FORESTRY ENGINEERING GROUP

Charity Number – IAgrE 257303

Forestry Engineering Group
Annual Symposium
Thursday 8th September 2016
Newton Rigg Campus, Penrith

"Engineering to Stem the Flow"

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FEG Synposium 2016 Bookings			
1	Graeme	White	FEG Chair (FC)
2	Bruce	Hamilton	FEG Sec (FC)
3	Geoff	Freedman	FEG Treasurer (Rural Bridges)
4	Alastair	Taylor	IAgrE CEO
5	Morgan	Vuillermoz	Speaker (FCBA French Speaker)
6	Andrew	Black	Speaker (Dundee Uni)
7	Tom	Nisbet	Speaker (Forest Research)
8	Alan	Eves	Speaker (Forestry Commission)
9	Jock	McKie	Speaker (John Deere)
10	Fiona	McLay	Speaker (SEPA)
11	Hugh	Chalmers	Speaker (Tweed Forum)
12	Conor	Price	Speaker (Scot Bord. Council)
13	Alan	Drake	Forestry Commission
14	Keith	Jenkins	Natural Resouces Wales
15	Neil	McInnes	Forestry Commission
16	Alan	Gale	Forestry Commission
17	Russ	Jobson	Woodland Trust
18	Steve	Penny	Forest Research
19	Granvilee	Davies	Yorkshire Water
20	Malcolm	Cattermole	FEG Committee
21	James	Christie	FEG Committee
22	Mark	Andrew	Caterpillar (UK)
23	Julie	McMorran	FEG Committee
24	Kate	Grimsditch	SEPA
25	Jackie	Galley	SEPA
26	Roland	Stiven	Timber Transport Forum
27	Stuart	Wilkie	Scottish Woodlands
28	Colin	Saunders	Forestry Commission
29	Colin	Binnie	Forestry Commission
30	Simon	Turner	Forestry Commission
31	Sallie	Bailey	Forestry Commission
32	Sara	Iversen	Cumbria University
33	Eddie	Addis	Tilhill
34	John	Evans	Bronwin & Co
35	Kevin	Ferguson	Forestry Commission
36	Chris	Slater	Forestry Commission
37	Max	McLaughlan	Forestry Commission
38	Neville	Geddes	Forestry Commission
39	Richard	Kennedy	Forestry Commission
40	Duncan	Ferguson	Spey Fishery Board
41	Peter	Leeson	Woodland Trust
42	David	Kennedy	Forestry Commission
43	Chris	Whetnall	IAgrE
44	Jim	O'Neil	Forestry Commission
45	Jonathan	Farries	Forestry Commission
46	James	Simpson	Forestry Commission
47	Ben	Drake	Student with Egger Forestry
48	James	Slater	Student with Egger Forestry
49	Nick	Foster	Independent Consultant
50	Penny	Oliver	Forestry Commission

"Engineering to Stem the Flow"

(Lessons Learnt – UK and Europe)

Thursday 8th September 2016, 0900-1600 hrs

Newton Rigg Campus, Penrith

LIST OF PROCEEDING'S

- **Programme of Talks**
- **Morgan Vuillermoz Abstract and Presentation**
- **Dr Andrew Black Abstract & Presentation**
- **Tom Nisbet Joint Abstract with Alan Eves & Presentation**
- **Alan Eves Presentation**
- **Jock McKie Abstract & Presentation**
- **Copy of John Scott's (JST Scotland) Citation for IAgrE Special Award for Contributions to FEG**
- **Fiona McLay Abstract & Presentation**
- **Hugh Chalmers Abstract & Presentation**
- **Conor Price Abstract & Presentation**

FORESTRY ENGINEERING GROUP

“Engineering to Stem the Flow”

(Lessons Learnt – UK and Europe)

Thursday 8th September 2016, 0900-1600 hrs

Newton Rigg Campus, Penrith

Morning - Chair, Graeme White, Forestry Commission

9:30 – 9:45 Opening Address – Graeme White FEG Chairman

9:45 – 10:30 Morgan Vuillermoz - Ingénieure Etudes et Recherche, FCBA

10:30 – 10:50 Dr Andrew Black – Dundee University

10.50 – 11.05 **Break**

11:05 - 11:25 Tom Nisbet – Forest Research

11:25 – 11:45 Alan Eves – Forest Management Director Yorkshire Forest District

11:45 – 12:05 Jock McKie – John Deere Forestry

12:05 – 12:15 Question & Answers to Morning Speakers

12:15 – 12:25 Presentation to John Scott (JST Scotland) - IAgrE Special Award for Contributions to Forestry Engineering Group

12.30 – 13.30 **Lunch** – Speakers Photograph

Afternoon – Chair Jim Walker NFU (TBC)

13:30 – 14:00 Fiona McLay - SEPA

14:00 – 14:20 Hugh Chalmers – Tweed Forum

14:20 – 14:40 **Break**

14.40 – 15.00 Conor Price – Scottish Borders Council

15:00 – 15:30 Questions, Summary – Alastair Taylor, CEO IAgrE

Close – Tea and Coffee will be available for networking opportunities

Forestry Engineering Group

Experiences of Forest Engineering in France

Morgan Vuillermoz, Emmanuel Cacot,

Institut Technologique FCBA, 10 rue Galilée, F-77420 Champs sur Marne

Through this article, insights are provided into the practices of Forestry and Forest Engineering in France. Organisational and operational aspects are described, including experience from the last 2 major storms and crisis management in the immediate aftermath.

1. Introduction to French forestry and its forest-based sector

French forests occupy over 16 million hectares, hence covering 29% of the metropolitan land. Broadleaves and mixed forest are dominant, with only 3,1 million ha inventoried as pure softwood stands. This diversity is amplified by the ownership distribution which is mostly private (76% of the total area). Active forest management is provided by the forest service in public-owned units but the implementation of a management plan is only requested for private owners of more than 25 hectares.

Figure 1: Fragmentation of French forest resources per ownership type and size of management unit

					Distribution of the area		
	X 1.000 ha	%	Nb of mgmt units	Average area (ha)	<10 ha	10 to 25 ha	> 25 ha
State-owned	1 416	9%	1 328	1 066	-	-	100%
Other public forests	2 360	15%	15 268	155	0,3%	1,2%	98,5%
Private owned	11 801	76%	3 495 000	3,4	35%	16,6%	48,4%

Source: Memento FCBA 2014

About 40 million cubic meters are harvested and sold to the industry yearly from the 82 million annual increment. Additionally, 20 million are consumed directly as firewood without any market transaction. There is an increasing demand for softwood from the traditional forest-based industries (sawmills, pulp & paper mills and panel companies) and a raising interest from energy producers who can easily accept hardwoods as raw material. Meanwhile, the French national forest policy calls for an increase of wood mobilisation to maintain a resilient and competitive forest-based industry in rural areas and meet the national objectives regarding the European Energy Policy.

Forest engineering operates at the interface between this standing resource and the demanding markets. French professional stakeholders in this field of expertise can be characterized by their diversity in terms of size, organisation or range of interventions (Lebel & Bigot 2010). Diverse levels of integration result in the co-existence of forest cooperatives, the state forest service, independent wood suppliers or industry-integrated ones, logging contractors (entrepreneurs)…

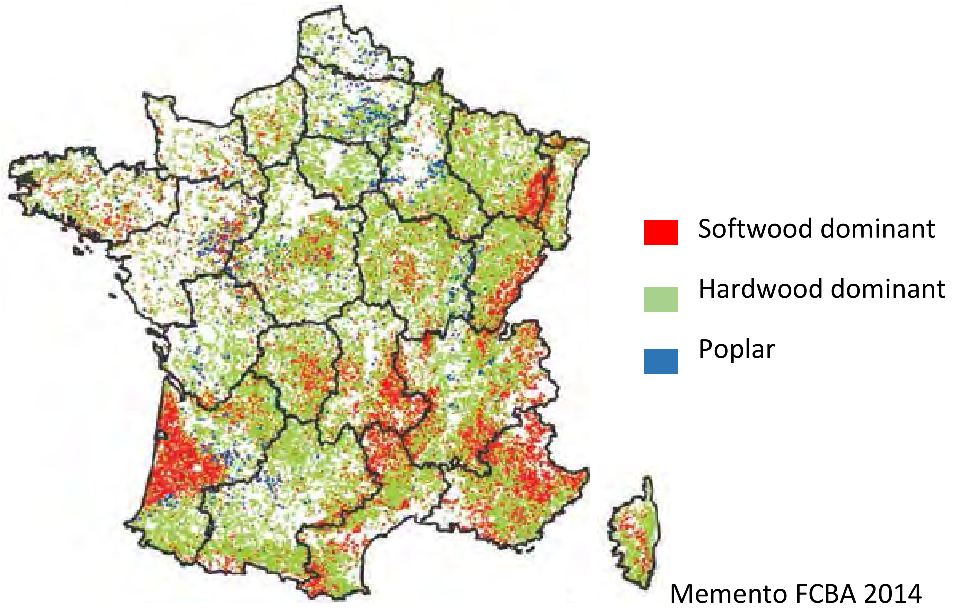

Figure 2: Distribution of the French forest cover, per species groups (Hardwood-, Softwood-, Poplar- dominant stands)

2. Forest engineering in France: status and challenges

Trice in 1992, 2004 and 2014, FCBA carried out prospective studies on progressive mechanization of logging operations in France. Forest machines are indeed identified as significant enablers to increase productivity and to reach the objectives for additional wood mobilization. This role is amplified by the continuous decline in the number of lumberjacks. It is estimated that the sector lost 400 workers per year during the last decade despite the use of foreign labor (Cacot et al., 2015). A population of a few more than 7,000 remained in 2013.

2.1 Forest machines: a diversified fleet

The national fleet of forest machines, including forwarders and skidders, is currently evaluated in France at 3,100 machines. As described in Figure 3, feller-bunchers and stump extractors add-up to 750 harvesters in the panel of machines dedicated to felling and processing forest resources (Bonnemazou and Ruch, 2014).

The 2004-2013 comparison of the total fleet shows an overall stability but hides a decline in recent years. Indeed, 3.400 machines were accounted for in 2009, in relation with higher level of harvest and a better economic situation. Compared to 2004, the number of harvesters increased by 40%. In 2013, the fleet includes 670 “full” harvesters and 80 harvesting heads mounted on excavators. A fourth of the latter process trees on the landing sites of cable-yarding operations, in steep terrain areas.

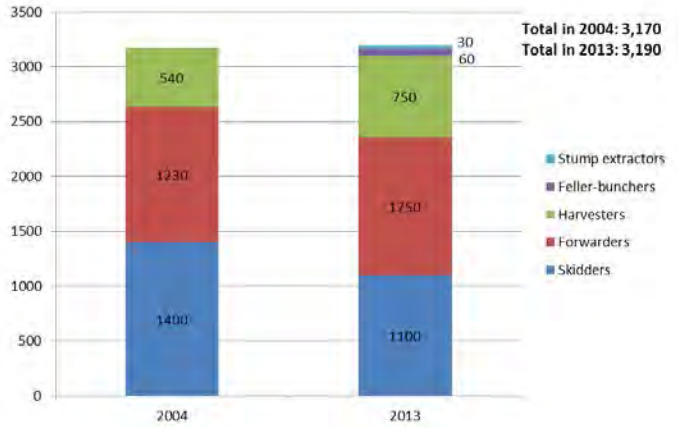

Figure 3: Evolution of forest machinery fleet from 2004 to 2013.

Apart from harvesters which are now capable of operating in cut-to-length system in both softwoods and hardwoods stands, diverse options are implemented to mechanize the harvesting of French forest resources:

- Felling heads, with shear or saw disc cutting system, are combined to excavators for whole-tree system. Such “feller-bunchers” (Figure 5) are mainly used in broadleaves stands to produce energy-products. From less than 10 machines, numbers rose in 3-4 years to 60 units by the end of 2013. Feedback from field practitioners as well as supportive financial incentives indicate that this trend should continue over the next 5 years. For now, 45 heads operate with shears and 15 with saw discs.
- Some entrepreneurs now choose to adapt their forwarders (Figure 4) or small excavators with a grapple-saw to mechanize the processing of big hardwood crowns (oak and beech); it is considered as a semi-mechanized system since the felling and a part of processing is made by lumberjacks beforehand;

Figures 4 and 5: Forwarder with a grapple-saw for the processing of big broadleaved crowns (left), feller-buncher with a saw-disc (right).

Stumps extractors do operate in Aquitaine to produce wood fuel. But this technique is hardly used in other forest area, primarily because it requires sandy soils to easily extract the stump and secondly because specific equipment is needed for later logistics and within the biomass boilers.

2.2 Options and respective productivities to mechanize felling and processing of French resources

For harvesters operating in softwoods, the range of annual productivities is very large: from 18,500 m^3/year in Massif Central (Douglas fir, mountainous area) to 56,000 m^3/year in Aquitaine (sandy flat soil, even-aged maritime pine, very regular stands) for 1,700 machine hours in average (Peuch and al., 2013; Ruch and al., 2015). When taking into account the distribution of the fleet in these different regions (Bonnemazou and Ruch, 2014), average productivity reaches 23,500 m^3/year. In 2004, the average production was approximately 17,000 m^3/ year (Laurier, 2005). Annual production increased over 10 years with a strong weight in the balance from machines working in Aquitaine where conditions are the most favorable.

Harvesters working in hardwoods stands are less numerous. About 50 harvesters operate regularly in such conditions and the average productivity is estimated to reach 14,000 m^3/year.

For feller-bunchers, annual production amount to 8,500 m^3/ year for shears head and 20,000 m^3/ year for the more powerful disc heads (Cacot et al., 2015).

2.3 Rate of mechanization in 2013

In 2004, only 24% of the total volume of wood was harvested and processed thanks to forest machines, and this share reached 44% for softwood. Several prospective scenarios for 2010 foresaw an increase in the number of forest machines and their productivity.

Based on information on the fleet and annual harvest (Memento FCBA, 2014), the mechanization rate was calculated: about 80% for softwood and just below 10% for hardwood. Therefore, about half of the total volume offered on the market is felled and processed with a machine in 2013.

For softwoods, the current mechanization rate corresponds to the "intense" scenario defined back in 2004. However, a decrease of the total volume harvested and a reduction in the number of harvesters both hide behind this ratio.

For hardwoods, actual evolution was disappointing despite the pull from the energy market: in 2004, scenarios foresaw that 5.0 million cubic meters (Mm^3) would be mechanized whereas currently only 1.5 Mm^3 are. But several issues identified then are still hindering this dynamic: yet unfulfilled needs for technical innovations and organization scheme in hardwood- and on slopes-dedicated situation, significant training needs…

	1990	1995	2002	2004	2013
Nr of harvesters in softwoods	60	185	500	540	700
Average annual productivity for harvester in softwoods (m^3/year)	8,300	11,000	17,000	17,000	23,500
Annual softwood volume felled and processed with a machine (Mm^3/year)	0.5	2.0	8.5	9.2	16.5
Rate of softwood mechanization (%)	3	9	40	44	80
Rate of global mechanization (softwood + hardwood) (%)	**1**	**4**	**22**	**24**	**48**

Figure 6: Mechanized felling and processing of French forest resources: evolution since 1990

2.4 2020 evolution perspectives for system-specific productivities

In recent years, the influence of latest technological improvements were quite indirect on actual productivity: embedded computers and management of production data, better accuracy for the processing of assortments, better ergonomic and safety for the operators… Furthermore the grouping of small stands into large logging units remains a challenge because of the structure of forest ownership in France (Memento FCBA, 2014). As a consequence, utilization rate are not maximal because forest machines often have to commute between sites. Although work is underway to propose gathering methods, there is little chance this would have a significant impact in the medium term.

And so far, forest machines were adopted almost exclusively in the most favorable areas in terms of stands, topography and accessibility. Harvesting additional resources in areas identified as under-mobilized (slopes, hardwoods) is more difficult technically and productivity is doomed to be lower than in the situation where forest machines currently operate.

At last, environmental concerns and risk mitigation on sensitive-soils will contribute to increasing the adoption of adapted machinery (extra wide tires and tracks, number of axles...) whose performances in terms of productivity will be expected to be at least equivalent to the current standard (Ruch, 2015). Another alternative would be to have smaller machines but such developments should remain limited in France because of disincentive productivity and cost per m^3 [Ulrich and al., 2014].

Taking all this into account, it is estimated that the productivity of softwood-dedicated machines should evolve further, but to a lesser extent than in the last 20 years. This asymptote-progression is already observed in some regions such as Aquitaine (Ruch and al, 2015).

For hardwoods, productivity gains will possibly be more important both for harvesters and feller-bunchers. Improvements for harvesting heads are already tested with pilot practitioners through more efficient delimbing systems. The latter come from an innovative shape of the delimbing knives on which ribs were integrated in the cutting area (Cacot et al, 2016). But there is still room for substantial technical progress (Chakroun and Cacot, 2014) such as hydraulic accumulator to gain power and speed for shear heads, development of smaller saw-disc heads... The organization of logging sites is also under scrutiny, for ways to be found to integrate the coproduction of pulp and energy products with feller-bunchers.

For the "semi-mechanized" systems, prospects remain dependent on the future adoption of grapple-saw by practitioners. The current level is extremely low but evaluations are now available on situation-dependent performances of alternative systems with one or two machines (Ruch et al, 2016). And the strong advantages in terms of health and safety should ease the word of mouth on these new options to process large hardwood crowns, especially when irritating caterpillars are present (Thaumetopoea processionnea in oak stands).

Meanwhile, cable-yarding in France is still quite confidential with only 20-25 teams (Magaud and Vuillermoz, 2016) and an almost extinct cable-culture. It is unlikely the number of machines would increase suddenly and the productivity of the machine working on the landing site (excavator with processing head for delimbing) should remain the same. The limiting factor is indeed not the delimbing capacity but the production of cable-cranes.

3. Investigations for the future

Apart from the earlier-mentioned research on the “hardware” part of forest engineering, other investigations are also underway to improve practices. Know-how and organization play a significant role in that strategy.

3.1 Skilled workforce: needs by 2020

Following a “reasonable” 2020 prospective scenario based on demands from the forest-based industry, it is estimated that 980 additional machines would be necessary in 2020. Considering that usual practice is to have 1.2 drivers per harvester and 1 for other machines (Peuch and al., 2013; Ruch and al., 2015), this 2020 scenario would also mean a call for about 1,040 additional drivers.

Assuming a linear increase in staff over the period 2014 to 2020 and taking into account the natural turnover, some 240 new operators have to be found and trained each year. Compared to the 70 new drivers who graduate annually from the training centers, of which only 30-40 are trained as harvester-drivers, this estimation underlines that needs far exceed the supply from the training system.

But since only 30% of current drivers were trained in a specialized center (Peuch and al., 2013; Ruch and al., 2015), there is no reason to believe that practitioners would suddenly start recruiting through this sole training pathway. Many of the future new positions will probably still be filled by workers with skidding experience, motor-manual loggers, or people with background in agriculture or other sectors. Still, the situation should evolve gradually towards a professionalization of the drivers with training centers able to supply 150-200 properly trained machine operators annually. A national consultation is underway since 2016 but possible solutions can only emerge from complex compromises between professional employers, training centers and respective public institution.

3.2 Organization schemes

Discussions with industrial stakeholders on the status-quo and possible scenario by 2020 also led to the consideration of possible changes in terms of organization and adjustments. Some of the following recommendations had already been voiced out in the past but none of the leads has been investigated enough for lessons to be learnt and acted upon yet:

- Introduce double shift systems for harvester drivers. Those machines keep being more and more expensive, utilization rate need to be higher and there is feedback to be collected on weathered experience from European countries whose practitioners chose that scheme;
- Promote everything contributing to increase the utilization rate of forest machines: increase the size of logging sites through up-stream pooling efforts and training of the forest managers/owners, consider revisiting macro-allocation to deal with fewer assortments on individual sites when possible, improve coordination across the supply chain and make the most of information available from the different actors;
- Develop jobs attractiveness by increasing attention to ergonomics, improving logging site organization and ensure that a minimum population of chain-saw operators is available to perform in the stands and situations where machines can’t replace them.

4. Being ready for the worst: Lessons learnt from the last 2 major storms

The last 15 years in France also brought the forest-based sector to realize that it should not only agree and be pro-active in implementing its national research & development strategy but that it should also stand ready for unpredictable and devastating episodes with long term effects on the intra-sectorial balance.

Storms Lothar and Martin which occurred in December 1999 caused huge damages over Western Europe. 140 million cubic meter were wind-thrown in France in addition to losses in equipment and human lives. Damaged timber and a lack of preparation towards such massive event caused enormous financial losses in the sector. Concerted action STODAFOR contributed to coordinate all European experiments and knowledge on harvesting and conservation of storm-damaged timber. A technical guide (Pischedda et al, 2004) was produced with contributions from 10 different countries by November 2004. Guidance was provided to answer questions in practitioners' mind when facing storm damage:

- How to harvest and process the wind-thrown or broken trees in safe, economic and environmental-friendly ways, while preventing fungus or insect degradations and mitigating fire risks, to allow future forest restoration (plantation and natural regeneration).
- How to maintain wood quality through efficient log storage and conservation methods in order to secure appropriate wood supply to the industry and sustain foresters' incomes.

But lessons learnt went beyond technical aspects and collective crisis management was also documented. After the chaos experience in 2000, it was considered of utmost importance to prepare and decide on, before the next storm, which actions would have to be taken from the first hours to the following weeks and month of dealing with the consequences. Procedures were created at different levels with the most significant examples being the national plan created by the State forest service (ONF) for its internal use and the regional action plan agreed upon in Alsace (FIBOIS Alsace, 2010).

Feedback collected after Lothar and Martin was meant to help practitioner take decisions, prepare future actions and improved cooperation in the case of new events. In January 2009, when Klaus hit south west France and most specifically the very productive maritime Pine forest in Aquitaine, the sector was indeed more prepared and swift to deal with the aftermath:

- *Collective plan for coherent and efficient interventions*: Responsibilities and to-dos were distributed to the role players based on up-dated procedure for crisis management, including regulations to comply with.
- *Safe and secure logging of the wind-blown stands*: memories from 99' were still warm. Recommendations for good practices were edited and disseminated anew to the stakeholders, first as a short brief 4 weeks after the storm, through special editions of professional press and then as a full illustrated guide in October 2009. Training were also provided together with briefing of non-local workforce.
- *Immediate and mid-term impact in terms of wood availability*: Remote sensing technologies were applied to document the quantitative situation. Discussion on the shared diagnosis granted the stakeholders with the possibility to plan efficient dispatch on short- and medium-term, but also foresee the potential future and agree upon schemes for replantation and later sylviculture.
- *Storage and conservation*: Methods described in STODAFOR and respective national knowledgeable experts were gathered almost instantly. Sites were identified and installed quickly, thanks to the detailed specifications and recommendations documented after 99'. Terrain, sectorial organization and financial capacities led to the creation of large and industry-related sites.
- Bark beetle: post-crisis organization was already in place and running when pest invasion struck the still standing maritime pines. Thanks to earlier efficiency in dealing with the storm

aftermath, stakeholders were enabled to react swiftly and salvage the green wood although it forced them to reorganize logging priorities and storage patterns.

Thanks to the lessons and how-how inherited from 99’, some energy and attention was left for stakeholders to deal with problems and situations that were either new or previously overlooked out of urgency-driven priorization. Hence, research actions were launched on topics most critical for the safe keeping of the value of recovered raw material:

- Instrumented monitoring of the conversation sites was installed with the six major stakeholders. A moisture model was developed and integrated in a decision support system for storage site management. Gains were made on energy (electricity consumption) and water when regulating water distribution (time and intensity).
- A DNA-based method was developed to detect the presence of Armilaria fungi. Early qualitative detection grants time for the conservation to be safe-guarded by treating the water circuit of the storage area.
- Scents of sawntimber produced out of stored-logs were characterized to objectify the dialogue between sellers and buyers.
- Species-specific methods for quality-preservating storage were documented. Poplar had been struck by Klaus and a technical guide “Popuklaus” was delivered to respective praticitioners.

Seven years after the storm, empty storage areas are now being converted for safekeeping in the event of a new crisis. Lessons learnt from Klaus also contribute to helping the sector stand ready for future possible events. A collaborative plan was for example agreed upon in 2016 to be prepared and reactive in the case of much feared nematode infestation.

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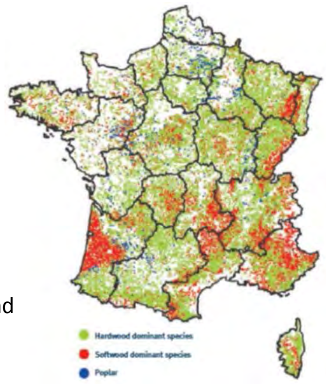
Experiences of forest engineering in France

Forestry Engineering Group, 2016-09-08

Morgan VUILLERMOZ, **Emmanuel CACOT**

Diversified forest resources

- 16 Million hectares
- 76% private-owned
- Only 3,1 Mha as pure softwood stands
- Diverse topography and weather conditions



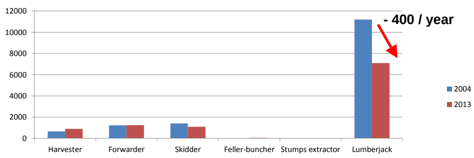
Stakeholders and demanding markets

- Diversity: from 1-man entreprise to up-stream or down-stream integrated companies
- 40 Million m3 sold on the market + 20 directly as firewood
- Increasing demand for softwood
- New opportunities for hardwood

Forest engineering: status-quo and challenges

- Prospective study for scenario planning with the industry and respective public institutions
  1992 - 2004 - 2014 …
- Key role played by forest machines since 2000
- Workforce : decreasing number of operators for motor-manual felling

Workforce for logging operations in France

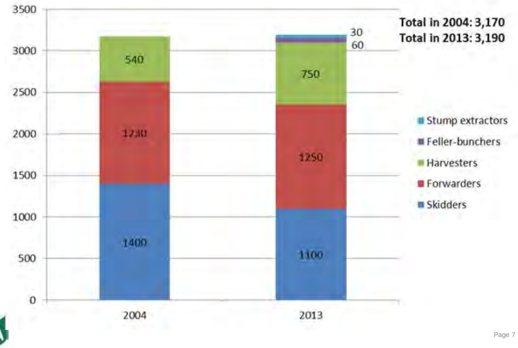


Lumberjacks: - 400/year, despite the use of foreign labor
=> 1 Mm^3 to be harvested with forest machines each year just to maintain total volume sold on the market

Diversified fleet of forest machines

- Felling and processing
- Fully mechanized hauling operations

Evolution and curent situation of the national fleet



FCBA

Types of machines used to fell and process French resources (1/2)

- Harvesters used in cut-to-length system,
  - for both softwood and broadleaves,
  - 10 synchrowinch (steep terrain up to 70%)

- Feller bunchers (Felling heads + excavator)
  - shear or saw disc cutting devices
  - whole-tree system to harvest energy wood,
  - mainly used for broadleaves in France

FCBA

Types of machines used to fell and process French resources (2/2)

- Processing heads on excavators to process trees on the landing site of cable-yarding operations, in steep terrain areas

- Grapple-saw on forwarders or small excavators
  - to mechanize the processing of big broadleaved crowns
  - semi-mechanized system: felling and stem processing handled by lumberjacks beforehand

FCBA

Evolution of annual productivities
(m^3/year)

Important gains from: more powerfull and more reliable machines, increased size of processed trees…

Machines (annual productivities in m^3)	2004	2013
Harvester (softwood / flat terrain)	17,000	23,500
Harvester (softwood / steep terrain, with synchrowinch option, slope: 35 to 65%)	-	15,000
Harvester (hardwood / flat terrain)	12,000	14,000
Processor on the landing site of cable-yarding op-	8,000	8,000
Feller-buncher (shear head)	-	8,500
Feller-buncher (saw-disc head)	-	-
Grapple-saw (big broadleaved crowns, flat terrain)	-	8,000

FCBA

Rate of mechanization in 2013

		1990	1995	2002	2004	2013
Softwood	Nb of harvesters	60	185	500	540	700
	Annual mechanized harvest (Mm^3)	0.5	2.0	8.5	9.2	16. 5
	Rate of mechanization (%)	3	9	40	44	80
Hardwood	Nb of harvesters	-	-	30	30	110
	Annual mechanized harvest (Mm^3)	-	-	0.4	0.4	1.5
	Rate of mechanization (%)	-	-	3	3	10
	Global rate of mechanization (softwood + hardwood)	**1**	**4**	**22**	**24**	**48**

Machines did compensate for the decrease of lumberjacks => **same total harvest level for several years (~ 36 Mm^3/year)**

FCBA

August 16

Evolution perspectives by 2020

- Felling and processing
- Fully mechanized hauling operations

FCBA

Harvesters used in cut-to-length system

- Stability for softwood
- Innovative solutions for hardwoods


- Organization-wise flexibility through good use of additional equipment

FCBA

Feller bunchers (Felling heads + excavator)

- Technical improvement still to be developed
  - Power and speed for shear heads
  - Smaller saw disc cutting devices

- Organization-wise adaptations in those whole-tree systems
  - Co-production of pulp & energy products
  - Better feedback on productivity & performances to better match the right machine to the right site (Trees, soil, value)

FCBA

Grapple-saw on forwarders or small excavators

- Dependent on future adoption by practitioners

1 machine system

2 machines system


FCBA

Steep terrain logging

- Probable stability in terms of productivity
- But possible evolution through adoption as an alternative solution in annual workplans
- "Social" approach underway through regional learning lab in Massif Central



FCBA

Evolution of annual productivities
(m^3/year)

Machines (annual productivities in m^3)	2004	2013	2020
Harvester (softwood / flat terrain)	17,000	23,500	25,000
Harvester (softwood / steep terrain, with synchrowinch option, slope: 35 to 65%)	-	15,000	17,000
Harvester (hardwood / flat terrain)	12,000	14,000	16,000
Processor after cable-crane	8,000	8,000	8,000
Feller-buncher (shear head)	-	8,500	10,000
Feller-buncher (saw-disc head)	-	-	13,000
Grapple-saw (big broadleaved crowns, flat terrain)	-	8,000	10,000

Less important productivity gains (except for hardwoods): technological improvements less focused on productivity (ergonomics, computers…), environmental issues, stands more difficult to mechanize…

FCBA

Scenario planning to evaluate needs for workforce

- + 980 machines in 2020 in comparison with 2013 (without machines renewal)
- 1,040 additional drivers in 2020 (mostly single-shift):
  - 170 additional drivers / year
  - 240 additional drivers / year taking into account the annual turn-over
- But only 70 new drivers graduating from training centers annually

FCBA

New organization schemes to make the most of available resources

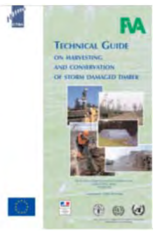
- Introduce double shift systems for harvesters
- Utilization rates to be boosted
  - Size of logging sites: up-stream pooling efforts, training of forest owners/managers
  - Macro allocations and assortments
  - Coordination and information sharing

… and work on job attractiveness

And stand ready for the worst…

Usefull heritage from Lothar and Martin

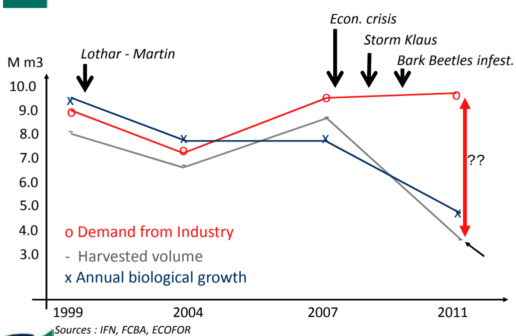
- 140 Mm3 in France over the 180 M in EU
- Dealing with chaos in France from Jan 2000
- Concerted action STODAFOR



Lessons learnt in the early 2000s

- Technical aspects : how to…
  - Harvest and process in safe, economic and environmental-friendly ways, while mitigating degradations and fire risks, to allow future forest restoration.
  - Maintain wood quality through efficient conservation to secure wood supply to the industry and sustain foresters' incomes.
- Collective crisis management: procedures, to-dos, regulations and financial support

Help to take decisions and improve cooperation when new crisis stroke



Good use of the 99 heritage

- Collective plan → coherent & efficient interventions
- Intense communication on safe and secure logging
- Immediate and mid-term impact in terms of wood availability
- Storage and conservation: experts and sites easily mobilized
- Bark beetle: swift reaction and reorganization thanks to earlier efficiency in dealing with 1st crisis

Energy left to deal with new or formerly overlooked issues

- Instrumented monitoring of the conversation sites
  →moisture model integrated in a decision support system for site management.
- A DNA-based method was developed to detect the presence of Armilaria fungi.
  →Early qualitative detection grants time for the conservation to be safe-guarded
- Scents of sawntimber were characterized to objectify the dialogue between sellers and buyers.

New guide on Poplar conservation Popuklaus

- Before Klaus: poplar considered too fragile for conservation
- Klaus: ½ Mm3 wind thrown 20 000 tons stored for conservation

- Guide
  – Best practices for forest in-situ temp. conversation and logging priorities
  – Water conservation: success factors now documented

INSTITUT TECHNOLOGIQUE

Thanks for your attention!
Any questions?

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Flood risk estimation and forestry

Andrew Black, Environment Research Group, University of Dundee: a.z.black@dundee.ac.uk

Under the European Flooding Directive, member states are required to implement systems of flood risk management which adopt a broad understanding of flood risk, addressing event probability, flood characteristics such as water velocity and depth, as well as the consequences of flooding – certainly on people, but also on other receptors such as historic buildings and the wider environment. While all this is important, many flood risk assessments still start with a question of probability: either

- how likely is a flood to exceed some threshold flow or level,
- or how big will a flood of some given probability be?

More than a century of research has been devoted to these questions, but answers are far from definite. Indeed, of late, there has been growing scepticism about the answers which are offered!

The methods available are complex to implement and can be grouped into four broad classes:

1. Rainfall-runoff methods, by which numerical models are used to predict peak flood flows by reference to rare rainfall totals. Estimation of extreme flood flows can be made by reference to a 'design rainfall' event, the latter assessed by reference to national databases.
2. Continuous simulation methods, in which 100 years or more of river flow rates can be simulated by reference to past and future climatic conditions: this is an extension of the rainfall-runoff method and is ideally suited to addressing climate change concerns.
3. Statistical methods, by which the physical characteristics of any catchment area are used to predict the relationship between peak flood flow and rarity.
4. Historically augmented analyses, by which statistical estimation can be adapted to take account of long-term data sets where they exist: opportunities to adopt this method are typically rare.

Methods 1 and 3 above are the most commonly applied methods in practice. However, all the above methods are affected by past and future climate change, as well as potentially by the effects of changes in land use and management. So, there is much scope for uncertainty.

Best practice in hydrology tends to be to assess flood risks by applying at least two independent methods to the same site to estimate flows. The above methods rely on national databases, but heavily forested and small catchments make up a small minority of all the gauged catchments in the UK. Only 5% of river gauging stations on the National River Flow Archive drain catchments of <10 km^2: many of them are quite wet (the median is 1000 mm), but the "woodland" cover of these catchments is only 9%.

The presentation makes a case for considering whether more flood data should be collected from forested catchments to help with design needs in future. This could be based on peak water levels or channel cross-sectional areas, rather than flows. While there is a growing body of research on the effectiveness of runoff mitigation in forested areas, flood risks are expected to increase through the 21st century. Improving record keeping of extreme floods in forest areas may particularly assist bridge design. Existing recommendations for culvert design, suggesting upsizing as an adaptation strategy, looks to continue to be pragmatic for the foreseeable future.

Flood risk estimation and forestry

Andrew Black

FEG annual symposium

September 2016

An increasingly common sight?

What's the problem?

- How much water to expect with a given level of probability, e.g. once in 100 years on average
- Estimating peak level from a flow estimate
- How rare was a recent high flow? – we'll need to design higher than that!
- What about climate change?
- Does anybody believe in probabilistic flood risk estimation any more?

Operations Note 25

It is now common for the Environment Agency to expect culverts to have a much greater safety margin as a result of changes in weather patterns, due to climate change.

Table 3: Talbot values

Catchment Area in ha	1.0	1.7	3.7	4.7	6.6	11.0	16.0	20.0	24.0	33.0	43.0	47.0
Pipe Dia. in mm	300	450	500	600	700	800	900	1000	1200	1300	1400	1500

Note: Culverts of 600mm and over need to have cut off culverts installed to the discharge ditch, as shown in Figure 6 above. Further guidance should be obtained from the Environment Agency or a qualified Civil or Agricultural Engineer.

This is especially important in mountainous areas, on steep or recently felled areas, or areas where thin or saturated soil overlies impermeable bedrock, such as granite, and where water will be able to shed very quickly. Springs and drains may exist which can greatly increase the volume of water at wet times of the year, and may even bring in water from outside the catchment area.

If in doubt, specify a larger diameter of pipe as the extra cost is minimal compared to rebuilding a washed out culvert and track. Also, remember that small pipes tend to block up more easily with debris, so it is better to have one large pipe than 2 smaller ones.

Scaling up: bridge crossings

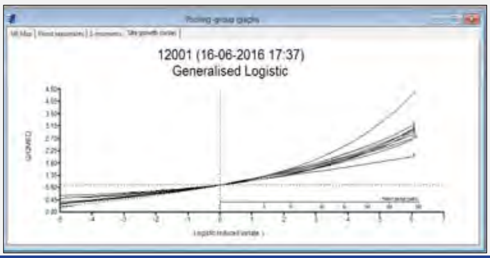
Design flow can be estimated by reference to either:

- Statistical method – predict peak flow by reference to catchment characteristics, or
- Rainfall-runoff method – predict peak flow by reference to a design rainfall and conversion to a flow hydrograph

Methods are complex and subject to considerable complexity

Pooling analysis

- The shape of the growth curve is estimated by reference to analysis of floods from other physically similar catchments



Common problems in applying standard methods

- Uncertainties in flood flow observations
- Effects of climate change/variability on past and future flood flows
- Effects of land use change
- Suitability of model calibration data sets

The UK National River Flow Archive

- 1540 gauging stations
- 5% are in catchments < 10 km^2 (1000 ha)
- Of those, the median annual rainfall is 1004 mm
- Of the same catchments, the median "woodland" cover is 9%
- i.e., national databases are not richly populated with catchments similar to typical forest estates

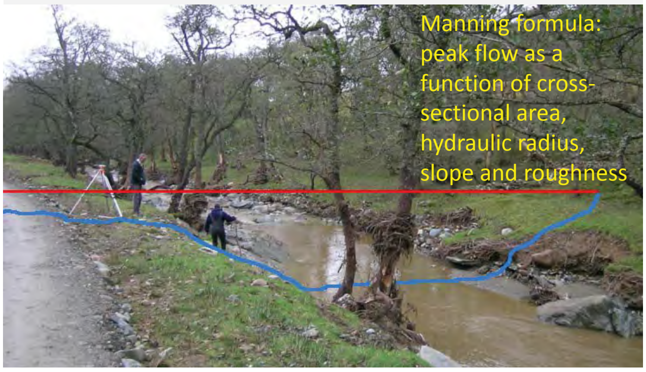
Good guidance in flood risk estimation

- Use more than one independent method, and compare results
- If they differ, use the worst-case scenario
- Use local data if at all possible

Local data?

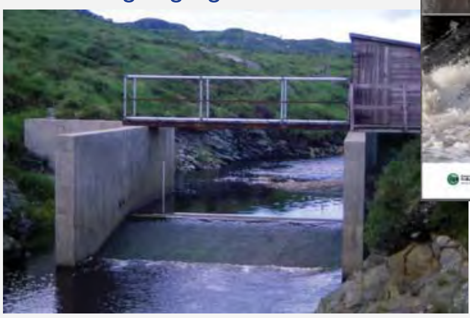
- 'Trash-line' surveys

$$Q = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$



Local data?

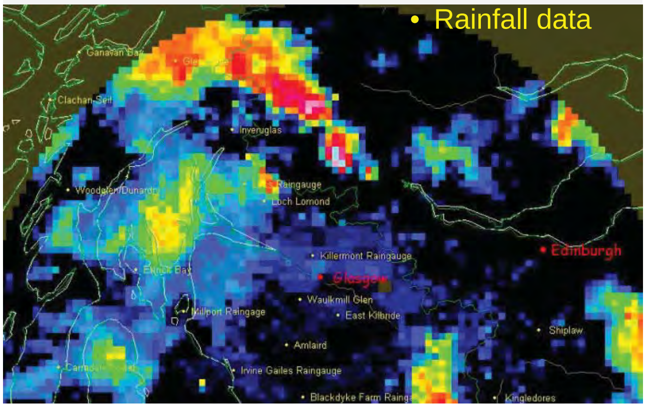
- Local gauging stations



Local data?

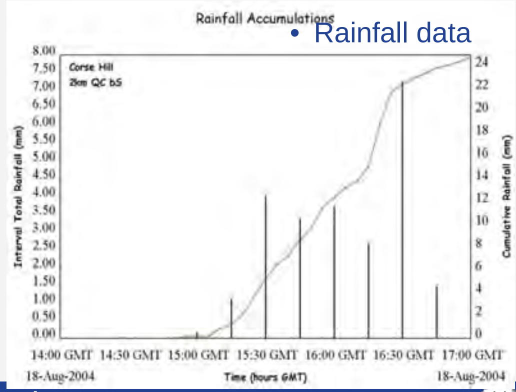
Local data?

- Rainfall data

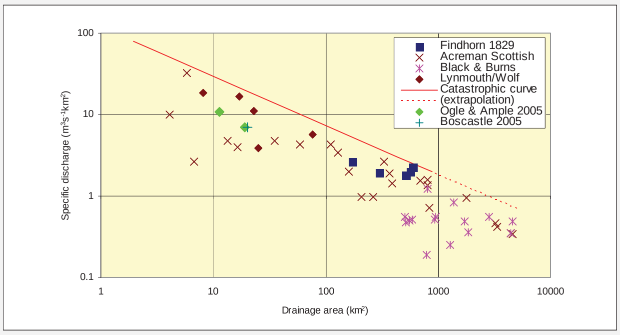


Local data?

- Rainfall data



ICE Catastrophic Flood envelope curve



What about runoff mitigation?

- Flow restrictors, ditch blocking, barriers, basins… should all help
- Meantime, we expect climate change to increase risks and we don't really know by how much
- Forests & Water Guidelines advice on best practice

Recommendations

- Culvert sizing – pragmatic advice is to err or side of caution
- Bridge design – get a hydrologist if you project justifies one
- Let's consider how information from recent extreme floods can be collated and used to improve flood risk estimation for forested catchments
- Remember: many sources of uncertainty

Slowing the Flow at Pickering

'Slowing the Flow' is one of three Defra sponsored projects looking at how changes in land use and land management can help to reduce flood risk, as well as provide other benefits such as improved water quality, enhanced biodiversity and carbon sequestration. The main aim is to work with natural processes to reduce, slow and store more flood water within landscapes to help protect downstream communities impacted by flooding. This catchment-based approach is being applied to the land draining to the town of Pickering and adjacent village of Sinnington in North Yorkshire. Pickering is particularly affected by flooding with around 20 properties flooded in 1999, 2000 and 2002, and 85 in the severe flood of 2007, which cost ~£7 million of damage.

Slowing the Flow is a partnership project led by Forest Research and involving the Environment Agency (EA), Forestry Commission England (FCE), Natural England, North York Moors National Park Authority, Local Authorities, Durham University and other local partners. It has relied on partners working together to implement a range of 'measures' on the ground, with mapping and modelling used to guide the design and placement of these for best effect. Modelling revealed the importance of avoiding locations where slowing the flow can actually make things worse by synchronising upstream flood flows.

The project began in 2009 and has delivered the following measures in the Pickering Beck and neighbouring River Seven catchments:

- 167 large woody dams constructed within streams and rivers to re-wet the floodplain and hold back flood waters.
- A trial of two novel 'timber bunds' as a potentially low-cost and low-impact method for retaining flood waters.
- 187 heather bale check dams constructed within moorland drains and gullies to slow run-off and reduce erosion.
- 29 ha of riparian woodland plus 15 ha of farm woodland planted to reduce and slow flood flows.
- Forest plans revised to help secure opportunities for forest re-design and management to reduce flood run-off, including restoring 5.9 ha of riparian woodland buffers (affecting 2.8 km of streamside).
- No-burn buffer zones established along all moorland watercourses and 3.2 ha of bare ground re-seeded with heather to increase soil infiltration and reduce flood generation.
- Roof, yard and soil works undertaken on 10 farms to reduce site run-off and diffuse pollution, as part of Catchment Sensitive Farming.
- A large flood storage area constructed to store 120,000 m^3 of flood water.
- A network of water level recorders installed to monitor the effects of specific land management changes on flood flows.

By reducing and slowing the flow of flood waters from the catchment, these measures now achieve the primary objective of protecting Pickering from at least a 1 in 25 year flood, reducing the chance of flooding in the town from 25% to less then 4% in any given year. The large flood storage area alone is designed to deliver this standard of protection and was the most expensive measure with its construction costing £2.7 million. Over half of this was funded by contributions from Ryedale District Council, North Yorkshire County Council, the Yorkshire Regional Flood and Coastal Committee and Pickering Town Council. The other measures have cost around £0.4 million and act to enhance the level of protection provided to Pickering, as well as help to reduce the risk of flooding in Sinnington.

The measures have been observed to be working as intended and the local communities certainly believe they are making a real difference. There is some evidence from both catchments that the behaviour of the response of the respective rivers has changed and that during recent events flood peaks were smoothed out and reduced.

On Boxing Day 2015 the combined effect of the flood storage area and other measures was tested for the first time in response to Storm Eva. Analysis of river levels and historic data suggests that without these interventions there would have been minor flooding in Pickering, with peak flows reduced by around 20% compared with records for similar rainfall events in previous years. It is thought that more than half of the flow reduction achieved may have been attributable to the land management measures upstream of the flood storage area. Longer runs of data are needed to determine the impact of the project on higher flood flows.

Aside from meeting the target for reducing flood risk, other key project outcomes are:

- A very strong and enthused local partnership is in place to take forward the established demonstration project, including maintaining the implemented measures and seeking opportunities to extend these to further reduce the risk of flooding in Pickering and Sinnington.
- An engaged local community, who have embraced the concept of working with natural processes and believe this new approach is making a difference.
- A much more joined up and inclusive approach to flood, water and land use management, driven by stronger local and regional delivery partnerships, including those developing the Local Flood Risk Strategy, associated Flood Risk Management Plans and the new Derwent Catchment Strategic Plan.
- Helped raise awareness of the multiple benefits provided by working with natural processes and informed the economic evaluation of ecosystem services. Allowing for the costs of the measures and for the timing of these plus benefits (over a nominal 100 year period) gave aggregated net present values ranging from £0.6m to £3.2m, with a central estimate of £1.9m.

The success of the project has led to a number of national initiatives to extend 'Slowing the Flow' to other parts of the country. In particular, FCE working with the EA has developed a 'Woodlands for Water' scheme to incentivise landowners through the Rural Development Programme to target planting to reduce flood risk and/or diffuse pollution. This resulted in 1,857 ha of woodland creation across England under the previous English Woodland Grant Scheme and continues to attract new applications under the replacement Countryside Stewardship. An ongoing FCE/EA Woodland for Water project is working to secure targeted woodland planting on private land where it can best make a difference.

The project has clearly demonstrated how a strong partnership approach can succeed in delivering an integrated set of land management measures to reduce flood risk at the catchment scale, as well as provide wider multiple benefits for local communities.

See www.forestry.gov.uk/fr/slowingtheflow for more information about the project.

Tom Nisbet (Forest Research) and Alan Eves (Forestry Commission England)

Forest Research

Slowing the Flow at Pickering: Background and Outcomes

'The Project Partnership'

Sinnington Parish Council

Forest Research

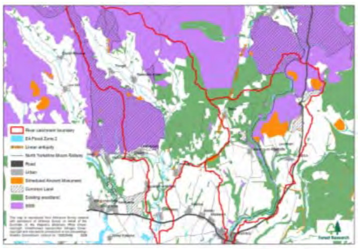
Background

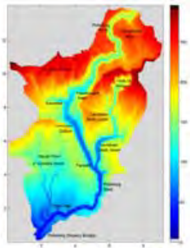
- Four recent floods in Pickering (1999, 2000, 2002, 2007) <1:10;
- 20-85 properties flooded, up to £7m damages;
- £6.6m flood defence scheme developed in 2003 – public objection;
- Ryedale Flood Research Group formed in 2008 – 'Making space for people';
- Pitt Review – 2008;
- Defra funding for three multi-objective demonstration projects - 2009.

Forest Research

Catchment Approach

Aim: To demonstrate how the integrated application of a range of 'Natural Flood Management' measures can help reduce flood risk at Pickering (from 25% to 4%), as well as deliver wider multiple benefits for the local community (www.forestry.gov.uk/fr/slowingtheflow).





Forest Research

List of Measures

Demonstration of 7 measures:

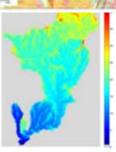
- Construct low-level earthen flood storage area(s)
- Plant 50 ha riparian woodland and 30 ha of floodplain woodland
- Plant 5 ha farm woodland
- Construct 150 Large Woody Dams (LWD)
- Implement sustainable forest drainage systems and review felling plans
- Block moorland drains
- Implement a range of farm-scale measures

Forest Research

Importance of Targeting

Use of mapping and modelling to optimise design and location of measures:

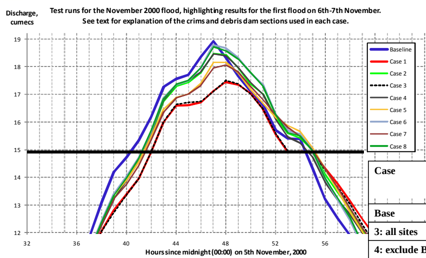
- Propensity of soils to generate rapid runoff, flow routing and timing vary across the landscape;
- Placement of measures is key, which can determine if impact is positive or negative;
- Modelling can be used to optimise the design of measures for reducing flood flows.



Forest Research

Predicting Impact on Flood Risk

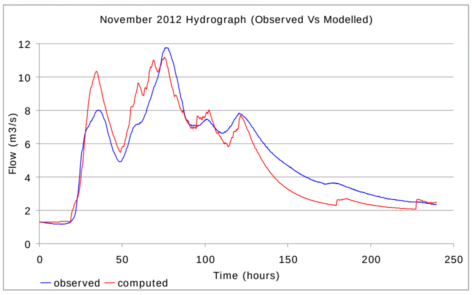
Modelling impact on 1 in 25 year flood:



Case	Peak discharge, cumecs	Flood reduction 000s m³
Base	18.9	-
3: all sites	17.5	37
4: exclude Beck	18.5	5
7: 100 lwd dams	18.1	15

Planting 50 ha of riparian woodland and installing 100 LWDs (Case 7) reduced 1 in 25 yr peak by 4% (21% of margin).

Did Measures Reduce 2012 flood?



1st peak 26% lower than predicted; second peak 6% higher but delayed (single vs multiple peak); and slower recession.

Did Measures Reduce 2015 'flood'?

Analysis indicates that measures reduced the Boxing Day peak flow by 2 cumecs or 15-20%, preventing flooding of properties on the Beck Isle; half of reduction due to upstream measures.

Outcomes

- Protected Pickering from at least a 1 in 25 year flood, reducing chance of flooding from 25% to <4%;
- An engaged local community, who have embraced the whole-catchment approach and believe it is already making a difference;
- Helped guide and integrate government policy on flood risk and land use management, notably by woodland for water initiatives.

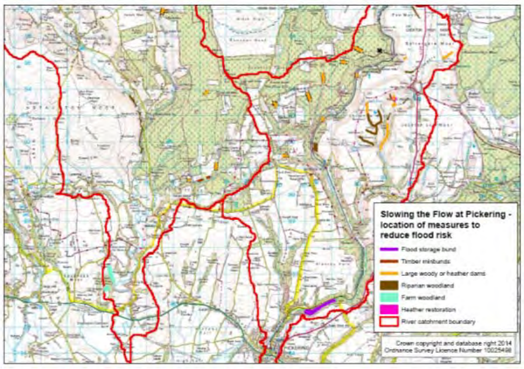
Lessons

- Work in partnership and focus on priority catchments;
- Integrate measures and plan long-term; some measures need consent;
- Woodland creation is generally good and felling or woodland removal bad for FRM;
- Seek advice and visit demonstration studies;
- Use mapping and modelling to select best sites and to tailor design to maximise benefits;
- Avoid being risk averse;
- Monitor, maintain and allow time to develop;
- Manage expectations: measures have limits!

Slowing the Flow at Pickering: Practical Measures

'The Project Partnership'

Location of Measures



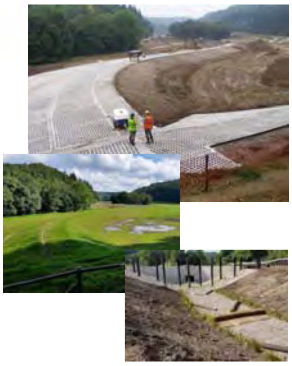
Large Woody Dams (LWDs)

- 129 LWDs installed in Pickering Beck and 38 in River Seven catchment, each storing between 1 & 109 m^3 water;
- Cost £50-£500 per dam;
- Large dams more cost effective (£5/m^3 storage vs £22/m^3 for small dam);
- Need securing in place;
- Limit to <5 m wide channels but favour wider floodplains;
- Apply 7-10x rule.

Timber Bunds

- Trial of two timber bunds, storing between 1,260-3,620 m^3 water;
- 1.5 m high, 16.5 m and 57.5 m wide;
- Cost £5k/bund;
- Potentially, most cost effective form of storage at <£2/m^3, but issues of longevity and responsibility;
- Need care in designing;

Large Flood Storage Area



- Constructed 2 km upstream of Pickering;
- Work started January 2014 and completed September 2015;
- Stores 120,000 m^3 water, culvert controlled at 14.5 cumecs;
- ~£2.7m construction cost (£22.50/m^3);

Woodland Creation

19 ha of riparian woodland planted in Pickering Beck catchment and 10 ha in River Seven catchment, plus 15 ha of farm woodland planted in River Seven catchment

Forestry Commission England

Forest Design & Management

Reviewed felling plans, revised operational planning system and restored 5.9 ha (2.8 km length of streamside) of riparian buffer

Forestry Commission England

Moorland Measures

187 heather bale check dams installed in moorland drains, 18 LWDs in moorland streams, established 10 m wide no-burn buffer zones along all watercourses, 3.2 ha of heather restored and 800 m of footpath repaired

Forestry Commission England

Farm Measures

Mixture of roof and yard works, check dams and soil aeration treatments on 10 farms under CSFDI Capital Grant Scheme

Forestry Commission England

The Measures Work!

Forestry Commission England

But they need Maintaining!

Channel interventions require regular checking and maintenance; the more dams, the less risk of debris moving downstream

Forestry Commission England

Conclusion:

The project has clearly demonstrated how a strong partnership approach can succeed in delivering an integrated set of land management measures to reduce flood risk at the catchment scale, as well as provide wider multiple benefits for the local community

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As time progresses, and varying factors take effect, the landscape and challenges of timber harvesting evolve.

- Global climate change has had a major effect on the environment where machinery is expected to work and this is not restricted to the Northern European Forests where frozen ground and frozen lakes are a necessity for logging operations. Here in the UK we have experienced higher precipitation and longer periods of "higher temperatures" resulting in higher ground temperatures.

- Engine emmission technology has had a period of huge acceleration during the past 15 years and this has provided constant adjustments on machine design.

- Other design criteria and legislation has also driven weight increases in machine design

- The past 15 years have seen a changing business climate where the UK timber industry had faced growing competition from our European neighbours, this has resulted in increasing pressure on harvesting rates

The above factors have created the following customer demand:

We have a demand for stronger, more durable and more reliable machines. The machines should be lighter than currently available and they should offer increased performance on steep ground whilst also offering solutions to enhance soft soil logging capabilities!!

- This demand has driven many solutions from many manufacturers and accessory suppliers and these will be introduced for discussion and understanding within the presentation.
- The demand has driven major changes in recent machine design and will continue to shape the machines of the future.

- Present at this years FEG Symposium will be the latest in modern harvesting technology, The John Deere 1270G.

FEG Symposium

Newton Rigg, September 2016

"Engineering to Stem the Flow"

Challenges Facing Machinery Manufacturers

Background

Changes to the global climate have drastically changed the environment where forest machines are required to operate. Increasing ground temperatures in northern areas are the biggest challenge in this respect.

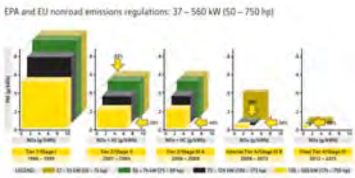
Other Factors:

- Safety Legislation
- Environmental Legislation
- Changing business climate for customers

Environmental Change

- As a general rule we can see that ground temperatures have increased over the past 20 years
- We can also see that the higher temperatures are evident for longer periods of the year
- ***Ground is softer..***
- ***Lakes dont freeze so much..***
- This had had a huge effect on logging in Northern Areas – Russia, Scandinavia & Baltic States where there
- This has also an effect in the UK with milder winters and higher precipitation

Environmental Legislation Change



- Engine legislation has been a major driver in machine design over the past 15 years
- Advances to the fuel systems have in most cases driven the need for additional components, and therefore adding weight to machines

Engine Comparison

- The weight inrease due to engine package is over 200kg
- This does not calculate additonal weight for larger hoods, longer chassis etc

Safety Legislation

- Adjustments in safety legislation have also driven design changes which have increased machine weights..
- ROPS
  - ISO 8082; 1994, only cabin part of machine included for ROPS mass (if free rotating possible)
  - ISO 8082; 2003, whole machine weight is used as ROPS mass excluding towing equipment and any load

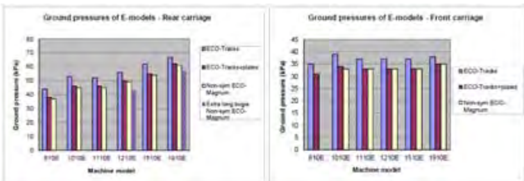
Business Climate

- Increasing pressures on harvesting rates have actioned a demand for larger, more productive equipment.
- Do current contract practices encourage longer term thinking on machines fleets and ensure the correct machine for the correct application?
- Customers generally buy larger machines with a view they can "do anything"..

Average UK Forwarder..

	1110C	1510E	Variance
Engine Power	113kW	156kW	43kW, +38%
Torque	620Nm	900Nm	280Nm, +45%
Boom Length	7.2m	8.5m	
Boom Power	99kNm	135kNm	36kNm, +36%
Tractive Effort	150kN	185kN	35kN, +23%
Work Pump	125cc	180cc	55cc, +44%
Load Rating	11,000kg	15,000kg	
Weight	15,800kg	19,800kg	
Typical Laden Weight	**App 30,000kg**	**App 37,000kg**	**7000kg, +23%**

Ground Pressure Data



- A small forwarder with correctly specified tracks can offer Ground Pressures as low as 37kPa, *5.3psi*
- A large forwarder doing the same job is unable to get below 54kPa, *7.8psi*
- This represents a 50% increase in ground pressure...

The result..

We have heavier equipment operating in generally softer ground conditions..

The result..

And worse...

The Customer Demand:

We have a demand for more powerful, more durable, more productive machines. The machines should be lighter than currently available yet offer increased climbing capabilities and lower ground pressure solutions...

Solutions...

- Machine to surface interface
  - Additional Axles
  - Track Solutions
  - Winch Solutions

Machine to Surface Interface

- This is the obvious area of focus and we can see progressive solutions in this area
  - 6WD forwarders are a distant memory in UK forests
  - Most major manuafacturers offer 8WD harvester solutions



- 1270G 8WD offers a 37% reduction in ground pressure compared to 6WD model
- It is also designed to climd a 37deg slope
  - This is one of the few areas where we can see LGP solutions also have benefits in steep slopes

Machine to Surface Interface

- Forwarder LGP solutions have become more diverse and localised in the design
- The UK offers unique challenges where we can have a peat bog on the side of a mountain!!!


Additional Axles
- These have been relatively successful in Baltic logging conditions
- Limitations where pockets of hard ground are evident that force durability issues
- Expensive solution

Wide & Twin Tyre Solutions
- Limitations where width is an issue
- Chassis restraints & special build can be required
- Axle durability issues have been evident
- Tough environment for wide tyres




Extended LGP Boggie
- Durable long term solution
- No changes to machine design
- Machine is also able to function somewhat on steeper sites
- No difference to machine width
- 26% reduction in GP on 1210E
  - Offers levels of ground pressure on 810E class unit

Track Solutions


- Track design has developed quickly during last years
- The correct tracks can have a substantial benefit in lowering the GP
- On the examples shown the fitting of the top tracks can reduce GP by 15%



Other Solutions..

- Boom Solutions
  - Longer harvester booms allow greater amount of slash within the roads, harvester booms are now available up to 12m..
  - Longer forwarder booms can reduce the need to visit every line of produce with 10m booms becoming increasingly popular...

- IT Solutions
  - GSP data can ensure machine is only where it should be!
    - Warnings on potential soft ground
  - Ability to see the production within an area determines the need to be there...
  - Follow or avoid your previous tracks?
    - Tested to 0.5m accuracy

The future...

- Perhaps the optimum solution has yet to be found.....

JOHN DEERE

JOHN DEERE

The Institution of Agricultural Engineers

Founded 1938 – Incorporated 1960

Special IAgrE Award 2016

John Scott

John Scott has been involved in Haulage for over 30 years, starting his own business JST Services in 1993. Now, with a dedicated team behind him, JST Services is now one of the largest timber handling businesses in Europe whilst at the same time diversifying into shipping and port handling solutions.

Having started life as an HGV driver John was well aware of the problems faced at all levels of the transport industry.

What set John apart was how he reacted when confronted with problems. He would thoroughly research into all the relevant information, and would identify the facts from the speculation. This thoroughness is frequently seen during his regular attendances at Conferences and Symposia where he is well known for challenging both accepted wisdom and fanciful speculation.

Having identified a problem he would readily devise new approaches that tackled the problem by either adapting existing technology or by introducing new innovative solutions.

For instance John has been a major figure in developing the transportation of timber by sea. Using FFG funding (Freight Facilities Grant), JST built a bespoke floating pier and linkspan structure allowing large boats to link to small piers in remote coastal locations. This has helped to promote coastal shipping of timber to such an extent that it has now become mainstream.

Also on sea transport, JST have created a fleet of large mobile cranes capable of being deployed to small ports and setting up in a matter of minutes. This has changed the commercial viability of harbours with limited facilities, and has revolutionized timber handling making multi-modal haulage a reality.

John has also been at the forefront of the introduction of central-tyre inflation to the UK which is now fast becoming the standard for timber wagons. His innovative approach has extended this technology to in-forest running vehicle. These use multiple axles and staggered wheel configurations to carry payloads of up to 45 tonnes to the forest entrance while at the same time looking after the roads they run on.

As adaptation of existing equipment and the costs of prototype manufacturing often present a barrier to new approaches, JST has over the years built up a workshop facility capable of producing and maintaining prototypes for the existing JST Fleet.

There was further evidence of his standing within the industry when recently he was chosen to represent the road-haulage sector on a feasibility study for a proposed £5.2 million lorry-to-rail transfer complex.

He has been a long term supporter of the IAgrE's Forest Engineering Group and their annual symposia. He also proved to be an excellent host to the FEG at this year's AGM in March where he demonstrated his latest fleet of vehicles.

Overall, John has never been afraid to invest in innovation, taking risks with his own money and demonstrating new ways to move forward our industry

IAgrE

There are 108, 000 properties at risk of flooding in Scotland, with expected Annual Average Damages of £252 million.

The Flood Risk Management Scotland Act establishes the principle of Sustainable Flood Risk Management to manage this risk.

A key aspect of this is "working with nature" or Natural Flood Management (NFM).

In December 2015 SEPA published Flood Risk Management Strategies which set the national direction of future flood risk management, helping to target investment and coordinate actions across public bodies.

For each Potentially Vulnerable Area the strategies identify agreed objectives and targeted and prioritised actions for managing flooding, including a number of NFM schemes and studies into the potential for NFM.

This talk will provide an overview of SEPA's Natural Flood Management Handbook which aims to provide the necessary information for those responsible for delivering Natural Flood Management to implement measures.

SEPA's Natural Flood Management Handbook

Fiona McLay

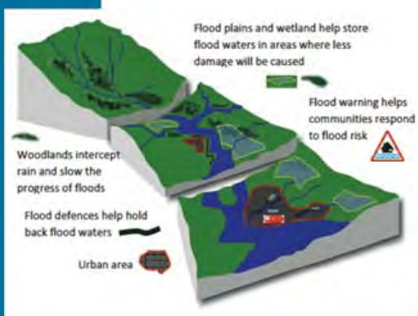
Senior Scientist

Scottish Environment Protection Agency

Flood Risk in Scotland

- 108,000 properties at flood risk in Scotland.
- 73% residential
- ~30% rural.
- Flood risk is projected to increase due to climate change.
- Traditionally hard flood defences:
  - Expensive, low cost benefit for small communities/isolated properties
  - Loss of amenity
  - Environmental impact
  - Public perception

Sustainable Flood Risk Management



- Flood Risk Management (Scotland) Act 2009 establishes principle of Sustainable Flood Risk Management
  - Whole catchment approach
  - 'Working with nature' or natural flood management (NFM).

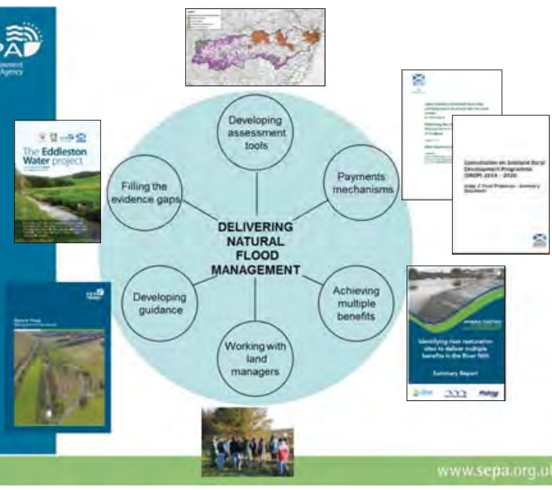
Scottish Forest strategy. Area of woodland cover to increase from 17% to 25% by the second half of the 21st Century.

FRM Strategies

- Improved understanding of flooding
- Agreed objectives
- Targeted and prioritised actions
- NFM Schemes/Works
  - 4 NFM works
  - 10 FPS with an NFM element

FRM Strategies

- NFM Studies
  - 69 FPS studies with an NFM element
  - 23 NFM only studies.

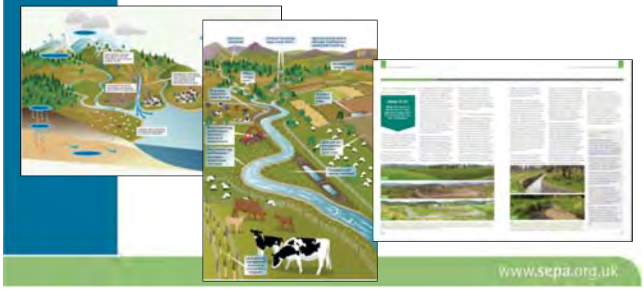


Natural Flood Management Handbook

- '*To provide those responsible for delivery with the necessary information to achieve its targeted delivery.*'
- Based on work undertaken by SEPA and partners in recent years to inform delivery of NFM
- Aims to be balanced – i.e. to acknowledge potential benefits as well as risks and unknowns
- Not a technical design manual but provides details of where to get such information

Content 2: River and catchment based NFM

- Background - impacts of land management on water cycle, current and future flood risk, NFM objectives
- River and catchment based NFM measures



Woodland NFM

- Woodland Creation
  - Floodplain woodlands
  - Riparian woodlands
  - Catchment woodlands
- Other Relevant Measures
  - Forest Management
  - Land and soil management practices (Forest Water Guidelines)
  - Agricultural and upland drainage modifications
  - River bank restoration
  - River morphology and floodplain restoration
  - Instream structures


An instream structure in the Eddleston Water catchment, Scottish Borders (© Tweed Forum).

Content 3: Coastal NFM

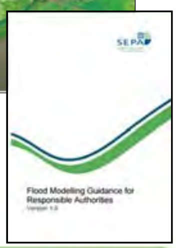
- Background – coastal processes, current and future coastal flood risk
- Coastal NFM measures

Content 4: Multiple benefits of NFM

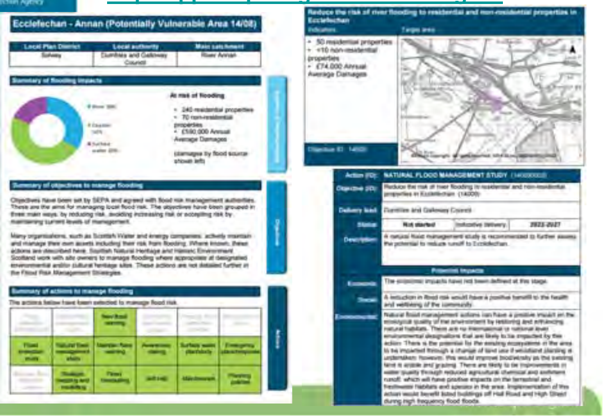
- Summary of potential multiple benefits and outcomes, including ecosystem services

Content: 5. NFM assessment tools

- Choosing the most appropriate tool and level of assessment.
- Examples of tools
  - opportunity mapping and conceptual tools
  - hydrological assessment models
  - fluvial hydraulic models
- Supporting information in SEPA's Flood Modelling Guidance for Responsible Authorities https://www.sepa.org.uk/media/163437/flood_model_guidance.pdf



Flood Risk Management Strategies - http://apps.sepa.org.uk/FRMStrategies/



Is there a Flood Risk? – Flood Hazard and Risk Maps http://map.sepa.org.uk/floodmap/map.htm

Opportunity Mapping

- SEPA's NFM Maps
  - runoff reduction;
  - floodplain storage;
  - sediment management;
  - estuarine surge attenuation; and
  - wave energy dissipation
- http://map.sepa.org.uk/floodmap/map.htm
- Inform NFM actions in FRM Strategies
- Forestry Commission Scotland Woodlands for Water
- http://maps.forestry.gov.uk/imf/imf.jsp?site=fcscotland_ext&

Understanding the Catchment

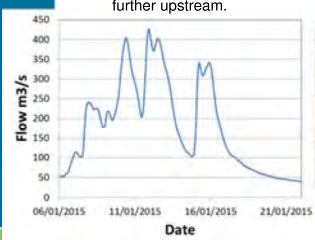
Source	Pathway	Receptor	Impacts
• rainfall • wind • waves	• overtopping • overflow	• property • people • environment	• loss of life • stress • material damage • environmental degradation

Data

- Flood history
- Gauge data
- Previous studies
- Catchment walk over, Ordnance Survey maps, aerial photography
- SEPA's flood maps http://map.sepa.org.uk/floodmap/map.htm
- FRM strategies.

Risks or Perceptions?

- Synchronisation
- Could woody debris exacerbate flooding?
  - Structure blockages
  - Dam failure
- or be perceived to…
  - Debris from multiple sources not necessarily forest planting
  - Woodlands may trap debris further upstream.

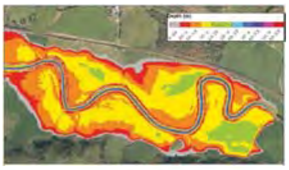


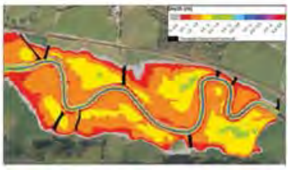
Hydrological Modelling

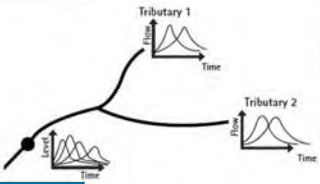
- Simplified representations of processes which influence the amount of rainfall entering rivers e.g. runoff, soil storage.
- Do not provide flood levels or extents, but can provide inflows for hydraulic models.
- Multiple sources of uncertainty for predicted changes due NFM measures for a particular rainfall event. Uses:
  - Where in a catchment changes may have most effect.
  - Sensitivity testing to determine the possible range of changes to peak flows and hydrograph shape resulting from the implementation of NFM measures
  - Scenario testing to determine the impact of possible changes in flow hydrographs on receptors, using hydraulic models.
  - Can be used to look at the effect of changes in the wider catchment on flows e.g. upland grip blocking and woodland creation.
- Typically used for wider catchment NFM measures e.g. upland grip blocking and woodland creation.

Hydraulic Modelling

- Scenario testing effect of changes in flows and phasing due to NFM in the wider catchment.
- Investigating effects of physical changes e.g. roughness, changes to hydraulic structures

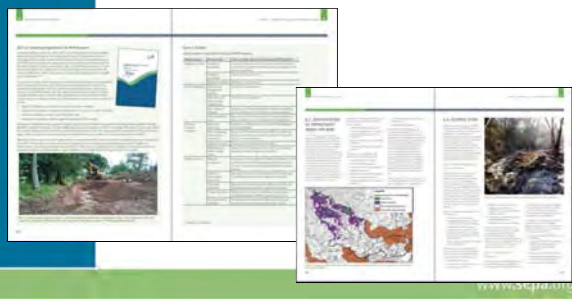






Content: 6. Implementing an NFM project

- Individual stages from conception to delivery
- Consenting requirements
- FAQs and land manager considerations

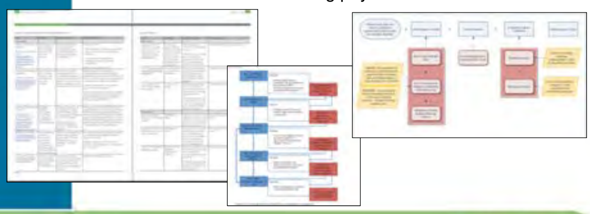


Content: 7. Managing an NFM project

- Key elements of successful project management and partnership working
- Project structure

Content: 8. Funding

- Sources of funding for capital works
- Compensation payments:
  - Types and features of different compensation mechanisms
  - Process for negotiating compensation agreements
  - Process for determining payment rates



Content: 9. Monitoring

- Brief overview of the objectives and planning of monitoring programmes, including:
  - structure and level of detail
  - monitoring parameters
  - monitoring timescales

Content: 10. Case studies

- Five case studies:
  - including funding mechanisms and lessons learnt

Future iterations

Not a static document but will be updated as new data becomes available, e.g.

- evidence base
- reference to new technical guidance
- coastal assessment tools
- new case studies
- suggestions welcomed.


Acknowledgements

Forestry Commission Scotland, Forest Research, Risk and Policy Analysts Ltd., the River Restoration Centre, the Scottish Advisory and Implementation Forum for Flooding, Scottish Government, Scottish Natural Heritage, Tweed Forum, the University of Dundee, West Sands Partnership, the James Hutton Institute, and JBA Consulting.

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

www.sepa.org.uk

“Engineering to stem the flow”

Forestry Engineering Group Symposium, 8th September 2016, Penrith.

Natural Flood Management. Lessons learned and practical examples from the river Tweed catchment.

The presentation looks at how natural flood management techniques can be incorporated into land use changes. Examples from two sub-catchments of the river Tweed are shown.

On the Eddleston catchment, a large scale (70km^2) trial is under way to try to measure the effect of installing natural flood management techniques in a variety of land use scenarios, from headwaters in forestry plantations, constructing stormwater ponds, riparian native tree planting, removing artificial river banks and re-meandering a straightened water body. The drivers for this Scottish Government funded project are the Water Framework Directive (2000/60/EC), as the Eddleston water was straightened 200 years before, and the Flood Risk Management (Scotland) Act 2009. The questions the project seeks to answer are; how can we improve the quality of a waterbody and reduce flooding by manipulating land use, and how much will it cost?

On the upper Teviot water sub-catchment (around 200km^2), Tweed Forum is working with Scottish Borders Council to investigate the potential to use NFM techniques to reduce flood risk through the town of Hawick, as part of a more traditional flood reduction scheme which is proposed for the town. Tweed Forum will be visiting all the farmers in the catchment to discuss land use changes which could slow the flow of rainfall run-off. However, over 30% of the catchment is under commercial forestry, much of it now at the end of its first rotation, and the opportunities to enhance forest management to reduce flooding is examined. Tweed Forum has been working with private forestry companies to implement opportunities as described in the latest edition of the *Forest and water UK Forestry Standard Guidelines* (edition 4, 2011).

Behind this work is an appreciation of Integrated Catchment Management and a pragmatic approach which takes into consideration that forest and farm land is firstly a productive resource, but which with a bit of knowledge and willingness can be managed contribute a broad range of goods and services to the wider community.

Hugh Chalmers

Collaborative Action Coordinator, Tweed Forum. 30.8.16

FEG Symposium - Newton Rigg 08.09.16

The River Tweed catchment – 5000km^2 113,807 people. 12,500km watercourses

Land Use; arable land upland livestock farming and forestry

Livestock farming dominates the landscape

Land Use; fertile arable land

Land Use; Drinking water to Edinburgh (2,000,000 litres/day)

Land Use;
Commercial forestry and upland sheep and cattle.

Who we are

GOVERNMENT DEPARTMENTS AND AGENCIES

Department of the Environment Food and Rural Affairs
Environment Agency
Forestry Commission Scotland
Natural England
Scottish Environment Protection Agency
Scottish Government
Scottish Natural Heritage
Scottish Water
Scottish Enterprise
Visit Scotland

LOCAL AUTHORITIES

Northumberland County Council
Northumberland National Park Authority
Scottish Borders Council

PRIVATE / VOLUNTARY SECTOR

Borders Anglers Federation
Borders Forest Trust
Northumbrian Water
Northumbrian Wildlife Trust
River Tweed Commission
Royal Society for the Protection of Birds
Scotland's Rural College
Scottish Land and Estates
Scottish National Farmers Union
Southern Uplands Partnership
Tweed Foundation

What we do

Tweed Forum roles – adding value

- **Facilitating and Enabling**
  - Mediator/Honest Broker – defuse potential conflicts
  - promote integration, coordination and cooperation
  - pool resources and secure funding
- **Seizing Opportunities**
- **Filling Gaps**
  - encourage others to action, or
  - taking direct action
- **Communicating**
  - improve flow of information
  - articulate and promote collective aims and objectives

Moving from opportunism to strategic focus – development of the catchment management plan

www.tweedforum.org

Climate change landscape unadapted

Climate change landscape adapting

Current focus - working with land managers to bring about.........

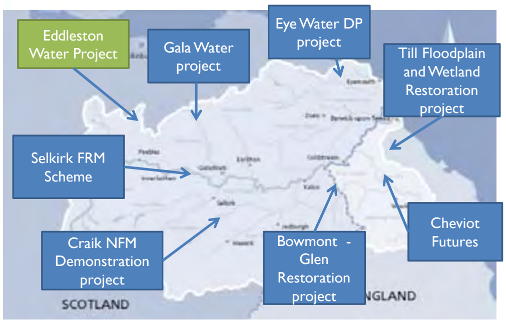
Good ecological status through:

- Habitat restoration: wetland creation, riparian enhancements, morphological restoration, woodland planting, invasive species control etc. ....

But also...........

- Biodiversity, designated sites/species, landscape
- Woodland expansion
- Climate change adaptation – increasing resilience
- Natural flood management schemes
- Diffuse pollution control
- Fishery enhancement
- Access and recreation
- Education and interpretation
- Built heritage

Recent restoration projects in the Tweed catchment




CYMAG
KILLS RABBITS & RATS
SOREX

Natural Flood Management

- slowing the pathway from raindrop to river
- interception by vegetation
- evapotranspiration
- infiltration into the soil
- disconnecting ditches
- flow restrictors
- temporary flood storage
- floodplain re-connection

- Doing whatever is in our power as land managers.

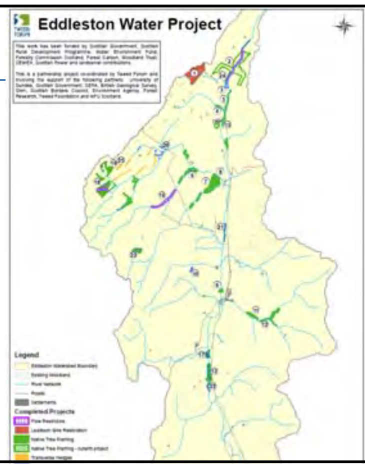
Natural Flood Management. Examples

1. Eddleston Water; whole catchment NFM techniques
2. Upper Teviot; Forest and Water Guidelines +
3. Eddleston Water; High Flow Restrictors on Forestry Commission land.

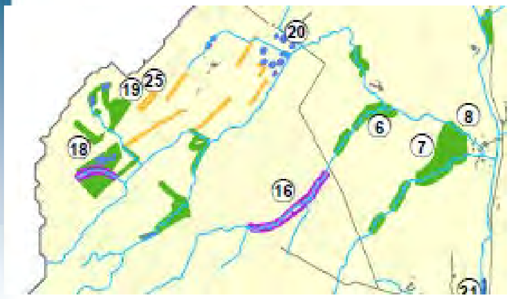
Eddleston Water Project

Background - Why Eddleston?

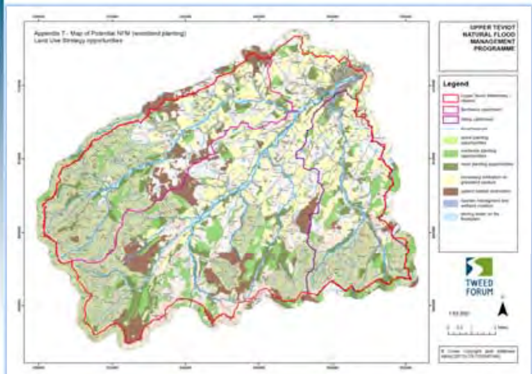
- Scale – 70 km2
- Variety of land use types
- Good source-pathway-receptor model
- Substantial modification over time – ‘bad’ status
- Flooding issues in Eddleston and Peebles



Riparian tree planting, flow restrictors, stormwater ponds, transverse hedges.

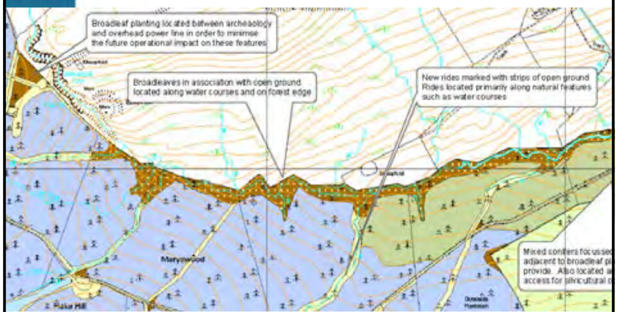


The importance of commercial forest and NFM in the catchment above Hawick.



Opportunities for NFM. Going the extra mile with Forest and Water Guidelines

clear felling the c.40 year old spruce which was planted close to both sides of the burn for around 1500m.
Replanting following F&WG



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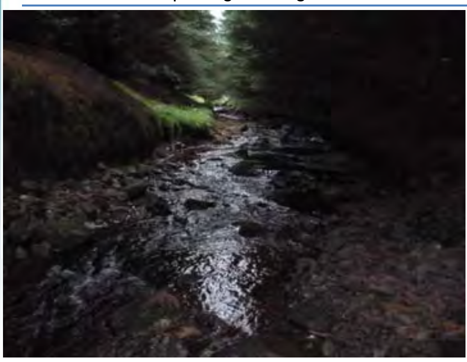


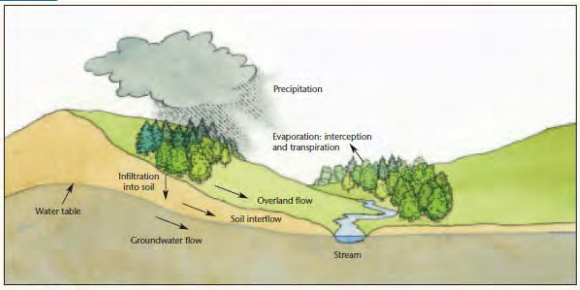


Figure 1 Water pathways.

TWEED FORUM

Issues- distinguishing between watercourse and ditch.
Disconnect the ditches, look after the watercourses.

TWEED FORUM

Issues- distinguishing between watercourse and ditch.
Disconnect the ditches, look after the watercourses.

TWEED FORUM

FORESTS & WATER GUIDELINES

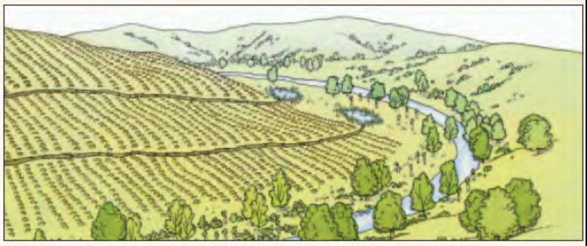


Figure 7 It is necessary to align drains up-valley in order to maintain an even, shallow gradient.

TWEED FORUM

Difficult in practice…

TWEED FORUM

Multiple woody dams

Extracts from FOREST AND WATER GUIDELINES 2011.

P41. The restoration of floodplain forests and **riparian woodland** could play an important role in attenuating flood peaks, as well as providing many other environmental benefits. Flood flows are able to spread out over natural floodplains, and the presence of a diverse forest structure, for example in the form of **multiple woody dams** within water channels and on the forest floor, can aid the retention and delay the release of floodwaters. Strategically placed floodplain forests and riparian woods may therefore offer a means of mitigating downstream flooding, although care is required to avoid sites where the backing-up of floodwaters upstream could affect local properties, or the washout of large woody debris could block downstream structures.

P43. Retain large woody debris within streams unless it is clear that it forms a barrier to fish or poses a flood risk; design and manage riparian woodland to sustain the delivery of large woody debris to small watercourses (<5 m wide)

Following guidelines to provide multiple benefits..

TWEED FORUM

Multiple woody dams

Large streamside conifers have been felled across the stream to create multiple woody dams

Multiple woody dams

Essential to allow free passage of migratory fish, but we still get the NFM benefit

Multiple woody dams

Essential to allow free passage of migratory fish, but we still get the NFM benefit

Multiple woody dams

Multiple woody dams

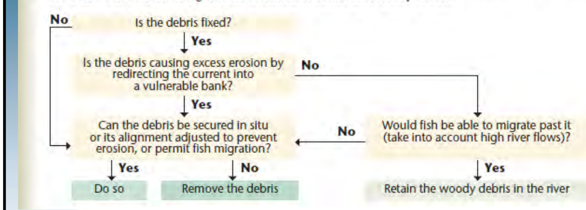
Excessive amounts of brash may need to be cleared to allow fish passage

Multiple woody dams

River banks are in a delicate state after felling, but recover quickly. Bank erosion…

Multiple woody dams

Retaining fallen timber in the river is the best way of increasing the abundance of LWD. The decision tree below can be used as a guide for retention or removal of woody debris.



Riparian re-stocking with native broadleaves

Riparian tree planting, flow restrictors, balancing ponds, transverse hedges.

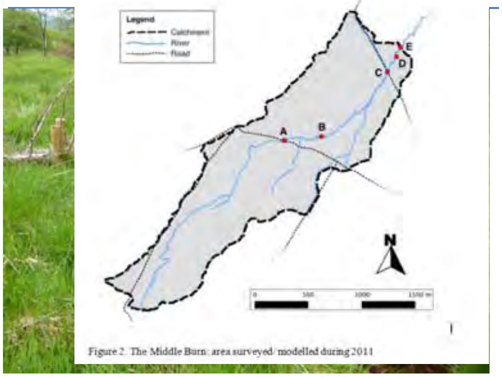
Riparian tree planting beside flow restrictors,.

35 flow restrictors along a 2km stretch. low water

35 flow restrictors along a 2km stretch. low water

35 flow restrictors along a 2km stretch. low water

Middle Burn Flow restrictors at Cloich FC. Delayed flows by 70 minutes (depends on size of flood)



Middle Burn Flow restrictors at Cloich FC High water December 2015

Middle Burn Flow restrictors at Cloich FC High water December 2015

Productive forestry, F&WG, NFM

selkirk flood protection scheme

A Scheme under the new Act

Engineering Natural Solutions

Selkirk – a major Scheme

QUESTIONS & ANSWERS

selkirk flood protection scheme

"Engineering to Stem the Flow"

selkirk flood protection scheme

What is Natural Flood Management (NFM)?

What is an engineered flood protection measure?

What is it that we seek to achieve?

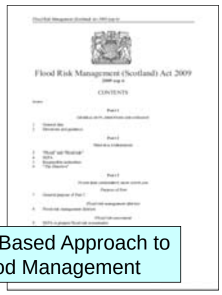
selkirk flood protection scheme

The Flood Risk Management (Scotland) Act 2009

selkirk flood protection scheme

The Flood Risk Management (Scotland) Act 2009 (FRM):

- This (new) Act superseded the (old) Flood Prevention (Scotland) Act 1961
- Maps out how flood risk will be managed in Scotland and who will be responsible for managing that risk
- New approach – i.e. professionally manage: not just bigger walls



Ethos of Act: Catchment & Risk Based Approach to Sustainable & Natural Flood Management

What is a Flood Protection Scheme?

The Flood Risk Management (Scotland) Act 2009 (FRM):

- FPS's are defined in Section 60 & Schedule 2:

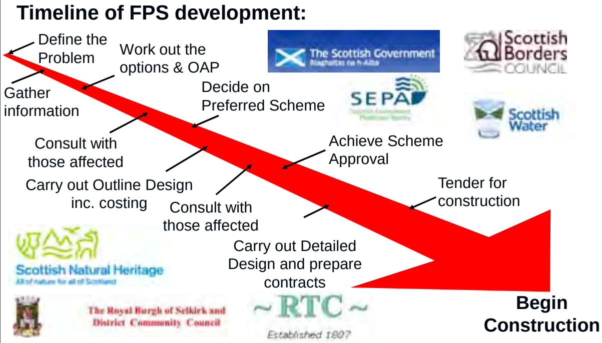
> *Flood protection schemes*
>
> **60 Flood protection schemes**
>
> (1) A flood protection scheme is a scheme by a local authority for the management of flood risk within the authority's area.

- What is a flood protection scheme?:

> A combination of engineering options that will provide a designed level of flood protection to a defined area for a defined timescale

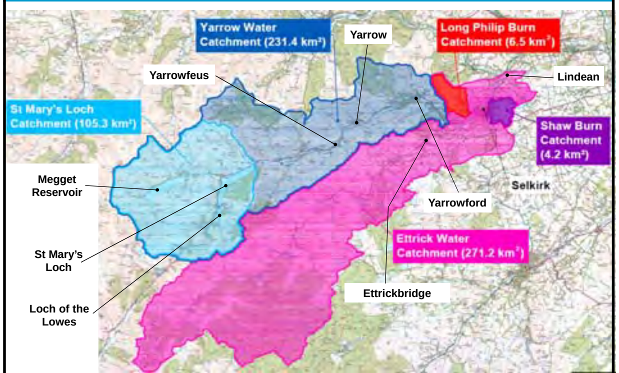
How is a flood protection scheme advanced?

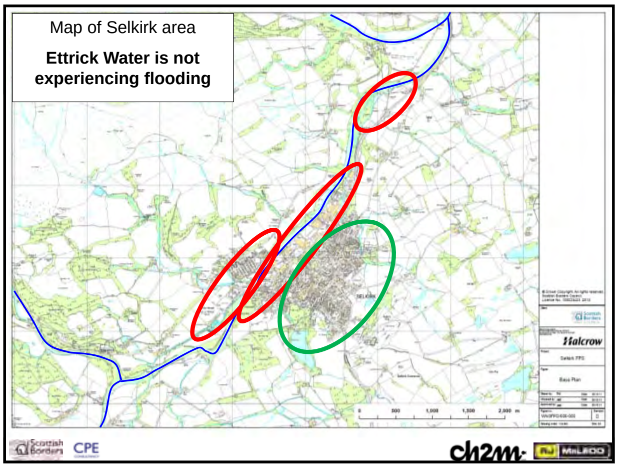
Timeline of FPS development:

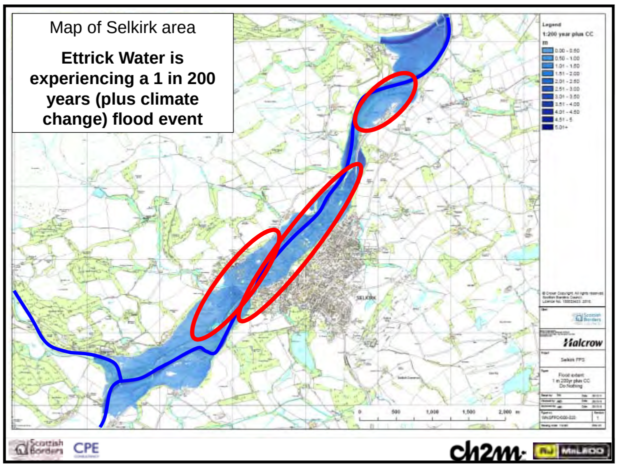


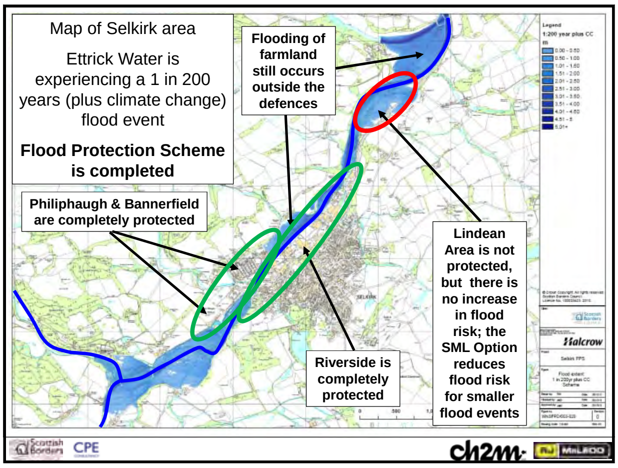
What is the flood risk to Selkirk?

The Ettrick and Yarrow catchment

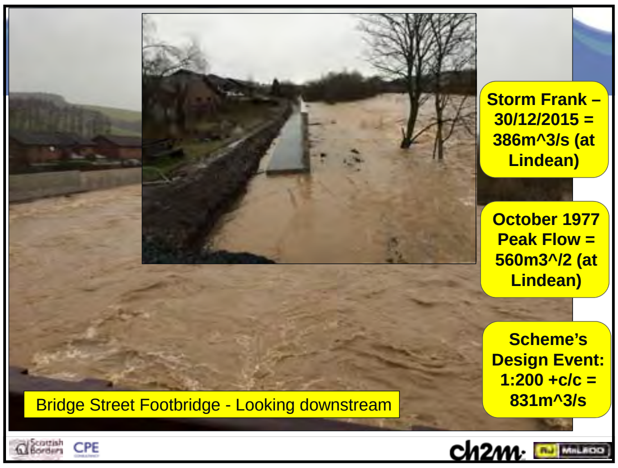


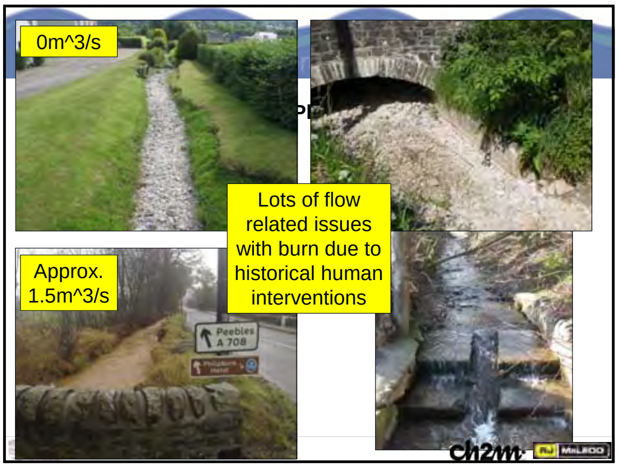

Map of Selkirk area
Ettrick Water is not experiencing flooding
Halcrow
ch2m
CPE


Map of Selkirk area
Ettrick Water is experiencing a 1 in 200 years (plus climate change) flood event
Halcrow
ch2m
CPE


Map of Selkirk area
Ettrick Water is experiencing a 1 in 200 years (plus climate change) flood event
Flood Protection Scheme is completed
Flooding of farmland still occurs outside the defences
Philiphaugh & Bannerfield are completely protected
Riverside is completely protected
Lindean Area is not protected, but there is no increase in flood risk; the SML Option reduces flood risk for smaller flood events
Halcrow
ch2m
CPE


2nd fastest rising and falling river in Scotland
July 2014 – Peak Flow = 16m3^/2 (at Lindean)
Bridge Street Footbridge - Looking downstream
ch2m
CPE


Storm Frank – 30/12/2015 = 386m^3/s (at Lindean)
October 1977 Peak Flow = 560m3^/2 (at Lindean)
Scheme's Design Event: 1:200 +c/c = 831m^3/s
Bridge Street Footbridge - Looking downstream
ch2m
CPE


0m^3/s
Approx. 1.5m^3/s
Lots of flow related issues with burn due to historical human interventions
Peebles A 708
ch2m

selkirk flood protection scheme

Selkirk's Flood Risk:

1:200 = approx. 13m^3/s

Long Philip Burn – May 2003

Probable 1:200 Years Flood Event – with debris burst like Boscastle

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Selkirk – Scheme Overview

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MAJOR / COMPLEX CIVIL ENGINEERING PROJECT

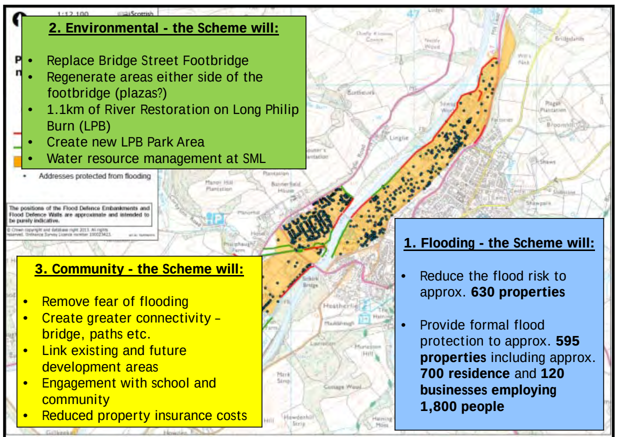
(£31.4M & BCR = 1.92)

6.5km OF FLOOD DEFENCE WALLS AND EMBANKMENTS

PROTECTION AGAINST MAJOR FLOOD EVENTS

1:200 YEAR (+ C/C)

595 PROPERTIES



2. Environmental - the Scheme will:

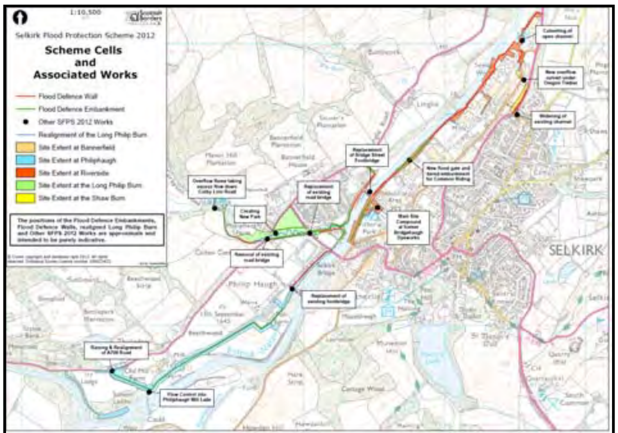
- Replace Bridge Street Footbridge
- Regenerate areas either side of the footbridge (plazas?)
- 1.1km of River Restoration on Long Philip Burn (LPB)
- Create new LPB Park Area
- Water resource management at SML

3. Community - the Scheme will:

- Remove fear of flooding
- Create greater connectivity – bridge, paths etc.
- Link existing and future development areas
- Engagement with school and community
- Reduced property insurance costs

1. Flooding - the Scheme will:

- Reduce the flood risk to approx. **630 properties**
- Provide formal flood protection to approx. **595 properties** including approx. **700 residence** and **120 businesses employing 1,800 people**



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ENGINEERING NATURAL SOLUTIONS

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- The Scheme strove to develop bespoke FRM solutions at each location that best fit the local environment
- There was no one-size fits all approach

Catchment Management	**NFM**	**Environmental Improvements**
The St. Mary's Loch Intelligent Water Management System	Restoration on the Long Philip Burn including obstacle removal and catchment measures	Replace Bridge Street Footbridge Remove existing Infrastructure Retreat the line of flood defences

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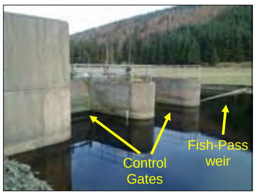
Specific Example – St. Mary's Loch Intelligent Water Management System (SMLIWMS)

St. Mary's Loch in Context:

- SML is a large (approx. 57M m³ of water) and deep (up to 47m deep) natural fresh water Loch
- The outlet has been altered by human design for centuries – e.g. Mill Owners in Selkirk
- Was SW owned: Now SBC owned



Summary of the evolution of the SML Option:

The St. Mary's Loch Working Group (SMLWG)

Develop SML Feasibility Study

The St. Mary's Loch Option	A desire to develop the flood protection potential was identified. SW and local opinion agreed with the concept in principle.
The St. Mary's Loch Flood Storage Option	The project team developed the concept into a technical option whereby SML would store water during a flood thereby attenuating the flood risk downstream.
The St. Mary's Loch Intelligent Water Management System	Re-naming / re-branding in recognition of the benefits delivered towards Water Management i.e. both flood and drought risk reduction.

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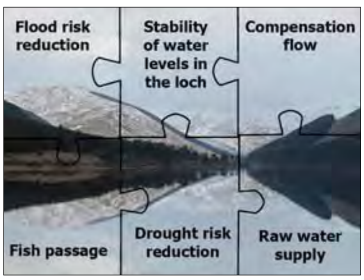
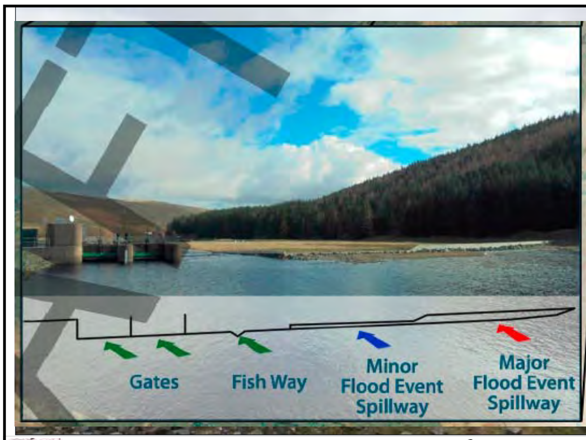
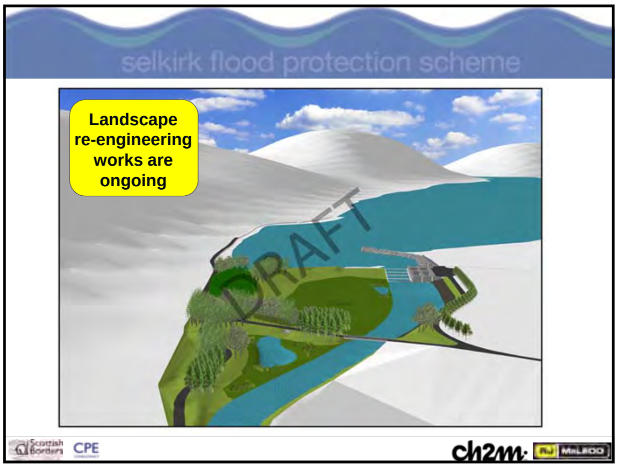
The benefits of the new system:







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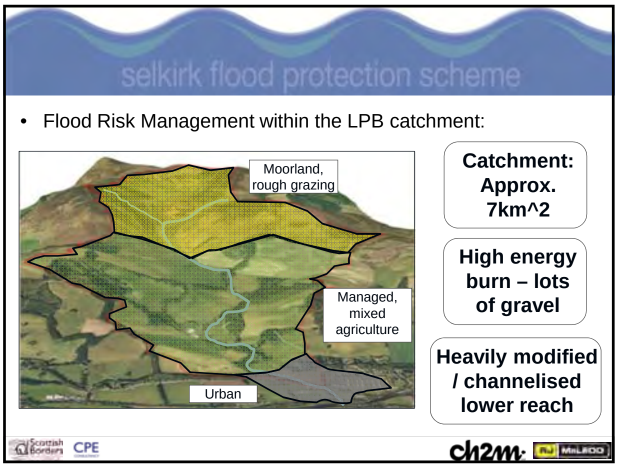
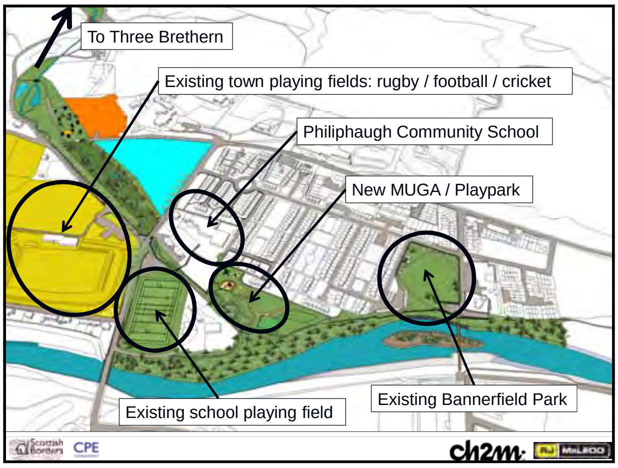
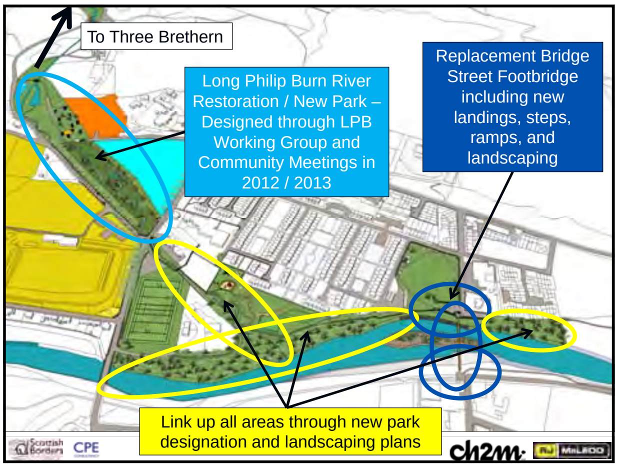
Specific Example – Long Philip Burn River Restoration

Scottish Borders CPE ch2m







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- Flood Risk Management within the LPB catchment:

Remove A708 Road Bridge	Create new flood plain / corridor	Stabilise gravel within system
Replace A707 Road Bridge	Engineering outer defences	Traditional NFM to slow the flow
Removal of historical weir	Re-meander burn within the space	Develop public park in the space

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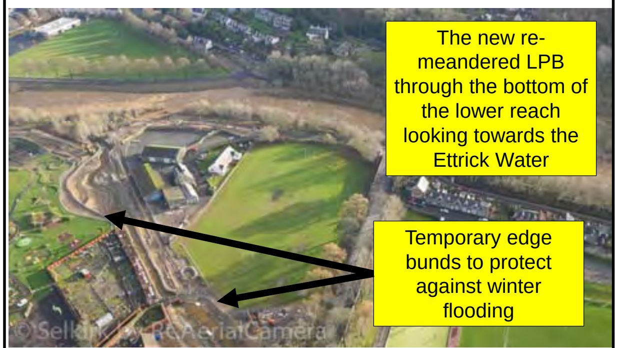

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- Flood Risk Management within the LPB catchment:

Traditional engineering, catchment management, and NFM woven together to form one overall solution

Catchment: NFM & Land Management

Engineered flood defences

Re-meandering 3-stage burn within FPS

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Thank you for listening to my presentation