ENVIRONMENT AGENCY

REVIEW OF FLOOD DEFENCE PRACTICES ON THE SOMERSET LEVELS AND MOORS

THE APPENDICES

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REVIEW OF FLOOD DEFENCE PRACTICES ON THE SOMERSET LEVELS AND MOORS

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APPENDIX A

The Tidal Reaches

APPENDIX A THE TIDAL REACHES

A.1 General Description and Historical Context

Prior to the reclamation that commenced in the early 13th Century, high tides reached inland through the river system to influence the majority of the levels and moors in Somerset. The work undertaken over the centuries, including the construction of sea defences, embanking of the tidal rivers, outfalls through these banks and tidal exclusion structures on the rivers, has left only the Parrett and its tributaries open to the tide. Mean high spring tides can reach to Oath Lock [S49] on the Parrett, some 28 km inland, with exceptionally high tides reaching the redundant Langport Lock a further 3.5 km upstream. On the River Tone, spring tides reach Hook Bridge [S89], some 26 km inland.

The tidal limits of the main rivers are summarised in Table A.1.

Table A.1 Main River Tidal Limits

River or Drain	Tidal Limit	NGR	Map Reference Number
River Parrett	Oath Lock Sluice	ST 382 279	S49
River Tone	New Bridge Sluice	ST 316 269	S89
King's Sedgemoor Drain	Dunball Sluice	ST 310 408	S12
Huntspill River	Huntspill Sluice	ST 293 457	N60
River Brue	Highbridge Clyse	ST 313 472	N48
River Axe	Brean Cross Sluice	ST 309 562	N1

The tidal regime in the Bristol Channel affects the flood defence interests in a number of ways:-

- extreme high tides may overtop the sea or estuary defences
- high tidal levels prevent the efficient discharge of fluvial flood flows, and the resulting tide-lock may cause overtopping of the upstream defences
- the high silt load causes siltation problems in the tidal reaches and at tidal exclusion structures.

A.2 Tidal Levels

The tidal range of the Bristol Channel of up to 14 metres, is one of the largest in world. Predicted high tide levels can be raised by wind and atmospheric pressure by up to 2 metres, and constant vigilance is required during spring tide cycles to ensure the integrity of the defences. The gradually tapering waterway of the Severn Estuary causes a general increase in the level of high tides from the North Devon coast to Avonmouth. The 1 in 100 year tidal level in the estuaries of the river draining the Somerset Levels and Moors is approximately 8.0m AOD.

The historical development of the tidal embankments has resulted in flood defences which are difficult to maintain. Along the tidal reaches of the Parrett and Tone, the defences protect many hundred properties from tidal inundation, but they are often too narrow, with over-steepened slopes and roads and properties have been built in close proximity to them. They have been constructed over the centuries from a range of materials, some of which are not an ideal choice for embankments which need to be watertight over the full tidal cycle. An ongoing programme of capital investment has brought the majority of the defences to an acceptable standard, but as the defences deteriorate over time, further major works and continuing maintenance is required.

A.3 Tide Lock

High tide levels prevent the rivers from discharging to the Bristol Channel and this can result in "tide-lock" for up to $4^1/_2$ hours on the peak of a tide. During this period, the fluvial flows in the rivers have to be stored within their channels or floodplains. When tide lock coincides with flood flows in the rivers, all available storage will be needed, including the Levels and Moors themselves.

Where land and drain levels are higher, such as in the costal belt, gravity drainage through flapped outfalls may only be significantly tide locked for a short period on high spring tides. Most of these outfalls into tidal waters are on the Parrett and Tone, shown on Key Map 1.

The drainage from lower land in the levels and moors is pumped into the highland carriers, thereby reducing the effect of tide lock. Gold Corner Pumping Station [NPS6] lifts water from the South Drain and the Brue, via the Cripps River, into the wide Huntspill River, which acts as a storage reservoir over the peak of the spring tides. Some lowland areas, such as those draining to the King's Sedgemoor Drain, drain by gravity without any assistance from pumps, and tide lock is accommodated within the channels.

A.4 Siltation

The silt load in the Bristol Channel is particularly high, because the large tidal range gives rise to very strong tidal streams. These sweep up sediments from the estuary so effectively that during spring tides, the large majority of the fine material in the channel is in suspension, leaving the majority of the bed as bare rock. Only along the shoreline and in the estuaries is the characteristic mud to be found at such times. The waters in the tidal reach of the River Parrett can contain up to 10% of suspended solids.

The tidal curve of the estuary is asymmetric and for example in the River Parrett, the flood flow is only about one third the length of the ebb flow. As a result, the ebb velocities are very much lower than those developed on the flood tide and this causes silt to drop out of suspension. The progressive build up of silt on each tide can result in deep deposits. Observations in the past have shown that over a summer season, 2 metres of silt has been deposited at the tidal exclusion structure on the River Axe, $2^1/_2$ metres at Highbridge Clyse and some 4 metres at Dunball Clyse.

As a consequence, the channel size in the tidal reach progressively reduces and mean velocities increase to the point where the scouring effect caused by the tidal flows establishes a situation of dynamic equilibrium. Because twice-daily tidal flows dominate these lower reaches, the natural size of the tidal reaches is determined by tidal influences and is almost independent of fluvial flows and the size of the natural catchments. When a river channel has reached its natural size it is said to be 'in regime' and in this case it is the tidal influence which determines the channel geometry.

In the case of the River Parrett, the regime size at Burrowbridge is so small that the river overflows its banks upstream several times per year almost without fail. In fact it has only about one quarter the capacity needed to convey a 100 year flood without overtopping.

So why not artificially enlarge the channels to provide the capacity needed to accommodate flood flows? The roads and properties in close proximity to the tidal channel would make this a very difficult operation. In any case the siltation process is so quick that any enlargement provided would be substantially re-silted within 6 months of the dredging, and the bigger the enlargement, the faster would be the initial rate of re-siltation. Furthermore the volumes of material involved are so enormous that the cost of the requisite dredging would be quite disproportionate to the value of the benefits realised.

APPENDIX B

The River Parrett above Langport

APPENDIX B THE RIVER PARRETT ABOVE LANGPORT

B.1 General Catchment Description

The **River Parrett** rises in the limestone ridge on the Somerset/Dorset border south of Crewkerne. The overlying soils are slow draining calcareous, clayey soils, which generate a rapid response to rainfall, but with low base flows in dry weather. The catchment area of the upper Parrett is some 150 sq km and is joined by the **River Isle** catchment of 164 sq km, 3 km south of Langport. The Isle catchment is mainly overlain by clay soils with low permeability. With steep upper reaches and urban runoff from Chard, the Isle exhibits an even more flashy response to rainfall than the Parrett.

The **River Yeo** is the major tributary of the Parrett with a catchment area of some 340 sq km, joining the river just upstream of Langport. The upper reaches of the Yeo pass through the permeable soils of the Upper Liassic Yeovil Sands and together with generally flatter slopes, it has a much slower response to rainfall than the Parrett and Isle. The flow in the upper Yeo is regulated to a minor degree by Sutton Bingham Reservoir and Sherborne Lake. The compensation flow from the reservoir helps to maintain low flows during dry periods.

Great Bow Bridge carries the A378 over the Parrett at Langport. The river flows through the gap at this point between the Curry Rivel Ridge and the land which rises to the east from Langport to Somerton. The location is significant therefore, as unlike the areas upstream and downstream, the total flow of the river has to pass through the relatively narrow gap, between floodbanks and without any assistance from floodplain flow, which is clearly shown in Figure B1, from the February 1990 flood event.

B.2 The Historical Context

The reclamation of the upper Parrett moors probably commenced on land owned by Muchelney Abbey, which was founded on an island surrounded by bogs and lakes, in the 10th Century. The Abbey continued to be at the forefront of drainage activity until the dissolution of the monasteries in 1539. The Commission of Sewers established in 1304 and commissions issued after that date, continued the installation of embankments and ditches to improve the agricultural potential of the moors. A peak of activity of drainage improvements at the beginning of the 17th Century was followed by a period of relative inactivity until the beginning of the 19th Century, when West Moor, Wet Moor and King's Moor were all improved. The upper Parrett catchment had lagged behind the drainage improvements which had been earlier and more extensive in other areas.

The draining of West Moor in 1833 was one of the major schemes in the area prior to the pumped drainage schemes which followed. The West Moor Catchwater drain was dug to intercept the runoff from the uplands to the south and this had provision to discharge at either end into the Parrett or the Westport Canal.

The rivers in the Parrett Basin were used for navigation from the end of the 18th Century and by 1836 this extended from the Yeo into the Upper Parrett and Isle. Improvements to the main channels and raising of banks were planned to give a waterway of 3 feet in depth which necessitated the construction of a lock at Langport.

The raised water levels in the main channels had a detrimental effect on the land drainage. Pressure from landowners on the Parrett Navigation Company resulted in special provisions to make the draining of the moors above Langport independent of the main rivers if required.

The moors north of the Yeo were drained by the Long Sutton Catchwater Drain which joined the Portlake Rhyne which flowed through and under Langport. The moors on the left bank of the Yeo were also provided with new channels which flowed through culverts under the River Yeo into the Long Sutton Catchwater.

The improvements to the gravity drainage of the moors upstream of Langport had some effect in aggravating the flood risk in the downstream moors and, to some extent, in Langport itself. Landowners and the independent Drainage Boards, created to represent their common interests, looked into the provision of steam pumping stations which had operated successfully in the Fens since 1820. The first pumping station had been built in Westonzoyland Moor in 1830.

Plans in the late 1860's to install pumping stations to drain the moors upstream of Langport were halted by objections from the residents of Langport. They considered that upstream pumping stations would only worsen the "inconvenience suffered by the town in times of flood". The problem of balancing a variety of interests in the moors and levels has a long history.

It was not until the early 1960's that pumping stations were built at Midelney, Huish Episcopi and Westover followed by Long Load in 1974.

B.3 The River System

Map 1 shows the river system upstream of Langport with the main arterial rivers, the Parrett, Yeo and Isle and their tributaries. The map also shows the drainage channels which drain directly to the rivers or are pumped into them and the main channels carrying the summer water supply. The lengths of the embanked rivers, which carry water from the upper catchment through the Levels and Moors, are differentiated from the natural rivers and non-embanked channels. The embankments allowed the reclamation of the moors and protected them from the lower order flood events. The majority of the control structures through the embankments act as inlets to the rhyne network for summer water supply.

Unlike some other moors in Somerset, where highland carriers overtop at recognised spillways, the moors above Langport all flood from widespread overtopping of the main river embankments.

B.4 The Levels and Moors above Langport

The Levels and Moors above Langport all lie within the Langport Drainage Board Area. The moors are all overlain by clay and alluvium rather than peat.

- **Huish Level** and **Perry Moor** lie on the left bank of the River Parrett and drain to Westover Pumping Station [SPS7] via the main drain known as Huish Level Rhyne. The moors are separated by Perrymoor Bank, with the main drain passing beneath the bank. This is shown in detail in Figure B4 at the end of this Appendix.

  Units in the Westover Trading Estate have been built on low lying land connected to Huish Level, and these are therefore at flood risk.

- **West Moor** lies between the Parrett and the Isle and drains to Midelney Pumping Station [SPS9] via the West Moor Main Drain. The arrangements in the vicinity of Midelney Pumping Station are shown in Figure B2.

- A 400m long section of the drain immediately upstream of the pumping station was widened in the 1960's River Isle-Midelney Pumping Scheme to form a reservoir for the pumps. The West Moor Main Drain can drain into the River Isle near its confluence with the Parrett via a gravity outfall, if levels in the River Isle are low enough.

- **South Moor** lies on the left bank of the Isle and drains to Midelney Pumping Station through the South Moor Main Drain. This drain flows into the Westover Catchwater which then discharges via the Midelney Tunnel under the River Isle into the West Moor Main Drain. (See Figure B2).

- **Wet Moor**, on the left bank of the River Yeo, drains to Huish Episcopi Pumping Station (HEPS) through the Long Load Main Drain (see Figures B3 and B4). The drain was dug under the HEPS Scheme in 1958 and 1959 and the spoil was used to strengthen the Yeo flood banks and also to build the North Barrier Bank. This bank divides Wet Moor from Muchelney Level and North Barrier Sluice is used to control the flow of the Long Load Main Drain through the bank.

- **Muchelney Level, Hay Moor and Barry Moor**, on the left bank of the Yeo are drained to HEPS through the Thorney Moor Main Drain. These moors are crossed by roads to Muchelney which are vulnerable to being cut by flood waters.

- **Thorney Moor** lies on the right bank of the Parrett and is drained northwards to HEPS through the Thorney Moor Main Drain. The South Barrier Bank crosses the narrow part of the moor between the Parrett Banks and higher ground in Muchelney although it has been lowered in the recent past to relieve upstream flood levels.. The flow of the Thorney Moor Main Drain through the Bank is controlled through South Barrier Sluice, a 1m square hand operated sluice gate. Closure of this gate, combined with closure of the North Barrier Bank Sluice, allows HEPS to relieve the Muchelney Area of flooding at an earlier stage. Figure B4 shows the barrier banks.

- **Ablake Moor** lies on the right bank of the Yeo, but is drained to HEPS on the left bank via the Ablake Tunnel on the line of the Ablake Weir [S63] which penns the river at this point. The arrangements in the vicinity of HEPS are shown in Figure B3.

- The Long Sutton Main Drain runs parallel to the Yeo on its right bank for some 3km upstream of Ablake and this drains **Hay Moor, Hammocks, Wet Crouds, With Moor, Rod Moor and Little Moor** via the Ablake Tunnel. The Main Lake Catchwater takes flow from the Long Sutton area in an elevated channel across Rod Moor. The Long Sutton Main Drain passes under this elevated channel in a culvert, to allow Rod Moor and Little Moor to drain to HEPS.

- **Witcombe Bottom,** on the left bank of the Yeo drains through the Witcombe Bottom Main Drain which runs from the Bearley Brook to Long Load Pumping Station.

- **King's Moor**, on the right bank of the Yeo also drains to the Long Load Pumping Station. King's Moor Main Drain discharges into the Witcombe Bottom Main Drain, close to the pumping station via a tunnel under the Yeo.

B.5 Pumping Stations

The previous section outlined the pumping stations which drain the moors upstream of Langport. Table B.1 summarises the stations.

Table B.1 Pumping Station Details

Pumping Station	Catchment km^2	Approx. Capacity m^3/sec	Year Installed	Draining	% of Catchment as upland
Westover [SPS7]	10	1.86	1965	Huish Level, Perry Moor, Westover Trading Estate	84%
Midelney [SPS9]	22	3.3	1963	West Moor South Moor (T)	71%
Huish Episcopi [SPS8]	30	5.1	1963	Wet Moor, Muchelney Level, Hay Moor, Barry Moor, Thorney Moor, Ablake Moor (T), Hay Moor (T), Hammocks (T), Wet Crouds (T), With Moor (T), Rod Moor (T) Little Moor (T)	66%
Long Load [SPS11]	33	4.4	1977	Witcombe Bottom, King's Moor (T)	57%

Note: (T) indicates drainage through a tunnel under the main river.
The percentages of upland catchment quoted in the table above refer to water flowing directly into the catchment. It does not include for floodwater overtopping the embanked arterial rivers.

These pumping stations were all designed to operate on off-peak electricity tariffs, with pumps running to 17 hours per day on average in return for greatly reduced electricity costs. By a special arrangement, in the past, Westover Pumping Station has run for 24 hours per day if industrial units on the Westover Trading Estate are threatened. A similar arrangement has also been agreed for Huish Episcopi Pumping Station when flood levels have affected roads and threatened to cut off the village of Muchelney. The lifting of the restriction has been obtained by negotiation with SWEB, who cannot guarantee that the concession will be repeated in future events.

B.6 Summer Water Supply

The summer water feed into the moors above Langport is diverted by inlets from the Parrett, Yeo and Isle. The main control structures which allow the higher water levels to be achieved in the main carriers are:-

- **Oath Lock Sluice** [S49], downstream of Langport is used to penn water in the upper Parrett in the summer months to a level of 6.6m AOD. Upstream of the Isle confluence, sluices at **Thorney Mill** [S83] penn the Parrett to a target level of 10.3m AOD in the summer and to 10.05m AOD in the winter.

- **Ablake Weir** and Sluice [S63], alongside Huish Episcopi Pumping Station, penns water in the Yeo to a target level of 7.3m AOD in the summer. (See figure B3).

- **Midelney Lock** Control Structure [S77] penns water in the River Isle just upstream of its confluence with the Parrett to a level of 7.15m AOD in the summer and 6.40m AOD in the winter.

- **Slabgate Weir** [S80] is located just downstream of Hambridge Bridge on the River Isle. It penns the Isle to a level of 7.4m AOD and this then drives water through sluices at Slabgate Inlets into the West Moor Catchwater. (See detail in Figure B2).

The inlets into the moors are controlled by sluices operated by either the Environment Agency or the Langport Drainage Board. Other structures on main drains and viewed rhynes and the settings at pumping stations control water levels throughout the network.

B.7 Flood Procedures

Flood events upstream of Langport can be particularly damaging and disruptive. Flooding in February 1990 and again in December 1994 to February 1995, which was assessed as a 1 in 30 year event, inundated the moors for long periods. The village of Muchelney was cut off for several weeks and buildings were flooded on Westover Trading Estate, which is directly linked to Huish Level. Figure B1 shows the moors flooded in the 1990 event.

During flood events, the Environment Agency and Langport Drainage Board operate a number of structures, particularly to avoid damage to property and the closure of roads to villages.

- the sluice at Thorney Mill [S83], which penns water in the Parrett is opened

- sluices at Huish Episcopi Pumping Station (Ablake Weir Sluice) [S63] and Load Bridge (Long Load Weir Sluice) [S121], both of which penn water in the Yeo, are opened

- the sluice at Midelney Lock [S77], which raises water levels in the Isle is opened

- North Barrier Bank Sluice [S64] on the Thorney Moor Main Drain and South Barrier Bank Sluice [S76] on the Long Load Main Drain. The sluices are both left open as long as the Langport to Muchelney Road is not at risk of flooding, but if levels rise to threaten closure of the road, the sluices are closed to allow Huish Episcopi Pumping Station to evacuate the central area of the Muchelney Level and Thorney Moor first. In major events, South Barrier Bank Sluice will be by-passed by water overtopping the spillway over the bank. (See Figure B4).
- all inlets to the levels and moors used to provide a summer water supply are closed during flood events.

During flood events, procedures are followed which establish the priorities for evacuation of floodwater. All the pumping stations upstream of Langport have to be operated to ensure that water is not pumped into the main carriers, only to overtop into moors downstream of Langport. Experience during a flood in the winter of 1994/5 demonstrated that operation of the Upper Parrett Pumping Stations resulted in overtopping of Hook Bridge Spillway on the River Tone into Curry Moor within an hour. Because of the effect they can have downstream, Langport pumps are left switched off, even when their Moors are badly flooded, until downstream levels can accept the increase.

If the Langport to Muchelney Road is not likely to be flooded in any particular event, all pumping stations would be run, although they might not run at full capacity if overtopping downstream of Langport would otherwise occur.

If the road is threatened, all pumps at Long Load, Midelney and Westover are turned off to allow HEPS to evacuate the maximum possible volume, commensurate with conditions downstream of Langport.

Care is taken in the operation of North and South Barrier Bank Sluices discussed above. Property can be affected in all three compartments separated by these banks. North Barrier Bank Sluice can therefore be operated to make the most of available storage, whilst still avoiding the flooding of the roads.

Figure B4 shows how the banks divide the area draining to Westover Pumping Station and HEPS into compartments.

APPENDIX C

The River Parrett System Below Langport

APPENDIX C THE RIVER PARRETT SYSTEM BELOW LANGPORT

C.1 General Catchment Description

The **River Parrett** flows in an embanked channel below Langport to its outfall in the Bristol Channel. The river is influenced by the tides downstream of Oath Lock [S49] and the channel is characterised by relatively steep banks with silt deposits which acrete, slip and erode as a continuing process.

The **River Tone**, with a catchment area of 414 sq km joins the Parrett on its left bank just upstream of Burrowbridge. The tributaries of the River Tone rise in the Blackdown, Brendon and Quantock Hills which lie to the south, west and north of the valley. The River Tone then flows through Taunton before reaching the Levels and Moors, through which it is carried as an embanked channel. Outside the Levels and Moors area, the River Tone upstream and downstream of Taunton and also the Hillfarrance Brook which rises above Wiveliscombe, are vulnerable to flooding. There have been damaging flood events in the catchment in the past and these were the catalyst for a number of flood alleviation schemes involving both channel improvements and flood defences. The list of schemes carried out is included at the end of Chapter 3 of this Overview. The Tone becomes tidal below New Bridge Sluice [S89].

The **River Cary** rises south of Castle Cary in the clay capped oolitic limestone ridge and joins the Levels and Moors after passing through a narrow gap in higher ground at Somerton. The Cary runs into the man-made **King's Sedgemoor Drain** (KSD) at Henley Corner [S101].

The KSD drains the adjacent moors by gravity, without any assistance from pumping stations, and discharges through Dunball Sluice [S12] to the tidal Parrett Estuary. The KSD system includes a number of engineering channels described in the following sections.

The **Sowy River** is a flood channel which connects the Parrett and Cary valleys. It originates at Monks Leaze Clyse and skirts the higher ground or 'zoys' on which the villages of Othery, Middlezoy and Westonzoyland sit.

C.2 The Historical Context

The lower Parrett valley had seen much reclamation activity in the Middle Ages. The early works extended the fertile island of Othery, Middlezoy and Westonzoyland into the surrounding moors by the construction of banks and walls. At that time the Cary joined the Parrett at Burrowbridge and the surrounding moors had been reclaimed by an extensive embankment on the right bank of the Parrett from Burrowbridge to Langport, and the following cross banks between islands of higher ground.

- Burrow Wall between Burrowbridge and Othery
- Southlake Wall from Othery and Turn Hill, near Aller
- Beer Wall between Othery to the Parrett embankment
- Greylake Fosse between Middlezoy and Moorlinch

- Lake Wall between Westonzoyland and the Parrett banks at Andersey.

In the Middle Ages, the River Tone reached the Parrett by a series of meandering channels through Curry Moor, North Moor and Salt Moor. The channels were re-routed, with minor reclamations preceding more ambitious schemes. Throughout this process, land exchanges and deals between the church and other landowners overcame the problems created by improvements being made in one area at the expense of another. Major advances included:

- The enclosure of Curry Moor, Hay Moor and Stan Moor in 1311.
- The diversion of the lower Tone into a new embanked channel in 1374-5.
- The protection of Salt Moor from the Tone floodwaters by the construction of Balt Moor Wall in the 14th century.

For several hundred years, attempts were made to drain King's Sedgemoor. Piecemeal improvements had been made, but it was still under water for most of the year. In 1791 an Act was passed for the Draining and Dividing of King's Sedgemoor. Despite some 1800 allowed claims for commoners who used the moor, the Act was passed. The new King's Sedgemoor Drain was cut to smaller dimensions than today's channel. The new channel ran from Henley Corner, taking the flow of the River Cary through some 16 km of peat lands and 3 km of clay belt to a new outfall at Dunball.

Throughout the 19th century, King's Sedgemoor Drain had many major problems. These were caused by the cill of Dunball Clyse which had been set at too high a level, failure of the tidal doors, and instability of the banks of the new cut. It was not until the 1940's that the major problems were overcome in the MAFF grant-aided scheme.

The Parrett Relief channel, or Sowy River was completed in 1972, to provide an alternative outfall to the sea via the King's Sedgemoor Drain when levels were high in the lower reaches of the River Parrett. The KSD's capacity was increased to accommodate the additional flood flow.

The 1970's Penzoy River Scheme created a new channel, mainly by enlarging the existing rhyne system, from Southlake Moor south of Burrow Wall, through to the King's Sedgemoor Drain near Chedzoy. It allowed the abandonment of Southlake Pumping Station which had previously drained Southlake Moor into the ....

C.3 The River System

Map 1 shows the arterial channels of the Parrett/Tone/KSD/Cary system. These arterial channels include the important man-made channels described in the previous section.

The Parrett Relief Channel, or Sowy River receives water from the Parrett, through Monk's Leaze Clyse and also by overtopping of the Parrett Banks at Aller Moor Spillway and Beasley's Bank Spillway. Figure C1 shows the arrangements at the upstream end of the Relief Channel. The operation of this is described in more detail under 'Flood Procedures' below.

C.4 The Levels and Moors of the Lower Parrett and Tone

A number of Drainage Boards manage the drainage system in this area and their boundaries are shown on Key Map 1. Drainage of the moors adjacent to the River Tone and on the left bank of the Parrett is achieved through a number of pumping stations. Apart from the pumping station at Westonzoyland [SPS3], drainage of the Cary/KSD moors and those on the right bank of the Parrett is achieved by gravity.

The lowland areas are:

C.4.1 Parrett left bank and Tone

- **West Sedgemoor** and **Wick Moor** are mainly overlain with peat soils. They drain to West Sedgemoor Pumping Station [SPS6] on the left bank of the Parrett via the West Sedgemoor Main Drain.

- **Stan Moor** lies on the left bank of the Parrett and is isolated from the River Tone by the ancient Stanmoor Bank Wall, which carries a road and string of houses along its length. The historical development of this peat soil moor has left it with a relatively high standard of flood protection and it receives a low percentage of its water from outside its own lowland catchment. It drains to Stanmoor Pumping Station [SPS5] through the Stanmoor Main Drain.

- **Salt Moor** lies on the left banks of the Rivers Parrett and Tone at their confluence. The moors have alluvium soils overlaying the peat found on the adjacent North Moor and is drained through Salt Moor Main Drain to Salt Moor Pumping Station [SPS4]. The moor is unusual in that its catchment is entirely lowland within its own boundary.

- **North Moor** adjoins Salt Moor and is covered partly in peat soils. North Moor Main Drain is the main channel for the 20 sq km of the catchment of which some 12 km is lowland. Park Brook and Kingscliffe Streams, both flow into North Moor via syphons under the Bridgwater and Taunton Canal. These rise on the slopes of the Quantock Hills and have a total catchment of 22 sq km. The discharge of these streams is normally by gravity through Elson Clyse [S25].

- **Stock Moor**, upstream of the built up area of the left bank of the Parrett, drains through Stock Moor Rhyne to outfall by gravity to the Parrett. In flood conditions, Stock Moor Pumping Station [SPS1] is used to pump to the Parrett.

- **Curry Moor** lies on the north bank of the River Tone and drains to Curry Moor Pumping Station through the 6 km long Curry Moor Main Drain. From the 14th Century Balt Moor Wall has contained floodwaters in Curry Moor to the benefit of North Moor and Salt Moor. This remains so today, as floodwater overspills from the River Tone at Hook Bridge Spillway [S88] to relieve water levels and avoid flooding of properties alongside the Tone. **Hay Moor** and **West Moor** on the south of the River Tone, connect to Curry Moor via syphons under the main river, increasing the available flood storage volume. The peat soils on these moors are overlain by alluvium, deposited from its frequent flooding throughout history.

C.4.2 Parrett right bank

- **Aller Moor** lies on the right bank of the Parrett downstream of Langport. The Sowy River acts as the Parrett Relief Channel, allowing floodwater from the Langport area to be evacuated through Aller Moor to the KSD without increasing levels in the tidal rivers Parrett and Tone. The Langacre Rhyne acts as the main drain through Aller Moor and **North Moor**, south of Beer Wall.

- **Southlake Moor** was enclosed by embankments and walls from the Middle Ages. Southlake Pumping Station used to pump out this area into the Parrett, but flow is now taken under the A361 into the Penzoy River.

- **Earlake Moor** and **Weston Level** drain via the Penzoy River to the King's Sedgemoor Drain. In flood conditions, Westonzoyland Pumping Station [SPS3] lifts water into the Parrett.

C.4.3 King's Sedgemoor Drain/Cary

- **Somerton Moor** and **Red Lake** drain northwards into the Eighteen Feet Rhyne, which also drains **Burleigh Moor** to the north, before joining the KSD.

- **King's Sedgemoor** with peat soils, lies on both banks of the main KSD. Ground levels here are the lowest along KSD/Cary and the KSD is embanked where required to prevent flood flows spilling into the moors. The KSD Back Ditch, on the north bank of the main drain, acts as a collector ditch draining the moors to the north and to distribute summer water supply. It outfalls to the KSD at Parchey Outfall [S105]. **West Moor** and **Bawdrip Level** lie on the right bank of the KSD downstream of Parchey Outfall.

C.5 Pumping Stations

Table C.1 details the pumping stations in the Lower Parrett and Tone system. There are no floodwater pumping stations on the KSD/Cary, although there is a station at Henley Corner [SPS12] which pumps summer water from the KSD into the reach of the Cary upstream of the Henley Corner sluice and weir.

Table C.1 Pumping Station Details

Pumping Station	Catchment Sq km	Approx. Capacity M3/sec	Year installed	Draining	% of Catchment as Upland
West Sedgemoor (Parrett) [SPS6]	44.5	4.4 plus 1.2	1944 and 1988	West Sedgemoor Wick Moor	71
Stan Moor (Parrett) [SPS5]	4	0.9	1949 and 1994	Stan Moor	20
Salt Moor (Parrett) [SPS4]	2.47	0.9	1942 and 1990	Salt Moor	0
North Moor (Parrett) [SPS2]	20	2.2	1942 and 1996	North Moor	36 (excl.Quantock Streams)
Stock Moor (Parrett) [SPS1]	7	1.42	1977	Stock Moor	50
Westonzoyland (Parrett) [SPS3]	10.4	1	1947	Earlake Moor Weston Level South Moor	2
Curry Moor (Tone) [SPS10]	15.5	3.5	1955 and 1983	Curry Moor Hay Moor West Moor	63 (excl. Tone overspill)

C.6 Summer Water Supply

C.6.1 The Parrett and King's Sedgemoor Drain

Within the Lower Parrett system, there are complex arrangements for summer water supply, often involving options for the source of water, depending on relative flows in the channels.

- The Parrett is penned at Oath Lock [S49] in the summer months, and this allows water to flow through 3 inlets into **West Sedgemoor** and **Wick Moor**. There is also a feed into West Sedgemoor from spring sources on the Curry Rivel ridge and from its upland catchment of the southwest.

- The raised level in the Parrett also allows flow through inlets on the right bank into **Aller Moor** and beyond into the Sowy and Penzoy systems. The main flood control inlet to the Sowy River at Monk's Leaze [S55] has a smaller summer water sluice alongside it and at this point there is also an inlet to the Poolmead Rhyne/Middlemoor rhyne/Langacre Rhyne system, through the operation of tilting weirs and sluices. (See Figure C1). There is considerable flexibility to move water between the Sowy and the rhyne systems, through the operation of tilting weirs and sluices.

- Water is fed into **Southlake Moor** and, via the Penzoy river, into **Earlake Moor**, **Weston Level** and **South Moor**, through the operation of Aller Drove Tilting weir and Inlet Sluice [S38].

- At Beer Wall [S40] a tilting weir on the Sowy river penns water and allows water to be fed into Bimpits Rhyne on the left bank, which is itself controlled by a tilting weir. This water is used in **King's Sedgemoor** on the left bank of the Sowy River.

- The Langacre rhyne on the right bank of the Sowy River is used to supply water in summer months to **King's Sedge Moor**.

- Water is penned on the KSD at Dunball Sluice, [S12] to a level of 2.44m in summer and 2.13m in winter. The main penning structure on the KSD is Greylake Sluice [S100] which penns water upstream to a summer level of 3.50m. This allows flow into the KSD back ditch for distribution to **Moorlinch Moor** and **West Moor** on the right bank of the KSD.

- Upstream of Henley Corner [S101], the flow in the Cary is often insufficient to meet the upstream needs. The pumping station at this point was installed to allow water to be pumped upstream into the Cary, held at a higher level by Henley Sluice.

C.6.2 The Tone

The Tone is used to feed summer water to moors on the right and left bank of the river.

- The Tone is penned to a level of 6.12m at New Bridge Sluice [S89] in the summer. This allows water to be fed into **Curry Moor** Main Drain through Knap Inlet [S90] and New Bridge Inlet [S89].
- Summer water is fed into **Hay Moor** through the Haymoor Inlet [S119].

C.6.3 Curry Moor Connections

There are a number of connections between the moors on the right and left banks of the Tone and these are shown in Figure C2.

- There is a syphon at Hook Bridge [S88] connecting Curry Moor and Hay Moor. This has no controls and is a free connection between the moors.
- A 450mm diameter culvert connects **North Moor** and **Curry Moor** under Balt Moor Wall. This culvert also provides a connection between **Curry Moor** and Salt Moor.
- A 450mm diameter culvert connects **Hay Moor** and **Stan Moor**.

These connections allow water from the non-tidal Tone above New Bridge to be used for summer water supply in a wide area. The possible use of these connections in flood events is discussed in following sections.

C.6.4 Park Brook and King's Cliffe Streams

The Park Brook and King's Cliffe Streams run into **North Moor** and **Hay Moor** to the north and some use is made of the water as a summer water supply and for raised water level areas in North Moor.

C.7 Flood Procedures

The historical development of this area previously described and the structures, pumping stations, channels, walls and embankments which have been constructed have fixed many of the flood procedures that are now in place. The installations and practices in the past have also been major influences on the way that housing development and infrastructure has been located. The whole system is used in flood events and the way that floodwater is moved, stored and discharged is dependent on tidal conditions in the Parrett and relative flows in the Parrett, Tone and Cary/KSD.

The main flood procedures involve the following:

- Oath Sluice [S49] on the Parrett is opened.
- Newbridge Sluices [S89] on the Tone are opened.
- Dunball [S12] and Greylake [S100] Sluices are opened on the KSD.
- All inlets for summer water feed are closed.
- Monk's Leaze Clyse [S55] is operated to take the maximum flow it is able to whilst remaining in bank. This is some 17m3/sec. If the River Parrett continues to rise, water will flow firstly over Beasley's Bank and, on rising further, over Aller Moor Spillway into the Sowy River. Monk's Leaze Clyse is progressively closed to try to keep the flow in the Relief Channel within its maximum capacity.
- No flood flow is allowed through the Penzoy River from the Sowy River.
- For river levels above 7.42m at Curry Moor Pumping Station, the Tone will overtop Hook Bridge Spillway into Curry Moor and into Hay Moor via the syphon.
- To avoid flood conditions being worsened by pumping additional water into the main rivers,
  - Curry Moor Pumping Station does not pump if levels in the River Tone exceed 7.4m.
  - West Sedgemoor Pumping Station stops pumping into the Parrett when Parrett levels exceed 7.45m.
  - Pumping at Northmoor and Westonzoyland Pumping Stations can be restricted by tidal levels exceeding 7.5m.

If in an extreme event Curry Moor continues to fill to its capacity, water will eventually begin to overflow the spillway at Athelney over the A361 into Salt Moor. (See figure C2). Although properties will be at flood risk when this occurs, it is preferable to any overtopping of the ancient Baltmoor Wall. Failure of the wall would have serious consequences, with a flood wave affecting a wide area in North Moor and Salt Moor, including important road and rail routes. Procedures are in place to monitor the condition of the wall and take precautionary action. A major capital scheme is being considered to ensure the wall would be stable if overtopped.

The connections between Curry Moor/Hay Moor, Stan Moor, North Moor and Salt Moor were described under "Summer Water Supply" above. The presence of the connections has led to pressure to utilise the connections during flood events, mainly with the objective of evacuating Curry Moor earlier. This proposal was investigated following particularly damaging flood events in the 1989/90 winter. These caused an extensive grass kill in Curry Moor, which was under water for some 45 days. The investigation showed in that event and other serious floods in 1968 and 1985/86, the opportunity to divert water to other pumping stations to assist in evacuating flood water would not have had a significant effect. Other pumping stations were evacuating their own catchments for some days and their limited capacity, particularly of the nearby Stan Moor and Salt Moor pumps, compared with the large installed capacity at Curry Moor, would only have evacuated Curry Moor and Hay Moor a few days earlier. Nevertheless, flood procedures now allow some movement of water through these connections in major events, providing this does not worsen flooding in other areas.

APPENDIX D

The River Brue and Huntspill System

APPENDIX D THE RIVER BRUE AND HUNTSPILL SYSTEM

D.1 General Catchment Description

The **River Brue** rises 9 km to the east of Bruton and flows west over impermeable clays. The river then crosses the limestone ridge through Bruton. The river reaches the Levels and Moors south of Glastonbury Tor in Kennard and South Moors. Tributaries to the north, the **Sheppey and Whitelake** also follow a east to west route from the clyse and Mercia Mudstones into the alluvium and peat of the moors.

The Brue valley has the lowest land levels in Somerset, in places at less than 2m AOD, or some 6m below highest tidal levels in the Bristol Channel. The valley also has the most extensive areas of peat in Somerset, to depths of some 7m on some moors.

The drainage system within the Levels and Moors relies on long lengths of embanked channels and man-made channels including the **South and North Drains** and **Huntspill River.** The system is shown on Map 2.

D.2 The Historical Context

The early history of the drainage of the Brue Valley is complicated by uncertainties in the original routes of some of the watercourses. The valley floor is very flat and undoubtably the courses have changed over the centuries. The Brue itself may have flowed through the gap at Panborough to join the Axe valley to the north.

Significant new channels and embankments were constructed in the Brue valley as early as the 13^{th} century. By 1485, the bridge over the Brue at Highbridge had been converted into a Clyse, by the addition of tidal doors. The Clyse on its present site dates from 1802, built to replace the original structure, which was inefficient, particularly because of the siltation problem.

The reclamation of the Brue Valley preceded other areas of the Levels and Moors. This may seem surprising, as the land levels are so low, but probably arose because Highbridge Clyse excluded tidal incursion from the moors earlier than in other valleys. Embanked channels and new cuts proceeded on a piecemeal basis and by 1650 long lengths of the Brue, Sheppey and Hartlake were embanked and new cuts in use in the Meare Poole area. The embankments, particularly upstream of Glastonbury, were associated with milling operations as well as the exclusion of floodwater.

Other important developments in the valley were:

- 1775. A new drain was dug through Tadham Moor, on the line of the present day North Drain.
- 1780-1800. The reclamation of most of the remaining moors in the Brue Valley. Although reclamation referred to the exclusion of frequent floods, severe events still resulted in the moors often remaining under water for many months.
- 1802. New Highbridge Clyse.

- 1804. Start of construction of the South Drain.
- 1829. Construction of the Glastonbury Canal for navigation.
- 1940. Construction of the Huntspill River, based on plans suggested initially in 1853.
- 1942. Construction of Gold Corner Pumping Station and connecting channels.
- 1959. Construction of North Drain Pumping Station.
- 1973 Construction of Backford Moor Pumping Station.

Prior to 1940, the Brue Valley had remained waterlogged or under water for many months of most years. The cutting of the Huntspill River and the major pumping installations, has resulted in the Brue Valley flooding less frequently, but also being cleared of flood water in a few days rather than in the few weeks taken in some of the moors in the Parrett catchment.

D.3 The River System and Moors

Map 2 shows the layout of the river system. Points to note are:

- The long lengths of embanked channels on both the natural rivers and man-made drains.

- Under normal conditions, the **South Drain** discharges to the **River Brue** through the **Cripps River**. In flood conditions, Gold Corner Pumping Station [NPS6] lifts excess water from the **South Drain** into the **Huntspill River**. The arrangements are shown in more detail in Figure D1.

- The **Huntspill River** has an average width of 61m, an average depth of 4m and a total retained capacity of 1 million cubic metres. The main purpose of the river was to provide a water supply for the nearby Royal Ordnance Factory during the Second World War. Its main purpose now is to act as a flood relief channel to store water against the tide in winter and as a reservoir for summer water supply.

- The tributaries of the **Brue** (**Sheppey, Whitelake and Hartlake**) gravitate to it through embanked channels. The **North Drain** conveys water from the moors north of the Brue (**Tealham, Tadham, Westhay and Godney**) to the gravity outfall and North Drain Pumping Station [NPS7] (See Figure D1). The pumping station is used to evacuate water into the Brue, for gravity discharge if possible through Highbridge Clyse [N60]. In flood conditions, the Cripps River will convey water to Gold Corner Pumping Station [NPS6] where it is lifted into the Huntspill River.

- The **Panborough Drain**, which joins the North Drain, receives flow from the rhyne network in **Wedmore Moor** on the left bank of the River Axe. This is known as the "Axe Connection" as it drains approximately 15% of the Upper Axe Drainage Board area.

- The **Mark Yeo** also connects the Brue and Axe catchments. In summer, water from the Axe is fed south to the Brue catchment via the Mark Yeo. In high flows, the sluice at Rook's Bridge [N35] acts as the watershed, with flow north to the Axe and south to the Brue. The **Blind Pill Rhyne** and **Brent River** drain south to the Brue through the tilting weir at Walrow [N46].

The majority of the moors in the Brue Valley east of the Cripps River have peat soils with up to 7m of underlying peat. The peat extraction industry influences the landscape in large tracts of the area of **Shapwick, Meare** and **Westhay Heath** and in the northern production zone on **Westhay Moor**.

D.4 Pumping Stations

The pumping stations in the Brue Valley are shown in Table D1.

Table D.1 Pumping Station Details

Pumping Station	Catchment km2	Approx. Capacity m3/sec	Year Installed	% of Catchment As Upland
Gold Corner [NPS6]	104	17.5	1942	84
North Drain [NPS7]	35.1	5.5	1959	65
Blackford Moor [NPS5]	1.9	0.26	1973	0
Withy Drove [NPS8]	Summer Water	0.13	Refurb. 1991	-
Sloway Lane [NPS9]	Summer Water	0.13	Refurb. 1991	-

The pumping stations at Withy Drove and Sloway Lane are for irrigation, in summer, of the coastal clay belt, but are included in the table for completeness.

D.5 Summer Water Supply

The main penning structure on the Brue is at Hackness Sluice [N45]. Because of the flatness of the gradient on the Brue, the effect of the summer penn level of 1.68m is felt over large areas of the moors. The penned water in the Brue can also be used to feed the South Drain through the Cripps River. The Brue flow can also be used to feed the Huntspill River, and its summer water pumping stations, by using Gold Corner Pumping Station when levels allow.

The North Drain is penned at the Pumping Station [NP57] to a level of 1.85m. At its upstream end, the North Drain can receive flow from the River Sheppey through Hurn Weir [N51].

The role of the Blind Pill Rhyne/Brent River and the Mark Yeo has been discussed above. The pumping station and sluice at White House [NPS4] lifts summer works from the penned River Axe into the Mark Yeo system, for use in Brue Valley moors.

D.6 Flood Procedures

The main flood procedures involve the following:

- Checks to ensure that Bruton flood detention reservoir is operating correctly.
  Summer water inlets are closed.

- Gold Corner Sluice [N61] is opened to allow flow from the Cripps River (from the Brue) into the Huntspill River if Huntspill Sluice is open. (See Figure D1).

- Hackness Sluice [N45], Highbridge Clyse [N48] and all sluices on Huntspill and South Drain Back Ditches are open.

- Blackford Pumping Station is used to evacuate Blackford Moor and Shipham Rhyne. Pumping may need to be suspended if high levels in the rhyne threaten to flood the Mark to Wedmore road.

- Gold Corner Pumping Station is used to lift flow from the South Drain into the Huntspill River when flows are too high to permit gravity drainage through Cripps River and the Brue. Target water levels in the Huntspill River are 3.56m AOD in the summer and 2.74m AOD in the winter, compared with South Drain and Back Ditches' target water levels of 1.68m AOD in the summer and 1.52m AOD in the winter.

- North Drain Pumping Station evacuates North Drain flows into the Brue. There is a limited capacity for gravity flow in flood conditions if the Brue is sufficiently low.

APPENDIX E

The Upper and Lower Axe System

APPENDIX E THE UPPER AND LOWER AXE AND MARK YEO SYSTEM

E.1 General Catchment Descriptions

The **River Axe** rises from the Carboniferous Limestone districts of the Mendips. The soluble nature of the limestone has led to the creation of cavities within the rock into which surface streams plunge. After running through subterranean passages, the waters finally emerge in great springs such as those at Cheddar and Wookey Hole which are the source of the Axe. The Axe reaches the Levels and Moors only some 5km from its source at Wookey Hole.

The Axe valley runs between the Mendip Hills to the north east and the Wedmore ridge to the south west, before the valley opens up to the south in moors drained by the Mark Yeo and Shipham Rhyne. The **Cheddar Yeo** rises from the Mendips at Cheddar and joins the Axe south of Compton Bishop before the river is also joined by the **Lox Yeo River**, which rises at Winscombe. The Axe meanders, with some straightened reaches, across the coastal clay belt before outfalling to the Bristol Channel between Brean Down and Uphill.

The floor of the Axe Valley influenced the progress of draining and reclamation. Much of this area is covered by grey silty estuarine clay, a result of the tidal incursions. Much of this lies below the level of the natural levees of the rivers and was therefore often flooded and waterlogged. In places the surface is covered with some ½ metre of peaty clay, which gives way to true peat in some of the moors furthest from the coast.

E.2 The Historical Context

Appendix D described how the Brue and Axe valleys were historically connected and indeed Axe Valley moors still drain to the Brue System. In the 13th century, the Abbot of Glastonbury was able to use waterways to transport stone, lime and corn from the Axe Valley to Glastonbury. This would not be possible today.

One of the earliest references to reclamation in the Levels is to Lympsham in the Lower Axe Valley. The old subdivisions of the lowland and the original network of drainage ditches have been lost in the subsequent developments in the valley.

From the 14 th century, there is mention of channel diversions and sluices, many associated with mills in the upper and middle Axe. The straightened courses of the Axe, which cuts across many meanders, and of the Cheddar Yeo, probably date from that time.

Reclamation of Bleadon Level on the Axe Estuary in the 17th century, made use of wind pumps for drainage purposes, which is one of only two such pumps known to have been used in the Levels. Generally in the Axe Valley, the drainage improvements followed those in other areas. The relatively narrow valley, the diversion of the Brue flows away from the lower Axe and the permeable nature of the Mendip limestone meant that there was less pressure for change.

The major influence on the Axe Valley was the construction in 1810 of a clyse at Hobb's Boat, south of Bleadon. This tidal exclusion allowed the agricultural improvement of the upstream moors.

The major penning structure on the Axe, Bleadon Sluice [N2], was constructed in 1924 and electrified in in the 1950's.

Clewer Pumping Station [NPS2] was constructed in 1972 to provide flood relief and drainage to upstream moors on the right bank of the River Axe.

Brean Cross Sluice [N1] was constructed in 1973 as the main tidal exclusion structure for the Axe.

Cross Moor Pumping Station was built in 1980 to lift water from Middle Rhyne on Cross Moor into the embanked Cheddar Yeo.

E.3 The River System and Moors

There are a number of weirs and sluices in Wookey which split the flow of **the River Axe** into two branches, the northern **Knowle Branch** and the southern **Bleadney Branch**. The flow split is at Highover Weir/Cluice [N80] and the normal operation of this structure by the Environment Agency aims to achieve an equal split in the flow. Mills on the Bleadney Branch at Burcott Mill [N29] and Bleadney Mill [N23] require the operation of local sluices to divert water to drive the mill wheel at Burcott and the turbine at Bleadney.

The **Hixham Rhyne** is a 7 km watercourse draining the moors on the right bank of the Axe which is embanked over this length. The rhyne drains to **Clewer Pumping Station** [NPS2]. Here it is discharged to the Axe under gravity or, when flows are high, the pumps lift into the Axe. The pumping station is also used in the summer to lift flows in the Hixham Rhyne into the penned River Axe.

The **Wedmore and Panborough Moors** on the left bank of the Axe between Panborough and Clewer drain south to the Brue catchment as discussed in Appendix D.

Downstream of Clewer, the **Cheddar Yeo** runs through the valley to join the Axe near Compton Bishop, upstream of the confluence with the **Lox Yeo River**, which also runs off the Mendips. Bristol Waterworks have The has a major water abstraction from the Cheddar Yeo near its source, and this has an effect on downstream flows. **Cross Moor** is pumped into the Cheddar Yeo on its right bank by Crossmoor Pumping Station [NPS1].

The Mark Yeo has been described in Appendix D, as it links the Brue and Axe valleys. Rook's Bridge, on the A38, is the natural watershed for the river.

The Axe between the confluence of the Lox Yeo and the Mark Yeo, has been cut across an old loop which used to run south towards Biddisham. The Axe has been further straightened downstream at Bleadon.

E.4 Pumping Stations

The main pumping stations in the catchment have been discussed in previous sections. The table below summarises the installations.

Table E.1 Pumping Station Details

Pumping Station	Catchment Sq km	Approx. Capacity M3/sec	Year installed	Draining	% of Catchment as Upland
Clewer [NPS2]	34.5	6	1972	Cheddar Moor Stoke Moor Westbury Moor Knowle Moor Draycott Moor	74
Cross Moor [NPS1]	3.7	0.72	1980	Cross Moor	60
South Hill [NPS3]	Summer water to Bleadon Level	0.74	1963	-	-
White House [NPS4]	Summer water level to Mark Yeo	0.74	1963	-	-

E.5 Summer Water Supply

The Summer water supply is achieved through the following arrangements:

- **Brean Cross Sluice** [N1] is used both as a tidal exclusion structre and a penning structure. In summer the pen from this structure, to a level of 2.2m AOD, is effective to Bleadon Slice [N2], which penns water to 4.7m AOD. In winter, **Bleadon Sluice** is open and the penn level of 2.2m AOD is effective upstream of Bleadon.

- In summer the sluice at **White House** [NPS4] on the Mark Yeo is closed and water is penning to a maximum of 5.10m AOD. When required, and providing Axe levels exceed 4.0m AOD, **White House Pumping Station** lifts water into the Mark Yeo for use in the lowlands between the Axe and the Brue.

- The pumping station at **South Hill** [NPS3] is used to transfer water from the Axe to the rhynes in the Bleadon Levels.

- There are a number of fixed weirs on the Upper Axe, which hold water levels up over the upstream reaches, but which are drowned out at high flows and therefore do not affect flood levels. These have mainly been installed for fisheries purposes.

- Inlets are used to divert water from the penned rivers into moors on both banks of the Axe. There are many small sluices and penning arrangements operated by the Upper and Lower Axe Drainage Boards and by private landowners, which are used for the supper water supply.

E.6 Flood Procedures

The flood procedures are relatively straightforward in the Axe catchment. The main sluices at **Brean Cross** [N1] and, in the summer, **Bleadon Sluice** [N2] are opened along with penning structures and tilting weirs on the main drains. Brean Cross is the main tidal exclusion structure and discharge may be restricted (tide locked) when tide levels in the estuary are high. The sluice on the Mark Yeo at **White House** [NPS4] is opened if required. Summer water inlets are closed.

The pumping stations at Cross Moor [NPS1] and Clewer [NPS2] are automatically controlled. At Clewer, the three pumps have different start and stop settings and changes in the order of cut-in of the pumps can be used totarget upstream water level requirements of the Drainage Board at particular times.

APPENDIX F

Routine Maintenance

APPENDIX F ROUTINE MAINTENANCE

F.1 Introduction

The rivers and channels on the Somerset Levels and Moors have been highly managed for many years.

The following spreadsheet gives a generalised indication of the routine work carried out on the Somerset Levels and Moors now and in the 1980's. It is based on Environment Agency employee knowledge and old data related to current practices detailed in the weedcutting/flail service level agreement in Appendix G.

Reasons for carrying out the work, and benefits which result are included. Work on the ground can vary dependent on weather, ground conditions and work programming, but what is shown is the target for the year.

F.2 Grass Cutting and Aquatic Weedcutting Service Level Agreement January 1998

F.2.1 Introduction

The object of the specification is to provide guidance on the appropriate level of annual routine maintenance to be adopted taking into consideration the operational need, its impact on conservation and the level of service required.

F.2.2 The Specification

The following clauses and drawings are the specification to be adopted when carrying out routine weedcutting and tractor flailing. It is in generalised pictorial form to be used as guide and every effort should be made to comply with the overall principles.

Obviously each site is individual and different and it is inevitable that some interpretation will be required on the ground.

Copies of the specification will be issued to all supervisors and drivers as appropriate.

F.2.3 Clauses

1) Grass cutting and aquatic weedcutting should be carried out generally in accordance with the following clauses and detailed drawings.

2) Where sections of the river and bank are inaccessible for mechanical plant, or obstructions exist, then these sections will be expected to be maintained to the same standard as those cut by mechanical means unless specified otherwise.

3) Where work under overhead cables is required and a safe system of work for working within the "restricted zone" with land based machines cannot be agreed with the Power Authority, then a single cut by hand, weedboat or other agreed method should be carried out.

4) Any cut weed and vegetation which collects around the screens, weirs, sluices, intakes, bridges, culverts or other structures must be removed so that blockages are not allowed to accumulate and/or interfere with the operation of such devices.

5) Cut weed and vegetation should be deposited linearly as work proceeds. It should be placed on the non-working bank where the machine reach permits, otherwise on the working bank such that it does not form a hazard during times of high water and flooding.

6) If cut weed and vegetation falls into the watercourse then it must be removed.

7) Weed and vegetation is to be cut to a maximum length of 100mm, leaving fringes and patches where specified.

8) Grass cutting and aquatic weedcutting must be completed between May and October inclusive. Normal timings are indicated on the detailed schedule with variations up to 2 weeks either side being acceptable. Exact timings will depend on weed growth and may be varied with the agreement of the Engineer.

9) Grass cutting will normally precede aquatic weedcutting by up to 2 weeks.

10) On lengths of river where only grass cutting is carried out (eg upper reaches, estuary banks) then these would normally be cut in September/October.

11) Where grass cutting is carried out adjacent to public highways then this should be done monthly.

F.2.4 Special Instructions

In order to minimise the environmental risks the following procedures MUST be followed.

(1) Lists of the following weeks weedcutting must be faxed to the North Wessex Flood Defence Client (01278 444326) on the preceding Thursday morning. The information should include Supervisors Name, River, Approximate Location (bridge name, grid ref, if possible), Drivers Name and PMR number or mobile telephone number.

(2) Each morning before starting work the machine driver must inspect the previous days work to check for environmental problems (eg, fish in distress).

(3) If "fish in distress" or other problems are evident either from the previous days work or as work proceeds then the driver must stop work immediately and report it to his line manager.

(4) The Contractor must report any environmental problems immediately to the North Wessex Flood Defence Client who will co-ordinate appropriate action from Fisheries and Water Quality.

F.3 Explanation of Headings Used

Fluvial River: Natural river.

Embanked Channel: A river or channel bounded by raised banks designed to contain normal or flood flows.

Flood Defence: Those rivers or channels which are deemed to benefit from the work by reducing the risk of the banks overtopping or the spillways running resulting in flooding to properties, roads and land.

Drainage: Channels which convey normal or flood water from local or area ditch systems either to a pumping station or by gravity to the natural river.

Summer Feed Main: Main summer feed channels convey irrigation water from one district/river/rhyne to another in order to supply other Local ditch networks.

Summer Feed Local: Channels which feed the local ditch network.

Access: Channels/embankments where vehicular access is important.

Managed Water Levels: Channels where structures/weirs/pumping stations maintain water levels within prescribed limits.

Fishery: Channels where the fishery is generally deemed to benefit from the work.

Amenity: Channels where public relations and aesthetics are important.

Spec: Letters refer to the relevant Drawing from the Routine Maintenance Service Level Agreement, showing the various specifications used in the work.

Weedcut: Weedgrowth increases the hydraulic resistance of the channel. This can have significant implications when managing water levels. Water levels at most penning structures have, over many years been agreed between the Environment Agency and the Internal Drainage Boards. In recent times these arrangements have been documented as part of Water Level Management Plans. Tolerances in many circumstances are small, a few centimetres and deviations are not considered acceptable.

Normally two cuts are undertaken although some channels only require one and others three. This depends on the speed of growth and the importance of maintaining flow and level.

Summer feed flows can be significantly reduced by weed growth, starving areas of water and causing high and low levels outside the agreed tolerances.

Drainage is reduced by weed growth preventing flows reaching the pumping stations. It is particularly serious during summer floods. Pumping Station efficiency is reduced because excess weed blocks the weedscreen, and weed disposal can be a problem.

Significant weedgrowth will increase the hydraulic resistance leading to an increased risk of flood flows overtopping the banks.

Flail Cut: Routine grass cutting of banks and embankments where they are not grazed helps keep the sward in reasonable condition. It reduces susceptibility to erosion, ensures that the banks can be inspected for damage by animals or high flows, bank stability/slips can be identified and vehicular access is possible to carry out repairs. Cutting within the channel controls scrub growth, improves visibility when weedcutting and improves the hydraulic resistance thus lowering flood water levels.

Herb: Aquatic herbicides are a useful tool in managing weedgrowth where mechanical methods are not practical. However, resistance to them is increasing and therefore usage has been significantly reduced. This has, however, led to an increased use of mechanical methods.

REVIEW OF ROUTINE FLOOD DEFENCE PRACTICES

Specification X = Special

RIVER	REACH	Fluvial River	Embanked Channel	Flood Defence	Drainage	Summer Main	Feed Local	Access	Managed Water Levels	Fishery	Amenity	circa 1980 Work: Spec. Type	circa 1980 Work: Weed Cuts	circa 1980 Work: Flail Cuts	circa 1980 Work: Herbicide	1997 Work: Spec. Type	1997 Work: Weed Cuts	1997 Work: Flail Cuts	1997 Work: Herbicide
AXE	U/S Weare Bridge	yes		yes			yes			yes		E	1	2		B	2	1	
AXE	D/S Weare Br to Whitehouse PS [NPS4]	yes	yes	yes			yes	yes	yes	yes		E	1	2		L	2	1	
AXE	Knowle Branch to Hanger Foot Br	yes	yes	yes			yes	yes	yes	yes		L	1	2		L	2	1	
AXE	Bleadney Branch to Bleadney Br [N21]	yes	yes	yes			yes	yes	yes	yes		L	1	2		L	2	1	
BALTONSBOROUGH M.S.		yes	yes	yes	yes		yes	yes	yes			L	2	2		K	2/3	1	
BARTON & LYDFORD M.S.		yes	yes	yes	yes		yes	yes	yes	yes		L	2	2		K	2/3	1	
BIMPITS RHYNE					yes	yes			yes			E	1	1		E	2	1	
BLIND PILL RHYNE					yes	yes			yes			E	2	2		A	2	1	
BRENT RIVER					yes	yes			yes	yes		E	2	2		B	2	1	
BRUE	Lovington to Tootle Bridge [N82]	yes		yes								E	1	1		K	1	0	
BRUE	Tootle Bridge [N82] to Westhay Bridge	yes	yes	yes			yes	yes		yes		L	2	1		K	2	1	
BRUE	Westhay Bridge to Cripps River	yes	yes	yes			yes	yes	yes	yes		L	1	1		K	1	1	
BURROW WALL RHYNE					yes				yes			E	1	1	yes	F	1	0	
CARY	Downstream of Somerton	yes	yes	yes			yes	yes	yes	yes		E	1	1	yes	B	1	1	
CARY	Upstream of Somerton	yes		yes								E	1	1		B	1	1	
CHALLIS WALL RHYNE	North East of [S37]				yes	yes			yes			E	2	1		F	2	0	
CHEDDAR YEO	Upstream of Crossmoor P.S. [NPS1]	yes	yes	yes			yes	yes		yes		L	2	2	yes	L	2	1	yes
CHEDDAR YEO	D/stream of Crossmoor P.S. [NPS1]	yes		yes			yes			yes		E	2	2		B	2	1	
CHEDZOY NEW CUT	Parkwall to Penzoy				yes		yes		yes	yes		E	1	1	yes	B	1	1	
CHEDZOY NEW CUT	Penzoy to K.S.D [S42]				yes		yes		yes	yes		E	1	1	yes	F	1	0	
COXBRIDGE BROOK		yes	yes	yes			yes	yes				L	2	1		K	2/3	1	
CRIPPS RIVER			yes	yes	yes	yes		yes	yes	yes		L	1	1		K	1	1	
CURRYMOOR ENGINE RHYNE	Railway to Curry Moor P.S [SPS10]				yes	yes			yes	yes		E	2	2	yes	F	2	0	
CURRYMOOR MAIN DRAIN					yes	yes			yes	yes		E	2	2	yes	F	2	0	
DECOY RHYNE	Allermoor [S54] to Middlemoor Rhyne				yes				yes			E	1	1	yes	F	2	0	
DECOY RHYNE	Sheppey - Downstream of [N58]	yes	yes	yes			yes	yes	yes	yes		L	2	1		K	2	1	
DIVISION RHYNE	Downstream of Hartlake		yes	yes			yes	yes	yes	yes		L	2	1		K	2	1	
DUNBALL RHYNE					yes		yes		yes			E	2	2	yes	F	2	0	
EIGHTEEN FOOT RHYNE					yes		yes		yes	yes		E	1	1	yes	B	1	1	
GLASTONBURY CANAL			yes		yes		yes	yes	yes	yes		L	1	1		K	2	1	
GLASTONBURY MILL STREAM		yes	yes	yes	yes	yes		yes	yes	yes		L	2	2		L	2/3	1	
HAMBRIDGE MILL STREAM		yes	yes	yes				yes		yes		L	1	1		K	2	1	
HARTLAKE		yes	yes	yes			yes	yes		yes		L	2	1		K	2	1	
HAYMOOR MAIN DRAIN					yes	yes			yes			E	2	2	yes	F	2	1	
HIXHAM RHYNE	Upstream of Nyeland Bridge				yes		yes		yes	yes		E	2	2		A	2	1	
HIXHAM RHYNE	Downstream of Nyeland Bridge				yes		yes		yes	yes		E	2	2		B	2	1	
HUISH LEVEL RHYNE					yes		yes		yes	yes		E	1	1	yes	F	2	0	
HUNTSPILL BACK DITCHES					yes	yes			yes			E	2	2		A	2/3	1	
HUNTSPILL ACID DITCH					yes							E	2	2		A	1	1	
RIVER ISLE	Upstream of Westport Canal	yes		yes			yes			yes		E	0	1	yes	F	1	0	
RIVER ISLE	Downstream of Westport Canal	yes	yes	yes			yes	yes	yes	yes		L	1	1	yes	K	1	1	
ISLE BREWERS MILL STREAM	[S93]	yes	yes	yes				yes	yes			L	1	0		K	2	1	
JAMES WEAR RIVER		yes	yes	yes			yes	yes	yes	yes		L	2	1		K	2	1	
KEWARD BROOK		yes		yes								E	hand	hand			0	0	
KING'S SEDGEMOOR DRAIN	Upstream of Eighteen Foot Rhyne		yes		yes	yes			yes	yes		E	1	1		C	0/1	0	
K.S.D. BACK DITCH					yes	yes			yes			E	2	1		A	2	1	
KING'S MOOR MAIN DRAIN	Upstream of Driveway Drove				yes		yes		yes	yes		E	1	1	yes	B	1	1	
KING'S MOOR MAIN DRAIN	Pumping Stn [SPS11] to Driveway Drove				yes		yes		yes	yes		E	1	1	yes	F	1	0	
LANGACRE RHYNE	Upstream of Aller Drove [S38]				yes	yes			yes	yes		E	2	1	yes	B	2	1	
LANGACRE RHYNE	Downstream of Aller Drove [S38]				yes	yes			yes	yes		E	2	1	yes	F	2	0	
LONG LOAD MAIN DRAIN					yes		yes		yes	yes		E	2	1	yes	F	2	0	
LONG SUTTON CATCHWATER			yes		yes		yes	yes	yes			L	1	1		L	2	1	
LONG SUTTON MAIN DRAIN					yes		yes		yes	yes		E	2	1	yes	F	2	0	yes
LOX YEO		yes		yes					yes	yes		E	2	2		B	2	1	
MARK YEO					yes	yes			yes	yes		E	2	2		A	2/1	1	
MIDDLEMOOR RHYNE	West of [S56]				yes				yes			E	1	1	yes	F	2	0	
MISBROOK RHYNE					yes	yes			yes			E	1	1	yes	B	2	1	

ENVIRONMENT AGENCY - SOUTH WEST REGION
NORTH WESSEX - SOMERSET AREA
REVIEW OF ROUTINE FLOOD DEFENCE PRACTICES

Specification X = Special

RIVER	REACH	Fluvial River	Embanked Channel	Flood Defence	Drainage	Summer Main	Feed Local	Access	Managed Water Levels	Fishery	Amenity	circa 1980 Work				1997 Work			
												Spec. Type	Weed Cuts	Flail Cuts	Herbicide	Spec. Type	Weed Cuts	Flail Cuts	Herbicide
NORTH DRAIN					yes		yes		yes	yes		E	2	1		F	2	0	
NORTH STREET RHYNE					yes		yes		yes			E	1	1		F	2	0	
NORTHMOOR INLET	North of [S44]				yes	yes			yes			E	2	1		E	2	1	
NORTHMOOR MAIN DRAIN					yes		yes		yes	yes		E	2	1		F	1	0	
OTHERY RHYNE					yes	yes			yes	yes		E	2	1		F	2	0	
PANBOROUGH DRAIN					yes	yes			yes	yes		E	1	1		F	2	0	
PANBOROUGH RELIEF CHANL.					yes	yes			yes	yes		E	1	1		F	2	0	
PARRETT-floodbanks not berms	Langport to Thorney Mill [S83]	yes	yes	yes			yes	yes	yes	yes		L	1	1		L	1	1	
PARRETT-floodbanks not berms	Tone confluence to Langport	yes	yes	yes			yes	yes	yes			S	0	1		S	0	1	
PARRETT TIDAL	Blake Br [S16] to Tone confluence		yes	yes				yes				S	0	2	yes	R	0	1	
PARRETT TIDAL	Huntspill to Blake Br.[S16] (Right Bk)		yes					yes				S	0	2	yes	R	0	1	
PARRETT TIDAL	Steart to Blake Br. [S16] (Left Bk)		yes					yes				S	0	2	yes	R	0	1	
PENZOY	A361 to W'zoyland Engine Rhyne				yes	yes			yes	yes		E	1	1	yes	B	2	1	
PENZOY	W'zoyland Engine Rhyne to Lakewall				yes	yes			yes	yes		E	1	1	yes	F	2	0	
PENZOY	Lakewall to Chedzoy New Cut				yes	yes			yes	yes		E	1	1	yes	F	1	0	
PENZOY	Southlake				yes	yes			yes	yes		E	2	1	yes	B	2	1	
POOLMEAD RHYNE					yes		yes		yes	yes		E	1	1		F	2	0	
REDLAKE		yes	yes	yes			yes	yes	yes	yes		L	2	1		K	2	1	
REEDMOOR RHYNE					yes						yes	E	1	1	yes	B	2	1	
SALTMOOR MAIN DRAIN	Baltmoor Wall to Basket Works				yes	yes			yes			E	1	1	yes	E	2	1	
SALTMOOR MAIN DRAIN	Basket Works to Saltmoor P.S.[SPS4]				yes		yes		yes			E	1	1		B	2	1	
RIVER SHEPPEY		yes	yes	yes		yes		yes	yes	yes		L	2	1		K	2	1	
SHIPHAM RHYNE					yes		yes		yes	yes		E	2	2		F	2	0	
SHORTWALL RHYNE					yes		yes		yes	yes		E	1	0		B	2	1	
SOUTH DRAIN	Ashcott Corner to Clyce Hole [N79]				yes		yes		yes	yes		E	1	1		B	2	1	
SOUTH DRAIN	Gold Corner NPS6] to Ashcott Corner				yes		yes					E	1	1		X	1	0	
SOUTH DRAIN BACK DITCH					yes	yes			yes			E	1	1		F	2/1	0	
SOUTHMOOR MAIN DRAIN					yes		yes		yes	yes		E	1	1		F	1	0	
SOWY			yes	yes	yes	yes		yes	yes	yes		E	1	1		F	1	0	
STANMOOR MAIN DRAIN					yes		yes		yes			E	1	1	yes	B	2	1	
TANK RHYNE			yes	yes	yes	yes		yes	yes			E	2	2		B	2	1	
THORNEYMOOR MAIN DRAIN					yes		yes		yes	yes		E	2	1	yes	B	2	1	
RIVER TONE	M5 to Ham [S91]	yes		yes			yes	yes		yes	yes	E	1	2		F	2	0	yes
RIVER TONE	Ham to New Bridge [S89]	yes	yes	yes			yes	yes	yes	yes	yes	L	1	2		L	2	1	
RIVER TONE TIDAL	New Bridge [S89] to River Parrett		yes	yes				yes				L	1	1	yes	L	2	1	
WEST SEDGEMOOR M.D					yes		yes		yes	yes		E	1	1	yes	F	2	0	
WEST SEDGEMOOR BACK DCH					yes		yes		yes			E	1	1		A	2	1	
WESTMOOR MAIN DRAIN					yes		yes		yes	yes		E	1	1		F	1	0	
W'ZOYLAND ENGINE RHYNE					yes				yes	yes		E	1	1	yes	B	1	1	
WESTPORT CANAL			yes		yes			yes	yes	yes	yes	E	1	1		B	1	1	
WHITELAKE		yes	yes	yes			yes	yes	yes	yes		L	2	1		K	2	1	
WICKMOOR RHYNE					yes	yes			yes'	yes		E	2	1	yes	B	2	1	
WITCOMBE BOTTOM MAIN D.	P.S.[SPS11] to Witcombe Drove				yes		yes		yes	yes		E	1	1	yes	F	1	0	
WITCOMBE BOTTOM MAIN D.	Upstream of Witcombe Drove				yes		yes		yes	yes		E	1	1	yes	B	1	1	
RIVER YEO	Parrett to Long Load P.S.[SPS11]	yes	yes	yes			yes	yes	yes	yes		L	1	1		L	1	1	
RIVER YEO	Upstream of Long Load P.S.[SPS11]	yes	yes	yes			yes	yes	yes			S	0	1		S	0	0	

APPENDIX G

Agriculture Benefits

APPENDIX G AGRICULTURE BENEFITS

G.1 Introduction and Purpose

Agriculture is the main land use in the Somerset Levels and Moors. The well being of the rural community and indeed the positive management of the rural environment, are closely linked to the viability and vitality of the farming industry.

This section links existing land use and farming practice in the Levels and Moors to Flood Defence standards of service, and the likely consequences of the adoption of a modified flood defence regime, whether this be 'do nothing' or some alternative intermediate option.

G.2 Approach

The study determines the physical and financial characteristics of farming in the Levels and Moors, and in the areas liable to flooding.

MAFF agricultural census data for 1990, 1994 and 1997 were obtained to determine land use and livestock numbers in the four study catchments. Given the need for confidentiality these were provided as 'small area statistics', i.e. parish groupings, for each specified catchment. The parishes chosen for inclusion within each catchment were based broadly on the IDB boundaries. Because of this, some parishes included spread beyond the catchment areas, while other areas containing only a small part of the parish were excluded. In some cases a number of parishes spread across an area that fits within two catchments. This is particularly the case in the area between the Axe and the Brue rivers, and where the River Tone joins to the Parrett. Nevertheless, the MAFF census data provides a broad overview of land use (grass, cropping or other), livestock numbers (dairy, beef, sheep) and the dominant form of farming system within each catchment specified.

Because of flood risk and drainage conditions there is greater degree of grassland in the flood plain than in the catchment as a whole. Estimates of land use and farm enterprises were modified accordingly, drawing on information from MAFF FRCA sources, especially pertaining to the adoption of ESA tier agreements. Additional information was drawn from other studies in the area, notably in Kingsmoor (Morris et al 1984), Salt Moor and North Moor (Spoor et al, 1994), Aller Moor (Morris 1994) and the Brue Valley (Morris and Hess 1988).

Information on the financial performance of farming in the Levels and Moors was drawn from the regional Farm Business Survey unit at the University of Exeter. This was supplemented by current standard estimates compiled specifically to assess the financial and economic performance of agriculture under different land drainage and flood defence conditions (Dunderdale and Morris, 1997, 1998).

G.3 Farming Systems and Land Use

In the four catchments of the Axe, Brue, Parrett and Tone, the agricultural economy is primarily based around livestock production systems. This is reflected in the land use, which is primarily grassland with some cropping.

Land use within the flood risk areas of the catchments of the Axe, Brue, Parrett and Tone tends to contain relatively less cropping and more grass than the catchment as a whole. Within the Axe and the Brue catchments the low lying moors that are subject to fluvial flooding and which are therefore best suited to dairying and stock rearing on permanent pasture, although the remote fields are not favoured for dairy cows in milk. In the River Parrett it is the moors east of Bridgwater, which consist of deep peat soils (West Sedgemoor, King's Sedgemoor, North Moor) and clay soils over peat (Wet Moor, West Moor, Aller Moor) that are subject to flood risk. They are most suited to permanent grassland, although where the flood risk is low cereals, and especially maize for fodder, are grown. Finally, Curry Moor alongside the River Tone is an area subjected to increased and frequent flooding and again is characterised by grassland production.

Table G.1 - Flood Plain Areas and Existing Land Use by Catchment

Land Use in Floodable Area (%)	Axe	Brue	Parrett	Tone	Total
Flood Plain Area (100 year) (ha)	2,198	8,056	13,276	2,505	26,035
Arable	11	3	13	10	37
Improved grass	22	47	45	40	154
Tier 1 (ESA)	61	26	26	45	158
Tier 1A (ESA)	4	9	2	3	18
Tier 2 (ESA)	23	12	3	2	40
Tier 3 (ESA)	0	3	9	0	12
Other (withy, peat, other)	0	..	3	..	3
Flood Plain Area (annual event) (ha)	200	1,300	2,100	200	3,800
Arable	31	0	11	0	42
Grass [a]	69	100	89	100	358

[a] In the Axe, the grassland area is divided equally between Tier 1, 1A and 2; in the Brue and Parrett the grassland is divided equally between Tier 1, 1A, 2 and 3; and in the Tone the grassland area is either in Tier 2 with the raised water level supplement or Tier 3.

G.4 Links Between Flood Defence and Farming Productivity

A combination of flood risk, high water table levels and soil types define the potential for agricultural land use in the Levels and Moors. Overland flooding results in direct damage to standing crops and cultivations, impedes crop growth and reduces access to fields to carry out important tasks whose timing is critical. Similarly, underground flooding, in the form of high water table levels which saturate the soil profile, can have an equally limiting affect on land use, farming practice and productivity.

The impacts of flooding and water logging vary considerably between crops and the stages of crop development. Flooding on grass during the dormant winter period has little impact, whereas in summer just before the silage cut, the major part of the crop can be lost. Cereals can withstand short duration floods after germination, but long inundation in winter, or pre-harvests summer flood can destroy the crop. The standards of flood defence and water table control required for commercial agriculture can be defined for particular types of land use, if significant damage or productivity is to be avoided. (Table G.2).

Based on previous research carried out for MAFF and the Environment Agency (and its predecessors), methods have been developed for estimating the impact of changes in flood risk and water-logging on agricultural performance (Hess and Morris, 1986, Dunderdale and Morris, 1996).

On grassland, productivity is a function of the production and use by animals of energy from grass. Drainage and flooding can affect the quality of the grass sward, grass growth conditions, ability to apply nitrogen, and access to fields for grazing livestock or machinery (to apply nitrogen and make silage). On arable crops, flooding reduces yields through depressed growth, direct damage, or delays to critical operations. A deterioration of drainage and an increased risk of flooding reduce crop options: for example forcing a switch from arable to grassland, or from intensive to extensive grass.

The benefits of improved drainage for agriculture are readily apparent on the Levels and Moors: improvement in grassland management and productivity, and where conditions permit, the introduction of arable cropping. A reduction in standards of drainage service would involve a reversion of land use to the pre-drained state, and the loss of associated potential benefits.

Table G.2 - Flood and Drainage Standards for Agriculture

Common minimum acceptable flood risk by land use

	Whole Year	**Summer April-October**
Land use		
Horticulture	20	100
Roots crops	10	25
Cereals	5	10
Intensive Grass	2	5
Extensive Grass	<1	3

Field water table levels, drainage conditions and freeboard in watercourses

Water table height from surface	**Drainage Status**	**Agricultural productivity**	**Freeboards in watercourses (natural drainage: no field drains)**	**Freeboards in watercourse (field drains)**
0.5m or more	Good, no impediment	Normal	1m (sands) to 2.1m (clays)	1.2m (clays) to 1.6m sands
0.3m to 0.49m	Bad, reduced yields, reduced field access	Low	0.7m (sands) to 1.9m (clays)	Temporarily submerged pipe outfalls
Less than 0.3m	Very Bad, severe constraints on land use, reduced yields, reduced field access	Very Low, unsuited to arable crops, confined to wet grassland	0.4m (sands) to 1m (clays)	Permanently submerged pipe outfalls

Freeboard here is the height difference between water in ditch and adjacent field surface level. Required field water tables relate to conditions for crop growth and field travel. Very low water tables can result in crop water stress.

Table G.3 - Land Use In the Flood Plains by Catchment and Flood Defence Scenario

Flood Plain Area (100year) ha		Axe 2198	Brue 8056	Parrett 13276	Tone 2505	Total 26035
Land Use		% of area				
Scenario 1: existing flood defence regime						
Arable		11%	3%	13%	10%	9%
Improved Grass		22%	47%	45%	40%	43%
Extensive Grass						
- Perm. Grass	ESA 1	61%	26%	26%	45%	31%
- Extensive Grass	ESA 1A	4%	9%	2%	3%	4%
- Wet Grass	ESA 2	2%	12%	3%	2%	6%
- Raised Level	ESA 3	0%	3%	9%	0%	6%
Withy		0%	0%	2%	0%	1%
Other		0%	0%	1%	0%	0%
Total		100%	100%	100%	100%	100%
Scenario 2: do nothing						
Arable		0%	0%	0%	0%	0%
Intensive Grass		0%	0%	0%	0%	0%
Extensive Grass						
- Perm. Grass	ESA 1	0%	0%	0%	0%	0%
- Extensive Grass	ESA 1A	0%	0%	0%	0%	0%
- Wet Grass	ESA 2	75%	10%	50%	67%	51%
- Raised Level	ESA 3	0%	0%	0%	0%	0%
Withy		0%	0%	0%	0%	0%
Other	Peat marsh	25%	90%	50%	33%	50%
Total		100%	100%	100%	100%	100%
Scenario 3: intermediate regime						
Arable		0%	0%	0%	0%	0%
Intensive Grass		0%	0%	0%	0%	0%
Extensive Grass						
- Perm. Grass	ESA 1	0%	0%	0%	0%	0%
- Extensive Grass	ESA 1A	0%	0%	0%	0%	0%
- Wet Grass	ESA 2	75%	50%	49%	67%	60%
Managed peats	ESA "4"	25%	50%	50%	33%	40%
Withy		0%	0%	2%	0%	0%
Other		0%	0%	0%	0%	0%
Total		100%	100%	100%	100%	100%

APPENDIX H

Wildlife and Nature Conservation Benefits

APPENDIX H WILDLIFE AND NATURE CONSERVATION BENEFITS

H.1 Introduction and Purpose

This section aims to assess the impact of different Flood Defence scenarios on the nature conservation assets in the floodplains of the four river catchments under consideration. The study area contains 16 SSSIs, which have significant wetland interest and are subject to Flood Defence measures (Map 3). These contain the core wildlife resource of the area, and this assessment will be focused on these sites, though it should be remembered that the long-term future of the area's wildlife depends upon an ecologically sustainable management of the landscape as a whole. The purpose is to evaluate the likely effect of an alteration to the current flood-defence regime on wildlife and to comment whether the impact would be positive or negative in terms of the area's nature conservation interest. Information has been drawn from published sources and from Silsoe's research experience, having studied the ecohydrology of the area for the past twelve years (e.g. Spoor and Chapman, 1992; Gowing et al., 1997). Emphasis has been placed on the vegetation structure of the sites, as this is the aspect most directly affected by alteration in flood regime and which determines the habitat value of the site for other groups.

H.2 Approach

The approach taken has been to identify the major feature of each of the sites from information supplied by English Nature (1997). These are then considered in the context of the wider catchment and assessed for their conservation importance on a range of scales with reference to the various designations assigned to them. The impact of flood-defence scenarios on the habitats are then derived from information on the relationship between vegetation type and site hydrology and this information interpreted both in terms of nature conservation interest and of local conservation strategies.

H.3 Wildlife and Conservation Policy Review

The study area has been identified as being of great conservation importance at a range of scales. At an international level, parts of it have been identified both as a wetland of international importance under the terms of the Ramsar Convention and as a Special Protection Area (SPA) under the European Union (EU) Bird Directive of 1979. No habitats or species in the area have resulted in candidate Special Areas for Conservation (cSAC) being notified under Annexes I or II of the EU Habitat Directive (1992), but the provisions of that legislation apply to SPAs anyway.

At a national level, the majority of the area has been designated an Environmentally Sensitive Area (ESA) by MAFF and a number of Sites of Special Scientific Interest have been notified by English Nature. The area contains the largest block of lowland wet grassland remaining in England and contains plant communities, invertebrates and bird species which are considered rare or threatened on a national scale.

On a local level, a number of County Wildlife Sites have been designated, reserves have been bought and managed by conservation organisations such as the Somerset Wildlife Trust and the Royal Society for the Protection of Birds (RSPB). Other local initiatives such as the

Avalon Marshes project and the Levels and Moors Partnership have been launched to conserve the Area's natural heritage.

The four catchments under consideration do not differ markedly in their nature conservation interest (Table H.1), all containing lowland wet grassland and the associated ditch networks. The Brue catchment has the added interest of remnant raised bogs on its flood plain giving rise to a distinct soil type which in turn supports vegetation communities not found elsewhere in the study area. As a result, the Brue catchment has been identified as a Prime Biodiversity Area by the local English Nature Team.

Table H. 1 - The Nature Conservation Sites Considered in this Study

Biological SSSI	Catchment	Major wildlife interest(s)
Catcott, Eddington and Chilton Moors	Brue and Axe	Wet grasslands (inc. spp rich), wet heath and associated ditches
Curry and Hay Moor	Tone	Wet grasslands and associated ditches
King's Sedgemoor	Parrett	Wet grasslands (inc. spp rich) and associated ditches
Langmead and Weston Level	Parrett	Wet grasslands (inc. spp rich) and associated ditches
Meare Heath	Brue and Axe	Wet grasslands and associated ditches
Moorlinch	Parrett	Wet grasslands (inc. spp rich) and associated ditches
North Moor	Parrett	Wet grasslands and associated ditches
Shapwick Heath	Brue and Axe	Remnant raised bog, wet heath, woodland, reedbed and swamp communities
Southlake Moor	Parrett	Wet grasslands (inc. spp rich) and associated ditches
Street Heath	Brue and Axe	Wet heath
Tadham and Tealham Moors	Brue and Axe	Wet grasslands (inc. spp rich) and associated ditches
West Moor	Parrett	Wet grasslands and associated ditches
West Sedgemoor	Parrett	Wet grasslands (inc. spp rich) and associated ditches
Westhay Heath	Brue and Axe	Reedbed and swamp communities
Westhay Moor	Brue and Axe	Wet grasslands (inc. spp rich), remnant raised bog, wet heath, swamp communities and their associated ditches
Wet Moor	Parrett	Wet grasslands (inc. spp rich) and associated ditches

The wildlife interest of the area is predominantly linked to wetlands, and therefore water level management policy is a key component of any nature conservation initiative. An Environment Agency Steering group is currently in the process of reviewing water level management strategy and formulating an action plan (Environment Agency, 1999).

H.4 Links Between Wildlife and Flood Defence

H.4.1 Breeding Waders

The bird species included in this category are Snipe, Redshank, Curlew, Lapwing and Black-tailed Godwit. The preferred water regime varies from species to species but in general a high water table (<300 mm from surface) is required during the breeding season (March-June), to provide soil soft enough to probe and/or small pools of surface water in which to feed. Extensive floods during this season are undesirable as they may disrupt nesting in these ground-dwelling species. Breeding pairs require quite large contiguous territories away from cover which could conceal predators. Therefore the provision of small blocks of suitable habitat is not effective.

H.4.2 Over-Wintering and Passage Wildfowl

This group includes the species in the previous section plus other waders such as Golden Plover and Whimbrel, waterfowl including Bewick swans, Gadwall, Teal, Pochard and Widgeon and other migrants including the Short-eared Owl and the Bittern. All of these are attracted by large areas of surface water varying in depth from a couple of centimetres to half a metre in depth. The period from December to March is the most relevant to them.

H.4.3 Lowland Wet Grassland Plant Communities

This category encompasses a wide range of both water regimes and of plant communities. The latter being largely determined by the former. The regimes range from ones in which the surface is inundated by water only for a few days each year to one where water ponds on the surface for several months. From stable water tables, constantly in the top 500 mm of the soil profile to rapidly fluctuating ones which are drawn down to over a metre's depth in summer. Flood defence management affects these regimes in two respects: the frequency and magnitude of flood events and the land drainage service provided by the network of pumps and water courses managed as part of the area's flood defence scheme. Vegetation is very sensitive to waterlogging and the duration of flood events can have a major impact of the composition of plant communities. An alteration to flood defence management has a potentially significant effect on this habitat.

The most important requirement for the maintenance of this habitat however is continued pastoral agriculture either through cropping the grassland for silage or hay and/or grazing the land. These operations require some degree of water-table control to be viable and it is here that flood-defence management may make a greater impact on this habitat than via its direct influence on water regimes *per se*. An unmanaged grassland will succeed to a different vegetation type relatively quickly and the habitat type will be lost to the fauna it supports. For this type of habitat there is potential synergy between farming and environmental objectives.

H.4.4 Reedbed and Swamp Vegetation

These vegetation types are rather less sensitive to small variations in water levels, their composition being more readily influenced by water quality and vegetation management parameters. The key requirement is for surface water (or at least saturated soil conditions) to be present through late winter and into spring (February-May). If the requirement is not met the emergent vegetation will tend to succeed to less specialist herbaceous vegetation and scrub. The vegetation will tolerate surface water throughout the year and is not likely to suffer from flooding, unless the floods are more than 1.5 metres in depth and prolonged during the growing season.

H.4.5 Remnant Mire Communities and Wet Heaths

The most exacting environmental factor in these communities is the availability of plant nutrients. This is intrinsically tied to soil water regime, but in this instance the water quality of flood waters become as great a concern as the frequency and duration of floods themselves. The acidic nature of the soils is a product of leaching by rainwater and the areas would be above the normal flood level of the base rich river water. It would be inappropriate therefore to encourage external flood waters on to this vegetation type more than perhaps once in ten years. The vegetation is very resilient to high water levels and demands a water table within 400 mm of the surface throughout spring and early summer (March-July). These conditions are necessary to prevent free oxygen diffusion into the soil, which would result in the mineralisation of nutrients and the succession to a more competitive community. Furthermore such aeration of the soil would promote peat wastage and the loss of some of the area's key natural assets (Spoor et al., 1999). In summary this vegetation type would decline if any change to flood defence management caused either an increase in the soil's drainage efficiency or an increase in the frequency of river flooding.

H.4.6 Aquatic Vegetation

The plant communities found within the drainage ditches associated with the wet grassland and fen sites in the area are of great conservation interest. They are composed of both floating and submerged species which require regular maintenance to prevent light exclusion by emergent species. In terms of water level, they thrive best under a constant regime with ditches almost full. This situation allows the water surface to be fully illuminated by sunlight. They are tolerant of some fluctuation however and are less sensitive to falls in level during winter compared to during the growing season. Water quality and clarity is an important factor in this habitat. Most of the communities are adapted to relatively base rich conditions and as such are tolerant of flooding by river water. Water quality is more likely to suffer if the water levels fall during summer and there is no dilution of drainage water from intensively farmed areas. A continuous steady flow of water through the ditch system is ideal, preventing the accumulation of nutrients and the development of anaerobic conditions during summer.

H.4.7 Terrestrial Invertebrates

Wet grasslands support a diverse range of insects, especially ground beetles, and of other invertebrate groups. Whilst having conservation value in their own right they are often considered in relation to water management as primarily a food source for bird populations. Earthworms are major prey items for species such as Snipe. They do not tolerate prolonged flooding if it causes the surface soil to become anoxic.

H.4.8 Aquatic Invertebrates

The area is an important stronghold of species such as the Hairy Dragonfly and the Variable Damselfly whose nymphs overwinter in water-filled ditches. These require a relatively stable water level through the year and perhaps more importantly a constant flow of water along the ditches to disperse high nutrient concentrations and to aid oxygenation of the water (RSPB, EN & ITE, 1997).

H.5 Existing Arrangements for Obtaining Wildlife Objectives

The major scheme within the area aimed at promoting wildlife objectives is the ESA initiative funded by MAFF. Other initiatives are in place but tend to be more limited in extent, such as English Nature management agreements on SSSIs, wildlife reserves run by conservation organisations and smaller scale projects undertaken by individual landowners.

The most significant arrangement with respect to water level management is the Tier 3 option within the ESA scheme. This allows landowners to enter their grassland into a Raised Water Level Area (RWLA) in return for enhanced hectarage payments. RWLAs aim to hold water in ditches at mean field level during the period November to April in order to create surface splashing. This is done for the purpose of creating appropriate feeding conditions for wading birds (Snipe, Redshank, Curlew, Lapwing etc.) during their breeding season. It also has an impact on the plant community present, the terrestrial invertebrate community and the management of the vegetation.

Ideally Tier 3 would be applied to entire hydrological units so as to allow water flows to remain unaffected, the ditches merely being held at a higher level. In practice, however, RWLAs tend to be small blocks within such units that have been engineered out of the traditional drainage system in order to manage them independently.

The low-lying moors have an important flood-storage function. This facility may be used at any time of year following heavy rainfall within the local catchments. In winter it is of particular importance for creating large areas of surface water to attract winter passage wildfowl. Once filled with water, many of the moors rely on active pumping to drain them if river levels remain high. In some instances gravity drainage will empty the moors once river levels subside slightly. The duration of such inundation events is of importance not only to birdlife but also to plant communities particularly during the growing season (March-September), because species-rich assemblages can be dramatically affected as a result of anaerobic conditions developing in the surface soil.

H.6 Impact of Predicted Changes in Flood Defence on Wildlife Interests

H.6.1 Scenario 1: Current Maintenance Standards

Vegetation communities are generally assumed to have already reached equilibrium with respect to current water regime management. The exceptions to this are those areas which have been engineered to meet the Tier 3 requirements of the ESA scheme. Such work has been done within the last 10 years and the vegetation is still in a state of flux. These areas are being monitored by various bodies (ADAS, 1994; RSPB, 1994; English Nature, 1994) and there is some concern that species rich grasslands are losing some of their diversity as a result. In response to these concerns, MAFF amended the Tier 3 guidelines in 1996 to allow an earlier drawdown in spring to protect such swards.

It is less clear as to whether Breeding Wader populations have reached a stable level and the extent to which the marked declines in these populations over the past 20 years are a result of improved drainage. The situation has been confused by the run of very low rainfall summers experienced by the area between 1988 and 1996, which have resulted in sub-optimal soil conditions during the breeding season. It is possible that maintenance of current standards will result in a continued decline in some populations.

Current standards with the inclusion of 'Tier 3' areas appears to be meeting the requirements of over-wintering and passage wildfowl. It is estimated that most sites would experience 8 weeks of floodwater during winter. As the floods are not necessarily synchronised in all areas, the mobile flocks could be expected to find suitable conditions throughout the season, especially with the addition of Tier 3 zones.
Aquatic communities of both plants and invertebrates may have stabilised with respect to the current regime, but are put at risk by the practice of drawing down water levels in winter. They are also not favoured by the current practice of isolating blocks of land to create Tier 3 zones as these interrupt the through flow of water.

H.6.2 Scenario 2: No Maintenance

This scenario assumes that two flood events will occur each year and that each will persist for up to three months and extend over the area denoted as fluvial floodplain by the section 105 survey (EA/Mott MacDonald, 1997). Under these assumptions, it is likely that the affected areas will be covered by surface water until early May. Table H.2 indicates which of the SSSIs listed in Table H.1 would be influenced in this way. It is likely that the species-rich swards which are classified as either MG5 or MG8 under the NVC or the related *Carex-Agrostis* communities would be substantially changed under this regime because of the prolonged anaerobic conditions created. It would be slightly wetter than Tier 3 level use at present. The other group to suffer would be the terrestrial invertebrates which in turn may have an impact on breeding waders. The waders themselves may be prevented from nesting by such prolonged and extensive floods. The groups likely to benefit from this scenario are the swamp and reedbed communities which would encroach on to former grassland, where management was no longer viable. The extent of suitable habitat for wintering and passage wildfowl would improve, but it is unclear to what extent populations would respond as they are perhaps limited by other constraints.

Aquatic communities would benefit from the transfer of propagules in the extensive floods but would suffer if the ditch management regime were relaxed as a result of cessation of grassland management.

Table H.2 - Those Sites Affected Under the 'No Maintenance' Scenario.

Biological SSSI	Total area (ha)	Extent of area affected
Catcott, Eddington and Chilton Moors	1083	approx. 90%
Curry and Hay Moor	472	All
King's Sedgemoor	822	approx. 80%
Langmead and Weston Level	169	All
Meare Heath	225	approx. 95%
Moorlinch	226	All
North Moor	676	All
Shapwick Heath	394	approx. 30%
Southlake Moor	196	All
Street Heath	12	None
Tadham and Tealham Moors	917	approx. 95%
West Moor	213	All
West Sedgemoor	809	All
Westhay Heath	26	All
Westhay Moor	574	approx. 85%
Wet Moor	491	All

H.6.3 Scenario 3: Reduced Maintenance

This scenario assumes that the moors would be allowed to retain more water in winter, that the frequency of floods from rivers would double, but the capacity to pump water back into rivers following a flood would be largely retained. Retaining more winter water on the moors into spring would benefit the aquatic communities and the breeding wader habitat. If water level control could be maintained via pumps then conditions suitable for species-rich grassland could also be achieved. Occasional summer flooding of the moors would not damage wildlife interest if it were possible to remove surface water via pumps in less than a week and thereby avoid anoxic conditions developing at the soil surface. Such a system would remove the need for separately engineered Tier 3 blocks and therefore bring ditches back into normal flow conditions with benefits to aquatic life.

This flood defence scenario would also facilitate traditional and extensive grassland management practices which favour these environmental qualities (such as wet grassland plant communities, wet heath, aquatic vegetation and terrestrial invertebrates) associated with controlled water regimes.

H.7 Opportunities for Wildlife Enhancement via Changes in Flood Defence Management

As discussed at the end of the previous section, it should be possible to enhance the wetland habitats of the study area by reducing the current standard of service with respect to land drainage. Holding a higher penning level in winter and allowing flood water to enter the moors more frequently would both have positive wildlife benefits. However, it is necessary to maintain the traditional farming practice of haymaking and aftermath grazing with cattle if these benefits are to be realised.

One could suggest environmental objectives such as increasing current breeding wader populations, conserving the remaining stands of species-rich wet grassland and permitting areas to diversify and reducing the rates of peat wastage. In terms of target locations for these objectives, it would be appropriate to focus on the peat moors initially, where soils belonging to the Altcar association respond well to careful water management. It would be necessary to implement management changes alongside the relaxation in drainage service. These would include the installation of additional ditches to allow sub-irrigation of fields in summer and the re-instatement of surface gutters within the field to aid the distribution of water and to provide feeding areas for wader chicks. Soils of the Midelney series would also respond to such management and could form the secondary target area.

H.8 Implications for the Design and Operation of Wildlife and Agro-environmental Schemes

Under Scenario 1, the current schemes would continue as at present. The ESA Tier 3 option is kept under review and may require further amendment to conserve biodiversity whilst maintaining viable farming activity.

Scenario 2 would create the need for a fundamental re-assessment of current agricultural practice on the moors and a parallel overhaul of the schemes designed to support traditional management. The SSSIs which still contain species-rich grassland have a combined area of approx. 5300 ha. Of this 92% is deemed to be floodable if maintenance is stopped. It is conceivable that in such a situation conservation objectives would require lower water levels than the norm and environmental agencies would be prepared to meet the cost of pumping and channel maintenance in order to protect grassland communities and to manage sites effectively for breeding waders and ditch communities.

If Scenario 3 were implemented, then there would be scope to re-focus wildlife schemes. Rather than concentrating on holding ditch water at a high level, as at present, they could re-direct their funding toward meeting the capital and maintenance costs of improving the water distribution systems in order to wet up field centres. The management of pumps and main rivers would provide suitable water levels in the ditches. Such a re-allocation of resources would have benefits for the threatened water meadow/flood pasture communities, for breeding waders and for the conservation of the peat itself.

This targeting of the peat areas under an intermediate flood defence scenario is referred to as Tier "4" in the economic section in Section 4 above.

APPENDIX I

Urban Benefits

APPENDIX I URBAN BENEFITS

I.1 Introduction and Purpose

Fluvial and tidal flood alleviation through the centuries has enabled the development of a well established built property infrastructure in both the urban and rural environment throughout the Levels and Moors, particularly in the tidal coastal flood plain of the River Parrett within Bridgwater. The existing pattern of social and economic activity in the area is very dependent on the continued operation and maintenance of flood defence and land drainage systems.

The purpose of this part of the strategic review is to quantify the value of the built infrastructure and estimate the event damage and annual average damage associated with residual flooding over and above existing design standards.

I.2 Scope and Approach

This section focuses on the likely impact of a change in standards of flood defence on non residential and residential property within the following flood plain areas. Table I.1 summarises the scope of the study.

Table I.1 - Scope of Study

Flood plain Type/SoS	Axe	Brue	Parrett	Tone
Fluvial	✓	✓	✓	✓
Defended fluvial (100 yrs)	✓	✓	✓	✓
Tidal	x	X	✓	x
Defended tidal (200 yrs)	x	X	✓	x

The benefits provided by the existing standard of flood defence service are derived by comparing the total Present Value of Damages (PVd) for the existing standard of service with damages associated with the 'Do Nothing' scenario - abandonment of the flood defences and associated land drainage ('Walkaway') - and a 'Do Minimum' scenario - repairing breaches to the Bridgwater defences as they occur.

I.3 Property Data Collection

The Environment Agency has obtained from Experian a list of post codes within the above flood plain areas. Addresses within these post codes were derived from the Hopewiser RAINS database. The database was neither ground or screen 'truthed' to eliminate properties within a post code whose geocentres are within the flood plain but whose actual location are located outside the flood plain. Also the property data does not include those properties within the flood plain whose geocentre is outside the flood plain. At this strategic level the 'swings and roundabouts' philosophy is deemed to apply.

Table 1.2 - Built Property Summary for Flood Zones

Flood Zone	Property Type (no.)								
	Residential	Retail & related	Distribution Sector	Offices	Leisure	Public Buildings	Public Houses	Farms	Unspecified Commercial
BRUE									
100 yr fluvial floodplain	74	3	0	0	1	0	2	30	8
100 yr defended fluvial	Non within Levels and Moors IDB								
AXE									
100 yr fluvial floodplain	16	0	0	0	0	0	0	16	8
100 yr defended fluvial	Non within Levels and Moors IDB								
TONE									
100 yr fluvial floodplain	222	0	0	0	0	0	3	15	15
100 yr defended fluvial	Non within Levels and Moors IDB								
PARRETT									
100 yr fluvial floodplain	424	1	0	0	1	4	3	34	22
200 yr defended *	2143	135	39	28	3	13	26	4	232
200 yr tidal floodplain	215	1	0	0	0	1	1	25	65
200 yr defended **	4911	27	3	6	2	9	4	7	41
Total	8005	167	42	34	7	27	39	131	391
Capital Value (£)	551,048,190	93,097,490	29,127,000	17,644,300	4,808,580	18,547,380	5,850,000	12,947,778	271,158,500

* Tidal/Fluvial East of A38
** Tidal Fluvial West of A38
Total Capital Value for property (£) 1,004,229,218

Total Property numbers by type for each flood plain category are detailed by location in Appendix 2 and summarised for the whole Levels and Moors in Table I.2. In total over 8,000 residential properties and over 800 non-residential properties have been identified. Of these some 6,800 (85%) of the residential properties and some 526 (65%) commercial properties are within the area of tidal protection afforded to Bridgwater.

Without field checking it is not possible to categorise all commercial properties. Where this is the case an unspecified category is provided.

I.4 Standards of Service Scenarios

To gain some understanding of the value of the defences, the annual average damages associated with maintaining the various existing standards of service (fluvial - 100 year defended and tidal - 200 year defended and fluvial and tidal unprotected flood plain) are estimated and compared with the 'Do Nothing' losses. The difference between the two losses represents the damage avoided, or benefits, of the existing levels of protection.

Comparing 'Do Nothing' losses with 'Do Minimum' losses (firefighting), i.e. stopping all maintenance activities until a breach in the defences occurs, then effecting repairs only, with no routine maintenance, is presented as an alternative scenario to enable the evaluation of deferred maintenance as and when a breach event causes damage

It is assumed that, even though the fluvial flood plains of the Levels and Moors are largely undefended, the 'Do Nothing' scenario, as in the defended areas, will lead to abandoning of built property in the villages and the isolated properties of the Levels and Moors.

The scenarios are presented below.

I.4.1 Maintain Existing Standard of Service

This assumes:

- Calculate the100 year flood losses for undefended fluvial flood plains plus residual losses above the 100 year and 200 year defended areas (mainly Bridgwater).
- Calculate an estimate of the 30 year losses for the undefended fluvial floodplains
- Assume that the mean annual flood causes zero property damage in the Levels and Moors.
- Calculate the Annual Average Damage (AAD) and PVd from these event damage estimates
- Calculate the Present Value of benefit (PVb) associated with maintaining the existing level of service.

I.4.2 'Do Nothing'

This assumes

- As above until year 5 (when the defences fail)
- Exposure to damage from an uncertain magnitude of flooding for 3 years; add AAD for increased flood exposure in Bridgwater to AAD in undefended Levels and Moors
- Calculate 'walkaway' scenario for Year 8, when repeated flooding forces abandonment of built property.
- Following walkaway, future damage is zero

The cash flow schematic in Table I.3 summarises the above.

Table I.3 - 'Do Nothing' Cash Flow Schematic

Year	0	➡	Year 5	➡	Year 8	Yr 9	➡	49
Damage	AAD	➡	AAD	➡	Capital Value	Zero	➡	Zero
	Undefended		Undefended/ defended		All built property			

I.4.3 'Do Minimum'

This assumes:

- As for 'Do Nothing' but no Walkaway
- Any breach in Year 5 is repaired immediately to pre-breach standard of service with damages in year 5 equal to the undefended and defended AAD. AAD in year 6 reverts to the undefended AAD. A further breach will be expected in year 10 and the cycle of AAD is repeated over the time horizon of the project appraisal (Table I.4):

Table I.4 - 'Do Minimum' Cash Flow Schematic

Year	0	➡	Year 5	Year 6	➡	Year 10	Year 11
Breach	No		Yes	Repaired		Yes	Repaired
Damage	AAD	➡	AAD	AAD	➡	AAD	AAD
	Undef		Undef/def	Undef		Undef/def	Undef

{ }
{repeat cycle to yr 49 ➡ }

I.5 Repeat Flooding Depth/Damage Data

At this high level strategic analysis there is no hydraulic data nor property threshold data to link the selected flood return periods (Mean Annual[1], 30 years, 100 years, and 200 years) to property depth and therefore damage. A PAGN style analysis is wholly inappropriate given the time scale for the assessment. However, EA's R&D Technical Report W126, prepared in 1998 by JB Chatterton & Associates, provides weighted frequency/damage data for property groupings.

The principle governing this data is that, as the depth of flooding by frequency of each property on the flood plain is not known, each property is given a weighted mean value of flood damage from an analysis of the depth of flooding for successive flood frequencies, based on a sample of 12,000 properties elsewhere in England and Wales for which depth/damage and frequency are known. For example, a 30 year and a 100 year flood for residential property gives weighted damages of £3291 and £7,103 respectively. Appendix 2 contains standard damage estimates for other property types based on surveys in other regions.

[1] It is assumed that there would be no property flooding during the Mean annual flood event

These weighted frequency/damage values were applied to all property within each location and for each flood plain zone in the Levels and Moors (Table I.5). Total Annual Average Damages are estimated at £9.63 million.

I.6 Do Nothing Property Capital Values

The 'Do nothing' scenario assumes that, at a critical point tidal flooding may become so repetitive and frequent that socio-economic activity will cease. Though people and commerce will move elsewhere, the physical infrastructure (property/roads) etc. will be abandoned. Though furniture and inventory will be moved, fixed assets will be left to decay. The value of these assets lost is equivalent to their discounted market value at the time they are abandoned.

I.6.1 Non-Residential Property

There are various ways in which **commercial property** might be valued, such as using standard tables of rebuild costs on an area basis. However, it is our contention that capitalised rental values offer a more realistic reflection of property values, as they reflect more accurately their commercial worth. It is understood that the values derived in this way vary to some degree from those derived by other methods, but for the purpose of this high level strategic study, variation will not be significant.

Valuation of industrial and commercial property is divided into three main categories:

I.6.1.1 Primary Industrial (Prime Modern Development)

The rental levels of these properties can vary between £37.5 and £50 per square metre depending on size. Yields will vary between 10% and 12% depending on age, condition, position and covenant of the tenants. Capital valuations based on yield and rent are as follows:

up to 500 m2	@ £50 per m2	= £500 per m2
5,000-10,000 m2	@ £42.5 per m2	= £380 per m2
over 10,000 m2	@37.5 per m2	= £310 per m2

For this study where property areas are unknown a figure of £380 per m2 is taken and applied to the total area of all properties designated as 'Distribution' and 'Unspecified Commercial'

Table I.5 - Urban Flood Damage Summaries for Flood Zones

Flood Zone	30 year damages (£)	100 year Damages (£)	200 year damages (£)	Annual Average damages (£)
AXE				
100 yr fluvial floodplain	1,815,822	2,668,454	n/a	440,226
100 yr defended fluvial		not applicable to Moors & Levels		
BRUE				
100 yr fluvial floodplain	2,530,901	3,826,321	n/a	616,137
100 yr defended fluvial	not applicable to Moors & Levels			
PARRETT				
100 yr fluvial floodplain	11,666,597	17,452,996	n/a	2,835,776
100 yr defended fluvial >		10,019,367	n/a	100,194
200 yr defended tidal *	n/a	n/a	136,340,108	681,701
200 yr defended tidal**	n/a	n/a	63,793,701	318,969
200 yr tidal floodplain	14,702,520	21,539,525	25,830,316	3,591,132
TONE				
100 yr fluvial floodplain	4,298,710	6,567,782	n/a	1,048,141
100 yr defended fluvial	not applicable	to Moors &	Levels	
Total	20,312,030	62,074,445	225,964,125	9,632,275

Notes to table I.5: for tidal and fluvial defended flood zones the damage relates to flood events exceeding the suggested design standard

* Tidal/Fluvial West of A38 ** Tidal/Fluvial East of A38 > Ilchester & Langport

***** Annual average damage following a breach in the Bridgwater defences = £22,708,652**
(i.e. Bridgwater no longer defended)
Total Annual average damage using breach in Bridgwater defences scenario = £31,340,258
(assuming Lanport and Ilchester defences not breached)

I.6.1.2 Secondary Industrial (Older Industrial Units)

Yields for these properties have been assumed to be 13% and rentals £35 per m2 with capital valuations as follows:

Up to 500 m2	@ £35 per m2	= £270 per m2
Over 500 m2		= £150 per m2

Although an average of £220 per m2 could be used, properties divided into these categories have not been distinguished in this high level strategic study.

I.6.1.3 B1 Commercial (Prime commercial/Office development)

This type of property will achieve rentals of between £100 and £120 per square metres with yields of between 9.5% and 11% depending on size, condition and covenant, giving an average capital property value of £1070 per square metre. This figure is applied to retail and related properties, even though these vary between newer supermarkets with a far higher capital value and older high street shops with a lower value. It is also applied to offices, leisure complexes and public buildings.

Given that **agricultural buildings** tend to remain in the same ownership throughout their lives, the best approach to valuation is taken to be rebuild costs. Data for assessing the market value of agricultural buildings is derived from the Nix Farm Management Pocketbook and Agricultural Budgeting and Costing. Again the strategic nature of the study precluded the individual categorisation of farm buildings, but considering the predominance of dutch barns and general purpose buildings, the capital value is set at an average of £75 per square metre.

Public Houses have been ascribed a value of £150,000.

I.6.2 Residential Property

Capital or market values for residential property was derived as a weighted average of the community charge band valuations for Sedgemoor District Council and Taunton Deane District Council, as shown in Table 6.6 and 6.7 respectively.

Table 6.6 - Sedgemoor DC

Band	No. Props in Band	% of total	Band	No. Props in Band	% of total
A (to £40K)	10,503	23.55	E (88-120K)	3,904	8.75
B (40-52K)	10,941	24.53	F (120-160K)	2,027	4.54
C (52-68K)	9,372	21.01	G (160-320K)	1,216	2.73
D (68-88K)	6,585	14.76	H (>£320K)	58	0.13

Table I.7 - Taunton Deane DC

Band	No. Props in Band	% of total	Band	No. Props in Band	% of total
A (to £40K)	6,088	14.18	E (88-120K)	4,568	10.64
B (40-52K)	14,087	32.82	F (120-160K)	2,737	6.38
C (52-68K)	8,048	18.75	G (160-320K)	1,200	2.80
D (68-88K)	6,118	14.25	H (>£320K)	79	0.18

The mean residential values for Sedgemoor and Taunton Deane DCs are £67,247 and £70,428, respectively.

Averaging the two values gives a residential property value estimate for the Levels and Moors of £ 68,838.

These commercial and residential estimates for capital values were applied to all locations and flood plain zones in the Levels and Moors. The total Capital value estimate for all residential property is £ 551 millions and for all commercial property is £ 453 millions giving a total estimated capital value of slightly more than £ 1 billion.

APPENDIX J

Other Sectors Benefits

APPENDIX J OTHER SECTORS BENEFITS

This section reviews sectors which engage human activity and draw their characteristics from the particular features from the Levels and Moors. These include tourism and recreation, archaeology, fisheries and angling, and peat and withy production. The links between these activities and flood defence are also explored.

J.1 Tourism and Recreation

Tourism, recreation and related activities are important to the economic and social well being of Somerset as a county. The Levels and Moors play an important and integrated part in the provision of such services, both to visitors from outside the area and to its local population.

J.1.1 Tourism in Somerset and the Levels and Moors

Table J.1 contains summary statistics on tourism in the county of Somerset, a tourist being defined as an out-of-county visitor. It is a significant sector, both in terms of contribution to income, employment and the local economy as a whole. Most tourist activities focus on the seaside and coastal districts of Sedgemoor and West Somerset. The long term trend in tourist activity is positive: a 5% increase over the period 1991 to 1997. There has been a small relative decline in visitor inputs in the non-coastal areas.

Of almost 8 million visitor inputs, 62% involved British holiday visitors, 23% were British business visitors and 15% were overseas holiday visitors. Overseas visitors were particularly drawn by the historic and cultural inland attractions.

The tourist holiday trade is seasonal, predominantly summer. Average annual occupancy rates varied from 30% in hotels through to 60% in static caravans. Bed and breakfast and farm accommodation annual occupancy rates are about 35%. In the peak summer periods, occupancy rates approach full capacity in self catering and about 70% in B&B/farm accommodation. 66% of UK visitors and 74% of overseas visitors visited Somerset in Spring/Summer (April-September), mostly (over 40%) in the July to September period.

'Scenery' was the dominant reason for visiting Somerset, accounting for 20% of responses in the 1997 Somerset Leisure Visitor Survey. 'Peace and quiet' and 'history and heritage' were other common responses.

The link between flood defence and tourism is complex. An increase in flooding would impact negatively on tourist participation if this resulted in the risk of personal damage, disruption, reduced mobility and reduced access to tourist attractions. Conversely, where increased flooding enhanced the quality of the environmental attributes which attract tourists to the area, such as the wildlife, nature conservation, landscape and amenity values associated with wetlands, then the tourist experience and the tourist trade could be enhanced.

Table J.1 - Tourism in Somerset, General Facts and Figures

- Estimated **annual tourism expenditure = £422 million**, split 61% by visitors making staying trips and 39% day visits from home.
- There are approximately **2.5 million staying visitors** to Somerset annually and approximately **0.8 million day visitors**.
- Tourism generates an estimated **17,500 jobs** in Somerset - 79% of these jobs are directly supported by visitor spend.
- The Somerset **accommodation** industry creates approximately **8,000 jobs**.
- Approximately **9% of employees in Somerset** are in **tourism** related industries.
- Approximately **7.9 million Visitor Nights** were spent in Somerset in 1997:-
  19% in Serviced Accommodation
  56% in Self Catering Units
  25% in Touring Caravans and Tents
- The two **coastal districts** of Sedgemoor and West Somerset accommodated over three quarters of the County's Visitor Nights.
- There are an estimated **55,500 bed spaces/pitches** in Somerset:-
  10,300 = Serviced Accommodation
  45,200 = Not Serviced Accommodation & Holiday Camps (1 pitch = 3.4 bed spaces).

J.1.2 Recreation

There is a range of land and water based recreation pursuits in the Levels and Moors. Cycling and canoeing are popular activities in the Axe and Brue catchments. There is a proposed Pedal the Levels Cycleway using the disused railway from Glastonbury. The Avalon Marshes wetland restoration project, using spent peat working, aims to provide public enjoyment and understanding of the area through bird watching, walking and environmental education. Public footpaths follow the rivers Axe and Brue, and Local Governments are taking action to secure rights of way and access to extend and improve the existing network of footpaths.

The Parrett Trail, opened in 1995, provides a long distance footpath from source to sea, through the Levels and Moors. The Environment Agency owns land adjacent to some of the main water courses which are open for public access, for walking and bird watching. There are plans to enhance the value of King Sedgemoor Drain for conservation and recreation. There is scope to promote the use of existing bridleways and droves for horse riding and cycling, as well as walking. In the Tone Flood Plain downstream of Taunton, opportunities have been identified for enhancing the recreational value of the riverside footpaths.

A change in flood defence standards of service would impact on both land based and water based recreation in and around the Levels and Moors. Those outdoor recreation and amenity pursuits whose value is associated with the appreciation of wildlife, natural habitats and landscape would, for the most part, be enhanced by increased winter flooding and the switch to less intensive wet grassland. The same would generally apply to water based recreation activities such as angling, canoeing and selected water sports whose quality could be enhanced by increased bodies of open water. In all cases, however, direct user benefits depend on access and rights to use.

J.2 Fisheries

J.2.1 Characteristics

Fisheries in the Axe and Brue mainly comprise fast coarse fishing in the low and middle reaches and trout in the upper reaches. Both the Brue and Axe Rivers are popular angling venues, with local regional and national fishing competitions in the rivers and larger drains. Many of the smaller drains are used for coarse fishing. Most coarse fishing rights are held by clubs with open membership, or by the Environment Agency and leased to clubs with open membership. There are also private fisheries in worked out peat extractions. There is some limited fishing for eels and elvers controlled by bye-laws and subject to licence.

Fisheries in the Parrett catchment follow a similar pattern, with coarse fishing in the middle reach of the Parrett and the King Sedgemoor Drain, and fast coarse in the upper reaches. In the Levels and Moors section of the catchment, most of the major water courses are important coarse fisheries with roach, bream, pike, tench, ruff and eels as the dominant species. In this area, most of the water courses are the product of flood defence works and conditions are determined by on-going desilting and vegetation control. This has reduced the variety of habitat, but has encouraged development of aquatic and bankside plant growth.

The management of water levels for agriculture, with levels dropped and rivers free flowing in winter for drainage, and levels retained and rivers penned in summer, causes problems for fisheries in terms of habitat and fish movement. The sluices and penning structures restrict fish migration. Dredging and weed cutting for flood defence purposes can disturb spawning fish, remove spawn or reduce cover for fry. High velocities of rivers main watercourses in flood conditions can adversely affect fish populations. In this respect, washlands and backwaters in the flood plain can provide refuge areas. The presence of shallow and weedy waters in summer is important for spawning and fish recruitment. There are a number of managed lakes and farm ponds which could add to the fisheries resource.

Angling in the Parrett is mainly controlled by licences held by the Environment Agency and let to clubs with open membership. The King Sedgemoor Drain is used for the National Angling Championships. There is no commercial fishing for wild stock in the fresh water part of the Parrett Catchment, but elvers are commercially fished from January to May in the Tidal Parrett.

The lower reaches of the Tone below Taunton are regularly dredged and weedcut for flood defence, with potential negative impacts on spawning fish, spawn and cover for fry. The presence and operation of sluices and tidal doors has a significant impact on fisheries. They obstruct fish movement when closed, but when open high velocities may increase fish losses.

J.2.2 Links between Fisheries and Flood Defence

The existing flood defence regime has a variable impact on fish resources. The variety and quality of fisheries habitat and resource is for the most part reduced as a consequence of flood defence activities such as river training, desilting and vegetation control, and in some cases, the routing and rapid evacuation of flood waters. Simultaneously, however, the managed water regime delivers benefits in the form of managed fisheries habitats, related to weirs, artificial channels and discrete water bodies.

In recent years, flood defence design and operation have been modified in order to protect and enhance the wild fish resource, especially through habitat restoration and management. A switch from the current flood defence regime to a 'do nothing' would enhance the size and diversity of fish habitats and population, both in the river and water courses, and in the shallow floodwaters which would provide spawning and recruitment areas into the breeding season. The adoption of a intermediary degree of flood defence which increased the extent of winter water and retained ditch levels in the summer would favour fish supporting habitats.

The inherent 'non-user' quality of the fish stock would increase, and the pressures currently experienced on fisheries associated with land drainage for agriculture would be relieved. Anglers would draw benefit from improved recreational quality, and this may be evident in additional licence payments and revenues to the regulating authorities. Some of this benefit, however, may constitute diversion of angling activities from elsewhere.

J.3 Archaeology

J.3.1 Characteristics

The Somerset Levels and Moors and surrounding areas contain some of the oldest sites, remnants and relics of human settlement and activity in the British Isles. Many of these are Scheduled Ancient Monuments (SAMs), but a far greater number are thought to lie hidden and preserved in the waterlogged peat soils . The draining of these soils however, for agriculture and other uses, including peat extraction, has degraded, exposed or directly damaged these historic artefacts. Paradoxically, there is a link between peat extraction and knowledge of archaeological remains. Peat extraction exposes archaeological assets but by doing so puts them at risk.

The four catchments of the Levels and Moors contain a wealth of archaeological remains which cover several thousand years of human history as well as the remains of plants, invertebrates, fish and mammals which occupied the pre-historic wetlands and forests of the low lying valleys.

There was little settlement in the Axe and Brue valleys themselves, but there is historic evidence of a net work of inland waterway communication and transportation, and of summer grazing, fishing and early peat workings in the floodplain. A network of wooden trackways was built across the wetlands to allow passage to island communities and lake villages. These are some of the oldest known trackways in the world, dating back to Neolithic times. The best known is the Sweet Track which runs for 2km south of Meare. Archaeological artefacts of national significance have been found along these communication routes and their ancient linked settlements. The Axe and Brue contain the remains of medieval flood defence systems and river works which include numerous small ports, fish weirs, mills, bridges, revetments. These, together with early flood defence and land reclamation measures by the Monasteries, are themselves of significant historical relevance.

Likewise in the Parrett catchment, most settlement occurred on the higher ground, but archaeological remains are evident in and the Roman and medieval fish ponds and river infrastructure, including mills, harbour, and flood defence works. Early land reclamation activities date back to the 11th century. Many of the bridges associated with historic communication routes were removed during later flood defence works. However, the archaeology of the Levels and Moors now also comprises the sites of active and disused pumping stations which are testaments to local drainage history. The Parrett catchment contains two important battle sites, Langport and Sedgemoor.

The Tone catchment contains many pre-historic remains, much of which is thought to remain hidden under deposits of clay and peat. The river valley has produced relics and artefacts from the Bronze Age. The river was navigable almost to Taunton, and there is evidence of water powered mills and weirs for fisheries. River training works date back to the 12th century. Former river channels contain evidence of fisheries, river craft, mills, bridges, medieval flood defences, revetments and small landing facilities.

Drainage for agriculture and other uses has dried out the land and consequently damaged or destroyed archaeological remains. Peat extraction in particular can destroy archaeological interests by removing artefacts and other evidence. Once destroyed the site cannot provide benefits of knowledge, education and recreation.

The Somerset Levels and Moors Strategy has identified sites worthy of scheduling as SAMs. The County Council has designated Areas of high Archaeological Potential which are identified in the County Structure Plan.

J.3.2 Links between Archaeology and Flood Defence

The archaeological interest of the Levels and Moors relate to both its pre-and post drainage history. A lower standard of drainage service which increases soil wetness tends to favour the preservation of historic remains. Archaeological interests would also be served by a reduction in peat abstraction and the intensity of farming. A return to traditional landscapes and water bodies would further compliment the man-made cultural and historic aspects of the area. Some historic remains, especially those associated with drainage and water transport history, could however be placed at risk from increased flooding.

It is difficult to place reliable values on archaeological assets. Some of the benefits are obtained by 'users' who visit sites as part of an educational, scientific, cultural or recreational activity. Visits to archaeological collections and sites are an important part of the tourist and leisure pursuits in the Levels and Moors, delivering social and economic benefits to visitors and those who service them. Furthermore, the designation of SAMs status to many Somerset Sites (and the feeling that many more potentially designated sites are as yet unknown) demonstrates that there are significant 'non user' benefits associated with existence and bequest values. The estimation of archaeological user and non-user benefits goes beyond the remit of this study.

J.4 The Peat Industry

J.4.1 Characteristics

The peat industry is mainly located in the catchment of the Brue, where there are existing processing works. The Structure Plan of Somerset County Council recognises the conflicting interests regarding the use and management of Peats in theMoors, whether these concern extraction, drainage for use for intensive farming, or retention as wetland sites for wildlife and preserved archaeological remains.

The County Council controls the allocation of land for peat extraction through the award of planning consent for extraction. The County Council's 1992 Local Plan refers to a total reserve in the county of 7.5 million m^3 of peat. The Local Plan defined two peat production zones comprising 1277ha , one to the north (1082 ha) and one to the south (195 ha)of Meare. Virtually all extraction is now in these zones. . There are major workings in Shapwick, Meare, Ashcott, Westhay, Walton, Glastonbury and Street Heaths. A 1998 review of peat reserves with existing permits to extract (valid up to the year 2042) in the Special Protection Areas estimated total reserves at 2.5 million $m^{3,}$ equivalent to 10 years working at the current annual extraction rate of 250,000 m^3.

Much of the land within the production zones is not owned by the peat industry itself, but must be acquired by peat producers from landowners. Release of land for peat abstraction depends, therefore, on the decisions of individual landowners who are influenced by other factors, including the relative attractiveness of other options for land use.

J.4.2 Environmental Impacts

The peat producing areas are for the most part set in flat, low lying basins. Workings and related buildings have significant landscape impact. The processing factories also impose a significant landscape effect, with industrial buildings, plant and equipment, and stockpiles of peat material and products. Peat extraction has been associated with loss of fenwoods, notable birch and alder, of field boundaries and hedgerows, and a lowering of ground levels by 3 to 4 m. The artificial lowering of water table levels in peat workings has an impact on water levels in adjacent areas, with consequences for habitats and wildlife.

The peat areas contain some of the most important wetland sites in Somerset and the UK. Permissions to extract peat were given before the importance of the area for nature conservation was fully recognised. It remains to be seen how the New Habitats Directive will impact on existing extraction licences. The County Council is particularly committed to resisting proposals for extraction in SSSIs.

In the past, little attention was given to reclamation of partially or completely worked-out sites such that negative landscape and other impacts continued after cessation of works. The County and District Councils are committed to reducing the negative impacts of peat extraction through policies which require formal environmental impact assessments before award of consent. They require that extraction operations are concentrated to minimise the extraction period at any one site, and that actions are carried out to mitigate environmental impacts before, during and after –use.

Planning permission to extract peat has been granted over large areas of ecological interest, and for this reason extraction is likely to continue. Enforcements on impact mitigation, however, are now in place. Whereas in the past, it was considered appropriate to restore peat workings for agricultural land-use, the relatively high cost of doing so, and the greater importance given to wildlife and nature conservation, has led to a review of reclamation standards and after-use. Emphasis is now given to site restoration designed to suit the needs of wildlife rather than food production, but still allow traditional farming practices such as grazing and haymaking. Particular habitats of interest for reclaimed working include shallow lakes, reed beds, marsh fen and carr. Although practised to a limited extent in the past, the County Council firmly excludes worked-out peat areas as suitable sites for disposing of controlled waste.

Table J.2 – Relation between Flood Defence and Tourism, Recreation and Archaeology Interest

Aspect	Characteristics	User criteria	Winter floods in L&M	Summer floods in L&M
Tourism	Mostly coastal based, accessing inland for scenery and day excursions	Accommodation Facilities Attractions Mobility	Limited impacts on coastal belt summer holiday resorts. Possible enhancement of summer scenery values	Impact on mobility and access to inland locations, attractions and events
	Residential farm and village based accommodation in Levels and Moors. Eco-tourism	Accommodation Facilities Mobility Attractions, especially country and wildlife based features	Potential enhancement of wetland experience, for both winter and summer visitors. Increased eco-tourism potential. Possible disruption to winter trade,	Possible enhancement of wetland values Flood impact on mobility and access.
Recreation and Amenity	Land based informal and formal outdoor recreations: walking, bird watching, cycling, horse riding,	Access, mobility and quality of recreation experience: infrastructure, scenery, landscape, habitats, wildlife, heritage, water quality aspects	Enhancement of winter wetland habitat landscape and amenity values. Possible increase in public access. Possible negative flood impact on mobility and access.	Possible negative flood impact on mobility and access. Enhancement of wetland value
	Water based activities Canoeing, Angling, water sports,	Access and mobility, facilities, water quality and water levels, land and landscape quality aspects	Increased area of water bodies and water space amenity	Increased water space, but possible disruptive impact on organised locations or events
Archaeology	Pre-historic remains and artefacts, Early flood defence infrastructure	Existence and bequest values, importance of artefacts in local cultural heritage, integration with recreation, amenity, tourism and education	Increased preservation of artefacts in in wetland environment, reduced damage due to drainage and peat workings, Enhanced value of Levels and Moors Heritage Site	Selected summer flood areas could enhance heritage sites Possible negative impact on mobility and access.

J.4.3 Impact of Flood Defence

The peat industry relies on a controlled water environment both in terms of flood protection and reduced water table levels in the vicinity of the workings. A reduction in the standard of the flood defence would require the industry to service its own needs through site specific flood protection and drainage operations. This would be difficult and expensive, especially given the high porosity of peat. Extensive winter flooding in peat production areas would have a significant negative effect on the industry.

J.5 The Withy Industry

J.5.1 Characteristics and Trends

Withies are willows used for the production of hurdles, conical plant support, basket making and so forth. Their flexible stems being ideal for the weaving process. The traditional variety used is the *Salix triandra*.

The Somerset Moors are perfect for willow production and the area is the centre of withy growing in Britain. Withies are currently concentrated around the Parrett and Tone catchments with areas of production on Curry Moor, Whitmoor, Stanmoor, Northmoor, Haymoor, Aller Moor, Saltmoor and West Sedge Moor. Overall, a total area of 160 hectares.

Planting of the crop usually takes place in early spring; this involves willow sets being pushed into the ground by hand at a density between 6,800 and 12,000 per hectare. By May they should be growing rapidly, putting on as much as two inches a day, making them one of the fastest growing woody plants in the northern hemisphere. It takes two to three years for the willows to produce stumps capable of producing a reasonable number of willow rods. They are at their most productive after about five years and last for up to 25 years. To be used in weaving the willow needs to reach a minimum of 8 feet. Harvesting takes place in winter, the willow dormant season, between November and March. Once cut the withies are then processed. This industry is concentrated in the village of Stoke St Gregory where the majority of the population is employed in the industry.

WS Atkins recently reviewed the withy industry in Somerset for the Environment Agency (WS Atkins, 1996) but found it difficult to obtain a complete picture of its structure and operating characteristics. . The turnover of the businesses employed in withy production and processing equates to between £12,000 and £26,000 per hectare depending on the product. For those producing bundled willow the turnover is about £4,400 per hectare. The estimated turnover of the total withy industry in Somerset for 1995 was £1.6 million. It was reported by industry representatives that turnover had recently been increasing at a rate of 15% per annum. Sales encompassed UK and export markets for both bundled willows and finished products.

Table J.3 - Summary of Data on Withy Growing in Somerset

Producer	Area of Withies	Manpower	Turnover (£'000 / year)
English Hurdles	40 ha	20	600
Willows and Wetlands Centre	24 ha	25 full time 10 part time	600
Stoke Willows	12 ha	1 full time 1 part time	20
P Gadsby	7 ha	3	
Musgrove	12 ha	2	
R Hector	16 ha	5	
Others	Approx. 60 ha		
Total	Approx. 160 ha		1600

Source: WS Atkins, 1996

J.5.2 Link between Flood Defence and Withy Production

Flooding leads to a number of problems for withy production which are outlined below. Producers have stated (WS Atkins, 1996) that in most cases they are affected by problems of flooding but this has tended to cause inconvenience rather than any longer term problems. Short duration flooding tends to have little effect on withies. Longer periods of flooding over a period of two to three months are more problematic.

Flooding problems

- If the ground on which the withies are grown is flooded for prolonged periods it is not possible to harvest the crop. If withies are not cut before the end of the dormant season they start to grow a second skin which makes them difficult to peel, a requirement for basket making but not hurdles. They may also start to produce side branches which affects their quality in the following year.
- If flooding occurs during cold weather a layer of ice may form around the plants at water level. If pumping is undertaken at this stage to evacuate the flooded areas whilst the ice is still present this may lead to plant collapse as a result of the added weight.
- If withies have already been cut when the flood occurs they may be washed away.
- Excessive flooding encourages reeds and wetland grasses which reduce the quality and quantity of withies and also can negatively affect soil quality.
- Where mechanical harvesting equipment is used on wet land soil structure can be damaged. This has led to one producer buying a large-tyred cutting machine which will allow earlier access onto wet land without causing excessive damage.
- Planting sometimes occurs during the winter period, this cannot happen in very wet or flooded conditions. The same would be true for any prolonged spring or summer flooding.

J.5.3 Impact of Flood Defence on Withy Industry

The current situation regarding flood defence within the Somerset Moors allows withy production to take place with little inconvenience caused. Data from the WS Atkins (1996) report states that yield from withies is about 740 bundles of rods per hectare with a price of £6 per bundle equating to about £4,400 per hectare. The figures reported for processed material varied between £16 and £35 per bundle or between £12,000 and £26,000 per hectare. Annual production costs quoted amounted to £1,325 per hectare for maintenance, transport and advertising plus 1,500 man hours per hectare.

A reduction in flood defence, leading to a greater occurrence and more prolonged period of flooding, could seriously affect the industry. In 1993/94 the flooding that occurred on Curry Moor meant that the area was inaccessible for 90 days. For the producers at English Hurdles this meant some 10 hectares, one quarter, of their production area was not harvested at the proper time and losses in quality amounted to approximately half of the raw material value of the crop, £2,200 per hectare. A second producer also reported some loss of crop.

Without flood defence the extent of flooding would be more serious, occurring across much of the area that is currently used for withy production and also for a longer duration. It is this prolonged period of flooding that creates the greatest problem, particularly during the winter harvesting period. Any prolonged period of flooding during this time would prevent the harvest occurring and could also reduce the quality of the product in future years.

Currently, moderate winter flooding is considered an inconvenience leading to a delayed harvest but not much more. The problem with any spring and summer flooding would be problems associated with the establishment and subsequent maintenance of the crop. In early spring, cattle are grazed in the withy beds to control premature growth. In September, sheep are used to clear grass and weeds prior to the cutting season. Where flooding occurs grazing of livestock would not be possible.

Additional effects of frequent and prolonged flooding are a reduction in soil quality and the encouragement of competition from reeds and wetland grasses. Overall, prolonged and more frequent periods of flooding would reduce both the quality and the quantity of the crop and in a number of areas it may be the case that withy production would cease altogether or require relocation.

Where the cessation of the maintenance of flood defence led to increased and prolonged flooding there are two options that would help alleviate this problem, the transfer of production to alternative land and the use of specialised equipment for waterlogged areas.

The potential for transferring withy production to alternative land is limited. Production is best suited to the Somerset Moors and there is limited availability of suitable land to which the industry could be transferred. Furthermore, the current excess market demand is encouraging producers to seek new land to bring into production. The current shortfall is made up of imports of the raw product.

The second option for withy producers is the purchase of specialised equipment for use on waterlogged land. As mentioned above, it is possible to purchase such equipment which will allow access without causing excessive damage. This could reduce the incidence of a poor quality product if increased flooding was allowed to occur through increasing the opportunities for access. However, the risk of not gaining access at the appropriate time would not be fully removed.

Thus the costs of a change in flood defence regime on the withy industry relate to either the efficiency losses due to relocating to a less suitable or productive site, or the increased damage or operating costs associated with remaining put.

APPENDIX K

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APPENDIX K REFERENCES AND BIBLIOGRAPHY

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