Geo Factsheet

Number 84

Managing the River Ganga (Ganges) I - Water Quantity

Management of the River Ganges has been split into two Factsheets - the first of these summarises the general problems of managing the river and the challenges of providing adequate water supply. The second Factsheet concentrates on water quality.

Introducing the challenge

There are a number of reasons why the Ganga is a very difficult river to manage – both physical and human.

- The Ganga is a very long river – about 2500 kilometres with a drainage basin area of nearly a million square kilometres. It includes a number of contrasting environments all with their own individual problems, and differing physical conditions. Its source is melt water from the great glaciers of the Himalayas. In this **collective** zone the head waters have eroded deep gorges through the remote, mountainous area.

At the **transfer** zone a number of rivers abruptly enter the plains, 'debouching' enormous supplies of sediment to form the highly fertile Ganga Valley and flood plains.

- At the **distributive** zone the Ganga combines with the Brahmaputra and Meghna to form the largest delta in the world – a zone of distributaries and frequent floods, yet home to 80% of Bangladeshis. These three zones are part of a linked, open system.

- The Ganga has a very variable and complex **regime**. From April to June, melting Himalayan snows feed large volumes of discharge into its North bank tributaries. Rainfall totals in the main basin vary from around 650 mm in the Upper Ganges to over 2000 mm in the Delta region. 90% of this rainfall occurs between July and October in the 'summer' SW monsoon season. This marked **seasonality** leads to periods of **very low flow** for example in March, at just the time of maximum demands for irrigation. Low flow compounds the water supply problem and exacerbates the pollution problems as the pollutants become highly concentrated. Conversely the extremely high flows in the Autumn can lead to enormous flood management problems, the severity of which depends partly on the interaction of the snow and rainfall elements of the discharge regime.

- The Ganga is an **International** drainage basin. The head waters come from NW India, Bhutan, Nepal and Tibet. Any human actions in these areas have a knock-on effect downstream in the plains of India and also in Bangladesh, 80% of which is made up of the delta region. One controversial issue is the role of deforestation of watershed areas in Nepal and NW India, and the contribution which sedimentation from eroded hillsides makes to river management issues in the plains and to flooding in Bangladesh. The use of dams for HEP or for irrigation, has major impacts downstream. India and Bangladesh have quarrelled over rights to water from the Ganges for over two decades, ever since India started taking water from the Farakka dam in 1975. The aim was to irrigate farm lands in West Bengal, and to improve shipping access to the port of Calcutta, by flushing silt out to sea. At a stroke - Bangladesh was faced with a huge drop in discharge as the dam was only 18 km from its border. Agreement has also to be made between India and Nepal about use of water for HEP in the Himalayan foothills.

The International nature of the catchment requires co-operation between the countries for successful and equitable management.

- The Ganga basin takes up 0.12% of the world's land mass, but is home to 10% of the world's population, some of the poorest people in the world, many of whom depend on the river for their livelihoods. In many places the population density of the Ganga plains exceeds 800 people per km^2. Along the Ganga's course are 29 cities, with several over 1 million, and 70 large towns.

  The rapidly growing concentrations of people leads to sewage discharge problems. Many of the cities such as Kanpur or Varanasi are important industrial cities, spearheading India's thrust to become a NIC. Thus pollution from toxic industrial effluents is a major issue. Equally the Ganga plains are heavily cultivated to meet the food needs of a growing population. The Green Revolution has led to increased outputs but increased use of fertilisers and pesticides, both of which are washed into the river system. The amount of pollution is growing **exponentially** and the river system cannot cope. Water borne diseases such as dysentery and cholera are rife and lead to high rates of infant mortality.

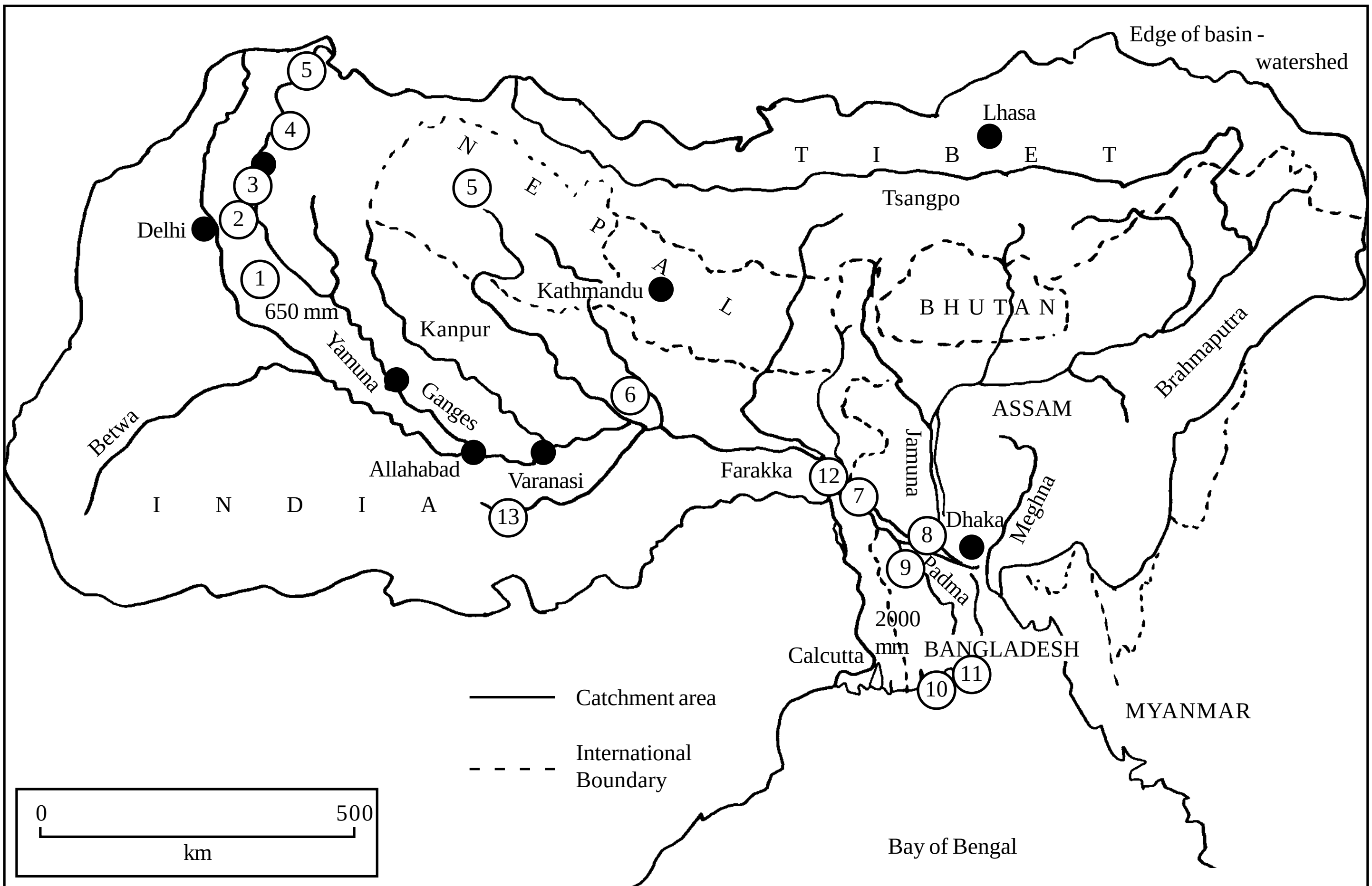
- The management problems are made more complex by the **conflicting** demands of users.

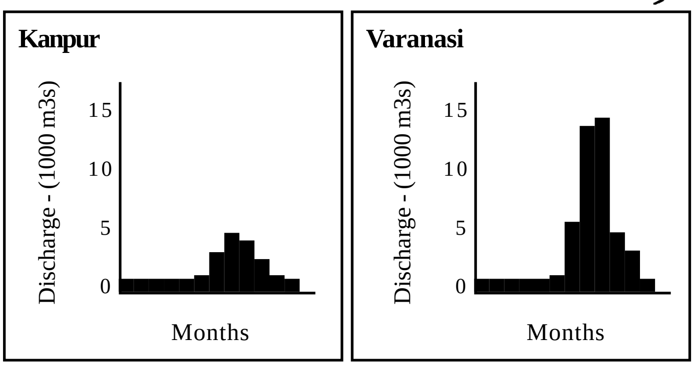
1. **Irrigation** – networks of gravity canals take out large volumes of water to sustain agriculture in the Ganga plains. This leads to a crucial drop in discharge downstream – especially a dry season low flow problem.
2. **Domestic Use** – both urban and rural settlements use the river as a source of drinking water for humans and animals, and at the same time for other domestic uses including sewage disposal.
3. **Industrial Use** – the river supplies water to industries mainly located in large urban areas – including the tanneries of Kanpur. Waste water from these tanneries, petrochemical and fertiliser complexes, pesticide factories, textile and paper mills, sugar cane refineries and distilleries is frequently released into the Ganga system, in spite of the fact that many factories have quite strict water quality requirements for processing.
4. Disposal of **waste water** from agricultural fields in periods of flooding is also practised. Many people argue that farmers do not pay enough for their irrigation water and are wasteful with it.
5. **Navigation**. In spite of the variable regime, the middle Ganga area below Allahabad and in West Bengal and Bangladesh is widely used as a waterway by rural people to transport their agricultural products.
6. **Religious Practices** – the waters of Ganga-Ma (mother Ganges) are holy to Hindus and the river is extensively used for bathing. On certain Holy Days millions of pilgrims bathe at key sites along the river such as Varanasi. To die and be cremated on the banks of the Ganga leads straight to salvation for Hindus and the ashes from cremated bodies are therefore disposed in the Ganga for this reason. A crisis has occurred because of the escalating costs of fuel wood, which means that many bodies are only partially burnt, thus adding to the pollution levels and dangers for bathing pilgrims and every day users. Such is the deep belief of the magical self cleansing properties of the Ganga that many Indians feel it is blasphemous to imply that 'a deity' like the Ganga needs human assistance to clean itself and were therefore opposed to management plans when they were first proposed in the 1980s.

Management Issues 1 - Water Quantity

The Ganga basin has major problems of both water quantity and water quality management. Fig 1 shows the locations where some of the most serious water quantity issues occur.

Fig 1. Issues of Quantity in the River Ganga Basin



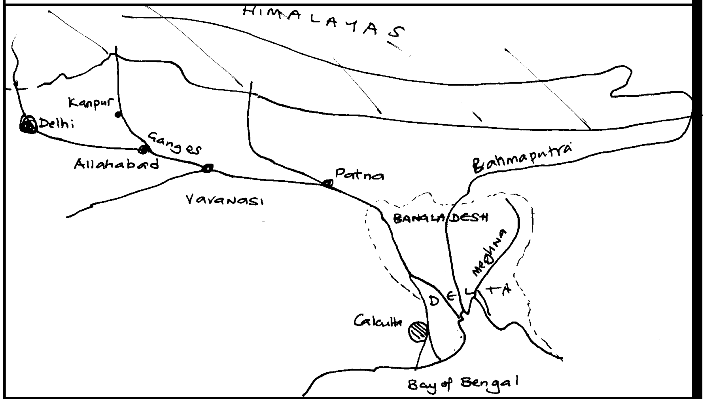


River Regimes
- note impact of monsoonal rains
- note huge variations in flow and low flows in winter

1. Major irrigation zone land between two rivers. Gravity canals take large volumes of water from river
2. Area of falling ground water table as more and more tube wells are dug and water extracted
3. Upper Ganges canals divert water from ganges zone of lower flow
4. Zone of massive sedimentation as tributaries leave moutain zone
5. Glacier fed north bank tributaries - max. discharge (snow melt) April - June
6. Massive deforestation leads to huge increases in sedimentation
7. Problems of sedimentation in low flow conditions
8. Problems of changing channels
9. Sunder ban delta
10. Area of subsidence creeping salinisation
11. Zone of coastal cyclones July - November
12. Dam built in 1975 major discharge loss downstream
13. Southern bank tributaries rain fed (98% July - October)

Exam Hint *- The Ganga basin is quite difficult to draw. Candidates should first practice drawing the River framework with major tributaries, and key towns. Then the map can be tailored to answer the focus of the exam question. For example, the water quantity issues map will end up in a very different form than the water quality map. If you draw an annotated map, it takes time, but you do not have to repeat information from the map as there is no double credit.*

How to make a base map 'fast'



1. Draw the coast
2. Put on the main rivers and a suggestion of a delta
3. Name the countries. I may be a good idea to delimit Bangladesh
4. Put on the edge of the Himalayas (brown)
5. Mark on the 'million' cities (red dots)
   Then add around 6 key annotations designed for question (see Fig 1 and 2) on to this framework.

(A) Managing Water Quantity Issues – lows and highs

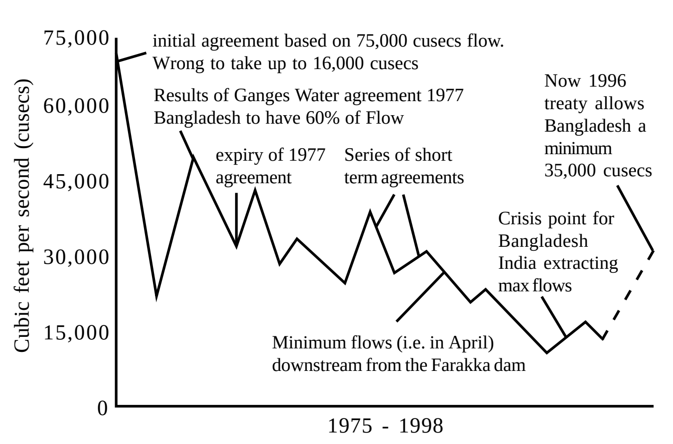
If you have a look at Figure 1 you will see two graphs of river regimes for the Ganga. Notice that they have a basic **similarity** of a minimal flow (low flow period) from November to May and a high flow period from July to October which coincides with the summer monsoon rainfall. However some significant differences emerge in that the peak regime at Varanasi is 3 times as great, for two reasons. Firstly rainfall totals increase eastwards from around 650 mm at Kanpur to over 2000 mm in Bengal. Secondly, and this is the main reason, the Ganga has joined up with its most significant tributary – the Yamuna, by the time it reaches Varanasi. A third minor difference is that at Kanpur the peak is in July, whereas further downstream at Vananasi it is in August, possibly because of the more significant impact of snow melt at Kanpur.

This marked seasonality is difficult to manage. The main users of water, who actually take it out of the system are farmers in the Ganges plain growing a second winter crop. They need the water, in the dry period, especially for some of the new hydrid strains of millet and wheat. In times of low flow, pollutants and toxic substances become more concentrated, for example from the tanneries of Kanpur. High levels of silt deposition also occur so navigation is therefore limited. A further problem, which is not apparent from the graphs is that of **rainfall unreliability**; the monsoon rains are sometimes very late, or are more limited in amount. This causes major problems of drought for both progressive farmers of Uttarpradesh, and peasant farmers in Bihar, one of India's poorest regions – here famine can occur.

Low flow problems may not only occur **temporally** but also be located **spatially**, for example downstream from major irrigation schemes.

The most contentious site on the Ganga has been the Farakka dam, some 18 kilometres from the Bangladeshi border. In 1975 India first began operating the barrage to divert water through a feeder canal to the Bhagirathi river which flows to Calcutta. During the rainy season, when silting is not a problem, India opens the dam gates to allow the swollen Ganges, carrying as much as 2.5 million cubic feet per second to flow freely to Bangladesh (the water is not really needed!). But during the critical dry period from January to May, when total flow falls to as little as 55,000 cusecs, India siphons off water to Calcutta:- the dam can divert up to 40,000 cusecs ie 75% of the total minimum flow. Bangladesh argues that the dam has led to serious water shortages, and environmental degradation in its South West region, with changes in river morphology, and saline intrusion, as India is diverting far too much water. Fig 2 shows the impact of this below the Farakka dam.

Fig 2. The impact of the Farakka dam on minimum flows 1974-98



The decreased water flow in the Ganges, leads to a drying up of the River Goral (a tributary of the Ganges) which is an important source of fresh water to SW Bangladesh. The lack of water combined with the increased salinity has had a major impact on farm productivity, as farmers have to plant crops later in the rainy season and risk destruction by flood and then later suffer damage from the salty ground water. Fisheries and navigation are also affected, because of the decreased quantity and subsequent quality of the water. In 1976 Bangladesh claimed that the direct damage affected 1/3rd of the population and cost the country $3.5 billion.

In 1975 an original agreement allowed India to divert between 11,000 and 16,000 cusecs over a 40 day period during the driest months in April and May, but there has been a history of disregard by India of these limits and frequent renegotiations.

In 1977 the Ganges Waters Agreement allowed Bangladesh an average of 60% of the flow below Farakka, with an increase to 80% in the driest period. When this agreement expired short-term deals prevailed, with no sharing arrangements. This led to a souring of relationships between the two countries. It was not until 1996 that serious negotiations started again with new leaders in power. As far as India was concerned the use of the scheme to flush out silt from port channels of Calcutta never worked, but without some of the Ganges flow Calcutta's drinking water would become very saline, and the water is increasingly needed for farmers in West Bengal and Bihar. Bangladesh needs to find a solution to guarantee at least a minimum flow of the vital water, **and** needs the co-operation of India to help with any future flood control schemes. At last in 1996 the Ganges River Treaty (between India and Bangladesh) and the Mahakali River Treaty (between India and Nepal) were signed essentially to make mutually beneficial, optimal use of water resources in the fields of flood management, irrigation, river basin development and the future generation of HEP.

The case study emphasises how important it is to manage low flow, as the results are less widely publicised than the life threatening and regular problems caused by the Bangladesh floods. Whilst annual floods (known as barsha) are a feature of the Ganges plain and delta area and are essential and desirable for the overall growth of the Bangladesh delta area and economy, the high magnitude floods (known as the bonna) are very destructive and cause millions of pounds of drainage and lead to serious loss of life. Currently 120 million people live in Bangladesh, but this total is estimated to rise to 180 million by 2010 with very high rural densities. Many of these people are peasant farmers and farm the delta area. The major concern is that the high magnitude events have been much more frequent in recent years and almost an annual occurrence. Whether the area floods or not, depends on the water carrying capacity of the river channels (there are some 300 major rivers and channels in Bangladesh), in relation to the elevation of the land with respect to **base level.**

The causes of the high magnitude floods are summarised on Fig 3. They can be analysed in terms of short term (immediate causes) marked (S) and longer term processed marked (L) which are slowly occurring phenomena. These longer term processes cannot be linked to the flood problem directly, but can combine to make short-term processes more severe.

In terms of **short term** processes the primary cause is the monsoon rainfall and how heavy and concentrated it is. At the same time the **degree of synchronisation** of the flood peaks from the three major rivers feeding into the delta is the other discharge key factor. Clearly if they all come together as they did in the 1988 flood the discharge peak will be enormous in lower Bangladesh. However to explain the floods of 1984, 1987, 1991 and 1998, further explanations have to be sought – in particular processes which reduce the water carrying capacity of the drainage system and decrease land elevation with respect to base level. The sediment budget of the delta region is crucial for its long term survival.

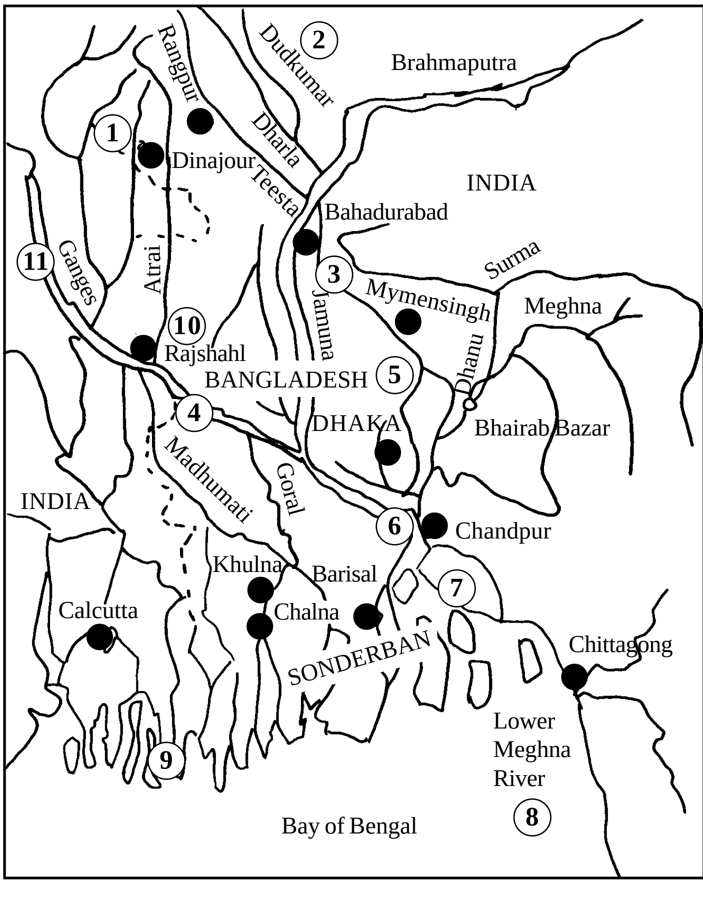
A further consideration is the rising levels of urbanisation within the basin which lead to a more flashy run off.

Processes which reduce the water carrying capacity of the drainage system include increased river bed aggregation as a result of impacts of dams (reduced flow) or possibly deforestation and the resultant landslides upstream, or soil erosion from increased arable tillage which leads to increased supplies of sediment.

The rising base level can be linked to the impact of world wide global warming, and also to delta subsidence locally, which prevents the flood water escaping freely to the sea. These long term processes are called geologic processes and may be responsible for the gradual worsening of the Bangladesh floods.

Solutions to the complex causes are far from straightforward. They can be divided into structural or **hard engineering** solutions or alternative solutions which work with the geologic processes. Structura solutions have been favoured in the recent World Bank funded scheme – a flood control project known as the **Flood Action Plan** (FAP) which requires the construction of hundreds of 2500 kilometres of tall embankments along the rivers of the delta, enormous drains, and 'compartments' which are areas protected by embankments (usually high value areas). Controlled flooding will be managed via intakes from rivers and off takes through the drains.

Fig 3. Causes of Flooding in Bangladesh



(L) = Long term
(S) = Short term

1. (L) Possible onset of seismic activity seems to be associated with major floods
2. (L) Deforestation of upstream region accelerates soil erosion and landslides, also increased cultivation leads to more aggradation downstream
3. (S) Flashfloods from bare hillsides
4. (L) River bed aggradation reduces water carrying capacity of channels and causes them to overflow
5. (L) Impact of rapid urbanisation aggravates problem
6. (S) Upstream - snow melt throughflow. Impact of 3 flood peaks (Ganga, Brahmaputra and Meghna becoming synchronised and the greater this is the higher the peak
7. (L) Inadequate and reduced sediment accumulation again points to lowering of land levels
8. (L) Localised relative sea level rise caused by delta subsidence and rising sea levels worldwide - increase in base level height ponds back floodwater
9. (S) Impact of rainfall from tropical cyclones combined with onshore SW winds, high tides, and storm surges cause coastal flooding of delta zone
10. (S) Rain floods caused by monsoonal downpours occasionally the Monsoon rains are well above average
11. (L) Damming of river - reduced velocity downstream causing aggradation

There are many concerns about this project. They include:-

- The embankments cut off the river from its flood plain preventing channel movement and sedimentation – so the land elevation will fall as the delta shrinks.
- A severe 1 in 100 year event could over top the embankments causing widespread death and destruction (as happened in the Mississippi).
- The systems will be subject to silting and very costly to maintain, as well as being a very expensive (multi-million pound scheme) to build.
- They will take up valuable land required for agriculture, and prevent subsistence farmers from fishing and using the annual silt inundations.
- Most importantly they will make the geologic causes even worse leading to loss of delta land and increased salinisation and marine encroachment and will not tackle the coastal problem. Nevertheless several parts of this scheme have been implemented.

The embankments are just one approach. Stream storage using dams (2 dams would take 40 years to complete at a cost of £40 billion and may not succeed), constructing 12-15 flood water retention basins, or artificial down drain of ground water have also been considered as possible alternatives.

Geological or alternative solutions will above all **dredge** and re-excavate the rivers The soil from this can be dumped on the land and could help the delta grow. The capacity of the rivers is increased to speed up flood water disposal.

Other measures include **indigenous solutions** to prevent land degradation (the soil erosion adds to the river bed sediments) and **flood preparedness** such as warning systems and provision of flood shelters on high ground. Longer term increased international and inter-regional co-operation can develop improved measuring and monitoring, which is the basis of process understanding, and can explore holistic management schemes for the whole river.

Note this case study represents a brief summary. For full details consult Flood Plains or Flood Plans? by R. Hughes published by IIED May 1994. International Rivers Network irr.web@irn.org is a useful site.

Acknowledgements;
This Geo Factsheet was researched and written by Sue Warn
Geo Press, Unit 305B, The Big peg,
120 Vyse Street, Birmingham, B18 6NF

ISSN 1351-5136