FLOODING

Understanding The Natural Water Cycle, Why Flooding Happens and The Holistic Management of River Catchments.

Dr Rod Everett Feb 2016.

The Natural Water Cycle

In an undamaged natural system, rainwater falls on blanket bog and mire on the top of our hills and mountains. There the rainwater is absorbed into the mosses and the underlying peat. These both act like a large sponge. (Blanket bog can be around 85% water).

Blanket Bog ,Whitmoor, N.Lancs.
Tussocks of heather and mosses absorb and cool water.

The dwarf scrub of species like heather, ling, bilberry and cranberry shade water from the hot sunlight. When wind blows across this type of vegetation water is cooled towards 4 degrees C. At this temperature water is at it's most dense, absorbs into the land easily then enters the subsurface water. There it continues cooling towards 4 degrees (when it is most dense and heavy) and sinks further down into the warmer core of earth filling up our deep cycle aquifers. On reaching the warmer parts deep in the earth (maybe months later) the water warms and becomes less dense and rises towards the surface. It eventually comes out as spring water adding mineral rich water to the streams and rivers.

Most of our hill tops were clothed in trees many centuries ago. This is revealed by pollen records and by ancient bog oak occasionally coming to the surface or excavated out of a ditch on the fells indicating the prevalence of upland forestation. The water from rainfall cools and becomes

absorbed into the deep leaf litter and humus of the woodlands resulting in the same sinking process continuing the deep water cycle process. The Pontbren project in Wales found that water flowed down the tree roots and was absorbed 67 times more on land with trees compared to grazed pasture – a massive absorption rate. https://www.woodlandtrust.org.uk/mediafile/100263187/rr-wt-71014-pontbren-project-2014.pdf?cb=f9f7c9ebfcdd42b8be8975db01ec48a5

A vital process to stop flash flooding in rivers is by encouraging woodland and blanket bog in slowing down the water flow going back to the rivers and streams.

In undamaged river systems it may take around a week for the river to rise after heavy rain. The rise and fall of river levels should be slow and predictable. The best fishing and canoeing rivers usually have this form of flow (such as the River Spey in Scotland. Mires and bogs are are an important part of the River Spey catchment area).
Water evaporates and transpires from the action of wind and sun on the blanket bog and woodland vegetation. This puts moisture back into the air, which in turn forms clouds and eventually leading to predictable rainfall on the lee, the drier, side of hills and mountains.
In this natural situation the water flow is predictable and doesn't cause damage from flooding. The aquatic life thrives and fish are abundant. Under the partial shade of the trees, rivers and streams flow with longitudinal vortices (going with the river flow) creating deep channels in the rivers. The vortices also concentrate fish food within their central core making it easier for the fish to feed.

Longitudinal vortices help keep the river U shaped and healthy

A healthy river has a steady meandering shape with deep pools on the outside edge of the bends. The longitudinal ,down stream, vortical movement of water helps to remove pathogenic anaerobic bacteria from the water by constant incorporation of oxygen.

When you look at the surface of water or when it falls over a rock you can see distinct rope like structures. These “strings” are often of slightly different temperatures. With this form of flow a steady down stream flow is established.

Strings of water in its natural form

Rocks standing proud within the river bed change the flow and meander of the water. They can help the water dig deeper pools and help to take energy out of the water slowing the flow. Rocks acting as an upstream vane pulling the water into the river centre away from the bank

Streams and rivers start with a branch-tree like shape at their source leading into a main river. This then flows more gently down towards the flood plane where any excess water will flow over the surrounding land in a gentle manner. Down at the estuary the river then fans out as it enters the sea. The fresh water entering the sea and the rainwater evaporating from the sea are of similar proportions. This gives a predictable rainfall.

What has altered to give us more frequent and extreme flooding?

Hard impenetrable surfaces
Urban development with roads, roofs and concrete surfaces prevent the water sinking into the land. These get hot when the sun shines and the moisture on them evaporates.

Canalisation and hard edged water channels
Canalisation of water courses, hard flood barriers, road bridges, culverts, concrete drainage channels prevent water from releasing its forceful energy and this speeds up the water flow leading to more erosion and causing the land to be deluged in water with flash flooding.

Land drainage
Over the whole length of the river, land drainage from agricultural land speeds up the run-off from higher land.

Overgrazing on a regular basis
Regular grazing of fields can lead to soil compaction and damage to the humus rich layer in the top of the soil .This reduces the water holding capacity of soil

Depleted aquifers and natural springs
Where land is bare or overgrazed, the land heats up quickly and water runs off faster than land covered in vegetation. This prevents the water from sinking down into and filling the deep water aquifers. These aquifers become depleted and the water level sinks. In many places the natural deep water springs have dried up.

Exposure to excess sunlight
Infra red light from the sun alters the water molecule structure so it coalesces into much larger drops which have a -ve charge on the outside and a +ve centre. These large clusters of water molecules run off the surfaces faster than smaller drops (like cold water onto a hot plate) and can cause erosion on any land it encounters. This effect causes problems when ground is bare of vegetation or it is grazed short when the land surface has a -ve charge.

Reduced quality of natural soil biota
The high use of artificial fertilizers and agricultural chemicals deplete the rich natural soil biota. The soil loses its humus layer and reduces the land's water carrying capacity.

Waxy hydrophobic soils caused by fires and heavy sheep grazing
Without spring and underground water, and a cover of blanket bog or trees the land becomes drier and 'waxy'. In this state it becomes hydrophobic, repelling water. The effect of fires (from muir burn) can increase the waxy nature of the soil over a number of years.
http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051899.pdf.
This is in contrast to soils rich in plant roots, soil micro-organisms, and soil fauna that help break down the hydrophobic layer.

High levels of evaporation leading to more rain
The higher heat on bare or short vegetation land and water running over the land surface leads to high levels of evaporation, creating more rainfall. This is in contrast to a steady gentle evaporation and transpiration from plants and trees over a longer period from land that has absorbed the water and protected it from direct sunshine.

Reduced infiltration to the deep aquifers
Simultaneously, water is lost before it's infiltration into our deep aquifers. This drops the water table level. This is happening all over the world and creates wet deserts---lots of water, but little held in the ground.
The **High levels of evaporation leading to more rain** and **Reduced infiltration to the deep aquifers** contribute to climate change. Michal Kravčík explains this in detail in "Water for the Recovery of the Climate - A New Water Paradigm".
http://www.waterparadigm.org/indexen.php?web=./home/homeen.html

Temperature differences between rainfall and stream water
The relative temperatures of the land and the temperature of the rain are important. If we have warm dry land, warm river water and heavy cold rain then, because of the temperature difference, the two bodies of water are prevented from mixing. The fast run-off of cold, denser water goes under the less dense warmer water. This creates horizontal vortices across the water course rather than normal longitudinal vortices going down the river. These vortices undermine the banks and dig holes in the river bed. This effect usually only occurs on a few days in the year. (The devastation of the Wray flood, North Lancashire in 1967 was enhanced because of this.)
The horizontal vortices act like a dam for the water coming behind and it spreads out across the river creating wide flat bottoms in rivers and streams that heat up easily in the sun. Many of our rivers are now like this and it is an indicator of over heated land in the catchment.

Horizontal flow holding back the water and spreading the vortices across the river. These flatten the river bed and undermine the banks

Sphagnum damage from pollution, fires and over grazing
On the top of the fells there are other problems that lead to flooding and erosion. Industrial pollution has damaged the sphagnum mosses and there have often been fires that have burnt out the blanket bog and underlying peat. Often these fires have been started to encourage young growth of heather for grouse. When this damage occurs then sweeter grasses invade the land which are more palatable to sheep. Grazing livestock then concentrate on these areas and damage the vegetation. When there is erosion and bare peat, soil hags develop. The sheep use these for shelter causing further erosion.

Subsidies in the past have encouraged high sheep numbers and this has led to badly damaged blanket bog and rapid erosion. Once the erosion starts then run off is more rapid. Upland mires can have their natural dams broken by this rush of water and they lose their water holding capacity -once lost, these mires cannot naturally be recreated.

Landslip exposing bare shale in Warm Beck, Roeburndale, Lancashire. This started in 1967 and appears to be the after-effect of fire damage creating bare ground on Whitmoor. The catchment area of this stream.

Landslips

The fast run-off directly from field surface or from land drainage systems can get into clay and silty soil under woodland cover. In extreme rain conditions the clay becomes fluid and starts slipping. This undermines the integrity of the soil and the trees start to move downhill as a landslip. These landslips ,with tons of soil and trees ,slip down into the river and damage structures over and along the bank of the river.

Landslip during Flood Desmond caused by small field drain and overland water liquifying the clay soil.

Trees damming the river
Where a river or stream narrows, trees can get caught and build up a dam. Water collects behind this and when the force of water is too strong the tree dam breaks. This causes a rush of water and trees down to the next narrow or constricted area where the same process occurs. (This was the main reason for Wray flood, North Lancashire in 1967).

Water catchment features full with no designed overflow
Another type of flooding occurs after persistent long term rain. This was the situation with Storm Desmond and Storm Eva Dec 2015.
All the top soil and water catchment features become full of water and then excess of water has nowhere to go except rush off down the river causing flooding. The drought over the summer and into the autumn 2015 reduced the ability of the land to absorb any more water. The surface was water logged but the deeper ground was dry. Without trees and their root systems acting as lines of water flow, water doesn't infiltrate. Rapid evaporation leads to more rain.
During Storm Desmond Thirlmere reservoir in the central Lake District became inundated with water from Helvellyn and the release of the water contributed to the flooding down stream settlements such as Cockermouth.

Measures to stop flooding

Restoring blanket bog, check dams and blocking drainage grips
High in the catchment area, restoring the blanket bog with its water retention capacity, is very important. The Peak District project has done excellent restoration work of this type. It has removed livestock from some areas allowing the dwarf shrubs to grow, stopped burning the heather and restored bare patches left by fires by re-vegetating with cotton grass and other grasses.
Moors For the Future Partnership:
https://www.rgs.org/NR/rdonlyres/495096B2-4A15-439E-A89A-48E7A9460E49/0/MoorlandrestorationinthePeakDistrictNationalPark.pdf
http://www.moorsforthefuture.org.uk/repairing-bare-peat

Heather Bale check dam in the Peak District slowing the flow from eroded peat moor.

Eroded gullies in the peat have been slowed down with a combination of small check dams made with heather bales, timber and stones. Check dams hold the water back at the same time as letting it leak through. The flat water surface from the top of one check dam to the bottom of the one upstream slows the water down and catches sediment. These eventually lead to stable areas of sediment that can re vegetate. The over hangs on the edge of peat gullies (hags) were profiled so that they could be planted. Where drainage grips were present on the fells these can be blocked increasing the areas water holding capacity.

Replanting uplands

The Carrifran project (www.**carrifran**.org.uk) has replanted a high water shed area in Southern Scotland. This was based on the species found by pollen analysis of the soil. The very successful replanting shows that these high ground areas can be covered in native trees. Once established, then the water holding capacity greatly increases.

Catchment dams slowing the flow

Above Pickering, N. Yorkshire, most of the small streams in the catchment area have small check dams installed. Just above Pickering there is a much larger flood catchment scheme which hold back extreme floods. The combination of these schemes was considered to have saved the town from flooding in the recent storms (Dec 2015). Lower down in areas planted with conifers, they have created very wide timber check dams that allow the main flow to go under the water gate. In times of high water flow the water spreads out into the woodland and slows its flow.

Wide timber check dam that allow normal stream flow but holds back extreme flooding and spreads it out into the woodland. This is just one of many in the catchment above Pickering.

Contour tree planting

In Wales on the upper reaches of the Severn, in the Pontbren Valley, farmers have worked together to bring back a stable river flow. Planting trees along the contours fairly quickly increased the water infiltration to up to 67 times the previous levels.
http://www.coedcymru.org.uk/images/user/5472%20Pontbren%20CS%20v12.pdf
This has also brought back otters and a healthy fish population.

Water retention measures
In Slovakia, Michal Kravčík and his colleagues established a 10 year programme to hold water in Slovakia and enabling the water bodies to moderate the climate. In a short period of just 18 months, 488 villages and towns were involved in the programme. In total, about 100,000 individual water retention elements were carried out with a total landscape water retention capacity of approximately 10 million m^3. This work provided a total of 7,700 seasonal jobs for local people, and in the vast majority of cases utilised local natural materials such as soil, stone and wood. The positive impacts of this approach were twofold. Firstly, the public funds invested provided positive local community outcomes far beyond the direct impacts of the revitalisation measures themselves. Secondly, by engaging the local community in designing and building the solutions themselves, the community took onboard ownership and stewardship of the solutions. "After us the desert and the deluge" details some of the work carried out.
http://ludiaavoda.sk/data/files/44_kravcik-after-us-the-desert-and-the-deluge.pdf Kravčík has recently published a "A global action plan for the restoration of natural water cycles and climate" http://bio4climate.org/downloads/Kravcik_Global_Action_Plan.pdf.

Kravčík states 'The prevention of floods, drought and climate change can be tackled in a three step approach based on the following sequence:
(i) capturing rainwater in the eco-system where it falls – retaining
(ii) accumuling rainwater in the eco-system – storing
(iii) releasing the excess rainwater, which the ecosystem is not capable of absorbing – draining

One of the basic steps for the prevention of floods, drought and climate change will be the restoration of an ecosystem's water basin to its natural self-sustaining state where it will be able to retain rain water, permit its infiltration into the soil and thus increase the quality of the soil. The restoration of the functions of an ecosystem will revitalize the use of the land for its inhabitants It will strengthen ecological quality and productive potential in such a way, that water basins will no longer be sources of drought and flooding At the same time biodiversity will be increased and the climate revitalized.'

Engaging the local community
Rajendra Singh http://tarunbharatsangh.in/the-flow-research-network-frn/ the recipient of the 2015 Stockholm Water prize emphasises the importance of engaging people in the process. The Stockholm Water Prize Committee says that "today's water problems cannot be solved by science or technology alone. They are instead human problems of governance, policy, leadership, and social resilience". Rajendra Singh's life work has been in building social capacity to solve local water problems through participatory action, empowerment of women, linking indigenous know-how with modern scientific and technical approaches and upending traditional patterns of development, resource use, and social norms."

Education
The change in thinking and our understanding of water with householders, landowners, developers, local authorities, agencies and NGOs is critical to making these changes happen. It might be that the recent UK floods have engaged most of our population in the awareness of flooding and its consequences. Education with a real understanding of water at this point in time will be an important route to making changes for the benefit of our future.

Contour swale water holding features
Permaculture practitioners have been working with swales to catch and spread water. Geoff Lawton has implemented contour swale constructions in many parts of the world as a way of spreading and sinking water. Backsbottom Farm in Lancashire has implemented a double swale system in Roeburndale that catches and spreads the excess water from an area of fell. The trees planted on the

lower side will help this water to infiltrate into the ground.

This is one of 2 swale lines that are at 2 metre height difference from each other. In heavy rain they catch water and spread it across the contour. The trees will eventually help the water to infiltrate deep into the ground.

Swales at work https://www.youtube.com/watch?v=xZ55w6K70Dk .

Keyline planting

Darren Doherty has a similar system with very gently sloping tree lines using a keyline pattern. the tree mounds aren't on contours, but rather they gently slope away from the valleys -the naturally moist areas-towards the ridges -the naturally dry areas-therefore aiming to even out the moisture levels across the landscape. For a comparison of the 2 systems see http://permaculturenews.org/2009/11/30/keyline-swales-a-geoff-lawtondarren-doherty-hybrid/
Richard Perkins has implemented this keyline system on his farm Ridgedale in Sweden. http://www.ridgedalepermaculture.com/keyline-design.html
This system uses trees to absorb the water in a similar way to the Pontbren Project.

Natural revegetation with gorse, alder and willows

In Roeburndale the badly eroded valley floor and the shale banks rising up from gullies that formed after the 1967 Wray flood have naturally re-vegetated with gorse. Gorse is a nitrogen fixer and protects the land from grazing. Now a number of these areas have developed a good woodland cover which is taking over from the gorse.

Gorse has self seeded onto the eroded bank after the Wray floods in 1967 . It has protected the bank from grazing, added nitrogen and encouraged the growth of trees.

The floating seeds of the alder tree have germinated on bare banks and have now grown into a strong bank protection woodland that can easily cope with flooding.

Self seeded alder trees protecting the bank of the River Roeburn. This bank was being undercut 15 years ago.

Many areas of river bank and river flood areas have been planted with willow. These slow the flow and protect the bank from erosion.

Willow flood area on the River Lune

In River Training

In Austria Otman Grober has been working with rivers for over 30 years. By careful placement of rocks in the river bed in a narrow funnel shape with the open wider end upstream, he has enabled the water in the river to scour out the centre of the river and pull its flow away from the river banks. He was stimulated by the earlier work and deep understanding of water and its properties by Victor Schauberger. See Otman Grober's paper in http://pro.hansgrohe.co.uk/assets/global/water-symposium-2010_ways-of-water.pdf and http://www.tubechop.com/watch/7549101

Christine Sindelar from Gatz Technical University now at IWHW, Boku, Vienna, has further developed the In River Training work. This is the modification of flow with small submerged instream structures (natural materials) which induce large scale helical patterns to achieve channel stabilization, flow and bed heterogeneity, sediment management or initiation of dynamic river development. She has worked with Niels Werdenberg and others to assess the effectiveness of micro- groins, meandering rams, stream barbs and rock vanes where small changes to the rocks in the river bed are preventing flood damage. (Werdenberg, Mende, Sindelar 2014_Instream River Training: fundamentals & practical example. River Flow 2014 Schleiss et al.)

A natural Vane deepening the centre of the. river .

A natural micro-groin pulling the flow away from the bank.

One of their techniques uses a wide funnel shape of spaced boulders and a blocked top with the open end facing downstream. This shape pulls the water back into the centre area through the gaps in the rocks and makes the river bottom deeper. Rosen has worked with cross-vanes, W-weir s and J-hook vane structures for river restoration and stream stabilization. All these structures only project a small way from the river bed and are nearly always submerged. These are gentle and effective structures.
http://www.hydrology.bee.cornell.edu/BEE4730Handouts/Rosgen_Vanes.pdf

Induced meandering
Bill Zeedyk and Van Clothier have been working in Southern USA to let water do the work to induce river and stream meandering to slow the water flow and reduce erosion. They are using picket (stake), rock baffles and post vanes to create meandering. (Reference : Let the Water Do the Work: Induced Meandering, an Evolving Method for Restoring Incised Channels)
http://quiviracoalition.org/images/pdfs/1025-Leaving_It_Better_Presentation-Zeedyk.pdf

With a deeper understanding of the effect of rocks on water flow these In River Training techniques can provide a relatively cheap way of creating meanders in a straightened water course, protecting the banks, collecting gravel beds for fish spawning and deepening the river to slow the flow down-stream. A short video explains their effect:
https://www.youtube.com/watch?v=1mtTTJfCfIY

Upstream groin on River Lune protecting the bank after Storm Desmond. This has enabled the water flow to dig the river deeper in the centre of the channel (5m deep).

Upstream micro-groin on River Kent collecting gravel behind it.

On a number of fishing rivers in Scotland, groins (croys) have been used with success and others have now been removed. These are more complex and expensive engineering structures of rigid rock structure. Rod Everett has been reviewing the effect of rocks and groins in the water flow on the River Lune (Lancs) and the River Kent (Cumbria). These were put in by the angling clubs. The results show that a few small well planned groins which go out and upstream in the river have protected the banks in Storm Desmond -Dec 2015. Down stream groins, rock armouring of the bank and V shaped rocks coming out from the bank have caused extensive erosion leading to 1000's of tons of soil washing down river. Great caution is needed with groins and their effect**s.**
Building up a knowledge that enables us to understand the way rocks, wood debris, and other obstacles effect and alter the direction and speed of river flow is important to prevent further floods.

River Kent below Kendal showing erosion caused by the flood water being pulled into the bank by rock armouring of the bank and the water flow between the rocks.

River Lune downstream groin and eroded bank The groin has pulled the water into the bank.

Beavers

Another method of slowing the water flow is to work with nature's water engineers – beavers.
In Knapdale, Scotland beavers, have been released as a trial. The research has now been published.
http://www.snh.org.uk/pdfs/publications/research/Beavers%20in%20Scotland%20-%20Final%20-%2010%20June%202015.pdf
In the right place with lots of trees and suitable areas to flood, beavers may show us the best way to manage water flow and prevent flash flooding.

Regenerative Agriculture and mob grazing

The concept of Regenerative Agriculture http://www.regenag.co.uk/
where soil and land resilience are built up by good agricultural practice is an important element to water retention.
In the UK, The Village Farm http://www.thevillagefarm.co.uk/ on the coast in Devon, is working with a mob grazing technique. They have sheep, goats and pigs grazing together at high densities for only one day and then the field gets at least 100 days rest. The stock eat the diverse vegetation evenly and trample some into the ground. Their manure combines with this to build up a high humus and carbon rich soil. With the hard grazing of tall vegetation, the root systems die back and contribute to the fertility. The root channels help with water infiltration. And a healthy earthworm population keeps the soil aerated. On the farm they have instigated keyline contour planting of trees and shrubs. This is an excellent example of where farming might develop to provide good quality food and a range of ecosystem services including an increased water holding capacity.

Existing flood management projects

Lancaster University have developed an online catalogue of flood management projects.
http://www.jbatrust.org/sites/www.jbatrust.org/files/documents/W15-0603%20-%20Nature-Based%20approaches%20to%20Catchment%20Improvements%20-%20Sept%202015%20FINAL_v0.1.pdf
This is a useful tool for looking at current projects.

The Scottish Environment Protection Agency have produced an excellent book on Natural Flood Management. It is defined thus: “Natural flood management involves techniques that aim to work with natural hydrological and morphological processes, features and characteristics to manage the sources and pathways of flood waters. These techniques include the restoration, enhancement and alteration of natural features and characteristics, but exclude traditional flood defence engineering that works against or disrupts these natural processes”.
(This does not include any details on the use of rocks for vanes as in In River Training.)

http://www.sepa.org.uk/media/163560/sepa-natural-flood-management-handbook1.pdf

The Scottish Rivers Handbook A guide to the physical character of Scotland's rivers is useful to help understand rivers better.
http://www.crew.ac.uk/sites/www.crew.ac.uk/files/publications/scottish%20rivers%20handbook%20web.pdf

The River Restoration Centre (RRC) Manual of River Restoration Techniques aims to help river managers identify potential restoration techniques for use in river restoration and sustainable river management. It now includes 64 case examples
http://www.therrc.co.uk/manual-river-restoration-techniques .

SUDS Sustainable drainage systems
These are drainage solutions that provide alternatives to the direct channelling of surface water through networks of pipes and sewers to nearby watercourses.
By mimicking natural drainage regimes, SUDS aim to reduce surface water flooding, improve water quality and enhance the amenity and biodiversity value of the environment. SUDS achieve this by lowering flow rates, increasing water storage capacity and reducing the transport of pollution to the water environment.

In towns and villages the importance of water retaining and infiltration can be improved with tree planting and green roofs. http://www.uksuds.com/

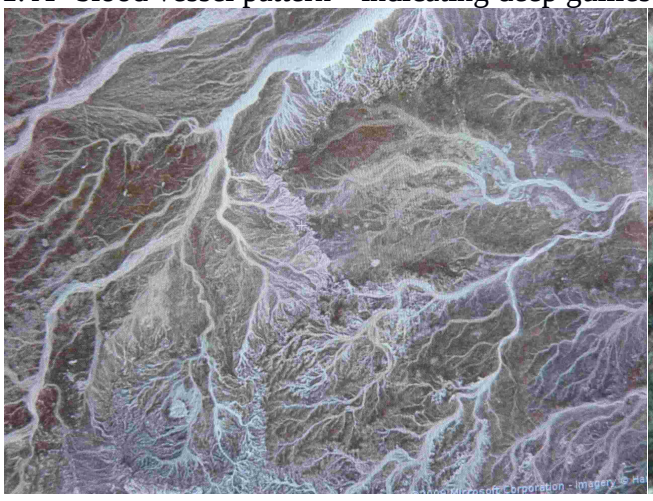
http://www.sepa.org.uk/regulations/water/diffuse-pollution/diffuse-pollution-in-the-urban-environment/#sustainable

BlueGreenCities is a research project that aims to recreate a naturally-oriented water cycle while contributing to the amenity of the city by bringing water management and green infrastructure.
http://www.bluegreencities.ac.uk/bluegreencities/about/about.aspx

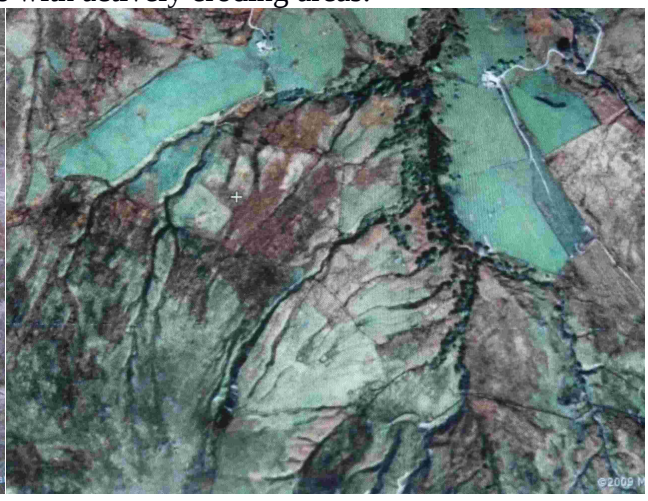
Identifying where excessive water run-off leads to flash flooding.

There are 6 main indicators that can be identified from aerial photos.

1. A "blood vessel pattern" indicating deep gullies with actively eroding areas.



This erosion pattern is in a badly eroded part of Jordan. Dry Desert.



This pattern is at the head of Roeburndale leading up to Mallowdale Pike- A Wet Desert.

These deep gullies within 50 m of the top of Mallowdale shows up as a blood vessel pattern in aerial photos.

Eroded woodland gullies like this in Roeburndale are hidden under the tree canopy and do not show up clearly on aerial photos.

2. Peat hag areas with badly eroded blanket bog show up as fractured pattern.

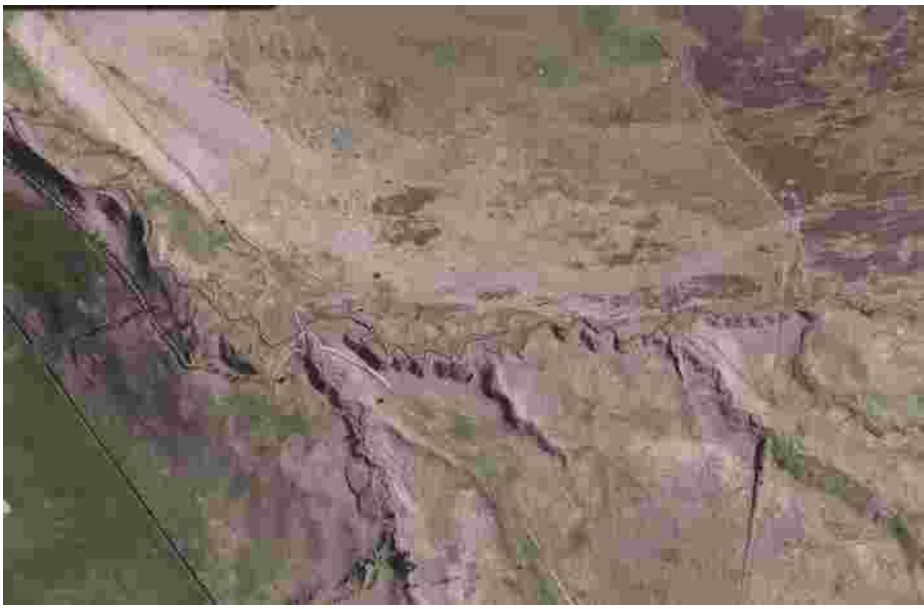
Eroded peat hags Roeburndale contribute to fast run-off and high sediment levels in the river. -from Bing Aerial Map

3. Bare areas with no vegetation such as Embledon Mires above Cockermouth cause damage by having a fast runoff.

4. A very zig zag stream pattern indicates an area above that has been over heated and will give a very fast run-off (Embledon).

Zig Zag stream coming off Embledon Mires in Cumbria. The shape of the stream indicates over heating of catchment from current bare rock. This area used to be mires that held back the water.

These conditions create a very degraded area with high speed run off.



5. Looking at modern and historical aerial photos gives a good indication of where and when a problem with erosion started ie: past overgrazing, muirburn from fires and poor land management.

1960s aerial photo of part of Whitmoor Common. The central eroded area led to the gully formation of Warm Beck in 1967 which contributed to the bad Wray flood 1967.

From Mario Lancashire historical Aerial photos

Bing Maps Aerial is useful as you can drive the map down a river or across an eroding area. https://www.bing.com/maps/ and it can help identify such things as large boulders or groins in a river. Google Earth can also be used. Check which has the best quality photos.

6. A careful study of large boulders in a river can identify where these boulders are causing the river to erode the bank. A line of boulders starting from the bank and going downstream as they come out from the bank will pull the water in a flood towards the bank and is likely to cause erosion in high flood conditions. Badly designed groins are often the starting point for erosion.

Bing Aerial photo of groins facing downstream near Nether Burrow. The above photo shows the bank erosion caused by these groins in Storm Desmond (Dec 2015)

Infra red mapping

The great importance of land temperature on the nature of water flow and its flood damage suggests that infra red aerial mapping may be a good way to focus in on the more extremes of damaged land. This would help flood protection measures to be implemented where they are most needed.

River Restoration Priorities

Once the problem areas in a river catchment area have been identified, then it important to start the river restoration at the highest point and then work down the river.

It is a complete waste of money and time putting up expensive flood barriers or dredging rivers if the start of the erosion isn't addressed first.

This means that restoring blanket bog and planting trees high up in the catchment should be given the highest priority.

"The farming practice of the upper reaches of river catchments are especially important in determining flood risk. These are also typically the most highly subsidised types of farming, with the lowest agricultural yields. Thus the costs to outputs of adapting practice are lowest, yet they have the highest benefits in reducing flood risk by holding water."
Flood defence Time for a Radical rethink **Dieter Helm**
http://www.dieterhelm.co.uk/sites/default/files/Flood%20defence%20-%20time%20for%20a%20radical%20rethink.pdf

The essential rules in all sections of the river catchment are:

Slow the water
Spread the water
Sink the water
Releasing the water that cannot be stored gently back into the watercourses

Water in rivers is, if you like, a gift which the community higher in the watershed hands down to the communities lower on the river. The society which acts as the bearer of such a gift should not try to plunder it, but should pass it down in a fit and cared-for state.
M.Kravcik

Benefits from River and Water Catchment Restoration

Reduction in erosion
Landslips and undercutting of banks should be reduced
This will benefit farmers who are losing soil.
"A farmers wealth is in the soil. Don't lose it".

Reduction in sediment
Reducing water discolouration and sediment loss from the upper catchment area and the river banks further downstream is essential because these sediments are valuable soil nutrients for the land. They use up oxygen in the river making it less able to clean the pollution reducing the rivers ability to support a rich aquatic life.

Slower run-off
By protecting the ground surface and re-vegetating the land water run-off is slower.

Refilled aquifers
By holding the water longer in the landscape it gives it more chance of infiltrating into the underground aquifers and into the soil structure. The water retained in the underground and soil is hundreds of times larger than the water visible in lakes and rivers.

"It is also paradoxical that soil partially saturated with water is capable of better absorbing more water than dried out soil. If precipitation falls on compacted and dried out soil, infiltration to deeper layers occurs only after a period of ten minutes or more. In the first minutes, however, the soil behaves like an impermeable surface. During extreme rains, there is a rapid run-off and concentration of rainwater to river beds. This same rainfall--- would be easily absorbed in land healthily saturated with water." Kravcik.

Spring water
When spring water is flowing regularly then small streams will not dry out.
In recent years, side streams that have never been dry, have been empty of water for weeks. When this happens much of the aquatic life dies. It may also remove areas important for fish spawning.
These springs are important for grazing livestock as they provide mineral rich water.
Recent boreholes have been getting deeper indicating the depletion of our valuable underground water resources.

Diversity in numbers and sizes of fish
With a more stable water flow and less scouring of the river out by flash floods, the successful spawning of brown and sea trout should improve leading eventually to restored fish stocks similar to those in the 1920's.

Viable fishing
When fish have increased in rivers then fishing would become a viable activity. This would give potential added income for farmers and landowners down the river.

Potential livestock marketing
Restoring the river catchment will give opportunities for livestock marketing. In Wales the Pontbren farmers group (a group of 10 neighbouring small farms located in the heart of the Welsh countryside) have restored their water catchment in order to bring otters back and have developed a marketing group based on their highest possible standards of environmental management, particularly around water management and slowing the water run off.

Reduced Pollution
With flash floods, animal manures are picked up from the land and washed into the river.
They create a horizontal rolling flow instead of the normal longitudinal vortex flow down the river whereby the manure does not get cleaned as it moves downstream causing pollution problems.
With a steady river flow and longitudinal vortices, the light harmful anaerobic bacteria get thrown to the outer edge of the vortex where they are killed by high levels of oxygen.
Within a few hundred yards the river can be cleaned. This benefit extends to cleaner beaches near the river estuary.

Increase in Biodiversity.
A steady flow of water in the river would benefit wildlife. Birds like dippers would increase with less acid input from the peat. Dragon flies and amphibians like newts, would make use of any water held in the landscape. Otters would return with increased fish stocks.
It would enable the fresh water limpet to re establish in the side streams.

Increased habitat for game cover and natural game feed.
Planting trees, encouraging heather regeneration and wetland creation make ideal game habitat.

Reduced risk of peat fires
More water in the soil and more moisture in the blanket bog will help to reduce the Risk of fires in very dry conditions.

Reduced flood damage to buildings and highways
The damage to buildings , roads, services and much more, as can be seen from the recent floods in December and January 2015/16, would be eliminated or reduced.

More stable potential for water power
Increased potential for water power and water use further down the river.

Education
Understanding how to honour and love your river will be very important in the education of the younger generation.

Building community resilience
Building a resilient community capable of looking after our water resources, leads to self empowerment and responsible citizenship.

Potential wider benefit for climate moderation.
M Kravick argues that this form of river restoration is vital for climate moderation. The upper catchment will hold more water and then will enable evaporation into the atmosphere in warm conditions. This has a moderating effect on temperature and weather and will protect the ground from overheating.
"a surface with no ability to evaporate water creates not only favourable conditions for the origin of extreme weather, but also exacerbates the effects of such weather."
The weather effects will be both local and to the drier east side of the country.
In addition a reduction in the loss of peat reduces the release of CO2 and methane. These gases contribute to global warming.

"The draining of the land is like living on debts. Water falling from the large water cycle is like a state subsidy. It comes for free but not regularly, often to wrong recipients and in the wrong amounts. It sometimes brings more harm than good. To rely on it is risky because today it is here, but tomorrow it may not be." M.Kravcik

CONCLUSION

The need for a holistic water catchment based strategy is essential for the resilient future of our countryside, towns and cities. This need is urgent and is a priority with the more extreme weather conditions that we have started to experience.

"I have been impressed with the urgency of doing. Knowing is not enough; we must apply. Being willing is not enough; we must do."

"*Water* is the driving force of all nature." - *Leonardo da Vinci*

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