PUWAKGAHAWELA LANDSLIDE: A PRELIMINARY STUDY

JMSB Jayasundara* and Jayantha Wickramasingha**

[see pases 137 and 138 for Illaustrations]

Introduction

This paper presents findings of a preliminary study on a "Landslide" occurred at Puwakgahawela, in proximity to Belihuloya-Pambahinna, at around 6.30 pm on Saturday 5th October, 2002. The flow of earth mass has taken start at the peak of Paraviyangala, which is above around 1400 msl and moved breaking the bridge on A4 Colombo – Badulla road between 163 and 164 km. Passing the road the flow entered to the broad valley below, which is consisted of paddy fields depositing debris on them. Then the water moved to Samanalawewa tank with floating logs and other material. A house located on the valley at paddy fields had been washed away, consign a loss of six lives. This event has been recorded as the largest landslide ever occurred in Sri Lanka during the recent past. A whole of a paddy field went down the debris and no more cultivable paddy tracts, high economic loss to the families affected. The valley has been cleared from all kinds of vegetation existed before.

It seems that the event is a result of a complex of environmental processes and can not be explained by a mono-disciplinary approach. Can it be categorized as a landslide? A large volume of water moved instantly, which makes difficult in defining the event as a landslide. Within this whole process a cascade of landslides were taken place. The questions arise where such a large volume of water was collected? Why in the neighboring valleys do not carry such evidence of large water flow simultaneously? Why such amount of rainfall has not been recorded in the rainguage located in the vicinity? Is this a singular event and will not occur again? What are the forces lead to creating such kind of hazard and what has to be done to prevent such a disaster? The above Puwakgahawela phenomenon pauses us all above questions. The present preliminary study is an attempt to investigate the nature of the event through an environmental management approach.

Methodology

This study was conducted using spectrum of research methods including direct measurements, observations, photographic observation and monitoring, interviews and

*. Dr. JMSB Jayasundara, (MSc,), (PhD), Senior Lecturer (Environmental Management), Rajarata University of Sri Lanka. E-mail: jayasundarasamarakoon@yahoo.com

**.Jayantha Wickramasingha, BA (Sp.), Visiting Lecturer, Rajarata University of Sri Lanka. E-mail: jayantha1016@yahoo.com

questionnaire and literature survey. Systems approach and concept of environmental change was the basis for conceptualizing the research problem and analyzing the process.

The research team visited the place three occasions to measure the physical dimensions of the process within several days after the event. The team observed and measured the components from the end point of mass deposit down stream to the top of the hill at which the flow took start. Photographic recording of phases of the event was conducted during the field visit. The researcher was monitoring the environmental processes in this mountain range for the four years before the event and took photographs of the place in hill top where the event trigged. It gives evidence of the movement of this mass.

Occasional interviews were conducted among the people around the place to capture eye witness and to assess the peoples' perception on the phenomenon. Information collected by other researchers using a questionnaire scheduled to study the event which was also used to analyze process and impact of the event. Another researcher intensively involved in the study of the event was also interviewed.

Theoretical background of the components of the phenomena such as clarification of technical terms was done through referring to relevant monographs, text books, and encyclopedias. Some media reports relevant to the event were also studied. Required management measures were also similarly assessed.

Results

Environment Around Puwakgahawela

The top of Paraviyangala hill is an area covered with forest degradation. The peak consists of rock outcrops. It is evident that in the past, this hill slope up to the top had been cleared for tea cultivation. Remnants of land preparation practices like terracing still exist. In the past the mountain range was covered by thick vegetation. Sub-montane tree species are dominated in the mountain and intermediate upland dry vegetation flourished in the valleys. Reverine wet zone vegetation along the water ways is visible. This degradation of forest accelerated due to weathering process and erosion. Steep slopes with rock outcrops retard the process of regaining the vegetation. Forest fires are a common phenomenon in this mountain ranges each year in August and in September which further destroys existing vegetation. At present, dominant vegetation is grass. There are several blocks of forest plantations with pines. Stretches of natural tree vegetation characterises closer to waterways in the valleys. These stretches run up to the tops of hill along main streams. Lower broader valleys are occupied by paddy fields cultivated where water is available. The settlements are located along the roads and on the ridges. Home gardens are full of all kinds of trees. The house located in the valley in Puwakgahawela is not a common situation in this area.

The Paraviyangala mountain range consists of three peaks with northeast – southwest orientation. The range isolated from Horton plains in the southeast by a deep narrow valley of Belihuloya. Mountain slopes are cut by a dense and deep valley range and Puwakgahawela is

one of them. People name it as "Henagahana Ella". The slope reduces and valley becomes broad in the downstream. The A4 road has been constructed in this area on the slope. Further, all these valleys drain to Samanalawewa reservoir. General slope of the mountain range and the plain below represent concave shape. The parent rocks in this mountain ranges consist of high proportion of silicate that may create landslides as the bond in such rocks are weak. The disintegration of rocks is faster in such areas. The slopes are also steep that accelerate the weathering process.

The area is located in the intermediate climatic zone. However, from the tops of the hill to Samanalaweva, there are distinctive micro level differences in the climate, mainly due to rapid change in the height of mean sea level. Convective rainfall dominates in the annual distribution pattern bringing more rainfall from March to May and October to November ranging around 1800 mm. Dry hot days and cool night with clear sky at night are the prevailing weather pattern in the area. Down the slope cool valley winds at night improves the climatic comfort of the area.

Disintegration of rocks into pieces or physical weathering are mainly a result of temperature fluctuation within a shorter period. The rocks cools down to around 10 C0 at night and during the day rising it up to around 80 C0 making a drastic fluctuation range within one day. The rocks covered with a soil layer and the vegetations, especially under a forest cover are not exposed to such heat fluctuations. Therefore degradation of forest has also accelerated the process. Forest fires are more dangerous in this regard. Temperature fluctuation may crop up more than 400 C0 during several minutes as a result of fire. The rocks may break into large blocks in a such fire within several minutes. Some people use this as a technique to break stones into pieces. Forest fires accelerate and act in several ways on landslides.

Parent rocks in most of the area in the mountain range from Haputale to Ratnapura consist of the same type and may create landslide situations effortlessly. Steep slopes of these mountains make possible faster downward movement of matter. Heavy rainfall with thundershowers during convective rainfall in inter-monsoon periods provides required driving force.

Forest fires were observed in this mountain range during last all four years before this event. It seems that this was a continuous incident each year. However, forest fire occurred at the top of the hill where moving mass in this event taken start only in 2002. The fire continued two days until it had been extinguish by rain followed. The area for was covered with smoke of fire two days.

Nature of the Process

This mass flow incident had started with a falling of a large block of rock around 30 m down from the lowest top of three peaks of Paraviyangala range. As the slope in this point is almost 90^0, the rocks had fallen directly to the ground. The soil has been washed out in a comparatively larger area around the place where the rock has been fallen down, only sand and pieces of rocks remained. Grass vegetation had been washed away. The flow had been divided into two branches 30m down stream. This division make evidence of large water movement that

had occurred from that point because, if only rocks moved, the branching would not happened. Again both streams joined 20 m down stream. The stream again made two branches after another around 20 m. and within next 30 m. again joins. If there was a hevy rain it had occurred only to this valley and into a small area. Fallen rocks and water with washed grass and soil hit a block of tree vegetation block and the tree block also washed down with other material. This all happened in the slope with above 600 angle and material moved around 100m with a fast destructive force. There were no such evidences of big volume of water flow in adjoining valleys at the same height and below. This nature gives evidence that there was a flow of rocks with big volume of water from the starting of this flow.

The large volume of water with debris, soil, vegetation, rocks and stones entered to the well formed V shape valley with the gentle slope with about 40 to 60 degrees. This stretch is little longer than 1km and the force scratched down every thing in the valley. Now the both sides of this valley made unstable and the materials on the valley will slide and may make another several landslides in the same valley to stabilize sides. At the end of this stretch the fast moving material bearded the height reaching 10m in less than 50 m width. The valley cleared from all vegetation and most of the rocks on the way and newly cut V shaped valley was appeared. Both sides of the valley is now unstable, no vegetation by the sides and may wash down by any amount of rainfall.

Just after the bridge on the main road the flow enter to a broad valley occupied with mainly paddy fields. The maximum width of this effected valley reaches 500m. Accumulated force of water, mud and stones at the bridge instantly blown away the bridge and the force enter the broad valley. The flow lost vertical force entering to the broad open area with around 10^0 slope and start deposition of heavy material. Large blocks of rocks deposited closer to the road. One of them is as large as around 13,000 m^3. The size of deposited rocks gradually reduced. Only small rocks are deposited at the end of the broad valley. Mud and sand also deposited in this stage. The length of this deposition area is around 800m.

Further the valley become narrow and only the water and floating material are transported. At this stage unusual vertical force was lost and the slope angle reduces and only the water flow moved along the normal path of the valley paying 5km to Samanalawewa reservoir. This flow of water transported only logs and other vegetative material. Two dead bodies were also found in Samanalawewa. Occasionally sand deposits are found on the way of this stage giving evidence for the movement of large amount of water.

Comparable Experiences

There are similarities of experiences with many mass movement incidents in the world and many landslides in Sri Lanka. Most prominent examples are discussed in this section. Having similarities in the process, the causes for the events are diverse.

Following experiences were collected from the information reported by Senevirathne (2006). Story 1. Primary reason for instability for causing **massive landslide at Beragala in 1966**

is steepness of slope, thin layer of stony soil and blockage of stream by slope rubble. The activator was heavy rainfall (103mm in 2 days) prior to the slide. Loss of 12 lives was a result of bank collapse and tree fall along the side of the slide path. Story 2. Primary cause of the landslide was indiscriminate gemming in the channel of Nedola in **1967**. Six lives were lost, but authorities were not responding to the damage done to the riverbed. The stream was blocked by excessive amount of rock and vegetative debris. Though it was limited to above two stories which summaries the causes of landslides, there are a lot of studies conducted on landslides occurred in Sri Lanka.

Spatial Analysis of the Process

The spatial nature of the process provides the basis for classification of the path according to its properties. The path of flow can be divided in to five stages:

1. The first stage is **rock fall** at the top of hill with the slope of more than 85 degrees. This rock fall may induced either by tectonic factor that is explained in other section or by the weathering process which was accelerated by fires or by both factors. In any case the event took place after two days of heavy rainfall of convective type. This section consists of rock outcrops, may be opened up as a long-term impact of land clearance for tea plantation some 100 years back. Still there are such blocks of rocks those may make another disaster in the future.

2. The second stage is 60 m stretch with the slope angle of around 60 to 85 degrees. The mass flow consists of water, pieces of rock, soil and grass.

3. The third stage with average slope of 40 to 60 degrees represented rock fall with water and debris of vegetation, rock and soil. Water and rock were dominated in the flow of this stage. Along the line of movement not much of the disturbance made to the valley as the flow had less than 12 meters wide. This was a rapid flow estimated around 10 meters per second.

4. The fourth stage is characterized almost nearly as a flow explained as Siel flow: comparatively higher speed as 5 meter per second brought huge amount of muddy water with stones and vegetation. This stretch is wider than the above third one and the average width is approximately 20 meters with increased width at the lower part. The stage is spread in 1500 meters long distance. The flow in this section transferred everything in the valley down. After the flow moved down in this stage, a correct V – shape valley was made with unstable slopes which may further move down with another heavy rainfall.

5. The mass moved in the above stages which stood out of water was blocked at the bridge for less than five minutes and suddenly moved down breaking the bridge. Concrete and metal pieces of the bridge were thrown to 60 meters away. After breaking the bridge the flow enter to wider valley where paddy field was. Stones and mud deposited in this field. There were several stones huge as the largest one consisted 13,000 m3. The only house located in the left side of the valley was also smashed and six lives lost. Slope in this stage varies from 10 to 30 degrees and spread in 850 meters distance.

6. After the deposition of large blocks of rocks and the most of the mud the flow moved down through the normal course of the stream without much signs of a landslide. Sand had been deposited in several places. Paying way of around five km the flow enter to Samanalawewa reservoir.

From the hilltop to the place where the flow crossed the main road there was a big vertical force and the force lost in the broader valley and deposited. It seems that all types of landslides from rock falls to mud flow are found within this phenomenon. However the major component of the flow is water. This process of flow reminds the three stages of river rather than a type of landslides. According to definitions of landslides a major portion of slipped land has to be found in close proximity at down. In this phenomenon most of the land slipped has been washed away.

Table 1. Characteristics of flow in different Stages of Puwakgahawela siel flow

Stage	Slope in degrees	Lengthm	Content	Velocity m/sec	Comments
I – Rock fall	>85	30	Rock	15	Fall of several peaces
II – Rock fall	60-85	60	Water/ derbies	12	
III – Rock fall with water	40-60	100	Water/ derbies/vegetation	10	
IV – Siel flow	30-40	1500	Water/mud/stone/vegetation	5	
V - deposition	10-30	800	Water/mud/stone/vegetation	2	Deposition of mud & vegetation
VI – Muddy water tide	0-20	5000	Water/vegetation/mud	1	

The Conceptual Question

Question rises where such a volume of water collected at the top of the hill? During convective rainfall period, when this event has taken place, cumulonimbus clouds with some times 7 km vertical extent are formed. Such a cloud may contain large amount of water. However, in that case the rainfall should be experienced in a larger area at least in several squire kilometers. The day was a rainy for the area but there was no such intensive rainfall occurred around. Sabaragamuwa University that is located in the vicinity has recorded 62 mm of rainfall on the day.

People's Perception

Information collected from the people around the area was interesting and some times they are speculative, however, the study pays attention on the opinion of people as to get insight of the event and to understand their perception about the event.

People's perception on the phenomenon is different from any scientific explanation on landslides. The area people said that this was not a landslide but "Diyahenaya", which means thunder of water. This implies that a heavy shower hits a certain place and this is fairly known event for them. Some people heard an unusually big thunder for a moment before the event occurred. Area people used to call the valley "Henagahathi Ella" before this event, meaning, "place with thunder fall". The people's explanations were thought speculative. Because it was considered that they say something to ignore the role of forest fires made by them on this event.

Same type of event has been recorded by people at Agalawatta estate in Matale in 1950s. "A large flow of water from hill top washed away everything in the valley including huge trees. Nothing left in the valley". Their explanation 50 years back in a geographically very distant area also was the same, "Diyahenaya". Same type of event occurred at Murutoluwa hill slope in Matale district some five years back. People's explanation was the same "Diyahenaya". In this event people described, "the water disappeared at the dawn stream". Disappearance may be as in the case of Puwakgahawela last stage: water flowed without marked signs of damage or remarkable deposition.

There are many cases when people's non-scientific expressions later found scientific explanations. These expressions often time tested rather than tested by a scientific method. These are called also indigenous knowledge. Therefore this "Diyahenaya" concept also should be considered in search of any scientific explanation.

Systems Approach to the Question

The system is a method of analyzing relationships within a unit and consists of a number of components among which there are linkages. When opposing forces, or inputs and outputs,

are balanced, the system is said to be in a state of dynamic equilibrium. If one element in the system changes because of some outside influence, then it affects this equilibrium and affects the other components. A slope is a dynamic open system affected by ***biotic, climatic, gravitational, groundwater and tectonic inputs*** which vary in scale and time. The amount, rate and type of movement depend upon the degree of slope failure (Waugh, 1995).

In this episode almost all the types of landslides have taken place. Rock-falls, Earth slips, Debris flow and subsidence are observed. Therefore it is almost impossible to define the type of this landslide according to present landslide classifications.

Most likely meteorological event is tornado, which may have diameter as small as 500m. Certainly, such small meteorological event may not be recorded by normal meteorological observations other than by satellite photographs. But the problem is that at the center of tornado everything on the ground lifted up rather than brings down. Anti- cyclonic tornado is also recorded in rare cases in the northern hemisphere. Formation of anticyclonic tornado may be induced by specific topography of the area like mountain range. Anticyclonic tornado acted on a cumulonimbus cloud can collect water in the cloud into small area and move down with high velocity. It may result strong thunder and lightning. When we call anticyclonic tornado meant tornado with clockwise direction of rotation and characteristic downward movement.

"Anticyclonic" Tornado

Original term for tornado comes from French as " Trombe", from Italian " Tromba" which means a tube. The term tornado is used in USA.

> "Tornado is a strong whirlwind on land masses which emerge below thunderclouds....Appears in hot weather in highly unstable stratification of the atmosphere." (Geography Encyclopedic Dictionary.1988.)

Tornado sometimes forms as a result of thunderstorm (Battan, 1985). The diameter of a tornado is often 100 – 200m. Tornado exists several minutes and some times several hours. The whirlwind attract clouds from up and dust from down and seems as a trumpet of an elephant hanging over the cloud. Condensation takes place in this situation resulting thundershower, lightning and hail. The wind spins around the axis of whirl moving upward anticlockwise in the northern hemisphere called "cyclonic tornado" however, occasionally comes to pass "anticyclonic tornado" (Battan, 1985) that of the wind spins around the axis of whirl moving downward clockwise. The wind speed of tornado may reach 50 to 100 m/sec. Upward movement is also very high resulting uptake of materials in the ground. This wind breaks constructions; people and animals are thrown far distance and breaks and uproot trees. Sometimes it is used the term "water tornado" (Kromov, 1983) which may means a tornado formed in a rainy cloud and results a pouring of water. This may happened with a tropical cumulonimbus clouds which may high as 18 km and contain lot of water.

Mass Movement

Mass movement is the downward movement of material on a slope as a result of gravity. Conditions which promote rapid mass movement include a steep slope angle, an absence of binding vegetation and the availability of sufficient moisture to cause saturation. The types of mass movement are: soil creep, earth flow, rock falls and landslides (Harper, 1989). Landslide is an occurrence in which a large mass of earth and rock breaks loose and falls or slides. The special types of landslide include slump, earth flow and mud flow. Landslides are categorized as a type of rapid mass wastage (A Team of Experts, 2000). The term mass movement describes all downhill movements of weathered material (regolith), including soil, loose stones and rocks, in response to gravity. However, it excludes movements where the material is carried by ice, water and wind (Waugh, 1995).

The types of mass movement are classified according to speed of movement and the amount of water necessary to assist this movement. There are slow movements, flow movements, rapid movements and very rapid movements. Earth flows and mud flows are come under **flow movements** whereas speed of the movement may reach 10m/sec (Waugh, 1995).

"Siel flow"

This was a flow of water with heavy load of rocks, soil mud and vegetation. The term "Siel" in Russian after Arabic word "Sail" means heavy flow of water with rocks, mud and other material.

> Siel is "(Stormy torrent) muddy or mud-stony stream, suddenly appearing in river beds of mountain areas and defined by short-term abrupt rise of (water) level with a wavy movement and lack of any periodicity. Siel forms due to heavy torrents, intensive melting of ice and snow from glaciers, rarely as a result of earthquakes, volcano eruption, break of lake straight and as a result of human activities (such as explosions in hill sides). Preconditions for formation of Siel are accumulation of large amount of products of weathering on hill slopes, their steepness of the slope frequently long-term abundant moistening of ground that reducing their stability. Content of heavy material in Siel changes from 10 – 15 to 75%. They are classified by the content as mud-stony, water-stony and muddy. Siel is also classified by its physical types as: bonded and not bonded. Single peaces of broken material transported in Siel may weigh as mush as 100 – 200 tones or more. Siel moves sometimes with the velocity of more than 10 m/sec. Volume of instant cast may reach hundred thousands or millions m3. Possessing high velocity and volume Siel often brings large destructions receiving in more catastrophic situations characteristics of natural hazards. Primary measures against Siel destructions are stabilization of soil and

vegetation in hill slopes, prophylactic discharge of lakes in highlands which may make danger, construction of protective dikes and other Siel protection constructions, Siel is prominent in mountains and foothills with continental climate....." (Geography Encyclopedic Dictionary.1988).

Further it describes that this flow exist for a very shorter period, which appears suddenly. This may be a wavy movement with no periodicity. The cause for Siel is heavy rain. It explains further several many other possible courses such as earthquakes, volcano eruptions, explosions in mountains etc. This phenomenon intensifies by collecting of weathered rocks in slopes, by steepness of slopes etc,. Siel may content debris from 10, 15 to 75% of the total mass other portion being water. There are several types of Siel identified according to their content: 1. Mud-stone, 2. Water-stone, 3. Mud 4. Water-vegetation. Some heavy blocks moved may weigh 100 to 200 tones. This flow with high velocity and large mass may break large constructions. It seems that the term "sial" would suit more to Puwakgahawela phenomenon than landslide. Following measures suggested for protection against Siel: stabilization of soil and vegetation in slopes, build dams and other Siel protection constructions. This type of disaster experienced in mountains of South Kazakhstan, East of Caucasus. This is a separate sub-discipline under the soviet geography.

'Rainfall-induced rapid long-traveling flow phenomenon' is the term used in English literature recently (www.springerlink.com/index/P0X4H6CJ08MXPJ74.pdf) in many other studies.

Environmental Change

Change is a norm for any environment and that is more apparent in the context of recent climatic change induces by enhanced green house effect. In response to the climatic change with increase of active thermal energy in the atmosphere the frequency and intensity of storms, tornados and related phenomena will increase multiplying the vulnerability of sloppy lands in tropical region.

Conclusions and Suggestions

Applied value of a study on such phenomenon laid on the validity of present methods to identify potential areas for landslides and on the methods to mitigate disasters. Therefore, it is important to know, is this unique phenomenon or a common one? Small block of rocks departed at a steep slope may make big effect in valley down. There is a need Therefore for more attention to be paid on such rocks on steep slopes in a hilly area. One way to be protected against such type of events is not building and removal of houses on the valley rather they are to be built on the ridge. Forest cover on top of hills and protection of those forests from fires are also important aspect in mitigating such types of events.