# Flood risk management in the context of Integrated Water Resource Management (IWRM)

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**ABSTRACT**

" *IWRM is a process which promotes the co-ordinated management and development of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*" (Global Water Partnership 2000).

I shall argue that starting with an IWRM perspective, which is currently being implemented in Europe through the EU's Water Framework Directive, changes: how we think about floods; how we make choices as to how to manage the risk of flooding; and what we do to manage those risks. Taking an IWRM approach requires that we integrate across three dimensions: across the catchment; between land and water management; and cross the different functions and uses of water. But taking this perspective will not change the basic conditions of water management. Secondly, the appropriate water management policy must be based upon local conditions and water management is also only one aspect of sustainable development. Finally, if IWRM is taken as a precondition for sustainable water management, this leaves us with the problem of whether and how we can actually achieve IWRM. I will examine some of the problems, particularly the organisational problems, of actually delivering sustainable water management and sustainable flood risk management in particular.

**Keywords:** Integrated Water Resource Management, floods, flood risk management, choice, change

## 1 INTRODUCTION

I've have argued elsewhere (Green et al 2000) that China has one of the two best flood risk management strategies the world (Wang 2002) – the other being the Rhine (International Committee for the Protection of the Rhine 1998). It has also has one of the most difficult contexts in which to manage the flood risk although Bangladesh – the deltaic plain of three massive rivers – and Japan - a coastal flood plain lying at the foot of a mountain range from which rivers whose flood flows are hundreds of times the average flows (River Bureau 1985) – might dispute this claim. China has the further problem that it is in the process of transition from a rural, agricultural based economy to an urban, industrial and service based economy. Hence, the flood risk management strategy adopted must meet present needs whilst providing an adjustment path to the future. In turn, China may learn from other countries but it will not generally be appropriate to adopt flood risk management strategies from other countries. Western Europe, for example, has largely completed the transition from an agricultural economy to an industrial/service based economy and this has radical implications for the entire way in which we manage water. The problem with looking at flood risk management in the USA is that it does not have a water problem – no country with a population of 28 per square kilometre, nearly 0.7 hectares of arable land per capita, and around 10,000 m3 of runoff per person per year has a water problem although the USA does have a management problem. The USA has yet to make the transition from a water management policy geared towards an agrarian economy to one suited to its current conditions.

Indeed, one of the main conclusions I shall draw is that, if anything, China has been too willing to adopt practices from other countries and insufficiently critical in assessing what often appear to be offered as instant panaceas for all the problems of water management.

## 2 THE CRITICAL ASPECTS OF WATER MANAGEMENT

There are five fundamental general truths about water management that do not change between different contexts:

- agriculture

- economies of scale
- capital intensity
- energy cost
- economies of scope

Of these, the two most important are water management is always about agriculture and the economies of scale. It is not providing the 110 litres per person per day needed for household uses that is the problem but supplying the 2-6 tonnes of water needed to grow the food that person eats during the day at the times when the crops need it. Secondly, historically, the poor spent 60-70% of their income on food and the poor in some countries (e.g. Ethiopia) are still spending this proportion of their income. Similarly, in the past, the majority of the population was engaged in agriculture. Hence, governments have necessarily been very much concerned with trying to ensure both that food availability and prices were held steady and food supplies were sufficient to meet minimum needs.

What has happened as development has taken place is that both the proportion of the population engaged in agriculture has fallen dramatically – and this has consequences both in terms of migration to the cities and in terms of farm sizes – and so has the proportion of household income spent on food. In the UK, expenditure on food is now 16% of average household income and it is even lower in the USA. Conversely, I have argued (Green 2003d) that the key determinant of the flood risk management policy in England in 2080 will be the world price of basic food stuffs; if the proportion of household income spent on food were to rebound to anything like 40% of household income, governments would be desperate to increase national food production and the land we are currently taking out of production would be put back to arable use. This possibility cannot be ruled out as historically food prices have been alarmingly volatile (Clark 2003; Fischer 1996).

Finally, agriculture is important because its demand, and the nature of that demand, for land. The ideal agricultural land has a good soil, ready availability of water, and is flat. For these reasons, rivers can be described as nature's way of building farm land; the deep sediment layers deposited by thousands of years of floods generally providing fertile soils. The land is also flat whilst farming on slopes is always difficult and there are often problems of soil erosion. This competitive advantage of flood plains is increased when we start, for example, to consider laser levelling as a means of making the best use of water for irrigation. Hence, the attraction of flood plains for human settlement over the millennia. Land is also scarce and always in some existing use such as forest or grassland. China is, of course, very short of good arable land.

The other great determinant of water management has been economies of scale; it is generally cheaper for a community to act together than for each individual to make their own provision. This true for urban potable water provision – piped water supplies being cheaper than either each household constructing their own well or buying water from water vendors – and also for flood risk management. At some density of development, it is cheaper for a community to build a flood embankment than for each household to try to flood proof their property. It is these economies of scale that can be argued to have determined historically the way in which water has been managed. Looking around the world we see community based collective action to manage water whether it is draining land (the Waterschappen in the Netherlands), flood protection (the Levee districts in the USA), irrigation (the Huerta of Spain and the Subak of Bali), or urban water supply (municipal water supply companies around the world).

## 3 MANAGING THE TRANSITION

The problem for China is to have a water management system that meets the needs of the present whilst providing a path of transition to the very different needs of the country in 50 years time. Then, the economy will be perhaps 30 times its present size and since it is not possible to scale up the economy by such a factor, the economy will be structurally very different. If the historical models of development are followed, there will be a shift of perhaps 500 million people to urban settlements and out of agriculture. Where will those settlements be? Is it possible to direct or control that urbanisation? Are there alternatives for a service and industrial based economy to large city models of Europe and North America (World Bank 2000)? This urbanisation will be accompanied by massive changes in farming: with the reduction in the population engaged in farming, farms will have to be bigger. The farming population will also tend to older: the young seeing better opportunities in other forms of employment. Terraces take a great deal of labour to maintain and so many will disappear; this will have effects both upon runoff and soil erosion. The proportion of meat in diets will tend to increase – so increasing agricultural water needs – and away from rice paddies. In turn, the water storage and groundwater recharge provided by rice paddies will be reduced, as will methane emissions.

The two advantages for China in this transition is that you are not stuck with a large fixed past investments; in the UK, currently we are only replacing 0.1% of our housing stock per annum which means we will have try to deliver sustainable development very largely with the building stock that we already have. Secondly, you can leapfrog those technologies in which the countries that developed earlier have invested heavily. Western sewerage systems are essentially a nineteenth century technology with some modern bits tacked on the end. We probably would not do the same thing if we were now starting from scratch.

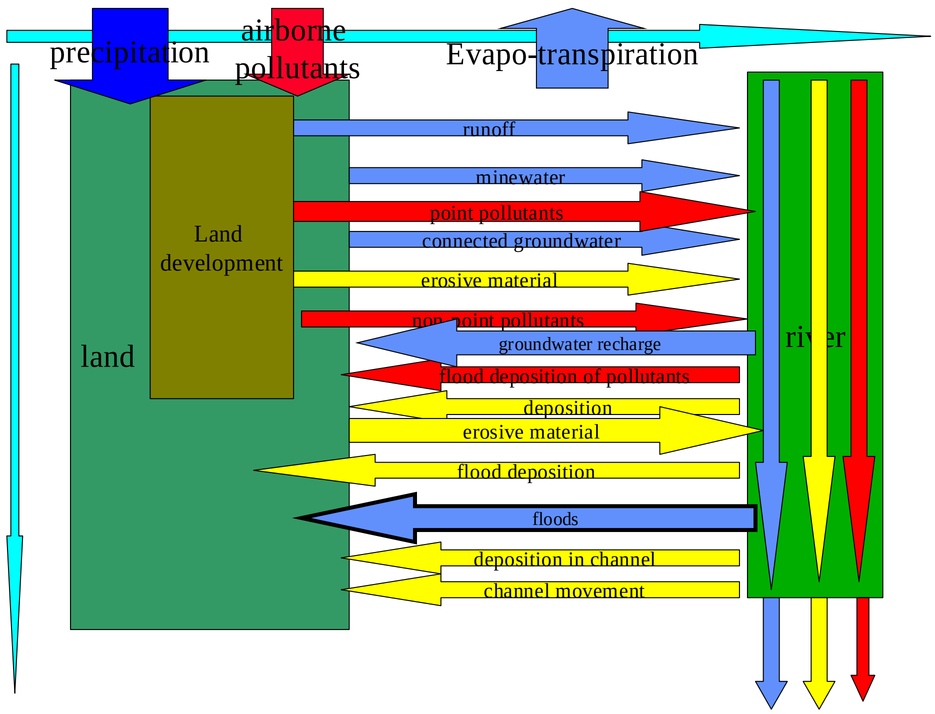


**Figure 1.** The catchment as a dynamic system

## 4 WHAT IS INTEGRATED FLOOD MANAGEMENT?

Integrated water resource management involves integration:

- Across the catchment
- Between land and water management
- Between the different uses and functions of water management.

This is challenging to say the least, not least because in human terms, catchments are arbitrary units, varying greatly in size and whose boundaries do not coincide with traditional cultural, religious, political and ethnic boundaries. Actually achieving IWRM will therefore be difficult but we can gain significant insights into flood risk management just from thinking in these terms (Technical Support Unit 2003).

I argue that adopting an IWRM framework will change:

- How we think about floods
- How we make choices as to what to do
- What options we seek to adopt
- How we implement those options

### 4.1 Changing the Way We Think About Floods

If we take an IWRM perspective, we have to see a catchment as a system that varies dynamically in both space and time (**Figure 1**). We have therefore to manage not only flows of water, but also variations in water quality and also the erosion and deposition of soil (Newson 1997).

Looking at water quantity in particular, we have to manage the variability in water quantity (Figure 2). The first implication is that we cannot think about floods, water resources, and droughts as different issues but all as aspects of managing variability in water quantity. Notably, in arid climates, floods are the water resource; if we do not capture the flood flows, then there will be no water available for the rest of the year.

Secondly, variability has three different components:

- Cyclical variation
- Trends
- Unexplained variation

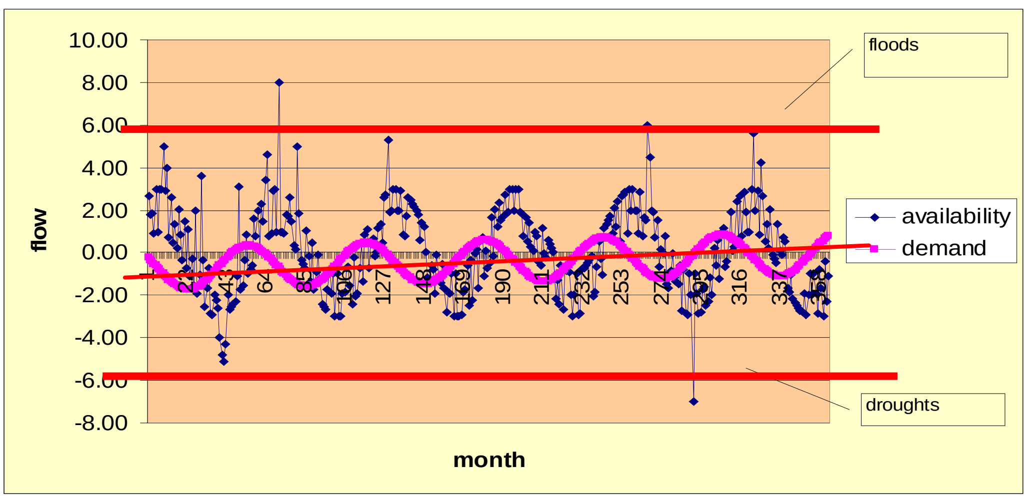


**Figure 2.** Managing variability in water quantity

Seasonal changes are the obvious example of cyclical variation and the cyclical variation in both rainfall and river flows relative to the crop demand for water are key aspects of water management. But there are also signs of other forms of cyclical variation. Kiem et al (2003) have shown that the South Pacific Oscillation has a marked influence on the risk of flooding in Australia and Werrity (2003) has found that the North Atlantic Oscillation has similar effects on the risk of flooding in Scotland.

Climate change is one trend change but others include change in land uses as well as changes in the form of the river. Moreover, in making choices we are setting out to choose the future, to change the future from that which would otherwise occur. The changes to be expected in China over the next fifty years as the economy grows are enormous; the movement of the population into urban areas being the largest migration in human history.

The remaining component of variation is unexplained variance: variance which appears to follow no pattern. It is common to refer this to random variation but this is not true: it is simply that we do not know what is happening. In particular, floods are not random or generated by a random process, it is simply that if asked to predict whether or not there will be a flood of a given magnitude next year, we can do no better than by throwing a dice with very many sides. This patternless variation may be the outcome of a chaotic process (Gleick 1987).

Thinking about flood risk management in this wider perspective also implies we will cease to think about flood risk management but instead will think about how we can intervene to enhance the performance of the catchment as a whole, how the dynamic performance of the catchment could be improved. Importantly, the purpose of flood risk management is not to minimise flood losses but to maximise the performance of the catchment as a whole; if flood losses double but at the same time, Gross Domestic Product (GDP) trebles as a result of the way in which catchments are managed, this is a success and not a failure.

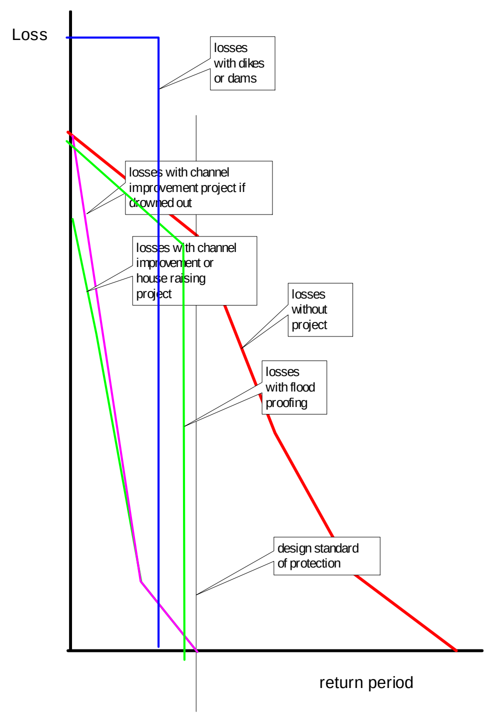


**Figure 3.** Managing all floods and not just some

Similarly, we will take a wider perspective than a local flooding problem. In turn, we are likely to have a preference for options that do more than change the risk of flooding, to look for multi-functional options. We may, for example, in a small urban catchment be able to simultaneously reduce the risk of flooding, improve river water quality and enhance water resources by adopting rainwater harvesting. Or, a wetland might provide flood storage, provide for groundwater recharge and enhance biodiversity. Again, a reservoir may provide flood storage, conserve water for the dry season or against variability in rainfall, and provide electricity.

If we think in terms of managing variability then an implication is that we must think about how to manage all floods and not just some (Green 2002). We need to stop thinking about achieving some design standard of protection be this the predicted 100 year return period flood or the 1000 year return period flood. Instead we need to think about we would cope with even an extreme flood. The loss-probability curve is a commonly used device to examine the consequences of flooding, the loss being plotted against y axis and the exceedance probability of the flood against the x axis (Figure 3). In this context, it is what happens in events more extreme than the design standard of protection that is important. The different options perform in very different ways; for example, if a river is deepened or widened there will always be less water out of bank causing flooding however extreme the flood. Similarly, potentially any form of storage can store the peak of even the most extreme flood and so reduce the extent of the flooding. Conversely, if a dike fails then the results may be catastrophic.

The interventions may also fail in conditions less extreme than the design standard flood. Dikes may fail as a result of erosion, slippage or other problems, and it continues to be very difficult to provide reliable systems of flood warning.

When a failure threatens, whether this is from an extreme flood or other reason, we do not give up but seek frantically to prevent failure. Indeed, in the case of dikes, the real choice is whether to raise them when they are built or to raise them temporarily when a flood threatens. We need therefore to think about what we will do in such an event. We are also likely to prefer interventions that fail slowly rather catastrophically and with plenty of warning, as well as it being possible to raise their performance in an extreme event (Green 2002).

### 4.2 Changing how we Choose

We want to make ‘better’ choices though using project appraisal techniques such as cost-benefit analysis, strategic environmental assessment, and multi-criteria analysis. To do so means that we must address both the nature of choice itself and decide what we mean by ‘better’.

There are two conditions for a choice to exist: the options must be mutually exclusive and we must be uncertain as to which option to choose (Green 2003c). In addition, choice is always about the future, we are trying to choose a future.

The fundamental reason why the options are mutually exclusive is that there is at least one reason for preferring one option and at least another reason for preferring another option. Those reasons can be categorised as different forms of conflict: in time and space, between the objectives we bring to the choice, and because we cannot agree what importance should be given to these different objectives (Green 2003c). Finally, scarcity of resources is an external constraint on the choice. Whilst the fundamental reason why we must choose will be, for example, that a reservoir and a mature broadleaf forest cannot exist in the same space, the scarcity of resources is also a limiting factor. Even supposing that we can agree that education policy A is to be preferred to education policy B, and flood risk management policy M should be preferred to flood risk management policy N, scarcity of resources will force us to choose between combinations A plus N and B plus M.

The second condition for a choice to exist is that we be uncertain what option to choose; if all are agreed that one option ought to be preferred to all others then the choice has been made. We therefore need to distinguish between uncertainty about what to do (‘doubt’) from uncertainty as to the state of the world (‘knowledge’). What is important is whether we ought reasonably to be uncertain what to do. Uncertainty as to the state of the world now and more especially in the future is only one reason why we may be uncertain what to do; the other is that we are unable to resolve the conflicts that make the choice necessary (Green 2003c).

### 4.3 Changing what we Do

There are only a limited range of options however we characterise them. Physically, we can:

- Change runoff
- Increase storage
- Improve conveyancing capacity of the river
- Separate the river and human activities.

Another way of thinking of the problem is to consider vulnerability as the outcome of the challenge versus the coping capacity of the human systems (Green 2003a). So, we can either try to reduce the challenge or enhance the coping capacity of the human systems by, for example, providing flood warnings, and flood refuges. When considering vulnerability it is necessary to avoid thinking about only vulnerability to floods but consider instead vulnerability to the full spectrum of disturbances that can occur (Green 2003d). In turn, we can try to create 'resilient' systems (De Bruijn 2003) as a means of improving our capacity to cope with extreme events.

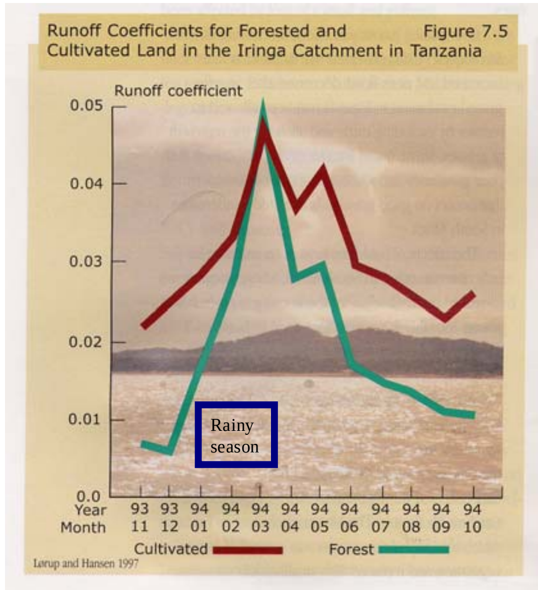


**Figure 4.** Runoff from forests versus agricultural land (Source: Hirji et al 2002)

### 4.3.1 Source control

Source control is an apparently attractive option, including reafforestation. But in considering afforestation it is necessary to consider the effects across the entire year. **Figure 4** compares the rates of runoff from agricultural land and forested areas in Tanzania (Hirji et al 2002); at the end of the rainy season, there is no real difference between the two because the land is saturated by the earlier rain. The biggest difference is during the dry seasons so there is a potential risk from afforestation that river flows in the dry seasons will be significantly reduced, with damaging effects on ecosystems. Shaxson and Barber (2003) also argue that it is not the trees as such that are important in reducing runoff but the plants growing beneath the trees and the litter on the forest floor.

In Japan, it has been argued that rice paddies provide a significant degree of storage during floods (Yoshida 2003). Rice paddies have other advantages as well, notably in groundwater recharge; some surface water irrigation systems in India are now being operated so as to increase groundwater recharge (IWMI-TATA 2002). How much storage is provided by paddies in the Yangtze catchment is therefore an interesting question. What we should expect is that the area in rice paddy will decrease over time as living standards increase and the number of farmers both decreases and those farmers switch into higher valued crops such as vegetables. How much flood storage will consequently be lost?

Dryland farming can be quite effective in capturing rainfall for storage in the soil and groundwater (Shaxson and Barber 2003). What we must do is always consider the dynamic response over time of such interventions and what happens to the water. The scarcity of water in China means that evaporation is undesirable but groundwater storage may be attractive.

Cities are often highly efficient systems of rainwater harvesting, more water being exported from cities as runoff than water is required as potable water (Green 2003c). Hence urban source control can be an attractive option particularly when rainwater harvesting can be exploited to replace some urban uses – if water is scarce. The problem with other forms of source control (Maskell and Sheriff 1992) at present is that they require space and hence tend to require low development densities. In England, where 22% of all land is already in some form of urban use, the government is demanding an increase in the density of development in order to reduce the losses of previously undeveloped land. This policy conflicts directly with the other policy of promoting source control.

### 4.3.2 Flood insurance

Much of the enthusiasm for flood insurance seems to be based upon a misunderstanding of the US National Flood Insurance Programme (NFIP) and the context out of which that programme arose. Historically, the Federal government has compensated victims of disasters but constitutionally the police powers are reserved to the individual states. Hence, the Federal government can neither introduce land use controls and building regulations nor require the individual states and local governments to introduce such regulations. The NFIP provided a way in which the Federal government could require the introduction of some limited building regulations as a way of reducing its exposure to future compensation claims. Politically, it would be impossible to require the introduction of land use controls; indeed, some local governments, notably the city of Houston, have no land use controls for any purpose whatsoever.

In most other countries, the national government can introduce or require the introduction of both land and building controls, although the effectiveness of both is open to question. So, in countries like China, the case for flood insurance must stand on its own merits rather than being used as a means to introduce land and building controls.

A second misunderstanding about flood insurance is that the insurance industry does not exist to take risks but to make profits. It makes profits by selecting those risks which are profitable to insure, whether a risk can be profitably insured then depends upon the nature of the risk and management costs of providing that insurance. On average, premium income must exceed the sum of the losses plus the costs of administering the risk. So, the two extremes of profitable insurance are, on the one hand, those, usually major losses, where the person wishing to be insured is prepared to pay a premium many times the statistically expected loss. On the other hand are mass sales of policies covering against only small individual losses where those individual policies are cheap to administer.

Against these alternatives, cover for domestic properties against flooding is a poor risk to cover for insurance: there are potentially very large concentrated losses from small policies, where since the risk is concentrated, the costs of assessing that risk would also be high. In consequence, insurance cover against flooding is only available in the form of public-private partnerships, otherwise it is an uninsurable risk (Gaschen et al 1998).

Another suggestion that has been made is that the insurance industry could institute requirements that those insured take action to reduce the risk to which they are exposed. This simply increases the costs to the insurance industry of writing premiums and makes cover against flooding even less attractive as a risk against which to offer cover. For a profit seeking company, the ideal strategy is not to increase its own costs but to shift those costs on to others, notably the government. Government also has a political legitimacy that profit maximising companies do not have for implementing what are in effect regulations.

From a government's perspective, one of the problems with insurance is that the wrong people are insured: since the take-up of insurance increases with income, those who most need insurance, the poor, are least likely to be insured (H M Treasury 1999). State subsidised insurance systems, such as the NFIP, thus subsidise the better off.

In consequence, the best option is likely to be a public-private partnership which capitalises on the relative strengths of each (Green 2003b). One such model is shown in Figure 5; the state provides a universal payment to all flood victims, sufficient to provide for the basic needs of the poor. In the next layer, all household insurance policies would include cover against flood losses in the same way as the French insurance system. Those outside of the areas at risk of flooding would thus cross-subsidise those at risk of flooding, and the approach might be extended to cover all natural hazards (e.g. earthquakes). Insurance cover in this level would limited to some amount which might be related to average household income. The insurance companies could cover the potential disaster losses in part through the commercial reinsurance market; above this threshold, the state would have to act as the reinsurer of the last resort which governments in practice always are since governments can rarely allow insurance companies to go bankrupt with unpaid claims against them.

Above that limit of cover, the third layer is purely commercial insurance: those at risk could buy additional cover from any company prepared to provide it at the premium rate that the company was prepared to offer.

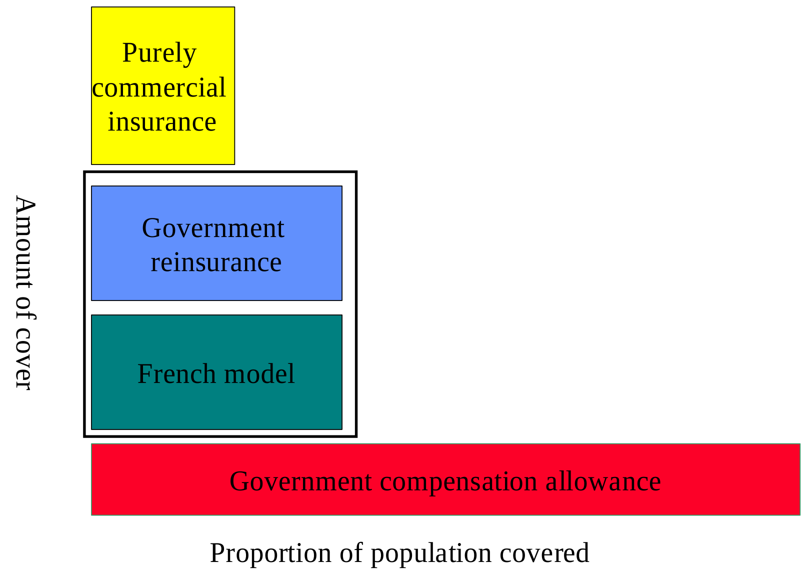


**Figure 5.** Layered system for compensation and insurance

Another suggestion that is made is that governments should take out one of a number of different possible forms of bonds or insurance, such as CATs, to cover the costs of natural disasters. This does not look a good idea for large countries for a number of reasons. In particular, for large countries, both the probability and consequences of natural disasters seem to be lower than those of banking, fiscal or monetary crises (Green 2003a). Buying such instruments as CATs simply shifts the country's exposure from natural hazards to foreign exchange risks, stock market crises and the like. The money required to cover the expected payout in the event of a natural disaster will not be sitting in a bank vault but it will be invested in a stockmarket or in bonds in some country. If the stockmarket crashes then the funds will not necessarily be available to make the pay out against the natural disasters; following the stockmarket crash after September 11th, a number of governments have had to relax to the reserves requirements of insurance companies as the value of their holdings of shares fell dramatically with the crash.

This does not solve the problem of how governments can fund the restoration of national infrastructure and make any compensation to the victims of those disasters. Although natural disasters seldom exceed a loss of more than few percentage points of National Income, the hit on government expenditure is likely to be higher. What is noticeable in China is the very low percentage of National Income that is taken by central government so that a disaster that results in losses of, say, 3% of National Income can become a loss equal to 15% of central government income. If this has to taken out of investment and current expenditure, it would severely disrupt spending. However, China has extensive experience of charges and taxes raised for specific purposes and a 'disaster recovery levy' may well prove to be the best way of funding recovery.

### 4.3.3 Land use planning

Land use control is an obvious idea commonly proposed. With the massive urbanisation anticipated in China over the next 30-50 years, it is highly desirable that development takes account of the relative risks. But there are two questions:

1. what should be the aim of land use planning? And

2. how can we do it?

As with catchment management as a whole, the aim of land use planning should be to make the best use of the catchment as a whole rather than to minimise flood losses. It should remain multi-objective in purpose and take account of multiple constraints in practice. To control land use solely with the purpose of minimising flood losses would be inefficient and simply create other problems which might be worse. For some purposes, relatively flat land is essential as, for other purposes, is access to water a requirement. The problem is therefore: what development should be allowed on which flood plains under what conditions?

It would also seem to be a lot easier to call for land use control than to implement it effectively. Strategic plans, commonly termed 'master' plans, have been prepared for most major cities in the world at one time or another; what has happened on the ground is usually not what was defined on paper. Land use control can be considered in terms of pressures: the pressure for development versus the pressure to resist development. Where the pressure for development is strong and particularly where the local community desires development, then whatever the stated land use planning policy, development is likely to take place (Green et al 2000); land use control can reduce but probably not prevent intensification of development on flood plains (Pottier 1998). The most extreme example is the informal settlement that has taken place in many countries in the world as urbanisation took place. Since this settlement has ignored notional land ownership, it is not surprising that formal land use controls were powerless to the control it (Hamer 1985; Lauria and Whittington 1989; Rakodi and Leduka 2003; Shorter 1989). The rate and process of urbanisation anticipated in China will be a major management challenge.

There is also a danger, and it seems to occur in practice in a number of countries, that land use controls simply provide a new opportunity for corruption. Hence, I have doubts whether formal land use controls will be effective in controlling development. Where the local community wants development to provide jobs, for example, or a major company says it wants to develop in a particular location, the formal land use plan is likely to be waived.

A possible alternative is to establish growth attractors instead of trying to keep development out of particular areas. I'm not convinced that this will be sufficient to keep development out of areas where it is desired to limit development but I'm very pessimistic as to the chances of a formal land use policy and land use controls being effective in most areas.

Where there is already undesirable development in areas of high flood risk, then a practice in Canada, the USA and France is buy up those properties and demolish them. In the USA, entire villages have relocated off the flood plain but the USA has the advantage of having an incredibly low population density – for example, the 1993 Mississippi flood affected only 50,000 properties (Galloway 1994). I would expect that the scope for such an approach to be limited in China at present.

#### 4.3.4 Wetlands

The restoration of wetlands as a means of flood risk management has been widely recommended. What is less clear is how and when wetlands will be more effective than any other form of storage. A large, flat area is potentially a very useful means of flood risk management. It needs to be flat both parallel and perpendicular to the direction of flow but it can be a wetlands, a lake, a detention basin or reservoir. Indeed, in terms of flood risk management, there is not much difference between a wetlands and a reservoir.

Such a large flat area does two things; firstly, it slows down the flood flow and here the high frictional resistance of a wetlands helps. Secondly, it stores some of the flood flow and the potential advantage of any system of storage is that it can reduce the flood peak of any flood however large. It can only do so if both inflow and outflow are controlled. The annual flood is allowed to flood the area but when an extreme flood is occurring, the storage needs to be held empty until the flood peak arrives and it is this flood peak which is stored.

Any large flat area will do; in England, we use agricultural land to convey and store extreme floods. We do so because extreme floods occur in winter out of the growing season and it is not then possible in economic terms to justify protecting agricultural land to a design standard of more than the 5 to 10 year return period flood. A probable explanation of the set back flood embankments on the main rivers in England versus the tightly constrained rivers in central Europe is then the difference in the timing of floods and the growing season; in central Europe, the extreme floods occur in summer and destroy the standing crop.

There are a number of technical definitions of a wetland:

*"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For the purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrata is predominantly undrained hydric soil; and (3) the substrata is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of the year." (Cowardin et al 1979).*

*"A wetland is an ecosystem that depends on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate. The minimum essential characteristics of a wetland are recurrent, sustained inundation or saturation at or near the surface and the presence of physical, chemical, and biological features reflective of recurrent, sustained inundation or saturation. Common diagnostic features of wetlands are hydric soils and hydrophytic vegetation. These features will be present except where specific physicochemical, biotic, or anthropogenic factors have removed them or prevented their development." (US NRC 1995)*

The United States National Research Council goes on to define required extent of the inundation or saturation as a "*duration of saturation approximately 14 days during the growing season in at least 50% of years in the upper root zone (e.g. 30 cms)*" (US NRC 1995).

In England, the floods do not coincide with the growing season of hydrophytes whereas the floods in eastern Europe do so. Hence, under natural conditions, the area of wetlands along the major English rivers would be relatively small but it was relatively large along the rivers of eastern Europe.

As a storage system, wetlands and reservoirs share most of the same advantages and disadvantages. They both take up space, wetlands taking up more space, and hence more people will have to be resettled. Because wetlands are located in flat lands, the soil is highly fertile, and a large area is needed, more people will have to be resettled per unit volume of storage for a wetland than for an upland reservoir. Since one purpose of both wetlands and reservoirs is to slow flows, in both cases, sediment loads carried by the water will settle out resulting in a loss of storage. All land is already in use for some purpose, including environmental uses, and so the conversion of land to either a reservoir or a wetland involves sacrificing those existing uses. Whether on balance a reservoir or a wetland is a better option therefore depends upon local and national circumstances. In Europe and North America, taking land out of the production of heavily subsidised crops and converting that land back to wetlands is an attractive option given the expectation that in case of need, we will be able to buy food on the world market relatively cheaply.

### 4.3.5 Flood proofing

The problem with flood proofing is the way in which it fails; what happens if a deeper flood than which is intended cope occurs or if it fails technically. The two options are to raise buildings either on mounds or embankments or on stilts, or to try to keep water out of the building itself.

Constructing buildings on mounds or on embankments (for example, the Japanese super embankments which are intended to provide space for development) would not seem to have problems with failure but the other two strategies potentially fail catastrophically. If buildings are built on stilts then under some conditions the locally high flood velocities around the stilts will cause erosion and the failure of the columns and consequently the collapse of the entire building (USACE 1998). A high standard of technical design and construction is necessary if this problem is to be avoided.

Keeping the water out of the building is only an option is shallow, slow moving and short lived floods. In England, where the majority of homes are constructed with brick load bearing external walls, if the difference in the depth of water between the outside and inside is greater than about a metre then the masonry walls can be expected to fail partially or completely (Kelman 2002). In longer lasting floods coupled to local ground conditions, the flood water may force its way up through the floor.

More generally, flood proofing will only be cheaper than other options such as flood embankments if the density of development is low as discussed earlier.

### 4.4 Changing the Way we Do it

Actually delivering IWRM is a major challenge; catchment management has to be integrated with national and regional policies of different types and there are many different institutions responsible for different activities. So, what is locally appropriate has to be integrated with a series of holistic and strategic concepts.

Secondly, the problem with any institution is that it has to have both geographical and functional boundaries which define what it must do, what it may do, what it may not do, and where it may do it. In the past, we have tend to try to solve integration problems by establishing larger institutions, ones with wider functional and geographical boundaries. These tend to become clumsy, to lose touch with local needs, and to simply internalise the problems of working across institutional boundaries. I believe that we have to learn instead how we can co-operate across institutional boundaries, to deliver IWRM through fragmented institutions.

## 5 CONCLUSIONS

It is important to avoid implementing the right flood risk management strategy on the wrong river or at the wrong time. In particular, the appropriate flood risk management strategy for the Yangtze in fifty years time is likely to be markedly different from that which is appropriate now. In turn, the problem now is to implement that flood risk management strategy which is appropriate to present conditions and which also provides a path of transition to that strategy which will be appropriate in the future. The present is tightly constrained limiting the options that can be adopted; the future will hopefully be less so.

Choices are also difficult; if they were not, then there would not be any choices to make because the answer would be obvious. There are no panaceas, no painless solutions but I have argued that adopting the Integrated Water Resource Management approach can provide new insights which can help us to make better choices.

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