CHAPTER IV

SOIL EROSION : MECHANISM AND PROCESSES

INTRODUCTION :

This chapter deals with mechanisms and processes of soil erosion . Since the study area is affected by fluvial erosion , mechanisms of various forms of it have been discussed . Those dealt in details are splash , sheet , rill , gully , stream bank , pothole , tunnel and sloughing erosion along with lands slides .

4.1 SPLASH EROSION :

The most important cause of break up of soil clods is the impact of fast falling rain drops in a severe storm , as they possess very considerable kinetic energy and momentum . The greater the intensity of the storm , larger is the drops and faster they fall. Their velocity may even exceed that for free fall because of air turbulence in the storm . The falling rain drops accelerate until the frictional resistance of air is equal to the gravitational force and then continues to fall at that velocity , called the terminal velocity (Datta , 1986) . The frictional resistance of air against the accelerating rain drops is a function of surface area per unit volume of it , which in turn , is affected by intensity of rain , air resistance , atmospheric pressure , temperature and humidity . Hence, larger the rain drops , higher is the terminal velocity . In general , as the height of fall of rain drops increases , velocity increases only up to a height of 10.5 mt after which terminal velocity is achieved (Michael , 1981) . A drop of one mm diameter , typical of fairly light rain , will have a terminal velocity of almost 3.8 mt per second and a drop of 4.5 mm in diameter , typical of a heavy storm , will have one of 9 mt per second , but its kinetic energy will be 500 times , and its momentum 200 times , greater than that of the smaller drop (Davies , 1988) . Thus, more violent the storm , greater is the shattering effect of rain drops . The kinetic energy is such that a rainfall of 50 mm an hour is sufficient force to lift 180 mm of top soil to a height of 910 mm 86 times during an hour's rain (Osborn , 1969) . Rain drop impact shatters clods and causes splash , and some of the droplets blown up carry fine soil granules and sand grains . A single rain drop may splash wet soil as much as 60 cm high and 150 cm away from the spot where it hits (Michael , 1981) . The force of falling rain drops may be 10000 times the energy of the surface run off in hard storms , even of steep slopes (Osborn , 1969) . As a result of splash , some of the finer particles , which contain much of the soil humus , disperse in water and run off the land leaving coarser sand particles behind . Thus , erosion due to splash and run off , tends to coarsen the texture of soil left behind . On level ground , where drops strike vertically , throwing up action by bombarding rain drops , and dispersal of soil charged water droplets tend to cancel one another , leaving the same amount of soil on the site at the end of rain . Experiments have shown that drops striking standard sand at different angles , indicated that the percentage of detached material moving down hill amounted to 50 percent plus the percentage of slope and on a 10 percent slope , movement down hill was three times higher than that uphill (Osborn , 1969) . Even on level ground , where the rain drops hitting vertically , they create extreme turbulence in the slowly moving thin film of muddy water. This enables it to carry far larger quantity of the splashed material than its carrying capacity would , otherwise , allow . The sealing of microscopic pores is yet another important effect of rain drops that needs elaboration.

The churning action of beating rain drops makes dispersed material into a pasty mass . In the violent shifting of particles on surface , finer ones are filled in between the coarser ones making an impervious seal which , coupled with levelling of soil surface due to break up of isolated clods and its compaction by the impact of rain drops , causes a resistant surface cap to be formed . Frequently this surface sealing is perfect enough to keep soil below a small distance quite dry even with continued rain , and after its drying and stiffening , strong enough not to let sprouting seeds (in loose soil beneath) to push through it (Bennett , 1955) . Besides

, this seal enhances run off dramatically . Detachability of soil particles is the parameter affecting the intensity of splash erosion.

There is a close relationship between soil detachment and splash erosion . Detachability is influenced by size and shape of particles . The most easily dislodged are fine sand , the coarser ones resisting the detachment because of their greater size and weight . Fine textures soils are less detachable because of aggregation of particles . The shape of particles affects detachability through differences in the degree of interlocking of particles . Other factors affecting detachability are structure , content of organic matter , moisture and tilth . Vegetation plays an important role in respect of splash erosion . The plant cover on the land offers natural resistance to the splash erosion process . By intercepting the shooting rain drops , vegetation dissipates their energy and reduces quantum of soil splashed . Essential criteria for adequate protection of soil against this menace is complete canopy over the land , either by litter on the ground or by standing vegetation provided , if it is tall enough to produce splash from drippings , under storey and ground cover , too , is present . In general , amount of vegetation is more important than its kind in its role of protection of soils against splash . Effective (95 percent) control of rain drop energy requires approximately 2000 kgs of sod grass , or 4000 kgs of ordinary crop , or 7000 kgs of tall grass per hectare and the vegetal cover after some rain is known to have interrupted .3 metric ton of splash soil per metric ton of oven dry weight of vegetation (Osborn , 1969) . This is only a small part of whole soil involved as beating rain drops continuously wash down intercepted splash material . In case of sandy areas subjected to aeolian erosion , soil conditioners , such as bitumen , polyacrylamide , and polyuria are known to reduce splash erosion by 88 , 90 and 91 percent , respectively , after one hour of rain fall of intensity of 40 mm per hour (De Kesel , 1990) .

Since the rain fall is quite stormy in the study area , any bare soil is subjected to serious dangers of splash erosion . This is specially so in cultivated areas with ploughed soils . Tea garden areas with poor density of tea bush canopy are also subjected to splash erosion as also the degraded forest areas. Splash erosion is seen in Ambootia tea garden where soils on slopes have been ploughed. The new plantation of tea takes five to ten years to cover the ground fully. This patch of Ambootia tea garden shall go on eroding for next many years. It should be thoroughly mulched during rains through straw to protect the soil. The patches having low canopy density of tea bushes in Single tea garden are also suffering from splash erosion. A younger tea plantation of Maharani tea garden is also seen affected by splash erosion. Some patches of Chhota Ringtong tea garden are also seen severely affected by splash erosion. A newly cut road in Chhota Ringtong is also showing large scale splash erosion. The Pumong Phatak-Dudhia road, which is newly cut, is also suffering from splash erosion. In hills, potato tuber is harvested during July by excavation of soil. The excavated soil is exposed to the full force of the monsoon showers. Large scale splash erosion is seen from the potato fields. The vegetables such as beans, cabbage etc. are planted after harvesting of potato. But they hardly provide any protection against lashing rain storms. In Dhobijhora and Mahaldram forest splash erosion is assisted by overgrazing. The soils loosened by hoofs of cattle are splashed around. So is also the case of the Senchal reserve forest area. In degraded forests of Senchal splash erosion is very surreptitious.

4.2 SHEET EROSION :

The run off takes the form of sheet flow and channelized flow ; former coupled with rain drop action produces sheet erosion . Its effects are gradual and often go unnoticed until most of the top soil is removed . It is the least conspicuous but the most extensive and insidious type of erosion (Bennett , 1955) . Areas where loose , shallow top soil overlies a tight sub soil are most susceptible to this form of erosion (Schawab , 1971) . Excess water collecting on the surface moves down hill and gains velocity in accordance with its depth and amount of vertical fall . The energy present is only that of translation , and is seldom of consequence in soil movement . As the depth of flow increases , turbulent patches form and travel down slope . The frequency of patches increases with increased depth and velocity until the entire flow is turbulent . Turbulence is accompanied by great increase in kinetic energy and erosivity

. The impacts of falling drops contribute greatly to erosion by such flows . Direct impact of splashes is reduced by as little as 2.5 mm depth of water but the energies of falling drops are transferred to the surface flow in form of turbulence . Strong vertical velocities in the water are directed downwards , to detach the soil , and upwards , to support the detached material . Under such conditions , sheet flow may carry large amount of soil , specially the finer fractions , and lighter organic and soluble materials , even without sufficiently erosive horizontal velocities . It is through the combined action of rain drop erosion and sheet flow that rain storms are able to remove fairly uniform layers of soils from large areas . This form of erosion involves selection and sorting of the erode material . Since selection process of erosion includes the washing out of valuable soluble substances from the soil , this process is one of great economic importance . The substances that may be washed out of soil in this way include those soluble in weak acid solutions , and humus substances of low molecular weight , both of which groups are very important for fertility of soil (Zachar , 1984) .

Frequently the removal of soil by sheet erosion is so slow and insidious that land appears absolutely protected but appears to be turning light coloured as the removal of dark hued top soil exposes relatively light coloured sub - surface material . Sheet washing is also indicated by change in texture towards coarseness and reduced plant growth . One may also recognize the extent of sheet washing by measuring the depth of A horizon in various parts of the field . As a rule

, depth of this horizon is fairly uniform unless erode . The departure of depth of A horizon from the normal is an accurate measure of the degree of sheet washing (Jacob , 1965) . Various factors affect the susceptibility of soils to sheet erosion .

The differences in susceptibility of various soils to sheet erosion depends , principally , on slope , climate , and the character of the soil . Steep and moderately steep lands and those subjected to heavy or intense rains are likely to be the most troublesome . Areas where loose shallow top soil overlies a tight dense clay sub-soil or other impervious sub-layers are most susceptible to sheet erosion (Schwab , 1971) . Fine grained soils (silt loam) , fragile sandy soils , and soils deficient in organic matter are also exceptionally vulnerable . Sheet erosion is quite intense in the study area.

In this region , from June to September 20 - 27 rainy days occur in each month with 5 - 20 days having rain fall more than 50 mm (Starkel , 1970) . Such a situation makes bare grounds , poor canopy density tea bush areas , deforested areas, over grazed areas and areas affected by forest fires quite prone to sheet washing . The extent of sheet erosion is easily seen in ploughed fields where small boulders , singles , or pebbles are seen lodged on small columns of soil after rain as the surrounding soil is washed away by sheet erosion . Often farmers put small boulders , singles on the bunds to protect it from sheet washing .

In the study area, sheet washing is seen in degraded forest areas of Mahaldram, Dhobijhora, Senchal and

Ghoom Simana. The reserve forest areas of Senchal and Rongbull are the worst affected. In Mahaldram forest, the degraded patch above Sepoydhura and Maharani tea gardens is very severely sheet washed. Overgrazing assists the process. In Ghoom-Simana reserve forest, a patch between Lepchajagat and Sukiapokhari also shows appreciable amount of sheet washing. The high rainfall in the area does not spare even lands covered with scrub vegetation. Such scrub lands, occurring in tea garden forest extensively, are also being sheet washed surreptitiously. Maling bamboo, which comes above 2000 mt altitude, gives fairly good cover but can not stop sheet washing of the soil. Patches of tea gardens in Springside, Ambootia, Singel, Maharani & Margarate's Hope, having scanty tea bushes , are being sheet washed extensively. Younger tea plantations are very susceptible to sheet washing and need protection by mulching. Abandoned agricultural lands in and around Sonada, Sepoydhura, Dilaram, Tung, Chatakpur, Rongbul, and Sukiapokhari are also showing sheet washing.

Sheet erosion even though not quite visible at initiation , more often than not , soon degenerates into yet another advanced stage of soil erosion called rill erosion which is discussed next .

4.3 RILL EROSION :

Rill erosion is more apparent than ordinary sheet washing but is almost always neglected . Minute rilling takes place simultaneously with the first detachment and movement of soil particles . Constant meander and change of position of these microscopic rills under the impact of beating rain drops obscure their presence from normal observation . As the severity of sheet washing increases , micro-rills develop further producing more pronounced irregularities in the land surface which could not be obliterated by the action of beating rain drops . These tend to concentrate the flowing sheet water along certain lines and obstructions make the flow turbulent and more erosive . As the amount of water in the channel grows , velocity and turbulence increase . Minor rills coalesce down slope to form larger ones , and the run off is progressively concentrated in streams of greater violence . Thus larger and larger proportions of run off energy is directed against smaller and smaller portions of land surface . The scouring action of concentrated flow carves out rills a few centimetres wide and channelized flow removes soil by scouring along the lines of its travel , and , because of its great concentration of kinetic energy , carries away the detached soil fed into it by sheet flow and rain drop splashes .

Conventionally , rill erosion is said to occur when flow channels have become sufficiently large and stable to be readily seen . Rill erosion is considered as the advanced stage of sheet erosion and can be regarded as transition stage between sheet erosion and gullying . Thus , there is no sharp line of demarcation where sheet erosion ends and rill erosion begins , but rill erosion is more readily apparent than sheet erosion , the indentation in the ground being small enough to be obliterated by normal tillage operations . On soft freshly ploughed soils , especially those of high silt content and having slopes greater than 4 or 5 percent , rilling is probably the commonest form of soil erosion (Bennett , 1955) . This is more severe on fallow lands . Considerable rill erosion is caused by heavy rains on bare soils at a time when frost is coming out of ground . Exposed B horizons are vulnerable to rill erosion which situation is commonly encountered in zones of podzolisation and yellow soils .

Although rill erosion is often overlooked , it is this one which erodes the soils the most (Schwab, 1971) . In the study area rill erosion is seen in fallow lands and degraded forest areas. Rill erosion is seen in the overgrazed wooded lands of Nahar tea garden (Plate 3). Banks of Ghatta jhora show rill erosion of its upper reaches. Extensive rilling is seen on the steeper slopes of Pachim and Gorabari basty. Rilling has also been seen in Nahar, Oaks and Chhota Ringtong tea gardens. Invariably, rills are located on steeper slopes having very little vegetation. Rilling has also been seen in Avongrove tea garden and Nagari spur. Pubong and Tomsong tea gardens also show rilling in areas having low density of tea bushes. Govt. forests of Mahaldram and Senchal show rill erosion. Rills develop fast in overgrazed forests. Dhupi plantations contain very little ground flora. Rills develop faster in Dhupi plantations. In Senchal forests, the areas located above Rongbull and Sonada are the worst affected. Ghoom-Simana reserve forest also shows rill erosion in and around Lepchajagat and Sukiapokhari.

PLATE 3: RILL EROSION IN OVERGRAZED TREELANDS
(SINGLE T. G.)

Rills are also seen in forest around Debrepani FRH where some bathans are located. Area is heavily grazed. This promotes rilling. Abandoned agricultural fields
between Sonada and Rongbull show copious amount of rill erosion. Rilling is predominant in all tea gardens having poor canopy of tea bushes . The rill erosion , if unchecked , soon degenerates into still more damaging gully erosion.

4.4 GULLY EROSION :

In the study area, gully develops from rills and their development is influenced by several factors which , according to their intensity , affect , both , the extent and the development of gullying . The meteorological factors affecting gullying in the study area are rainfall intensity and its duration , temperature , and solar radiation . Geomorphological and pedological factors include slope , relief , soil structure , parent material , soil moisture holding capacity , degree of soil cover , aspect of the site and pattern of seasonal changes .

Recent and continuous orogenic uplift is chief cause of gully erosion in parts of the areas. Gullying is independent of other factors in such areas. Thermal changes in the lower parts of the crust or compression due to foreland / hinterland in orogenic belt may be reason of such uplift (Ahmad, 1973).

Man , too , affects it greatly . Gullies are most frequently found on convex slopes , appearing first on the steepest lower edges . On concave slopes they are less frequent , and where they do occur , tendency is to appear on the upper reaches of the slopes . On straight slopes , gullying begins roughly in the mid region and spreads down towards the foot. (Sakatula , 1984) . Loams and sandy soils are most susceptible to gullying while skeletal soils suffer the least . Cultivation techniques and agricultural practices have bearing on the susceptibility of any soil to gullying . Mechanism of erosion and transportation of soil particles by flowing water is of crucial significance to understand the gullying.

Run off energies of concentrated flows act parallel to the land surface and are most efficient in transporting detached material down slope . Besides this , such concentrated flows in gullies also brings about detachment of soil particles by rolling , lifting , and abrading . Kinetic energy off flow act horizontally on particles in the direction of flow . The forces may be enough to dislodge particles from the soil mass by rolling them out of position . A rough soil surface contains many small depressions between clods and crumbs where water has little or no horizontal movement while that just above may be flowing rapidly . The different velocities set up pressure differences which produce vertical current and eddies , and upward movement of water past soil particles lifts them off their anchorage and sets them in motion . Soil detachment by abrading occurs when moving particles strike over others in soil surface and set them in motion . Transportation of detached material takes place through surface creep , when particles roll or slide along the surface of stream bed , through saltation , when uneven forces of turbulence make them movealong by steps or jumps , and through suspension , when upward velocities of turbulence exceeds the settling velocity of the detached material . Size , density , and shape of particles , on the other hand , affect their settling velocities . Larger the surface area per unit mass of particles , larger the resistance offered and lower is the settling velocities . Higher the density of particles , higher is the settling velocity . The closest the particle shape to sphere , lower is the settling velocity and higher the transportability . All these factors of detachment and transportation of soil particles come in full play wherever concentrated run off from a slope is sufficient in volume and velocity to cut trenches and to keep continue cutting in the same groove long enough to form destructive soil incisions . Gullies often have their beginnings in slight depressions in field or below it . Ordinarily , they carry water only during or immediately after rains and cannot be obliterated by normal tillage . In woodlands , gully is usually defined as a newly erode channel deep enough to expose the main lateral roots of large trees . There are several distinctly identifiable stages in the development of gullies which are discussed next .

A gully passes through four distinct stages in its development (Datta , 1985) . The first is the formation stage which marks the initiation and is characterised by down ward scour of the top soil and this stage proceeds slowly where top soil is fairly resistant to erosion . The second is the development stage and is marked by upward movement of gully head accompanied with widening and deepening of the channel , development of water fall erosion at the gully head and exposure of `C' horizon . This phase involves the most rapid development of gully and some gullies are known to have extended upslope more than 30 mt during a single rain (Bennett , 1955) . The entrenching channel immediately develops three elements of landscape - the channel bottom , the valley slope , and the upland . The valley slope is most susceptible to erosion during the development stage of the gully (Smith , 1969) . The third is the healing stage when vegetation begins to grow . The fourth stage is the stage of stabilisation . During this stage vegetation cover spreads over the gully surface and gradient of the main channel and side slopes become more stable . During the last two stages the rate of run off into the gully head decreases due to reduction in drainage area as gully head moves progressively up . Remaining portions of run off enters the gully at different points along its length and stage is set for branching and rejuvenation of gully in the side branches . Shape of the gullies , too , are characteristic for each stage of development.

Gullies formed by channel erosion usually have sloping heads and sides and are often called ` V ' gullies ( Tejwani et al, 1961 ). As the scouring continues , the gully becomes larger , deeper and wider . The lengthening of gully is usually much faster than it widening . The rate of deepening of gully in the steeper upper parts of the area is very rapid . ` U ´ - shaped gullies with straight , more or less vertical sides , and broad bottoms are generally less winding than the ` V ´ - shaped ones because of the soft material at the base of the sides tend to give way to the impact of current rather than to resist deflect the flow back and forth across the channel . Undercutting type , broad bottomed

` U ´ - shaped gullies are most difficult to control because of the instability of under strata as stated. In regions of high rain fall erosivity and high soil erodibility , the process of gullying , unless interrupted in its early stages , self propagates and may lead to wide spread removal of soil (Edward , 1990).

In the study area gullies in the traditional meaning of the term do not exist because of steep terrain , high permeability of soil mantle , and tendency of any water fall action , except when it occurs on rock outcrops , to degenerate soon into a land slide . Most of gullying action in the study area is restricted to the first and second stage of gully development . Unlike ravines , where gully head having a water fall travels up during the second stage of the formation of gully , what moves up in these parts is not a distinct gully head but a slump of bank from all three sides of flow and further the upslope movement of this slumps is preceded with cracks on the up slope side . The flow of water soon becomes sub- terrainean and takes the form of a debris flow , and unless checked right at the initial stage , deeper and deeper layers of soils gét lubricated pushing plane of failure progressively downwards . This leads to development of landslides where , unlike usual gullies , deep seated shear planes are the cause of the entire phenomena visible on surface . Cattle tracks often degenerate into gully (Plate 4).

4.5 STREAM BANK EROSION :

Besides gullying , another important soil degradation process is stream bank erosion. The stream bank erosion is yet another form of fluvial erosion . The scouring , gouging and under cutting of banks and mud flows are major processes of bank deterioration . The stream bank erosion differs from the gully erosion in that the former applies to the lower end tributaries and to the streams that have continuous flow and relatively flat gradient (Michael et al , 1981) . As the velocity and volume of discharge increases , flow of stream becomes turbulent and vertical eddies develop . These eddies scour deep holes in the river bed (Ray, 1954). The swirling water cuts on the outer side and deposits its sediment load on the inner side where velocity is lower . This generates a debris bar on the inner side of the bending stream which pushes the stream further outwards initiating fresh under cutting and tumbling down of vertical slices from the bank . The debris is quickly removed by the by the stream and the stage is further set for fresh under cutting (Plate 5). The process continues so long the velocity of the flowing water continues to be erosive . It often so happens that area lost on one bank is recovered on the other . The quality

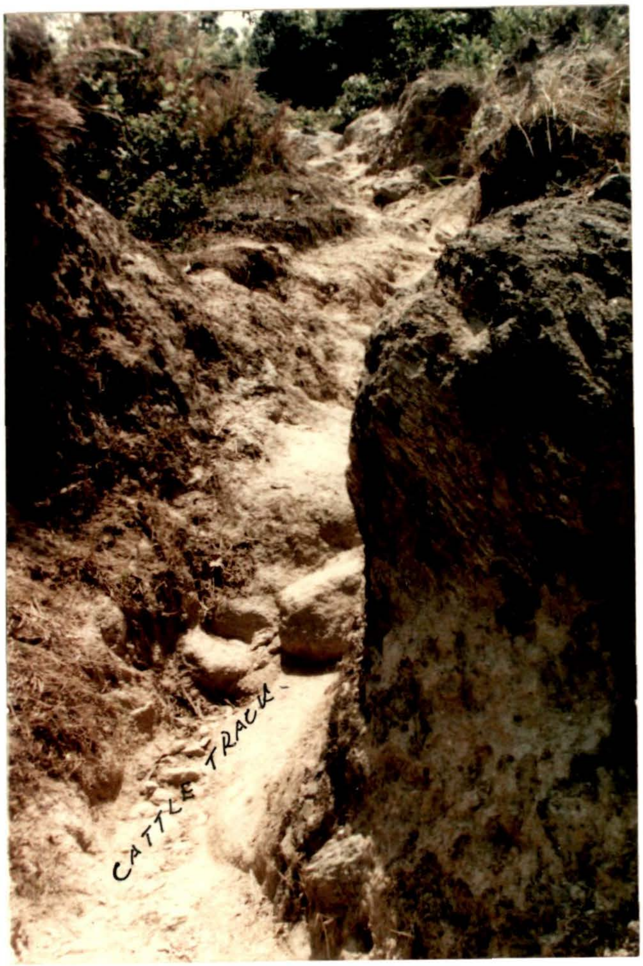

PLATE 4: CATTLE TRACK DEGENERATING INTO A GULLY (SEPOYDHURA)

PLATE 5: SEVERE STREAM BANK EROSION (BALASON RIVER)

and the fertility of the recovered land is , however , often not of the same order as that of the lost soil . Stream bank erosion is affected by soil character , cover , size and character of floods , velocity of current , land use , stability of stream beds during floods and climatic conditions .

Stream bank erosion is very severe in higher order sections of river in the study area. Such erosions are seen opposite the confluence point of Rinchintong and Balson. Banks of Balason are severely eroded. Bank slumping is seen in the lower 200 mt reach of Rongmuk. Banks of Ghatta - Hussain khola near Single tea estate also show severe bank erosion.

4.6 POT HOLE AND TUNNEL EROSION :

Pot hole erosion occurs when an easily erodible part in stream bed is more eroded than its surroundings and , hence , pot holes develop . This is usually encountered in areas where gully passes through a stretch having great difference in levels (Datta , 1986) . Internal erosion and tunnel erosion are the two sub - surface forms of soil degradation . In the former , gravitational water washes away the finer particles and humus of the soil reducing the quality of the soil in the same way as surface erosion , although the consequences of internal erosion are usually worse . The former leaves a gravelly or stony surface which inhibits further erosion , the latter intensifies it as it progresses . The internal erosion is closely related with tunnel erosion. Genetically, tunnel erosion forms the same class as the internal erosion . In it a system of horizontal and vertical tunnels are created (Zachar , 1984) . These forms develop as a result of flow of ground water over impermeable strata . The size of tunnel may increase until its roof caves in , thus causing a sub - surface phenomena to appear as surface form . In other cases , washing out and corrosion of upper subsiding layer can lead to a land slide . Like other erosion forms , this , too , is affected by several factors .

The factors influencing pot hole and tunnel erosion include geomorphology , petrology , and pedology of the area as well as weather , vegetation and its type and predominant economic use of the area by man .

4.7 SLOUGHING EROSION :

Another form of important erosional process is sloughing erosion. In sloughing , a natural slope , a man made cut or embankment , under certain hydraulic conditions experiences a severe reduction of strength and the soil flows like a thick fluid . It is a retrogressive landslide , in which the failure surface develops through tension cracks and soil liquifies under undrained conditions (Figure 4.1 and 4.2) . Poorly graded fine sand or silt is the seat of such a failure and takes place on account of hydro-dynamic forces , erosive action of water , and non - homogeneity of deposits (Patel , 1980) . Soils in

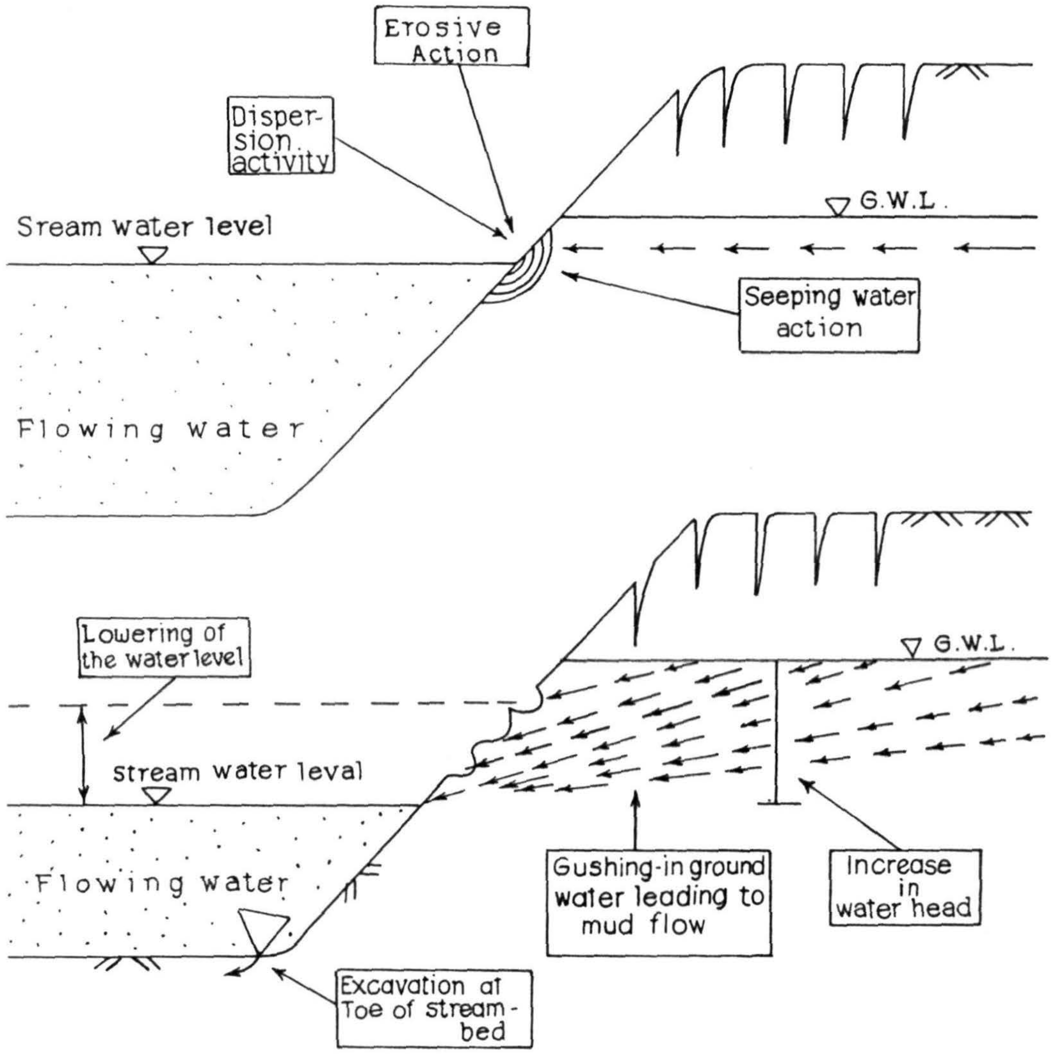

Fig. 4·1. Diagramme illustrating the mechanism of sloughing when groundwater level is higher than the stream water level. Sudden creation of difference in water heads in channel and the banks led to gushing in of groundwater. Along with this flowing in groundwater non-cohesive fine grained soils started flowing leading to mudflow and large scale sloughing of the banks.

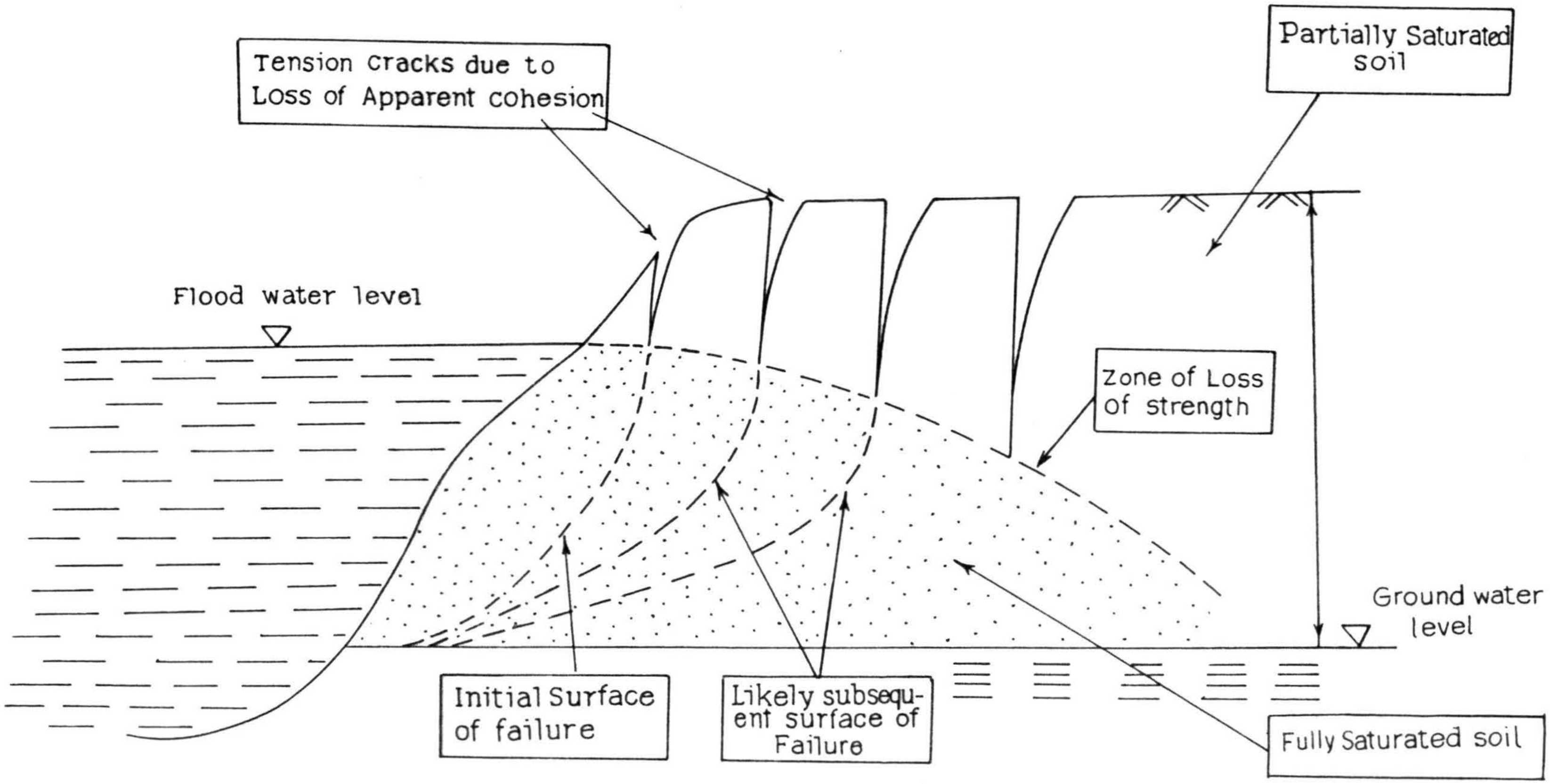

Fig. 4·2 Diagramme Illustrating Retrogressive Mature of Failure through Sloughing .

such location is also found to be non - cohesive and non - plastic with higher water permeability (Lakhanpal et al , 1980) . As is revealed from Figure 4.1 , both , water flowing in the channel as well as that seeping out of banks , create dents and notches . Excavation of beds or under cutting accentuates sloughing , too , in addition to stream bank erosion .

The contribution of apparent cohesion is of considerable significance in fine grained soils which have low angle of shearing resistance . Saturation of partially saturated embankment soil due to infiltration of water at higher flood levels destroys the apparent cohesion . This happens more severely whenever streams swell exceedingly during pre - monsoon and early monsoon showers following dry weather . When the seepage line from the embankments meets the slope face , soil in the region of emergence gets softened and local failure takes place . This leads to formation of steeper surface and instability in the higher levels causing successive slides of retrogressive nature (Figure 4.2) . The soils which show sloughing under the influence of seeping water are mainly of rounded grains , of fine variety , of poor gradation , non - cohesive in nature having poor compaction characteristics and high natural void ratio . Fine sands and coarse silts are chief among such soils and they liquify without any sudden or violent shock . Several past examples of sloughing in Darjeeling hills are available, one of which is that which took place in Tista bazzar .

During a very severe storm in 1968 mighty river Tista draining a large Himalayan tract was partly blocked near Tista bazzar where an arch bridge over Tista was clogged by uprooted trees flowing down stream . The river swelled enormously before the bridge gave way . Sloughing and serious subsidence set in resulting in abandonment of entire bazzar.

In the study area, many of the bank failures are a result of combined actions of stream bank erosion and sloughing . Such failures often take place during the first flooding of the season , especially if it is sever in nature.

4.8 LANDSLIDES :

A landslide is a natural geological process resulting from interacting topographical , hydrological , geological , seismological and biotic factors involving a displacement or settlement of a mass of rock or residual soil along a slope , the centre of gravity of the moving mass advancing in downward and upward direction . From an engineering point of view , a landslide is primarily the result of shear failure of a mass of soil or rock (Som , 1980) . Geotechnical , geomorphological , hydrological and seismological concepts explaining the behaviour of natural slopes are severely limited and it is seen that , in light of these concepts , slopes appearing only marginally stable do not fail even after a severe earthquake while those appearing more stable crumble down . Sites having shallow soils with pronounced sub-surface flow system are highly susceptible to landslides (Malkania, 1989). These concepts , however , provide an insight into the behaviour of landslides .

Weak geological formations constitute one of the biggest factors responsible for failure of slopes . In general , the clays , clay shales , over consolidated clays and phyllitic formations are invariably associated with most of the areas showing instability of slopes. Seismological factors , too , contribute by setting in long term instability in intensely uplifting young mountain ranges like Himalayas . The hydrological factors are , however , most important causative factors in Himalayas , especially in north eastern part of it . Excessive wetting of soil weakens them and brings about increased pore pressure leading to instability . Paddy cultivation by impounding water often leads to landslides (Plate 6). About 100 mm to 200 mm precipitation in 24 hours is usually sufficient to cause failure in Darjeeling Himalayas (Starkel , 1972). Accumulated amount of rainfall from 350 to 400 mm during a spell of rain brings about disasters (Haruyama, 1980). Higher the accumulated amount of preceding rainfall, lower is the required threshold intensity of rainfall for a given degree of sliding (Fukuoka, 1980). Closer the water table to the surface , higher are the chances of slope failure (Aoyama et al , 1980) . Excessive moisture increases unit weight and decreases shear strength of soils . For some soils water entering into the voids dissolved the binding material causing instability . In fine grained cohesionless soils saturation eliminates surface tension holding soil particles together and ,

PLATE 6 : PADDY CULTIVATION BY IMPOUNDING WATER LEADING TO LANDSLIDE

thus , brings about instability . Mudstone, shales and sandstones are most susceptible to sliding (Aoyama et al, 1980). Excessive moisture ruptures silica - cementing agent skeleton and slope fail (Natrajan et al, 1980). Besides this, indiscriminate use of explosives also brings about instability (Dogra, 1993). Incessant mud flows and rock falls are also triggered by earthquakes (Times of India, 1992).

Notorious Ambootia landslide lies at the southern tip of the study area. Towards the top and the middle of the landslide, an organic clay horizon in the sedimentary cover, is observed. It is located 8 to 10 mt below the valley floor. This impervious horizon of black clay is 20 cm thick. Water percolates down up to this layer at the top and the middle part of the slide area. At the lower level percolating water reaches major weak planes of weathered gneiss up to the level of 60 mt below the top of the scarp. Here water forms minor to fairly large drainage lines which later give rise to larger drainage system. The failure of slip surface seems to be as deep as the percolating water is reported to reach (Bandopadhyay, 1978).

CONCLUSION :

Thus it is seen that splash erosion is capable of causing large scale deterioration of soils in the study area on account of high rainfall and occurrence of storms of high intensity . Thin cover makes soils very much prone to this soil degradation process . Sheet erosion is also quite damaging in areas having poor structure , low organic carbon content and poor vegetal cover . Rill erosion is often seen in areas where proper protection against the splash and sheet erosion is not taken . These forms of erosions are also apparent in tea gardens wherever tea bush canopy does not provide optimum coverage . Gully erosion in traditional meaning of term is not seen in the study area . A gully invariably leads to slope failure on both of its sides and often degenerates into a landslide , if it is located well down the rim of the basin , or into a debris slide if located on the upper reaches . Stream bank erosion is seen along the rivers of higher orders and assumes serious dimensions when excessive flooding of river banks takes place immediately following summer season . Pot hole erosion is of lesser consequence as the steeper gradient of river beds soon degrades and the bed becomes bouldery . No pot hole can sustain itself on account of fragile coarse textured soils in the study area . Tunnel erosion is quite important and most of the active landslides , where water moves more underground than on the surface , are affected by this leading to subsidence of soil surface . Sloughing erosion becomes important whenever water impounding in river beds takes place on account of damming of channel by excessive bed load or on account of debris flow from landslides . Landslides are a major cause of concern , but they are one of the least understood soil degradational processes , specially huge ones having deep seated failure plains . Surficial landslides are simple slope failures not more than a few meters in thickness .

The discussion on soil erosion mechanisms and processes shows how various soil degradation processes work . There actual impact in the study area could be assessed by taking a look at problems related to soil erosion and their effects . These can be discussed in the next chapter .