UNIVERSITI MALAYA

Rivers - Our Heritage Our Future

ugural Lecture University of Malaya
9 December 2003

by
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Abstract

The growth, development, evolution and sustenance of our civilization are dependent on rivers. The river basin system provides the basic resources for economic growth and development. This includes land for agriculture and urbanization, water for residential and commercial use, water for irrigation and generation of hydropower energy, eco-tourism activities in upstream basins, and the mining of river alluvium such as river sand for the construction industry. However, limited understanding and the disruptions of river basin process-response systems are also associated with the emergence of new processes and intensifying existing processes that posed serious challenges to not only the continued sustenance of the economic activities but are by themselves environmental hazards that threatens the welfare and comfort of the basin dweller. Mismanagement of river resources have led to increasing frequencies and magnitudes (intensities) of environmental hazards such as floods, rapid slope failures, river bank erosion and slumping, accelerated soil erosion, and problems associated with sedimentation. It can also be argued that even urban pollution is also associated with mismanagement of the river basin system. This lecture is an attempt to describe the importance and contribution of *fluvial geomorphological* studies in understanding river basin process - response systems and its contribution to a sustained development of river basin resources. The discussion of this lecture would be based on the research, presentations, consultancy work and publications that I have carried out since the last 15 years.

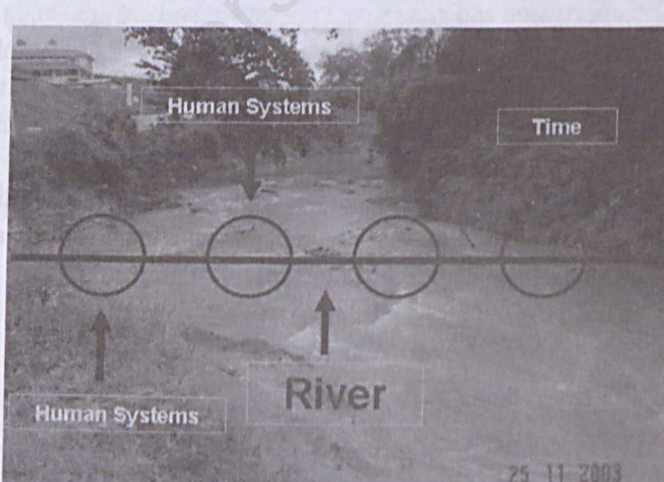
Preamble

Bismillahir Rahmannir Rahim
Assalamualaikum Warahmatulahi Wabarakatuh
A Very Good Morning and Fine Day to All

Ladies and Gentleman, before I begin let me express my deepest appreciation and thanks to Yg. Bhg., Dato' Professor Dr Hashim Yaccob, Vice Chancellor, University of Malaya for giving me this opportunity to present my inaugural lecture and also for his kind attendance to grace this important function of my academic life. Thank you, Yg. Bhg. Dato', and May God Bless You, *Insyallah.*

Ladies and Gentleman, perhaps it would be best that I elaborate on the title of my lecture – *Rivers Our Heritage Our Future*. Rivers had evolved since the last 4.5 billion years (~) and this process had continue through geological time even after the *demise* of a particular human civilization, this is our heritage, inheriting the result of thousand of years of work and sculpturing by *forces of nature*, in this case the processes of running water.

Human civilizations on the other hand had evolved and become more developed since the last 10,000 years (~) and this evolution had been dependent on river resources. Looking from a moment in time where this utilization of river resources had taken place, it shows that the growth, development and evolution of human civilization is part of this continuum, this is our future (Figure 1).



Thus the earliest known civilizations such as the Mesopotamian Civilization (for example the Sumerians, Babylonians and Assyrians, see also Plate 1a and 1b) also known as "the civilization of the land between two rivers"(i.e. the Tigris and Euphrates) , the Indus Civilization (the nomenclature Sindhu-Sarasvati Civilization is sometimes used, the Ancient Nile Civilization of Egypt and the Hwang Ho Civilization also known as the "Cradle of the Chinese Civilizations" are earliest form of human civilizations whose growth, evolution and *decay* have been attributed mainly to the river that flows through the region.

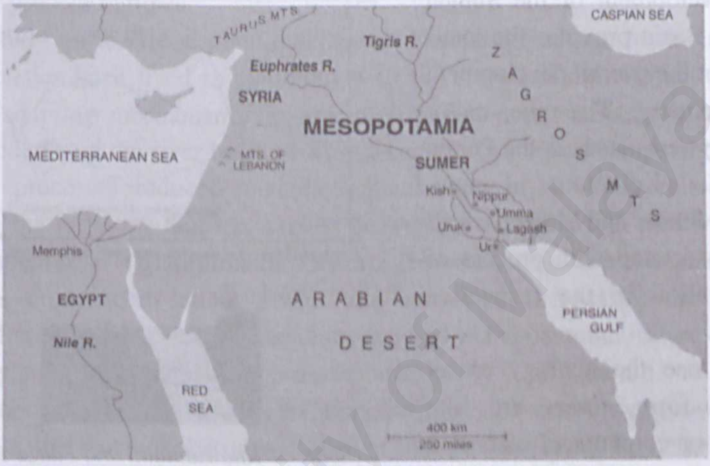
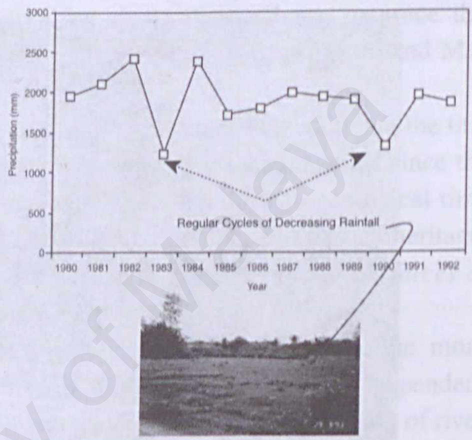


Plate 1a: The Growth, Development, Evolution, Sustenance and Eventual Decay of the Mesopotamian Civilizations are attributed to the Flow Regimes of the Euphrates and Tigris Rivers Systems *(source : the Internet)*

Plate 1b: The Impact of Civilization and the overall growth of a Region *(source: the internet)*

These earliest forms of human civilization in fact also influenced the growth, development and expansion of future civilizations in earth's history. Even today, the development and prosperity of the human civilization is dependent on the river. River systems such as the St Lawrence and Mississippi in North America, Amazon and La Plata in South America, Rhine, Volga, Elbe and Danube in Europe, Nile and Orange in South America, Mekong in Asia and many other river systems provided the thrust for agriculture and industrial development and urbanization in the developing and developed countries. In Malaysia, the growth and development of the Sungai Kelang Basin provides the locus point for the overall development of the country. The other major rivers systems such as the Perak, Pahang, Kelantan, Langat, Linggi, Johore and Muda have all been associated with process of urbanization in the respective regions.



(Source : Khairulmaini and Fauza 1997)

To use the analogy of an organic form, rivers are like arteries or conduits of elaborate circulation systems, transporting nutrients and water for metabolic functions thus governing the growth and sustenance of the organic form. Severing the flow of these circulation systems would thus disrupt metabolic processes, growth and the sustenance of life, and culminating with the eventual death of the organic form. Metaphorically rivers are not only living entities, but it provides for life and sustains it. In fact rivers are symbiont with life itself.

In Malaysia, for example, my study (Fauza and Khairulmaini 1995; Khairulmaini 1997) on the factors influencing the decay of traditional agricultural systems in Negeri Sembilan was mainly attributed to the fluctuations in the rainfall - river hydrological regimes as one of the major factors influencing the cultural geography of the state (Figure 2). It could be argued here that traditional cultural systems flourish and decayed as a result of changing river hydrological regimes. In Malaysia, the existence of great expanse of idle and abandoned lands attests to the importance of the river hydrological regimes in sustaining irrigation practices that are crucial in padi cultivation (Khairulmaini and Fauza1997).

INTRODUCTION

Rivers fascinates me for the simple reason that it is the main driving force that can imposed tremendous changes (imperceptible or rapid) to the surface of the earth (morphology) and the results of which thus governs the *wellbeing* (river resources utilization) and at the same time imposed *threats* (river floods) to whoever lies is in its path. In a nutshell rivers are closely related to the survival of a particular community, and societies had evolved adapting to the river process regimes.

A study on the flood plain dwellers of Kampung Morten, Malacca shows how societies have lived in symbiont with the river process regimes through various adapting mechanisms (in many cases, however, societies have yet to better understand the river basin process – regimes, such that the potential risks to river processes induced hazards remains very high). Such relationships describe the harmony that has existed between civilization and the river since time immemorial (Khairulmaini 1994a). However, this harmony has made societies complacent about rivers and with the increasing problem of overexploitation, societies become more exposed to the potential hazards that the changing patterns of the river process regimes posed (Plates 2a ,2b and 2c).

Rivers sustains life (provides opportunities for economic growth) and terminates life (such as the impact of river induced disasters). Sometimes these changes produced picturesque landscapes that show clearly the tremendous *power* that a river has. However in other cases the changes are very subtle that one can never associate it with river processes.

Plate 2a – Urbanization and industrialization intensifies river pollution (the suds in the describes waste detergents been flushed into the Sungai Kerayong, a tributary of the Sungai Kelang

Plate 2b-The magnitude and frequency of river bank erosion intensifies with urbanization

Plate 2c - Societies adpt to river basin process-responce regimes. However limited knowledge on human induced changes on the process-response regimes makes the process of adaption a continuous effort which sometimes can lead to complacency and threat of potential risks

More important rivers are *everywhere* and thus manifest on those life forms that inhabit the surface of the earth (Man, Plants and Animals). Thus rivers are often describe as "sustenance of life" and intertwined on our daily lives quite regularly and needs to be understood. To use the analogy "understand your friend or your foe, before you do something stupid", rivers need to be studied and understood before they are developed. Preliminary appraisal of river basin process – response regimes can help in better decision making in river basin resources development, and the implementation of best practices.

As past experiences have shown, the limited understanding of the river process regimes are often associated with increasing intensities of environmental hazards and emerging regularity in the occurrence (frequencies) of environmental disasters. I must admit here that my contribution to river studies is but a grain in an ocean of knowledge.

It is the main objective of this lecture to show my contribution to this vast knowledge of river studies and how I have tried to go about understanding the subject. To *understand* rivers, we need to refer to the science of geomorphology – a *scientific study of the morphology of the surface of the earth*. In layman terms, geomorphology is the study of landforms and how they are formed, and are time dependent.

There are two basic considerations in understanding landforms, (1) landforms are the result of the opposing interactions between *shear stress forces* and the *shear strength forces* of the surface of the earth and (2) landforms are geometric features (morphological structures) that can assume dimensions at different spatial scales. Landforms are in fact expressions of *losses* and *gains* on the surface of the earth. Soil erosion pillars, for example are landforms seen at the micro level of spatial resolution (Khairulmaini 1991). These micro-landform features describe a simple model of stress – strength relationships that exist in geomorphological systems. The shear stress forces here is rainfall forces and the shear strength forces are the size of the soil erosion pillar cappings and the characteristics of the materials that constitute the erosion pillars (Plate 3). Shear stress forces have an energy gradient to it. These energy gradients are brought about by many major agents of *change*, including water, air, gravity and currents.

Gregory (1972) proposed a simple geomorphological equation to describe landform formation, where, F (Landform) is a function of P (processes) on M (materials) over time. However, my study on the soil erosion pillars suggest that this equation needs to be improved (Khairulmaini 1991; 1996a) where, the revised equation states that, *Landform Response* is a function of *Shear Stress Forces* on the *Shear Strength Forces* of a particular geomorphological system.

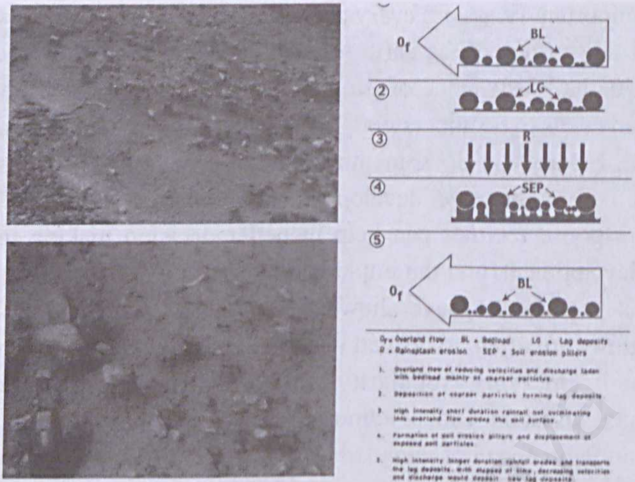


Plate 3- Soil Erosion Pillars are Micro-Geomorphological Systems that describes the Shear Stress – Shear Strength relationships in Geomorphological Systems *(Source Khairulmaini 1991)*

Landform response not only refers to the morphology of a particular landform, but also the *losses* and *gains* that occurs within and from the system (these includes sediments, solutes and water). The shear strength forces are determined by the system's characteristics (these are the intrinsic and extrinsic and properties of the basin). Extrinsic system characteristics include for example vegetation cover density, for example plays a very important role in neutralizing the impact of shear stress forces induced by rainfall through interception. Conversely, the binding effects of its root systems significantly increase the shear strength of the materials or soil systems on the slopes (Khairulmaini 1992a and 1996a). Slope morphology could also influence the intensity of shear stress forces of run off processes. Convex slopes are associated with increasing momentum and thus increase the shear stress forces acting downslope and the converse is true for concave slopes (Khairulmaini 1995b). Intrinsic system factors are related to the physical and chemical properties of the materials that constitute the system. Consolidated materials such as rocks are generally associated with greater shear strength when compared with unconsolidated materials such as soils and sediments. However, shear strength properties between rock types can also show variation. Sandstones are in general much weaker than granites to resist the shear stress forces of weathering and rainfall. Limestones for example are highly susceptible to chemical weathering forces. In the Ipoh Region, Perak, this weakness of limestone rock formations manifests itself on the picturesque landscapes of the region.

Fluvial geomorphology is that branch of geomorphology that studies the action of running water on land and the evolution of landforms, as opposed to coastal geomorphology that studies the role of water in the marine environment. The action of water on land follows different pathways (surface and subsurface flows) but coalesced into a river basin or sometimes also referred to as a drainage basin. The evolution of this basin eventually governs the overall evolution of the earth's surface (Figure 3). Each river system is associated with its own basin. The formation of this basin is the result of the cumulative action of water flow processes within the basin.

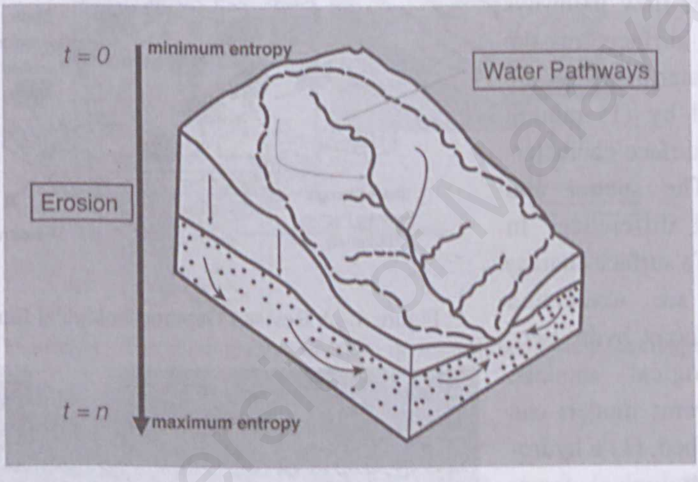


Figure 3 - The evolution of the basin governs the overall evolution of the earth's surface

The Revised Geomorphological Equation provides a useful conceptual framework by which river basin geomorphology can be better understood and studied (Figure 4; Plate 4). The river basin summarizes the cumulative effects of water flow processes within a morphological distinct geometric surface feature of the earth's surface. My study on valleyfloor fills (Khairulmaini 1989; 1993) and valleyside colluvium (Khairulmaini 1995a) describes the role of changing hydrological regimes on the erosion, transportation and deposition of drainage basins' sediments. Both of these studies show that the morphology of the basin (geomorphometric properties) and its valleyfloor and valleyside slopes geometry governs the water flow processes and influences the development of the basin system (Figures 5a and 5b).

The Early Years – How a River System Evolves

There are many ways a river can form (see for example Knighton 1985). However, the growth, development and evolution of river basins are dependent on two basic factors, (1) regular rainfall and (2) a surface flow that is capable to form a permanent channel and sustain it. River basin evolution can be best understood by referring to hydro-geomorphological models.

These models describe the water flow pathways on the surface of the earth. Water pathways are governed by (1) rainfall and (2) surface characteristics. The spatial and temporal differences in the earth's surface characteristic are associated with different hydro-geomorphological models. Two extreme models can be described, (1) a hydro-geomorphological fewer than 100% vegetation cover, and (2) a hydro-geomorphological model under 0% vegetation cover.

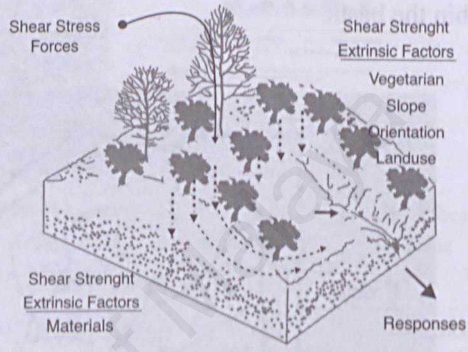


Figure 4 - A Revised Geomorphological Equation

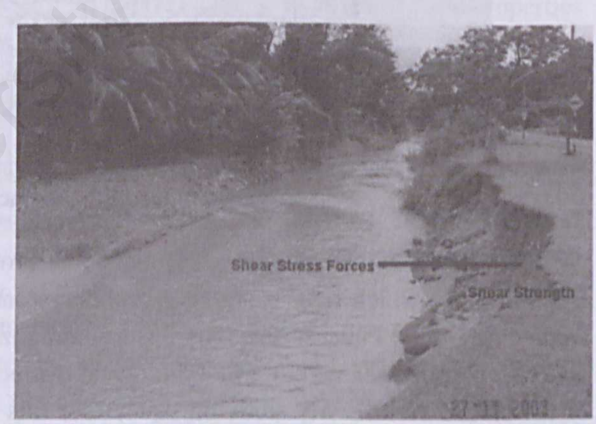


Plate 4 – The Relationships between Response, Shear Stress Forces and Shear Strength in River Channels

The former model best describes Tropical Humid Denudation Systems and the latter model describes an Arid Denudation System. Man's activities on earth can change earth's surface characteristics, such that through the process of de-vegetation a Tropical Humid Systems can change from being a 100% vegetation cover basin (Plate 5) to a 0% vegetation cover basin and the de-vegetated basin then assumes an Arid Denudation System (Plate 6).

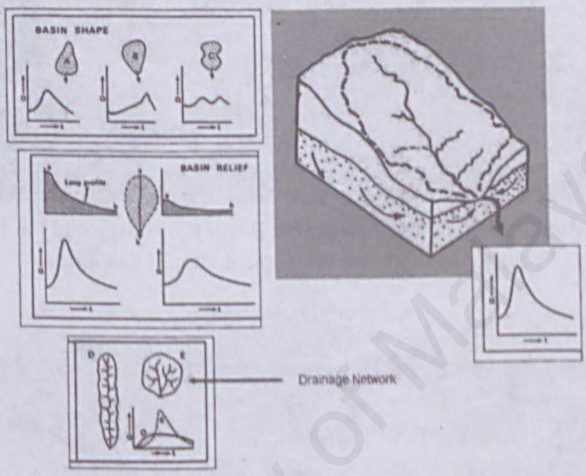
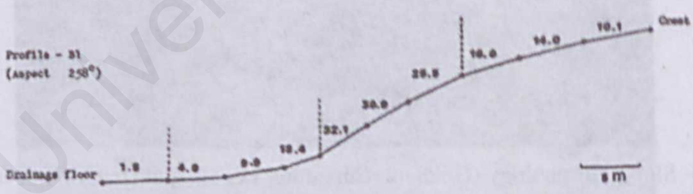


Figure 5a - The relationships of basin qeomorphometry and discharge



Vegetation cover (%)	10.4	7.6	6.8	2.2	1.8	4.0	2.0	7.6	6.5	8.4
Colluvium thickness(cm)	25.0	14.8	14.0	14.8	2.0	4.5	4.4	13.9	7.4	11.3
Subjacent materials	marl			weathered conglomerate				loose gravels		weathered sandstone
	There is surface gravel throughout,but no rock outcrops,with mostly semi-natural vegetation of low shrubs,except for terraced dryland cultivation in the drainage floor									

Plate 5- Vegetation Characteristics Governs Basin Hydrology and the Evolution of Drainage Systems under Tropical Humid Conditions

Plate 5- Vegetation Characteristics Governs Basin Hydrology and the Evolution of Drainage Systems under Tropical Humid Conditions

Plate 6- Slope Morphology (Gradient, Curvature, Length and Height) Governs Basin Hydrology under Arid Systems and Disturbed Geomorphological Systems

There is close relationships between vegetation characteristics, slope morphology and soil characteristics on valleyside slopes to influence the valleyside slope hydrology regime and the growth of incipient drainage channels. My study on valleyside slopes covered with *dellinea suffriticosa* describes how vegetation characteristics such as leaf area, branch density, tree structure, root density, canopy cover and species height have significant relationships with soil development so as to influence the local hydrological regimes and initiation incipient drainage lines on the basin slopes (Plate 7; Khairulmaini 1992a; 1996a).

These hydro-geomorphological models are also "systems of losses", where sediments and chemical are been flushed out from the river basin. Depending on the rate of losses, these would govern the evolution of the basin. Tropical Humid Basins are associated with chemical losses and Arid Basins are associated with sediment losses. It is for this simple reason that river basin evolution is more pronounced in Arid Regions. My study on semi-arid and disturbed

Plate 7 - The relationships between vegetation cover, slope morphology, soil characteristics and slope hydrological regime on the initiation of incipient gully systems

Plate 8 - The growth of incipient gullies are more intense and elaborate under limited vegetation coverm typical of arid and disturbed geomorphological systems.

geomorphological systems (Khairulmaini 1987a; 1993; 1995b) describes a number of phases in the growth, development and evolution of drainage basins under homogeneous materials. These processes also describe the general evolution of river channels and the valleyside slopes.

Figure 6a and 6b summarizes the various stages of drainage basin evolution under semi-arid / disturbed conditions and under Tropical Humid conditions for small basins. Under Tropical Humid conditions, vegetation systems play a very critical role in influencing growth and evolution of the basin system. In general these studies conform to the findings of other studies that describe drainage network growth and evolution. However, local environmental settings could change the pattern of evolution, such as the structural geology of underlying rocks, valleyside slope orientation, and also the type of landuse practices. The relationships between vegetation, slope morphology and soil characteristics on selected Tropical Humid basins show that the growth of drainage basin systems is very dependent on the controls of vegetation on slope and soil development in the basins (Khairulmaini 1996a). The relationships govern the nature of the slope hydrological regime and growth of incipient run off processes on the slopes and the growth of incipient gullies on the valleyside slopes (Plate 8; Khairulmaini 1994b). In general, both of these studies describe that drainage systems evolution involves, (1) initiation, (2) elongation, (3) maximum elongation, (4) integration and (5) abstraction. Given sufficient energy gradients drainage basin evolution describes very dynamic environmental systems.

Drainage basin evolution also influenced the development of valleyside slopes and the channel slope subsystems. However, in my study of valleyside slope colluvium in Semi Arid Basins (Khairulmaini 1995c) and in Tropical Humid Basins (Khairulmaini 1996a), valleyside slope evolution is dependent on the mass movement and mass transport processes on the slopes. The model postulated in each case is based on a convexo-concave slope decline model (Figure 7a).

In relation to valleyside slope evolution my study on the channel processes at the Upper Basin System of Sungai Linggi (Figure 7b;1997) shows that channel slope processes of entrainment, erosion and transportation works independent of valleyside slope processes and the hydro-geomorphological models that describes basin evolution I mentioned earlier. However, it must be mentioned here the net basin evolution model is a cumulative effect of processes that occur on the valleyside slope and the channel slope. The overall denudation system of the basin, however, is a continuum (valleyside slope – channel slope – drainage basin sediment yield), contributing to the final sediment output of the basin system.

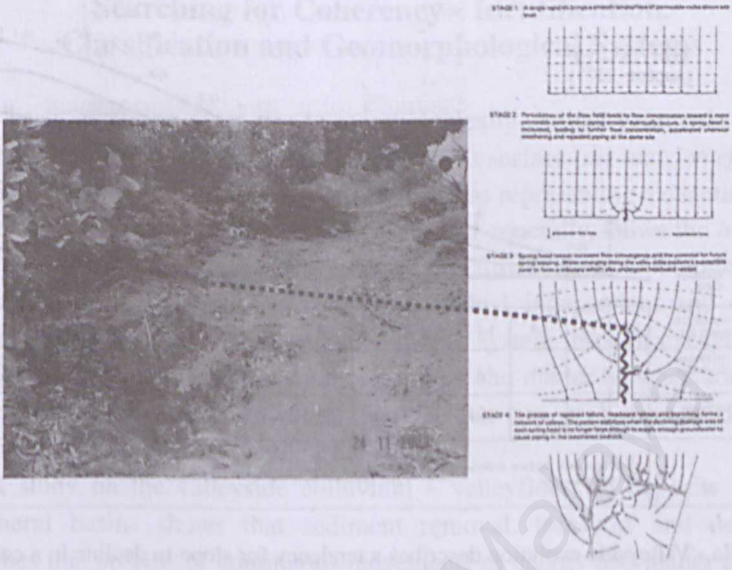


Figure 6a - The Stages of Drainage Basin Evolution Under Tropical Humid Systems

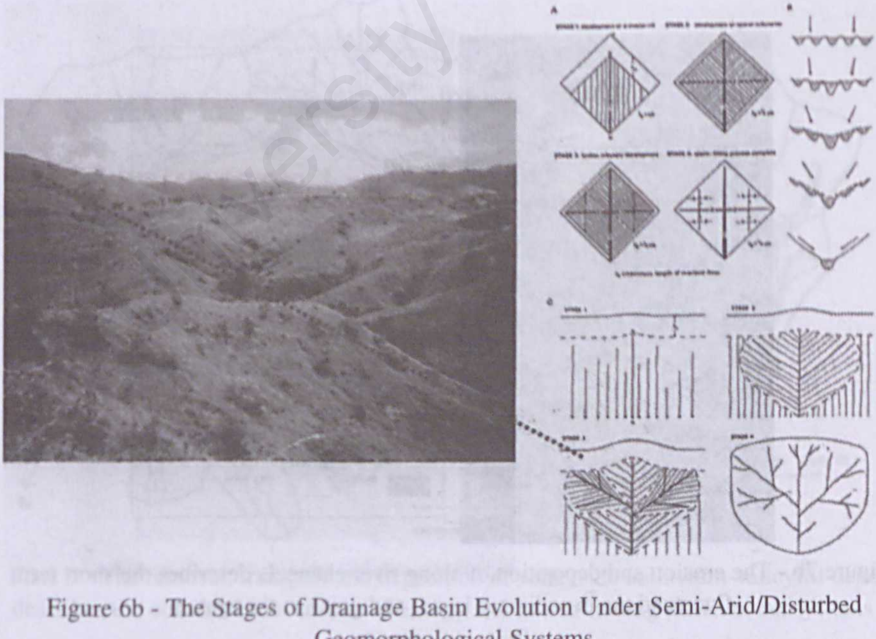
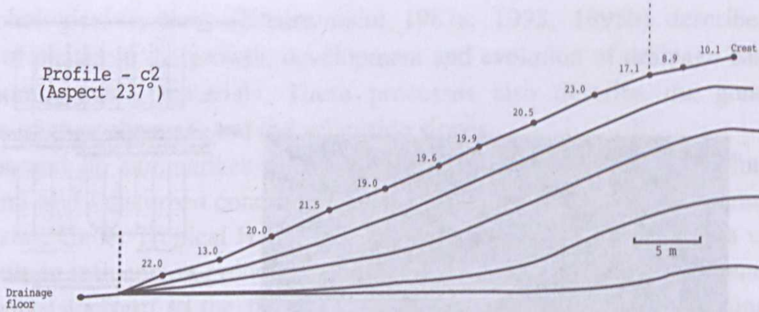


Figure 6b - The Stages of Drainage Basin Evolution Under Semi-Arid/Disturbed Geomorphological Systems



Vegetation cover (%)	15.5	3.0	2.6	5.2	10.8	6.6	5.6	4.0	13.0	3.0	5.2	6.6	6.6
Colluvian thickness (ca)	18.2	5.0	7.0	7.6	8.1	13.9	10.7	10.7	14.3	4.6	6.6	12.3	12.2
Subjacent materials	marl	cc	marl	loose gravele		marl	loose gravele	marl	loose gravele				
	There are much surface gravele throughout the slope CC - conglomerate												

Figure 7a - Valleyside evolution describes a tendency for slope to decline in a convex - concavex - concave from

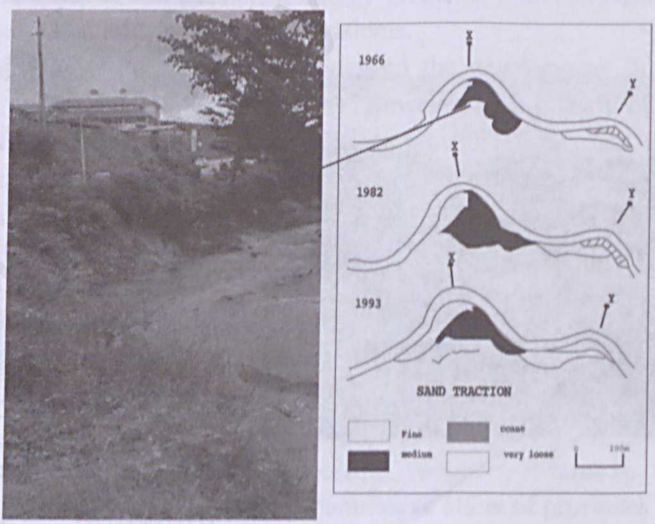


Figure 7b - The erosion and deposition of along river channels describes the short term flucctuations in sediment losses and gains in the system

Searching for Coherency - Identification, Classification and Geomorphological Systems

River basin evolution gives rise to morphologically distinct geometric features (Khairulmaini 1987b; 1989; 1994c) on the earth's surface *(the incision effect)*. To a layman these features could best be described as representing a chaotic pattern on the earth's surface (degraded landscapes) and generally shows the *highs* and *lows* of the earth's surface. However, to the fluvial geomorphologist, these features describe the existence of (1) individual independent and dynamic systems, and (2) which forms part of a bigger system through exchanges and maintenance of a continuous transfer of energy and matter between component subsystems. This transfer of energy and matter are in a state of flux and determines the equilibrium state of the system.

A study on the valleyside colluvium – valleyfloor fill deposits in small ephemeral basins shows that sediment removal, transport and deposition describes this process of continuous movements of energy and matter that links the different subsystems of the drainage basins (Plate 9; Khairulmaini 1994d).

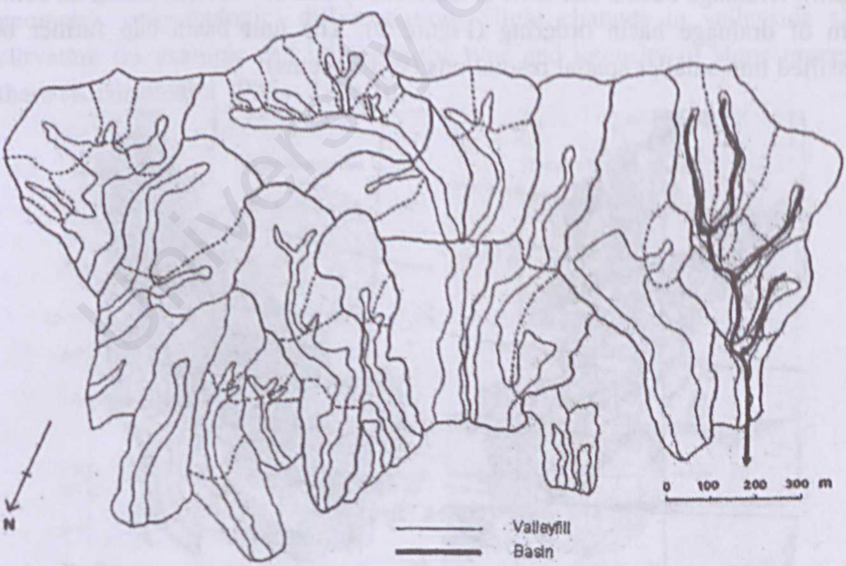


Plate 9 - The removal, transport and deposition of valleyside colluvium-valleyfill deposit describes the continual movements of energy and matter linking different subsystems of the drainage basins

Fluvial geomorphological systems (the basin system and its subsystems of, valleyside slopes and channel slopes) can be mapped using large scale aerial photographs and satellite imageries. These mapping techniques are becoming more precise with the advent of digital satellite technology. Fluvial geomorphological systems can be mapped and classified with precision to the 1 meter resolution.

The ability to recognize fluvial geomorphological systems have greatly improved natural resources developments through better decision making and planning (Khairulmaini 1991; 1992b; 1994e; 1996b; 2001a; 2003a; 2003b).The production of an Asian Mega-Geomorphology Map for example could facilitate better air traffic navigation and land communication in Asia (Figure 8; Chen and Khairulmaini 1996; Khairulmaini 1991). These geometric features are specifically called geomorphological systems based on their morphogenetic differentiation (fluvial geomorphological systems as to coastal geomorphological systems, or aeolian geomorphological systems or glacial geomorphological systems).

The basic geomorphological system unit is the drainage basin. It summarizes the effects of all the drainage pathways within a geometric form (basin). Drainage basins can exist at different spatial resolutions based on some form of drainage basin ordering (Figure 9). The unit basin can further be classified into smaller spatial resolutions (sub-systems).

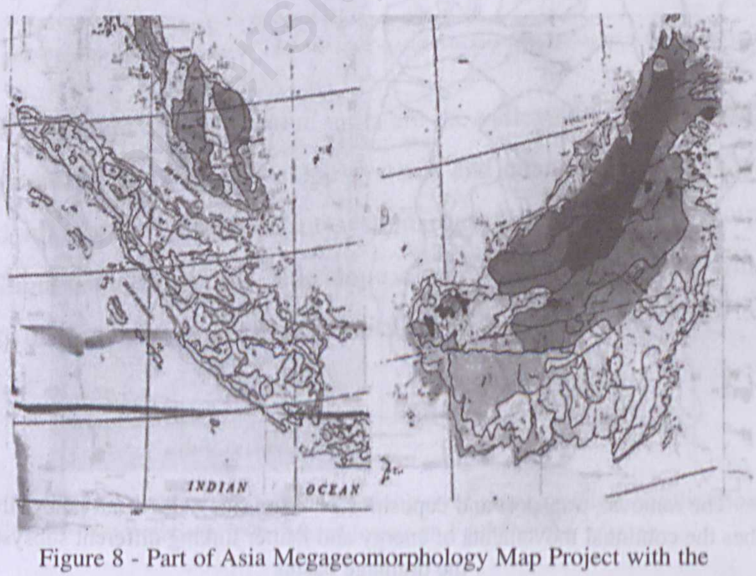


Figure 8 - Part of Asia Megageomorphology Map Project with the Chinese Academy of Science

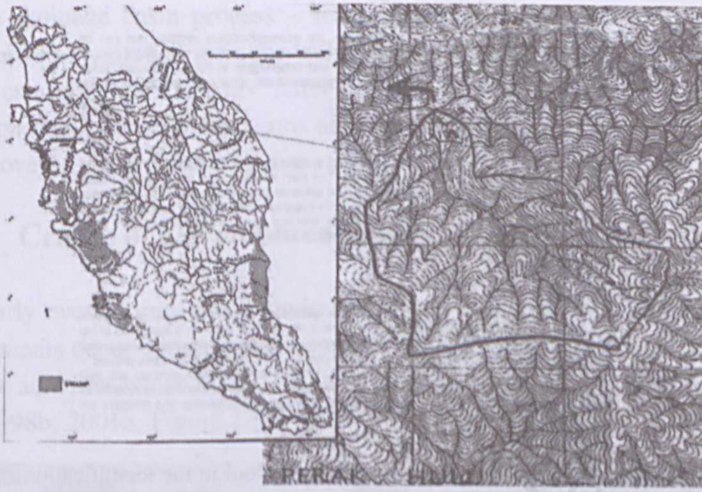


Figure 9 - The drainage basin system can exist at different levels of spatial differentiation for example based on simple ordering system

The most important of these spatial units are the valleyside slope systems and the channel slope systems. The valleyside slope systems and channel slope systems can be further classified into smaller independent systems based on geometric (morphologic) differentiation. Slight changes in valleyside slope curvature for example can influence the type and intensity of slope processes there (Khairulmaini 1995a; Plate 10).

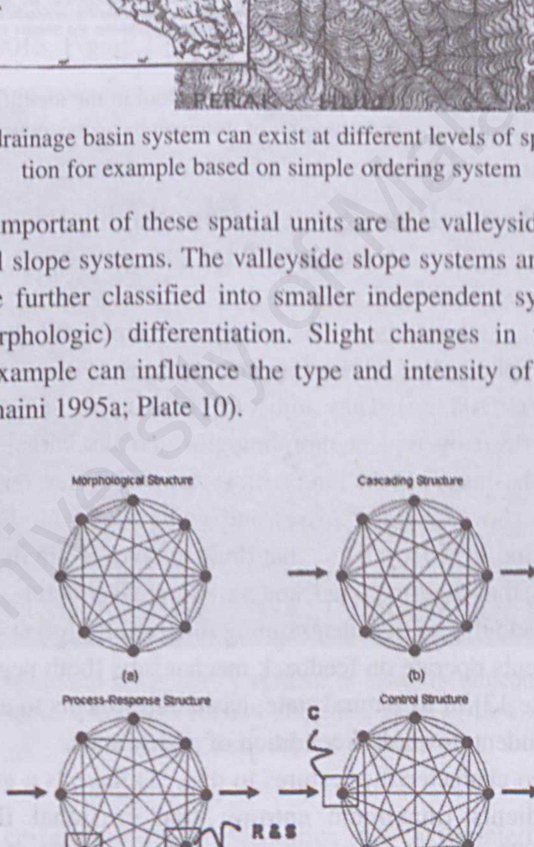
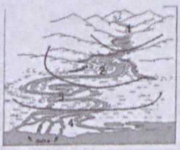


Figure 10 - Drainage basins are open sstems whose internal structures regulates the flow of energy and matter. Drainage basins era systems in dynamic equilibrium and can achieved steady state canditions in a moment in time

1

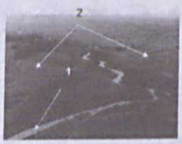
Drainage basins are geomorphological systems that can be classified based on an ordering systems, for example Horton, Strahler, Shreve and Scheidegger. In Strahler's system, lower order basins are associated with upper catchment areas and high energy gradients

2



Geomorphological systems can also be classified based on the drainage zones. The main drainage types are upper (1), middle (2), lower (3) and estuarine (4) drainage zones. Each drainage zones is a process-response system with its typical forms and processes. Upper drainage zones are associated with steep slopes and high energy gradients.

3



Geomorphological systems are often divided based on valleyside slopes and channel systems. Each system is a subsystem of the drainage basin system but the process – response characteristics of each system operates independently of the basin process – response system. Urban geomorphological systems are best appraised by understanding its hill slope and channel systems as most of the urban geomorphological hazards and disasters are associated with these systems.

Plate 10 – Aerial Photo Mapping is a useful tool in the identification, classification and mapping of drainage basin systems

How does a River System Function? - Process – Response Models

The drainage basin and its subsystems (valleyside slopes and channel slopes) as with other geomorphological systems are open systems (Figure 10; Khairulmaini 1998; 2001b; 2002; 2003c ;). They adjust to given inputs of energy and matter and are characterized by typical morphologies and discharges (sediment and water). Drainage basins are in the long term systems of *losses*, but in shorter time periods they can show *cycles of losses* and *gains* (Plate 11; Figure 11). This ability to adjust and to react tells us that drainage basins are dynamic process-response systems, they are functional, and have internal structures that govern the inputs of energy and matter thus determining the overall process-response of the system. Adjustments operate on feedback mechanisms [both negative, Plate 12, and positive, Plate 13].In its natural state; basin adjustments to energy and matter are time-dependent, towards a condition of steady state.

There are two characteristic features to this, [1] there is a general decay in the energy gradients [maximum entropy, that erosional fluvial regimes (Khairulmaini 1995a) to depositional fluvial regimes (Khairulmaini 1989), Plates 14a], the penultimate end [maximum entropy] is the base level or zero energy, [2] rivers can adjust to fluctuations in the input regimes of its process-response system [geological and climatic perturbations].Both form of adjustments describe the general natural life cycle of the river system.

The drainage basin process – response systems operates within a set of continuous links, starting from the valleyside slopes to channel slopes and finally to the estuarine zones. This latter in turn influences the coastal-marine geomorphological systems in terms as inputs into the systems thus to a certain extent governs the process-response regimes of the coastal systems (Plate 14b).

Cradle of Development - River Basin Resources

Nearly every form of economic activity associated with natural resources developments occur within the perspective of the drainage basin system, including those activities which occurs in the estuarine and coastal zones (Khairulmaini 2000; 1998b; 2001b; Figure 12).

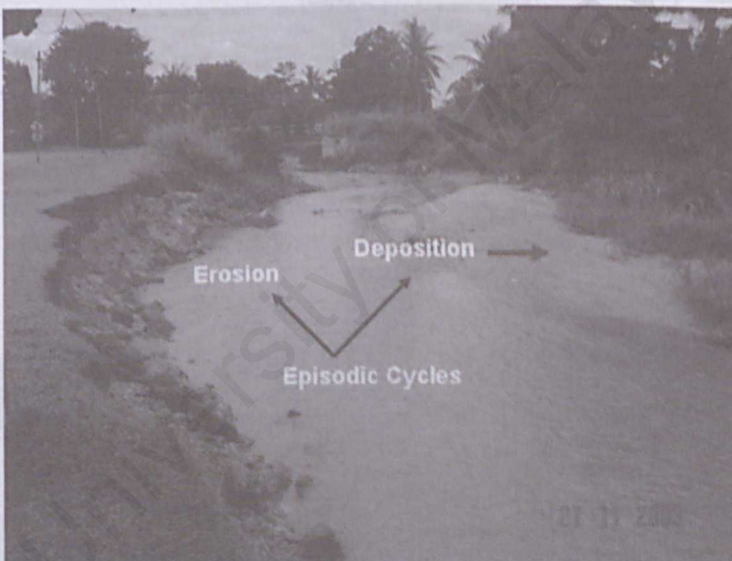
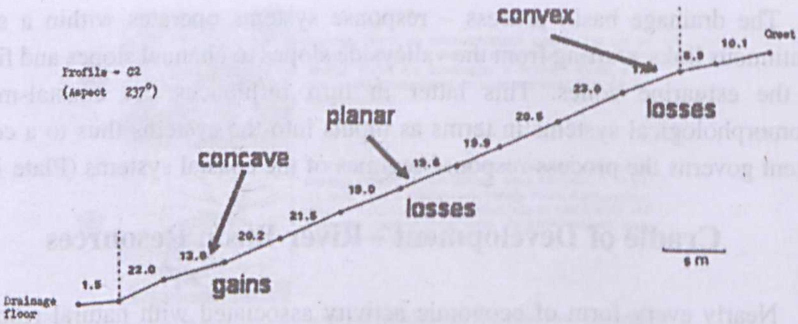


Plate 11 – Drainage basins are primarily systems of losses (sediments) but in the short term its subsystems also show cycles of losses and gains as the system adjusts to changing hydrological regimes

However, certain economic activities are associated with resource developments within specific drainage basin subsystems. Others, for example transgress different basin subsystems.

Upper drainage systems, for example are watershed areas reserved for water resources development for residential, commercial, industrial and agricultural



Vegetation cover (%)	15.5	3.0	2.6	5.2	10.8	6.6	5.6	4.0	13.0	3.0	5.2	6.6	6.6
Colluvium thickness (cm)	18.2	5.0	7.0	7.6	8.1	13.9	10.7	10.7	14.3	4.6	6.6	12.3	12.2
Subjacent materials	marl	CG	marl	loose gravels		marl	loose gravels	marl	loose gravels				
	There are such surface gravels throughout the slope CG = conglomerate												

Figure 11 - Slope curvanture influences the process - response regimes (losses and gains) on the valleyside slopes

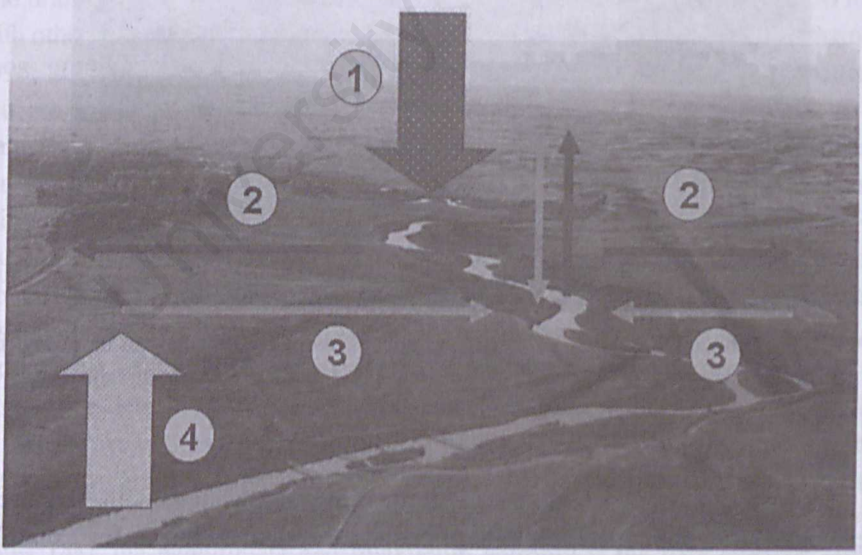


Plate 12 - Nagative feedback loops dominates at the scale of the unit basin system

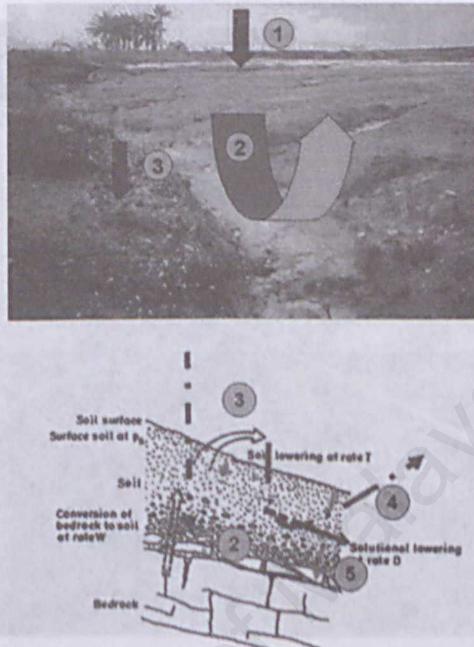


Plate - Positive feedback loops operates on the drainage basin valley side slope

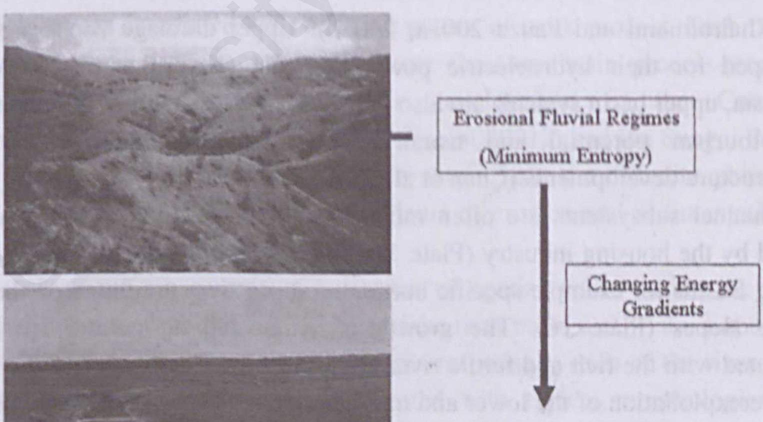


Plate 14 - The general decay of energy gradients describes the changing fluvial regimes of drainage basins

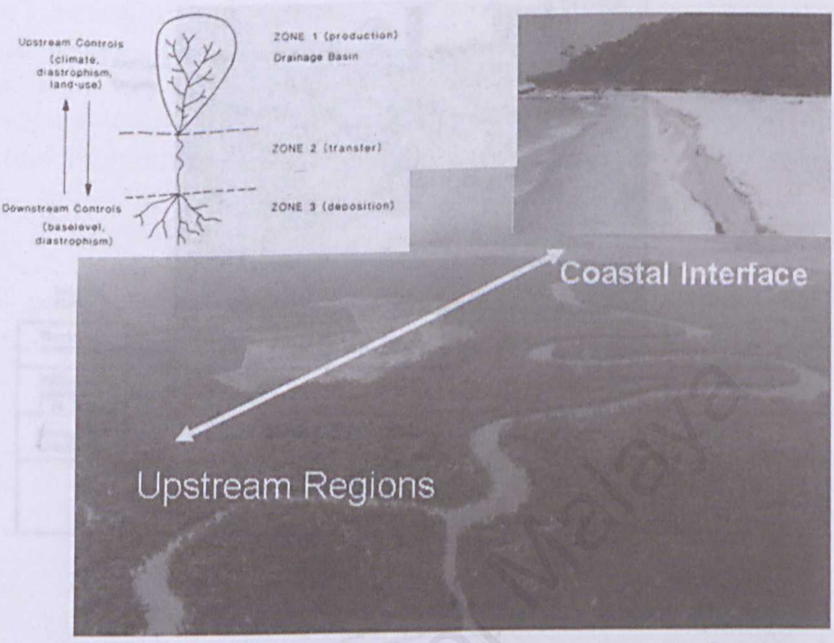


Figure 14b - The drainage basin system influences the coastal zone interface through sediment inputs into th system

use (Khairulmaini and Fauza 2003a; 2003b). Upper drainage zones are also developed for their hydroelectric power potential (Khairulmaini 2002a). In Malaysia, upper basin systems are also new frontier areas rapidly developed for their tourism potential and usually involve intense urbanization and infrastructure developments (Chan et al. 2001).

Channel subsystems are often mined for their rich sand deposits highly needed by the housing industry (Plate 15). In the Cameron Highlands – Batang Padang Basins for example specific horticultural practices are found on the valleyside slopes (Plate 16). The growth of cities and agriculture are often associated with the rich and fertile river alluvial lands. This has led to the rapid and overexploitation of the lower and middle drainage zones of drainage basins. The rapid urbanization process and the need to escape from problems associated with this city growth and urbanization have led to intense development on the upper basin systems (through urbanization and infrastructural developments; Plate 17), which are generally characterized by their very steep valleyside slopes, heavy rainfall, superficial soils, dense vegetation and high energy gradients (Khairulmaini 2001b).

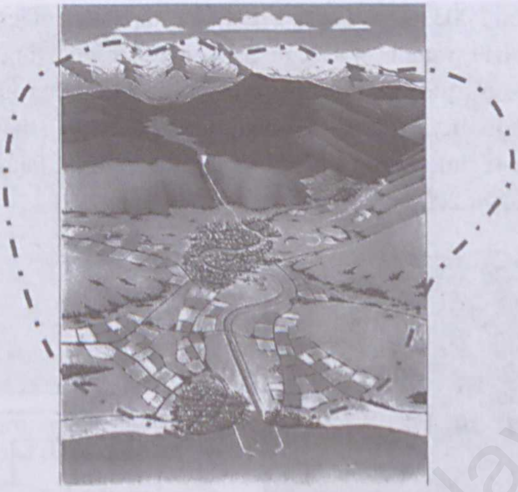


Figure 13 - Disruptions of the basin process - response regimes as a result of environmental resource development

Human Control Systems and Induced Changes

Man disrupts the river basin process-response regimes through the development of river resources [Figure 13; Khairulmaini 1999a].Every form of resources development are associated with different phases of work process. Each of this work process can lead to a change in the drainage basin process-response regimes. My study on hydropower development in the Cameron Highlands – Batang Padang Basin (Khairulmaini 2001a) and the Sungai Pergau Basin (Khairulmaini 1999b), for example shows how the different phases of development had contributed to the problems of erosion and sedimentation in Upper Basin Systems (Figure 14).

Development can assume at a number of spatial scales within the basin [valleyside slopes, river channel slopes and the river basin unit,] - the cumulative effect of which is the overall on the process-response system of the river basin system. River basin evolution is associated with typical morphologies and sediment loss.

There are two ways that river basin regimes can be disrupted, [1] changes to river basin inputs, and [2] changes to the extrinsic and intrinsic characteristics of the basin. River resources development, through various landuse practices could change the geomorphometric properties of river basin, which in turn can govern the sediment discharge and flow characteristics of river basins (Khairulmaini

1987a; Jailani et al 2003, also refer to Figure 5a). These changes bring about new processes into the system or accelerate/decelerate existing processes. The changing values of the process parameters would determine the state of environmental quality, hazard and potential risk that the changed process-response regime posed to man (Khairulmaini and Fauza 2001a; 2001b; 2003b; Khairulmaini 2003d; 2003e).

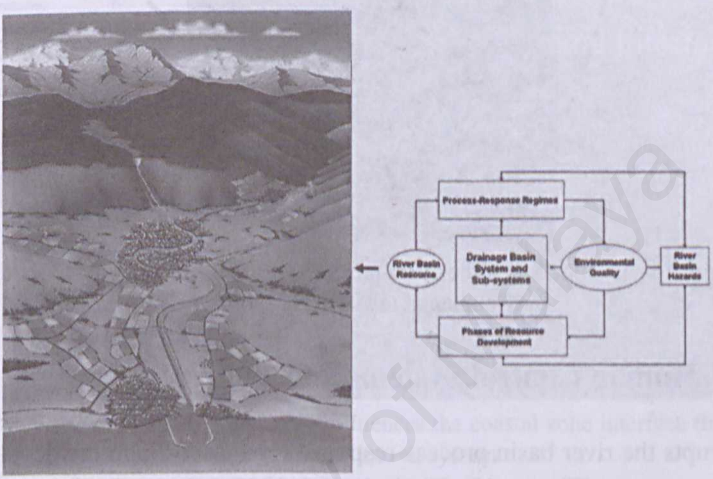


Figure 14 - Hydropower development is associated with different phases of work process. Each work phase could have a detrimental effect on the environment subsystems.

Plate 15 - Sand Mining at Upper basin Systems not only disrupts the local channel process-response regime but also on the downstream cahnnel process response regime, ultimately influencing the sediment budget to adjoining coastal systems

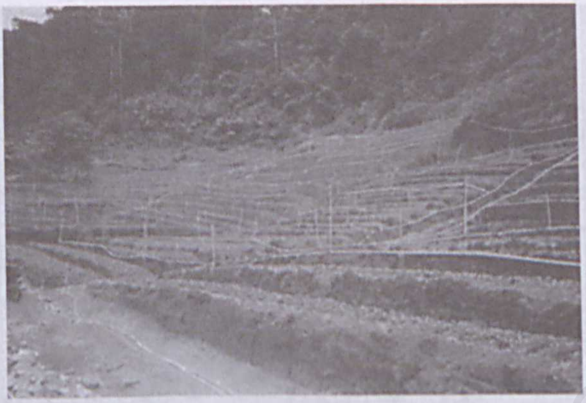


Plate 16 - Poor horticural practices on valleyside slopes can contribute to sedimentation and chemical pollution of adjoining channel systems

Degradation of Environment and Quality of Life

River basin resources development brings about changes in the quality of life of the basin dweller. Changes in the process-response regimes parameters influence the comfort and eventual welfare of the basin dweller (Plate 18; Khairulmaini and Fauza 2003b; Khairulmaini 2003d; Fauza and Khairulmaini 2001;

Plate 17 - New Frontier Development are oftem associated with Upper Basin Systems. The Tourism for example, have led to rapid urbanization and infrastructural developments which in most cases led to severe dissruptions in the process - response systemsof the Upper Basin Systems.

Plate 18 - Environmental quality degradation are associated with changing parameters of the basin processs - response regimes which in turn influences the quality of life of the basin dweller.

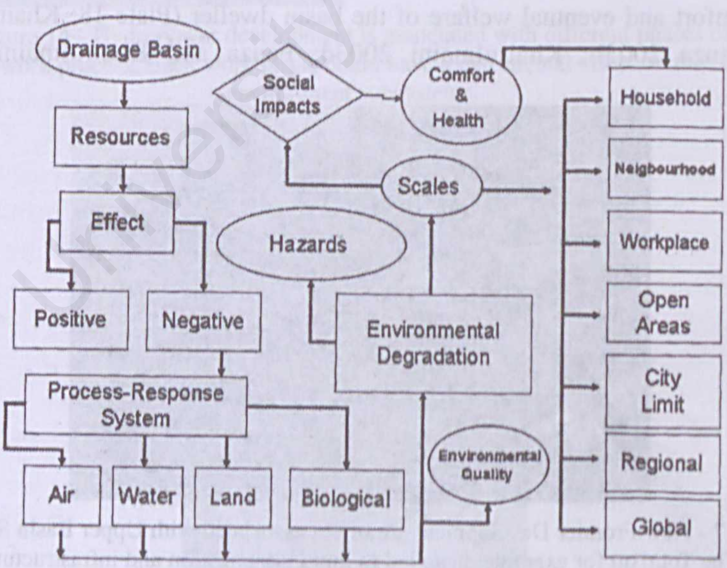


Plate 15 - Degradation of environmental quality affects different levels of society

Khairulmaini and Fauza 2001a). These changes can operate at different spatial scales and thus can be seen to influence the basin dweller at the level of the household unit, neighbourhood (local community) and the overall basin unit itself (Figure 15).

Degradation of environmental quality attributed to changes in the basin process-response regimes can be related to different sources of occurrence, generally, these includes (1) point sources, such as river bank erosion, slope failure and slope erosion, (2) linear sources, such as floods (limited to short duration overbank flow), and certain forms of water pollution, and (3) spatial sources, such as floods (continuous rainfall can lead to overbank flow which could assumed a widespread areal coverage of the basin) and certain forms of water pollution.

Environmental degradation attributed to a particular river basin process could also be modeled by describing the problem within a source – pathway – target model (Khairulmaini 2002b; Figure 16). This model also summarizes the spatial dimension of the impacts of changes in the basin process – response regimes on the quality of life.

Degrading environmental quality due to air and water pollution can also be related to the geomorphometric properties of the drainage basin. Each drainage basin system has its own *conveyor* system that transmits the air and water pollutants from within the basin and replaces it with non-polluted air and water through cycle mechanisms that are controlled by pressure gradient forces within the basins (air and water cycles). Hypothetically, these gradient forces are much more intense for bigger basins, and can only transmits pollutants accordingly. When pollutants in the basins exceed this transmitting capacity, the problem of air pollution and flooding of contaminated water can occur within the basin, which puts greater risks to the basin dweller (Khairulmaini 2001b; Figure 17).

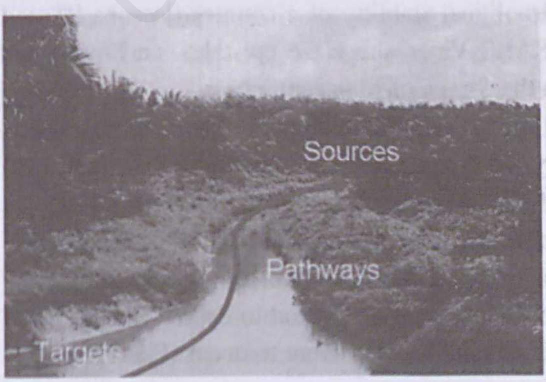


Figure 16 - Environmental degradation and its impact could be model basedon sources, pathways and targets of the hazards. River systems are flow systems and are vector entities thus the induced impacts at the source, along their pathways and eventually at the end of the destination (targets)

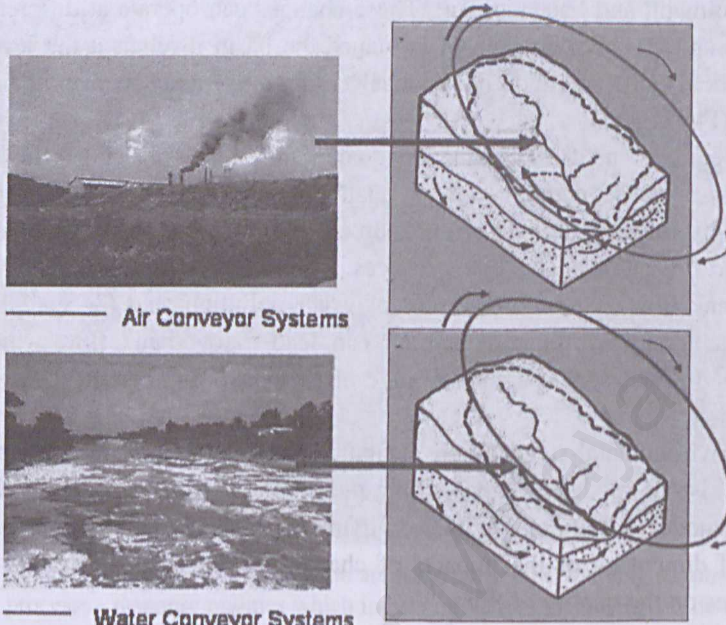


Figure 17 - Drainage basin geomorphometric prperties, pressure gradient forces and pollution dispersal (air and water)

Challenges to National Aspirations – National Security

Environmental security is a subject of continuing Global interests, as compelling evidence of the relationships between resource developments and the increasing intensity of hazards and frequent occurrence of disaster related tragedies have shown to exacerbate risks on human welfare and health and eventually undermining the economic and political stability of a country (lessons learned from the outbreak of JE and SARS Virus, the Haze episodes, and numerous incidences of water pollution in the Straits of Malacca).

Malaysia provides a focus for discussion for a number of reasons, mainly, as she moves into the 21[st] Century the frequencies and magnitudes of traditional hazards (such as flooding) have become more intense. In relation to this Malaysia are becoming more exposed to new threats within her drainage basins (for example slope failures, slope erosion, and channel erosion). Indirectly also, Malaysia's dominant role in global trade and her vision to become a developed nation status could be crippled if a major disaster were to occur (Plate 19).

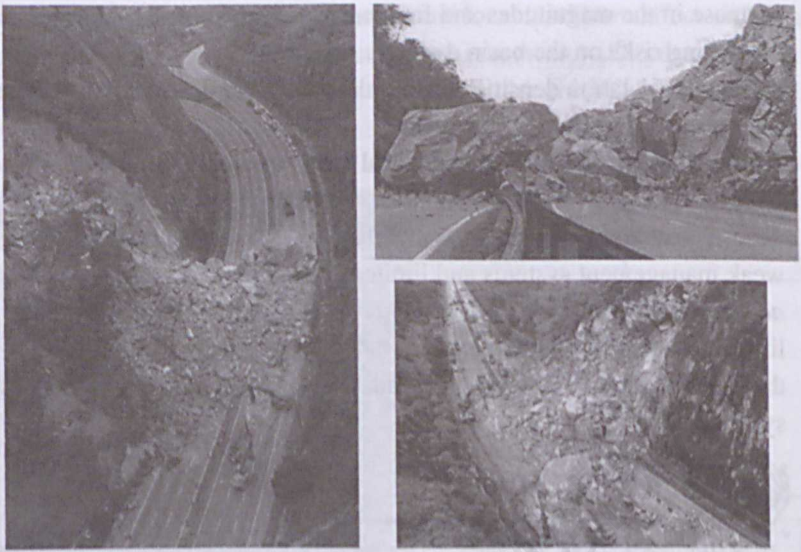


Plate 19 - Poor understanding of basin valleyside slope process - response regimes culminates into rapid slope failures which had crippled Malaysia's part of her transportation system (Bukit Lanjan incident, December 2003)

Finally, Malaysia has that added responsibility to other less developed countries that are dependent on her for investment and other forms of aids to be economically strong and politically stable, as environmental disasters as mentioned could serious disrupt this. Failure to address the potential threat of environmental problems on security is likely to result in economic and political instability, life-threatening effects and possible conflict.

Malaysia's interest in environmental security and conflict resolution could be observed at a number of spatial scales (Khairulmaini 2003d).

There a number of environmental issues that transcends district and state borders. These include river erosion, overbank and inter-tidal flooding, river pollution, degraded riparian ecosystems, waste deposal, and water resources issues (Figure 18).

Drainage Basin Management

Environmental degradation and the impending risks on quality of life within the basin system suggest the need for an effective drainage basin management system. There are a number of reasons for this, and includes the following;

- increase in the magnitudes and frequencies of environmental hazards
- increasing risks on the basin dweller
- increase population densities toward the lower and upper basin systems
- intense river corridor development
- rapid urbanization and infrastructural built-up areas on middle and lower river basin
- general decay in environmental quality thus influencing quality of life
- weak management systems and limited integration
- *ad-hoc* development vs. systematic development
- limited stakeholder participation
- the effects of environmental degradation on adjoining geomorphological systems (coastal zone system)

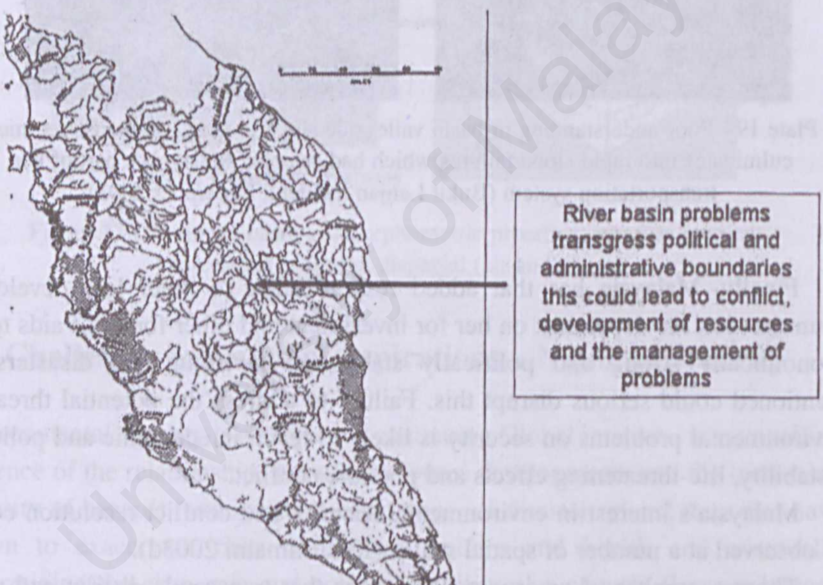


Figure 18 - River basins transgress political and administrative boundaries, thus river basin problems could lead to conflicct, management and development of resources and coordination in managing problems

Current and future river resources development activities and patterns have created and would continue to have a considerable impact on the quality and intrinsic value of drainage basins and in particular the sustainability of environmental resources in Malaysia. Ironically associated with these development activities are a myriad of water-related legislations, regulations, and programs implemented at the federal, state and local level have affected the planning, use and management of land and water resources within drainage basins (Khairulmaini and Fauza 2000a; Fauza and Khairulmaini 2000b).

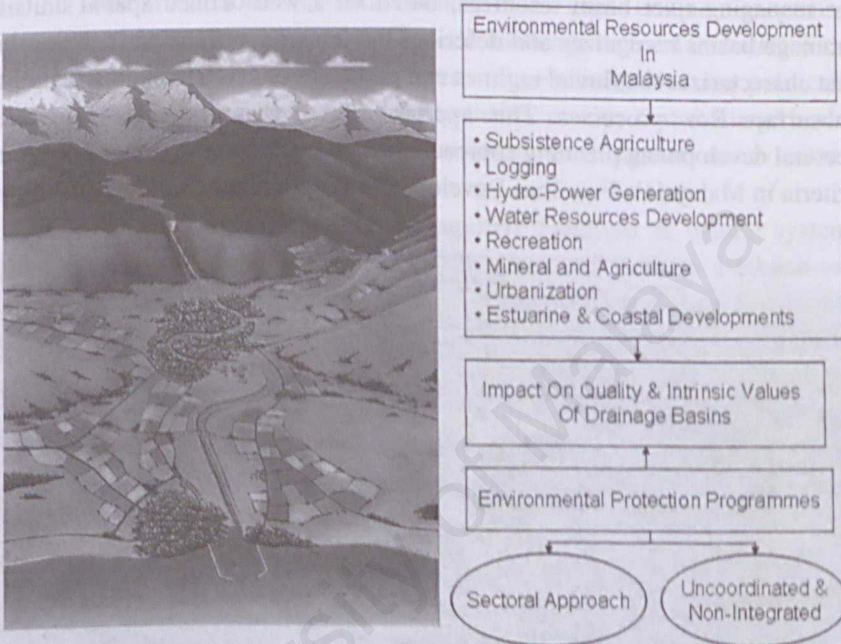


Figure 19 - Environmental recources development in Malaysia

These discrete and usually uncoordinated activities involves the setting up of standards, water quality monitoring, inspection and enforcement, management of waste water treatment and water treatment facilities, urban non-point source pollution control and agricultural non-point source control and river engineering works. Furthermore, numerous educational, technical and financial assistance programs relating to river resources management within the basins have been carried out to manage and control the fluvial regimes of drainage basins (Figure 19).

These activities are carried out by numerous government agencies and are often not adequately coordinated or integrated and are generally sectoral in approach. The challenge here is to design an effective drainage basin partnership among local governments, state agencies, designated area-wide planning agencies, regulated communities, non-governmental organizations relating to environmental conservation works, the private sector and the general public to achieve cost-effective and environmentally-effective solutions to the goals of a sustainable drainage basin program.

The future approach in spatial development planning demands a new model for managing river basin resources, based on a well-defined spatial units-the drainage basins recognizes and describes the interconnections and relationships that characterizes the fluvial regimes and processes on land, including that of the subsurface flow processes. This approach, however transgress the prevalent sectoral development planning approach that are based on well defined economic criteria in Malaysia's Five Year Development Programmes (Figure 20).

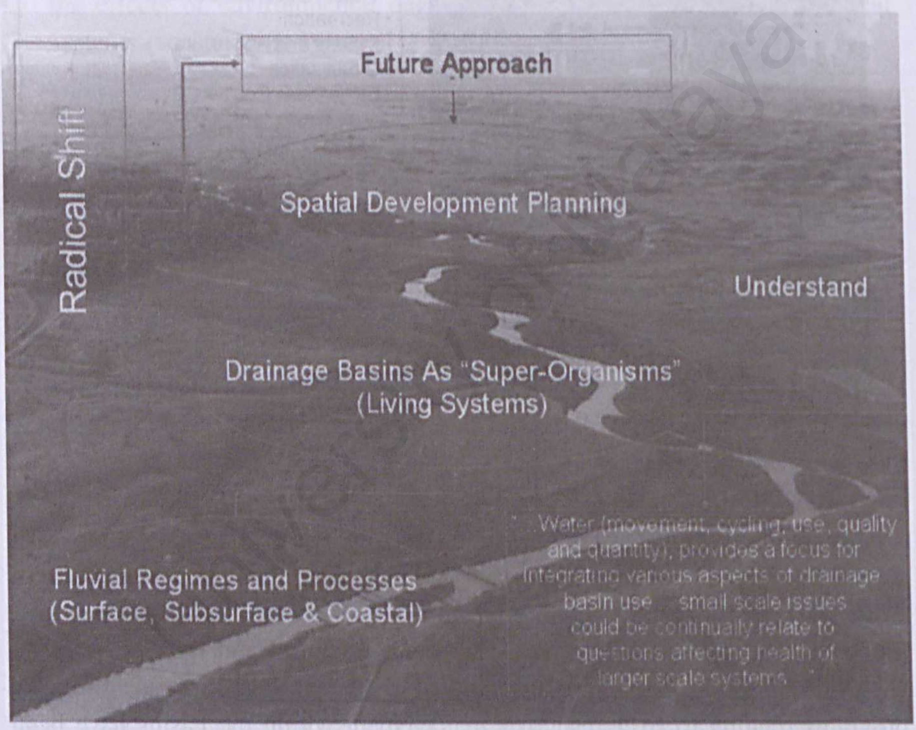


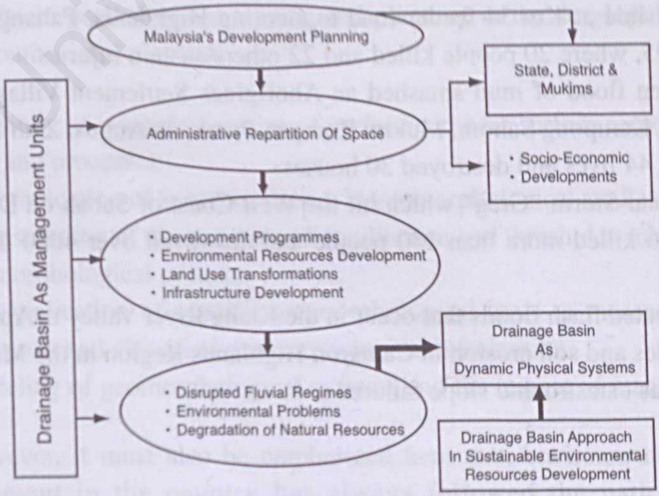
Figure 20- The needs of radical shift in drainage basin management involves the need to appraised drainage basins and its subsystems as dynamic process-response systems

Under the sectoral approach, development projects are implemented using the state or regions which are delineated based on existing administrative boundaries. These spatial units do not conform to the hydrological regimes of drainage basins (they tend to obliterate the process-response regimes of geomorphological systems). Drainage basin system boundaries (including its subsystems) seldom if ever coincide with jurisdictional boundaries such as states, cities, or district boundaries.

Like drainage basins, aquifers (phreatic divides) too are natural hydrological units that seldom match jurisdictional boundaries but needs unique management techniques. This has long presented a special challenge to local and state water resource managers whose geographic areas of responsibilities are politically rather hydrologically based. It further complicates matters that drainage basins occur on a range of spatial scales from sub-national or regional down to local scales.

At any scales, drainage basins and aquifers functions as natural systems within which resource managers and stakeholders can work to establish and maintain the best possible combination of ecological conditions and human welfare and comfort. A radical shift is thus needed to manage the country's drainage basins – from that which describes drainage basins as purely as economic planning units to an approach that describes drainage basins as dynamic functional entities.

The drainage basins provide a powerful study and management unit which integrates the various components of the biophysical environment (Figure 21). The drainage basin is also a useful concept for integrating science with historical, cultural, economic and political issues. Water (movement, cycling, use, quality and quantity), provides a focus for integrating various aspects of drainage basin use and for making local and regional connections.



Focusing on the drainage basins as dynamic entities, one can start with a study of any of the small subsystems that make up a unit basin system and continually relate these small scale issues to questions affecting the health of larger scale drainage basin systems.

This new approach would be guided by the core principle that aim to prevent disruptions and changes to the quality and quantity of natural fluvial regimes, achieved and sustain environmental improvements and meet other goals that is needed for an effective sustainable environmental management.

Conclusion

It is beyond dispute that, to be successful, planners, environmental managers and developers, one needs to be well informed about the nature and character of geomorphological systems, and therefore need the services of the geomorphologists. However, in Malaysia, contribution by geomorphologists to further reinforce decision making in environmental resources development is still lacking.

The last decade, Malaysia has witnessed a tremendous increase in the frequency and magnitude of geomorphological disasters. These disasters have claimed many lives and have destroyed a sizeable amount of individual and national properties. The disasters include,

- The collapse of Highland Towers Condominium in Hulu Kelang, Selangor on December 11th 1993, where 48 people were killed.
- A Landslide at Km 34 feeder road to Genting Highlands, Pahang on June 30th 1995, where 20 people killed and 22 others sustain injuries.
- A sudden flood of mud smashed an Aborigines Settlement Village at Pos Dipang, Kampong Sahom, Mukim Kampar, Perak, on August 29th 1996 that claimed 44 lives and destroyed 30 houses.
- A Tropical Storm "Greg" which hit the West Coast of Sabah on December 26th 1996 killed more than 230 people and destroyed over 4000 dwellings there.
- The repeated flash floods that occur in the Klang River Valley in April 2001.
- Landslides and soil erosion in Cameron Highlands Region in the May 2001.
- Numerous catastrophic slope failures

There are other disasters that have badly affected the country. Most of these disasters have two major components to them, (1) they are directly related to man's activities on the environment (the exploitation of land resources), and (2) they are associated with fluvial geomorphological systems (drainage basins and their valleyside slopes and channel slopes). As geomorphological systems are affected it thus becomes obvious of the potential role that geomorphology have to play in hazard management and disaster reduction in the country.

This lecture describes the importance of fluvial geomorphological studies and how it can contribute to river basin development and sustenance, in light of the increasing utilization of river basin resources. Fluvial geomorphological studies is central to understanding rivers, as rivers are part of this morphogenetic assemblages (geometric) of the basin system, valley side slopes and channels slopes that describes the surface of the earth. The exploitation of river basin resources has increased tremendous risks to the basin dweller inherent in the changing parameters of the river basin process – response regimes.
Environmental problems such as floods, rapid slope failures, pollution, soil erosion, riparian ecosystem degradation and problems associated with sedimentation have all contributed to decaying quality of life in the basins. This hinges strongly on issues affecting the nation's welfare and not far from potential threats to national security. The importance of incorporating fluvial geomorphological knowledge can contribute to effective hazard management and the sustenance of not only river basin resources development but also a high quality of life for the basin dweller. This lecture had touched on a number of important issues in fluvial geomorphological studies, that is important prerequisite in good decision making and planning in the development of river basin resources, these include;

- The study of interrelationships of surface and near surface responses, materials and processes.
- The application of Systems Theory in geomorphological studies, such as the understanding of the concepts of equilibrium and thresholds inherent within geomorphological systems.
- The application of specific geomorphological tools to measure, analyses, interprets and classified geomorphological information.
- Modeling of geomorphological systems and the impact of man.

However, it must also be emphasized here that, environmental resources *development in the country has always followed the path of sectoral* development (Khairulmaini and Fauza 2000). The potential for development (such as economic factors) takes top priority as compared to the sensitivity of the environment (geomorphological systems). It is here, where the dilemma lies. Thus we have problems of floods, landslides, soil erosion and other forms of geomorphological hazards in areas where the geomorphologists would classify as sensitive or high risk (disaster prone) areas. Perhaps this could be one of the greatest frustration that geomorphologists encounter, knowing fully well that the amount of time and effort spend on good quality research would be overridden in the final decision making affecting environmental resources development. In spite of these, geomorphologists can contribute to effective decision making as mentioned above.

Wassalamualaikum Warahmatullahi Wabarakatuh and Salam Sejahtera.

Thank you for attending this inaugural lecture.

References

1. Chan, J.H., Khairulmaini, O.S., Harith, A., Low, K.S., Cho, F.K.and Awang, J, 2001. An Assessment of the sustainable development of Cameron Highlands. *Proceedings of the 6th Southeast Asian Geographers Conference on Southeast Asia's Quality of Life in the New Millennium.* 12-15 November, 2001, University Kebangsaan Malaysia, Bangi, Selangor, Malaysia.
2. Khairulmaini, O. S. 1994e. "Geomorphology and Bathymetrical Considerations in the Identification and Ranking of Potential Power Station Sites in Peninsular Malaysia." *Geoforum*, Pergamon Publications, London. Vol.25 (3), 1994, 381-399 pp.
3. Khairulmaini, O.S. 2003e. Globalisation and Environmental Degradation: An Appraisal. In: *Malaysia and Globalisation: Issues and Challenges in the 21st Century* (Eds. Khairulmaini, O.S. and Kanthasamy, N.), pp. 263 – 286.
4. Khairulmaini, O.S.1993. The water erosion and mass movement cascades of accelerated slope processes. *Malaysian Natural Resources-Sustainability, Development and Strategies*, Ipor, I.B. et al (eds). Faculty of Resource Science and Technology, University Malaysia Sarawak. 125 -132 pp.
5. Khairulmaini, O.S. 1987a. Erosion and Deposition in Semi – Arid Basins. Unpublished PhD Thesis, University of Sheffield, England.
6. Khairulmaini, O.S. 1987b. The application of Black and White Panchromatic Aerial Photographs in Drainage Basin Analysis. *Proceedings of the ASEAN-US Watershed Seminar*, Kuala Lumpur, 1987.
7. Khairulmaini, O.S. 1989. A Seismic Analysis of Valleyfloor Fills in Semi-Arid Drainage Basins. *Heinrich Rohdenburg Memorial Symposium – Theory and Simulation of Infiltration, Overland Flow, Erosion, and Deposition Processes and their relevance to Landscape Evolution*. 30th August – 2nd September, Braunschweig-Konigslutter, West Germany. International Association of Geomorphologists.
8. Khairulmaini, O.S. 1991. "Micro-Erosional Features: An Observation of Control Response Relationships of Soil Erosion Pillars". *Malaysian Journal of Tropical Geography*, Vol. 22(2), 1991, 113-123 pp.
9. Khairulmaini, O.S. et al. 1991. *The identification and selection of sites for future power stations in Malaysia*. Final Report. Institute of Advance Studies – TNBE.
10. Khairulmaini, O.S. 1992a. Process-Response Relationships under Secondary Vegetation Systems. *Proceedings of the Malaysian Ecological Conference 1*. University Pertanian Malaysia, 59-65 pp.

11. Khairulmaini, O.S. 1992b. Geomorphological and Bathymetrical Characteristics and their influence on the setting up of Nuclear Power Plants. Paper presented at the *Workshop on Quality Assurance Consideration and Technical Procedures for Site Selection of Nuclear Power Plants*, 15-25 June 1992. Kajang, Selangor, Tenaga Nasional Berhad, Nuclear Energy Unit, Ministry of Science, Technology and Environment and International Atomic Energy Agency.
12. Khairulmaini, O.S. 1993. "A Seismic Analysis of Valley fills In Ephemeral Drainage Basins". *Indonesian Journal of Geography*, Vol.23 (65), 1993, 135-163 pp.
13. Khairulmaini, O.S. 1994. Development and Man-Induced Processes- The Problem of Accelerated Slope Processes in Housing Estates. Paper presented at the *Fourth Malaysia-Singapore Forum*, Kuala Lumpur, Malaysia.
14. Khairulmaini, O.S. 1994a. "Perception and Adaptation to the Flood Hazard – A Preliminary Study". *Malaysian Journal of Tropical Geography*. Vol.25 (2), 1994, 99-106 pp.
15. Khairulmaini, O.S. 1994c. *Geographical Applications of Aerial Photographs* (C.P.Lo, Author). Dewan Bahasa Dan Pustaka, 1994. ISBN 983-62-1524-7
16. Khairulmaini, O.S. 1994d. "The Problem of Spatial Autoregression in Drainage Basin Analysis". *Jernal ILMU ALAM*, Vol.22, 1994, 95-109 pp.
17. Fauza, A.G. & Khairulmaini, O.S. 1995. "Kemerosotan Kegiatan Penanaman Padi Di Negeri Sembilan – Satu Kajian Kes Di Mukim Batu Hampar, Rembau, Negeri Sembilan. *Pemikiran Ekonomi Melayu*, 1995. Penerbitan Akademi Pengajian Melayu, Universiti Malaya. 132-146 pp.
18. Khairulmaini, O.S. 1995. "Erosional and Depositional Features of Disturbed Geomorphological Systems". *Indonesian Journal of Geography*, Vol.27 (69), 1995, 1-30 pp.
19. Khairulmaini, O.S. 1995b. "Colluvium Thickness and Its Relationships to Vegetation Cover Density and Slope Gradient. *Geografia Fisica E Dinamica Quaternaria, Bollettino del Comitato Glaciologico Italiano*.Vol.17, 1995, 209-217 pp.
20. Khairulmaini, O.S. 1996a. "The Effects of Vegetation On The Surface And Soil Subsystems Of Hillslopes". *Malaysian Journal Of Tropical Geography*, Vol. 27(1), 1996, 55-65 pp.
21. Chen Z., Khairulmaini, O.S. et al 1996.*Asian Geomorphic Map*. Nanjing Institute of Geography and Limnology, Academy of Science, China, IGU and UNESCO Publications 1996.

22. Khairulmaini, O.S. & Fauza, A.G. 1997. "Pemodelan Faktor Tolak – Tarik Di Dalam Pempupusan Kawasan Tradisi Penanaman Padi". *Jernal Sarjana*, Vol, 14. 1-18 pp.
23. Khairulmaini, O.S. 1997. "Channel Adjustments And Planform Changes – Part Of The Upper Linggi River System". *Akademika*, Vol.50, 1997, 43-55 pp.
24. Khairulmaini, O.S. 1998a. The Drainage Basin As A Fundamental Unit In Environmental Management Planning". *Jernal Sarjana*, Vol. 15. 16-33 pp.
25. Khairulmaini, O.S. 1998b. Environmental Issues and Management in Malaysia. *Lecture Series, 39th International Development and Cooperation Asia Seminar, 9th* October 1998, University of Hiroshima, Japan.
26. Khairulmaini, O.S. 1999a. "River Systems" In: Sham Sani (ed) *The Encyclopedia of Malaysia – The Environment*, Didier Millet Publications, Singapore. 44-45 pp.
27. Khairulmaini, O.S. 1999b. Issues And Challenges Affecting Hydropower Development In Malaysia: A Study Of The Sungai Pergau Basin. *Jernal Sarjana*, Vol.16. 75-87 pp. 75-87 pp.
28. Khairulmaini, O.S. 1999c. "The Titiwangsa Range" In: Sham Sani (Ed) *The Encyclopedia of Malaysia – The Environment*, Didier Millet Publications, Singapore. 30-31 pp.
29. Khairulmaini, O. S. and Fauza, A. G. 2000a. "A Flood Disaster Management Model for an Effective Disaster Management System in Malaysia". Chapter 20 in *Integrated Drainage Basin Management and Modeling*. Edited by Jamaluddin Md Jahi et.al. UKM Bangi, Selangor. 285-294 pp.
30. Khairulmaini, O. S. and Fauza. A. G. 2000b. "Drainage Basin Management in Sustainable Regional Development Planning". Chapter 21 in *Integrated Drainage Basin Management and Modeling*. Edited by Jamaluddin Md Jahi et.al. UKM Bangi, Selangor. 294-304 pp.
31. Khairulmaini, O.S. 2000b. Malaysia's role in sustainable development of natural resources. *Best Practices in Environmental Management* (Abu Bakar, A.M. ed). Malaysia's Institute of Islamic Understanding, Kuala Lumpur. Chapter 8, 151-177 pp.
32. Khairulmaini, O. S. 2001b. Natural Resources Development: Environmental Hazards and Geomorphological Systems Appraisal- Continuing Divergence or a Need for Convergence? *Paper Presented At The National Conference Of Geography In National Development,* 15-17 May 2001, University of Malaya, and Kuala Lumpur.

33. Khairulmaini, O.S. and Fauza, A.G. 2001a. The Flood Hazard Threat – A First Approximation Model. IRPA R&D RMK Project No. 08-02-03-0345. *Proceedings IRPA Seminar RM7,* University of Malaya. 685 – 689 pp.
34. Khairulmaini, O.S. and Fauza, A.G. 2001b. Environmental Management in Malaysia-A Perspective. *Indonesian Environmental History*. Eden Publications, Leiden, Netherlands. Vol.16, 6-9 pp.
35. Khairulmaini, O.S. et al. 2001a. *The Development of the Cameron Highlands – Batang Padang Hydroelectric Catchment Management Systems*. Institute of Advance Studies & Tenaga Nasional Bhd. Final Report 2001.Institute Of Advance Studies University of Malaya.
36. Khairulmaini, O.S 2002c.*Environmental Problems and Management in Malaysia.* Fo Guang University, Republic of China, Lecture Series, 24-20 November 2002.
37. Khairulmaini, O.S. 2002a. Drainage Basin Management for Hydropower Generation in Malaysia – Issues and Challenges in the Twenty First Century, the *Jahangnirgar Review*, Part 2: Social Science, Vols. 26-27, 2002, pp. 23 – 35.
38. Khairulmaini, O.S. 2002b. The Precautionary Principle – Improving Legal Instruments in ASEAN Environmental Law. In: *Malaysia, Singapore and ASEAN in an Age of Globalisation* (Eds. Khairulmaini, O.S. and Kong, L.), pp. 303 – 322.
39. Ahmad Jailani, M.Y.; Nobuka, N. and Khairulmaini, O.S. 2003. The effects of drainage basin geomorphometry on minimum low flow discharge – A study of small watersheds in the Kelang River Valley in Peninsular Malaysia. *Journal of Environmental Sciences*. Chinese Academy of Sciences. Vol.15 No.2. 241-249 pp.
40. Khairulmaini, O.S. 2003c. A Geomorphological System Appraisal of Urban Landslides in Malaysia. In: *Society, Space and Environment in a Globalised World* (Wan Ruslan Ismail et al. editors). University Sains Malaysia Publications, 330-347 pp.
41. Khairulmaini, O.S. 2003d. Environmental Hazard Management – A Case of Prevention Better than Cure. In : *Disaster Management – Disaster Risks and Vulnerabilities Reduction* (Badruddin A Rahman and Mohd Noor Mohd Sharif editors), University Utara Malaysia Publications, Volume 2, 1-12 pp.
42. Khairulmaini, O.S. and Fauza, A.G. 2003a. Social Impact Assessments and Environmental Resources Developments. In: *Population, Environment and the Challenge of Development.* Akansha Publishers, New Delhi, India, 48-68 pp.

43. Khairulmaini, O.S. and Fauza, A.G. 2003b. Urban Environmental Quality and its Impact on Urban Dwellers: A Model for the Klang Valley Basin. In: *Proceedings of the International Conference on Environmental Management and Technology* – 'A Clean Environment Towards Sustainable Development', MUCED-DUCED-SACUDE and TUCED, pp. 419 – 426.
44. Khairulmaini, O.S. and Fauza, A.G. 2003b.*Hydropower Development in Upper Basin Systems: A Case Study of Sustainable Development in Cameron Highlands-Batang Padang Basin, Malaysia.* First Southeast Asia Water Forum: Strengthening Regional Capacity Through Best Practices in IWRM, 17-21 November 2003, Chiang Mai, Thailand, 69 pp. Asian Institute of Technology.
45. Khairulmaini, O.S. et al. 2003a. *A Fast Track Analysis of Potential Power Station Sites in East Peninsular Malaysia.* Final Report. Institute of Advance Studies and Tenaga Nasional Berhad. University of Malaya
46. Khairulmaini, O.S. et al. 2003b. *A Reassessment Study and Ranking of Sites for Potential Coal Fires Stations in Peninsular Malaysia.* Final Report. Institute of Advance Studies and Tenaga Nasional Berhad. University of Malaya.
47. Khairulmaini, O.S. 1996b. "Route Evaluation For A 500KV Electric Transmission Line In Malaysia: An Environmental Assessment", *ASIAN Journal Of Environmental Management*, Hong Kong University Press. Vol. 4(1), 1996, 19-30 pp.
48. Fauza A. G. and Khairulmaini, O.S. 2000. "The Growth of Cities, Environmental Decay and the Impact on the Urban Poor: Experiences and Lessons from the City Of Kuala Lumpur".*(In: Cities in the 21st Century – Urban Issues and Challenges*", Editors Sharifah Norazizan, S.A.F. et al.). University Pertanian Malaysia Press. 24-44 pp.
49. Khairulmaini, O. S. and Fauza, A. G. 2000. "Modeling Urban Growth, Environmental Degradation and Urban Environmental Management – A Preliminary Appraisal for the Klang River Basin".(*In: Cities in the 21st Century – Urban Issues and Challenges*", Editors Sharifah Norazizan, S.A.F. et al.). University Pertanian Malaysia Press. 111-129 pp.
50. Khairulmaini,O.S. 1995. Erosion response and its relationships to vegetation cover density and slope gradient – An observation for part of Murcia Province SE Spain. Erosion and Land Degradation in the Mediterranean. International Geographical Union Study Group on Erosion and Desertification in Regions of the Mediterranean Climate, University of Aveiro, Portugal. 27 – 45 pp.