Integrated Washland Management for Flood Defence and Biodiversity.

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1. Context and Aim

A combination of reform of agricultural policy, changing priorities in the countryside, growing commitment to protect and enhance biodiversity, and concerns about increased flood risk in lowlands have drawn attention to the potential contribution that managed washlands can make to deliver benefits to biodiversity and flood management. In this context, and with funding from Defra and English Nature, the study reported here[1] set out to determine the scope for simultaneously achieving flood management and biodiversity objectives, and how this might be achieved in practice. The broad purpose is to inform policy on washland creation and management, including mechanisms for implementation if deemed appropriate.

2. Defining Washlands

It is recognised that the term washland can have a number of meanings. It can refer to land which is managed for the purpose of artificially storing water. It can also be used to refer to land on undefended floodplains over which water 'washes' during peak flows. In the context of UK, virtually all floodplains are managed in some way, and the retention or restoration of the natural functions of the flood plain also reflect decisions to manage hydrological processes. For this reason, the study adopted a broad, inclusive definition of a washland, namely:

"an area of the floodplain that is allowed to flood or is deliberately flooded by a river or stream for flood management purposes, with potential to form a wetland habitat"

This definition includes those washlands that are created as a consequence of setback of agricultural defences which previously gave relatively high protection from flooding.

3 Washland Classification based on Hydraulic and Habitat Characteristics

Washlands take a variety of forms and demonstrate a variety of characteristics. For management purposes these characteristics can be classified according to:

- flood regime,
- washland soil wetness (once flooding is over), and,
- land use and related habitats.

It is important that these characteristics are accommodated within a framework which can guide appropriate management strategies for the integration of flood management and biodiversity.

[1] Morris J, Hess T M, Gowing D J, Leeds-Harrison P B, Bannister N, Vivash R M N, and Wade M. (2003) Integrated Washland Management for Flood Management and Biodiversity, Draft Report to Defra and English Nature, Cranfield University at Silsoe, Silsoe, Beds MK45 4DT. www.silsoe.cranfield.ac.uk

For this purpose, a two staged approach was developed to classify washlands according to these characteristics, supported by a 'Menu of Interventions' which can be used to help achieve these characteristics. The approach is summarised in Figure 1.

Hydraulic Matrix
Classifies washlands according to degree of hydraulic control. Generally the greater is the degree of engineering intervention, the greater the degree of control with respect to inflow onto the washland from the source channel and outflow from the washland
(see Appendix 1)

Menu of Interventions
Interventions to 'engineer' or manage particular flooding and soil wetness regimes and thereby better exploit habitat potential
(see Appendix 3)

Habitat Matrix
Captures attributes of washland hydrology that define the type and quality of existing or potential habitats. From a vegetation viewpoint, habitat type and quality depend on

- duration of flooding
- seasonality of flooding,
- relative wetness of washland soils

(see Appendix 2)

The first stage, referred to as the Hydraulic Matrix, more fully described in Appendix 1, classifies washlands according to degree of control of flood water inflow and outflow, reflecting a mainly engineering and flood management perspective. Generally the greater the degree of engineering intervention, the greater is the degree of control.

The second stage, referred to as the Habitat Matrix, more fully described in Appendix 2, captures those attributes of washland hydrology that critically define the type and quality of the habitat that exists or can be created. From a vegetation viewpoint, habitat type and quality depend on the duration and seasonality of flooding and the relative wetness of washland soils beyond the period of the flood event. In many respects it is the latter that determines the habitat potential. From a wildlife point of view, non-hydrological features will also be important such as scale, freedom from human disturbance, and connectedness with migratory pathways.

A number of wetland species (birds, mammals, invertebrates, plants) and wetland habitats that may be compatible with washlands (e.g. lowland meadows, coastal and floodplain grazing marsh, wet woodland) feature in Biodiversity Actions Plans (BAPs). These contain specific targets for retention of or expansion of the named habitats. Washland creation may meet national or local BAP targets depending on where the washland is and what habitat it may provide. Because Government agency priorities and funding now focus on the implementation of BAPs, it is important that the link is made between this policy framework and the design and implementation of washland habitats. The habitat matrix can help in this respect.

Although there is no direct link between the Hydraulic and the Habitat matrices, it is possible to adopt interventions to 'engineer' and manage particular flooding and soil wetness regimes, and thereby better exploit habitat potential. These are contained in a 'Menu of Interventions' more fully described in Appendix 3. Interventions to change flooding regimes include, for example, the construction of spillways to facilitate overtopping, or the setback or removal of agricultural flood defences. Interventions to influence soil wetness regimes on the washland (beyond the flood event) include the construction of scrapes to retain surface water, or changes in pumping regimes.

The approach adopted here firmly integrates engineering and water regime management into the classification of washlands. The typology provides a logical framework for classifying washlands in terms of flood management and biodiversity. This classification is 'output/achievement' rather than 'input/methods' driven, perceiving engineering and management options as the means by which flood management and biodiversity objectives can be met. It is important to recognise that a given washland habitat can be achieved by different intervention methods, the choice and impact of which will vary accordingly to site circumstances.

4 Washland Case Study Examples

Five case study examples of washlands in England (Appendix 4) and four elsewhere in Europe were investigated to illustrate and confirm the validity of the washland typology. The sites were chosen to provide examples of the range of types according to the hydraulic matrix, the diversity of engineering interventions in place on washland and the various opportunities for biodiversity. The sites confirm the suitability of the typology and demonstrated the types of interventions which can be used to meet flood management and biodiversity objectives.

The English case studies, and responses from a survey of flood defence and conservation managers, show that at the present time there is limited evidence to date of any purposeful integration of flood management and biodiversity objectives is being achieved to any great extent. Changing farming circumstances and agri-environment incentives have however encouraged biodiversity initiatives on existing washlands, often independent of the management of the flooding regimes.

It is apparent that in the past, washland sites have been designed and operated to deliver against one dominant function, whether flood storage or biodiversity (in the latter case in the form of designated wetlands). Opportunities to exploit potential synergy have rarely been identified at the point of washland design. The cases do however point to potential compatibility of flood defence and biodiversity, and that the management of soil water levels in the washland beyond the flood event is a key to achieving biodiversity objectives. There are encouraging signs that opportunities are now being sought to achieve synergy where possible on existing washlands, and that synergy is being built into new scheme design. The case studies show that, by their very nature, given changing circumstances of and incentives to land managers, washland sites provide a context for the creation of wetland habitats.

5 Washland Classification based on Priority of Benefit Type

The case studies, and surveys of flood defence and conservation managers show that the priority given to flood defence and biodiversity varies amongst washland sites, reflecting a mix site of characteristics, historical origins, needs and opportunities, and the dominance of a particular interest to be served, whether flood defence or biodiversity. In this respect, it is possible to classify washland sites into three types according to priority of purpose. These are:

Type A: where flood management is the most important consideration and biodiversity is a secondary consideration. It is here that public safety and the protection of the built environment are the overriding priorities in the original design and subsequent management of washlands. Biodiversity objectives will be met as long as they do not significantly compromise flood management purposes. Case study examples include Beckingham Marsh and Leigh Barrier

Type B: where biodiversity is the most important consideration and flood management is a secondary consideration. Here, the creation and management of wetland habitats are the key objectives. Flooding regimes and the flood storage facility offered by the site are managed to support habitat quality. Flooding frequencies, depths and timings which might damage important plants and animals are to be avoided except perhaps in the most extreme events. Case study examples include Long Eau, and the Coombe Hill Nature Reserve Area.

Type C: where flood management and biodiversity have equal consideration and management regimes are sought which optimise potential synergy. The scope for full integration of flood management and biodiversity functions needs to be identified at initial project identification and design, with water regimes and intervention measures built in and managed accordingly. The Harbertonford case study is an example.

6 Washland Management Protocols

Management of the washlands is essential for effective flood defence and wildlife conservation. A review of the management protocols for washlands with particular reference to flood defence, soil water control, habitat creation and habitat maintenance concluded that considerable guidance already exists. This guidance, and supporting prescriptions, further informs the menu of interventions referred to earlier. The relevance and required detail of guidance will of course vary according to the objectives of the site management and site characteristics.

7 Administration and Funding

Arrangements for the management, administration and funding of washlands critically affect the feasibility and eventual success of an integrated approach to washland development. The main options are those associated with land purchase by an organisation responsible for washland management, the purchase of flood easements, and the use of annual management agreements. The case studies contained examples of all of these methods.

The choice of most suitable method appears to vary according to the dominant purpose of washland management, and the degree of control required by the responsible organisation. Land purchase and easements have been used for predominantly flood defence schemes. Land purchase and annual agri-environmental payments, sometimes combined, have been used to achieve wetland objectives in washland areas.

8 Scope for Achieving Synergy

Following discussions with key informants, a questionnaire survey of Environment Agency Area Flood Managers and Conservation Managers of mainly Non-Government Conservation Organisations, and workshop attended by 35 representatives of key stakeholder groups, a number of observations can be made with respect to the feasibility of the integration of flood management and biodiversity.

Potential Synergy and Conflicts. Although flood defence managers and conservation officers perceive potential synergy between flood management and biodiversity in washlands, conflicts of interest can arise with respect to the duration and timing of flooding, and the management of soil wetness beyond the flood event period. Flood managers usually want to get water away quickly while conservationists may wish to retain standing water and, more important for their purposes, retain soil wetness once flooding is over. Furthermore, there are potential conflicts between the flooding and wetness regimes of different conservation interests. The typologies referred to earlier goes some way to identifying potential synergy and conflict.

Actions to exploit potential synergy or resolve conflicts need to focus on the interface between the two functions in the context of site specific circumstances. The more general are the targets for biodiversity, such as increasing the area of wet grassland, the easier it is to deliver some environmental enhancement. More specific targets may place greater constraints on flood defence. For large washland areas, however, it is likely that there will be considerable scope for creating a mix of habitats, especially along the margins of the flooded area, without unduly compromising the flood defence function.

BAPs are now driving priorities and funding biodiversity, providing the link between policy and action on the ground. It is important therefore that these, together with the strategic approach to flood management incumbent in CFMPs, provide the foundation for integrated washland development.

Dominant Regimes. The dominant washland flooding regime is that of short duration flooding. There are differences of opinion amongst conservation officers whether this regime has conservation potential. However, under such short inundation regimes there can be considerable scope for enhancing biodiversity, especially if post-flood soil wetness is retained. For example species–rich grassland and some waders flourish in these conditions.

The Importance of Washland Wetness. Within a given flood regime, which may be largely dictated by flood management requirements, water table management beyond the flood period is probably the most critical factor which determines habitat potential. The key to successful washland biodiversity is a site specific water level management plan targeted at specific outcomes, with appropriate interventions in place to deliver this. Designs could provide adequate flood storage capacity, allowing some surface water to be held on the site after the floodwaters recede and retaining high ground water levels for biodiversity benefit. Opportunities for biodiversity are likely to be limited on infrequently flooded washland sites where rapid drainage of soil water allows arable farming. However, and on a positive note, some species-rich grassland requires short duration flooding followed by rapid soil drainage which is fully compatible with flood management preferences.

Design for Integration. The best results are achieved where washland sites are designed with biodiversity in mind, by manipulating the flooding and wetness regime to suit both flood management and biodiversity. This requires clarity of biodiversity objectives, water regime requirements and agreement on appropriate interventions. It also requires early engagement of stakeholder interests.

Washland farming. Where the objective is to retain the direct involvement of the farming community, washland farming, however extensive, must be perceived to be practical and capable of contributing to sustainable livelihoods. Otherwise farmers will not adopt or commit to washland options, other than as casual graziers or hay cutters when conditions allow. There is a need to design, test and demonstrate locally relevant washland farming and land management systems before farmers can be expected to take them up.

Catchment Scale. It is perceived that the search for compatibility must be considered at the catchment level, recognising that different sites will have potential to serve different needs. As previously referred to, there is a call to integrate CFMPs and BAPs as a means of actively searching out opportunities for compatibility of flood management and biodiversity. Multi-agency involvement is also deemed essential.

The bigger the size of the individual washland, the bigger is the scope for synergy of flood management, both within and along the margins of the washland where a range of habitats might be achieved. Small washland projects can however offer significant flood management and biodiversity when aggregated at catchment and regional level.

Funding. Flood managers and conservation managers agreed that designated funding for biodiversity enhancement on washlands was essential and felt that current funding streams did not suit joint delivery of flood management and biodiversity objectives.

Thus there is a general feeling that lack of integration policy and related funding mechanisms act as a barrier to integrated washland management. Flood defence funds cannot in principle be used for other purposes, and agri-environment schemes are insufficiently focussed or may not be readily available to support washland development. Yet the allocation of public funds into washland development could in some situations provide overall better value for money in terms of expenditure flood defence, nature conservation, and support to farm incomes.

Flood managers commonly expressed the view that the current priority scoring and benefit cost appraisal methods for judging scheme viability do not adequately recognise and value environmental benefits. This means that it is difficult to justify additional capital expenditure necessary to lever biodiversity gain on the back of a flood management scheme, even when it was felt this was desirable.

At the stakeholder workshop, it was felt that significant new funds, most likely involving multiple partners, would be needed to put together a washland programme that would make a difference. Views varied whether there should be a designated budget for washland biodiversity or a general biodiversity budget from which washland components could be funded. This source could be the dominant funding mechanism where the main purpose is biodiversity, or a supplementary source where other objectives such as flood management take precedence.

Administrative Options. Flood managers and conservation managers tend to prefer land purchase as a means of achieving greater control in pursuit of their particular interests within a washland, although agri-environmental payments to incumbent landowners are now a common vehicle for promoting biodiversity in less intensively farmed washlands. The latter approach has the advantage of retaining direct farmer involvement and related benefits for local livelihoods.

Attitudes and Motivation. Flood managers and conservation managers alike agreed that attitudes and motivation of land managers was critical to washland development and there was a need for increased awareness and understanding of washland options, including financial and environmental benefits, and what this meant for practical land management and farming. Furthermore, amongst flood and conservation personnel (and also amongst wider stakeholder groups) it was felt important to encourage a culture of 'flood management' rather than 'flood defence', a commitment to search for 'sustainable solutions' to flood management problems, and an improved understanding between flood management and biodiversity functions. Views varied as to the extent this was happening now, but there was optimism for future beneficial change. There is consensus that engaging stakeholders at an early stage is important for integrated washland proposals to succeed.

Facilitating Washland Projects. There appears to be a bias towards conventional solutions to flooding problems. The washland option is perceived (for the most part justified) to be a more complicated approach, even though there was wide appreciation that it has potential to provide a more sustainable outcome in the longer term. There is a call for guidance on the preparation and appraisal of washland development schemes, drawing on monitored pilot projects to help demonstrate good practice and help overcome some of the barriers to adoption.

Stakeholder Participation. Integrated washland development requires a partnership approach and considerable participation of stakeholders throughout the whole project management cycle of identification, design, appraisal, funding, implementation monitoring and evaluation.

Education, Training and Professional Development. There is a general feeling that more could be done to integrate flood management and biodiversity objectives but that a lack of awareness and understanding between the two functions can mean that opportunity for synergy is not identified or taken up. Knowledge of the way that BAPs, CFMPs and Rural Development initiatives can work together is an example of this. There is also evidence that guidance that does exist may not be accessible in the right form. The perceived relative complexity of the washland option involving multiple objectives and stakeholders, and more complicated appraisal methodology and funding mechanisms presents particular challenges. There appears to be a need for guidance, experience-based learning workshops and case study material to support washland development, targeting the needs of various stakeholder groups.

Research and Development. Although there is considerable knowledge about flood defence and biodiversity individually, there are gaps in understanding how these two functions can best be integrated to provide practical and robust sustainable flood management solutions. The key issues mentioned above capture the main elements of this challenge. There is a clear need to develop experienced based guidance on how to design, appraise and implement integrated washland management, and the conditions required for success. This could be pursued through selected catchment or sub catchment 'pilot' projects where an integrated approach can offer relative advantage to flood management, biodiversity and possibly other stakeholder interests such as farming and tourism.

9. Key Conclusions and Recommendations

Taking a broad definition of washlands, the classification by hydraulic, habitat, and dominant purpose can provide an improved understanding of the relationship between flood and water level management regimes and biodiversity. The classification system confirms that biodiversity gain depends very much on the management of water regimes beyond the flood period. The classification system can help to identify the range of interventions available to manipulate washland water regimes in accordance with objectives and local conditions.

The study concludes that there is scope for synergy of flood management and biodiversity objectives. Though there is general wish by flood and conservation managers to exploit synergy through an integrated approach, there is limited evidence to date that it has been achieved in practice.

It is felt that a strategic, catchment scale approach is required to promote integrated washland development. BAPs provide the key drivers for biodiversity targets and funding, and these should be integrated within CFMPs. Guidance on how this might best be achieved in practice is required.

There is concern that that current appraisal methods and funding mechanisms do not support an integrated approach, especially with respect to the incorporation and valuation of environmental benefits. It is recommended that this should be the subject of review. There was a call for a designated biodiversity budget, some of which could be used for washlands habitats. Defra should review the funding options and routes for delivering biodiversity targets as they relate to washlands.

Best results are achieved where biodiversity is built into initial washland design, rather than treated as an afterthought. Engaging all stakeholders in this process is critical. The washland option can be a more challenging but potentially more sustainable solution to flood management problems than the conventional flood defence approach. It is strongly recommended that Defra, EA, EN and relevant conservation organisations work together to develop and test an integrated approach to washland management within selected catchments/sub-catchments where it is perceived the approach can offer potential advantage. This will provide much needed experienced-based guidance on how to identify, prepare, appraise and implement a programme for integrated washland development.

Appendix 1. Hydraulic Matrix with Case Study Examples

		Inflow		
		Uncontrolled inflow	**Fixed controlled inflow**	**Variable controlled inflow**
Outflow	**Uncontrolled gravity return**	1 As river stage rises, water flows onto the washland and returns to the channel when the stage falls. This situation is akin to a natural flood plain and is the best example of on-line storage. Examples include the Long Eau and Steenwaard (Netherlands).	2 Water flows into the washland once a flood bank is overtopped, and returns to the channel in the same vicinity via a flapped outfall when the stage falls	3 Water is let into the washland via a sluice gate at the discretion of the flood manager, and returns to the channel via a flapped outfall when the stage falls.
	Fixed controlled gravity return	4 This situation is unlikely to occur as if water flow into the washland is unimpeded return flow should also be unimpeded.	5 Water flows into the washland once a flood bank or spillway is overtopped. Water returns to the channel back over the embankment /spillway or via a flapped outfall some distance downstream where there is sufficient head difference for gravity flow. Examples include Coombe Hill.	6 Water is let into the washland via a sluice gate at the discretion of the flood manager, and returns to the channel via a flapped outfall some distance downstream where there is sufficient head difference for gravity flow. Examples include the Alterheim Polders (Germany).
	Controlled return (sluices/pumps)	7 This situation is unlikely to occur as if water flow into the washland is unimpeded return flow should also be unimpeded. It could be conceived that water could enter via a flapped gate that prevents return flow and is then pumped back into the river, but this example was not found.	8 Water flows into the washland once a flood bank is overtopped, and is then pumped back into the river. Examples include Beckingham Marsh.	9 Water flows into the washland when a control on the river is closed (at the discretion of the flood manager), and returns to the channel once the control is re-opened. Examples include Harburtonford and the Leigh Barrier.

Appendix 2 Habitat Matrix : Classification of Washlands by Flood and Soil Water Regimes and Related Habitat Types.

	Winter flooding only			Flooding at any time of year		
	Rapid soil drainage	Moderate soil drainage	Slow soil drainage	Rapid soil drainage	Moderate soil drainage	Slow soil drainage
Short duration Flooding	**1** Arable Pasture Hay meadow Woodland	**2** Pasture Hay meadow Woodland	**3** Pasture Woodland	**4** Hay Meadow Pasture Woodland	**5** Woodland Pasture	**6** Swamp Pasture Woodland
Medium duration Flooding	**7** Hay meadow Pasture Woodland	**8** Pasture Woodland	**9** Pasture Swamp Woodland	**10** Pasture woodland	**11** Pasture Woodland Swamp	**12** Swamp Pasture
Long duration Flooding	**13** Pasture Woodland	**14** Pasture Woodland	**15** Swamp Pasture Woodland	**16** Swamp Woodland	**17** Swamp	**18** Swamp

Note:
Soil drainage is a function both of soil conductivity and drainage infrastructure
Rapid soil drainage = Follo wing inundation, water table typically falls by > 30 cm in < 10 days in winter
Moderate soil drainage = Following inundation, water table typically falls by > 30 cm in < 30 days in winter
Slow soil drainage = Water table does not fall below 30 cm following an inundation event in winter until late April

Short duration of surface water: typically 3 days per event.
Medium: typically less than 2 weeks per event.
Long: typically more than two weeks per event

Appendix 3 Intervention Methods

Table A3.1 shows the type of actions that can be taken to manipulate the inflow and outflow of water from the washland as this defines the frequency and duration of flooding. The actions are further classified in terms of their hydraulic impacts, washland impacts and in channel impacts. The link between actions and the cells in the Hydraulic Matrix (Appendix 1) is also given.

Table A3.1 Menu of Interventions to Modify the Frequency / Duration of Washland Flooding and the Downstream Hydrograph.

Action	**Hydraulic impact**	**Washland impact**	**In-channel impact**	**Hydraulic matrix cell(s).**
Set-back/removal of embankments	Increased on-line storage	Increased area	Reduced peak stage	2,5,8
Introducing/lowering spillways in banks	Increased frequency of off-line storage	Increased frequency of inundation	Reduced peak stage	2, 3, 5, 6, 8,,9
Decreased channel maintenance leading to increasing in river and bank vegetation	Change in stage-discharge relationship	Increased frequency of inundation	Increased stage at all discharges but this depends on the extent of vegetation	1,2,3,4,5,6,7,8,9
Creation of in-line dams/sluices	Increased back-water effect.	Increased frequency of inundation	Increased peak stage	1,2,3,4,5,6,7,8,9
Increased pumping/siphoning into washland	Variable	Increased frequency and duration of inundation	Reduced in-channel discharge (up to capacity of washland)	3, 6, 9
Reduced pumping/restricted gravity outflow from washland	Variable	Increased duration of inundation	Changed (reduced) in-channel discharge which is linked to the event frequency	3, 6, 9
Increased vegetation height on floodplain	Reduced rate of inflow and outflow	Change in duration of flooding	Increased floodplain roughness The vegetation on the washland may be such as to allow rapid run on but slow runoff	1,4,7
Lowering of floodplain	Increased off-line storage	Increased frequency and duration of inundation	None upstream	1,4,7
'Ecological flooding': retention and evacuation just in time for next flood	Increased off line storage	Increased duration of inundation for specific habitats	Reduced peak stage	6,9

Table A3.2 shows the actions that can be taken to manipulate the duration of soil water (including some surface water retention) once the main floodwaters have receded or have been evacuated. The table also shows the hydrological impact of the interventions, the impact on washland characteristics, and the impact on washland drainage channel.

Table A3.2 Menu of Interventions to Modify Washland Soil Drainage Conditions

Action	**Hydraulic impact**	**Washland impact**	**Drainage channel impact in the washland**
Improve natural retention	Decease peak outflow	Increased wetness	Increase channel capacity. This may be a possibility because increased washland channel capacity (part of the drainage system on the washland) allows the possibility of increased washland storage channel capacity
Control outflow sluices	Water retained Reduction in storage capacity	Wetter soil Higher water tables	Raised water levels
Change in pumping regime	Control outflow Effect on storage capacity	Wetter soil Higher water tables possible	Maintain water levels
Introduce hydrological compartments.	Retain water This reduces storage capacity If more water is retained then the following flood may exceed the total capacity of the system	Hydrological isolation of areas Retains wet areas	Re-route drainage channels so that hydrological compartments in the washland are connected by channels
Create scrapes	Holds water on the floodplain. Impact on flood storage capacity.	Remove soil Maintains wetness of site in localized areas	May connect scrapes to ditches. The drainage channel system ensures that the whole system is drained.
Modify ditches	Allow drainage of surface water. Store surface water.	Provides control over water table	Introduce control structures on ditches
Introduce subsurface pipes	Drains water through soil profile via pipes or provides sub-irrigation.	Provides control over water table	Requires ditch water level control of soil wetness when the surface water has been removed requires either soil drainage or sub-irrigation which is linked to ditch water levels
Increase ditch 'roughness'	Reduces flow rate and increase water held on washland.	Raises water levels and water tables	Reduced maintenance This may be part of a natural outflow control system

Appendix 3 continued
Using the Menu of Interventions to achieve Washland Management Objectives

Together these menus show the range of engineering and operational interventions that can be drawn on to deliver specific flood and wetness regimes. It is not possible to be prescriptive about the suitability of particular methods to achieve regime objectives without knowing the site conditions, such as existing hydraulic characteristics and control methods, soil types, and washland topography.

It is possible to change the position of a washland in the Hydraulic Matrix by implementing an action in the menu. For example, the action to set back the embankments on the Long Eau River, moved the washland from one with a threshold inflow control (cell 2 in Table 1) to one reliant on natural inflow control (cell 1). If the pumping regime at Beckingham Marshes is stopped entirely as proposed by RSPB, then the site would shift from one of 'fixed control inflow' and 'pump out' (cell 8) to one of 'fixed control inflow' and gravity out (cell 5). This demonstrates how the 'Menu of Actions' allows washland managers to change the washland type in the Hydraulic Matrix by changing the degree of hydraulic control.

The position of the washland on the Habitat Matrix can also be altered by the menus of intervention. For example, the creation of scrapes on the Harburtonford washland produced a permanent wetland area. This reduced the soil drainage and increased the duration of surface water on the site by increasing ponding. These actions increased the wetness of the washland by moving the habitat type from rapid soil drainage to moderate soil drainage, thereby changing the potential habitat from pasture to wet grassland/swamp.

Appendix 4
Summary of Five English Washland Case Studies

Site and age in years	Size (ha)	Main Soil type	Engineering solutions & Hydraulic Matrix type.	Av. Flood duration (days)	Av. Flood frequency (per year)	Seasonality of flooding	Vegetation	Biodiversity
Harbertonford (Devon) 3 years	3.5	Clay	Dam, sluices, scrapes, vegetation planting **Type 9**	2	Designed to retain 1:10 year event	Winter and Summer	Woodland and lowland wet grassland	Increase general biodiversity by recreating natural washland. **Habitat Matrix Cell: 11**
Leigh Barrier (Kent) 30 years	278	Clay	Embankments, radial gates, scrapes. **Type 9**	3-4	2	Winter	Pasture and small areas of woodland.	Increase general biodiversity via excavation of scrapes. **Habitat Matrix Cell: 8**
Long Eau (Lincolnshire) 7 years (25 years since original defences)	15	Clay	Setback embankments. **Type 1**	3-4	3-4	Winter	Pasture	Increase general biodiversity via grassland management. **Habitat Matrix Cell: 8**
Coombe Hill (Gloucestershire) 30 years, with later extension to wetland areas	650	Silty-clay	Non return valve, embankments, ditches. **Type 5**	Highly variable	Annually	Winter	Pasture/ hay meadow	Enhancements aimed at waterfowl **Habitat Matrix Cell: 14**
Beckingham Marshes (Nottinghamshire) 40 years, with recent wetland enhancement	1000	Clay	Pumps, Sluice gate, drainage ditches, embankments. **Type 8**	2-3	1:10	Winter	Arable	Enhancements aimed at waterfowl **Habitat Matrix Cell: 1**