# RAIN-INDUCED LANDSLIDE PROBLEMS IN WEST JAVA

**Dwikorita Karnawati** *)

**ABSTRACT**

*Rain-induced landslide is one of the most common types of natural disaster which frequently occur during the rain season in Java, particularly in West Java. This paper presents the reasons for the fact that West Java is considered as a high risk area for the landslide occurrences. Causes or factors controlling the occurrences of landslides and mechanism of their occurrences are discussed. Among those factors the slope hydrological aspect is the most difficult one to be observed and assessed. Therefore, the method to enable such aspect to be assessed rigorously is also suggested.*

## INTRODUCTION

One of the most common types of natural disaster in Indonesia is landslides. This is the type of disaster that always occur in the rainy seasons and it can result in a lot of casualties and substantial structural damages. For instance, during 1979 - 1983 there were 6,473 landslides in Indonesia, which caused 749 people killed and 253,639 people injured and also resulted in loss of material (structural damages) with the estimated cost about 105 milliard rupiahs (Saroso, 1992). Most of those landslides occurred in West Java. That is why the landslide was pointed as the second common natural disaster in this province. Furthermore, according to the reports by several local authorities in Java during 1994 to 1995 there were 86 landslides (30 of them are in West Java). These resulted in 28 people killed and destroyed 171 houses, 266 ha. field, 550 m road, 8 public structures and 2 bridges.

It is interesting to assess why the West Java is risky for the occurrence of rain-induced landslides. To do so, the geological conditions and the nature of this area which may significantly control the landslide occurrences are required to be identified, and the mechanism of such occurrences needs to be analysed. By understanding the controlling factors and mechanism of the landslides, measures required to prevent their occurrences could be suggested.

## FACTORS CONTROLLING LANDSLIDE IN WEST JAVA

According to Sampurno (1975), Heath and Saroso (1988), Heath et al (1988), Tjojudo (1985) and Saroso 1992, landslide in West Java is controlled by several factors such as geology and terrain conditions, characteristics of soil/rock material covering the slope, soil or rock structures within the slope, climate, and slope hydrology. Those would be explained as follows:

### Geology and Terrain Conditions

West Java lies on an active subduction zone, which results in tectonic uplifting and folding as well as volcanic activities (Van Bemmelen, 1949). Those leads to the formation of steep hilly and mountainous terrain conditions. Such conditions overwhelm the area. Steep terrain by nature is susceptible to slope failure (landslide). Thus, terrain condition is clearly a significant control on landslide distribution.

### Characteristics of soil/rock material covering the slope

It is apparent in some previous studies Sampurno (1975); IRRI-TRRL (1982), Heath et al (1988) and Saroso (1992) that the weathered volcanic deposits and colluvial deposits covering the steep slopes are the most sensitive deposits to fail. This is because those deposits, in particular those containing smectite clays, exhibit low shear strength. Unfortunately, those are the deposits which are abundant in West Java.

### Soil or rock structures within the slope, such as discontinuities (joints) and or contact planes.

Discontinuity and contact plane normally exhibit a contrast in soil permeability and shear strength. These could be the contact between weathered soil and the underlying more fresh bed rock, or contact between two different soil/ rock types. Naturally, such discontinuity or contact plane have very low shear strength, so the slope failure commonly pass through them.

*) **Dr. Ir. Dwikorita Karnawati**, M.Sc., **Lecturer in Dept. of Geological Engineering, Faculty of Engineering, Gadjah Mada University**.

**Climate**

It is evidence that landslides are strongly related to the high intensity of rainfall. Steep terrain such as in West Java by nature is susceptible to landslides. Unfortunately, this is worsened by the fact that the steep terrain also associates with high intensity rainfall. Berlaga (1949) established the peak rainfall rates based on rainfall records collected in Java over a period of 60 years. Peaks in rainfall occur between January and February and again between March and early May. They correspond with periods in which the majority of serious landslides were reported in 1982 to 1984 (Heath et al, 1988). The coincidence of landslide belts with high rainfall zones in West Java (Figure 1) also indicates that climate, i.e. rainfall, strongly controls landslide distribution.

Some studies suggested that landslide always occurs either during or immediately after periods of heavy rain. For instance, Van Bemmelen (1949) and Brand (1985) reported that slope failure usually followed the high intensity rainfall in which the precipitation rate exceeded 70 mm/hour.

Clearly, there is still no agreement yet on defining the rainfall characteristics that are most critical for triggering the slope failures. Some studies suggested the single event of high intensity of rainstorm but the others pointed to prolonged low intensity rainfalls occurring prior to the rainstorm. This disagreement arises because slope hydrological conditions were not completely investigated in those studies. Such studies were carried out by empirical observation and mostly reached conclusions based on statistical assessments. The absence of information on slope hydrology is the most important omission.

That is why Karnawati (1996) carried out the study to identify the triggering rainfall characteristics by incorporating slope hydrodynamic numerical modelling. In such modelling the dynamic conditions of slope hydrology in response to the rainfall infiltration could be assess more rigorously. This study concluded that the relatively low intensity of rainfall, i.e. 25 mm/day, could trigger the landslide in a slope with relatively low hydraulic conductivity

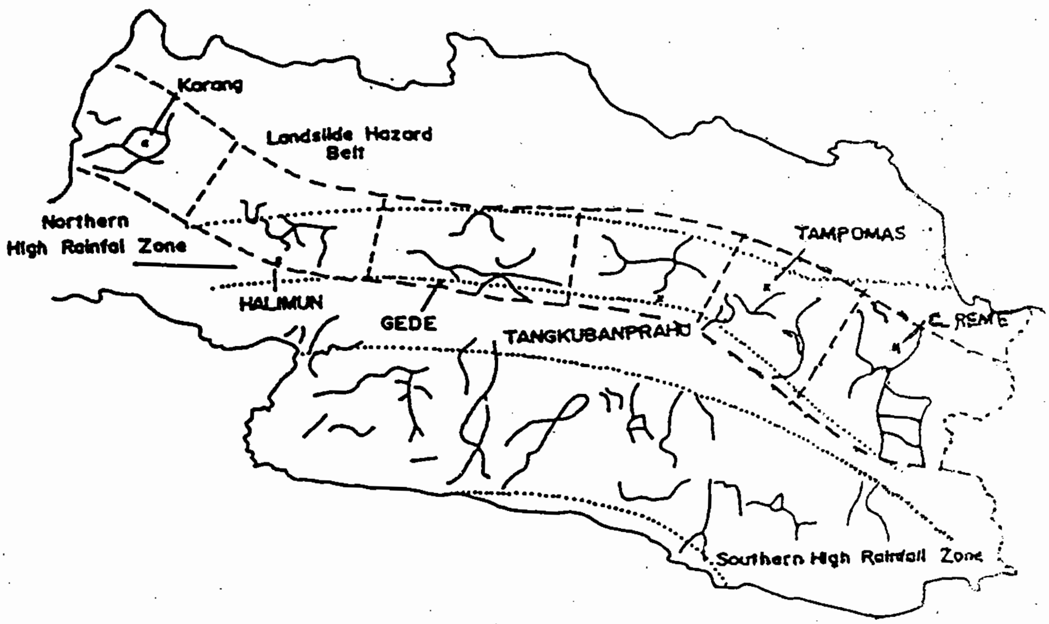


Figure 1. Landslide belts and high intensity rainfall areas (Heath, 1984, unpublished)

On the other hand, the IRRI-TRRL collaborative project (1982) indicated that the failures on some slopes in Java were mainly because of the accumulative effect of the prolonged low intensity rainfall, which deteriorated the slopes during the wet season. Meanwhile, the empirical observation by Heath et al (1988) shows that the intensity of triggering rainfall varies from about 22 mm to 122 mm per day. This is such a large range of variation.

($2.51 \times 10^{-6}$ m/sec) in which the initial groundwater table was shallow ( 1 to 3 m depth). It is also suggested that the triggering rainfall characteristics is strongly controlled by the permeability of soil/ rock covering the slope and the initial groundwater table of the particular area. Indeed, the triggering rainfall characteristics are typical for each area. Therefore, the characteristics of the triggering rainfall of one particular area could not be applied to different area with the different hydrological conditions.

## Slope hydrological conditions.

Among all factors controlling landslides stated above, the slope hydrological conditions is the one that very sensitive to change through the space and time, in response to the rainfall. Indeed, this is the most complicated one to be able to be analysed. 'Some thought believed that the slope hydrological conditions which is significantly controlled the slope stability is the groundwater table condition. Since, it controls the changes of pore water pressure which affect the shear strength of the slope. This is the reason why most of the landslide studies concern on the assessment on the groundwater conditions.

Whipkey and Kirkby (1978), suggested typical groundwater conditions which lead to failure in slopes. This is illustrated in Figure 2.

of lower permeability. The permeable zone then consists of :

a. a saturated sub zone of less permeable material
b. an unsaturated sub zone of higher permeability.

At a certain level of rainfall infiltration the upper, more permeable zone reaches the limits of its hydraulic conductivity after which back-up of saturation migrates up slope. Recharge from the upper slope then creates the worse conditions where water pressure in the lower part of the slope would built up rapidly. This often results in slope failure.

However, this hypothesis on the model of slope hydrological conditions (in particular the groundwater table condition) controlling the landslide occurrence in Indonesia is still quite difficult to be proved due to the lack of a tool which is capable to observe such conditions. The incorporation of numerical modelling in the landslide study enables the slope hydrological

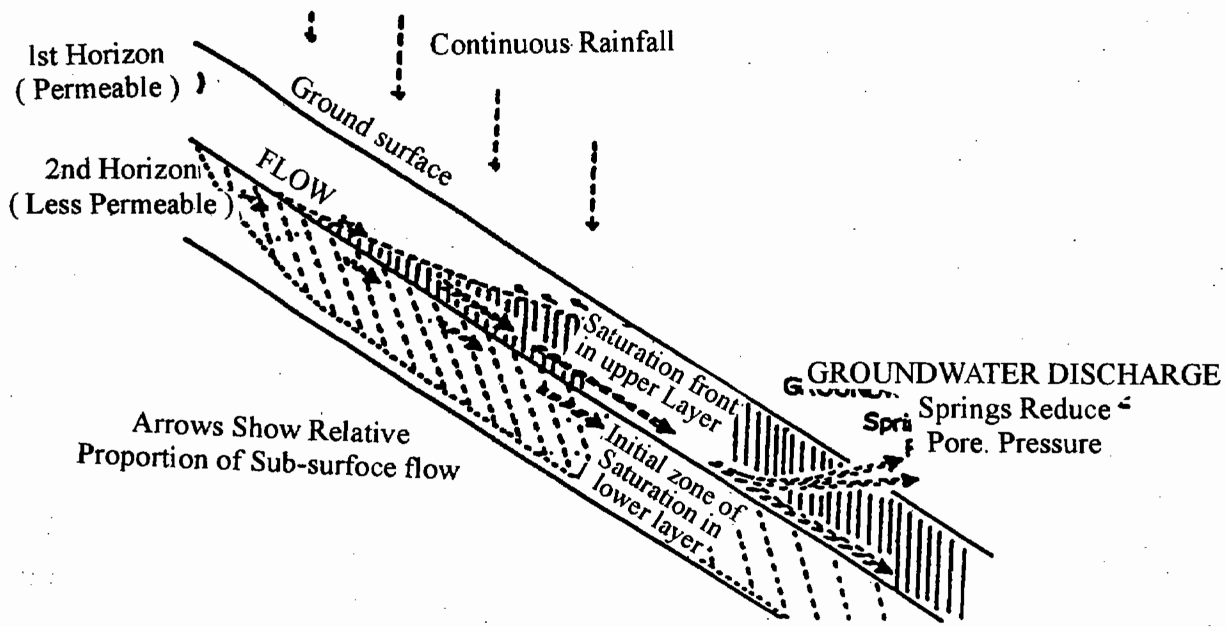


Figure 2. Condition of groundwater on slopes in Java (Whipkey and Kirkby, 1978 in Heath et al, 1988)

This condition may apply to Indonesian slopes.. Slopes in Java often have permeable layers, such as colluvium or residual soil, overlying less permeable layers, such as shale or clay. Either layer may function as an unconfined aquifer. The permeable layer often consist of two sub-layers of contrasting permeability, i.e. a less permeable layer on the bottom and more permeable layer above. Below a threshold infiltration rate groundwater is trapped in the sub zone

conditions to be simulated rigorously. Thus the response of such conditions to the rainfall and the effect of this response to slope stability will be able to be predicted more accurately.

### Other factors

There are several other factors that control landslide occurrence. Natural pipes and fissure networks in the slope can provide localised weakness and saturation, which significantly lowers the overall particular area could not be applied to different area with the different hydrological conditions.

## Slope hydrological conditions.

Among all factors controlling landslides stated above, the slope hydrological conditions is the one that very sensitive to change through the space and time, in response to the rainfall. Indeed, this is the most complicated one to be able to be analysed. Some thought believed that the slope hydrological conditions which is significantly controlled the slope stability is the groundwater table condition. Since, it controls the changes of pore water pressure which affect the shear strength of the slope. This is the reason why most of the landslide studies concern on the assessment on the groundwater conditions.

Whipkey and Kirkby (1978), suggested typical groundwater conditions which lead to failure in slopes. This is illustrated in Figure 2.

of lower permeability. The permeable zone then consists of :

a. a saturated sub zone of less permeable material
b. an unsaturated sub zone of higher permeability.

At a certain level of rainfall infiltration the upper, more permeable zone reaches the limits of its hydraulic conductivity after which back-up of saturation migrates up slope. Recharge from the upper slope then creates the worse conditions where water pressure in the lower part of the slope would built up rapidly. This often results in slope failure.
However, this hypothesis on the model of slope hydrological conditions (in particular the groundwater table condition) controlling the landslide occurrence in Indonesia is still quite difficult to be proved due to the lack of a tool which is capable to observe such conditions. The incorporation of numerical modelling in the landslide study enables the slope hydrological

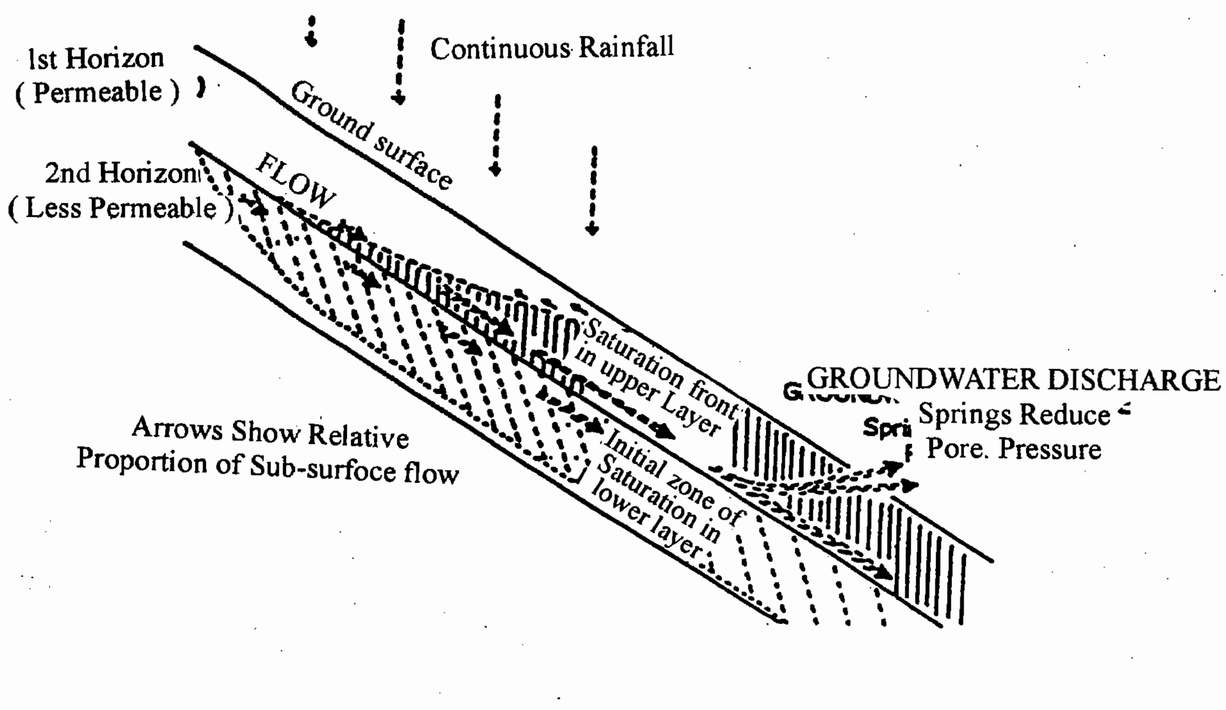


Figure 2. Condition of groundwater on slopes in Java (Whipkey and Kirkby, 1978 in Heath et al, 1988)

This condition may apply to Indonesian slopes.. Slopes in Java often have permeable layers, such as colluvium or residual soil, overlying less permeable layers, such as shale or clay. Either layer may function as an unconfined aquifer. The permeable layer often consist of two sub-layers of contrasting permeability, i.e. a less permeable layer on the bottom and more permeable layer above. Below a threshold infiltration rate groundwater is trapped in the sub zone

conditions to be simulated rigorously. Thus the response of such conditions to the rainfall and the effect of this response to slope stability will be able to be predicted more accurately.

### Other factors

There are several other factors that control landslide occurrence. Natural pipes and fissure networks in the slope can provide localised weakness and saturation, which significantly lowers the overall

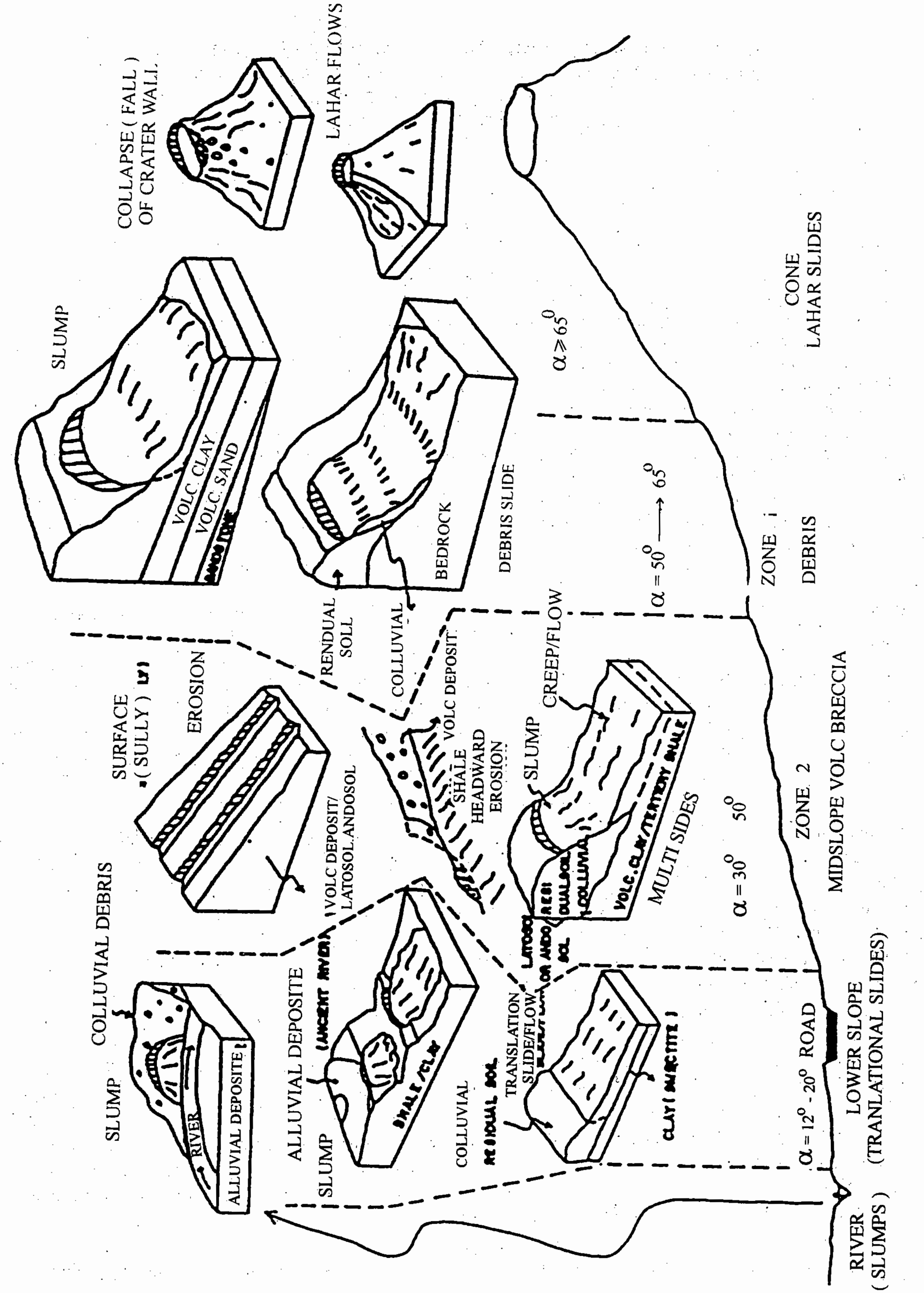


Figure 3. Landslide Problems in Java (Karnawati 1996, modified from Heath, et al 1988 and Saroso, 1992)