting techniques; the cost-benefit ratio method (CBR), the net present value method (NPV) and the internal-rate-of-return method (IRR). The cash flow of construction cost of the project is given in Table 4.3. The prime discount rate applied for the first two methods is 10 %. Economic viability of the project was evaluated by the three methods and the results are summarized as follow:

Methods	Value
CBR	1.96
NPV	Rs.214.10 million
IRR	47.7 %

From the economic evaluation results, the project is revealed to be economically and financially justifiable.

5. CONCLUSIONS AND RECOMMENDATIONS

The investigations have revealed the size and nature of the landslide at La Butte, and that without long term protective measures composed of prevention works and determent measures a disastrous landslide could be occurred by following continuous and heavy rainfall.

During the investigations some movements took place in a small secondary landslide but this was stopped by immediate protective measures.

For future long term protective of human life and property at risk below the landslide site an urgent program of protective works and determent works is recommended as follows:

MEASURE	QUANTITY
Drainage works:	
1) Drilling of horizontal boreholes	1670 m
2) Construction of drainage well	35 m (3 wells)
3) Construction of intermediate well	11 m (1 well)
4) Drilling of groundwater collection borehole	2100 m
5) Drilling of drainage borehole	200 m
Steel Piling Work:	
1) Vertical drilling (for main landslide)	8800 m
2) Pile installation (- do -)	8420 m
3) Vertical drilling (for small landslide)	576 m
4) Pile installation (- do -)	576 m

The total construction cost is estimated to be Rs.272.3 million, consisting of Rs.219.5 million for the foreign portion and Rs.52.8 million for the local portion.

The economic viability of the project was evaluated as 1.96 in CBR, Rs.214.10 million in NPV and 47.7 % in IRR. These results confirm that the project is economically highly viable.

The study has shown that the project recommended above will be technically and economically viable. If intangible benefits are included, such as removing the threat to human lives, the project becomes further highly viable. It is therefore strongly recommended that the project be proceeded with as soon as possible.

TABLES

TABLE 2.1(1/2) BOREHOLE DRILLING QUANTITY AND SUMMARY OF PERMEABILITY TEST

BOREHOLE No.	DEPTH (m)	WATER LEVEL (m)	CASING (m)	HEAD H(m)	CASING DIA. R (cm)	QUANTITY Q(l/min)	PERMEABILITY K (cm/sec)
BV-V1	10.0	9.50	0.00	9.50	4.2	4.0	3.04×10^{-3}
	15.0	15.00	0.00	15.00	4.2	72.7	3.50×10^{-2}
	20.0	20.00	0.12	20.12	4.2	>350.0	$>1.26 \times 10^{-1}$
	25.0	25.00	0.35	25.35	4.2	>350.0	$>9.96 \times 10^{-2}$
BV-V2	10.0	1.50	0.20	1.70	4.2	0.8	3.40×10^{-3}
	15.0	2.00	0.10	2.10	4.2	1.2	4.12×10^{-3}
	20.0	16.05	0.20	16.25	4.2	3.1	1.38×10^{-3}
BV-V3	10.0	7.30	0.70	8.00	4.2	5.0	4.51×10^{-3}
BV-V4	10.0	7.80	0.15	7.95	4.2	20.0	1.82×10^{-2}
	15.0	7.80	0.15	7.95	4.2	20.0	1.82×10^{-2}
	20.5	8.95	0.10	9.05	4.2	20.0	1.59×10^{-2}
BV-W1	10.0	8.85	0.10	8.95	4.2	37.4	3.01×10^{-2}
	15.5	15.50	0.25	15.75	4.2	48.0	2.20×10^{-2}
	20.0	20.00	0.10	20.10	4.2	73.0	2.62×10^{-2}
	25.0	25.00	0.21	25.21	4.2	21.1	6.04×10^{-3}
BV-W2	10.0	1.12	0.39	1.51	4.2	0.8	3.82×10^{-3}
	15.0	0.54	0.31	0.85	4.2	1.8	1.53×10^{-2}
	20.0	20.00	0.17	20.17	4.2	0.2	7.15×10^{-5}
	25.0	25.00	0.16	25.16	4.2	16.7	4.79×10^{-3}
BV-W3	10.0	8.19	0.16	8.35	4.2	0.1	8.64×10^{-5}
	20.0	14.17	0.24	14.41	4.2	0.1	5.01×10^{-5}
BV-X1	5.0	5.00	0.60	5.60	4.2	0.7	9.02×10^{-4}
	10.0	6.40	0.60	7.00	4.2	3.9	4.02×10^{-3}
	15.0	12.00	0.60	12.60	4.2	37.8	2.16×10^{-2}
	20.0	13.20	0.20	13.40	4.2	0.4	2.15×10^{-2}
BV-X2	10.0	10.00	0.50	10.50	4.2	1.8	1.24×10^{-3}
	15.0	15.00	0.50	15.50	4.2	2.5	1.16×10^{-3}
	20.0	8.45	0.50	8.95	4.2	0.2	1.61×10^{-4}
BV-X3	10.0	10.00	0.54	10.54	4.2	0.9	6.16×10^{-4}
	15.0	15.00	0.50	15.50	4.2	7.8	3.63×10^{-3}
	20.0	14.43	0.50	14.93	4.2	3.5	1.69×10^{-3}
BV-X4	5.0	1.30	0.15	1.45	4.2	0.4	1.99×10^{-3}
	10.0	0.95	0.15	1.10	4.2	0.4	2.62×10^{-3}
	15.0	7.98	0.15	8.13	4.2	1.0	8.87×10^{-4}

TABLE 2.1(2/2) BOREHOLE DRILLING QUANTITY AND SUMMARY OF PERMEABILITY TEST

BOREHOLE No.	DEPTH (m)	WATER LEVEL (m)	CASING (m)	HEAD H(m)	CASING DIA. R (cm)	QUANTITY Q(l/min)	PERMEABILITY K (cm/sec)
BV-Y1	10.0	10.00	0.23	10.23	4.2	0.2	1.41×10^{-4}
	15.0	1.12	0.22	1.34	4.2	0.2	1.08×10^{-3}
BV-Y2	10.0	0.95	0.32	1.27	4.2	2.4	1.36×10^{-2}
BV-Z1	5.0	4.25	0.20	4.45	4.2	1.1	1.78×10^{-3}
	10.0	8.17	0.20	8.37	4.2	1.1	9.48×10^{-4}
	15.0	11.15	0.20	11.35	4.2	1.0	6.36×10^{-4}
	20.0	12.55	0.60	13.15	4.2	1.0	5.49×10^{-4}
BV-Z2	5.0	5.00	0.40	5.40	4.2	1.5	2.00×10^{-3}
	10.0	8.91	0.50	9.41	4.2	2.4	1.84×10^{-3}
	15.0	10.32	0.50	10.82	4.2	4.2	2.80×10^{-3}

TABLE 2.2 PHYSICAL PROPERTY OF CLAYEY MATERIALS

Sample No.	Specific gravity	Liquid limit (%)	Plastic limit (%)	Plastic index (%)	Moisture content (%)	Unit weight (KN/m³)
S/R-1	2.65	122.3	45.7	76.6	35.3	18.3
					37.7	18.3
					41.6	17.8
					35.6	19.1
S/R-2	2.56	88.9	54.8	34.1	39.2	19.4
					37.6	18.6
					41.7	18.2
					36.0	19.2
D/W-1	2.58	110.8	40.5	70.3	36.6	16.8
					42.7	17.9
					36.6	16.4
					37.6	18.6
					33.0	18.3
D/W-2	2.79	67.5	46.7	20.8	24.7	17.2
					23.6	18.2
					26.2	17.4

* S/R : sample from the soil removal area
  D/W : sample from the drainage well

TABLE 2.3 MECHANICAL PROPERTIES OF CLAYEY MATERIALS

Sample No.	UNIAXIAL COMPRESSIVE TEST Strength (kg/cm²)	TRIAXIAL COMPRESSIVE TEST Cohesion (t/m²)	Friction angle (deg.)
S/R-1	2.08	1.8	9.2
	2.35		
	2.50		
	1.02		
S/R-2	2.35	2.1	5.5
	1.85		
	2.50		
	3.12		
D/W-1	0.15	3.0	10.0
	0.24		
	0.65		
	0.90		
	0.95		
D/W-2	0.95	1.0	28.0
	1.15		
	0.90		

* S/R : samples from the soil removal area
D/W : samples from the drainage well

TABLE 3.1 PRINCIPAL FEATURES AND MAJOR WORK QUANTITIES

Item	Dimension of Structures			Quantities
I. Drainage Well			(total of No.1 to 6)	422 cu.m
1. Drainage Well			(sub-total of No.1 to 5)	322 cu.m
(1) DW-2(No.1)				0 cu.m
(2) DW-3(No.2)				0 cu.m
(3) DW-4(No.3)	Diam.=3.5m	L=15m		142 cu.m
(4) DW-5(No.4)	Diam.=3.5m	L=10m		90 cu.m
(5) DW-6(No.5)	Diam.=3.5m	L=10m		90 cu.m
2. Intermediate Well				
(1) DW-2(No.6)	Diam.=3.5m	L=11m	(sub-total of No.6)	100 cu.m
3. Metal works				
(1) Liner plate	0.5m×1.57m×7pcs./ring			48 lin.m
(2) Ring stiffener	H-125×125			26 sets
(3) Vertical stiffener	H-175×175			4 sets
4. Horizontal boring				
(1) Water collection	Diam.=66mm	L=50-60m		2,100 lin.m
(2) Water drainage	Diam.=116mm	L=50m		200 lin.m
II. Horizontal Boring				
1. Horizontal Boring				
(1) Water collection	Diam.=66mm	L=30-50m		1,670 lin.m
III. Piling				
1. Vertical boring (416 nos.)			(total of section 1 to 13)	9,376 lin.m
(1) Section 1	Diam.=350mm,	L=13m×49 nos.		637 lin.m
(2) Section 2	Diam.=350mm,	L=17m×18 nos.		306 lin.m
(3) Section 3	Diam.=350mm,	L=21m×5 nos.		105 lin.m
(4) Section 4	Diam.=350mm,	L=25m×5 nos.		125 lin.m
(5) Section 5	Diam.=350mm,	L=29m×5 nos.		145 lin.m
(6) Section 6	Diam.=350mm,	L=33m×9 nos.		297 lin.m
(7) Section 7	Diam.=350mm,	L=37m×41 nos.		1,517 lin.m
(8) Section 8	Diam.=350mm,	L=33m×20 nos.		660 lin.m
(9) Section 9	Diam.=350mm,	L=25m×65 nos.		1,625 lin.m
(10) Section 10	Diam.=350mm,	L=25m×56 nos.		1,400 lin.m
(11) Section 11	Diam.=350mm,	L=21m×41 nos.		861 lin.m
(12) Section 12	Diam.=350mm,	L=17m×66 nos.		1,122 lin.m
(13) Section 13	Diam.=350mm,	L=16m×36 nos.		576 lin.m
2. Pile installation (416 nos.)	(total pile length)			8,996 lin.m
(1) Steel pile	Outer diam.=300mm,	t=17mm×380 nos.		8,420 lin.m
(2) Steel pile	Outer diam.=300mm,	t= 9mm× 36 nos.		576 lin.m
3. Plug works				
(1) Concrete filling	inside of piles	for 416 nos.		661 cu.m
(2) Mortar filling	outside of piles	for 416 nos.		254 cu.m
(3) Pile head plug	earth materials	for 116 nos.		11 cu.m
(4) Pile head plug	crushed stone	for 264 nos.		24 cu.m
(5) Pile head plug	asphalt	for 264 nos.		3 ton

TABLE 4.1 ANTICIPATED DAMAGE BY THE LANDSLIDE OCCURRENCE AT LA BUTTE

(Mill. Rs.)

ANTICIPATED DAMAGE ITEM	VALUE
1. Building and Properties	339.9
2. Traffic service	44.37
a. disruption of traffic service	(31.76)
b. treatment of debris deposits	(8.08)
c. road pavement	(4.53)
3. Water supply	17.64
4. Electric supply	1.12
5. Land value	-
6. Loss of human life	-
7. Regional economic activities	-
8. Increase in employment	-
9. Social psychological damage (each year excluding 1990)	14.08
TOTAL	417.11

TABLE 4.2 TOTAL PROJECT COST

Exchange Rate : 1.0US$=Rs.15.3=JYE146.0

Item	Foreign Portion (Rs.1,000)	Local Portion (Rs.1,000)	Total Amount (Rs.1,000)
A. Construction Cost			
A-1 General Item	33,218	6,048	39,266
A-2 Drainage Well	6,549	5,354	11,903
(1) Earth works	792	1,405	2,197
(2) Concrete works	17	116	133
(3) Metal works	1,586	352	1,938
(4) Safety facilities	186	76	262
(5) Water collection boring	3,423	2,412	5,835
(6) Water drainage boring	393	266	659
(7) Borehole protection	152	713	865
(8) Drainage channel	0	14	14
A-3 Horizontal Boring	1,978	1,995	3,973
(1) Water collection boring	1,897	1,450	3,347
(2) Borehole protection	64	518	582
(3) Drainage channel	17	27	44
A-4 Piling	136,566	15,930	152,496
(1) Earth works	54	78	132
(2) Vertical boring	101,929	11,769	113,698
(3) Pile installation	32,133	967	33,100
(4) Reset of machinery	50	175	225
(5) Disposal works	609	180	789
(6) Plug works	1,791	2,761	4,552
Total of A	178,311	29,327	207,638
B. Administration Expense	0	6,275	6,275
C. Price Escalation	0	5,200	5,200
D. Physical Contingency	17,789	4,098	21,887
E. Engineering Service	16,500	2,400	18,900
F. Interest during Construction	6,900	5,500	12,400
Total	219,500	52,800	272,300

TABLE 4.3 ANNUAL DISBURSEMENT SCHEDULE (Financial Cost)

(Unit : Mil.Rs.) Exchange Rate : 1.0US$=Rs.15.3=JYE146.0

	Total			First year			second year		
	F/C	L/C	total	F/C	L/C	total	F/C	L/C	total
A. Construction Works									
A-1 General Item	33.2	6.0	39.2	20.3	3.6	23.9	12.9	2.4	15.3
A-2 Drainage Well	6.5	5.4	11.9	1.0	0.8	1.8	5.5	4.6	10.1
A-3 Horizontal Boring	2.0	2.0	4.0	0.7	0.7	1.4	1.3	1.3	2.6
A-4 Piling	136.6	15.9	152.5	17.1	1.9	19.0	119.5	14.0	133.5
Total of A	178.3	29.3	207.6	39.1	7.0	46.1	139.2	22.3	161.5
B. Administration Expense	0.0	6.3	6.3	0.0	2.3	2.3	0.0	4.0	4.0
Total of A to B	178.3	35.6	213.9	39.1	9.3	48.4	139.2	26.3	165.5
C. Price Escalation	0.0	5.2	5.2	0.0	0.7	0.7	0.0	4.5	4.5
Total of A to C	178.3	40.8	219.1	39.1	10.0	49.1	139.2	30.8	170.0
D. Physical Contingency	17.8	4.1	21.9	3.9	1.0	4.9	13.9	3.1	17.0
E. Engineering Service	16.5	2.4	18.9	6.9	1.0	7.9	9.6	1.4	11.0
Total of A to E	212.6	47.3	259.9	49.9	12.0	61.9	162.7	35.3	198.0
F. Interest during Construction	6.9	5.5	12.4	1.3	1.1	2.4	5.6	4.4	10.0
Grand Total	219.5	52.8	272.3	51.2	13.1	64.3	168.3	39.7	208.0

TABLE 4.4 ANNUAL DISBURSEMENT SCHEDULE (Economic Cost)

(Unit : Mil.Rs.) Exchange Rate : 1.0US$ = Rs.15.3 = JYE146.0

	Total			First year			second year		
	F/C	L/C	total	F/C	L/C	total	F/C	L/C	total
A. Construction Works									
A-1 General Item	33.2	6.0	39.2	20.3	3.6	23.9	12.9	2.4	15.3
A-2 Drainage Well	6.5	5.4	11.9	1.0	0.8	1.8	5.5	4.6	10.1
A-3 Horizontal Boring	2.0	2.0	4.0	0.7	0.7	1.4	1.3	1.3	2.6
A-4 Piling	136.6	15.8	152.4	17.1	1.9	19.0	119.5	13.9	133.4
Total of A	178.3	29.2	207.5	39.1	7.0	46.1	139.2	22.2	161.4
B. Administration Expense	0.0	6.3	6.3	0.0	2.3	2.3	0.0	4.0	4.0
Total of A to B	178.3	35.5	213.8	39.1	9.3	48.4	139.2	26.2	165.4
C. Price Escalation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total of A to C	178.3	35.5	213.8	39.1	9.3	48.4	139.2	26.2	165.4
D. Physical Contingency	17.8	3.5	21.3	3.9	0.9	4.8	13.9	2.6	16.5
E. Engineering Service	16.5	2.4	18.9	6.9	1.0	7.9	9.6	1.4	11.0
Total of A to E	212.6	41.4	254.0	49.9	11.2	61.1	162.7	30.2	192.9
F. Interest during Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	212.6	41.4	254.0	49.9	11.2	61.1	162.7	30.2	192.9

TABLE 4.5 CASH FLOW OF THE PROJECT FOR THE LONG TERM PROTECTIVE MEASURES

	Social Discount Rate (r) r=0 %		r=10 %	
Year	Benefit	Cost	Benefit	Cost
1	0.00	3.60	0.00	3.60
2	14.08	165.70	12.80	150.64
3	14.08	84.40	11.64	69.75
4	417.11	0.00	313.38	0.00
5	14.08	0.00	9.62	0.00
6	14.08	0.00	8.74	0.00
7	14.08	0.00	7.95	0.00
8	14.08	0.00	7.23	0.00
9	14.08	0.00	6.57	0.00
10	14.08	0.00	5.97	0.00
11	14.08	0.00	5.43	0.00
12	14.08	0.00	4.93	0.00
13	14.08	0.00	4.49	0.00
14	14.08	0.00	4.08	0.00
15	14.08	0.00	3.71	0.00
16	14.08	0.00	3.37	0.00
17	14.08	0.00	3.06	0.00
18	14.08	0.00	2.79	0.00
19	14.08	0.00	2.53	0.00
20	14.08	0.00	2.30	0.00
21	14.08	0.00	2.09	0.00
22	14.08	0.00	1.90	0.00
23	14.08	0.00	1.73	0.00
24	14.08	0.00	1.57	0.00
25	14.08	0.00	1.43	0.00
26	14.08	0.00	1.30	0.00
27	14.08	0.00	1.18	0.00
28	14.08	0.00	1.07	0.00
29	14.08	0.00	0.98	0.00
30	14.08	0.00	0.89	0.00
31	14.08	0.00	0.81	0.00
32	14.08	0.00	0.73	0.00
33	14.08	0.00	0.67	0.00
34	14.08	0.00	0.61	0.00
35	14.08	0.00	0.55	0.00
	881.75	253.70	438.09	223.99

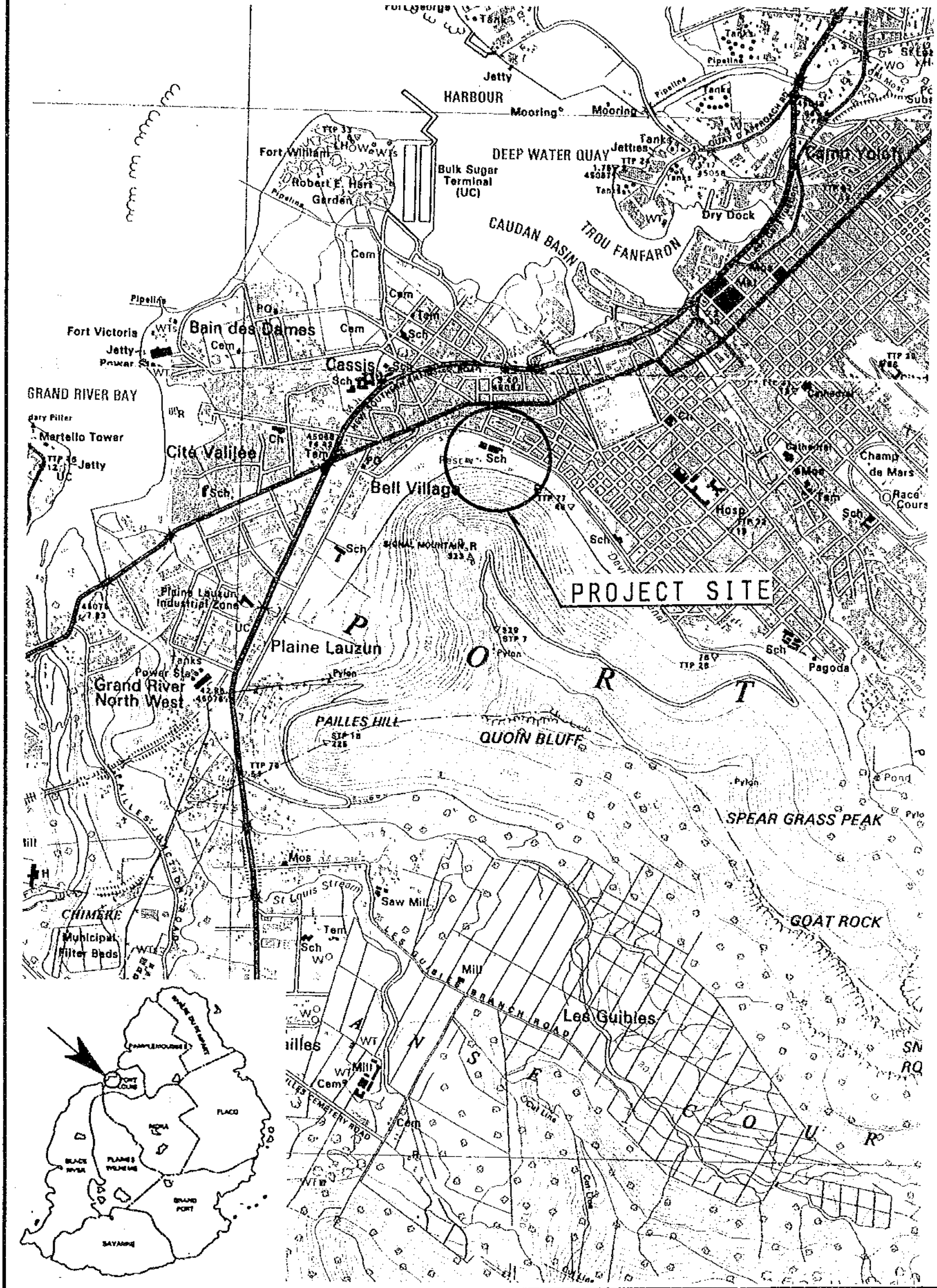
r=0 %	r=10 %
B= 881.75	B= 438.09
C= 253.70	C= 223.99
B−C= 628.05	B−C= 214.10

Net benfit : B−C =214.10

Cost benefit ratio : B/C =1.96

FIGURES

Fig. 1.1

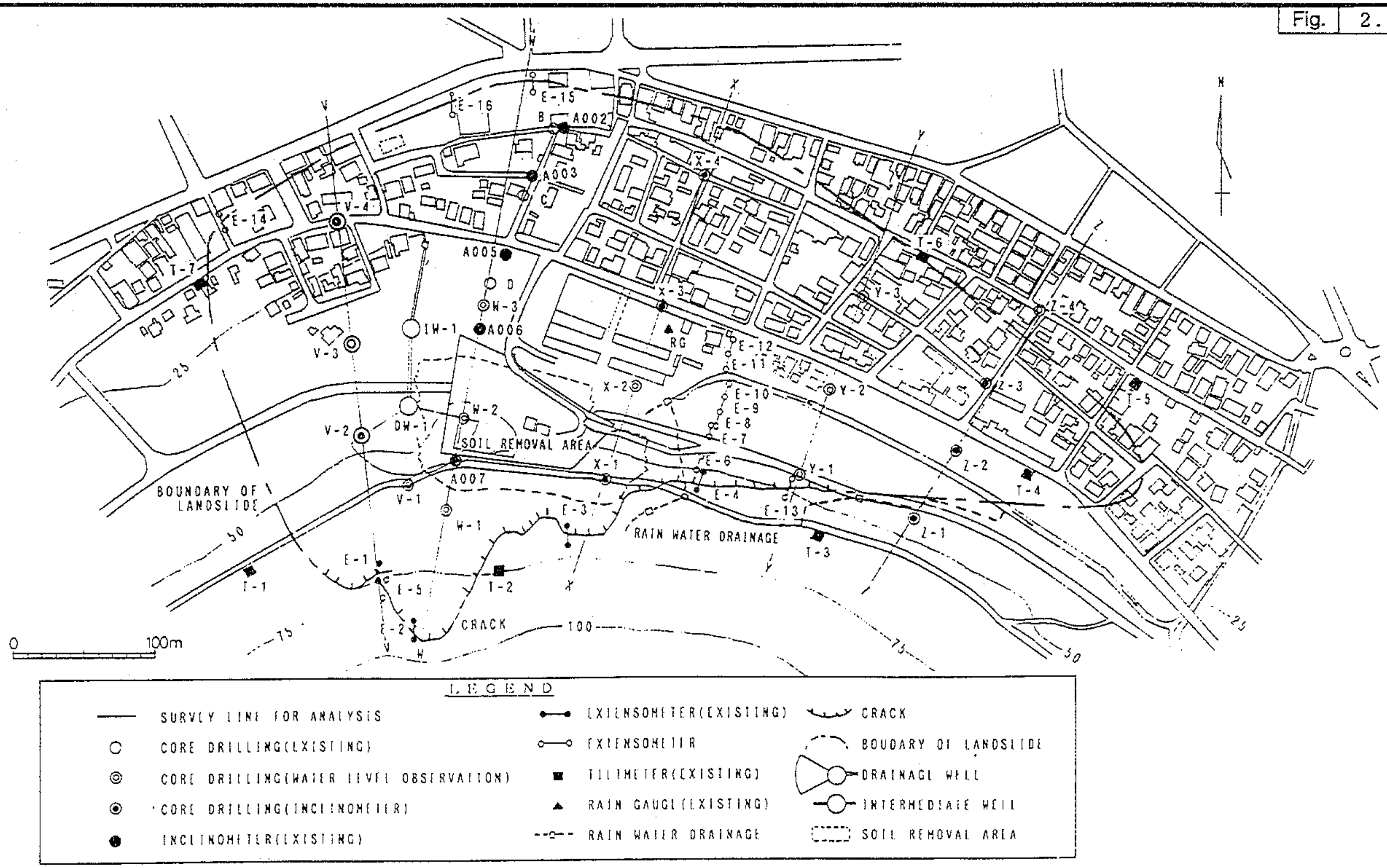


LOCATION MAP OF PROJECT SITE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 2.1

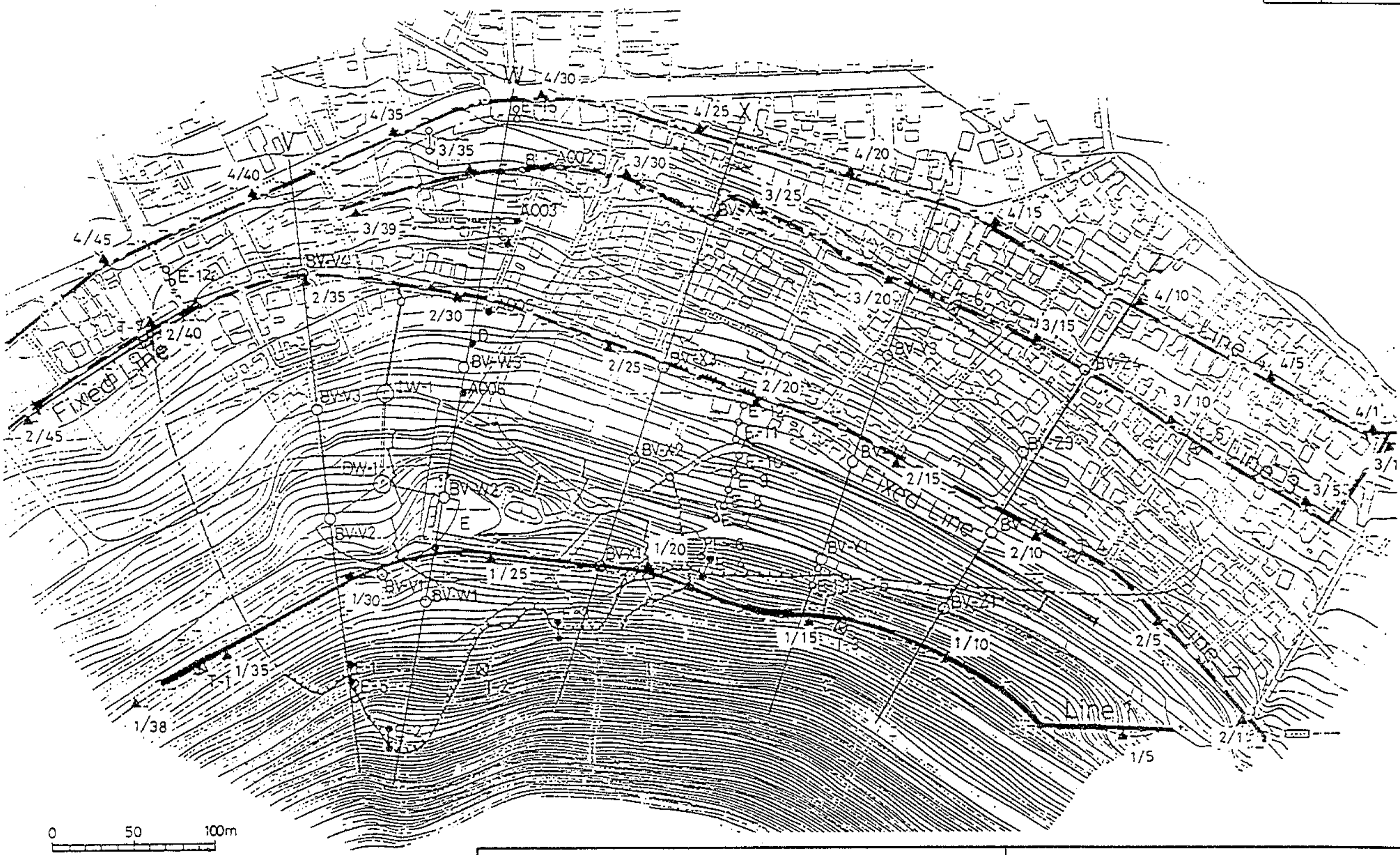


LOCATION MAP OF THE INVESTIGATION SITE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 2.2

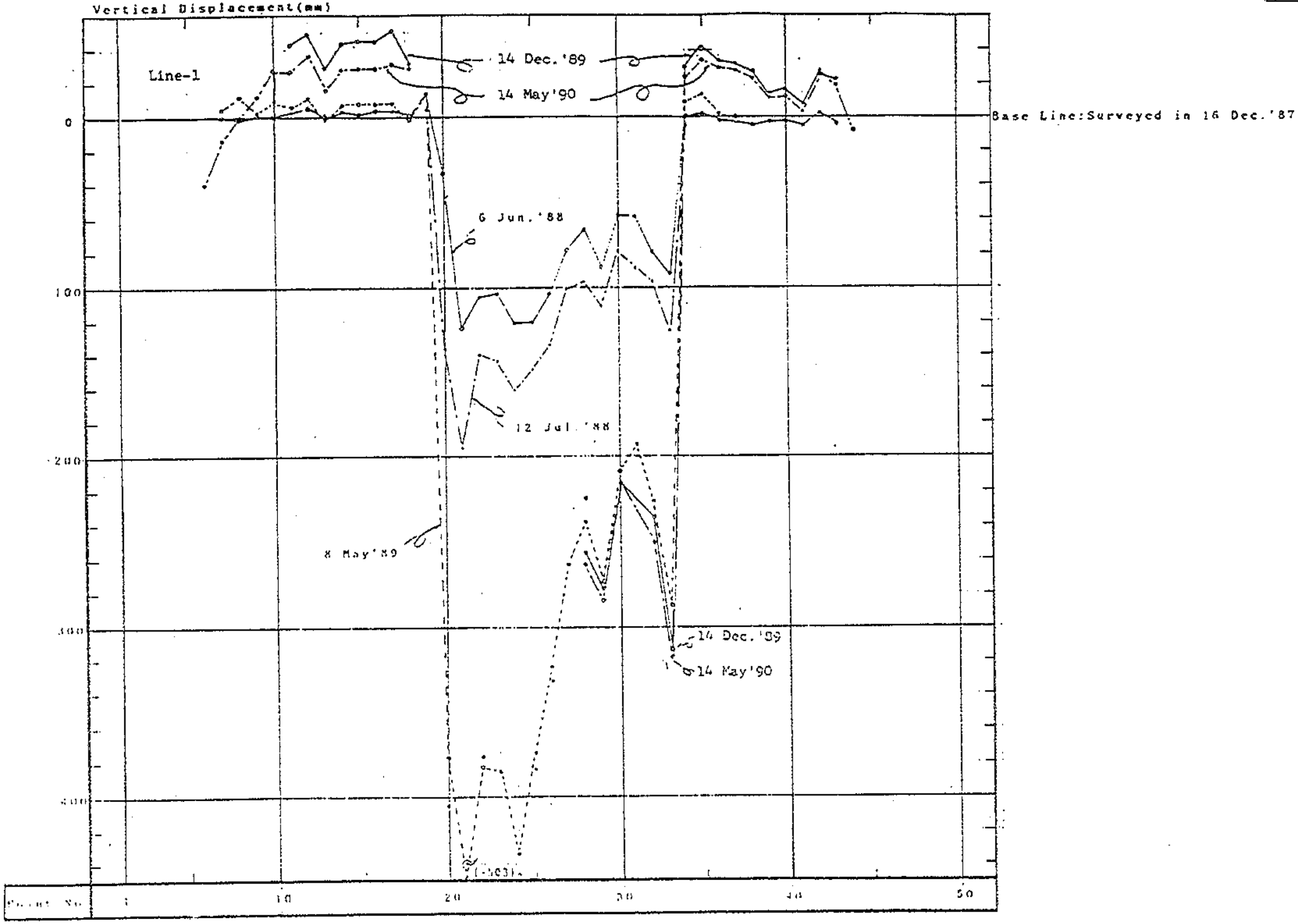


LOCATION MAP FOR THE GROUND SURVEY

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 2.3

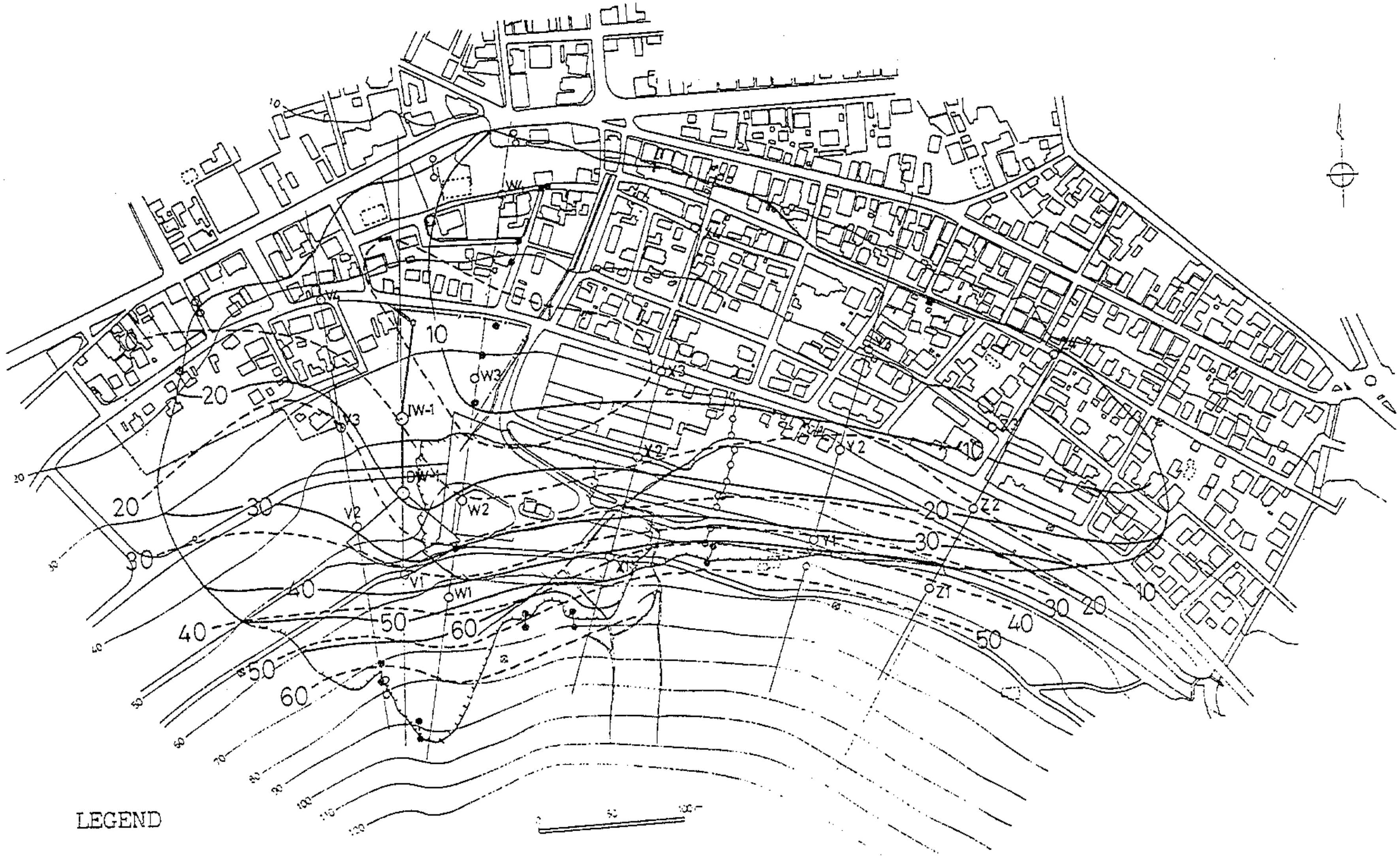


LEVELING SURVEY RESULT ALONG LINE-1

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 2.4



LEGEND

—10— SLIDE SURFACE(m)

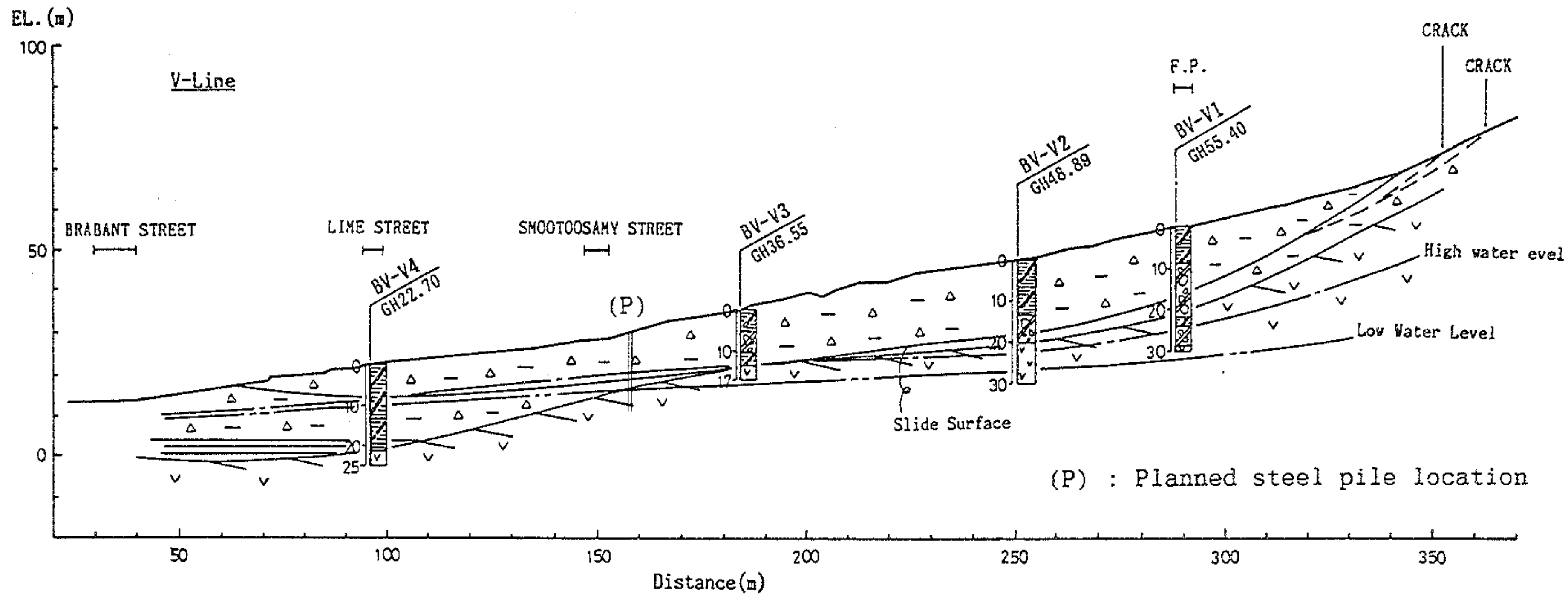
- - - -20 BEDROCK SURFACE(m)

CONTOUR MAP OF ASSUMED SLIDE SURFACE AND BEDROCK SURFACE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

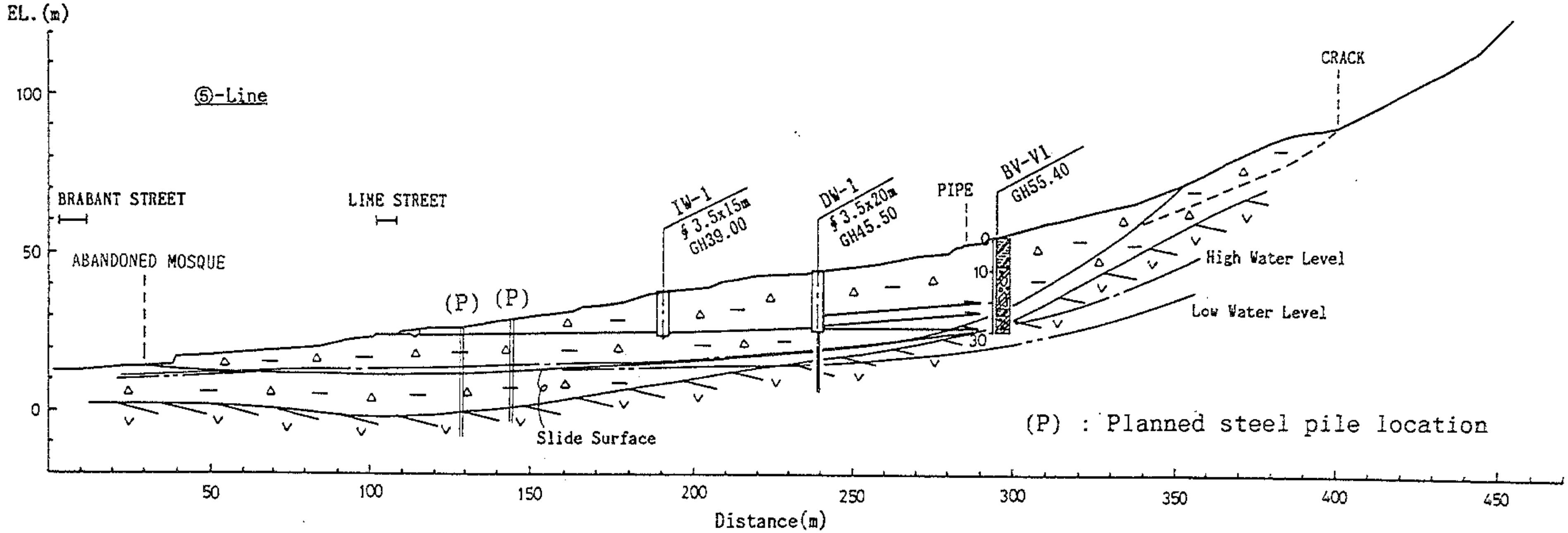
Fig. 2.5



GEOLOGICAL PROFILE ALONG V-LINE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 2.6

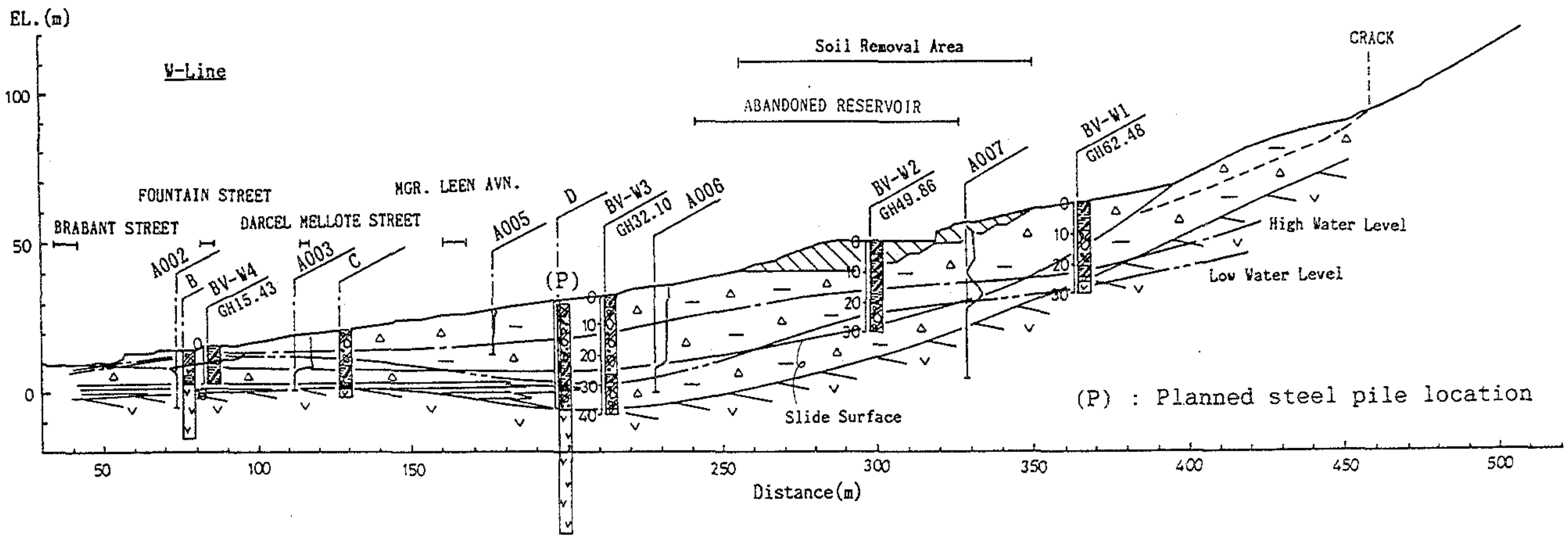


GEOLOGICAL PROFILE ALONG THE LINE THROUGH THE DRAINAGE WELL AND THE INTERMEDIATE WELL

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

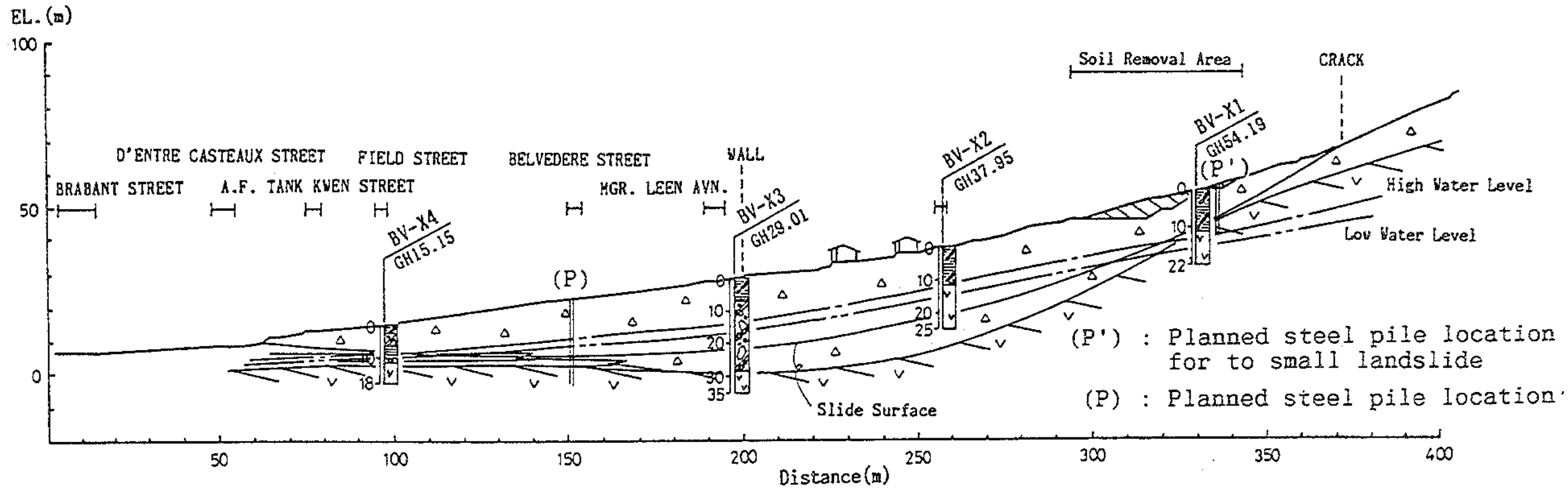
Fig. 2.7



GEOLOGICAL PROFILE ALONG W-LINE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

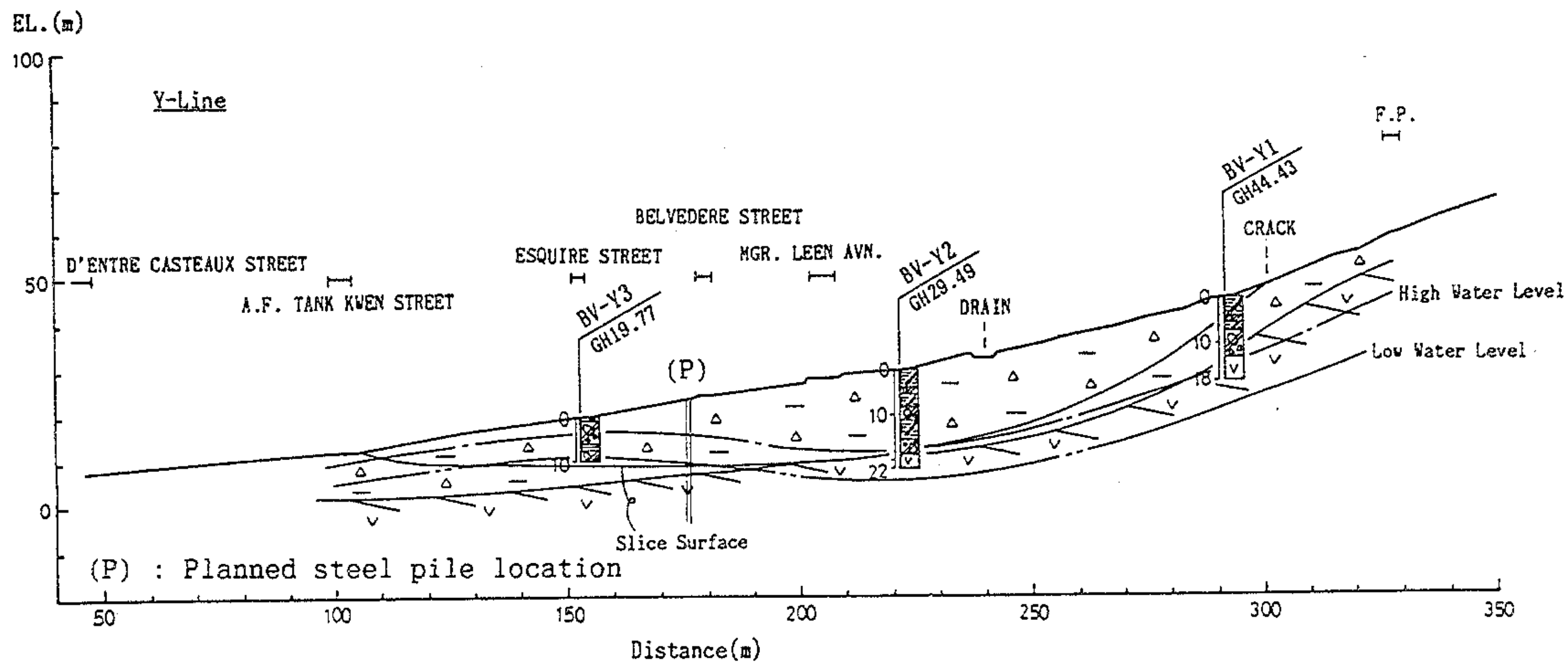
Fig. 2.8



GEOLOGICAL PROFILE ALONG X-LINE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

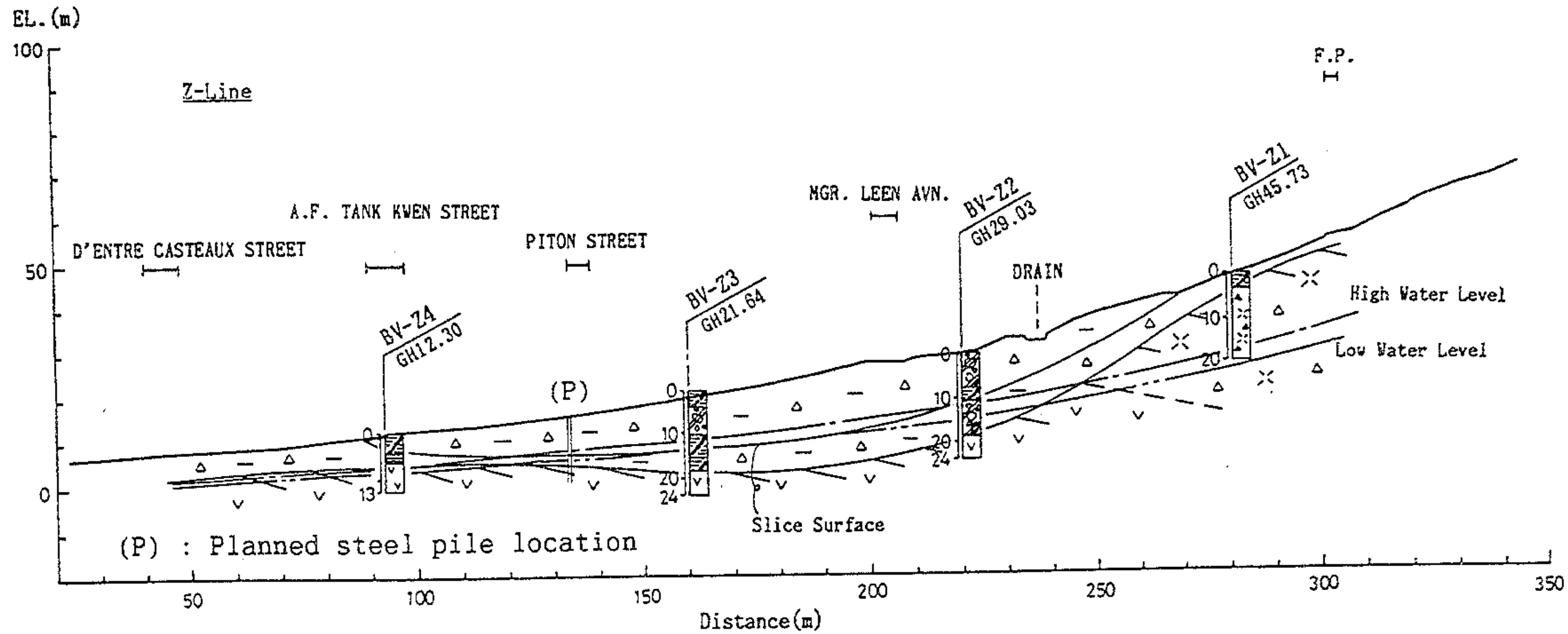
Fig. 2.9



GEOLOGICAL PROFILE ALONG Y-LINE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

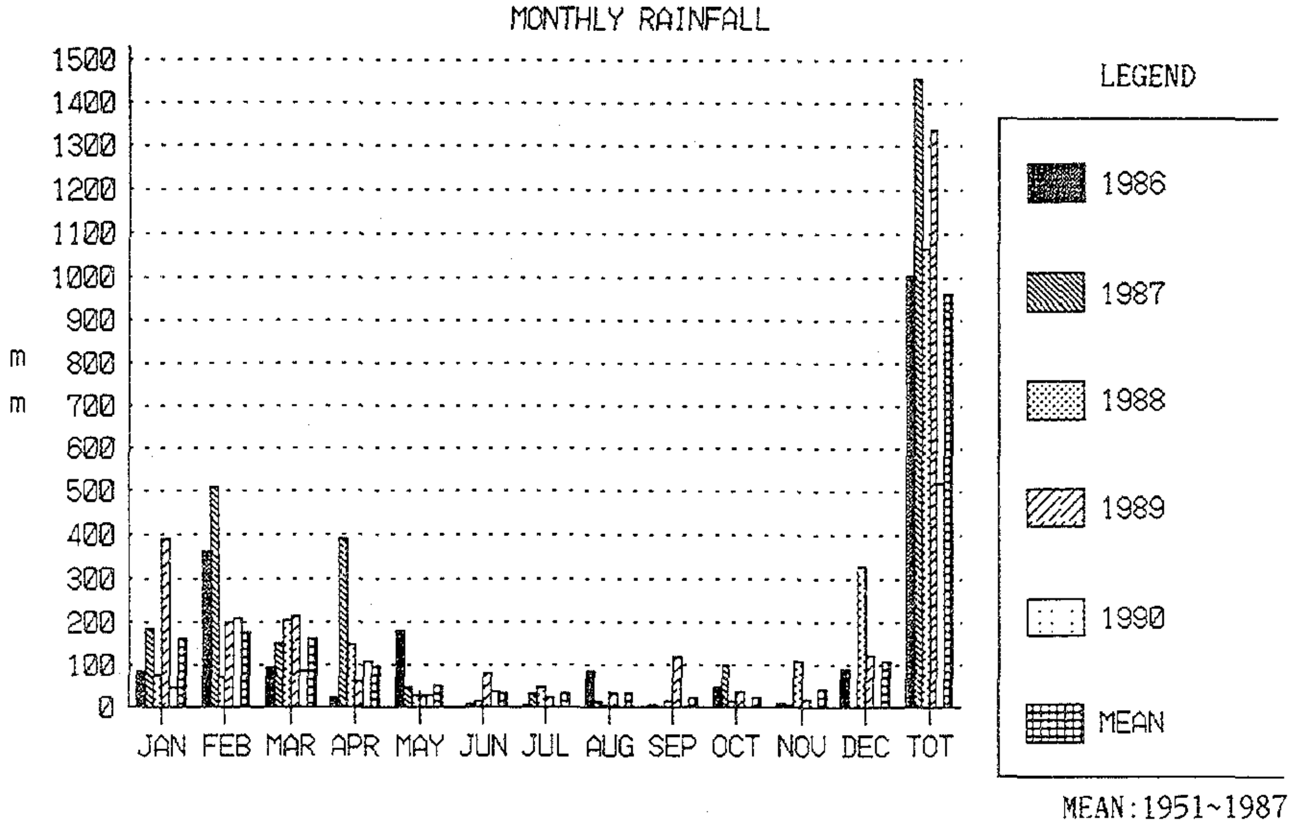
Fig. 2.10



GEOLOGICAL PROFILE ALONG Z-LINE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

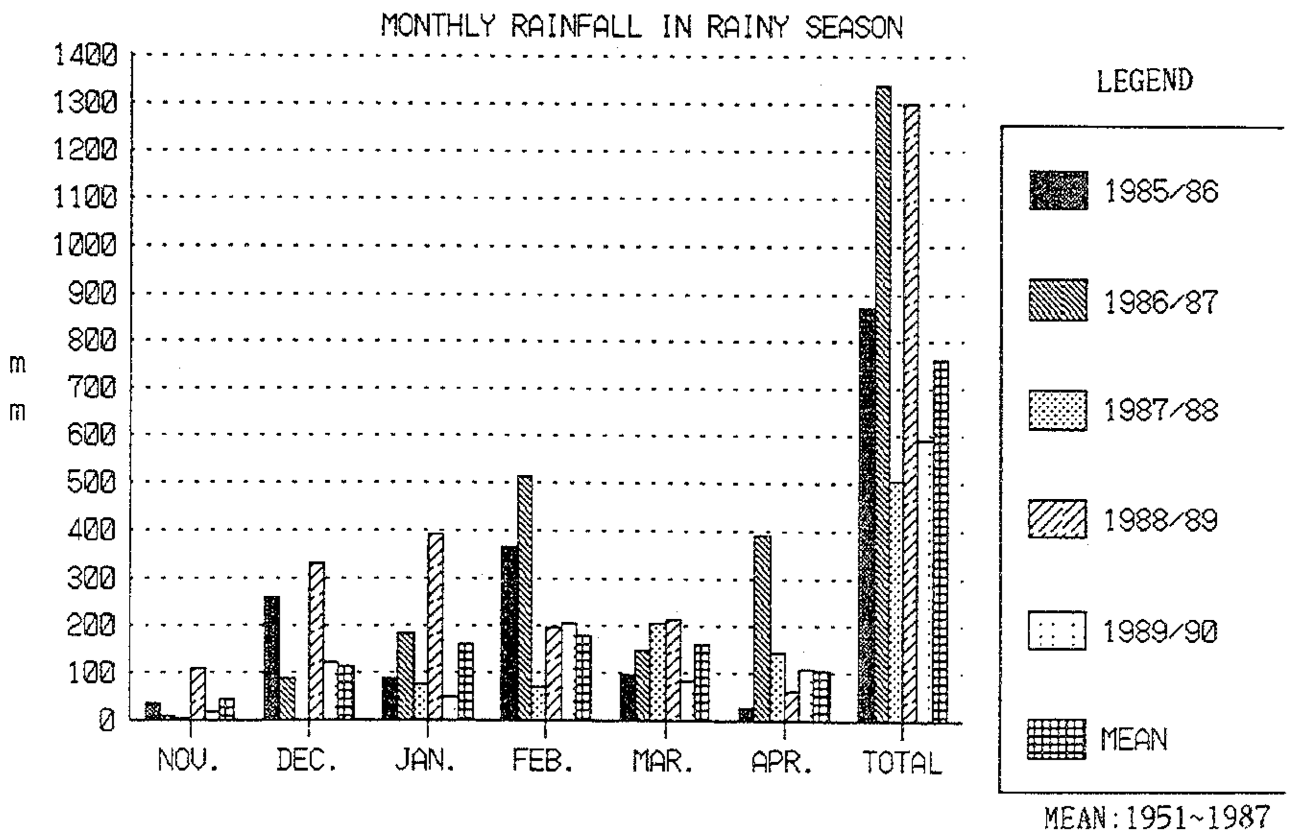
Fig. 2.11



MONTHLY RAINFALL FROM 1986 TO 1990

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 2.12

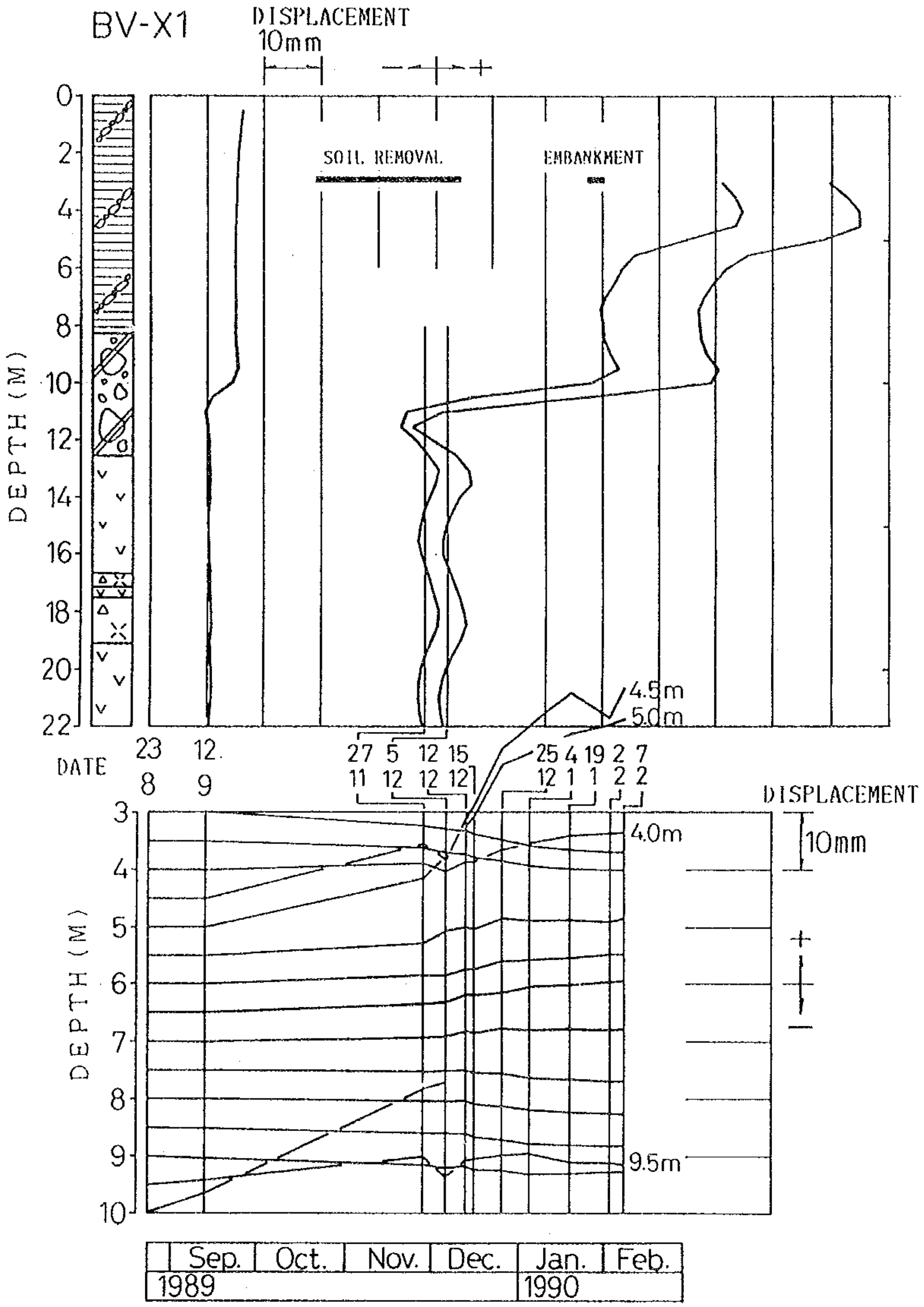


MONTHLY RAINFALL IN RAINY SEASON FROM 1985 TO 1990

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

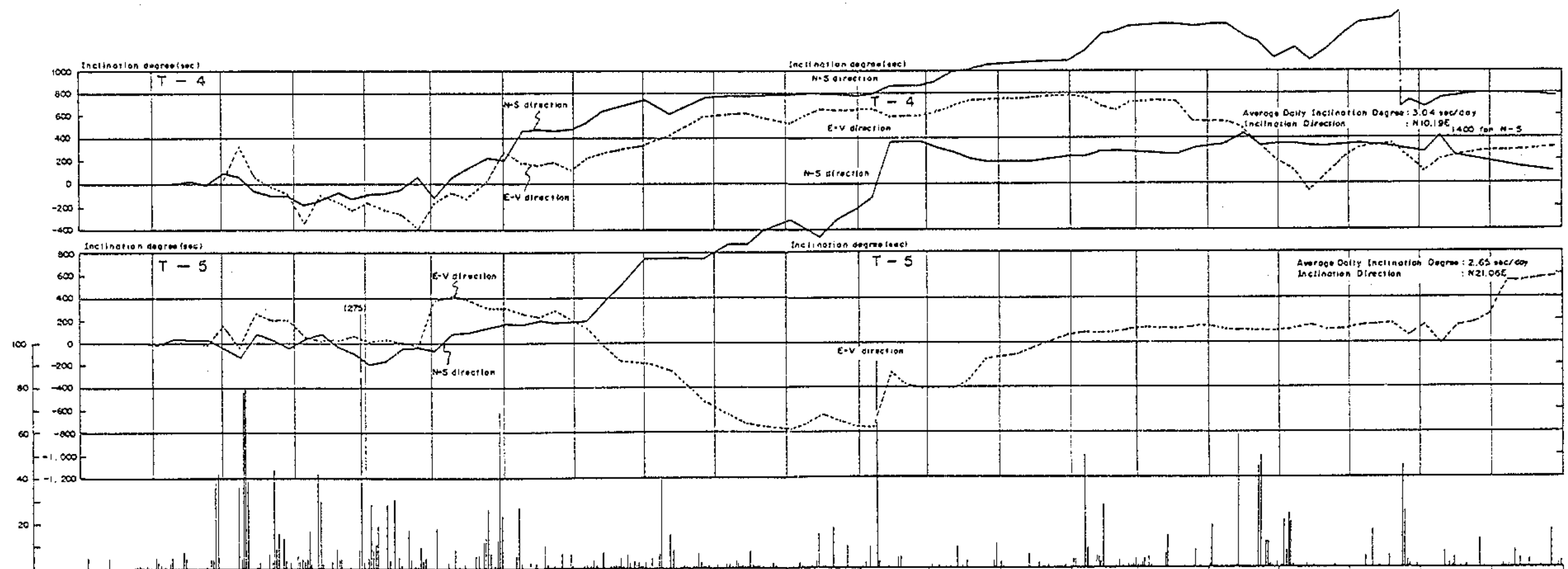
Fig. 2.13



DISPLACEMENT OF BOREHOLE INCLINOMETER IN BOREHOLE, BV-X1

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY



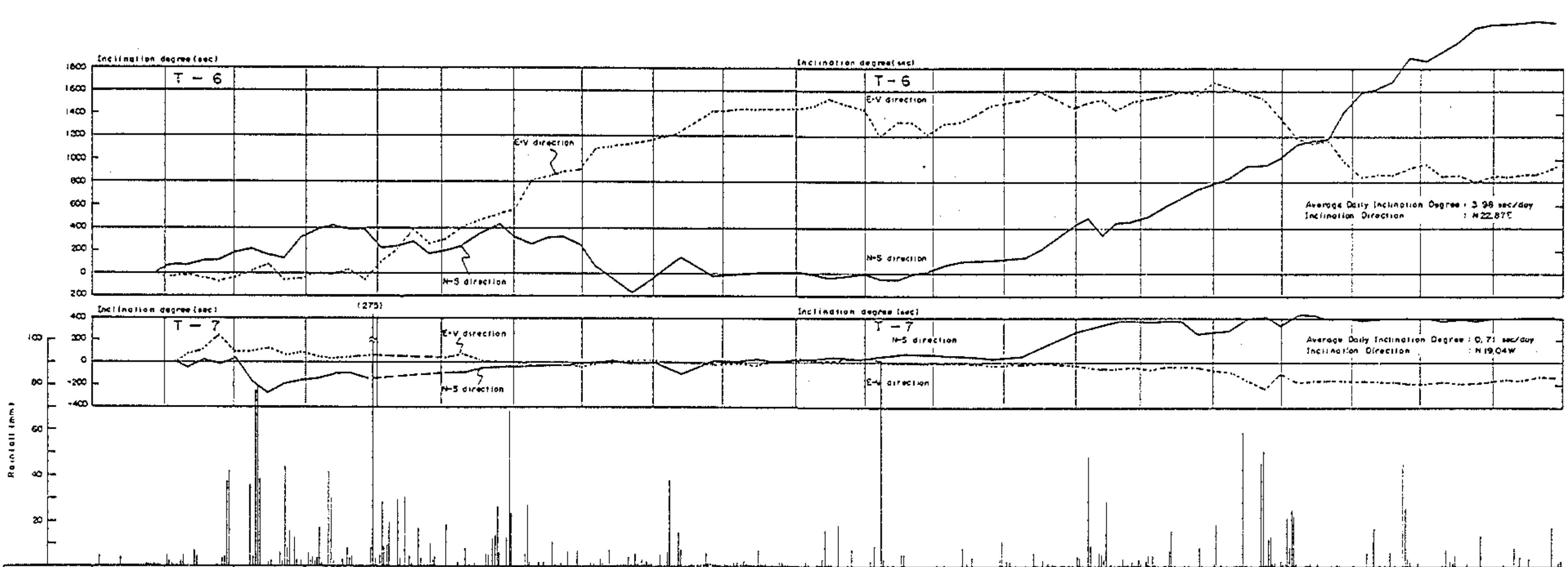
Date	Oct. '88	Nov.	Dec.	Jan. '89	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug. '89	Sep.	Oct.	Nov.	Dec.	Jan. '90	Feb.	Mar.	Apr.	May	Jun.
Rainfall	14.0	108.2/122.2	330.4/452.6	388.1/840.7	197.8/1038.5	215.1/1253.6	61.5/1315.1	28.8/1343.9	83.2/1427.1	23.4/1450.5	36.1	120.8	36.6	17.9	123.7	46.5	206.1	84.4	109.7	30.1	41.0

DISPLACEMENT OF TILTMETERS, T4～T5

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

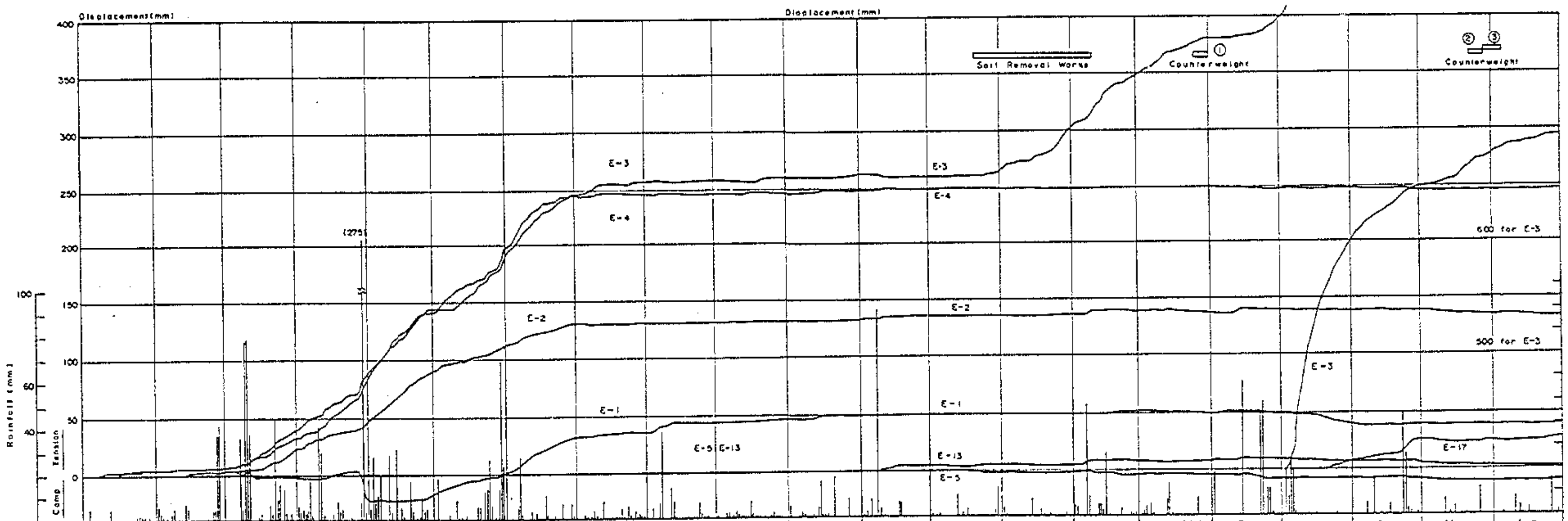
Fig. 2.15



Date	Oct '88	Nov.	Dec.	Jan. '89	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug. '89	Sep	Oct.	Nov.	Dec.	Jan. '90	Feb	Mar	Apr	May	Jun.
Rainfall	14.0	108.2/122.2	330.4/452.6	388.1/840.7	197.8/1038.5	215.1/1253.6	61.5/1315.1	28.8/1343.9	83.2/1427.1	23.4/1450.5	36.1	120.8	36.6	17.9	123.7	46.5	208.1	84.4	109.7	30.1	41.0

DISPLACEMENT OF TILTMETERS, T6～T7

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY



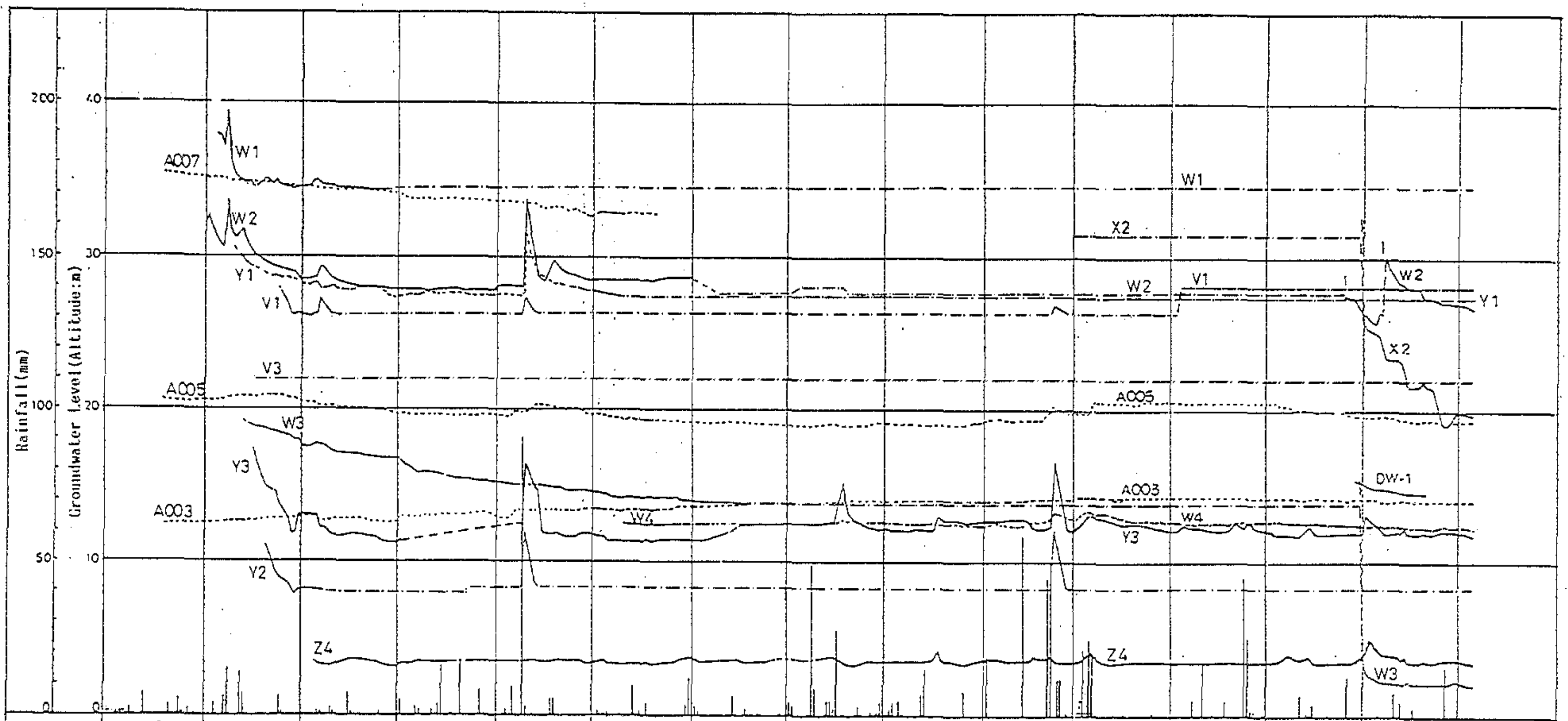
Date	Oct. '88	Nov.	Dec.	Jan. '89	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug. '89	Sep.	Oct.	Nov.	Dec.	Jan. '90	Feb.	Mar.	Apr.	May	Jun.
Monthly Rainfall	14.0	108.2/122.2	330.4/452.6	388.1/840.7	197.8/1038.5	215.1/1253.1	61.5/1315.1	288/1343.9	83.2/1427.1	23.4/1450.5	36.1	120.8	36.6	17.9	123.7	46.5	208.1	54.4	109.7	30.1	41.0

DISPLACEMENT OF EXTENSOMETER AT CROWN PORTION OF LANDSLIDE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 2.17



Date	May.'89	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan..'90	Feb.	Mar.	Apr.	May	Jun.	Jul.
Rainfall Monthly(mm)	28.8	83.2	23.4	36.1	120.8	36.6	17.9	123.7	46.5	208.1	84.4	109.7	30.1	41.0	

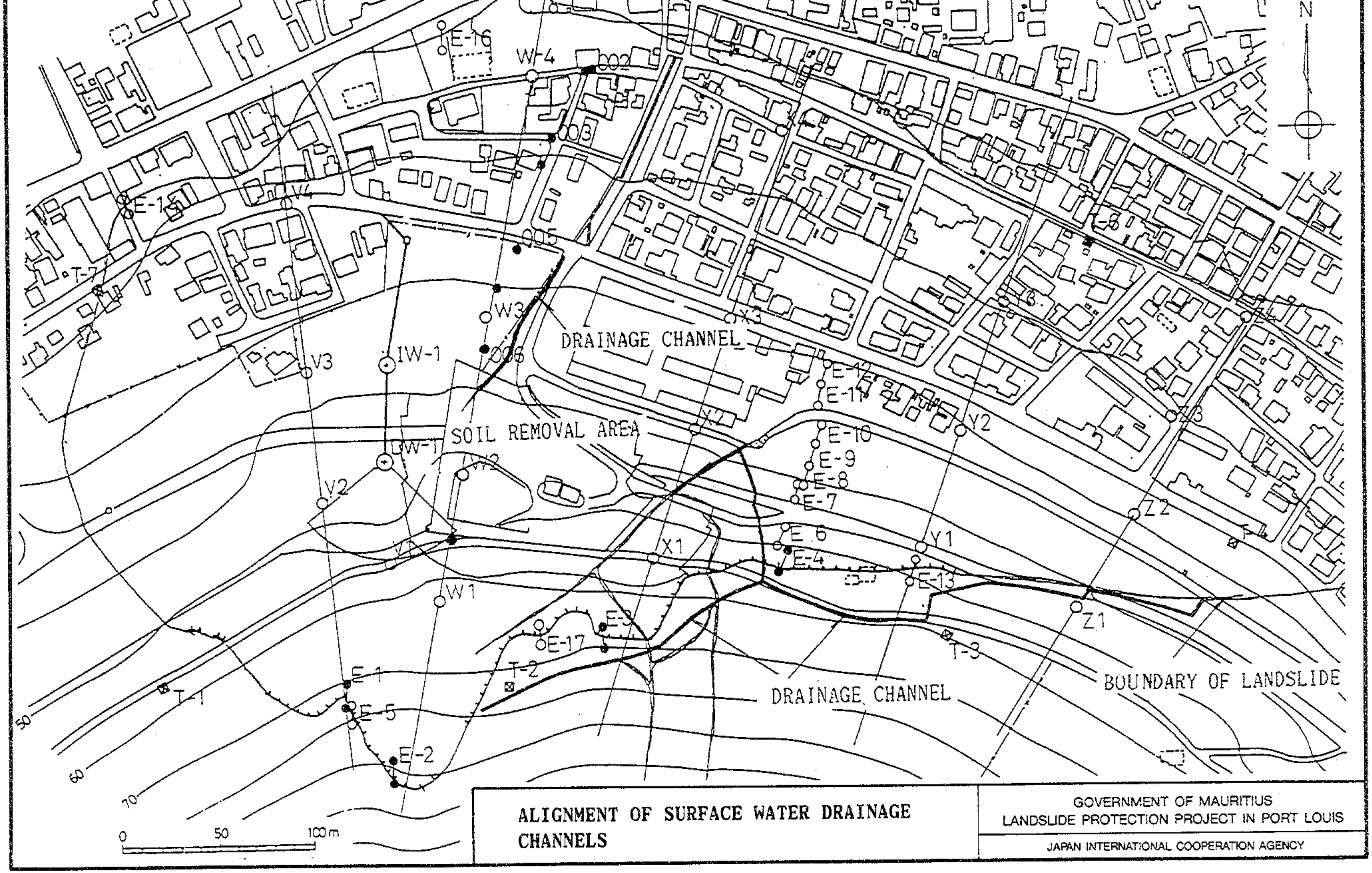
—·—·— :Groundwater level is deeper than the bottom of borehole

OBSERVATION RESULTS OF GROUNDWATER LEVELS IN BOREHOLES

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

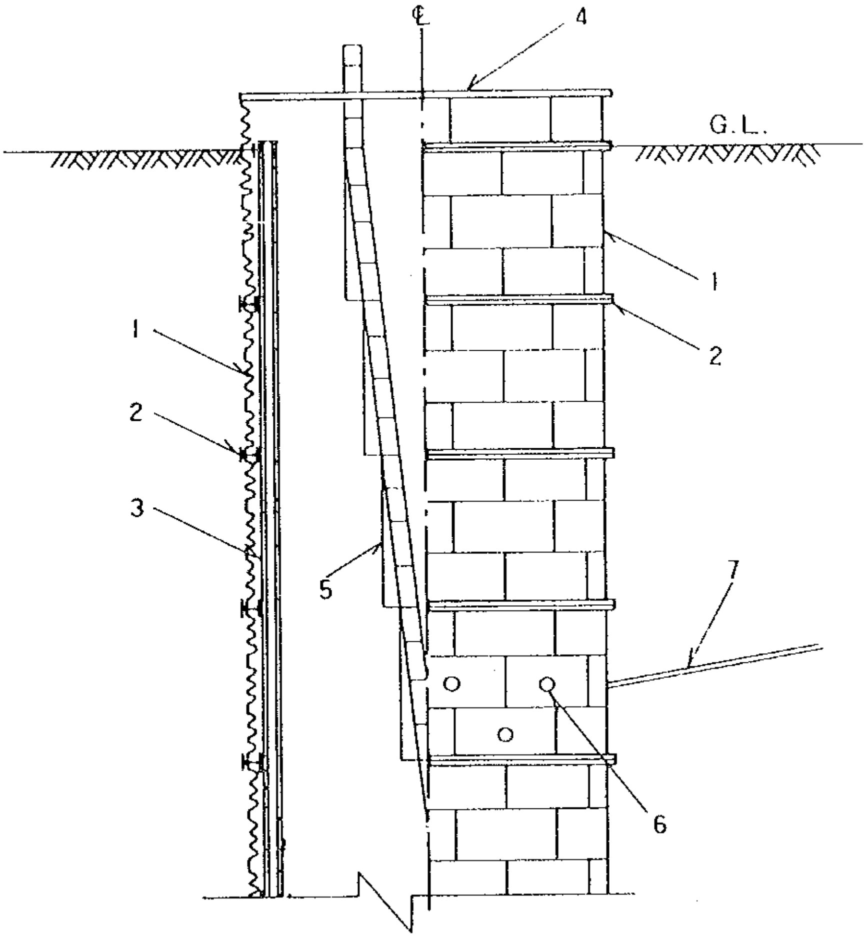
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 2.18



ALIGNMENT OF SURFACE WATER DRAINAGE CHANNELS

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY



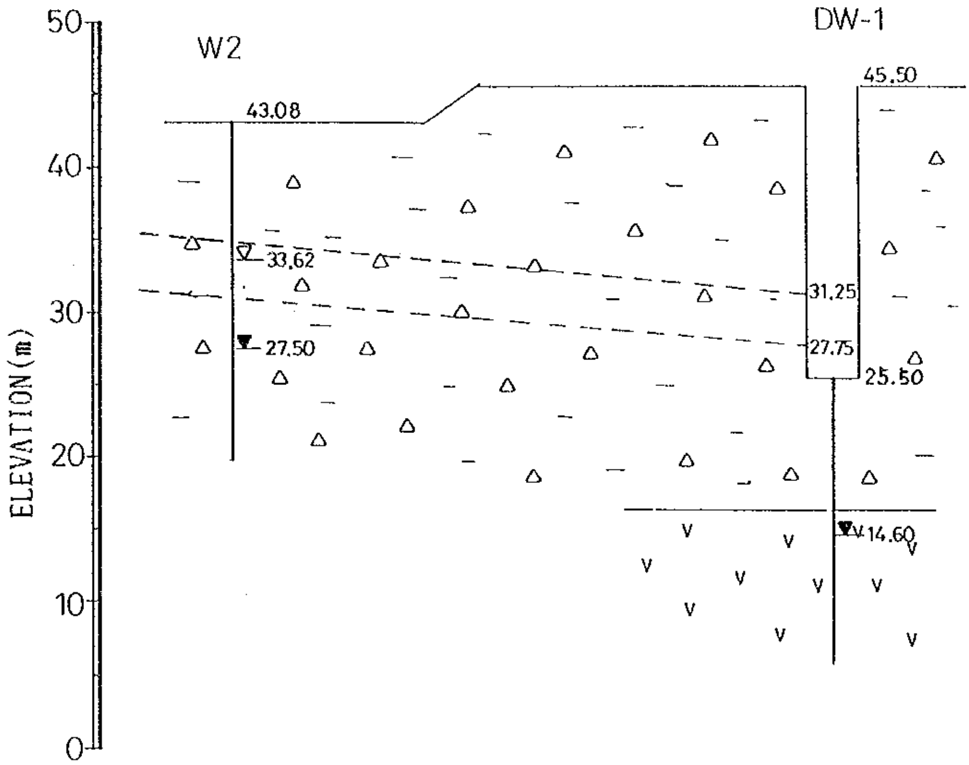
1. AN-TYPE LINER PLATE
2. STIFFENER RING
3. VERTICAL STIFFENER
4. COVER(EXPANDED METAL)
5. LADDER
6. WATER COLLECTION HOLES
7. GROUNDWATER COLLECTION BOREHOLE

STRUCTURE OF DRAINAGE WELL

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3.2



LEGEND

43.08 ELEVATION (m)

——— GROUNDWATER COLLECTION BOREHOLE

▽ GROUNDWATER TABLE (7, JUN., 1989)

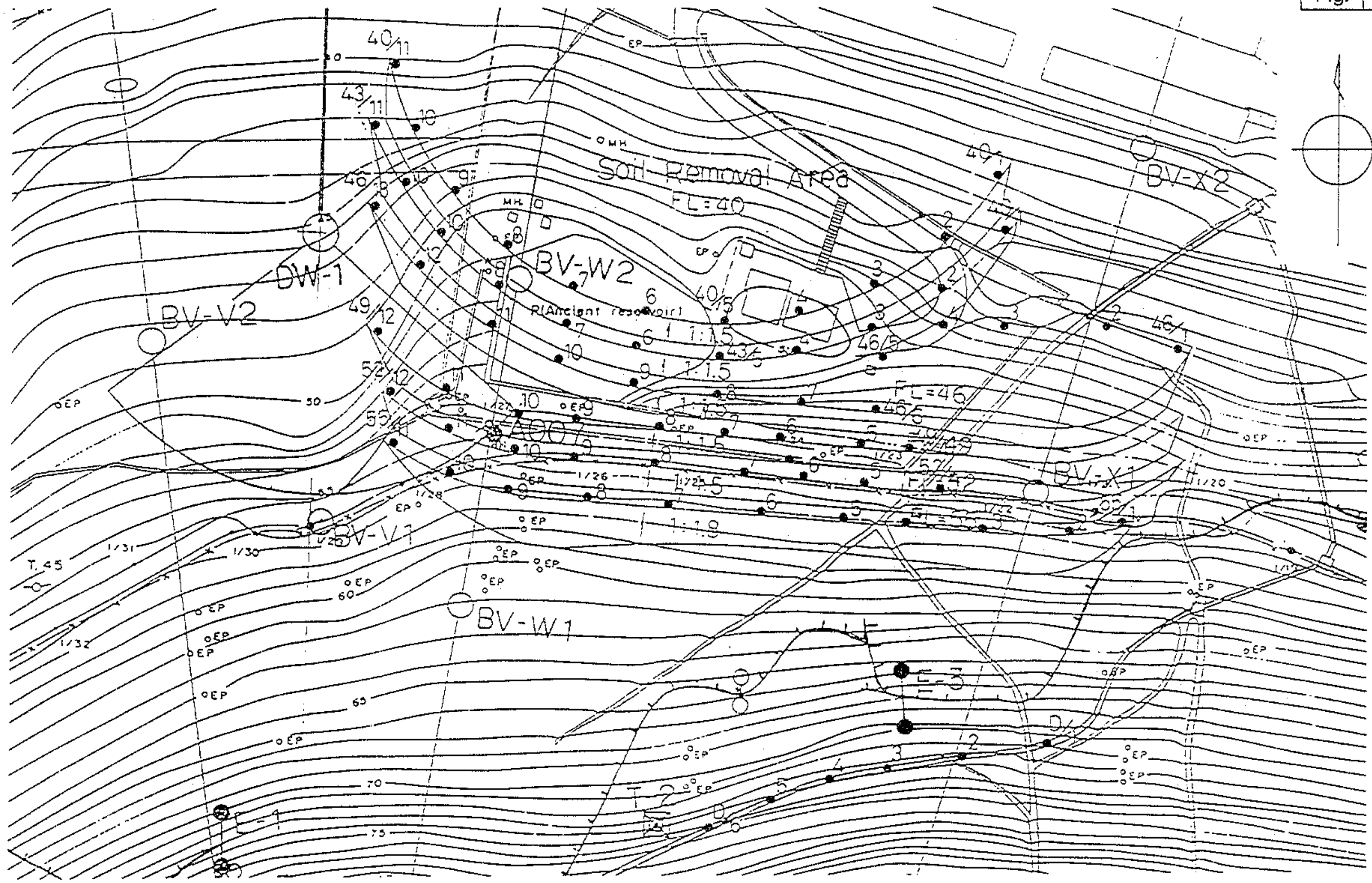
▼ GROUNDWATER TABLE (19, JUN., 1990)

GROUNDWATER LEVEL IN DRAINAGE WELL-1 AND BOREHOLE BV-W2

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3.3

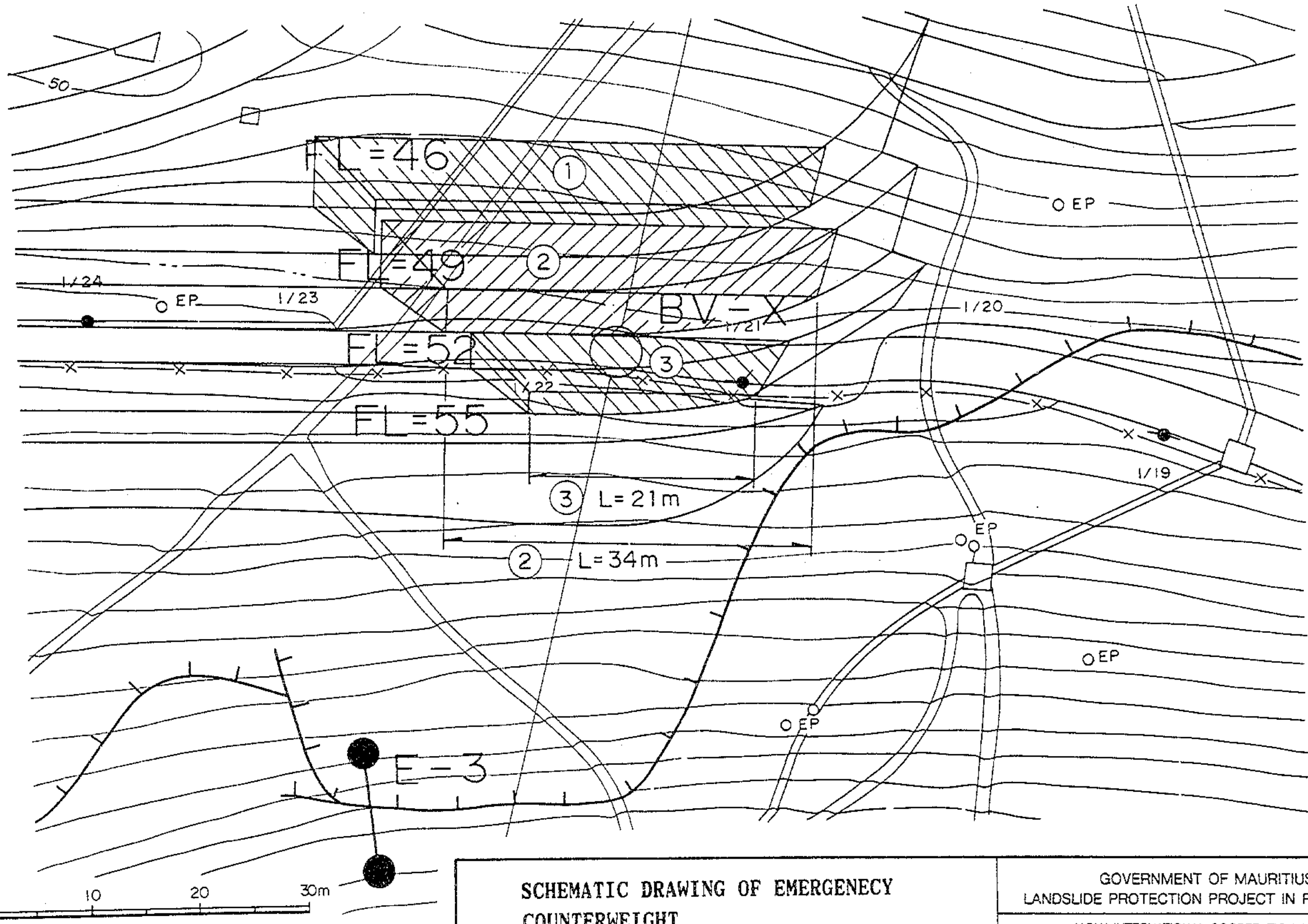


LAYOUT OF LEVELING SURVEY POINTS AT THE SOIL REMOVAL AREA

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

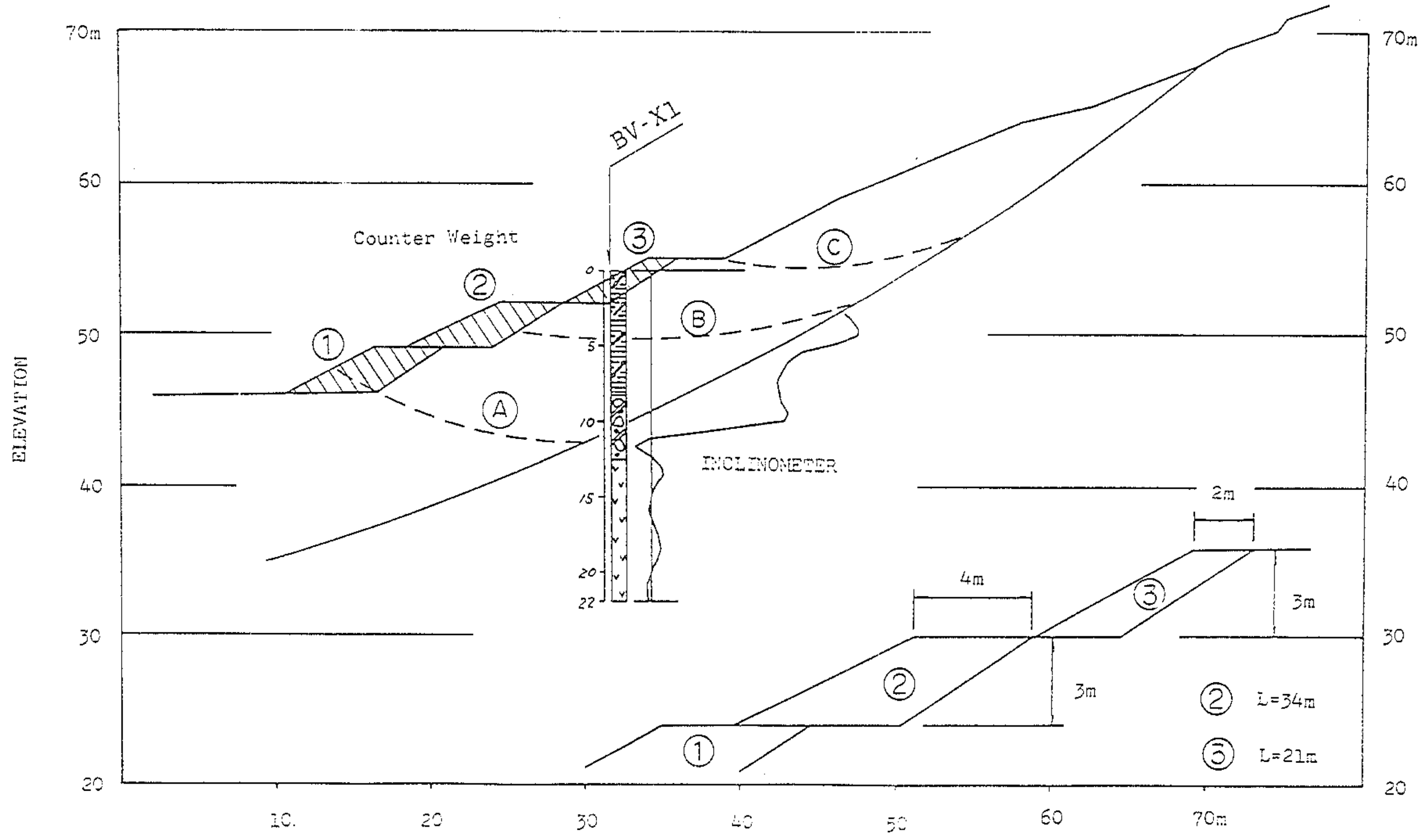
Fig. 3.4



SCHEMATIC DRAWING OF EMERGENECY COUNTERWEIGHT

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3.5

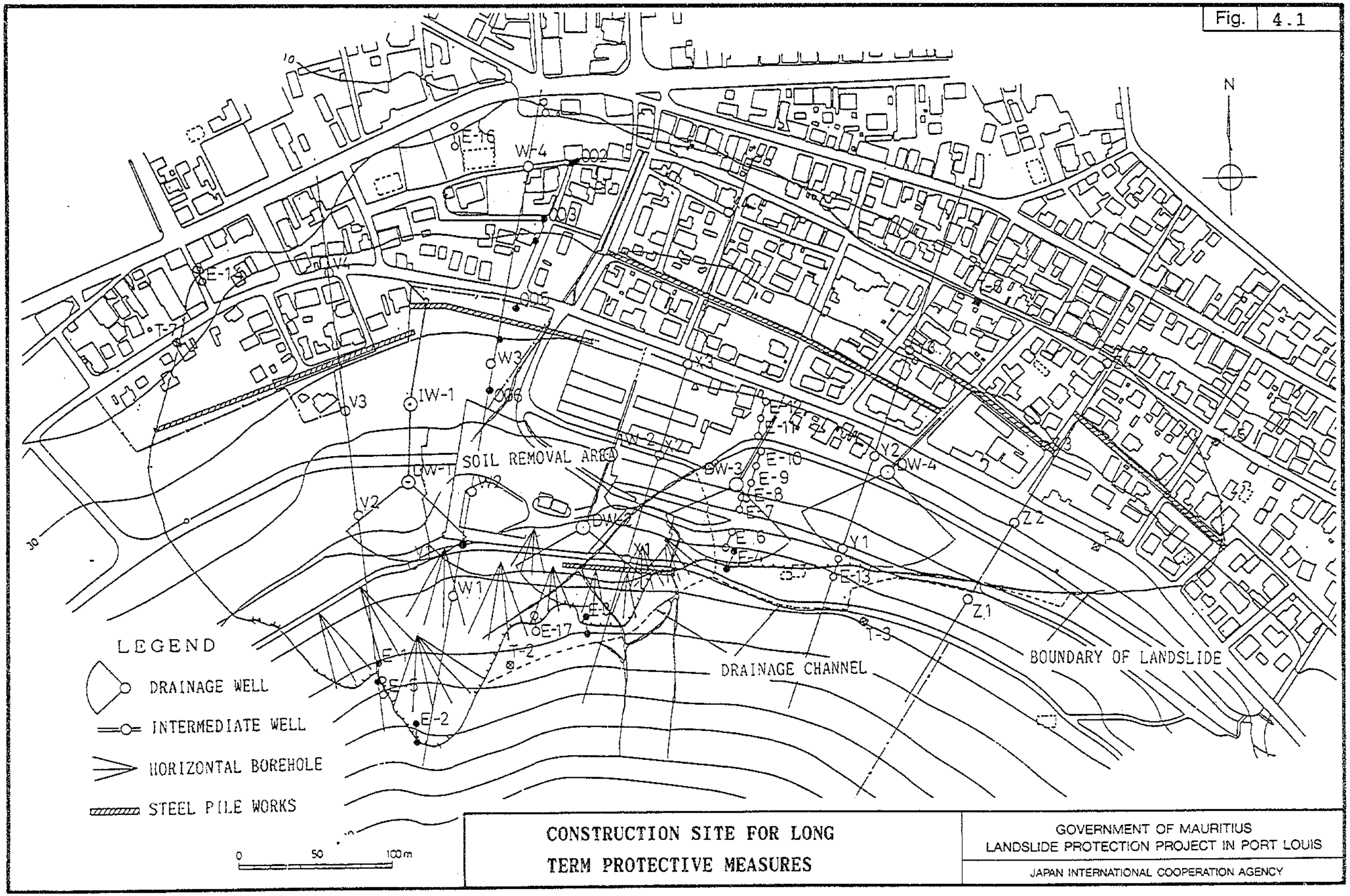


PROFILE OF EMERGENCY COUNTERWEIGHT

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

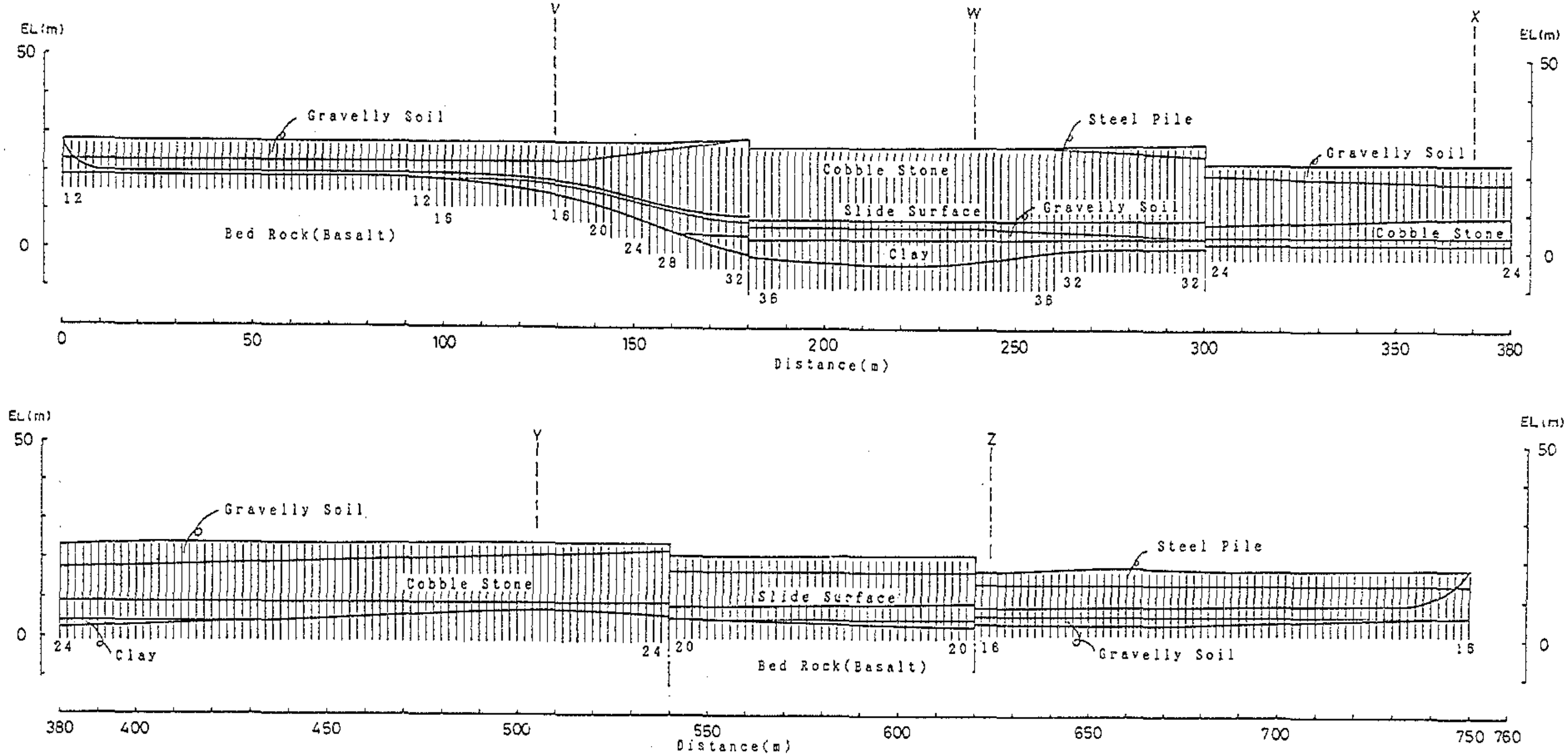
Fig. 4.1



CONSTRUCTION SITE FOR LONG TERM PROTECTIVE MEASURES

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

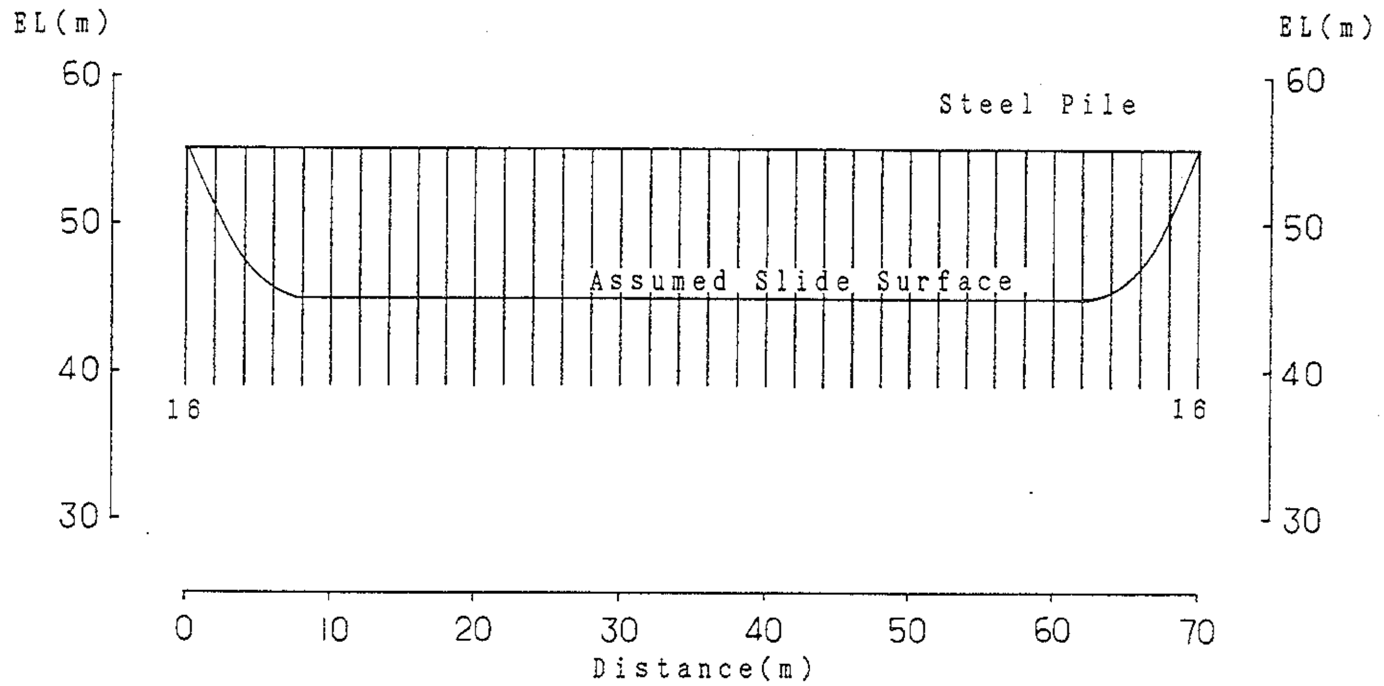
Fig. 4.2



CROSS SECTIONAL ALIGNMENT OF STEEL PILES FOR MAIN LANDSLIDE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 4.3



CROSS SECTIONAL ALIGNMENT OF STEEL PILES FOR SMALL LANDSLIDE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 4.4

Items	Quantity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
KEY EVENTS	L.S.		L/A					Contract	NTP														Completion
PRE-CONSTRUCTION STAGE																							
1.Loan Procedure	L.S.																						
2.Selection of Consultant	L.S.																						
3.Tender Document	L.S.																						
4.Tendering and Evaluation	L.S.																						
5.Contract and Award	L.S.																						
CONSTRUCTION STAGE																							
1.Mobilization	L.S.																						
2.Temporary Works	L.S.																						
3.Drainage Well												No.3 & 4				No.5 & 6							
a.Excavation	45 m																						
b.Water collection boring	2,100 m																						
c.Water drainage boring	200 m																						
4.Horizontal Boring	1,670 m																						
5.Piling																							
a.Vertical boring	9,376 m																						
b.Pile installation	8,420 m																						
c.Pile installation	576 m																						
d.Filling in piles	416 nos.																						
e.Plug works	416 nos.																						

IMPLEMENTATION TIME SCHEDULE

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 4.5

ANTICIPATED POTENTIALLY ENDANGER AREA

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY