Stream Corridors in Watershed Management

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Development Strategies for Fragile Lands

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STREAM CORRIDORS IN WATERSHED MANAGEMENT

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The U.S. Agency for International Development (USAID) Development Strategies for Fragile Lands project was initiated in 1986 to stimulate sustainable uses of steep and humid tropical lands where present practices lead to deterioration of productivity. Project activities include technical assistance, applied research, and communication of useful information among development researchers and practitioners. Fragile lands management in steep lands generally has taken a watershed focus because of the close interrelation among natural processes, human activities, and downstream effects. This paper addresses a critical element in maintenance of the quality of the water resource at the watershed scale.

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INTRODUCTION

The rhetoric of watershed management extols the benefits of clean water, flood control, and conserved soil, timber and wildlife. This enthusiasm is backed by greatly increased expenditures by donor agencies in the developing world. The problems are real: reservoir sedimentation rates are alarming; and increasing human pressure on the land has accelerated soil erosion, reduced local production and income levels, and created scarcities of wood and loss of natural systems. In practice, watershed management has focused on reforestation of degraded areas, on-farm soil conservation, and "works of art" -- as gabions and check dams are so delightfully referred to in Spanish and French. Interventions are rarely based on an integrated management plan addressing whether or where they are needed, if they are cost effective, or how they fit into an integrated management plan. Failure to distinguish in the field between relatively uncontrollable natural erosion processes and those that are accelerated by human activities can be costly and threatens the credibility of our management rhetoric.

The Development Strategies for Fragile Lands project is particularly concerned with the management of human activities in upper watersheds where inappropriate uses of resources and population pressure have led to accelerated resource deterioration. This paper specifically addresses the management of stream corridors. Sediments from uplands, together with materials excavated by streams themselves, move through a network of stream corridors. How these corridors are managed is critical to the achievement of both local and downstream benefits from overall watershed management activities.

Stream corridors form the transitional zone of significant interaction between a terrestrial and an aquatic ecosystem (Karr and Schlosser, 1978). In the context of this definition, the land-water interface may be abrupt, as in the case of a mountain stream in a V-shaped valley, or broad, along a meandering river in a floodplain. The terms riparian or buffer strip are often used in this paper and have approximately the same meaning as stream corridor. Agriculture, road building, and urban-industrial activities produce sediments, chemical compounds, and organic materials that can significantly impact downstream water resource values. Empirical and theoretical studies have demonstrated the technical and economic feasibility of utilizing the natural buffering or filtering capacity of stream corridor environments to mitigate these land-use impacts. In their 1978 *Science* paper, "The Land-Water Interface," Karr and Schlosser introduced concepts which have added a new dimension to watershed management in developing countries.

Stream corridor management includes the maintenance of riparian and instream vegetation and maintenance of overall channel morphology with its obstructions, rapids, meanders and adjacent wetlands. These actions together result in:

- Filtering of sediments contained in overland runoff;
- Reduction in bank erosion;
- Attenuation of flood peaks;
- Control of eutrophication in headwater streams;
- More productive fisheries; and
- Maintenance of the diversity of stream corridor ecosystems.

Stream corridor management is most effective in delivering these benefits if integrated into an overall program of watershed management. Effective management of headwater streams (1^{st}-3^{rd} order)[1] offers higher benefits per stream segment affected. If headwater stream corridors are neglected, management of river segments in the lower reaches of a watershed will be less effective (Petersen et al., 1987).

Financial resources are never sufficient to permit all possible management interventions in watersheds thousands of hectares in extent. Scarce resources must be allocated to those activities which together contribute most to overall system maintenance, the well-being of local populations, and to downstream water resource users. Stream corridor management, particularly along smaller streams in both upper watersheds and lowlands, can be a cost-effective contribution to a watershed management program.

CHARACTERISTICS OF A STREAM CORRIDOR

Stream corridors encompass the interface between the terrestrial and aquatic environments. This interface may be abrupt or a gradual transitional zone, depending on regional watershed climate and geology, and local lithology and geomorphology. Karr (1980) lists four major interrelated characteristics of a stream that determine its integrity or function within a watershed:

- Habitat structure -- stream corridor vegetation, rooted and floating instream vegetation, sorted materials ranging from silt to boulders, logs, riffles, pools and meanders;

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[1] Beginning with the uppermost tributaries along the stream system of a watershed are first-order streams; two first-order streams converge to form a second-order stream, two second-order streams to form a third-order stream, and so on. In each case, at least two streams of order *n* are required to form a stream of order *n+1*.

- Flow regime -- the variations in volume, rate of stream flow occurring seasonally or in response to a specific climatic event such as a storm, and to changes in land use within a watershed;

- Water quality -- physical and chemical parameters such as temperature, dissolved oxygen, suspended solids, nutrients, pH and toxic substances that reflect the natural state of a stream as well as the impact of human activities upstream; and

- Energetics -- form and source of energy and nutrients in a stream, and its process-oriented attributes such as production, respiration, energy flow, nutrient cycling, and trophic dynamics.

In the above list, habitat structure is the independent variable; any change in it will in turn affect flow regime, water quality, and energetics. Floodplain vegetation, including wetlands, serves to filter or settle out sediments and attached nutrients from uplands and flood waters and to attenuate flood peaks. Overhanging streamside or riparian vegetation serves the multiple functions of bank stabilization, water temperature modification through shading, and as a source of food for aquatic organisms. The instream habitat, both living and non-living, supports a variety of aquatic and amphibious organisms, traps sediments, and reduces stream erosive energy.

Habitat structure, flow regime, water quality, and energetics differ in each stream segment, but reflect the cumulative effects of natural processes and management upstream. The corridor ecosystem that has evolved within any stream segment of an undisturbed watershed can be assumed to be functioning optimally in terms of its productivity and capacity to provide downstream benefits. Each segment is physically, biologically, and functionally distinct. Any change in the structure, flow regime, or water quality of a particular segment is likely to be stressful to its integrity and to that of downstream segments.

The typical stream profile of concern focuses on the headwater segments:[2] first-, second-, and third-order streams. Low-order streams (1st-3rd order) generally have a riparian forest overhanging the stream bed. The development of this riparian zone is governed by local geomorphology and the duration of stream flow in the dry season. Since they are often shaded and receive large amounts of organic material from riparian vegetation, these streams are generally heterotrophic (after Warner and Hendrix, 1984).

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[2] Various classification systems for streams and stream habitats have been developed. Frissell et al. (1986) review several and go on to classify streams and watershed environments in the context of a regional biogeoclimatic landscape classification. This hierarchical framework classifies stream systems by stream, segment, reach, pool/riffle, and microhabitat.

Factors Affecting the Stream Corridor System

The overall stream corridor system, in the context of the river continuum concept (Vannote et al., 1980),[3] is shaped by both the physical environment and by inputs from further upstream. Figure 1 illustrates the various forces which interact with the terrestrial and aquatic environments to form the stream corridor ecosystem.

The diagram applies to any stream corridor environment. A particular stream will have its own characteristic structure and range of energy and material flows. For instance, a headwater stream in the mountains will be strongly influenced by the substrate morphology and geology, organic matter input directly from riparian vegetation, and the degree of shading by overhanging vegetation. Floodplain creeks are influenced by different conditions as they meander through a landscape of gentle slopes and subtle changes in the local pattern of river-laid sediments. Larger streams and rivers are more influenced by upstream inputs of organic matter and sediment and runoff regime than by inputs from adjacent lands.

The stream corridor system, after an extended period of time, will reach a dynamic equilibrium subject to periodic fluctuations with its physical environment (Mahoney and Erman, 1984). If a system has evolved over thousands of years with only gradual successional changes, then it may be assumed that the system has achieved optimum utilization of available energies for the creation and maintenance of an ecological structure adapted to a particular set of factor conditions. For example, in the streams of the *llanos* of Venezuela,[4] fishes have evolved various strategies in adapting to conditions of high water volume and suspended solids in the wet season and low-flow, clear-water conditions of the dry season (Dickinson, 1982). A marked change in the *llanos* system or the same conditions imposed suddenly on a different system would be highly stressful on many organisms and processes. It is not so important what the conditions are or that they differ markedly from one system to another, but rather that given sufficient time organisms achieve an optimum utilization of a particular habitat and that any major change is likely to be stressful to the integrity of the system.

In nature, systems and organisms evolve mechanisms to overcome or avoid stress. Adaptation to stress requires an expenditure of energy that would otherwise go into greater production and diversity had the stress not been present. Stress below certain threshold levels can give competitive advantage to certain ecosystems or organisms over others. Hurricanes, fire, and flooding serve to rejuvenate many systems by redistributing organic matter and minerals resulting in a burst of net production (Lugo, 1978).

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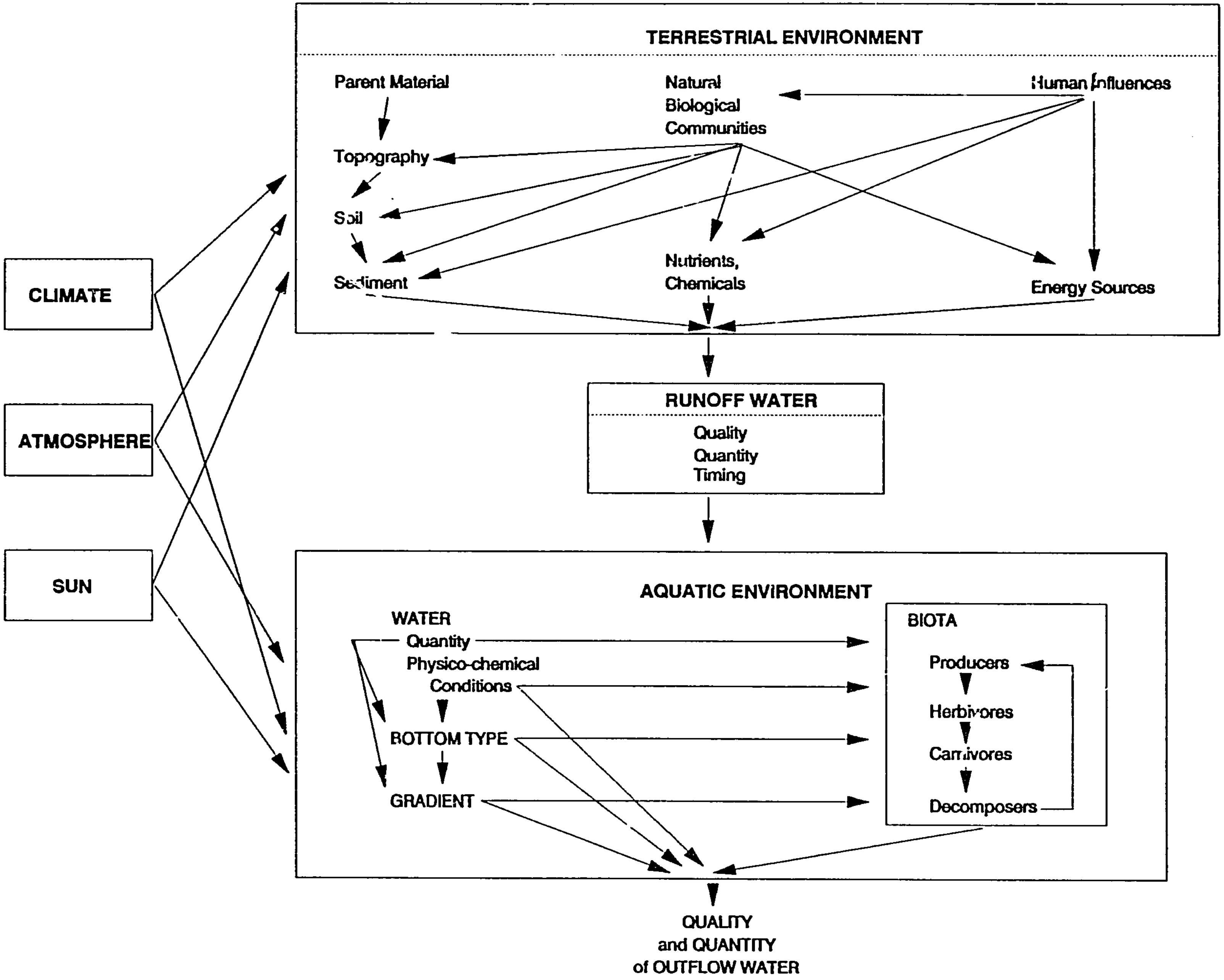
[3] They propose that the coalescing network of streams in a river drainage system constitutes a continuum of physical gradients and associated biotic adjustments.

[4] Part of an extensive alluvial plain subject to seasonal flooding from intense wet season rains and runoff from portions of the northern Andean Cordillera.

Figure 1. Conceptual model of the primary inputs and outputs of a stream corridor environment, showing the complexity of the land-water interface (Karr and Schlosser, 1977).



Quality of the Water Resource

The quality of the water resource, the underlying concept of stream corridor management, arose in response to questions about the efficacy of programs funded by the U.S. Environmental Protection Agency (EPA) designed to improve water quality (Karr and Schlosser, 1978). EPA programs to re-create fishable and swimmable waters as well as Soil Conservation Service small watershed projects designed to prevent flooding in rural areas all involved substantial investments in channelization, clearing of streamside vegetation and structures to stabilize grades and stream banks. The sanitary/civil engineering approach then favored by these influential agencies focused narrowly on physical/chemical measures of water quality. A straightened stream may receive water meeting the highest water quality standards, yet support only a fraction of the diversity and biomass of life that existed in the same stream prior to its "improvement." Furthermore, such modified stream corridors lack the capacity to buffer entering wastes or mitigate downstream flooding and sedimentation. In contrast, the broader perspective on the **quality of the water resource** addresses the intricate web of dynamic interactions among plants, animals, the physical substrate, and flowing water that characterize the stream corridor ecosystem.

Neither the establishment of water resource quality standards for sport fishing and swimming nor the maintenance of biological diversity are priority concerns of most developing countries. However, impacts of degraded water resource quality on subsistence and commercial fisheries, potable water supplies, and on flow regime are matters of immediate interest.

Goods and Services

Goods are tangible products provided by streams and their corridors which can be utilized by humans. Examples include water for domestic, industrial, and agricultural use; fish and other aquatic fauna; plant products such as timber and reeds; soil renewing sediment deposition; hydroelectric power; and, in some areas, sorted sand and gravel. Goods often have a price in the economy related to supply and demand functions and cost of extraction.

Services derive from the structure and functioning of the stream corridor ecosystem. A service of obvious value is the provision of conditions suitable for the sustained output of the goods mentioned above. A particularly valuable service of both riparian and wetland ecosystems is low-cost removal of wastes from upland runoff through physical, chemical, and biological processes (Karr and Schlosser, 1977; Karr 1980; Lowrance et al. 1984, 1985; Mahoney and Erman, 1984; Rhodes et al., 1985; Roseboom and Russell, 1985; Young et al., 1980). Odum has estimated that waste water treatment using wetlands required 1/25th of the fossil fuel energy that is required for tertiary treatment facilities (Odum, 1978). More than one process is involved. Perhaps most common is physical settling and trapping of sediment particles along with the mineral compounds, such as agricultural chemicals, adhering to the soil particles. This buffering effect is performed by the strip of vegetation forming the corridor which physically intercepts sediments. Efficiency is determined by various factors, including the physics of particle settling, corridor width, vegetation structure, and slope, as illustrated in Table 1.

Wildlife may use corridors as local habitat or pathways to move seasonally between upland and lowland habitats (Harris, 1984). Other important corridor values include the absorbing and slow release of flood waters, transportation, recreation, and the maintenance of the diversity of both the aquatic and terrestrial biota (Bojorquez, Aguirre, and Ortega. 1985; Burgess and Bider, 1980; Moring et al. 1985; Shah and Thames, 1985). Because international development financing is conditioned upon efforts to maintain biological diversity, this becomes a concern of both donor and recipient, especially in the tropics where much of the diversity loss is occurring (Agency for International Development, 1982). USAID is pledged to the maintenance of biological diversity as an integral part of the projects it funds as specified in the Foreign Assistance Act of 1985, Sections 118 and 119.

Limitations, Costs and Beneficiaries

All the goods and services mentioned above cannot be provided at a maximum rate simultaneously. Some uses are complementary while others are mutually exclusive. Harvesting of forage and selective cutting of timber are compatible with the conservation functions outlined above. On the other hand, hydroelectric power generation in the tropics precludes fish migration unless fish ladders can be devised for an array of fishes whose migratory habits and climbing abilities are unknown. Stream corridors have limits to their capacity to absorb the effluents of human activities. We can capitalize on the capabilities only up to a certain level without overloading the absorptive and regenerative capacities of an ecosystem with resultant deterioration of other values.

The direct cost of corridor maintenance is the cost of achieving appropriate land use through education, compensation, and enforcement. The difficulties should not be overestimated. Small farmers are strongly attracted to stream corridors as a source of water and other necessities, a transportation route, and as the location of fertile terraces and floodplains. These farmers have few options. However, well-planned and timely rural development investments in production intensification such as irrigation, soil conservation, water supply, and sanitation can more than compensate farmers for limitations imposed on corridor use and result in restored sources of goods and services mentioned above.

Downstream fisheries and users of water for agriculture, energy generation, transportation, and urban consumption benefit from the higher water quality and regulated flow regime. There are no direct means for the downstream beneficiaries of clean water to compensate those upstream whose use of the stream corridor may

TABLE 1.

Factors Affecting the Efficiency of Buffer Strips and Stream Channels in Removing Sediment and Nutrients from Surface Runoff

FACTORS	NATURE OF RELATIONSHIP
Width of Vegetated Strip	As the distance surface runoff flowing through a buffer strip increases, the proportion of original sediment and nutrient concentration remaining in surface flow decreases.
Slope of Vegetated Strip	Below some critical threshold slope, filtering efficiency is a constant. As slope increases above the critical angle, filtering efficiency declines.
Slope Length Before Water Reaches Buffer Strip	Longer and steeper slopes tend to yield more suspended solids. Thus, filter efficiency declines as these increase.
Vegetation Type	Precise functional relationships are not clearly known. In general, the more flow velocity is reduced, the greater the filter efficiency.
Water Depth Relative to Vegetation Height	Filter efficiency declines as water depth approaches the maximum height of vegetation.
Detention Time	Filter efficiency increases as detention time increases.
Size Distribution of Incoming Sediments	Filter efficiency increases as the mean size of particulates increases.
Application Rate of Water	Filter efficiency declines as the volume of water moving across a buffer strip increases.
Land Use in Watershed	Filter efficiency declines as flows of contaminants increase due to expansion of agricultural, urban and other land uses.
Season	Buffer strips will be more efficient during the season with more active and healthy vegetation.
Grazing Intensity	As grazing intensity increases, buffer strip efficiency declines.

Source: adapted from Karr, 1980.

have been restricted. State intervention, such as investment in rural development, is essential to maintain equity and assure the sustainability of watershed management benefits.

Corridor management involves the calculation of opportunity costs in economic, energetic, and cultural terms associated with proposed uses to establish a sustainable use strategy. This strategy involves the combined goals of minimizing impacts on the functioning of aquatic ecosystems while effectively utilizing their goods and services. Because many of the values, such as clean water, do not have a market price, the cost of their deterioration must be measured using nontraditional techniques (Dixon and Hufschmidt, 1986 and Repetto, 1989).

Land-Use Impacts

Upland activities extending into the stream corridor, such as agriculture and rangeland expansion, intensive logging, road construction, urban expansion, and mining all result singly or in combination in vegetation cover removal and soil disturbance. In less-populated tropical regions, widespread watershed problems have yet to develop but may well occur in the next few decades, especially where population pressures increase cultivation of steep slopes (Richter et al., 1985). Water quality changes, such as increased sediment load, eutrophication, and presence of disease organisms, reflect stream corridor system destruction and watershed deterioration that have overwhelmed the capacity of the corridor system to perform its functions. Hamilton and Pearce (1986) summarized the biophysical effects of different land uses in a watershed under six headings:

- Soil erosion at the land-use site;
- Harmful sediment off-site;
- Pollution of water by chemicals;
- Changes in total water yield in streams in the watershed;
- Changes in distribution (or timing) of water delivery in streams in the watershed -- low flows and floods; and
- Changes in water table.

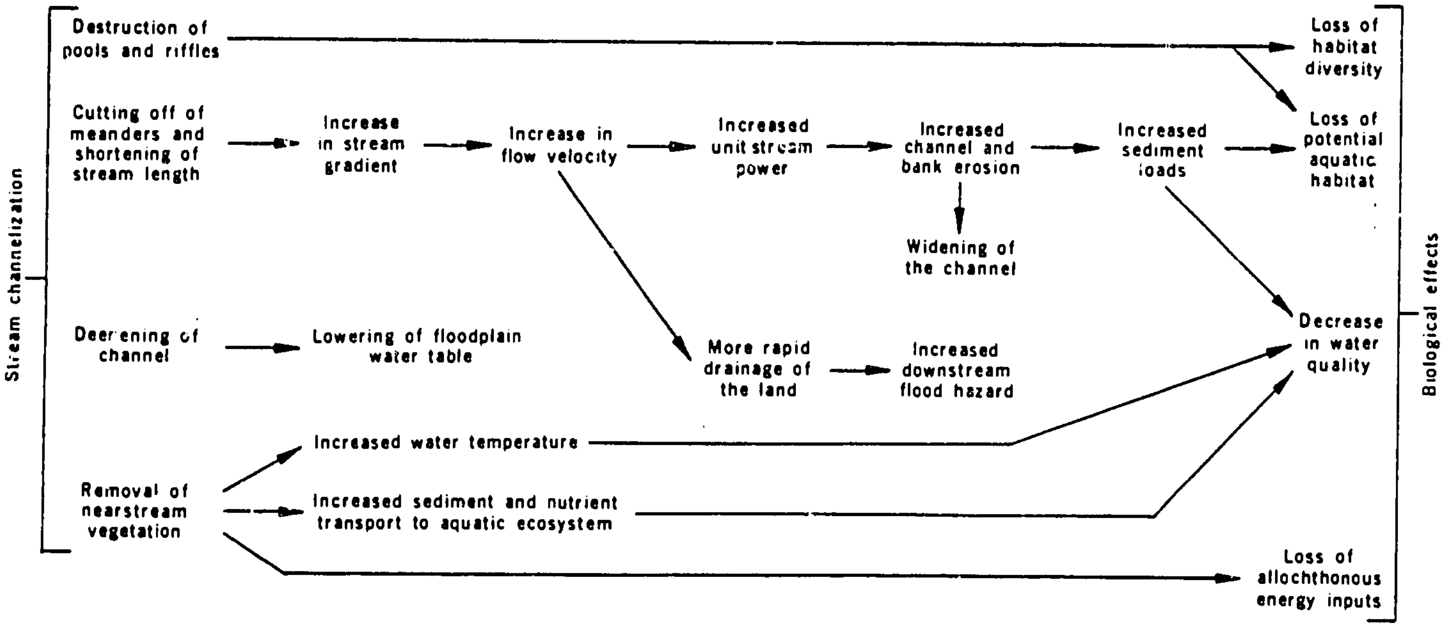
A Caveat - One should not expect to significantly modify natural geomorphic processes operating at the watershed scale as a result of stream corridor management alone, or in concert with comprehensive programs in watershed management. These processes, operating on a geologic time scale, are related to parent material, tectonic and seismic activity, topography, vegetation cover and climate. Management is primarily oriented toward minimizing the acceleration of natural processes. Important examples are the conservation of soil and water at the farm scale and the maintenance of productive fisheries. On the other hand, periodic extreme natural events may cause changes in the landscape beyond human control. Heavy rainfall associated with hurricanes Frederick and David in 1979 resulted in the deposition of the volume of sediments expected over several decades in the Valdésia and Tavera reservoirs of the Dominican Republic over a period of only several days (Hartshorn et al., 1981). In a parallel example, a 1987 earthquake in Ecuador resulted in the virtual denudation of many thousands of hectares of undisturbed primary forest due to landslides (personal communication, E. Figueroa). Mahood (1987), in a World Bank Study on reservoir sedimentation, shows that high concentrations of sediment in rivers are largely related to climatic, tectonic and geological factors. He goes on to indicate that existing sediment sources within a basin, that is, hillside colluvial deposits and valley floor and channel alluvial deposits, will compensate for any reductions realized by upland control practices.

Floodplain agriculture, drainage, and stream channelization can have appreciable effects upstream and downstream of the stream section directly affected. Removal of protective vegetation along the land-water interface, the rapid removal of water from the land by the construction of canals, and increasing the flow capacity and improving the navigability of natural streams and rivers by straightening channels and the removal of obstacles such as tree trunks and boulders and shoals, have similar impacts on the water resource due to upland land-use impacts.

Abnormal peak- and low-flow conditions and their timing, and changed organic material and nutrient inputs can have significant downstream effects on food chains, particularly if the channelized stream section constitutes a major proportion of the downstream flow. Upstream migration of organisms can be restricted or eliminated by loss of nesting and feeding habitats, low-flow conditions, and diversion of migrants into dead-end canals. The downstream ecosystem can suffer analogous effects as migrants attempt to traverse channelized sections going downstream. The combination of drainage and channelization impacts can result in a significant change in the capability of an aquatic ecosystem to provide the quantity, quality and range of products and services desirable to society. These effects are summarized in Figure 2.

Figure 2.

Effects of Channelization on the Physical Environment and Biota of Streams (Karr and Schlosser, 1977).



STREAM CORRIDOR MANAGEMENT

Easter and Hufschmidt (1985) define the watershed approach as:

> The application of integrated management in the planning and implementation of resource management and rural development projects or as part of planning for specific resource sectors such as agricultural, forestry or mining. Imbedded in the approach is the linkage between uplands and lowlands in both biophysical and socioeconomic contexts. (p.1)

Stream corridors constitute the predominant upland-lowland link, in both a biophysical and socioeconomic sense. Settlement advances up stream corridors and concentrates along them. In turn, corridors serve as avenues of trade and routes followed by wildlife migrations; they also collect and concentrate the accelerated runoff of water and sediment from the watersheds where settlement has occurred. Solving the obvious conflicts among sectors and interests that are concentrated in stream corridors becomes a special challenge in watershed management for sustainable development.

The most effective management of a stream corridor is to leave it alone, preserving as wide a buffer strip as possible. However, total exclusion of human activity from the corridor is generally not practical; therefore, various mitigative measures should be considered. These include:

- **Flood control** -- Avoid any disturbance of the stream channel itself. If removal of flood waters is essential, a relief canal can be constructed within the floodplain of the stream to capture flood waters;

- **Grazing** -- Stream bank vegetation should be maintained with minimal disturbance. Harvest of forage by hand for animals kept out of the corridor best preserves the filtering efficiency of grass cover. Overgrazing should be avoided because it reduces filtering efficiency and increases sediment generation;

- **Livestock watering** -- Stream access should be restricted to those locations where bank erosion can be kept to a minimum, including ephemeral channels. Alternatively, watering sites can be provided outside the corridor, which reduces overgrazing and bank erosion. This has been accomplished by small-scale diversions using gravity or low head pumps;

- **Agriculture** -- Stream bank vegetation should be preserved. Back from the banks, agricultural systems with a filtering capacity comparable to the natural system should be encouraged such as permanent crop agroforestry. If annual crops are to be grown, the most effective soil conservation practices should be employed;

- **Logging** -- Buffer strips should de required for predefined stream and catchment categories with widths specified in concessions and logging permits. Rules for road construction and equipment trails should minimize the number of stream crossings and include standards for crossings and road drainage; and

- **Road construction** -- Roads should be constructed as far from the stream as possible. Standard engineering practices to avoid sediment generation during and after construction should be employed.

An integrated two-step ecological engineering approach to stream corridor management is recommended. First is the establishment or preservation of the filtering capacity of the corridor vegetation that serves as the buffer between the stream itself and the rest of the watershed. Second is the maintenance of the biological and physical integrity of the stream ecosystem itself. This involves protecting the stream from such direct impacts as channelization, waste dumping, and livestock watering. If both steps are effective in maintaining the integrity of the corridor with its riparian and aquatic components, then the maximum range of goods and services of local or downstream value (fisheries and wildlife, recreation, water for domestic, agricultural and industrial use, and waste removal and treatment) can be provided. Smaller streams, because they compose a major proportion of the length of channels in a watershed, serve as the major area of interface between stream corridors and the surrounding watersheds.

SUMMARY AND RECOMMENDATIONS

The value of stream corridors in overall watershed management has been demonstrated. Below are summarized some of these values. Obviously, all values do not accrue from the same stream segments or at a given level of protection or management. However, when alternative uses of the stream corridor land are being evaluated, the following values merit consideration.

Corridors serve:

- As filters to **trap and/or detoxify sediment particles** which may have attached nutrients and toxic materials carried by runoff water;

- By **intercepting sediments** in runoff or preventing bank erosion along corridors themselves, to reduce the amount of damage due to sedimentation affecting the useful life of reservoirs, reduce the costs of sediment removal from irrigation systems and navigation canals, and limit damage to turbines from sediment particles;

- To **regulate the flow regime of streams**, thus reducing the damage due to flooding, bed and bank erosion, as well as maintaining low flow during the dry season, benefiting all downstream water users;

- To **reduce fecal contamination** of surface water from human and livestock sources, thus reducing the problem of pathogens surviving in water supplies;

- To **reduce the magnitude of water temperature fluctuations** in smaller streams where shading is important to ecological functioning;

- To **contribute to seasonal and/or year-round habitat conditions** essential to the diversity and productivity of fisheries, wildlife and plant species (the entire aquatic biota);
- To **maintain the biotic diversity** of important terrestrial species found in, or which migrate through, stream corridors; and
- To enhance **recreational opportunities** under carefully controlled management.

After an examination of stream management problems in a number of countries in different geographical areas, Petersen et al. (1987) present a series of guidelines applicable to all streams (Figu

Figure 3.

General Guidelines for Stream Management

- **Watershed management is the goal, riparian control the starting point.** The recurring pattern of wholesale watershed abuse will not be easy to change owing to the political, economic and behavioral heritage factors. Think big but start small; it is recommended that if watershed control is not practical then strong riparian control measures can constitute an effective starting point.
- **The riparian zone is the interface between the terrestrial and stream ecosystem.** The riparian zone controls the interaction between the stream and its surroundings. Besides functioning as nutrient filters and buffer zones between surface waters and agricultural lands, these strips are important refuges for a wide diversity of wildlife.
- **Short-term events may be far more damaging than average conditions.** The environmental impact due to average conditions in streams may be overridden by short-term extreme conditions.
- **Good management requires holistic approaches.** Stream management must include the entire problem. An often-cited law in ecology is that "everything is connected to everything else." This is obviously true when one management problem results in a disturbance in another seemingly unrelated area.
- **Some stream management problems are the result of global problems.** Some stream management problems, such as acidification due to acid rain, have their resolution far beyond the watershed boundary. They can only be resolved by international awareness and cooperation.

After Petersen et al., 1987

The purpose of this paper has been to demonstrate how stream corridor management plays an integral role in the management of watersheds for sustainable development. Stream corridors are among the most fragile elements of upper watersheds, both in mountainous areas and in the upper reaches of streams in the wet tropical lowlands. In addition to the multiple values represented by stream corridors, these areas are a magnet to conflicting uses. How human needs for food can be met while maintaining other values both on site and downstream has been our concern. Among the use strategies advocated for fragile lands has been the modification of existing small farm production activities by introducing tree-based agroforestry and silvopastoral systems to produce food and raw materials from combinations of annual and perennial cropping and livestock (Johnson, 1982). These uses are complementary to, and may even be included among, the uses advocated for stream corridors.

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