Land & Water Management in UK under Climate change - The Precautionary principle.

Risk reduction and future proofing.

(Chaos theory meets conspiracy theory.)

This paper is based on my own experiences and observations over the years in the field mostly overseas but also in UK and the growing number of scientific reports on the matter but notably the latest IPPC report. I have for many years agreed with those scientists that have been putting forward the concept of global warming in as much that we have been noticing significant changes in weather patterns, particularly an increased storm intensity and short periods of higher local temperatures; not only in UK but also in West Africa. The damage to the ozone layer brought home the fact that the activity of mankind could affect the atmosphere. We reduced CFC's and lo and behold the hole in The Ozone Layer started to close. It thus seems wholly plausible that the massive amounts of pollutants notably CO2, but also methane , Ammonia , nitrox, water vapour and a wide range of aerosols that are belching into the atmosphere, significantly more than the amount of CFCs that was discharged, must have an effect somewhere. Those old enough will remember the London smog caused by coal burning and that it took very little effort to sort that out – stop burning coal.

There is growing reliable evidence that:-

1/ the CO2 content in the atmosphere is rising as are other pollutants,

2/ the general temperature of the atmosphere is increasing,

3/ the surface water temperature of the sea is increasing

4/ the general level of the sea is rising,

5/ the acidity (pH) of the sea is increasing

6/ Storm intensity is on the increase both in terms of wind speed and volume of water (rain) delivered per storm.

7/ Air temperatures and wind speeds over the northern hemisphere – the main global land mass - are more volatile

8/ El Nino events in the largest mass of global water, the Pacific Ocean, increasingly do appear to have an effect on the weather patterns in other parts of the world but certainly the northern hemisphere. There is some evidence that it affects the energy balance of The Jet Stream.

9/ El Nino events have a major surface water mixing effect due to higher wind speeds that increase wave activity. This transfers warmer surface water down the oceanic profile – a heat sink in its own right – causing mixing which in turn affects deep ocean current activity that relies on temperature and salinity gradients to flow.

From these indicators and some basic physics there is every reason to believe that significantly more incoming solar energy is being trapped within the global atmosphere and oceans- the greenhouse effect - and that this extra energy, as it has to go somewhere, is highly likely to manifest itself in a more turbulent weather pattern. I would suggest that the growing number of flood and storm events in UK over the past few years are a manifestation of this increased climatic energy – the northern jet Stream is certainly more energetic and erratic, and this in turn makes land and water management a much more serious matter than hither to.

There is a growing need under this climatic uncertainty for a clear co-ordinated national programme that brings the wellbeing of the land and water in to one focus particularly in the light of the demands of a high and growing population and increasing global political instability.

Some will also say that a great deal more self-sufficiency in food and energy in a world that doesn't seem to be too worried over the possibility of climate change, nor politically stable just at this time, is no bad thing – I would agree. Hungry people short of resources- especially food - cause problems and having a surplus to help your friends, and indeed your enemies, is no bad thing.

We would thus be wise to follow the precautionary principal and start to develop, adopt and install nation-wide integrated land and water management

systems that take this possibility into account whilst also applying the principal of **"Do no harm**". This does not mean do nothing because change in itself will "do harm" from some ones point of view. It does mean however the wellbeing of the majority of the population and the natural resources. We must never forget that the present landscape wasn't derived from a gloriously co-ordinated set of Town and Country planning principals developed over hundreds of years. Quite the opposite, it is really the outcome of a series of historical mini- accidents. It seems to me that we have reached the limit of a free-for-all and it is high time some sort of sustainable order be planned and set in motion.

I have broken down the present problem, as I see it, in to the two main natural resources- Soil and non -saline water - and the visual outcome from the interaction of these two resources under the influence of man - The Landscape. Air quality is also critical as is the state of the oceans but I have not brought these into this discussion in any great depth despite the fact that the most critical of them all is most probably that of the seas and oceans.

1/ soil degradation

Soil is made up of a mix of natural materials sometimes derived directly from the parent material, the underlying rock, but more often weathered rock that has been mixed and moved by water, ice and wind. There are also soils that

are derived from organic deposits such as the chalks – the accumulation over tens of thousands of years of the skeletons of small sea creatures – and peat bogs – pickled plants. These can then be further mixed in a number of ways, often by water but earthquakes, land slips, wind and major changes in sea levels and in any number of proportions giving acidic clays and peaty-sands to alkaline chalks to neutral sandy loams. And a discrete range of plants over the years have adapted themselves to thrive in that particle soil along with its associated altitude, aspect, climate and drainage characteristics – a habitat. Any UK soil map will show that there is generally limited homogeneity in the soil over any significant area. And as the present field and land holding pattern is not consciously based on any particular soil type In-field and field to field variation is common.

Soil types have a descriptive name, usually local in nature and can be brought into an associated group (a soil series) where enough characteristics are common to all. This is easiest seen, but not that common, when a colour characteristic separates out, usually down a long gentle slope, into a Catena. These are best observed when the whole area is under cultivation as a gentle change of colour down the slope and can be quite dramatic. As this effect, as different parts of the soil separate out usually under the effect of water but also wind, follows the slope it falls by default into a natural contour effect.

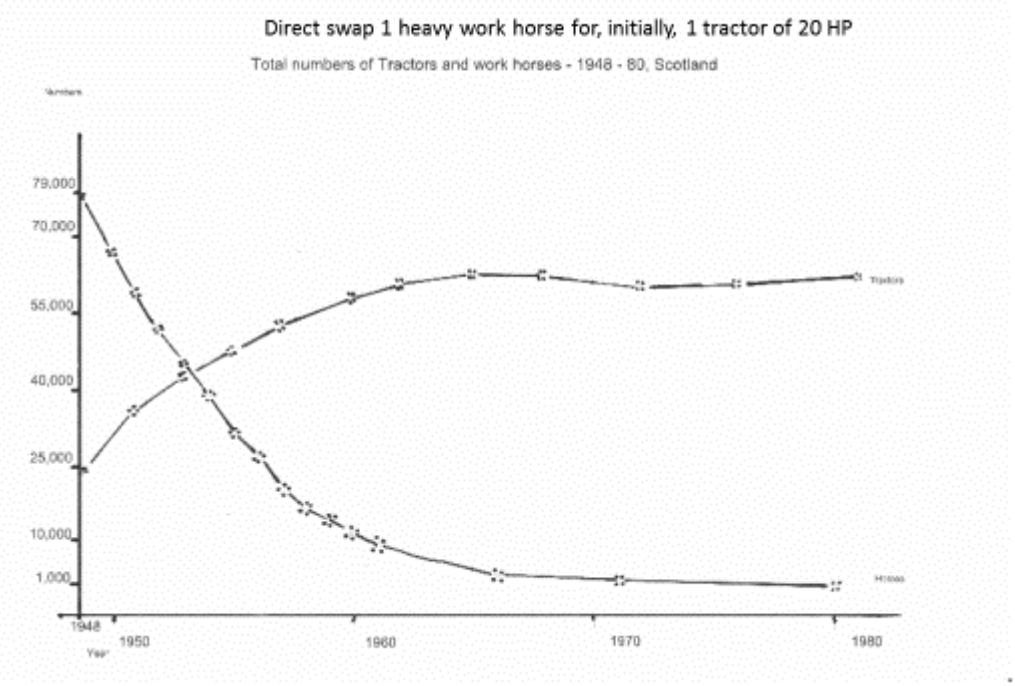
These different parts of the slope, depending on the degree of slope, have different drainage characteristics, soil depths and material content and thus the fertility and yield capacity of each type is different. There can be many other causes of soil colour patterns – volcanic deposition can also make pretty patterns but these tend to be elliptical rather than down the slope and in UK not that common.

The key point to note here is that the present physical field patterns do not take these important differences into account.

Soils if mistreated by compression, chemical reactions or mechanical damage, will break down from the open aggregations they have become into either discrete soil particles if sand based or large blocks if clay based. This breakdown also reduces the number and size of the pores in the soil thus damaging the capacity of the soil biota to carry out their metabolism by closing off the supply of air and water.

It is clear that the arrival of the tractor changed many things in agriculture but particularly cultivation and the force applied to the soil. A horse can pull around about a metric tonne in a two wheel cart and it needs as a minimum two horses to pull a single furrow plough working at about 4 to 5 inches depth. An early Ferguson tractor (nominal 20 HP) could pull 3 tonnes and a two furrow plough at 6 inches depth. Although there is clearly a difference in the

power available the key factor is a wheeled tractor can work in wetter soil conditions thereby making it easier to meet key operation windows such as planting. There is a price to pay for this timeliness if weather conditions are difficult and that is compaction. Depending on the clay content of the soil a pan will form at or just below the plough depth and damage to the soil structure also occurs. Just as the regular passage of heavy equipment on cultivated soil really too wet to travel on will also encourage a pan.



Graph Change - Horses against tractors (extract by TJRH from Gov. Statistics)

The graph shows a direct swap of one horse for one 20 to 30 HP reactor just after the 2nd world war – a massive increase in soil working capacity. And as I am sure everyone is aware agricultural tractors have now become very large

indeed. Although the understanding of the “foot-print” is wide spread and massive tyres and/or tracks seek to alleviate the problem the urgency of the appropriate window is paramount. Out of this comes the one-pass or no-till process as opposed to the more traditional multiple machine pass debate.

The two main outcomes, if care is not taken, are however soil disaggregation leading to significant erosion with the associated silting up of water courses and compaction which seriously limits water penetration and encourages surface run-off. This not only causes flash flooding but also seriously effects aquifer recharge.

Although not an exact science; we have really a very poor understanding of just what organisms live and do in any given soil and what role they play, it is now realised that there is a complex relationship between the soil particles, organic matter and the soil biota. There are certainly many very complex chemical reactions taking place that break down the materials into plant food as well as glues that hold the soil particles together. From the plants and micro-organisms point of view the pH is critical as are the many organic acids and tannins. There is clearly a highly specialized relationship between the plant root and a specific group of organisms associated with the soil type and that plant species. The Legumes and nitrogen fixing bacteria relationship is well

known but there are now understood to be many more such relationships between soil, plant roots and the mycorrhiza family of fungus.

Long term stability within the soil leads to stable habitats and thus a critical factor, in agricultural soils particularly, is the maintenance of a steady supply of organic matter as food for the soil organisms as well as maintaining the pH within a range that suites both the biota and the plant root system. There is good reason to believe that the aspect of organic matter has been badly neglected as various financial and environmental issues have changed farming systems. There have been significant reductions in livestock in many areas with the loss of a grassland break in the rotation plus the manure, apparently compensated for by the use of the readily available and once cheap bag fertilizer. The three main components being Nitrogen(N) mainly derived from the oil industry, Phosphate (P) and potash(K) both mainly mined these days. However their availability along with other key micro-nutrients is very strongly influenced by the pH – best at a neutral value of 7.0 or close to it - which is in turn managed by the applications of Calcium and Magnesium Carbonates (Lime). It is now emerging that bag manure has its problems as it feeds the crop within a season but it does not feed the soil biota over time. As the organic matter falls and thus natural biota activity also falls so does long term nutrient availability and the capacity of the soil to maintain its structure and

retain its moisture retention capacity. This in turn limits the capacity of the plant root to thrive. In drier years this shows up as patches where crop die back is occurring due to moisture stress. It invariable starts on the higher spots with in a field. **Longer drier spells with higher temperatures is thus not good news.** It has been interesting to note that a significant business of baling up straw and selling it off to areas that have livestock enterprises, mainly the upper areas, was built up especially after straw burning was banned. This now appears to be slowing down as more grain farmers fit straw chopper/spreaders so as to incorporate the material. Unfortunately I'm not sure which is the driver – the grain farmer beginning to realise he has an organic matter problem or the numbers of livestock falling nationally so the straw demand has fallen. This no doubt will sort itself out as The CAP crop production subsidies, that encouraged arable crop production on marginal land, have ceased and single farm payments are now the norm. It is to be hoped that land suitability will now become the main driver.

My Point – we need to be a bit more careful just how we treat the soil and its inhabitants. It would be wiser to manage it more as a complex living organism.

2/ Drainage and riverine degradation

Flooding is at the moment a big issue but in many cases this is just drainage badly managed. Maybe because today's media is able to bring the whole scene to us at one time and in splendid colour we appreciate the magnitude of the problem but it has been a problem for some time now.

Over historical time the activity of man has effected just about everywhere on the land and water on this planet. We can see this with the amount of rubbish that can be found anywhere you go from Everest to the Sargasso Sea. We can however appreciate the struggle that primitive man had to establish the early farms. Once the idea of sedentary agriculture had taken hold man started to form fields and to dig channels for water. The first early fields were really small patches, made by carrying off rocks and stones by hand to allow simple cropping, and then the stones are moved a little further and piled to form a stock proof boundary and become fields as we know them today.. Examples can be seen in Cornwall and The Black Isle in Scotland. The fields got ever bigger as more power could be applied by ox, horse and then tractor. In the hotter drier Middle East and Asia irrigation became very important. Complex channels were built pre the pharaohs, and the Persians and the Chinese dug water tunnels - qnats- deep below the ground. Due to the cooler climate, European agriculture particularly northern Europe, did not see irrigation as a pressing need, food preservation for a harsh winter was more important. In

Southern Europe, Spain being a good example, there was considerable irrigation but this was not European farmers but the Arab people from the Middle East who understood the value of all the year round agricultural production.

In general, Northern Europe was more interested in getting the water off the land so as to improve the production capacity. Early farms started to incorporate the field drains into the existing field pattern by placing drains at the foot of existing banks and hedges, which discharged directly into the natural riverine system. Small farm settlements tended – once security and land ownership had been considered - to be near the two key resources of water and wood. However, as these settlements expanded and the number of fields increased, so did the drainage system, but in an ad hoc way driven more by family and community needs. The Black Death caused a blip in land development, clearly demonstrating the value of labour in an agrarian society, but once the population got going again pressure for land took off and has never stopped since. However I would suggest that no one perceived any long term drainage problem. Quite the opposite as the growing urban population saw the natural drainage system as a cheap sewer. At the same time to meet the arable demand the natural surrounding woodland was being cut into. First as the source of firewood, then The Iron Age brought a boost in charcoal

demand followed by ship building, then mining and then wars all the while the population was increasing. There were thus two pressures – the need for wood and the need for farm land. Few thought in the longer term. Eventually the drainage has become, both locally and nationally, chaotic and the woodland, in general, forced increasingly up the slope and onto the poorer soils greatly reducing both the quality and quantity of the national forest. We now appear to have reached the climax of this chaotic expansion whereby the drainage and riverine system is seriously under pressure due to not only the fragmentation of the drainage system and the associated woodland loss but also the fragmentation of responsible authority. Certainly where drainage is concerned long running government agricultural policies, mainly accelerated by two world wars, of grants and subsidizes have encouraged large areas of annual crops into the poorer soils of the upper slopes**. Sadly the net margin is equal or close to the value of the subsidy.** These upper slopes are really a controlling sponge and have in the past been peat bogs and other wet areas along with a significant portion of the natural national forest. Not necessarily the best in quality of timber terms; being either poor quality conifers or a mix of Birch, Alder and other scrub species, but it created a massive sponge. Water, that took weeks even months to discharge, now comes down the river system in a day, even hours, and is more acidic as it is flushing out of rapidly

decaying organic material. It is actually worse as the tree, not seen as an agricultural crop for a very long time, if ever, had now become a form of monoculture in the uplands. The Forestry Commission, a non-agricultural institution, was obliged to plant large areas of fast growing conifers- mainly in the uplands- just after the first WW to meet a perceived urgent industrial and national defence requirement. This has had its effect on water quality. This aspect of the conifer mono-culture has now been addressed but "soonest done quickest mended". Please note however the conifers are a very important group of tree species and in a well-managed and balanced forestry strategy have a major role to play. On many wet upland soils the right conifer is without doubt the right tree in the right place.

To this sorry countryside tale I must add one more factor. As the urban population has grown so has the demand for domestic water. No big thing when a trip to the river was not a problem but once water had to be piped or wells dug a new dimension arrived – rapid urban growth. And then man discovered the water closet, sewage, guttering and tarmac. Now we have created urban drainage. Land was now actually needed to store water for domestic use and sewage had to be dealt with. Pretty much at the same time as urban and industrial growth took off the value of hydro-electricity became widely known. Coal had its problems and oil had yet to rear its head. The

construction of dams and hydro schemes have always had problems even 150 to 200 years ago, mainly unhappy land owners then, but now they face problems more of an environmental nature. I well remember the people of Devon trying to build a large reservoir on Dartmoor in the 60's mainly to serve the growing urban population and a rapidly expanding tourist industry. In the end good agricultural land was taken instead of low-grade moorland and a much smaller dam was built with limited hydroelectricity capacity - something to do with preservation of the natural environment I seem to remember. They still have water shortages, hose-pipe bans and a bit more Hydro-electricity would not go amiss. A large lake up on Dartmoor would have been by know a great wildlife habitat and recreational facility. In Scotland the value of hydro-electricity was better appreciated – true, not by all – and a significant number of high quality hydro- dams were built. It is also true that much of the land utilized was seen to have little value which I would suggest would not have been the case if woodland and timber had been in the land use system. However most of these reservoirs are now protected wildlife habitats and leisure facilities. Sadly very few of these dams, having cost a great deal to construct, allow for further downstream water management and there is still a massive energy potential in water all over UK. The sewage system, a massive

user of water, also has significant energy locked up in it that, through bio-digesters and methane, can be turned into a valuable product.

There is however no positive constructive link between national rainfalls, land drainage, riverine flows, water storage and the multiplicity of demands on the national water supply- including power generation. It cannot be said that the system has a clear co-ordinated policy. Indeed I would suggest quite the opposite with a wide range of entities having conflicting rights without any reference to responsibilities.

My point - Water is a massively valuable resource and not actually in short supply and if properly managed it can provide significantly more clean energy, irrigation and meet all the many industrial and domestic demands. Sadly, it is not, and it is often treated as if it was a waste product.

3/ Landscape degradation

If we take a step back and take a look at the aggregate effect of soil degradation and drainage/river degradation, The Big Picture some would say, we have today's landscape. Under pressure from man's demand for the products of the land, increasingly short term- effectively the parliamentary cycle of at best 5 years- competing with access to the land itself for urban development and increasingly leisure, what do we have?

200 years ago much of UK would not have looked as it looks now. I doubt Constable would recognize it. By the end of the Napoleonic wars the area of native timber forests was considered to be below 18% of the land. The Forestry Commission came into being in 1919 just because there was not enough timber within UK, after a massive war demand, to support the then perceived future needs of the military and the mines. Sadly the timber needed by mines and the military at that time was best obtained from conifers hence the early focus on Pines. Timber planting was also a rich man's pastime, tenant farmers did not plant timber as all timber belonged to the land owner no matter who planted it. Most owner-occupiers also didn't, as it took too much land out of the increasingly short term arable cycle. The Inland Revenue could also be problematic where standing timber was concerned with cost of maintenance allowances and valuations for Death or Estate Duties. Increasing cheap imports of exotic foreign timbers plus the arrival of plastics in the late 50s' also significantly reduced the value of local quality timber. It would seem that events over the past three hundred or more years had conspired against trees as a crop. Indeed I would suggest that it was actually consciously removed from any farms business plan by tax and subsidy policies to maximize the national arable area. Clearly a simple change in the Tax laws in the early

20th century would have encouraged land owners to plant and there may well have been no need for The Forestry Commission.

As I have mentioned before the land has always been under change. Many areas such as Norfolk have been drained with in the past 400 years and now the peat soil –superimposed on the partially weathered parent material and derived from tens of thousands of years of acid organic deposition under poor drainage- has been rapidly oxidizing away to a point where much of the land is at or below sea level. The Somerset levels had been drained by the monks for centuries so as to give quality summer grazing to their sheep – not for meat but for wool. It also provided quality roof thatching materials – reed is more durable than wheat straw. These changes took place over a long period of time.

This is not the case now. The many small fields; under the effects of war, government policy and the associated financial aspects, have now been, to a considerable degree and very quickly, amalgamated in to a larger field pattern. And with it the many hedges that carried a wide range of perennial growth upon it and a drain at foot have gone. This process has thus **not** been determined by a need to improve drainage on a farm scale nor even machine efficiency but really more to do with marginal costs and land investment values.

Large areas of the south west that used to be in perennial fruit crops in small fields were cleared along with the hedges for annual cereal crops and dairy – particularly in the 50s & 60s and on into the 70s and on ground really not suitable for annual cultivation due to soil constraints and slope; very free draining Devon shale on steep slopes.

There have also been other problems where we have not been careful or even strict enough that in my view affect The Landscape in the broadest sense. Where are the Elm Trees – lost to a disease carried by a beetle and now the Ash and no doubt others will follow? BSE and Foot-and mouth ravaged the country, TB is a terrible problem in cattle; possibly linked with badger populations or some other aspect of the environment not yet identified, and Schmallenberg in sheep has done considerable damage. All have significantly affected the national herd and flock. The number of dogs has increased carrying disease (various worm species) and attacking livestock as well as fouling footpaths. In The Highlands of Scotland high Red Deer numbers make it very difficult and certainly very costly to try to re-establish woodlands. High sheep numbers in the uplands all over UK prevent any natural regeneration along with high pony numbers in specific areas. Considerable areas of the upland are being damaged by “foot-fall”. That is by the large number of people walking (and cycling) through as part of the leisure industry. In parts of The

Lake district restrictions have had to put on the number of people using some of the trails. There is clearly a problem with a sound overall view and balance. Some have argued that the livestock problem is no bad thing and may well be an environmental reaction to too high a stock numbers. I personally do not support that view as I consider poor government policies covering plant and animal sanitation and poor decisions on land use are the main cause. Responsible behaviour at any level of society does not seem to be the order of the day.

There is every reason to believe that heavily subsidized farming during the 2nd world war and continuing up to today as the Common Agricultural policy (CAP) has given government a significant and disproportionate power and authority over the use of the land often encouraging inappropriate cultivation on poor land; the net margin being close to the subsidy payment, but from a farm or bank point of view profitable. This approach has reduced land use and water management into a parliamentary term policy (at best 5 years) that at farm level can only be a short term focused system and seriously damaging to the natural resources. This has also had a knock on effect on financial institutions and land values where much land of poor quality is – in my opinion- over-valued by an apparent positive margin and thus in demand causing a false high value.

From this I would suggest that The State has accumulated a very powerful indirect grip on just what is done with the land as has the various funding agencies including The Banks. If we add to this the more recent legislation concerning the environment, wildlife and access I ask the question who is actually managing this landscape and more pertinently with what objective?

Farmers and all other land owners have not been encouraged or do not wish to look at the bigger picture and appreciate that their own land unit is actually part of a much bigger land unit – the landscape – and The State has them jumping through a hoop. There is no doubt that there are parts of the UK landscape that are stunningly beautiful and there are parts that we have become accustomed to that we perceive as beautiful – such as The Moors and The Highlands - but if there is any truth in climate change we are going to need a more coordinated land and water management system to improve overall yield, store more water and generate more low carbon energy; either by wind, hydro and biomass, whilst seriously upgrading soil and land quality. All the while providing the very large leisure area the urban masses require. This surely means that the present landscape will have to change and quite dramatically. It is not apparently robust enough at present to cope with any short term minor change in the weather pattern whilst providing what the general population –mainly urban – feel is their right. The public expect safety

from the elements but also expects clean water to drink, water to flush their toilets and water for their gardens plus meat and bread from the land.

We most certainly cannot wait whilst a small group of grandees argue it out as to whether or not global warming and climate change is a figment of some scientist's imagination, and even it is not, come up with a policy. I would venture to suggest an awful lot of people are not going to like was has to be done either starting quietly and slowly now or in a great hurry if left till later.

If the weather pattern is on the change, if storm intensity is on the increase, if we can expect longer drier periods, is the present landscape resilient enough? I don't think so.

My Point -The key question – the elephant in the room – is who is actually responsible for coordinating the management of the water and the land. I believe that in reality, at this time, no one is.

Man has applied force to the land to bend it to his will right from the start of sedentary agriculture. However today we have the technology to apply massive force on a very large scale. I would suggest that we have not been well co-ordinated in the ways we have used much of this technology.

I have tried to show we have a problem with a steadily falling soil quality, increasingly prone to erosion and a massively degraded riverine system,

increasingly prone to flooding. This comes together in the landscape and brings with it other associated problems. The land and the water are inextricably linked such that different sets of plants and animals develop on and within it in an overlapping set of complex habitats. The association works slowly over long periods of time to form discrete habitats depending on the interplay of its various components. At present the human element appears to be doing its best to create a big problem.

A possible way forward

I have no complete answer to the present dilemma but suggest that a good point to start is as follows. It consists of two elements that have to be worked together as a policy and a strategy and is built around my belief in starting from a natural boundary and framework, in this case a water catchment area (WCA). That is that piece of land that along with its water drainage system can be clearly and easily mapped from the upland watershed to the coastal discharge point.

It could be argued that much of the chaos that surrounds land and water is because, when viewed from our patch on the ground, we cannot see over the horizon. That is no longer true. The linear map view is now both three dimensional and very much looking over the horizon. The Copernicus

programme of new Sentinel satellites that have moved on from the “primitive” Landsat programme gives us quite extra ordinary tools to define, map and organise such natural zones as a Water Catchment Area.

1/ Water management – Water catchment system

A water catchment area, sometimes referred to as a river basin, is that piece of land that forms the collecting bowl for a definable drainage system. It may consist of one river and its tributaries but usually it is a group of rivers that converge together to form one large river which then discharges: via a flood plain, into the sea. The movement of water down through this system has great value if managed well or can be a major cost.

Over and above the primary use of water which is to sustain the natural environment I would suggest that the there are five major uses by society:-

1/ Crop production – raw material production particularly food but fibres and pharmaceuticals.

2/ Power generation - hydro Electricity .

3/ Industrial usage - manufacturing/production of goods and services.

4/ Domestic – drinking/household & sewage.

5/ leisure & pleasure – Boating, fishing, swimming, wildlife.

All of these uses are managed today by at least five or more completely separate entities that rarely if ever talk to one another along with a mishmash of various government agencies, ministries and local governments having their say.

At present due to this multiplicity of authorities and/or legal rights there is no way that the full value of the water can be achieved. Environmental agencies, National Parks, Local Authorities, Water Boards , private water companies, canal authorities, land owners and no doubt others I have forgotten or never knew existed all vie for what they see as their little bit of power. More often than not their physical and legal boundaries are not the same and cross one another or cross in and out of a catchment area resulting in chaos. Any sort of co-ordinated genuine planning is clearly impossible. If water management is left to the many the obvious outcome is loss of control, leading to chaos leading to flooding and silting and a great deal of damage. If we now add the new dimension brought about by climate change of increased water flows and the associated increased silt load the degree of chaos can only increase.

Ideally a single Catchment area authority, staffed at the field level by people with demonstrable local knowledge, operating under the guidance of a national policy, should be able to carry out a strategy designed to maximise the value of the flow of water down and through the catchment area from top to

bottom. This means that a careful description of what society expects to get out of the water and the measures needed to achieve that has to be developed to first provide a cohesive national policy. From this policy people with local knowledge can built a strategy specific to the capacity of their catchment area.

If we take rainfall as the starting point and follow its movement through and across the soil profile we will find that much of this water is excess to immediate requirements and becomes surface flow collecting and gathering into a flow that forms a small stream and then by aggregation becomes a river and so on. This excess has great value but only if stored and not for a rainy day - quite the opposite.

At this initial stage we are clearly on-farm at any point within the catchment area. If I am right and hotter drier times are coming supplementary irrigation is going to be critical to maintain food production. As it is, the opportunity in UK to boost yields from supplementary irrigation is significant. I would suggest that there is a need for landowners to be obliged to store this excess water in a very large number of small on-farm dams. The design for this type of dam is simple, basically an earthen dam with a puddle clay core. It has to be fitted with a simple control gate that can be manual, electrical or hydraulic. This gate allows the dam to be filled or partly emptied by the local owner working under instructions on his mobile phone from the Water Catchment Authority, who in

turn is in minute by minute contact with the weather forecasters. Their responsibility is to control the amounts of water moving through the system in conjunction with weather reports for their area. These sluices or spillways can be opened to allow flows to maintain minimum agree river flows, closed to hold back excess flow until the storm has passed but always retaining, as a minimum the irrigation requirement of the farmer and to sustain the quality of the habitat. This is the landowner's incentive to participate.

Hydro-power relies on "the head" so it is most likely that it is in the upper areas of the catchment – usually more rugged and with steeper slopes –where most suitable sites for the larger dams will be found but not exclusively. There will also be suitable on farm sites and opportunities for one or more farms to cooperate to develop a larger unit. The bigger the dam however the higher the cost and associated risk. There is however a growing improvement in the technology and quite small working heads can give a useful electrical output. Any catchment area strategy must include the maximization of hydro-electricity generation. However this must always be done with in the overall management framework of all other possible uses. The water demand of the general public is massive – partly for consumption and other domestic uses including hose pipes but significantly for sewage disposal.

By having a strategy that is designed to maintain minimum river flows and that have been designed to take into account agricultural, industrial and domestic take off the Catchment Authority should be better able to manage the wellbeing of the whole WCA. They may well have to have back-up bore holes but as the strategy includes an effort to encourage aquifer replenishment – the more dams the better the recharge - this should not be a major problem.

My point – we as a nation need to have a national policy that is operated at the strategic and practical level by a Water Catchment Authority – with powers to ensure that the water received in that CA is fully utilized based on a complete understanding of the flows and needs.

2/ Land management

Going hand in glove with the management of the water in a catchment is the associated land. If water is contentious I think we will all agree land is likely to be even more so. At this stage of land use where population density pressure – particularly urban spread - and so-called intensive farming has brought every little parcel of good arable land into use, and where all the land is owned by someone and considerable value is put on that land, as well as debt, there does not appear too much room to manoeuvre.

Appropriate land use.

As I have mentioned earlier the present layout of the parcels of land that form the landscape at any level has not been derived from a logical process. There is very little natural resource logic to the shape of most land holdings. It certainly does not follow any clear drainage or soil type pattern.

Up till now this has been, up to a point, excusable but not now. Clearly the approach to land has been linear based on what we can see. And although we have had reasonably accurate land maps they are effectively based on a two dimensional approach. The arrival of the mapping satellite has shown that there are problems on the larger scale as we can now look at a three dimensional view taking into account local and general slopes, the overall topography, as well as the larger drainage patterns up to catchment area. This started with aerial photo analysis then LANDSAT but now we have the new EU funded Sentinel system specifically designed to allow a very high standard of land analysis and value assessment and pretty much at any scale.

Land owners and users are going to have to face the fact that over the next 50 to 60 years they are going to have to completely realign their drains, hedges and boundaries if the present problem is to be resolved. This will most certainly be true if the present types and size of subsidises –tax payers money-

are going to continue to be paid to the agricultural industry. And in the context of this discussion I include Forestry.

The land within the WCA will have to be mapped at, as a minimum, at 50 cm (better 20 cm) contour level. This is no problem with the present satellite capacity. The map will provide a logical framework for the design of drains with in the land to feed, in a controlled rate, in to the natural drainage lines. This in turn will identify those areas that will best suited for water storage of all sizes to be installed. As discussed these ponds, lakes and reservoirs must have a linked operating system that allows the full use of the storage capacity as well as allowing storm water management and commercial use. As is now, these in-field drains will follow the hedges but now the hedges are following a contour line with a small gradient. Indeed the new hedge line can be made up from a wide choice of plants. For myself I would like to see forestry come back on to the farms and many of the major drainage lines should be stabilized by planting of mixed woodland - at a minimum 50 metres wide. All permanent water courses should be wooded at 100 metre widths. The intermediary field drain lines can be similarly wooded but at 20 metre widths but can well be used to provide perennial fruit crops, coppicing material or bio-mass. What has been formed is a complex but rational network of drainage lines contained within a wooded belt all interconnected. These form wild life corridors

allowing species to move from place to place and to establish viable colonies in those area best suited. Wild Bee species are a good example as are other key crop pollinators. With this complex network no crop is that far away from a natural pollinator. Nor any crop pest from its predator.

As the land is now laid out on the contour the strips of land lying between the drainage lines will tend to be of a similar soil type having many common characteristics such as structure ,water penetration rate, fertility, water holding capacity and will thus tend to respond uniformly to any one particular treatment, such as a cultivation, and crop. As the land is based on a 50 cm contour the degree of slope will determine the width of the strip. The final choice of strip width will have to be based on the erosivity of the soil with in that strip. This is a function of the soil type and the degree of slope. A light sandy soil on a steep slope is going to erode easily under storm conditions but will be able to manage continuous steady rain as it has a high infiltration rate where as heavy clay will quickly start to have rapid surface flows.

Long, close to parallel, strips carefully engineered provide high machine efficiency reducing turning time and short work. These strips also lend themselves to the use of robotics. Small light robotic vehicles carrying just the right amounts of sprays, fertilizers and seeds guided by a GPS system can operate under a very much wider set of weather conditions as they will have a

light footprint. This in turn allows optimum planting and management targets to be achieved. The number of times heavy equipment – causing compaction - needs to go onto the land can be minimized.

Regular crop mapping by in-field drones using a multi-spectral camera will allow close analysis of the crop effectively plant by plant. This will enable a small machine to work down the row dealing with a specific problem such as a local hot spot of a disease or a nutrient deficiency. It will be able to fill in lost plants at a very early stage of emergency thus optimizing the plant population.

These land use systems are all very well, and we need to get the best out of the land, but this is not going to happen unless we keep the soil in good condition and that means getting the nutrient balance and the moisture retention capacity right. Up until quite recently we were of the belief that this could be done ad infinitum with bag fertilizer most of which was imported. This has proved to be incorrect both in terms of cost and soil condition. It is essential to get the organic matter balance right to maintain the soil biota and maximize water retention. There is good reason to believe that the general level of organic matter in UK soils has fallen from 8% to around 2%.

From where is this organic matter going to come from? In the past – certainly over 100 years ago - long crop rotations with a significant period in grass and livestock was the main provider of organic matter along with dung from in-

housed over wintered stock. The large number of horses, particularly in towns and cities for transport, provided large quantities – the internal combustion engine put paid to that. It is now highly likely that the number of on-farm livestock will also fall but certainly those keep in highly intensive systems is very likely to fall and traditional manures will be very much less available. In the past a great deal of organic manure also came from sewage especially around towns and cities – night soil - but this material due to a better understanding of hygiene and disease spread has become naturally unavailable.

However when we realize that a population of 70 million is producing approximately 14 thousand tons per day of raw sewage, most of which is at present rendered "safe" by an expensive process of aerobic digestion, there is clearly a great source of organic matter going to waste as well as a significant loss of energy. This material can be converted into energy by the use of anaerobic bio-digesters producing methane as a fuel for electricity generators, heat, digestat (compost) and a little CO2. The present loss of this digestat, as very little human sewage is processed by this system, is a national disgrace.

There are over 17 million hectares in active agricultural usage in UK of which 6.2 million is considered to be arable. However when we realize that the present human population of close to 70 million is producing not less than 14

thousand tons per day of raw sewage solids (200 gr/P/D); plus significant quantities of other household organic waste, probably greater than the 200 gm of faeces, there is clearly a great source of organic matter that easily replaces the more traditional sources and it is going to waste.

This material represents not less than 50 thousand tons per day of digestat that could be produced by anaerobic bio-digesters (18 million tons/annum) which equates to about 3 ton/annum for each of the 6.32 million arable hectares.

By having a fairly large number of bio-digesters operating near urban centres (70% of the UK population) the sewage can be kept fully contained and with no need to discharge excess under storm conditions into the coastal waters. This habit, bad enough now, will most certainly become extremely dangerous as water and air temperatures rise feeding large algae blooms just off shore putting in-shore fisheries at risk as well as bathing and surfing. The electricity generated must be feed into the grid as a priority source and the heat can be used either in the urban areas (hospitals, schools and municipal buildings) or for intensive undercover vegetable production as can the CO2. The digestat can be rendered fully safe by a process of pressure cooking (pasteurization) after the methane has been harvested. At present mainly due to the public's perception of this type of digestat, and not based on any scientific evidence,

there are massive restrictions on the use of sewage as a source of organic matter. In Germany a carefully managed licencing process and regular analysis of the digestat allows a great deal of this material to be used. However if the area of perennial crops, particularly fruit crops, woodlands and commercial timber, was increases this area alone would be able to take significant quantities without coming anywhere near an arable food crop.

To summarise:-

The soil and the water are the two key natural resources that come together in a water Catchment area to form a number of complementary landscapes. We as humans look to this landscape to provide us with food, water, materials and the space to live. If we recognize the complexity of this association between soil, water and people and appreciate that these are finite resources which cannot be replaced it becomes clear that they must managed in a coordinate manner so as not to damage the cycle. No one person or group of people can be allowed to hold any one of these resources such that society is being held to ransom. I would suggest that just at this time, luckily, we do not have a situation where a ransom is the issue more a situation whereby no one feels that they are in a position to start to open up the debate on how on an island with a population of 70 million plus can we manage the land and water area for the benefit of all. Yes - there are issues of land and water ownership, and

land owners will not give up land or control of land without a fight. Mind you I would suggest that in reality many have actually bartered their rights as their subsidy payment is their profit; and they have no control on the amounts paid. And as I have described, to go from the present boundaries to a mapped contour and rational drainage layout , even over a 50 or more years timetable, is possible from a simple scientific and rational approach but politically and socially not easy at all.

But we need to think the unthinkable as society has a bad habit of waiting until it runs up against the buffers and then tries to sort out the problem. This usually end up in tears. A good start would be to set in motion a very accurate mapping and land registration programme along with a nationwide coordinated rainfall and riverine measurement system.