APPENDIX F

Potential NFM measures

The information in the following tables has been used to identify potential NFM measures. These tables are reproduced directly from Nutt,2012.

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
Conifer woodland	Fluvial and pluvial Runoff reduction	Upper and middle catchment	Canopy interception reduces net rainfall and evapotranspiration reduces antecedent conditions	Large body of literature, refer to Section 3.1.2.E. Literature focuses on outdated practices and annual water yields. Assuming current best practice in place (no drainage) there is agreement that conifer forests delay and decrease runoff but there is disagreement over the extent of the effect (O'Connell et al., 2004). Consensus that the effects of forestation diminish with both catchment size and event magnitude. Location within catchment is significant. There is no FEH/FSR catchment descriptor for forest cover as no statistical significance can be identified.	Ability to modify runoff generation in a proportioned manner with flow routing element to estimate accumulated effects	With moderate uncertainty, complete conifer forest cover reduces runoff and may offer 10-20% reductions in flood peak when compared to grazing land uses. The pre-forest land use which the forest is compared against is significant.		Include within screening for high runoff areas and priority for assessment tool
Broadleaf woodland	Fluvial and pluvial Runoff reduction	Upper and middle catchment	Canopy interception reduces net rainfall and	Small body of literature, refer to Section 3.1.2.E.	Ability to modify runoff generation in a proportioned	With high uncertainty native deciduous trees	Could benefit from additional	Include within screening for high runoff areas and

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
			evapotranspiration reduces antecedent conditions	Literature focuses on conifer plantations. Compared to conifer forests there is more uncertainty, partly due to the seasonal fluctuations in leaf coverage but also due to less research interest. Consensus that the effects of forestation diminish with both catchment size and event magnitude. Location within catchment is significant. Jackson et al. (2008), whole catchment forestation using native woodland over pasture can reduce flood peaks by 10 to 54%. (This is one study and uses degraded pasture for higher estimate). O'Connell et al. (2007) replacing conifers with native woodland would increase flood peaks by around 10%. Robinson et al. (1986) replacing grassland with native woodland would	manner with flow routing element to estimate accumulated effects	reduce runoff and may reduce summer flood flows by similar amounts to conifers (10-20%) with reduced effect in winter months. The pre-forest land use which the forest is compared against is significant.	studies to support findings. There would also be benefit in more species specific data.	priority for assessment tool

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				reduce flood peaks by around 10%. There is no FEH/FSR catchment descriptor for forest cover as no statistical significance can be identified.				
Good muirburn practice (compliance with muirburn code)	Fluvial & pluvial Runoff reduction	Upper catchment	Improving ground cover through the provision of a mosaic of heather cover. The temporal and spatial spread of burnt bare ground ensures a relatively consistent ground cover. Good ground cover increases interception and slows overland runoff rates. May improve antecedent moisture condition.	Limited to annual interception rates (Nisbet, 2004) heather offers year round interception of 16-19% of annual rainfall. No information on interception capacity during intense events. Ramchunder et al (2009), relatively little is known about the effects of muirburn. It is speculated that catchment scale it does have an effect. Observations indicated that muirburn does reduce infiltration, increase runoff and extensive burns increase flood peaks (Mallik et al, 1984; Conway & Millar, 1960; Robinson, 1985; Dunn, 1986).	Ability to modify runoff generation in a proportioned manner with flow routing element to estimate accumulated effects. Literature gaps would require reliance on physical basis.	High uncertainty of runoff reduction. Absence of literature to quantify effects, Dunn (1986) reports a doubling of flood peaks for whole catchment burns.	National data of current muirburn practice	Include within screening for high runoff areas and priority for assessment tool
Reducing	Fluvial & pluvial	Upper and mid-	Improving the	Effects vary, some	Ability to modify	Moderate	National data	Include within

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
grazing pressure on pasture	Runoff reduction	catchment	hydrological condition of soils (increasing infiltration)	reports indicated up to double runoff volumes at field scale for degraded soils (Heathwaite et al., 1990) The more widely applicable method adopted by the Environment Agency (Packman et al., 2004) suggests a typical reduction of around 13% in percentage runoff for areas of pasture, but in some areas up to 41%. These figures are for English and Welsh catchments. Use of donor soil types to represent degraded soils (Packman et al., 2004). No land degradation data for Scotland.	runoff generation in a proportioned manner with flow routing element to estimate accumulated effects	uncertainty of runoff reduction, magnitude quantifiable. Field scale effects of soil degradation on runoff generation range from 0 to 100%. Varies with local conditions (soil, slope, land use intensity etc) Work by Packman et al. (2004) and the EA's CFMP Tool offer an existing means of quantifying hydrological benefits.	of soil degradation due to overgrazing	screening for high runoff areas and priority for assessment tool
Creation of cross slope tree shelter belts	Fluvial & Pluvial Runoff reduction	Catchment wide (Mainly sloping intensive upland areas)	In addition to benefits of forest (increased interception and reduced antecedent moisture) runoff from upslope can be infiltrated at the tree shelter belt Study of land use changes in the Pontbren catchment	The literature contains conflicting messages about the flood reducing effect of wetlands, some report increases other report decreases, (Bullock and Acreman, 2003) Most wetlands were identified as WRAP class 5 within the	Include within screening for high runoff areas and lower priority for assessment tool. In the absence of inclusion within the assessment tool provide outline of potential method to facilitate local assessment	Very high uncertainty, as literature relating to cross slope planting is only available from one source. May be very specific to local conditions	Detailed continuous simulation hydrological model which includes an accurate groundwater modelling component. Would require a large amount	Include within screening of high runoff areas and lower priority for assessment tool. In the absence of inclusion within the assessment tool provide outline of potential method to facilitate local assessment

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
			indicate that infiltration at young native woodland can be 60 times higher than improved pasture, (Jackson et al, 2008). Using strategically paced cross slope shelter belts could help reduce peak flows in large catchments during large events by 2 to 11%. A detailed distributed hydrological model that allows runoff generated upslope to be infiltrated on arrival at shelter belt	FSR, this is the class with the highest percentage runoff, (Boorman et al., 1995). Many bogs do not act to delay flow into streams and the sponge analogy is incorrect (Rydin and Jeglum, 2006)			of data and technical input to accurately represent a single wetland	
Reducing soil compaction in arable areas, improving soil texture and reducing bare earth in wetter seasons	Fluvial & pluvial Runoff reduction	Mid-catchment	Improving soils and ground cover (increasing interception, infiltration and overland flow rates)	Infiltration rates can be eight times less in ploughed ground to mature pasture (Holtan and Kirkpatrick, 1950) The EA's CFMP Land Management Tool suggests a reduction in flood flows of up to 7% when best practice in place. The flow reductions decrease with event magnitude. The effects are highly dependent on soil types, soil condition and land use.	Ability to modify runoff generation in a proportioned manner with flow routing element to estimate accumulated effects	Moderate uncertainty of runoff reduction, magnitude quantifiable. Varies with local conditions (soil, slope, crop cover intensity etc.) Work by Packman et al. (2004) and the EA's CFMP Tool offer an existing means of quantifying hydrological benefits.	Requires data of existing land management practices	Include within screening of high runoff areas and priority for assessment tool

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				Use of donor soil types to represent degraded soils (Packman et al., 2004)				
Changing agricultural field drainage	Fluvial (& pluvial) Runoff reduction (Rapid shallow groundwater)	Upper and mid-catchment	Field drains provide an improved route for water to reach watercourses (but can conversely lower antecedent moisture levels)	O'Connell et al. (2007) states that field drainage can speed or slow time to peaks by 2-3 times in both directions. IH113 reported that drainage does not alter the hydrograph volume. At a field scale the peak rate was reduced in clay soils and increased in permeable soils. At a catchment scale arterial channels accelerate runoff. Baseflow is generally increased with drainage, but effect on peak flows is site specific.	Complex distributed hydrological model with shallow groundwater component allowing the representation of modified antecedent conditions and the accelerated shallow water flow where pipes are present. Arterial ditches would require a flexible flow routing model that allows the presence of known arterial ditches to be represented.	Very high uncertainty of effect which can be positive and negative. Arterial channels have an increasing effect with event magnitude. Requires knowledge of the drainage network.	Requires detailed mapping of existing drains	Include within screening of high runoff areas and lower priority for assessment tool
Upland drain blocking	Fluvial Runoff reduction, delay/desync	Upper catchment	Drains provide an improved route for water to reach watercourses (but can conversely lower antecedent moisture levels). Upland drain blocking is a complex issue which requires consideration of soil type, topography and proximity to	Price et al (2003) efficiency depends on depth, spacing and hydraulic conductivity. Ramchunder et al (2009) noted drain direction (cross or downslope) is important. Downslope drains	Complex distributed hydrological model with shallow groundwater component allowing the representation of modified antecedent conditions and the accelerated shallow water flow where	A very high degree of uncertainty can reduce or increase flood peaks depending on local circumstances.	Requires detailed mapping of existing upland drains	Include within screening of high runoff areas and lower priority for assessment tool

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
			watercourse.	have a larger effect than cross slope. Robinson et al. (1988) suggests a 15 to 20% shortening (~1hr) of the time to peak for the Blacklaw catchment following introduction of drains. General agreement that upland drains can serve to lower antecedent moisture conditions but conversely serve to improve connectivity to watercourses. Ballard et al (2010) suggests that the quantification of effects is at the limit or beyond current capabilities.	pipes are present. Arterial ditches would require a flexible flow routing model that allows the presence of known arterial ditches to be represented.			
Floodplain reconnection	Fluvial Attenuation , delay/desync	In floodplains, mostly lower and middle parts of catchments where floodplains are sufficiently wide to merit flood protection embankments	Extends catchment time to peak by slowing travel time through the catchment. Can allow the desynchronisation of sub-catchment peaks. Often associated with river restoration which can also slow down the flow of water.	General consensus that floodplain reconnection can reduce flood flows, Bullock and Acreman (2003). Disagreement on magnitude of effects but this is probably due to local variation, Blackwell et al. (2006). Acreman et al. (2002) reports a 50 to 150%	Preferable to use a distributed or semi-distributed hydrological model which incorporates a detailed hydraulically based flow routing engine	A very high degree of uncertainty, normally reduces downstream flood peaks depending on local circumstances but can cause increases. Each case is unique and must be modelled. Realistically achievable upper limits appear to be	Requires detailed topographic data to enable modelling. Requires development of an appropriate hydrological model which includes a detailed hydraulic flow routing engine	Include within screening of channel/floodplain areas and lower priority for assessment tool. In the absence of inclusion within the assessment tool provide outline of potential method to facilitate local assessment.

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				increase in flood flows for watercourses which are entrenched and completely disconnected from the floodplain. A smaller 10 to 15% reduction for entrenched watercourses. Ratio of hydrograph volume to floodplain volume is significant, Ahilan (2009) and Potter (2006). Bullock and Acreman (2003) identified that in some circumstances increasing conveyance by restoring floodplains can increase downstream flood risk. Rapid estimation of desynchronisation benefits is not feasible, Odoni and Lane (2010). The case for desynchronisation reductions is speculative and unproven.		10-20% reduction in peaks	(1D-2D, diffuse wave)	
Creation of washlands	Fluvial Attenuation,	Mostly in lower and middle parts of catchments where	Increases the availability of storage of flood water within	Morris et al (2004) reported that washlands can have a	Preferable to use a distributed or semi-distributed	Uncertainty varies with the level of engineering used to	Requires detailed topographic	Include within screening of channel/floodplain

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
	delay/desync	floodplains are wide	the catchment, thus attenuating or delaying the flood peak. Engineer arrangements can serve to reserve volume for flood peak.	significant role to play in flood risk management. For ecological benefits it is necessary for the washland to be kept wet thus taking up some washland storage. Literature will be similar to floodplain reconnection with greater effects for some engineered washland configurations.	hydrological model which incorporates a detailed hydraulically based flow routing engine	control the inlet and outlet to the washland. Effects are similar to floodplain reconnection but marginally higher benefits can potentially be accrued via more efficient use of available storage.	data to enable modelling. Requires development of an appropriate hydrological model which includes a detailed hydraulic flow routing engine (1D-2D, diffuse wave)	areas and lower priority for assessment tool. In the absence of inclusion within the assessment tool provide outline of potential method to facilitate local assessment.
Creation of constructed farm wetlands or ponds	Fluvial (and pluvial) Attenuation, delay/desync	On minor watercourses and ephemeral flow routes	Increases the available storage within the catchment helping to attenuate flows.	Wilkinson et al (2010) present that an array of flood storage areas can be used to attenuate flows within a catchment. The implementation of flood storage requires the careful design and consideration of operation issues (Ackers & Bartlett, 2010; Hall et al., 1993). SAIFF (2011) states that constructed flood storage (particularly online) should not be considered as natural	Preferable to use a distributed or semi-distributed hydrological model which can allow the hydraulic representation of the flow controls. Can be represented using existing models	Uncertainty varies with the level of engineering used to control the inlet and outlet to the storage area. Additional uncertainty introduced through design, large number of interventions and need for maintenance. Effects are similar to traditional large flood storage areas but marginally lower benefits c accrued due to less efficient use of storage.	Requires detailed topographic data Could benefit for additional studies to support findings	Don't include within screening and not a priority for assessment tool. In the absence of inclusion within the assessment tool provide outline of potential method to facilitate local assessment.

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				flood management.				
Afforestation of floodplains	Fluvial Attenuation, delay/desync	In floodplains, mostly lower and middle parts of catchments with existing floodplains Not suitable for downstream of flood receptors	Extends catchment time to peak by slowing travel time through the catchment. Can allow the desynchronisation of sub-catchment peaks. Often associated with river restoration which can also slow down the flow of water.	All literature relates to modelling studies. Thomas and Nisbet (2006) reported that forestation of a 2.2km reach of floodplain on the River Parret reduced the average flow velocity of large floods by 78%. Nisbet and Thomas (2008) report a 0.3% reduction in 1 in 100yr flow on the River Laver using 40Ha of floodplain forest. The delay was identified as 1-3.5min/Ha, with the greatest delay for areas with the highest flow velocity. All studies use increased Manning's values within a hydraulic model to represent floodplain roughness. Ratio of hydrograph volume to floodplain volume is significant, Ahilan (2009) and Potter (2006). Backwater effects can result in an increase in upstream	Preferable to use a distributed or semi-distributed hydrological model which incorporates a detailed hydraulically based flow routing engine	A very high degree of uncertainty normally reduces downstream flood peaks depending on local circumstances but can cause increases. Each case is unique and must be modelled. Effects should increase with magnitude. Realistically achievable upper limits appear to be 10-20%	Requires detailed topographic data to enable modelling. Requires development of an appropriate hydrological model which includes a detailed hydraulic flow routing engine (1D-2D, diffuse wave)	Include within screening of channel/floodplain areas and lower priority for assessment tool. In the absence of inclusion within the assessment tool provide outline of potential assessment method to facilitate local assessment.

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				flood risk, Nisbet and Thomas (2008) and Thomas and Nisbet (2006). Rapid estimation of desynchronisation benefits is not feasible, Odoni and Lane (2010). The case for desynchronisation reductions is speculative and unproven.				
Reach restoration	Fluvial Attenuation or delay/desync	Catchment wide, typically lower reaches where naturally sinuous rivers have been straightened	Can slow flows and increase flow path length thus extending time to peak. Often increases connectivity with floodplain.	Acreman et al. (2002) reports a 10 to 15% reduction for entrenched watercourses where floodplain connection can be improved. Totally disconnected floodplains can increase flood flows by 150%.	Preferable to use a distributed or semi-distributed hydrological model which incorporates a detailed hydraulically based flow routing engine	For channels which are highly entrenched benefits can be very significant. Effects smaller for less entrenched channels. Local effects are very significant.		Include within screening of channel/floodplain areas and low priority for assessment tool. In the absence of inclusion within the assessment tool provide outline of potential assessment method to facilitate local assessment.
Creation of riparian woodland	Fluvial Delay/desync or attenuation	Catchment wide	Slows in channel flows by roughening channel banks and providing a supply of large woody debris for formation of debris dams. Slowed flow encourages floodplain linkage	Greatest benefit in narrow watercourses found in upper and mid catchment (Odoni and Lane, 2010). The Robinwood study (2008), Gregory et al (1985) reported that the effect would	Assessment requires a distributed hydrological model that has an integrated detailed hydraulic flow routing engine that is capable of representing the increased channel	A high degree of uncertainty particularly for cases relying on improving floodplain connection. Effects are marginal and there are indications that incorrect woodland placement can	Guidance on the natural spacing of large woody dams and how the Manning's roughness values vary with slope, channel size and vegetation	Include within screening and low priority for assessment tool. In the absence of inclusion within the assessment tool provide outline of potential assessment method to facilitate local

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				decrease with event size; Odoni and Lane (2008) report the opposite. The decrease in effect is taken to be more plausible due to observed data. There is general agreement within the literature that riparian woodland increases the supply of large woody debris within the channel. The effect of riparian woodland is modelled by Robinwood (2008), Odoni and Lane (2010) and others by increasing Manning's roughness of banks and channel within flow routing model. Gregory et al (1985) reported that it was necessary to reduce roughness with flow to match observations. Rapid estimation of desynchronisation benefits is not feasible (Odoni and Lane, 2010). The cases for desynchronisation reductions are	roughness and should allow for channel-floodplain flow linkage	increase risk.	type. Closure to the issue of where delay induced by large woody debris increases or decreases with flow.	assessment.

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				speculative and unproven.				
Gully woodland planting	Fluvial Delay/desync or attenuation	Upper catchment gullies or high energy watercourses (potential gullies)	Slows in channel flows by roughening channel banks and providing a supply of large woody debris for formation of debris dams. Helps stabilise sources of sediment that can lead to deposition and problems with channel capacity downstream.	Very little literature specific to hydrological effect of foresting gullies, refer to riparian woodland literature. Gullies can be a major supply of sediment within a catchment (Martinez-Casasnovas, 2003). Forestation of gullies can reduce sediment yield by 92.5% (Zhuo, 1992). A study of the Upper Wharfedale reported that the reforestation of steep gullies within the catchment would reduce the coarse sediment supply by 85% and offer a substantial reduction in flood risk (Lane, 2006)	Catchment data would bring efficiencies i.e. streampower maps and morphological pressures database Assessment requires a distributed hydrological model that has an integrated detailed hydraulic flow routing engine that is capable of representing the increased channel roughness and should allow for channel-floodplain flow linkage Ability to modify runoff generation in a proportion manner with flow routing element to estimate accumulated effects	Geomorphological aspects are very uncertain depending on local circumstances. Refer to riparian woodland for hydrological benefits.		Include within assessment via approaches for riparian woodland and the management of instabilities.
Placed large woody debris and boulders	Fluvial Attenuation or delay/desync	Mid catchment In channel, upstream of flood receptors	Slowing in channel flows and also increasing floodplain connectivity	Modelling work undertaken by Odoni and Lane (2010) in Pickering Beck identified a potential 7.5% reduction in flood flows for an observed flood event	Assessment requires a distributed hydrological model that has an integrated detailed hydraulic flow routing engine that	Very high uncertainty. Placed boulders and woody debris can be washed out or buried by sediments during flood events. Large number of	Requires guidance on the selection of Manning's roughness or other modelling technique	Include within screening and low priority for assessment tool. In the absence of inclusion within the assessment tool provide outline of

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				of unknown return period using 100 strategically placed large woody debris dams. Gregory et al (1985) reported that 36% of natural debris dams were destroyed or relocated within a 12 month period. Natural debris dams were estimated to slow the flood wave by 10 minutes over an observed 4km reach.	is capable of representing the increased channel roughness and should allow for channel-floodplain flow linkage	interventions required to generate significant impact.		potential assessment method to facilitate local assessment.
Reach restoration	Fluvial Convey/protect	At or immediately downstream of receptors where the channel is artificially constricted	Can assist in conveying water past receptors	Increasing conveyance of artificially constricted channels is a common flood risk management activity (Riley, 1998). Local effects are very significant. Can increase downstream flood risk.	Effects can be accurately modelled using existing hydraulic models	Relatively low degree of uncertainty of effect (assuming a stable geomorphological system) Local effects are very significant.	Improve quality of artificial structures database	Include within screening of channel/floodplain areas and not included within assessment tool. Provide outline of potential assessment method to facilitate local assessment.
Managing channel instabilities	Fluvial Protection	Catchment wide within the river channel and at flood receptors (When flooding can be attributed to geomorphological activity such as channel aggradation)	Reduces erosion and stabilises mobile sediments where measures are implemented and reduces consequent blockage of downstream watercourse near	A study of the Upper Wharfedale reported that the reforestation of steep gullies within the catchment would reduce the coarse sediment supply by 85% and offer a substantial	Current best approach is a (judgement based) study by a professional with geomorphological expertise. Catchment data would help identify	Site specific. Reduction in flood risk can be significant. Uncertainty is variable depending on cause of instability and the available predictive	Completion of the sediment budget modelling Development of new models, or validation of existing	Include within screening via sediment budget modelling being developed by the hydromorphology team. Do not include within assessment tool but

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
		Instabilities can be natural or caused by humans.	flood receptors May involve sediment being stored within the channel or on the floodplain or being moved to downstream reaches Can reduce risk of channel aggradation (a process which can trigger avulsion into property) or channel entrenchment (a process which can lead to additional sediment input and floodplain disconnection)	reduction in flood risk (Lane, 2006) Selkirk Flood Protection Scheme (Scottish Borders Council, 2010) reported that it was necessary to address the cause of deposition where it was occurring within a modified reach on the Long Philip Burn in addition to reducing the supply of sediments	causes of instability – principally sediment budget data should show where there are zones of aggradation and supply. Other datasets are also likely to be of use e.g., streampower and morphological pressures databases. Hydraulic impact of estimated or observed aggradation can be assessed using existing models Predicting rate of aggradation or incision, or locations of avulsion, requires complex and little-tested 2D dynamic modelling and carries high uncertainty.	tools (e.g., success less certain if giving a river room to move; more certainty of success if stabilising a head cut that is known to provide a major source of sediment)	dynamic models (e.g. CAESAR) that are able to predict rates of aggradation, rates of channel movement etc.	provide outline of a potential methodology for local assessment.
Use of SUDS	Urban drainage Reduce, delay and attenuate	Entire urban drainage system	By increasing attenuation, infiltration and mimicking natural processes the impact of urban development on the water environment can be reduced.	The use of SUDS is well document and understood (CIRIA, 2007) and SUDS are now standard practice in all developments across Scotland. The retrofitting of	Existing assessment techniques are appropriate	Well designed and maintained systems are known to be effective with a low degree of uncertainty		Don't include within screening. (Local assessment better placed to identify opportunities.

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
			Reduction of discharges to "greenfield rates"	SUDS to existing systems can be expensive and technically challenging (SNIFFER, 2006)				
Using high water demand vegetation to reduce groundwater levels	Groundwater Reduce recharge	Entire aquifer (benefits for locations where groundwater is close to the surface)	High water demand vegetation will reduce the recharge of groundwater. Some species may draw on water directly from the groundwater system.	There is consensus within the literature that high water demand can reduce the recharge to aquifers due to increased evapotranspiration. Calder (1992) presented a case where the evapotranspiration rate for a high water demand plantation exceeded the available rainfall by more than 50%. It was concluded that the plantation was importing water from other areas by drawing down the aquifer.	Existing groundwater modelling techniques are appropriate for making assessments	The impact of land use change on the seasonal recharge to aquifers can be made with a moderate level of confidence. The confidence reduces with aquifer complexity and for flood mechanisms driven by shorter storm durations.	National mapping of groundwater flood risk would be beneficial	Don't include within screening (local assessment better placed to identify opportunities). Provide outline of potential assessment method to facilitate local assessment.
Beach management (beach recharge schemes and shingle management)	Coastal Protect	Typically exposed coastal areas where beaches are eroding. If the source of material is related by coastal processes to the eroding area then this approach is termed recycling.	Artificial addition of sand or gravel material to maintain beach levels. Increased width and reduced slope of beach dissipates wave energy. Generally not possible in many	CIRIA (2011) reports that beach recharge projects are frequently undertaken to supplement existing beaches to manage coastal erosion and flooding.	Existing techniques are appropriate.	Provided appropriate study is undertaken the effects can be reasonably well predicted.		Include within screening. Don't include within assessment tool. Provide outline of methodology which can be used for local assessment.

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
			areas as depends on the availability of large quantities of suitable material from local sources e.g. port and harbour dredging. Often needs hard engineering structures to keep material in place and often needs to be replenished as material erodes away over time.	Beach recharge has been used at Aberdeen and St Andrews' West Strand.				
Artificial/ biogenic reefs and detached breakwaters	Coastal Protect	Exposed coastal areas	Establishment of biogenic reefs e.g. oyster and mussel beds to dissipate wave energy. Detached breakwaters reduce wave energy reaching the shoreline but do not completely isolate natural beach processes.	The use of artificial reefs and near shore breakwaters is well documented and such structures are frequently used to reduce coastal erosion. Biogenic oyster reefs can be used to protect eroding shorelines in lower energy systems (Cyphers et al., 2011).	Effects can be assessed using existing techniques	Provided appropriate study is undertaken the effects can be reasonably well predicted.		Include within screening. Don't include within assessment tool. Provide outline of methodology which can be used for local assessment.
Sand dune restoration (e.g. dune fencing and thatching, marram grass planting).	Coastal Protect	Exposed coastal areas behind sandy beaches were sand dunes would naturally form	Creates a defence between the beach and land to dissipate largest waves and a direct defence to high water levels	Defra FD1302 (2007) provides an overview on the use of sand dunes to manage coastal flood risk. It identifies that maintaining sand	Existing assessment techniques are appropriate	Provided appropriate study is undertaken the effects can be predicted with moderate uncertainty		Include within screening. Don't include within assessment tool. Provide outline of methodology which can be used for local

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				dunes in good condition is an effective means of reducing coastal erosion and flood risk. SNH (2000) provides guidance on a range of techniques which can be used to restore dune systems. 6000cum of recycled sand was used to restore degraded dunes at St. Andrews West Sands in 2010.				assessment.
Standline and beach management techniques	Coastal Attenuate	High amenity beaches.	Includes hand picking of litter rather than mechanical removal of litter leaving strandline in situ to reduce erosion and improve opportunity for vegetation cover to form.	It is understood that this approach is being trialled by West Sands Partnership, Fife and that University of St Andrews and Abertay University are undertaking research in this area. No literature has been identified however (pers comms) it is suggested that the early results are very promising in that retaining strandlines do increase the stability of the shoreward edge of dune systems.	No known assessment techniques. The validity of the approach would need to be assessed using the judgement of an experienced geomorphologist	Due to absence of literature there is a high degree of uncertainty about the magnitude of effects.	There is an absence of literature detailing the effectiveness of the altered maintenance approach	Local assessment best placed to undertake screening for opportunities and more detailed assessments.
Creation/	Coastal	Areas where flats	Creates an improved	Möller et al. (1999)	Site specific wave	Relatively low		Include within

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
restoration of intertidal area including mudflats and saltmarsh	Protect	would naturally form, typically estuarine Areas of reclaimed land and uneconomic flood defences. Areas of degraded mudflats and saltmarsh	buffer to dissipate wave energy.	reports that saltmarshes are more effective at dissipating wave energy than bare sand or mud flats, dissipating up to twice the energy.	run-up modelling using currently available software	degree of uncertainty (ignoring geomorphology issues) Up-to-doubling of wave energy dissipation.		screening. Don't include within assessment tool. Provide outline of methodology which can be used for local assessment.
Managed realignment, creation/ restoration of intertidal area including mudflats and saltmarsh	Coastal Delay/attenuate	Typically mid and upper estuaries. Areas of reclaimed land and uneconomic flood defences.	Provides increased volume for the storage of estuarine surges. The increased flooded area also increases the resistance to flow further helping to slow propagation up estuary. Allows natural processes to continue with no active intervention. Ensures natural morphological processes are sustained.	FHRC (2002) there is consensus between experts is that the method is effective at reducing estuarine surge. Scott et al (2011) identifies 51 managed breach, regulated exchanges and defence removal projects in the UK between 1990 and 2011 which create in total 1300Ha of coastal retreat. Coastal retreat at Alkborough (EA, 2008) is estimated to reduce the 1 in 200yr water level in the surrounding Humber Estuary by approximately 150mm. The approach of no active intervention has been adopted as components of	Effects can be modelled using existing hydrodynamic models	Moderate uncertainty A reduction of 150mm was reported in the Hull Estuary. Large areas of retreat will be most effective although location and connectively will be important factors too.	Baseline hydraulic models of all estuaries linked to potentially vulnerable zones would be beneficial.	Include within screening. Don't include within assessment tool. Provide outline of methodology which can be used for local assessment.

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
				shoreline management plans, for example the Fife Shoreline Management Plan (Fife Council, 2011). By allowing erosion to occur this provides a supply of sediment to other sections of the coastline.				
Regulated tidal exchange	Coastal Attenuate	Typically estuarine Areas of land claim and uneconomic flood defences.	Provides increased volume for the storage of estuarine surges. Can form buffer to dissipate wave energy.	FHRC (2002) there is consensus between experts is that the method is effective at reducing estuarine surge. Scott et al (2011) identifies 51 managed breaches, regulated exchanges and defence removal projects in the UK between 1990 and 2011 which create in total 1300Ha of coastal retreat. How the regulated exchange is operated can be significant. Extent, level relative to mean sea level and location within estuary will be important	Effects can be modelled using existing hydrodynamic models	Moderate uncertainty Large areas of retreat will be most effective although location and connectively will be important factors too.		Include within screening. Don't include within assessment tool. Provide outline of methodology which can be used for local assessment.
Removal of artificial channels	Coastal Delay/attenuate	Typically estuarine Areas where artificial channels have been	These channels may provide conduits for coastal surges to	No previous studies or projects identified within the literature.	Existing coastal surge analysis software is thought	High degree of uncertainty due to absence of	A dataset of artificially sustained	Not included within screening, local assessment best

NFM technique	Type Sub-type	Location	Principal action	Literature	Model requirements	Effect and uncertainty	Research or data need	Inclusion
		created/maintained for shipping or drainage purposes.	rapidly propagate inland/upstream/up estuary Dredging of channels can be detrimental to surrounding flats		to be capable of representing the effect	literature. Effects unknown.	channels would be beneficial	placed to identify opportunities. Don't include within assessment tool. Provide outline of methodology which can be used for local assessment.