

THE CONTRIBUTION OF WETLANDS TO THE ATTENUATION OF FLOODS



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1. Introduction

Wetlands are typically gently sloped, and when water from a stream channel enters a wetlands, flow tends to spread out across the wetlands surface, energy is dissipated, and the velocity of the water decreases. Wetlands are usually vegetated, and this vegetation is able to further dissipate the energy of the water. Through interception of storm runoff and storage of storm waters, wetlands are able to change sharp runoff peaks to slower discharges over longer periods of time (Mitsch and Gosselink, 1986). Since it is the flood peaks that produce flood damage, wetlands are potentially able to greatly reduce damage and loss of property and human lives (Mitsch and Gosselink, 1986; Dugan, 1990 De Laney, 1995) (see Section 2). As a general rule, if a catchment has 15% of it's area in wetlands, then flood peaks will be 60 - 65% lower than if no wetlands existed (Sather and Smith 1984).

Although the general ability of wetlands to spread and slow down flood waters, thus attenuating flood peaks is well known (Chow, 1959; Dugan, 1990) individual wetlands, may vary considerably in their effectiveness. The following attributes, which are described in Section 3, are most often cited as influencing the effectiveness of wetlands in controlling floods.

- Topography of the wetland site
- Wetland size
- Wetland shape
- Roughness of the wetland surface
- Location in the catchment.

- Water regime
- Permeability of the soil

2. Studies quantifying the flood attenuating effects of wetlands

There is a severe shortage of wetland research, awareness and manpower dedicated to wetlands in South Africa. We don't even have a national wetland inventory, nor wetland policy. It is therefore necessary to rely on case studies from the USA and Europe. Since the functioning and values of wetlands around the world are similar, the findings of these case studies would certainly apply to South Africa. These examples we will quote are only a few of the many that exist. We cannot ignore the enormous amount of research that has been done in the USA and Europe.

In America, the U.S. Army Corps of Engineers (USACE) concluded that a substantial reduction of floodwaters from the devastating hurricane of 1955, occurred along the Charles River in Massachusetts, because of the natural storage effect of wetlands flanking the channel. This contrasts with the far more serious flooding that occurred in the neighbouring Blackstone River, which is similar but lacks wetlands and natural storage areas (Childs, 1970 as cited by O'Brien, 1988). The inflow and outflow hydrographs of a 20 mile reach of the Charles was analyzed for the 1955 flood event. It was found that the peak flow was reduced by 65% and delayed 3 days through the reach. This was attributed to the wetland storage along the river. It was estimated further that 75% of the natural storage took place within 17 wetland areas totalling 3 400 ha. (USACE, 1971). These wetlands were deemed so effective for flood control by the U.S. Army Corps of Engineers that they purchased them for \$7 million rather than build a \$30 million flood control structure to protect the city of Boston (USACE, 1972; Mitsch and Gosselink, 1986). The study by USACE (1972) showed that if the 3 400 ha of wetland were in the Charles River basin were drained, it would increase flood damages by \$17 million per year.

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Figure a) Hydrograph, showing peak flow for the Charles River catchment is much lower than peak flow for the Blackstone River, a similar catchment with fewer remaining wetlands. (from Thibodeau and Ostro 1981)

Similar flood attenuation services have been demonstrated by riparian wetlands in the Mississippi Basin, in the USA. Gosselink *et al.* (1981) determined that the forested riparian wetlands adjacent to the Mississippi during pre-settlement times had the capacity to store about 60 days of river discharge. With the removal of wetlands through canalization, leveeing and draining, the remaining wetlands have a storage capacity of less than 12 days discharge, an 80% reduction of flood storage capacity. An important factor contributing to the severity and damage of the 1993 flood in the Mississippi Basin (the most severe flooding in recent US history) was, in fact, the extensive loss of wetlands that had occurred prior to the flooding (Daily *et al.*, 1997).

After the flooding in France and the Netherlands in 1995, the cost of the damage sustained in Northern Europe was calculated at nearly R21 000 million by Lloyds List. The floodplain of the Bassee River, performs a natural service by providing and overflow area when the Seine River floods upstream of Paris. The French government calculated that to replace this natural infrastructure with a flood control dam would cost between R650 and R2000 million (Ministere de l'amenagement du territoire et de l'environnement 1999). This highlights the economic need to conserve these natural systems.

A quantitative approach to the flood attenuation potential of wetlands was undertaken by Ogawa and Male (1986), who used a hydrological simulation model to investigate the relationship between upstream wetland removal and downstream flooding. The study found that the increase in peak streamflow was significant for all sizes of streams when wetlands were removed. Ogawa and Male (1986) found that for a 25% reduction of riparian wetland width, 72% of the simulation cases showed no effect. For a 50% reduction, 60% of the simulations yielded increased flows, and with a 100% reduction of wetland, 58% of the simulations yielded peak flow increases of 100% or more.

Scaggs *et al.* (1991) compared continuously measured outflow rates on paired 130 ha sites (an undrained wetland site with native vegetation and an adjacent site that was drained and planted to fescue pasture) on three different soil types. Runoff hydrographs are plotted on Fig. 2 for one of the soil types over a 19 day period that included two significant rainfall events. Scaggs *et al.* (1991) found that for all soil types, peak runoff rates for the developed sites were usually 2 to 4 times greater than those from undeveloped sites. Runoff rates between peaks were substantially lower for the developed sites, clearly demonstrating the attenuating potential of wetlands.

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Figure b) Runoff hydrographs from a natural (104) and a developed site (103) in a North Carolina wetland (from Scaggs *et al.*, 1991)

A similar attenuating effect by wetlands is exhibited at the larger scale of extensive river basins. In the Niger River, for example, at the lower end and downstream of the inner Niger Delta, peak flood-levels are reduced and low water-levels increased compared with that above the Delta.

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Figure c) Hydrograph showing discharge of the Niger River upstream of, in and downstream of the Inner Delta wetland. (Modified after Grove, 1985)

3. Factors contributing to the flood attenuating effect of wetlands

Topography of the wetland

Topography of the wetland site includes wetland slope, landform features such as channels and depressions and the nature of the wetland outlet. Wetlands with constricted outlets or no permanent outlets are considered to have a higher potential than those with unconstricted outlets (Adamus *et al.*, 1987). Similarly, the more gentle the slope the greater will be the attenuating ability of the wetland. Slope includes that of both the floodplain and any channels present in the floodplain. The common practice of straightening a naturally sinuous channel may result in the slope of the channel being increased several-fold without any change to the slope of the floodplain. Widening of the channel and building of artificial levees may also reduce flood storage by reducing the incidence of overbank flooding and excluding more floodflows from the floodplain (Gosselink *et al.*, 1990).

Depressions within a floodplain (e.g. oxbows) that hold flood waters further increase the flood storage capacity of wetlands, and these may also be lost through artificial drainage and filling practices.

Wetland size

Given other factors being constant, the larger the wetland, the greater the area provided for flood storage and velocity reduction.

Wetland shape

Length (parallel to flow) of a wetland is more influential than width in flood attenuation capacity (Lansley, 1994). Lansley (1994) compared the ratios of inflow peak to outflow peak for otherwise similar wetlands with lengths of 0.8, 1.6, 4 and 8 km. He found that in all cases of varying storm magnitude, increased wetland length yielded increased relative flood peak attenuation in a nearly linear fashion.

Hydraulic roughness of the wetland surface

The roughness of the wetland surface, which controls the water flow resistance of the wetland, is determined largely by the nature of the vegetation. Tall robust vegetation, which is characteristic of many wetlands, offers more frictional resistance than short softer vegetation. Microtopographic irregularities or ground surface roughness also contributes to the surface roughness of wetlands (Gosselink *et al.*, 1990). Many high altitude wetlands in KwaZulu-Natal and Mpumalanga have markedly hummocked surfaces (Kotze and O' Connor, 2000) which contributes to the hydraulic resistance of these wetlands. Essentially, the effectiveness with which vegetation attenuates floods is closely related to its effectiveness in sediment trapping, as both are a function of flow velocity reduction.

The effect of surface roughness on water flow can be determined through detailed examination of the involved hydrodynamics or through determination of the aggregate change in flood attenuation based on varying roughness values (e.g. that represented by Manning's roughness coefficient). The resistance offered by surface roughness would also depend greatly on the depth of flow, and if flow depth becomes very large, the influence of roughness will decrease.

Location

When looking at individual wetlands, the relative location of a wetland in a catchment can affect its flood attenuation capabilities. Ogawa and Male (1986) compared the peak flow increases as a result of degradation on individual upstream (stream order 1,2 and 3) versus individual downstream (stream order 5) wetlands. It was found that for downstream wetlands, the attenuating effect extended a considerable distance downstream. In upstream wetlands, which tend to be much smaller, the detectable percent increase in flow due to the degradation of the wetland declined quickly with distance downstream.

Wetlands however, cannot be seen as single units. When collectively examined on a catchment scale, they are all interlinked. Therefore, although an isolated wetland may perform a significant flood control function, effective control is more often the result of the combined effect of a series of wetlands within a particular catchment (Verry and Boelter, 1978). Thus when considered singly, upstream wetlands may appear to have an insignificant effect on flood attenuation. However, upstream wetlands are often very numerous, and when considered collectively their cumulative effect may be considerable.

De Laney (1995) indicated further how wetlands are interconnected within a catchment and that upstream wetlands, by detaining storm flows, reduce the likelihood of erosion damage to downstream wetlands and increase the likelihood of wetland vegetation becoming established.

Water regime

The potential for a given wetland to attenuate floodflow is lower if it is already covered with standing water (i.e. if it is flooded) than if it has no standing water. Thus, given other factors being constant, seasonally and temporarily flooded wetlands would tend to have greater flood attenuating capacities than permanently flooded wetlands. This would highlight the importance of South Africa's wetlands for attenuating floods, as most of them are either seasonal or temporary.

Permeability of the soil

Soils with a high infiltration potential have a higher flood attenuation capacity than those with a low infiltration capacity. However, if the soils are close to saturation then their capacity to take up flood water is low, irrespective of permeability. Thus,

due to the wet nature and inherently low infiltration potential of most wetland soils, this factor is often unimportant in the attenuation of floods by wetlands.

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