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ENVIRONMENTAL EFFECTS OF WATERSHED MODIFICATIONS

by

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I. Introduction

Whenever I am with a group of social and natural scientists, I usually find myself unable to communicate or interact effectively on the more pressing issues on resources allocation and management. This is partly due to the lack of common vocabulary and differences in training and experience. So I will start my paper by defining terms, hopefully, to express my basic concepts and assumptions.

A watershed or a river basin is defined by a reference line drawn across a river or stream. All areas whose surface runoff waters pass through this line constitute the watershed. Thus a watershed's boundaries are defined by fixed topographic properties of the areas upstream from the reference line. Hence, a basin may be subdivided into smaller basins or sub-basins and vice versa.

From the standpoint of resources conservation and management, a watershed or catchment area is best viewed as a land-based ecosystem with physically defined dimensions within which its land, animal, water, plant, atmospheric and other components are in a state of continuous interaction. A watershed or its components are continuously subject to natural and man-made modifications.

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Man-made modifications are for a variety of purposes Some are designed to bring about favorable environmental impacts such as erosion, flood and water quality control Others are for different reasons such as to satisfy basic human needs for food, fuelwood and shelter All modifications are, however, bound to have environmental side effects

The more significant environmental impacts of watershed modifications are hydrologic in nature- meaning, changes in some of the interactive processes in the hydrologic or water cycle Such changes trigger a chain of reactions in watersheds' ecosystems as water is an important determinant of natural resources potentials and is the major substance of all life processes.

Figure 1 presents a schematic diagram of the hydrologic cycle on a typical Philippine river basin The water cycle or the transfer of water from one form into another goes on continuously through the various processes as indicated by the arrows on Figure 2 The total runoff from rainfall (streamflow) may come from three different sources, namely, direct runoff or overland flow, interflow (from soil strata above the water table) and groundwater flow The time distribution and quality of runoff waters vary with the source or the pathway which the rain water follows in arriving at the waterway Groundwater flow or base flow is usually better in quality and takes longer time in reaching the river network since it passes through and gets filtered by the unsaturated and saturated soil strata The dry season or dependable flows from a basin come from groundwater storage

Overland flow is usually concentrated or high intensity flow of poorer quality and gets into the waterway sooner than baseflow and interflow This runoff component serves as the primary process for soil

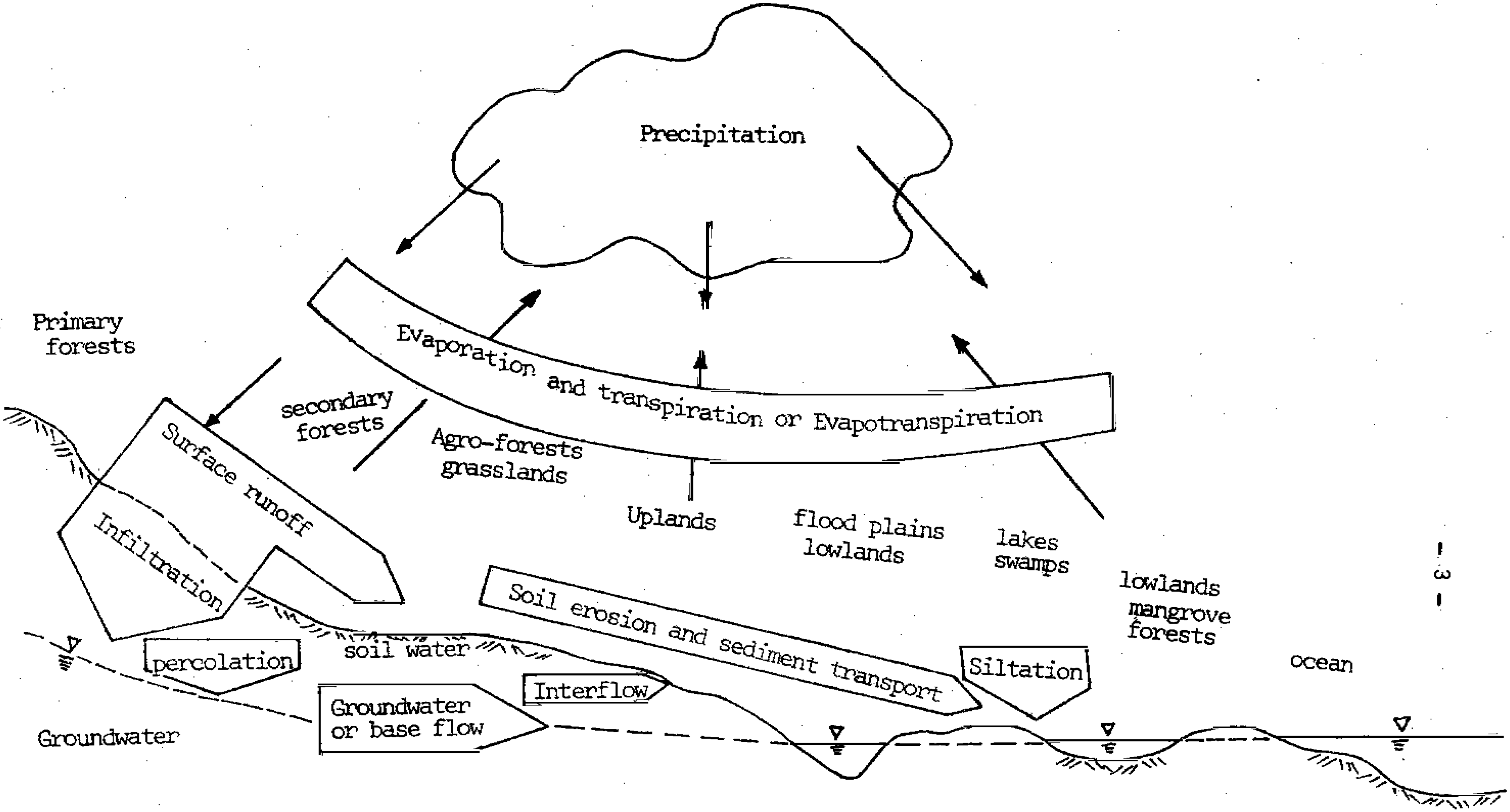

Figure 1. The water cycle on a typical river basin or watershed.

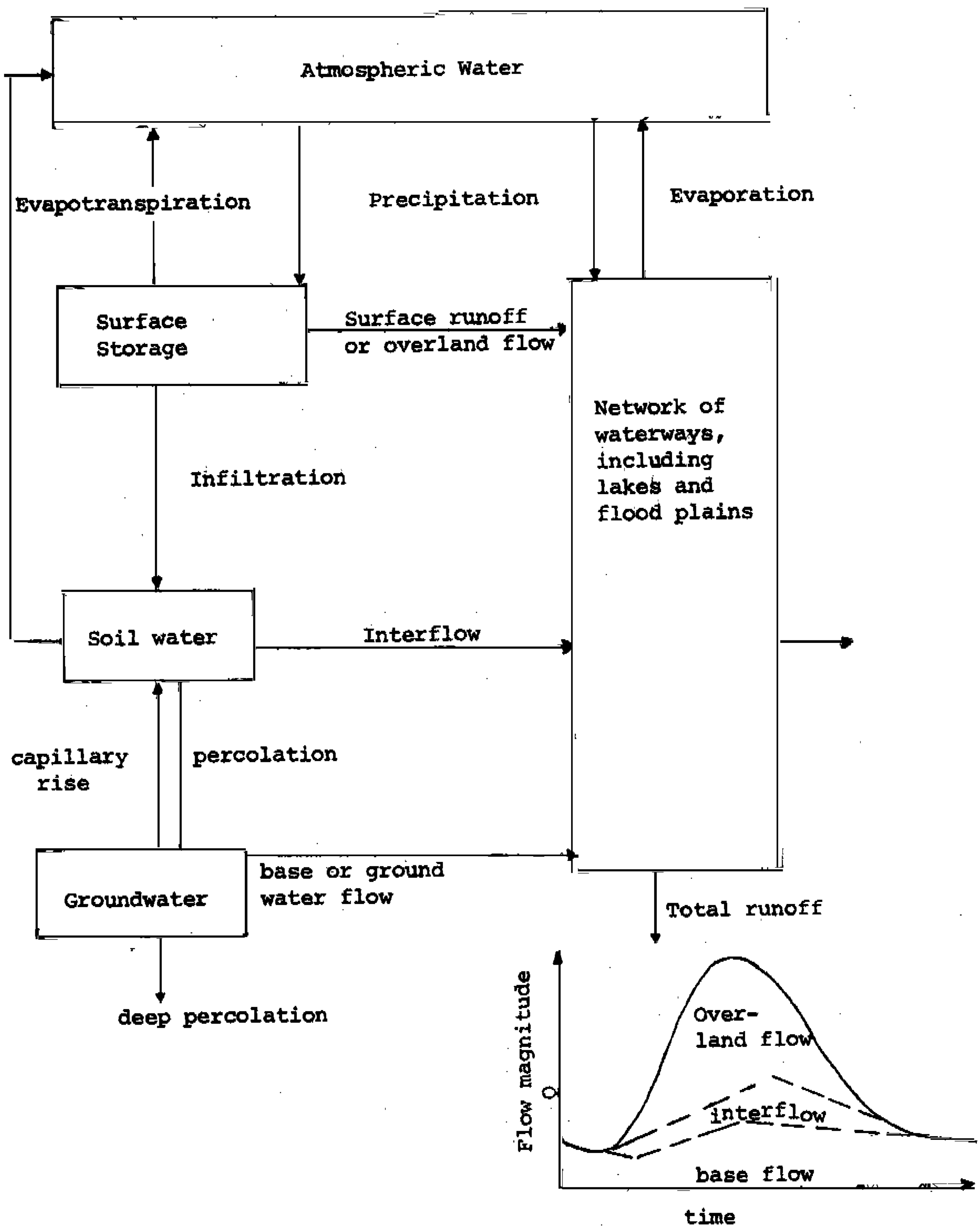

Figure 2. The water cycle in a river basin or catchment area.

detachment and transport downslope. It is associated with floods and carries the bulk of point and non-point pollutants into waterways and water bodies.

The relative contributions of overland flow, interflow and base flow to the total runoff varies with the watershed soil-cover complexes and other surface properties; the soil physical properties such as intake or infiltration characteristics, the ease with which the soil strata will allow the movement of water (conductivity) and the moisture holding capacity of the uppermost soil layer; the drainage network density; human activities designed to regulate runoff (e.g., reservoirs, terraces, contour farming) and the available energy and mechanism for dissipating water back into the atmosphere.

On the average, approximately 60 per cent of the rainfall over a watershed is lost through evaporation and transpiration, leaving the remaining 40 per cent to run off its river network. The combined process of evaporation and transpiration (evapotranspiration) plays a key role in the energy balance of a watershed. It is the primary mechanism for redistributing the radiant energy incident on the watershed and, hence, has an interactive effect on air temperature and relative humidity.

The human influences on the hydrologic cycle are the issues central to watershed management. Population pressures and political inertia force us to manipulate our watersheds without the overriding concerns on the environmental consequences of such manipulations outside the basin and the degree of manipulation our basins can be subjected to without irreversibly destroying their natural capacities for re-stabilization. The key to watershed management is relief from population pressures for the exploitation of more lands just enough to implement policies whereby the pressures of economic forces and public opinion reward the good and penalize the bad resource users. Such policies must, however, be premised on a full appreciation on the interdependence and the extent of interactions of the various components of watersheds' ecosystems. The same is true where relief from population pressures is to be achieved through improved technology which reduces the need for lands for producing basic human needs.

II. The Water Cycle and the Environment

Man's destiny is tied up to water. Water is the major substance of all living organisms. It is so widespread, a good coolant and comes close to being a universal solvent. It is capable of storage, diversion and transport. Moving water can possess enough energy to drive water turbines, detach and transport soil particles as well as dissolve and transport non-point pollutants. Thus the movement of water through the hydrologic cycle influences the physical, chemical and biological parameters or factors of our environment.

The effects of the water cycle on the physical properties of our environment stem largely on the key roles that water plays in a landscape's energy balance, in weathering rocks and determining the eventual nature of the soil that is formed, in soil erosion and sediment transportation and in the formation of landscapes. Differences in these physical properties or processes are due largely to the non-uniformities in the spatial and temporal distributions of water in its various forms. Too much concentration of rainfall and runoff, for example, results in floods which favor higher soil erosion rates, more gullies and waterways, and water loving vegetation. Too little rain water at certain periods, on the other hand, may adversely affect canopy type and density, air temperature and the rate of topsoil formation.

The human influences on the space and time distribution of water and on these physical properties are many and varied. The most important ones are: land use transformation or vegetative cover modifications, land treatments such as terraces, contour ridges, mulches, furrows and tillage, installation of drainage and irrigation systems, and surface water storage modifications.

Moving water carries solids, bases and other liquids in solution. Essential life process elements such as nitrogen, carbon and sulfur are volatile and soluble and, hence, can move throughout the water cycle. Runoff waters may carry essential plant nutrients, mineral salts and toxic elements in solution. Rain water may also pick up certain gases and solids in solution. Toxic elements coming from farm and industrial wastes and high mineral content may affect the suitability of water for agriculture, industries, domestic and wildlife conservation.

In forest and agricultural watersheds, the more significant modifications influencing chemical properties are land use transformations favoring intensified farming systems which increase farm chemicals usage, feedlot runoff, agricultural wastes, installation of irrigation and drainage systems that may lead to salt built-up, acid sulfate soil conditions, mining operations which increase the hazards from toxic chemicals like boron getting into waterways and construction of water impounding structures that interfere with the usual supply of plant nutrients and the leaching out or dilution of the concentration of the mineral contents of downstream waters.

Regardless of its form, water supports a multitude of living organisms. At any given time, this biological community is in a delicate state of ecological equilibrium. Even with small variations, the quality and quantity of flowing water can upset this delicate balance or equilibrium.

On the surface of the soil thrive not only the vegetative cover and wildlife but also a wide variety of microorganisms. These organisms break down organic materials to produce humus which is ultimately reduced into a mineral form. The action of these microorganisms not only influences soil fertility status but also affects the various processes in the hydrologic cycle. Humus not only has a high water retention capability but has a high infiltration rate. Higher infiltration rate implies less overland flow, more groundwater recharge and, hence, lower flood peaks and soil erosion and higher base or dependable flows.

Fresh water, whether in storage or in transport, is the habitat for complex plant and animal forms. From the headwaters of a watershed to shallow farm ponds, main waterways, lakes, marshes and estuaries, a particular population of complex organisms abounds. A given population exists in a state of precarious balance that depends primarily on competition for food and the quality of water and forms a part of the food chain of the aquatic ecosystem. Any disturbance on the water cycle may result in the destruction or rapid growth of another type of organism that may be pathogenic. Such a disturbance could occur from one or a combination of the following: increased in point and non-point pollutants moving within the hydrologic cycle; change in land use; change in the time and space distribution of rainfall and runoff; commercial exploitation of some forms of aquatic organisms, surface storage modifications such as reservoirs, flood control and irrigation infrastructures and fishponds and land treatment such as terracing, tillage and soil chemical amelioration

The above considerations on the relationships between the water cycle and the human environment focus only on the more important effects resulting from modifications of watersheds and their water cycles It is not possible to list down much less discuss all the foreseeable environmental impacts Moreover, time and space constraints will not allow me to deal with the above mentioned relationships between the water cycle and the human environment Hence, the following discussions will be **focused further** on the impacts of the more important forest watershed modifications on the water cycle and the physical environment

III Influence of Land Use on Watershed Behaviour

A <u>Forest Lands</u>

1 Influence of forests on precipitation

There is a widespread belief that forests increase precipitation There are, however, no theoretical basis nor experimental evidences to this hypothesis It is now generally agreed that forest, in comparison to other covers, does not affect significantly the rainfall over a catchment

The primary effects of forests are on the interception and distribution of rainfall into the soil system In areas with light and frequent rainfall, a forest cover dissipates a considerable amount of rainfall through the evaporation of intercepted rain water and delays the arrival of rain water into the soil surface

Evaporation from a wet forest canopy proceeds at the potential or maximum rate thus decreasing the amount or volume of rainfall for soil moisture storage and runoff. The retarding effect of a forest cover on rainfall provides more time for infiltration and increases the time for runoff thus decreasing flood flows and increasing interflows and base flows.

2. Influence of forests on infiltration

With the exception of few isolated man-made modifications such as deep tillage with contour ridges formation and mulching, the infiltration rate of the soil under a forest cover is greater than any other type of land use. High infiltration rates implies a reduction in surface runoff and soil erosion as well as increased groundwater recharge. In areas with distinct wet and dry seasons, however, groundwater withdrawal of deep rooted forest plants for evapotranspiration may negate the favorable effects on the base flow of the increase in groundwater recharge.

3. Influence of forests on runoff

The most favorable and dramatic impacts of forest cover are on the time distribution of runoff or runoff hydrograph, quality of runoff water and the protection of soil on erosion. A runoff hydrograph properties of interest are usually the peak or flood flows, the base or low flows, and the total runoff volume or water yield.

There are numerous experimental evidences documenting the effects of forest cover on streamflows. Table 1 summarizes the proportions of rainfalls with 10-year return periods that directly

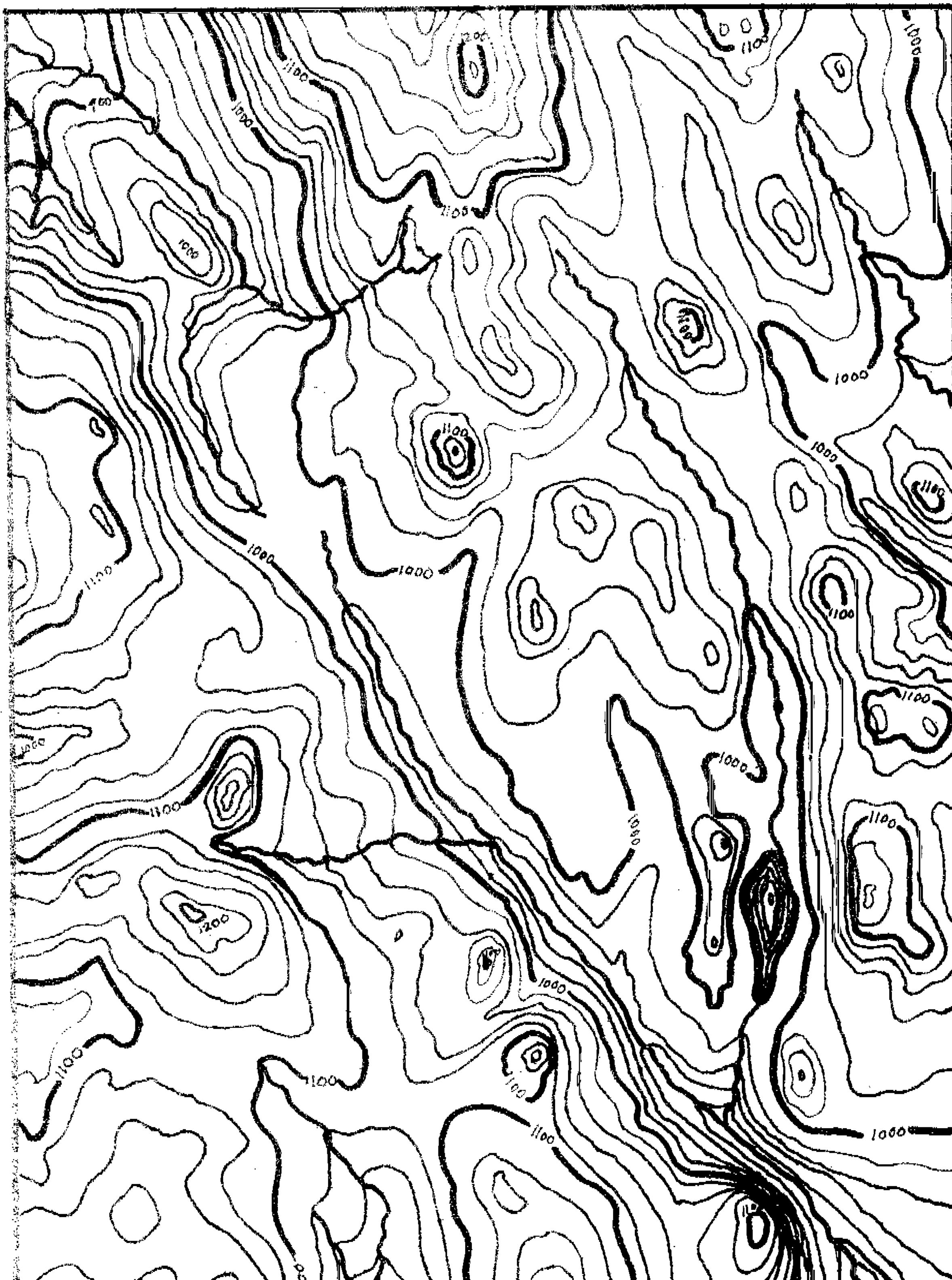

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Table 1. Direct runoff coefficients of small watershed.[1/]

Watershed cover or land use	Percentage of 10-year rainfall that goes into direct runoff or overland flow[2/]			
	1.0	3.0	6.0	10.0
1. Hardwood forest	0.02	0.12	0.16	0.22
2. Permanent pasture (well managed)	0.02	0.16	0.25	0.33
3. Wheat crop-with improved soil and water management practices	0.20	0.23	0.24	0.25
4. Second year meadow	0.33	0.38	0.43	0.45
5. Corn- with improved practices	0.52	0.59	0.64	0.68
6. Corn- prevailing practices	0.68	0.71	0.72	0.73

1/ Adopted from Schwab, et al. 1966. Soil and Water Conservation Engineering. John Wiley and Sons, Inc. New York.

2/ For small watersheds with moderately high runoff potentials and shallow, clay-textured soils.

runs over the soil surface in small watersheds of varying vegetative cover. An increase in flood flows of several order of magnitude may result by converting forest into meadows or crop lands.

The most extensive studies (Rakhmanov, 1962 and Bockhov, 1959) on the effects of forest cover on streamflows has been conducted in the U.S.S.R. where long term observations on more than 2000 highly-instrumented plots and more than 100 watersheds of varying sizes are fully documented. Their findings clearly demonstrated that forest cover yields more than agricultural lands as the combined effects of storage and infiltration exceeded those of increased evapotranspiration by forest. The flood flows when expressed in terms of the flood magnitudes to the average annual flows or coefficient of flood flow showed the following inverse relationship between floods and forest cover.

$$\text{Coefficient of flood flow} = A - 0.009F$$

where A is the flood flow coefficient for open areas and F is the proportion of the basin covered by forest.

There are also indications in the literature to the effect that the removal of some of the protection offered by forest tend to increase flood flows. Major forest fires in small and medium size watersheds in Australia showed a six-fold increase in the projected flood flows (based on the long-term streamflow records of the basin prior to the burning of the forest cover) resulting from high intensity storms, (UNESCO, 1972).

Clear cutting of forests have also been shown to reduce base or low flows, increase the water table in areas with permeable soils and increase stream temperatures (McGuiness and Harold, 1971; Brown and Krygier, 1970 and Bettenay, Blackmore and Hingstone, 1974).

In the Philippines, there is a dearth of information on the effects of forest cover on streamflow. Preliminary studies by the author on several river basins in the island of Mindoro gave some qualitative indications on the impacts of land use on the low flows of small and medium sized catchments. Table 2 shows that the levels of dependable flow per unit catchment area are lower in watersheds with less forest cover and high percentage of badly disturbed (Savannah) lands. The same trends were observed by the author in his

Table 2. Specific flows and land uses in three Mindoro watersheds.

	WATERSHEDS		
	Bucayao	Bugsuanga	Caguray
Catchment area, km^2	384	438	146
Specific dependable flows in $m^3/sec/km^2$, catchment			
80% dependability level	0.052	0.0064	0.0050
90% dependability level	0.037	0.0041	0.0036
Major land use Categories in %			
Forest	45	16	16
Cultivated area	33	18	10
Grasslands (good stand)	4	45	19
Savannah (cogon and talahib grasses with shrubs and brusher)	18	18	54

analyses of the dependable flows of many catchments in Southeast Asia in connection with his participation on the feasibility analyses of irrigation projects.

The long term wet and dry season flows of a small tributary of the Pampanga river give us some cause for alarm as far as human influences on small watersheds are concerned. The basin is small enough (150 square kilometer) that the effects of land use transformations are readily manifested. The conversion of forests and lowland rice paddies into urban and cultivated areas resulted in increased flood flows and decreased low flows as shown on Figures 3 and 4, respectively. At some point in time, the river ceases to be perennial and became ephemeral. Analysis of rainfall at the nearest rain gaging station showed no significant changes in the rainfall patterns. There were also no significant changes in the total water yield to indicate unmonitored diversions in and out of the basin.

An analysis of the streamflows of a few large river basins having long series of records did not reveal any significant changes in their flow patterns. It may be that the impacts of modifications on larger watersheds are manifested more slowly.

4. Influence of forests on soil erosion and sediment transport

Soil erosion has been identified by the National Environmental Protection Council (NEPC) as our most serious environmental problem today. More than half of the Philippine land area has been either badly eroded or is prone to severe soil erosion as a result of unplanned massive land use transformations, high rainfall intensity, unfavorable topography and shallow top soil. One does not have to look far to see widening circles of badly denuded lands and, with justification, most of us associate these with the destruction of our forests.

Soil erosion is a chain of the interrelated process of soil detachment by rainfall and runoff and downslope transport by these same processes. Soil detachment and transport by rainfall are

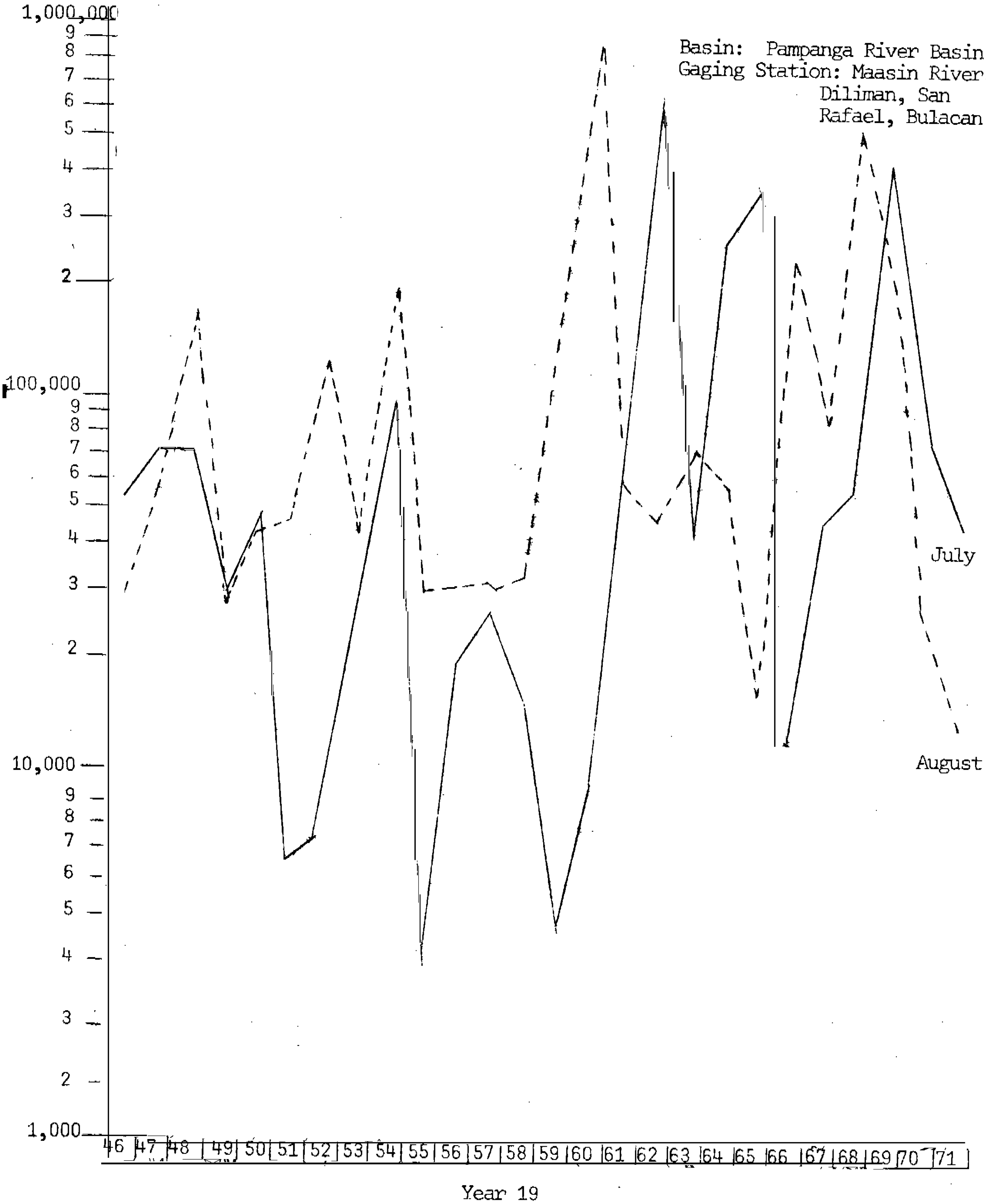

Figure 3. Maximum discharge for July and August for Maasin River

BASIN: PAMPANGA RIVER BASIN

Gaging Station: Maasin River, Diliman, San Rafael, Bulacan

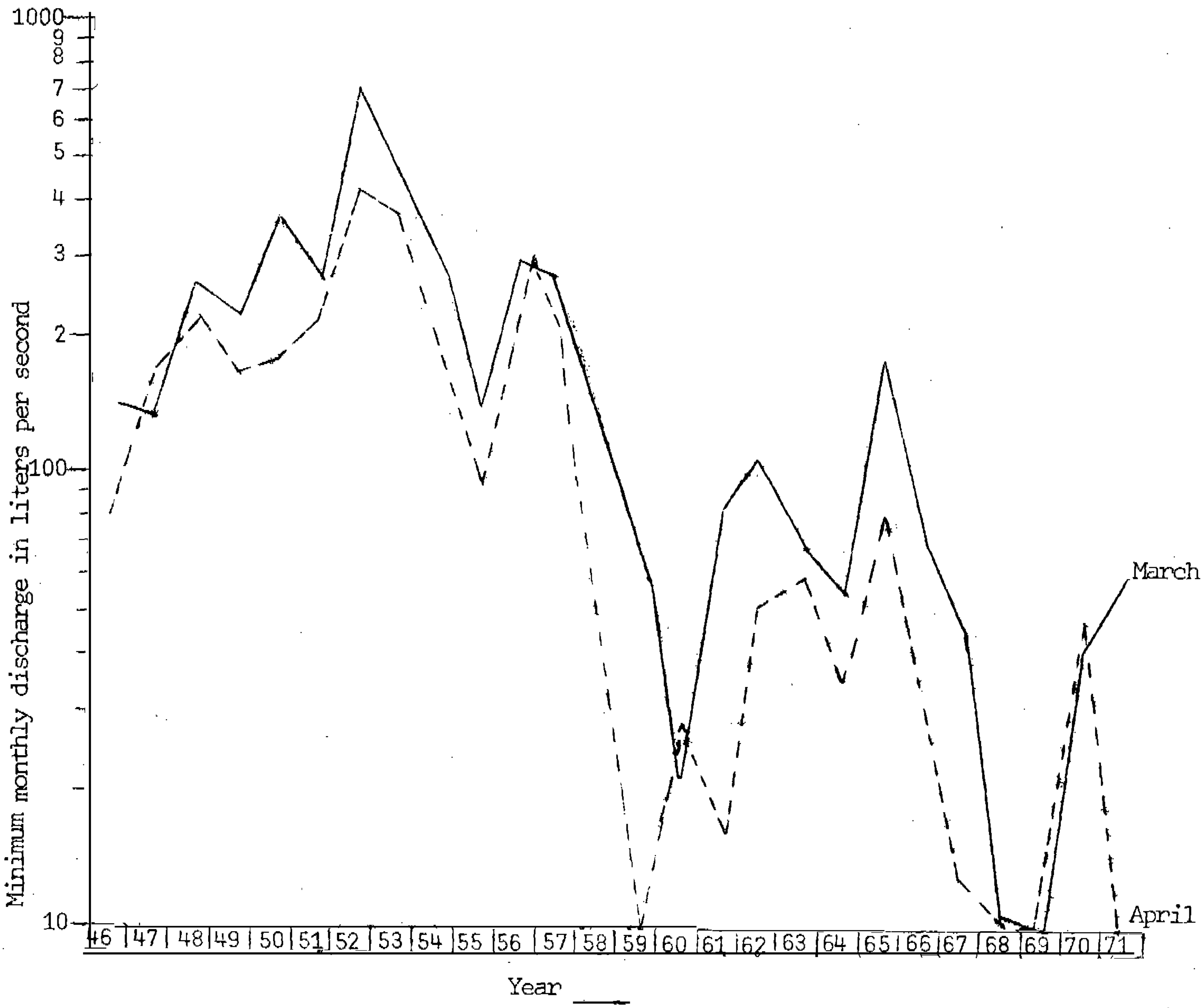

Figure 4. Minimum monthly discharge for March and April from Maasin river.

largely influenced by the erosivity or the energy of falling raindrops, the erodibility of the soil, slope and the soil cover. The detachment and transport capabilities of runoff, on the other hand, depend primary on the depth of overland flow, the flow rate and velocity, the hydraulic gradient of both overland and channelized flow, soil factors and the presence of soil stabilizing agents such as plants' root systems.

Soil erosion is of many forms. The uniform removal of a thin layer of soil over the watershed surface is known as sheet erosion. It is due mostly to raindrops splash and overland flow detachment and transport. The movement of soil particles may only be for a short distance before they are deposited downslope or all the way into the waterways and the mouth of the watershed.

The irregularities on the surface of a watershed result in the non-uniform concentration of overland flows. The overland flow may be concentrated on small depressions or rills. The resulting overland flow scour is termed as rill erosion. As rill erosion progresses unabated, deeper incisions or gullies may be formed. Gullies are usually formed on headwaters of established waterways.

The scouring and sediment transporting capabilities of flowing water in channels or water ways depend on the flow depth, velocity and magnitude. Empirical evidences showed that the suspended sediment carrying capacity of a river is directly proportional to its discharge raised to a power anywhere from 1.4 to 2.0. A two-fold increase in river discharge will, for example, increase the sediment carrying capability of a river from 2.6 to 4.0 times. This explains the fact that for most rivers in the Philippines (characterized by large variations in their discharges), more than 90 per cent of their sediments transported are attributed to the extreme 5 per cent of the flows.

The major effects of forests on soil erosion are in the cushioning of raindrop impact, reductions in the magnitude of overland and river flood flows as a result of the high water retention and infiltration capacities of forest soils and the stabilizing effects of tree-roots on waterways. Although there are other means of achieving these effects (mechanical methods of erosion control), forests have the added advantages of producing timber and forests by-products and preserving important fauna and flora.

Although numerous studies have been conducted on the rates of soil erosion under various covers in the Philippines, the results from such studies are of very limited use or value to watershed resources planners and policy makers. For example, the results of the two most cited studies are shown on Table 3. The reported erosion rates in the first study are unrealistically low while those in the second study are quite high (especially those measured on undisturbed areas, coffee and banana areas which usually provide good canopies or cover).

The large discrepancies in the reported soil loss rates and the obvious lack of accuracy in most of the local studies may be traced to the following reasons.

1) Instrumentation errors. Very often, the measuring instruments used disturb the surrounding soil, are not properly calibrated or served an added function of controlling soil erosion. This is more so in case of plot experiments where physical boundaries are erected thus modifying the slope and slope length. The weirs, flumes

Table 3. Effects of forest covers on soil loss rates.

Cover	Erosion rate, tons/ha/yr
A. Kellman (1969)	
Primary forest	0.09
Softwood fallow	0.13
Imperata or cogon grassland	0.18
New rice kaingin	0.38
12-year old kaingin	27.60
B. Veracion and Lozez (1979) on kaingin crops	
Pineapple	308.0[1/]
Coffee	318.0
Tiger grass	396.0
Castor bean	360.0
Banana	414.0
Banana/coffee/pineapple intercrops	421.0
Undisturbed areas	251.0

[1/] Converted from cm/yr by assuming a soil bulk density of 1.0.

or flow dividers that are used to measure flows disturb the natural flow conditions to such an extent that runoff water is impounded thus modifying the slope and slope length and promoting the deposition of suspended sediments.

More than others, the above reason explains the apparent inaccuracies in the monitored erosion rates in the two long-term studies on soil erosion in the country. In one study, several erosion plots with various covers were established in various locations all over the country. For a given location and a given cover, the soil loss rates did not correlate well with rainfall and runoff (R^2<0.4). In the other study, it was reported that "slope and land use have no effects on soil erosion rates". This finding tends to or simply violate the fundamental laws of physics and hydraulics.

2) Lack of control on many important parameters affecting soil erosion. Usually, only one or two parameters (e.g., rainfall and cover) are monitored without due consideration or control on the other parameters (e.g., slope, slope length, evapotranspiration, infiltration and overland flow).

3) Lack of understanding on the part of the researchers of the mechanics of soil erosion, the hydrologic forces at work and open channel hydraulics. Depending on the point of measurement within the watershed, the measured soil loss may only be sheet erosion or only part of sheet erosion (after deposition within the waterway) plus gully and river bank erosion.

An extensive review by the author on the reported erosion rates in both temperate and tropical countries showed that it is feasible to make some rough or first round approximations on the erosion rates under various cover, slope and rainfall conditions in Philippine watersheds. Using a modified universal soil loss equation of the form

$$A = R \times K \times SI \times C \times P$$

where

A = sheet and rill erosion rate in tons/ha/yr

R = index of rainfall energy which is derived from analyses of runs of daily rainfall intensity

K = index of soil erodibility which depends mainly on soil texture and degree of aggregation

SI = slope index = $aS^n + b$

a,b and n = constant

S = slope

C = index of soil cover and

P = conservation practice factor which was assumed to be equal to unity

estimates were made on the sheet and rill erosion rates over the 407,700 hectare Magat reservoir watershed.

In the above equation, the cover index C was assigned a range from zero to 100 to account for the full variations on the effects of cover on soil erosion. The estimated values of C are as shown on Table 4. Five rainfall stations with long series of daily rainfall records were used to delineate 5 subareas or rainfall polygons within the watershed. Six slope ranges and three soil erodibility categories were also mapped over the entire watershed.

Table 4. Relative influences of cover on sheet and rill erosion expressed as indices of cover (C) in the modified soil loss equation for the Magat reservoir watershed.

Cover	C value
Primary forest (with small patches of clearings)	0.10
Secondary forest (with small patches of shrubs, clearings and plantation crops)	0.70
Grassland, good cover, unburned, ungrazed annual upland crops with terrace	0.80
Established coconut, cacao, coffee and fruit tree orchards	1.0
Rangeland with good management, improved pastures, orchards with 3 to 5 year old trees, established ipil-ipil stand	1.5
Annual crops like corn, pineapple, field legumes in good rotation or intercropping, 1-3 year old ipil-ipil stands or banana plantation	4.0
Monoculture of corn, field crops, pineapple new kaingins, slightly overgrazed range land	8.0
Overgrazed areas, old kaingins, areas partly disturbed by earth moving operations (e.g., road construction)	25.0

The thiessen polygon, slope, land use and soil erodibility index maps were superimposed to generate a map showing annual sheet and rill erosion rates. The various subareas on the erosion maps were planimetered and the weighted erosion rates for the various categories were calculated Table 5 presents the estimated mean erosion rates for the various land use categories The disturbed areas (primary forests excluded) have a weighted mean of about 39 tons/ha/year For the entire watershed, the mean sheet and rill erosion rate was estimated at 29 tons/ha/yr

To check on the accuracy of the erosion rates estimates and for the purpose of calibrating or refining the numerical values assigned to the various erosion indices in the equation or model, 36 suspended sediment load measurements in the Magat river were analyzed and a suspended sediment rating curve was derived From the daily streamflows, the annual sediment loads for a 10-year period were calculated The bed loads of the Magat river were assumed to be 25 per cent of the suspended load

The results showed a mean annual total suspended load of 23 5 tons/ha/yr which was less than the estimated sheet erosion rate of 29 0 tons/ha/yr Considering the fact that gully erosion has yet to be added to the sheet and rill erosion estimates, it seems that the erosion model overestimates by at least 25 per cent the actual soil erosion loss

A closer investigation of the river network showed that there is considerable sediment deposition within the waterways along the long stretches of the Magat river and its tributaries upstream from the suspended sediment gaging point In some areas, the river bed

Table 5. Estimated mean sheet and rill erosion rates by major land use categories in the Magat watershed.

Land Use	Soil loss rate tons/ha/yr
1. Primary forest (with small patches of clearings)	3.0
2. Secondary forest (with patches of shrubs and small clearings)	12.0
3. Open grasslands	84.0
Hillside farms or kaingins (100)	
Overgrazed areas (250)	
Pastures ungrazed and slightly grazed (48.0)	
Newly reforested areas (30)	
Alienable and disposable areas of mixed land uses (48)	
4. Cultivated areas near settlements and along flood plains	6.4
1) Lowland rice paddies (1.8)	
2) Diversified upland crops (48.0)	
Weighted average	29.0

was raised by as much as 4 meters from its original level. Fresh mounds of river washings and islands are also being continuously formed indicating that the rate of soil erosion far exceeds the carrying capacity of the Magat river in the meantime. A physical manifestation of this fact is the constant meandering of the Magat river. At one location, its waterway has meandered by as much as 5 kilometers.

The main conclusion that can be drawn from this study is that as far as the Magat watershed is concerned (where there are available data from experimental areas on the effect of cover on soil erosion), the erosion model seems to yield fairly good results. The good thing about the model is that it assesses the impacts of various land uses in relation to soil, climatic and other topographic properties. It offers watershed planners and land use policy makers a wide range of land use options in managing watershed resources subject to the constraints on soil erosion, climate, topography and other fixed watershed properties.

The relative rankings and magnitudes of the cover indices on soil erosion shown on Table 5 are probably accurate to within 70 to 80 per cent as far as the present conditions in the Magat watershed are concerned. Forest stands and conditions of open areas vary from one watershed to another. Much remains to be done by way of refining these estimates and considering variations in canopy stands or conditions if the method is to be adopted to other watersheds.

5. Influence of forests on air temperature

The presence or absence of forests, especially where the alternative land use is bare soil or buil-up area may affect air temperature because of the removal of the cooling effect of evapotranspiration. Close to 600 gm-calories of heat is dissipated in every cubic centimeter of water that is evaporated. Also, the amount of incoming radiation that is reflected back (albedo) into space vary with surface cover. The average albedo of a forest cover (20-25%) is slightly greater than that of annual crops (15-20%), meadows (15% and moist bare soil (10-20%).

B. Grasslands

From the viewpoint of soil and water conservation, the term "grasslands" is a very loose definition as it attempts to consider a complex group of soil cover with a broad range of management practices into a single uniform land use. Every hydrologist, however, knows only too well the wide range of variations in infiltration, runoff, evapotranspiration and erosion behavior which arise from management practices. In some cases, grasslands are the natural products of deforestation. Without exploitation for other uses such as food crop and livestock production, the cover is transitional in nature representing an initial state in forest regeneration. In some exceptional cases, grass is considered as a major crop and is cultivated, fertilized, irrigated, mowed and managed for optimum forage yield thereby rendering the term grasslands hydrologically deceptive. Managed grasslands can not be differentiated from crop lands.

In most Philippine watersheds, grasslands are seldom left unexploited or managed. As a large proportion of these areas are governmental lands, there is a natural tendency to exploit them without regards to the environmental consequences. There are notable exceptions to this trend, however. Certain ethnic groups in the Philippines have traditional concern for land and the environment and tend to practice integrated and time-tried conservation and management practices for open areas. Some users who have long-term leasehold contracts manage their holdings for economic and posterity reasons.

The hydrologic effects of grasslands practices depend largely on the climate and level of management. The effects of a well managed grassland providing all year round or permanent cover closely resemble those of a good forest. This type of grassland usually has high infiltration capacity and provides a very high degree of soil protection. The other types of grasslands that are not overgrazed, regularly burned and mismanaged have effects on the hydrologic cycle and the environment which are in between those of a forest and those of cultivated annual crops. The relative influences of these land use types have been discussed in the section dealing with the influence of forests on the environment.

Mismanaged or overexploited grasslands tend to produce ephemeral streams, high flood peaks and large amounts of soil erosion. Eventually some grass species (e.g., imperata, themeda) which can take advantage of unfavorable water regimes and soil fertility conditions become dominant. Left by themselves, these dominant grass species tend to gradually improve the soil infiltration characteristics and afford good soil protection.

An interesting study on the hydrologic responses of the two most dominant grass species in the Philippines has recently been conducted using field plots, clay pots and 24 large, drainage type lysimeters

(Bueno, 1980). These two grass species proved extremely resistant to submergence in water and drought. Continuous flooding for more than 40 days did not significantly reduce their biomass production. They also survived a sustained moisture stresses of more than 15 bars. Hence, they can provide permanent cover even in very harsh soil and climatic conditions as long as they are not regularly burned and over-grazed.

Both grass species can thrive on heavily compacted soils with very little aeration. In fact, they dominate other grass species by initially compacting the soil. This is more so in the case of cogon which develops a dense underground root system with rhizomes. The natural release of nutrients from the soil and the action of organisms on the decaying organic materials eventually improve the soil chemical and physical properties which would enable other plant species to survive.

Undisturbed stands of both grasses give excellent soil protection against sheet erosion. The runoff peaks in cogonal areas are, however, slightly higher than those of other grass species. Hence, cogon stands tend to favor gully erosion.

The livestock carrying capacity of grasslands depends on climate, level of management and soil productive capability. A major reason for overgrazing is the failure to consider the natural variability of climatic parameters such as rainfall. There is a tendency to increase the population of livestock whenever a sequence of good climate occurs, with the consequence of extensive overgrazing in the inevitable dry years. Severe overgrazing results in heavy soil compaction, decreasing infiltration, falling water table, high erosion and sediment transport and, consequently, pressures to expand areas for pastures.

Again, there are indirect evidences showing the interrelated effects of climate and grazing conditions. Table 6 presents the monitored mean annual suspended sediments transported by several rivers in the island of Mindoro. The eastern side of the island (Mindoro Oriental) is characterized by high and more uniformly distributed rainfall while the western side have a very pronounced dry

Table 6. Estimated annual suspended sediment loads for selected rivers in Mindoro.

River	Catchment area, km^2	Mean annual sediment transport, tons/ha
A. Mindoro Oriental		
1. Pula	161	4.6
2. Bongabon	369	6.7
3. Bucayao	300	4.0
B. Mindoro Occidental		
1. Mamburao	144	438.2
2. Pagbahan	337	171.0
3. Busuanga	415	233.3

season lasting for 4 months or more. The watersheds on the western side of the island have over 60 per cent of their areas in pastures or open grasslands. This is approximately twice as much that for the watersheds in Mindoro Oriental. The more favorable climate of Mindoro Oriental makes crop cultivation more viable. Higher production levels also lessen the population pressures to exploit forests. Among others, these factors help explain the better conservation and land utilization practices in the province.

The watershed of western Mindoro are severely overgrazed. The results are severely eroded lands and annual sediment loads that are several orders of magnitude higher than those in Mindoro Oriental.

C. Arable Lands

As mentioned earlier, the conversion of forest lands into vegetations with shorter growth durations and status tends to decrease evapotranspiration and lessens the infiltration rates of soils. Thus clearing of trees for field crops production (e.g., cereals, field legumes, root crops and industrial crops) will result in higher overland flows, flood flows and erosion rates. A notable exception to these trends is conversion to lowland rice paddies. Lowland rice is grown under submerged conditions in level, bench terraces that trap rain water and conserve the soil.

The removal of a thick forest canopy and the cultivation of soil for seeding inevitably results in the loss of natural flow regulation and protection of raindrop energy. There are mechanical means, however, of simulating these beneficial effects of forests. These include broad based and bench terraces, farm ponds, gully plugs, contour farming and mulching. The most effective of these are terraces. They are, however, usually associated with high investment costs and unfavorable economic returns. Even with more than 50 per cent government subsidy, the payback period to individual farmer investors in United States, for example, is more than 30 years.

D. Urbanization and Industrialization

Urbanization affects the water cycle by the changes that it triggers on the soil infiltration and surface properties and on watersheds' energy balance and microclimate. Urbanization and industrialization may also have marked effects on the quality of water in the hydrologic cycle.

Urban infrastructures are usually impervious to water and hence, reduce the infiltrating surfaces. The effects are increased runoff and daily variations in temperature. Large thermal gradients and the increase in atmospheric particles that serves as condensation nuclei for rainfall tend to increase precipitation. The available information at present indicate that urbanization increases the number of thunderstorms which may increase the total precipitation over an area by as much as 10 per cent.

Urban and industrial areas are generally populated by people with divergent life styles and increasing standard of living. These, in turn, result in increasing demand for water and increasing volumes of domestic and industrial wastes which pollute land surfaces, moving and stagnant water and the atmosphere.

IV. The Influences of Other Man-Made Modifications on Watershed Behavior

A. Evaporation and Evapotranspiration Suppression

The effect of the use of anti-transpirant, shading, etc, to reduce transpiration and the use of mulches, plastic covering and soil additives on water yield and low flows is the same as that of reducing the amount of vegetation. Although mulches clearly reduce erosion, there are no significant evidences as to whether those practices affect peak flows and ground water quality and quantity (Larson, 1971).

B. Land Treatments

Terraces, contour ridges, furrows, tillage operation and mulches are mostly designed for soil erosion and water control. Field studies have shown that these practices result in the reduction of water yield and flood peaks and the subsequent increase in ground water storage, low flow, and surface water quality. In watersheds with level terraces, the streamflows tend to be more uniformly distributed over a long period of time (Harold and Dragoun, 1969, Shockey, et al, 1970). These effects are more pronounced in very small watersheds and diminish with watershed size (Richardson, 1972). There is little if any evidence as to whether these practices influence groundwater quality.

C. Installation of Drainage and Irrigation Systems

Surface drainage systems shorten the time base of flood hydrographs. Subsurface drains may result in a longer time lag of a storm hydrograph. They also strongly influence low flows and, to some extent, the water quality. Subsurface drains reduce low flow volumes. Flow through subsurface drains is usually poor in quality.

The effect of an irrigation system within a basin is usually localized in nature except for the return flow. Large scale irrigation from ground water supply may, however, lead to a sharp reduction in base or low flows.

D. Surface Storage Considerations

The modification of surface storage will have pronounced effects on water yield, flow rates and surface water quality. Two of the main functions of a reservoir are flood control and low flow augmentation. A reservoir usually traps about 85 percent of the combined bed-load and suspended sediment load of a waterway. Reservoirs, lakes, and farm ponds also affect the water table depth and stream temperatures (Williams, 1971).

Other modifications like importing or exporting water, intensive recreational use and urbanization can have far reaching hydrologic effects especially on the time and spatial distributions, water quality and quantity. With these modifications, however, a distinction between water use and consumption must be made. Water used, say, for domestic and industrial purposes may be re-used for other purposes like irrigation. Water consumed, say, by plants, may be considered as water loss.

There are other possible man-made modifications such as ground-water recharge, construction of infiltration galleries, desilting basins, cloud seeding, etc. An understanding of these and their hydrologic effects is basic to the protection of watersheds land and water resources.

V. Summary and Conclusions

The Philippines covers some 30 million hectares. The Philippines has never been any smaller. It will never be any bigger.

In 1920, there were only 10 million Filipinos. Today, there are about 50 million of us. The Philippines is still of the same size. Its land and water resources are bound to feel the strains from our needs and wants.

It has been estimated that less than 35 percent of the country's land area is still covered with forests. The rest has been disturbed and transformed into other land uses.

Of great environmental concern are the badly disturbed grasslands, uplands and pasture areas. These represent approximately one-third of the country's land area at present and increase in coverage at the rate that is about equal to the population growth rate as rural dwellers move into ever steeper slopes in search of food, fuelwood and shelter.

It is quite obvious that the root cause of all our environmental problems today is the rapid growth in population. Many of our long term policies and programs for natural resources development, control and management are becoming obsolete or socially unacceptable before they are fully realized because of the doubling of the human loads of our watersheds every 2 or 3 decades.

It is equally obvious that to be effective, a watershed management scheme must be premised on satisfying the basic needs of the people in and around the watershed and in allocating the natural, financial and technical resources on the basis of their individual and economic well being.

At this point, it should further be stressed that no two watersheds are alike Similarly, no two sets of human population will response in exactly the same manner to a given watershed management scheme Each watershed must be assessed carefully and given competent technical planning of multiple land uses that are vital to the present and future welfare of its human communities

This paper discussed the relevant environmental impacts of watershed modifications with the objective of providing sound physical bases for land use policies for rural and forest watersheds It is hoped that soil erosion, water quality and other hydrometeorological concerns be given proper consideration in this present and future management policy making exercises

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