European Journal of Scientific Research
ISSN 1450-216X Vol.40 No.3 (2010), pp.318-340

http://www.eurojournals.com/ejsr.htm

Environmental Risk Assessment on Hill Site Development in Penang, Malaysia: Recommendations on Management System

F Ahmad
School of Civil Engineering, University Science Malaysia, P. Pinang, Malaysia
E-mail: cefahmad@eng.usm.my
Tel: +604-599-6268; Fax: +604-594-1009

AS Yahaya
School of Civil Engineering, University Science Malaysia, P. Pinang, Malaysia
E-mail: shukri@eng.usm.my
Tel: +604-599-6270; Fax: +604-594-1009

MM Ali
Corresponding Author
School of Civil Engineering, University Science Malaysia, P. Pinang, Malaysia
E-mail: mohammad59@hotmail.com, cemmali@eng.usm.my
Tel: +604-599-6289; Fax: +604-594-1009

WNAM Hussain
School of Civil Engineering, University Science Malaysia, P. Pinang, Malaysia
E-mail: cewhossain@eng.usm.my
Tel: +604-599-5999; Fax: +604-594-1009

Abstract

Penang is one of the State in Malaysia which has corrugated and hilly topography. Construction activities in these areas are increasing day by day, primarily for residential and commercial purposes. Such rapid development put the environment at risk by natural disasters like flood, changes of climate, landslides etc., and becomes a safety threat to the life and property of local inhabitants. Development of a management system at an early stage can reduce the after effect of any environmental hazard due to the heavy construction. This paper identifies two areas: Paya Terubung and Tanjung Bungah-Batu Ferringhi which are exposed to such risk, and presents a management system by project evaluation at an early stage starting from geotechnical investigation. Assessment is made by rating system, and is summarized in the form of matrices. The rating systems are produced after modification from other existing guidelines and requirements. Some evaluation process and proposals for improving weaknesses in the reports are discussed. Results from the evaluations are also shown in environmental risk map with the application of Geographical Information System (GIS) to identify high, moderate or low risk areas. The paper also presents comparison of parameters between the two areas by using T-test. Results of the comparison show that soil profile at Tg. Bungah-Bt. Ferringhi are at higher risk than at Paya Terubung area, while shear strength at Paya Terubung is at higher risk than at Tg. Bungah-Bt. Ferringh area. The results also show that 12% of project sites are at high environmental risk in Paya Terubung, 44% at medium environmental risk and others 44%

at low environmental risk. However, 6% of project sites are at high environmental risk in Tg. Bungah-Bt. Ferringhi, 56% at medium environmental risk and others 38% at low environmental risk.

Keywords: Risk, GIS, Environmental Assessment, T-Test, Paya Terubong, Batu Feringgi.

1. Introduction

Currently land has become one of the circumscribed source in Penang due to its hilly topography and limited flat lands, which is about to exhaust. The State of P. Pinang is a rapid industrial state and the city is compact. In facing the future challenges due to rapid economic development, there are high demands for flat ground area requirements (Ahmad, 2005). Although some land reclamation has been completed, it is not enough to meet high demand of flat areas within the island. Therefore, developers move to hilly areas for new projects. Such development involves high risk since hilly areas are very sensitive with respect to environment.

Hilly areas are considered high potential for development due to the attractive setting they provide. However, such developments are open to risks to people and the environment. Examples of environmental risk include flood, soil erosion, landslide, failure of slopes, etc., which raises many issues such as, injury to people; danger to life; damage to property, environment and economy (Razman, 2005).

Risk assessment is considered as the initial and periodical step in a risk management process and is the determination of quantitative or qualitative value of risk related to a concrete situation, and a recognized threat. It may be the most important step in the risk management process, and may also be the most difficult task to perform as it is prone to numerous errors. Once risks have been identified and assessed, the steps to properly deal with them are much more programmatic.

Penang is one of the many rapidly industrializing State in Malaysia with a largely urban populace. In recent decades, efforts at industrialization and the development of other economic sectors have been intensified, leading to greater urbanization and more pressures on flat land (Sew et. al, 2003). Many hills and surroundings are already developed. This has led to many environmental problems such as deforestation, decimation of water catchments, destruction of endangered fauna and flora, soil erosion, landslides, water pollution, sedimentation and downstream flooding. Some of these problems have been worse and turned into disasters. Many projects in the hilly areas failed due to several geotechnical and environmental factors. The factors that affect this environmental risk and their relevant mitigation must be identified earlier before any recurrence of hazard to the environment. Hence, environmental risk assessment planning for every development project within the island becomes absolutely necessary.

This study aims at achieving three objectives with this planning analysis: i) evaluating the compliances of the initial project reports (Geotechnical Report) based on the existing requirements and confirming its enforcement, ii) understanding the geotechnical parameters that contribute to the environmental risk, and, iii) determining zones showing high, medium or low risk areas.

The location of the study areas are Paya Terubung and Batu Ferringhi of Tanjung Bungah as shown in Figure 1 and Figure 2 respectively.

Figure 1: Paya Terubung Area

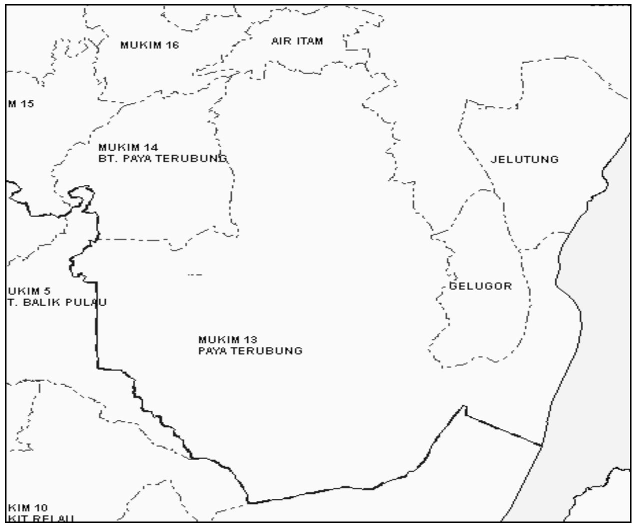
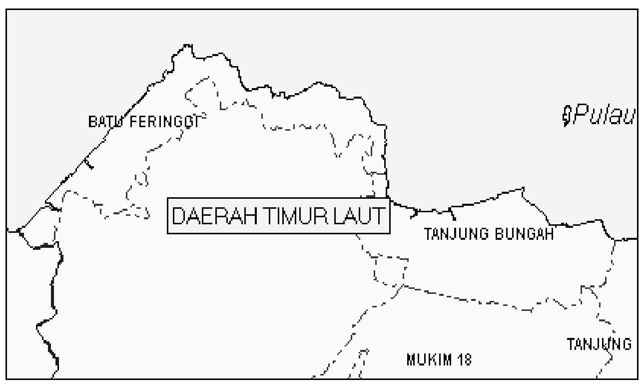


Figure 2: Batu Ferringi Area



2. Methodology

Evaluation of initial project reports is conducted undergoing through six main phases which are based on existing guidelines and findings of researchers with some modification on specific areas of interest.

Phase 1: Site and Parameters Selection: Sixteen sites were selected from each of the developed areas in Paya Terubung and Batu Ferringhi. The selection of the sites were mainly dependent on the availability of the geotechnical report. Parameter selection was based on the requirements of standard geotechnical reports.

The parameters chosen were: slope gradient (i), soil profile(ip), rock quality designation (RQD), plastic index (PI), shear strength parameters (c, ø), land-use suitability, recommendation on slope stabilization measures, stability analysis, rock fall analysis, recommendation on retaining and foundation systems, recommendation on soil erosion and sedimentation control, recommendation on maintenance monitoring, and groundwater level.

Phase 2: Classification of Risk. These parameters were classified into Risk Rating. The ratings are probable occurrence of environmental risk from very low (1) to very high (5). These risk ratings are modified and obtained from relevant existing guidelines and requirements.

The first classification is Slope Gradient. This classification is a modification from Terrain Classification and Landslide Hazard Zonation (Mineral and Geosciences Department of Malaysia, 2002) and given in Table 1.

Table 1: Probability of Environmental Risk with Respect to Slope Gradient (Modified from JMG, 2002)

Slope gradient (degrees)	Description	Risk
<15	Land is suitable to be developed. Soil erosion is very minimal and not danger to safety.	1
>15 - 25	Land is suitable to be developed but with some consideration, such as, the area is moderately populated, maximum height for building is five levels, and the building design follows the natural slope profile and reduces cuts and earth work.	2
>25 - 35	Land is moderately sensitive but suitable for development for tourism and recreation only. Development in this zone should be controlled and earth works, such as cutting slope to prepare platform shall be minimum.	3
> 35 - 60	Land is sensitive and development shall be strictly controlled. Since soil erosion and landslide occurrences are critical in this zone, earth works requiring cut of slopes, and benchmark shall also be strictly controlled for safety.	4
> 60	Land is very sensitive and strictly not allowed for any development, because in this zone soil erosion and landslide occurrences are very critical for the safety	5

The second is Soil Profile Classification which is taken from GEO (1998) and modified, as shown in Table 2. The classification considers N Schmidt rebound value including loading above the materials.

Table 2: Probability of Environmental Risk with Respect to Soil Profile Classification (Modified from GEO, 1998)

Description	Characteristic (N value)	Risk
Fresh rock with very high strength. Soil not exposed to erosion and landslides and have very low risk for safety.	>60	1
Slightly decomposed granite with high strength. Soil not exposed to erosion and landslide, and have low risk for safety	>45 – 60	2
Moderately decomposed granite with moderate strength. Soil exposed to moderate erosion and landslide and have moderate risk for safety	>25 – 45	3
Highly decomposed granite with minimum strength. Soil exposed to high erosion and landslide and have critical risk for safety	< 25	4
Residual soil / completely decomposed granite with very minimum strength. Soil exposed to very high erosion and landslide and have very critical risk for safety	No rebound from N Schmidt Hammer	5

Evaluation of the rock quality from Rock Quality Designation in percent is shown in Table 3. Other classifications of parameters are given in Table 4 through Table 14.

Table 3: Probability of Environmental Risk with Respect to RQD (Modified from Das, 2002)

Rock Quality Designation (%)	Rock Quality	Risk
>90 - 100	Excellent and very low ground instability effect that can cause landslide problem and human safety.	1
>75 – 90	Good and low ground instability effect that can cause landslide problem and human safety.	2
> 50 – 75	Fair and medium ground instability effect that can cause landslide problem and human safety.	3
>25 – 50	Poor and high ground instability effect that can cause landslide problem and human safety.	4
0 – 25	Very poor and very high ground instability effect that can cause landslide problem and human safety.	5

Table 4: Probability of Environmental Risk with Respect to Plasticity Index (Das, 2002)

Plasticity Index (%)	Description	Risk
>40	Very high plasticity	1
20 – 40	High plasticity	2
10 – 20	Medium plasticity	3
5 -10	Low plasticity	4
1-5	Slightly plastic	5

Table 5: Probability of Environmental Risk with Respect to Shear Strength of Coarse Grained Soil (IKRAM, 1998)

Relative density	Allowable soil pressure (kN/m^2)	Risk
Very dense	>470	1
Dense	280 - 470	2
Medium	80 - 280	3
Loose	0 - 80	4
Very loose	NOT SUITABLE	5

Table 6: Probability of Environmental Risk with Respect to Shear Strength of Fine Grained Soil (IKRAM, 1998)

Consistency	Strength (kN/m^2)	Risk
Hard	> 400	1
Stiff	100 – 400	2
Medium	50 – 100	3
Soft	25 – 50	4
Very soft	0 – 25	5

Table 7: Probability of Environmental Risk with Respect to Land-Use Classes (Modified from Taib, 2006)

Class	Description	Percentage of site area (%)	Risk
Class 1	Low geotechnical limitations. Insitu terrains with <15^o slope gradient, very minor erosion and environmental risk.	>80% - 100%	1
		> 60% - 80%	2
		> 40% - 60%	3
		> 20% - 40 %	4
		< 20 %	5
Class 2	Moderate geotechnical limitations. Insitu terrain with 16^o – 25^o slope gradient, minor erosion and environmental risk.	< 20 %	1
		> 20% - 40 %,	2
		> 40% - 60%	3
		> 60% - 80%	4
		>80% - 100%	5
Class 3	High geotechnical limitations. Insitu terrain with 26^o – 35^o slope gradient, severe erosion, landslide and environmental risk.	< 20 %	1
		> 20% - 40 %	2
		> 40% - 60%	3
		> 60% - 80%	4
		>80% - 100%	5
Class 4	Extreme geotechnical limitations. Insitu terrain with >35^o slope gradient, very severe erosion, landslide and environmental risk.	< 20 %	1
		> 20% - 40 %	2
		> 40% - 60% -	3
		> 60% - 80%	4
		>80% - 100%	5

Table 8: Probability of Environmental Risk with Respect to Recommendation of Slope Stabilization Measures (modified from Sew and Tan, 2003).

Description	Risk
Very good explanation of recommendation and planning for all expected failures, including drawing/plan, checking factor of safety of slopes and degrees of compaction for fill. material to avoid any environmental risk.	1
Good explanation of recommendation and planning for all expected failures including checking factor of safety for slopes and degrees of compaction for fill soil for improving stability and avoiding environmental risk, but no drawing/plan.	2
Moderate explanation of recommendation and planning for all expected failures including checking factor of safety of slopes for improving stability and avoiding environmental risk, but no degrees of compaction for fill soil.	3
Minimum explanation on recommendation and planning of all expected failures to improve ground stability and avoid environmental risk, no factor of safety checking for sloopes.	4
No recommendation or not enough recommendation/planning on factor of safety of slopes, drawings, degrees of compaction for fill soil included.	5

Table 9: Probability of Environmental Risk with Respect to Recommendation of Slope Stability Analysis (Modified from Chan, 1998)

Description	Risk
Very good analysis on slope stability including explanation and recommendation on slope gradient for cut and fill (not less than 1V:1.5H), FOS (not more than 1.4), settlement checking (if soft ground occur) and berm interval not more than 7 m to ensure stability of the slope and prevent slope from sliding and any environmental risk.	1
Good analysis on slope stability including explanation and recommendation on slope gradient for cut and fill (not less than 1V:1.5H), FOS (not more than 1.4), settlement checking (if soft ground occur) to ensure stability of the slope and prevent slope from sliding and any environmental risk but no berm interval stated.	2
Moderate analysis on slope stability including explanation and recommendation on FOS (not more than 1.4), settlement checking (if soft ground occur) and berm interval not more than 7 m to ensure stability of the slope and prevent slope from sliding and any environmental risk. However, no slope gradient for cut and fill or gradient less than 1V:1.5H recommended.	3
Minimum analysis on slope stability including explanation and recommendation on slope gradient for cut and fill (not less than 1V:1.5H) and berm interval not more than 7 m to ensure stability of the slope and prevent slope from sliding and any environmental risk but no settlement checking (if soft ground occur) and FOS or FOS more than 1.4.	4
No analysis on slope stability or not enough analysis with one slope for FOS, slope gradient for cut and fill slope or berm interval to prevent slope from sliding and environmental risk.	5

Table 10: Probability of Environmental Risk with Respect on Rock Fall Analysis (Modified from IEM, 2000)

Description	Risk
Very good analysis and recommendation on rock fall analysis including blasting guidance, drawing/plan and buffer zone more than 20 m to prevent environmental risk due to probability of rock falling.	1
Good analysis and recommendation on rock fall analysis including blasting guidance and buffer zone not less than 15 m to prevent environmental risk due to probability of rock falling but no drawing/plan to support the recommendations.	2
Moderate analysis and recommendation on rock fall analysis including blasting guidance and buffer zone not less than 10 m to prevent environmental risk due to probability of rock falling.	3
Minimum analysis and recommendation on rock fall analysis including buffer zone more than 7 m to prevent environmental risk due to probability of rock falling but no blasting guidance.	4
No or not enough analysis and recommendation on rock fall analysis except one of blasting guidance or buffer zone less than 7 m and exposed to environmental risk due to probability of rock falling.	5

Table 11: Probability of Environmental Risk with Respect to Recommendation on Maintenance Monitoring (Modified from Sew and Tan, 2003)

Description	Risk
Very good explanation and recommendation on maintenance monitoring plan due to control effects of development on environmental risk from time to time. The plan includes routine monitoring, engineering inspections, regular monitoring by firm and table of sequence for monitoring.	1
Good explanation and recommendation on maintenance monitoring plan due to control effects of development on environmental risk from time to time. The plan include routine monitoring, engineering inspections, regular monitoring by firm but no table of sequence for monitoring.	2
Moderate explanation and recommendation on maintenance monitoring plan due to control effects of development on environmental risk from time to time. The plan includes routine monitoring, engineering inspections but no regular monitoring by firm and table of sequence for monitoring.	3
Minimum explanation and recommendation on maintenance monitoring plan due to control effects of development on environmental risk from time to time. The plan includes engineering inspections but no routine and regular monitoring.	4
No or not enough explanation and recommendation on maintenance monitoring plan due to control effects of development on environmental risk from time to time. The plan excluding one of routine, regular monitoring or engineering inspections.	5

Table 12: Probability of Environmental Risk with Respect to Recommendation on Retaining and Foundation System (Modified after Sew and Tan, 2003)

Description	Risk
Very good explanation and recommendation of retaining and foundation system including drawings/plans and FOS (more than 1.4) for designs.	1
Good explanation and recommendation of retaining and foundation system including FOS (more than 1.4) for designs but no drawings/plans to support the explanations.	2
Moderate explanation and recommendation of retaining and foundation system including FOS (more than 1.4) for designs.	3
Minimum explanation and recommendation of retaining and foundation system including FOS less than 1.4 for designs.	4
No or not enough explanation and recommendation on retaining and foundation system except one drawings/plans or FOS for designs.	5

Table 13: Probability of Environmental Risk with Respect to Recommendation on Soil Erosion and Sedimentation Control Plan (Modified from Chan, 1998)

Description	Risk
Very good explanation of recommendation for soil erosion and sedimentation control plan including drawing/plan and proper drainage systems.	1
Good explanation of recommendation for soil erosion and sedimentation control plans including proper drainage systems but no drawing/plan to support the explanations.	2
Moderate explanation on recommendation for soil erosion and sedimentation control plan including minimum drainage systems.	3
Minimum explanation of recommendation for soil erosion and sedimentation control plan including improper drainage systems.	4
No or not enough explanation of recommendation for soil erosion and sedimentation control plan except one drainage systems or drawing/plan in the plan.	5

Table 14: Probability of Environmental Risk with Respect to Groundwater Monitoring (Modified from Department of the Environment, Water, Heritage and the Arts,)

Description	Rating
Very good explanation on groundwater monitoring including proper horizontal drain design with no seepage. Water levels >10 m from ground surface	1
Good explanation on groundwater monitoring including proper horizontal drains design and no seepage occurs. Water levels >5-10m from ground surface	2
Moderate explanation on groundwater monitoring including proper horizontal drain design and no seepage. Water levels >3 – 5m from ground surface.	3
Minimum explanation on groundwater monitoring including improper horizontal drains design and no seepage. Water levels >2-3m from ground surface.	4
No or not enough explanation on groundwater monitoring including improper horizontal drains design and seepage occur. Water levels <2m from ground surface	5

Phase 3: Report review. 32 reports were evaluated using the classification stated in phase 2 as guidelines. Rating results from the evaluation was stored as raw data for further analysis.
Phase 4: Rating. After evaluating all reports and storing the data, the rating risks were given and the average rating for each report were calculated. Parameters that usually contribute to very high risk and very low risk to report rating can be identified. Similarly, average rating of every report was analyzed to identify reports having very low risk, low risk, medium risk, high risk or very high risk using GIS.
Phase 5: Comparison. In order to know the effect of parameters between Paya Terubung area and Tanjung Bungah_Batu Ferringi area, t-test was done to study the differences. The test was done using SPSS software.
Phase 6: Mapping. The concept of analysis using GIS is manipulating and processing the data layers where all the collected data had been stored in attribute forms. For this purpose, every single data layer was run through several steps of analysis before the final layers overlay could be made to produce outputs of risk zonation maps. The data preparation and analysis includes following stages (Ahmad, 2005):

a). Data Collection

The existing data of contour and road network maps were collected from Universiti Sains Malaysia (USM) for Paya Terubung, and from Penang Geographic Information System (PEGIS) for Tanjung Bunga area. Non-digital data for this study were collected from component attribute data in the form of rating value. The attribute data for Tanjung Bungah and Paya Terubung are shown in Figure 3 and Figure 4.

b). Base Map Preparations

The GIS digital data preparations start with base maps preparation from sub setting and coordinating all the maps involved (district and project site) using geoprocessing utilities in the software.

c). Digitizing and Layering

Digitizing is the process of converting non-digital data into digital data formats expressed in either points, lines or polygons entities within the pre-specified coordinates.

d). Spatial Layer Conversion Processes

In this study the direct conversion processes using the software grid conversion utility was used. The number of spatial layers involved in this study are 13 (thirteen) for each study area and this parameters are referred as factors of the environmental risk.

e). Spatial Layer Overlay Processes

Overlay analysis used in this study are union and map calculation operation that can make data manipulations arrangement in different layers and to see relationship of each other.

f). Development of Risk Zonation Map

Environmental risk zonation refers to the zones within an area of land surface that indicate various parameters (geotechnical factors) that can significantly effect the earth failure. The zonation being used in identifying and delineating the unstable risk prone localities within the study area can then be used for hazard assessment.

3. Results and Discussion

After completing the review process for every report based on required parameters, the matrix analysis of environmental risk for Paya Terubung and Tg. Bungah-Bt. Ferringhi were carried out and the results are shown in Figure 3 and Figure 4.

The matrix allows environmental risk to be recorded in a qualitative manner and are classified as very low risk to very high risk using numbers 1-5. Probability of environmental risk contributed by parameters of each project was calculated as Average Probability Environmental Risk. These average values are shown in the second last row in the matrix, while the last row in the matrix shows the average values after rounding. Values in the last column of the matrix show the average probability of environmental risk of projects for each parameter.

Figure 5 is a graph that refers to environmental risk by projects showing P8 and P14 as the projects with highest risk and P7 as the lowest risk in Paya Terubung area. Figure 4 is a graph that refers to environmental risk by project that shows that T10 is the projects with highest risk and T5 with the lowest risk in Tg. Bungah-Bt.Ferringhi area.

Contribution of each parameter to environmental risk in Paya Terubung and Tg. Bungah-Bt. Ferringhi is shown in Figure 7 and Figure 8 based on average risk columns indicated in the matrices.

Main parameter that contributes to environmental risk in Paya Terubung is the shear strength, and soil profile is the main contributor to environmental risk in Tg. Bungah-Bt. Ferringhi area. This is because low shear strength of soil will cause landslides when heavy burden is imposed at the soil surface. Similarly, for soil profile in Tg. Bungah-Bt. Ferringhi area, if soil profile at the project site have low SPT (N value) with large overburden, it will cause danger to environment due to slope failures, especially in hilly areas.

Although both N-value and shear strength refers to ground strength, scope embodied by N-value has wider base on layer types all over the project site as compared with the shear strength which is obtained from soil sample collected from single point and tested in the laboratory only.

Figure 3: Matrix analysis of Environmental Risk for Paya Terubung

		Project Number																
		P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**	**P13**	**P14**	**P15**	**P16**	**Avg. Risk**
Geotechnical parameters	*Slope Gradient*	3	5	2	1	4	3	2	4	1	1	2	5	2	5	3	3	2.88
	Soil Profile	3	5	4	3	1	4	1	4	3	2	3	2	5	2	2	4	3.00
	Rock Quality Designation	3	4	1	4	3	4	3	5	3	5	3	3	3	4	4	2	3.38
	Plastic Index	5	3	2	2	5	3	3	5	3	4	3	4	5	3	3	5	3.63
	Shear Strength	5	2	5	2	5	5	2	5	3	4	5	5	4	5	3	1	3.81
	Ground water	1	1	1	3	3	1	1	2	4	3	3	3	1	1	1	2	1.94
	Land-use suitability	3	5	1	1	5	1	2	5	1	1	1	5	2	5	3	3	2.75
	Slope stabilization measure	1	2	1	1	4	2	1	1	4	3	3	2	1	4	1	1	2.00
	Stability Analysis	2	1	2	1	2	2	1	2	4	2	2	3	1	2	1	1	1.81
	Rock fall analysis	1	5	1	1	3	4	2	5	2	1	2	5	1	4	4	2	2.69
	Retaining and Foundation system	3	3	1	1	2	2	1	2	3	2	3	2	1	5	1	1	2.06
	Soil erosion and sedimentation control	4	1	3	1	2	2	1	3	2	2	3	3	3	4	1	3	2.38
	Maintenance monitoring	2	2	1	1	2	2	1	4	1	2	2	1	1	3	4	1	1.88
	Average risk	2.77	3.00	1.92	1.69	3.15	2.69	1.62	3.62	2.62	2.46	2.69	3.31	2.31	3.62	2.38	2.23	2.63
	Overall risk	3	3	2	2	3	3	2	4	3	2	3	3	2	4	2	2	3

Figure 4: Matrix analysis of Environmental Risk for Tg. Bungah-Bt. Ferringhi

		Project Number																
		T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**	**T15**	**T16**	**avg. risk**
Geotechnical parameters	*Slope Gradient*	3	3	3	3	3	3	5	2	3	5	2	4	3	3	2	3	3.13
	Soil Profile	4	5	4	3	2	3	4	4	5	4	4	4	4	3	3	5	3.81
	Rock Quality Designation	5	4	4	3	3	3	3	4	4	2	4	5	3	3	3	5	3.63
	Atterberg limit	4	3	2	5	3	4	3	3	3	5	3	4	3	3	4	3	3.44
	Strenght	3	2	2	5	2	2	5	3	2	2	3	2	3	2	2	5	2.81
	Ground water	1	2	1	2	1	1	1	1	3	1	3	2	1	2	2	3	1.69
	Land-use suitability	1	5	3	5	3	3	5	2	3	5	1	3	4	4	3	4	3.38
	Slope stabilization measure	2	1	3	1	1	2	1	2	3	4	1	1	1	4	2	1	1.88
	Stability Analysis	1	3	1	2	1	1	3	2	1	5	2	1	1	2	1	1	1.75
	Rock fall analysis	3	4	1	3	1	1	3	1	1	3	2	4	1	4	3	2	2.31
	Retaining and Foundation system	1	1	1	1	1	1	1	1	3	5	1	2	1	3	1	1	1.56
	Soil erosion and sedimentation control	4	3	1	3	1	2	4	1	2	3	3	1	3	2	2	1	2.25
	Maintenance monitoring	1	1	1	2	1	1	5	1	1	3	2	1	1	1	1	1	1.50
	Average risk	2.54	2.85	2.08	2.92	1.77	2.08	3.31	2.08	2.62	3.62	2.38	2.62	2.23	2.77	2.23	2.69	2.55
	Overall risk	3	3	2	3	2	2	3	2	3	4	2	3	2	3	2	3	3

Figure 5: Environmental Risk by Project at hill site areas in Paya Terubung

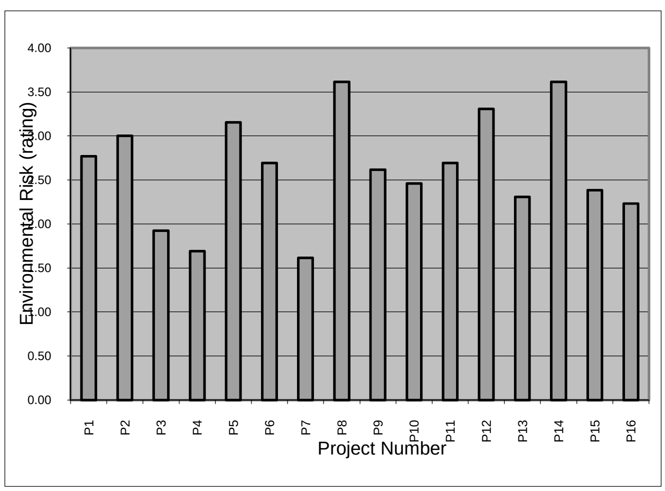


Figure 6: Environmental Risk by Project at hill site areas in Tg. Bungah-Bt. Ferringhi

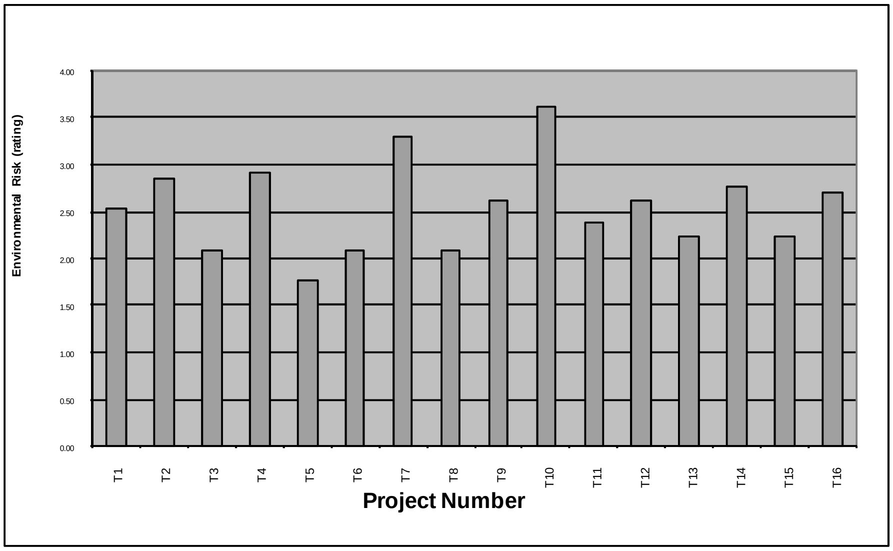


Figure 7: Environmental Risk contributed by parameters to hill site development (PayaTerubung)

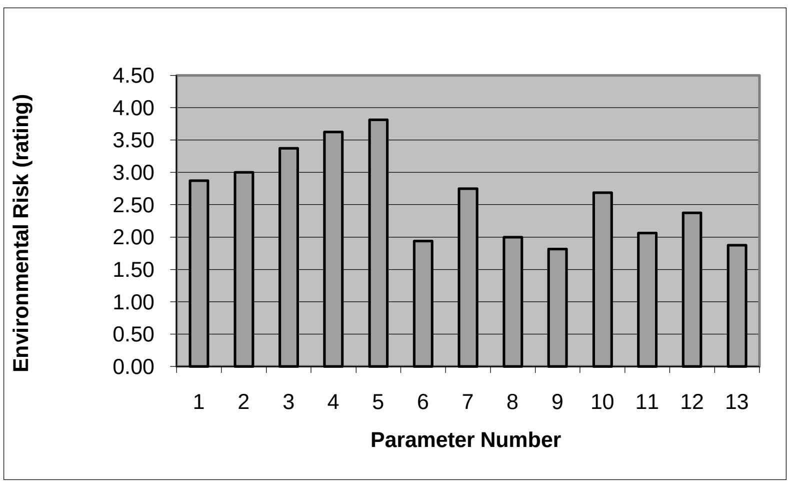
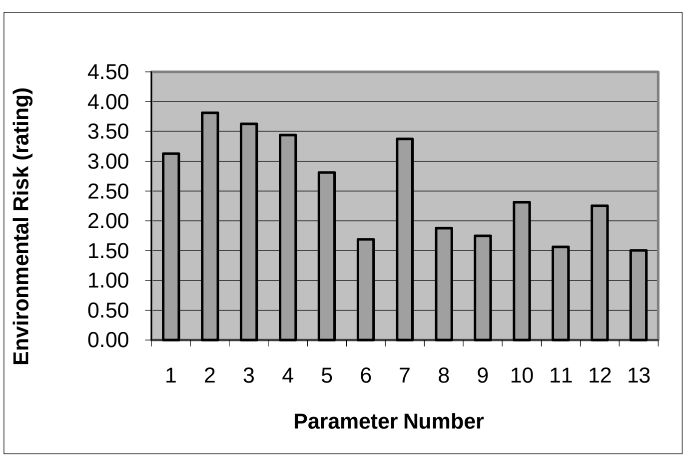


Figure 8: Environmental Risk contributed by parameters to hill site development (Tg. Bungah-Bt. Ferringhi)



In spatial layer conversion processes, all data from matrices are converted to spatial layer to be used in the layering process. The spatial layers are obtainable from conversion process product and represent distribution of environmental risk from very high risk to very low risk in both the study areas. A total of twenty six maps showing spatial layers of each of thirteen parameters for Paya Terubung and for Tg. Bungah-Bt. Ferringhi areas were developeded. However, few of these maps for selected parameters are presented in Figures 9 to16.

The final environmental risk zonation maps are shown in Figure 17 for Paya Terubung and Figure 18 for Tg. Bungah-Bt. Ferringhi. Two-project sites, P8 and P14 (12%) are in high environmental risk area in Paya Terubung, seven sites (44%) are in medium environmental risk area and seven others (44%) are in the low environmental risk area. However, in Tg. Bungah-Bt. Ferringhi only one site, P10 (6%) is in high environmental risk area, eight sites (56%) are in medium environmental risk area and other seven sites (38%) are in low environmental risk area

Figure 9: Environmental risk due to slope gradient for projects

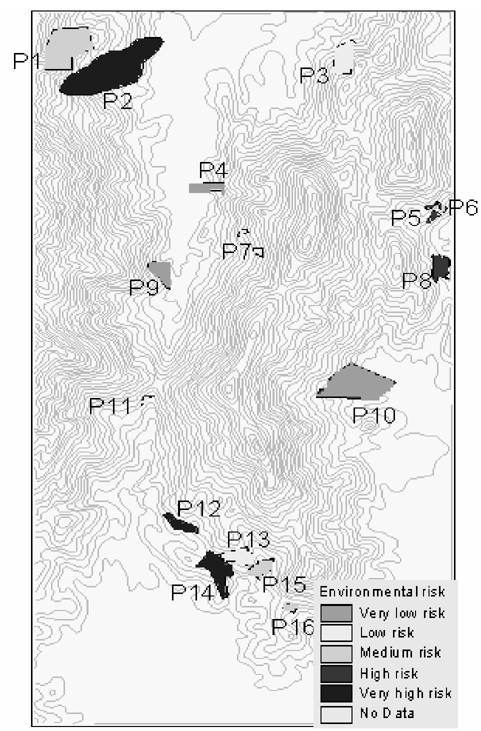


Figure 10: Environmental risk due to soil profile for projects

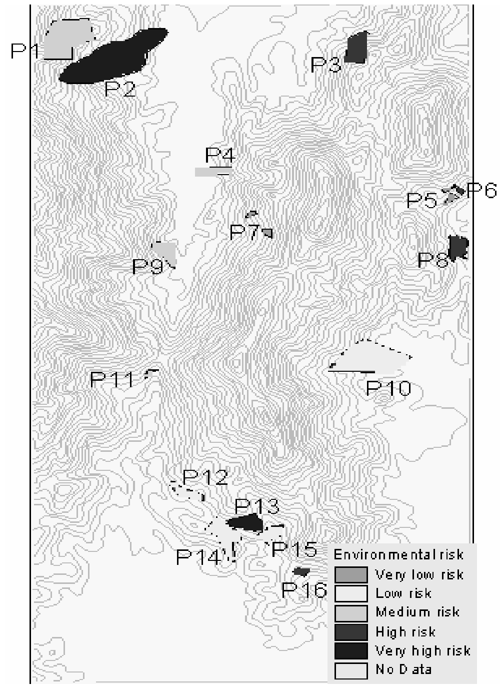


Figure 11: Environmental risk due to shear strength for projects

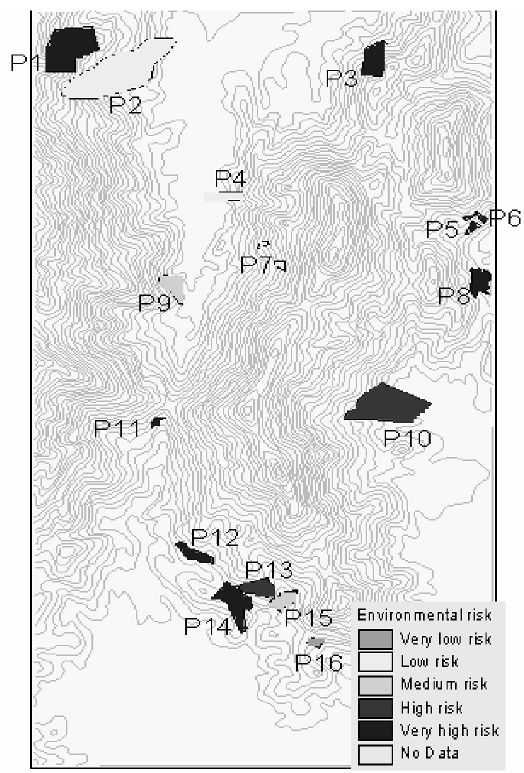


Figure 12: Environmental risk due to stability analysis for projects

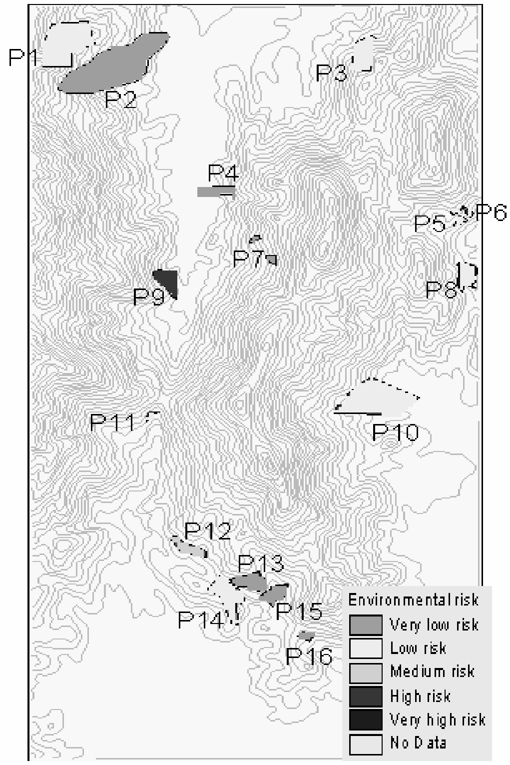


Figure 13: Environmental risk due to slope gradient for projects

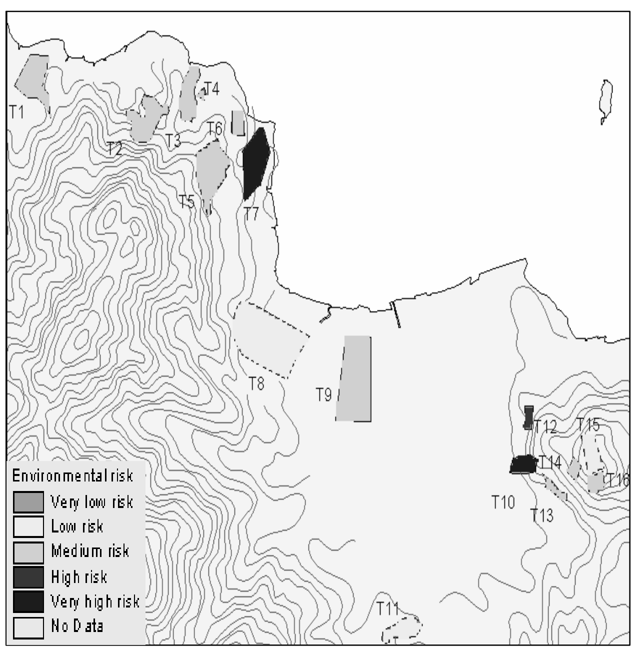


Figure 14: Environmental risk due to soil profile for projects

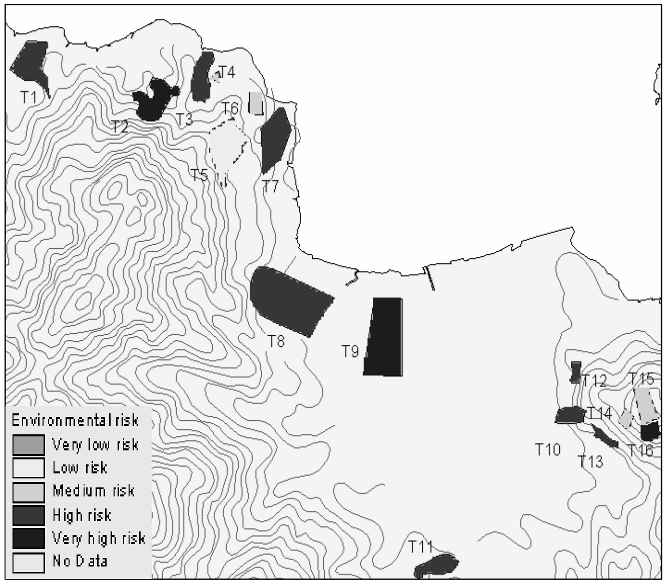


Figure 15: Environmental risk due to shear strength for projects

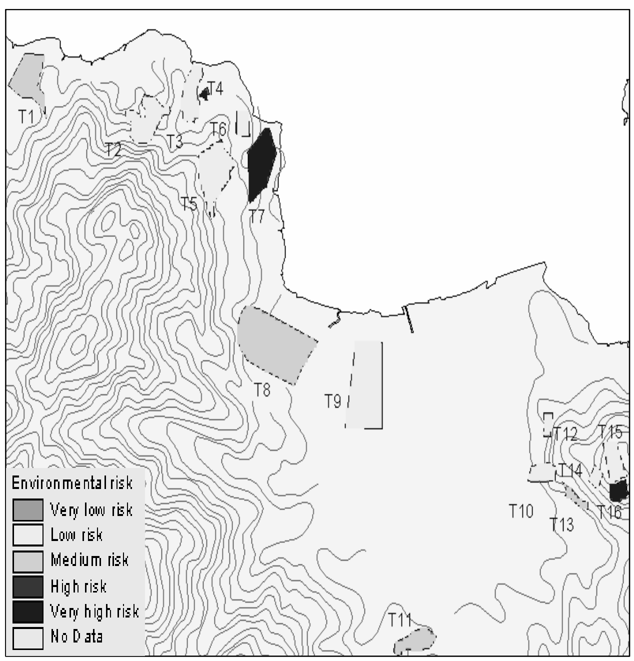


Figure 16: Environmental risk due to stability analysis for projects

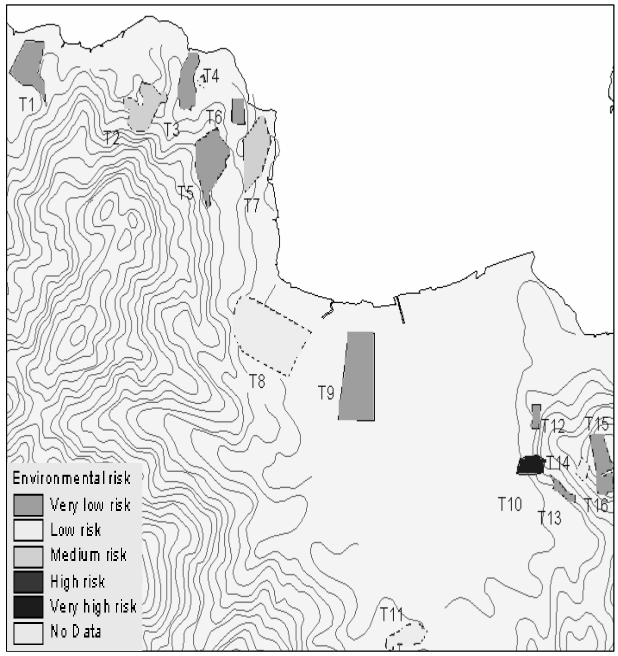


Figure 17: Distribution of environmental risk at Paya Terubung.

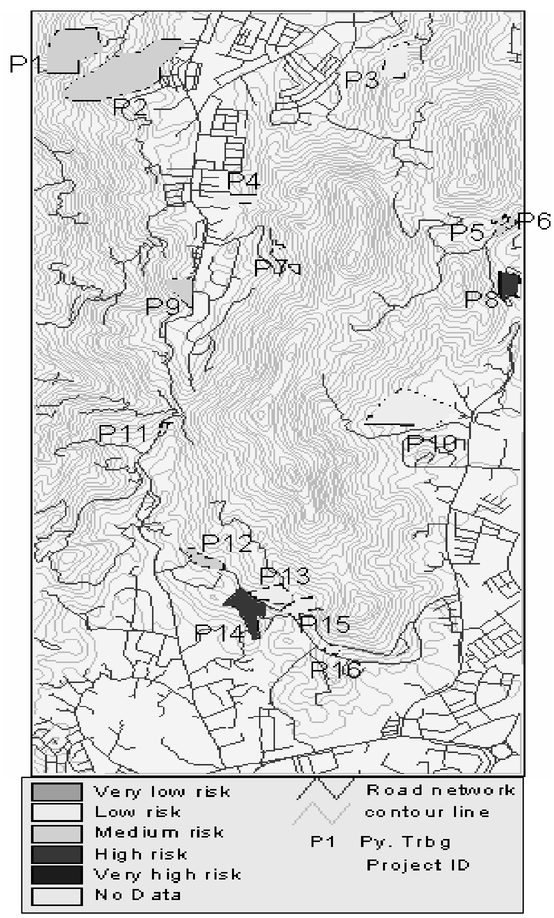
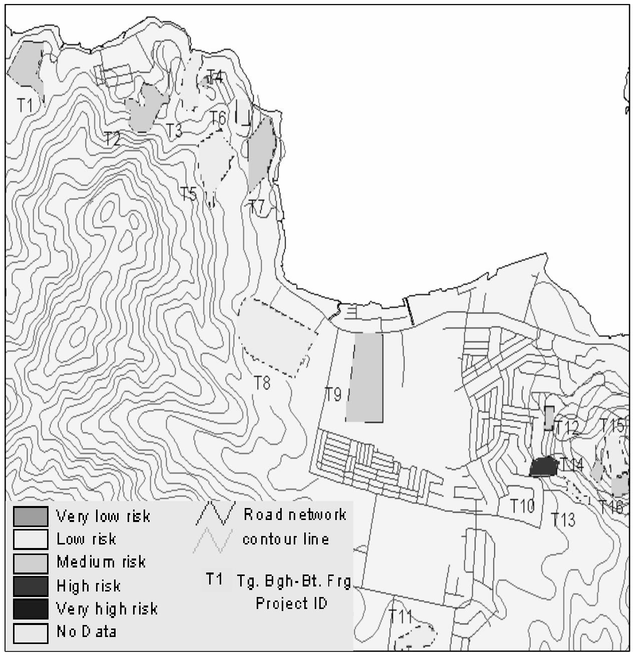


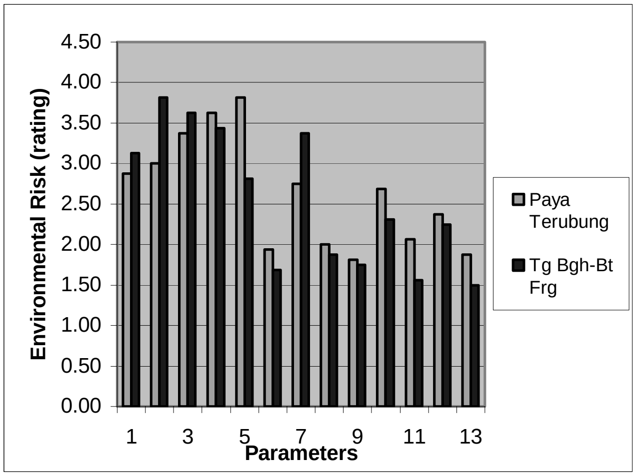
Figure 18: Distribution of environmental risk at Tg. Bungah-Bt. Ferringhi



Significant differences of rating as obtained between environmental risk at Paya Terubung and Tanjung Bungah-Batu Ferringhi are soil profile (0.81), shear strength (1.00) and land use suitability (0.63) as shown in Figure 19. Soil profile causes higher probability to environmental risk in Tanjung Bungah-Batu Ferringhi. This might be due to difference in nature of soil for the two locations. Furthermore, from review process, major factor comes from Highly Decomposed Granite and occasional presence of boulders in project site at Tanjung Bungah-Batu Ferringhi which contributes to higher probability environmental risk but at Paya Terubung area majority of the soil layer is Moderately Decomposed Granite with higher strength. This differences is confirmed from T-test results marked by circle in the last column of Figure 20

It appears that shear strength gives higher probability of risk in Paya Terubung area compared to Tanjung Bungah-Batu Ferringhi area. However, it is observed that many project reports for Paya Terubung area did not perform proper analysis and calculation on soil samples than project reports for Tanjung Bungah-Batu Ferringhi area. In addition, many project reports of Paya Terubung area did not include information about the results of soil test. Consequently, probabilities of environmental risk become higher. This differences is confirmed from T-test results marked by rectangle in last column of Figure 20.

Figure 19: Comparison between Paya Terubung and Tanjung Bungah-Batu Ferringhi



Land use suitability also gives higher probability risk at Tanjung Bungah-Batu Ferringhi area than Paya Terubung area, but results from T-test confirms no significant differences as shown in Figure 20 and can be neglected.

3.0. Recommendation for Overcome Environmental Risk

Interpretation of project status is represented in Table 15 as follows:

Table 15: Threshold rating

Risk Probability	Description
Very High Risk	The project is rejected
High Risk	The project needs to make necessary correction to the report and resubmit.
Medium Risk	Approved with proper recommendation to improve every shortcomings
Low Risk	Approved with proper further monitoring.
Very Low Risk	Approved

Projects which are in medium risk, high risk or very high-risk category requires more careful analysis. Weaknesses and responses must be taken in to consideration to reduce environmental risk by referring to final results of this study. Therefore, the responses related to the weaknesses recovered are summarized in Table 16 for P8, Table 17 for P14 and Table 18 for T10. For other project sites, the responses are illustrated in Table 19 for Paya Terubung study area and in Table 20 for Tanjung Bungah-Batu Ferringhi area.

4.0. Conclusion

Thirty-two reports were evaluated to comply requirements of thirteen parameters. Many projects did not fully comply with the requirements to provide proper primary data which was an obstacle in assigning risk category. In addition, project proposals did not synchronize with the existing problem from primary data which made it difficult to assign a risk factor.

Slope gradient, soil profile, plastic index of soil, shear strength of soil, groundwater and rock quality designation can be contributor to environmental risk in hill site developments if a very poor quality geotechnical report is prepared and submitted for a project.

With the help of Geographical Information System (GIS), the available geotechnical project reports of study areas can be shown in a map combined with the probability of environmental risk. In Paya Terubung area 12 % of project sites are at high environmental risk, 44% sites are at medium environmental risk and 44% are at low environmental risk. In Tg. Bungah-Bt. Ferringhi area, 6% of project sites are at high environmental risk, 56% are at medium environmental risk and other 38% are at low environmental risk.

In conclusion, environmental risk at hill site development can be detected from early stage through the provision of complete geotechnical report. It is very important and necessary to detect any environmental hazard with their response plan and to avoid any very high-risk (invalid) project to proceed.

Table 16: Responses to improve reports for P8

Parameter	**Responses**
Slope gradient	Include terrain classification map with percentage of site
Land use suitability	Include land use classification map with percentage for site
Soil profile	Too much loading above the ground, majority of which is consisting completely decomposed granite, periodic investigation should be recommended especially to groundwater with existing seepage problem, more constructive recommendation of retaining and foundation system and more proper recommendation on soil erosion and sedimentation control.
Rock Quality Designation	Carry out boreholes and seismic refraction survey and enclose results with explanation
Plastic Index	Carry out Atterberg limit tests and enclose results with explanation.
Rock fall analysis	Recommend buffer zone not less from 7 m especially in steep slope areas.
Recommendation on Maintenance monitoring	Maintenance monitoring must consider routine, regular and engineer’s inspection in planning

Table 17: Responses to improve reports for P14

Parameter	**Responses**
Slope gradient	Enclose terrain classification map in percentage for site project
Rock Quality Designation	Need more rock samples for testing
Shear strength	Enclose analysis results, need more sample for testing, need proper recommendation on retaining and foundation systems
Land use suitability	Enclose land use classification map in percentage for site project
Recommendation on Slope Stabilization Measures	Repair discussions and add various alternatives
Retaining and foundation system	Each recommendation needs to be included with factor of safety, stability checking and drawing
Recommendation on Soil erosion and sedimentation control	Need complete planning that including drawing
Rock fall analysis	Buffer zone must not be less than 7 m

Table 18: Responses to improve reports for T10

Parameter	Responses
Slope gradient	Enclose terrain map, terrain classification map in percentage for site project
Land use suitability	Enclose land use map, land use classification map in percentage for site project
Recommendation on Retaining and foundation system	each recommendation need to be included with factor of safety, stability checking and drawing
Recommendation on Slope Stabilization Measures	Repair discussion and add various alternatives
Plastic Index	Improve explanations and need more sample for testing
Soil profile	Need more attention to retaining structures such as soil nailing because many boulders at the site

Table 19: Responses to improve reports for projects at Paya Terubung

Project ID	Weaknesses	Response
P1	Recommendation on Soil erosion and sedimentation control Recommendation on Retaining and foundation system	Proper explanation and recommendation such as guniting, wire net, sedimentation trap and so on including drawings. Need more recommendations
P2	Rock fall analysis Recommendation on Retaining and foundation system	Include not less than 7 m buffer zones and proper guide for blasting. Include stability checking and explanation with drawings
P5	Stabilization measure Rock fall analysis	Need proper discussion especially for FOS and angle of cut and fill slope with drawing. Include guidelines for blasting activities.
P6	Rock fall analysis	Need buffer zone more than 7m and further explanation with drawings.
P11	Recommendation on Slope Stabilization measure Recommendation on Retaining and foundation system Recommendation on Soil erosion and sedimentation control	More recommendation and include angle of slope not more than 1V:1.5H. More recommendation and drawings of stability checking More recommendation
P12	Stability analysis Recommendation on Soil erosion and sedimentation control Rock fall analysis	Need more information of rock slope and soft ground at site and include drawings. Proper explanation and recommendation such as guniting, wire net, sedimentation trap and so on including drawings Include not less than 7 m buffer zones and proper guide for blasting.

Table 20: Responses to improve reports for projects at Tanjung Bungah-Batu Ferringhi

Project ID	Weaknesses	Response
T1	Recommendation on Soil erosion and sedimentation control Rock fall analysis	Need more recommendation on soil erosion and sedimentation control, proper explanation and ESCP drawing. Proper guide on blasting activities
T2	Stability analysis Recommendation on Soil erosion and sedimentation control Rock fall analysis	Include rock fall analysis and recommendations Need more recommendation on soil erosion and sedimentation control, proper explanation and ESCP drawing. Include recommendation for buffer zones more than 7m
T4	Recommendation on Soil erosion and sedimentation control Rock fall analysis	Need more recommendation on soil erosion and sedimentation control, proper explanation and ESCP drawing. Need buffer zone more than 7m and further explanation with drawings.
T7	Recommendation on Soil erosion and sedimentation control Recommendation on Maintenance monitoring	Need more recommendation on soil erosion and sedimentation control, proper explanation and ESCP drawing. Proper explanations including routine, regular and engineer inspections
T9	Recommendation on Retaining and foundation system Recommendation on Slope Stabilization measures	More recommendations More recommendations
T12	Rock fall analysis	Need buffer zone more than 7m and further explanation with drawings. Proper guide on blasting activities
T14	Retaining and foundation system	Need more recommendation including recommendation on foundation systems.

Figure 20: Results of T-test to compare between parameters at Paya Terubung and Tanjung Bungah-Batu Ferringhi

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
P1TB	Equal variances assumed	4.952	.034	.601	30	.552	.25	.416	-.599	1.099
	Equal variances not assumed			.601	25.250	.553	.25	.416	-.606	1.106
P2TB	Equal variances assumed	2.690	.111	2.145	30	.040	.81	.379	.039	1.586
	Equal variances not assumed			2.145	25.972	.041	.81	.379	.034	1.591
P3TB	Equal variances assumed	.063	.803	.739	30	.466	.25	.339	-.441	.941
	Equal variances not assumed			.739	29.378	.466	.25	.339	-.442	.942
P4TB	Equal variances assumed	3.202	.084	-.552	30	.585	-.19	.340	-.881	.506
	Equal variances not assumed			-.552	27.788	.585	-.19	.340	-.883	.508
P5TB	Equal variances assumed	1.876	.181	-2.172	30	.038	-1.00	.460	-1.940	-.060
	Equal variances not assumed			-2.172	28.884	.038	-1.00	.460	-1.942	-.058
P6TB	Equal variances assumed	3.158	.086	-.754	30	.457	-.25	.332	-.927	.427
	Equal variances not assumed			-.754	27.756	.457	-.25	.332	-.929	.429
P7TB	Equal variances assumed	2.862	.101	1.151	30	.259	.63	.543	-.484	1.734
	Equal variances not assumed			1.151	27.932	.259	.63	.543	-.487	1.737
P8TB	Equal variances assumed	.326	.572	-.307	30	.761	-.13	.407	-.956	.706
	Equal variances not assumed			-.307	29.661	.761	-.13	.407	-.957	.707
P9TB	Equal variances assumed	1.089	.305	-.178	30	.860	-.06	.350	-.778	.653
	Equal variances not assumed			-.178	27.660	.860	-.06	.350	-.780	.655
P10TB	Equal variances assumed	2.844	.102	-.757	30	.455	-.38	.495	-1.387	.637
	Equal variances not assumed			-.757	27.937	.455	-.38	.495	-1.390	.640
P11TB	Equal variances assumed	.001	.976	-1.242	30	.224	-.50	.402	-1.322	.322
	Equal variances not assumed			-1.242	29.980	.224	-.50	.402	-1.322	.322
P12TB	Equal variances assumed	.032	.860	-.338	30	.737	-.13	.369	-.879	.629
	Equal variances not assumed			-.338	29.956	.737	-.13	.369	-.879	.629
P13TB	Equal variances assumed	.004	.951	-1.000	30	.325	-.38	.375	-1.141	.391
	Equal variances not assumed			-1.000	29.867	.325	-.38	.375	-1.141	.391

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