BORD NA MÓNA -KILMACSHANE BOG

Drainage Management Plan

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Contents

Tables

Figures

EXECUTIVE SUMMARY

Kilmacshane Bog is located approximately 1.5km to the north of Banagher and c.3.5km south of Shannonbridge in Co. Galway, on the western banks of the River Shannon. The River Shannon is immediately adjacent to the eastern side and parts of Kilmacshane form part of the flood plain of the River Shannon, regularly flooding during winter and occasionally at other times when the water levels on the river are high.

The rehabilitation measures will generally result in reduced runoff and drainage from the existing peat fields through a mixture of techniques including wetland creation, drain blocking, cell bunding and re-profiling. It is assumed that these measures will not significantly alter the existing topographical catchments.

Three potential impacts were considered: the potential to reduce the drainage function to upstream lands, the potential for increased flows downstream and the potential for increased groundwater levels impacting adjacent lands. There is no potential for increased flows downstream and the rehabilitation of Kilmacshane Bog, based on evidence from other bogs, will reduce the runoff from the bog by returning the peatlands towards its natural water retention function. The avoidance of reduced drainage function to upstream lands depends on Bord na Móna retaining the drainage routes which traverse the bog upon which drainage of adjacent and upstream lands is dependent.

The potential for increased groundwater levels and to a lesser extent marginal alteration of the topographical catchments has been assessed based on a precautionary approach. With wetlands being mainly proposed for Kilmacshane Bog it is expected that water levels will rise above the surface of the peat fields. In this scenario adjacent lands which are at a lower level than these parts of the bog could potentially be impacted. Vulnerable areas have been defined through a zone of influence approach.

Each of the land parcels have been assessed based on its vulnerability to increased groundwater levels within the bog. With a lack of suitable boundary drains to separate the rehabilitation area and potentially vulnerable lands constraints to the bog rehabilitation plan were considered.

DMP measures include controlling the water levels in the proposed wetland areas, excluding parts of bog fields from the rehabilitation plan, retention of boundary and internal drains, upgrading of a boundary drain along one reach and creating a new reach of boundary drain. Maintenance of existing silt ponds and monitoring.

A suite of measures was identified in order to mitigate any future deterioration to adjacent lands should monitoring of these lands indicate a groundwater or drainage impact on these lands from the bog. This approach accounts for unknowns and limitations inherent in this DMP study and provides a precautionary approach to drainage management.

1 INTRODUCTION

Kilmacshane Bog is part of the Blackwater Bog Group. Bord na Móna operated peat extraction within the Blackwater Bog Group under IPC Licence (Ref. P0502-01) issued and administered by the EPA. Condition 10.2 of this licence requires the preparation of a Rehabilitation Plan for permanent rehabilitation of the boglands within the licensed area.

It is proposed by Government that Bord na Móna carry out enhanced decommissioning, rehabilitation and restoration under the Peatlands Climate Action Scheme on peatlands previously used for energy production. This proposed Scheme will significantly go beyond what is required to meet rehabilitation and decommissioning obligations under existing EPA IPC licence conditions. Improvements supported by the Scheme will ensure that environmental stabilisation is achieved and significant additional benefits, particularly relating to climate action and other ecosystem services, will also be delivered.

A key issue for Bord na Móna is the potential hydrological impact rehabilitation of this bog may have on the bog, surrounding lands and lands downstream which may be hydrologically linked to the bog. Rehabilitation measures generally seek to increase groundwater levels and surface water retention such that they are closer to the surface to encourage peat formation, the associated ecological benefits and carbon sequestration capacity. While in general terms this will reduce the volume of water released from the bog following a rainfall event, the impact on flood run-off is not well understood. Furthermore the increase in the local water table could result in negative impacts to surrounding lands if mitigation measures are not applied (e.g. to agriculture).

This Drainage Management Plan (DMP) for Kilmacshane Bog seeks to establish the baseline hydrological performance of the bog and the surrounding drainage network. The plan sets out the characterisation of the bog and surrounding lands, the existing performance of the drainage network and the level of flood risk. The plan identifies the potential hydrological zone of influence of the bog and the objectives, risks and opportunities associated with the rehabilitation of the bog. The plan assesses the potential impact of the various rehabilitation measures which are proposed on the local drainage network and flood risk. It sets out, where necessary, mitigation measures required to reduce impacts. The plan sets out the measures which are required to be delivered in advance or in parallel with the rehabilitation plan as well as the long term operation and retention of the drainage network and associated infrastructure. The plan assesses the level of residual risk, the potential impact due to climate change and the adaptability of measures in response to these climate change impacts.

1.1 Bog Details

Kilmacshane Bog is located approximately 1.5km to the north of Banagher and c.3.5km south of Shannonbridge in Co. Galway, on the western banks of the River Shannon. The surrounding landscape is a mosaic primarily consisting of low-lying agricultural land (pasture) interspersed with other raised bogs, many of which have also been managed by Bord na Móna for peat production, with some areas utilised for domestic turf-cutting. The River Shannon is immediately adjacent to the eastern side and parts of Kilmacshane form part of the flood plain of the River Shannon, regularly flooding during winter and occasionally at other times when the water levels on the river are high.

A rail line connects Kilmacshane Bog with Garryduff Bog to the north. There is also road access to the site alongside the railway line in the north and from a public road in the south-west. The only infrastructure on-site, apart from the rail links and associated machinery access roads and tracks, is a tea centre located at the northern end of the site next to Garryduff.

The site is bisected by one main railway line running roughly north-west to south-east and this is situated on the old route of the Ballnasloe section of the Grand Canal, which was infilled as part of the bog development.

Lehinch is a small low-lying island, prone to winter inundation, in the main Shannon river channel that is cut off by a narrow channel. The island was leased back to the owners when title was obtained by Bord na Móna and is grazed by cattle during the summer. The island has never been subject to peat extraction and does not form part of the rehabilitation work detailed here.

Kilmacshane Bog was drained and developed for industrial peat production in the 1960s and has been in active peat production since the 1968. Industrial peat production ceased in 2014. The peat was harvested from this site was used for fuel peat to supply the West Offaly Power Station in Shannonbridge.

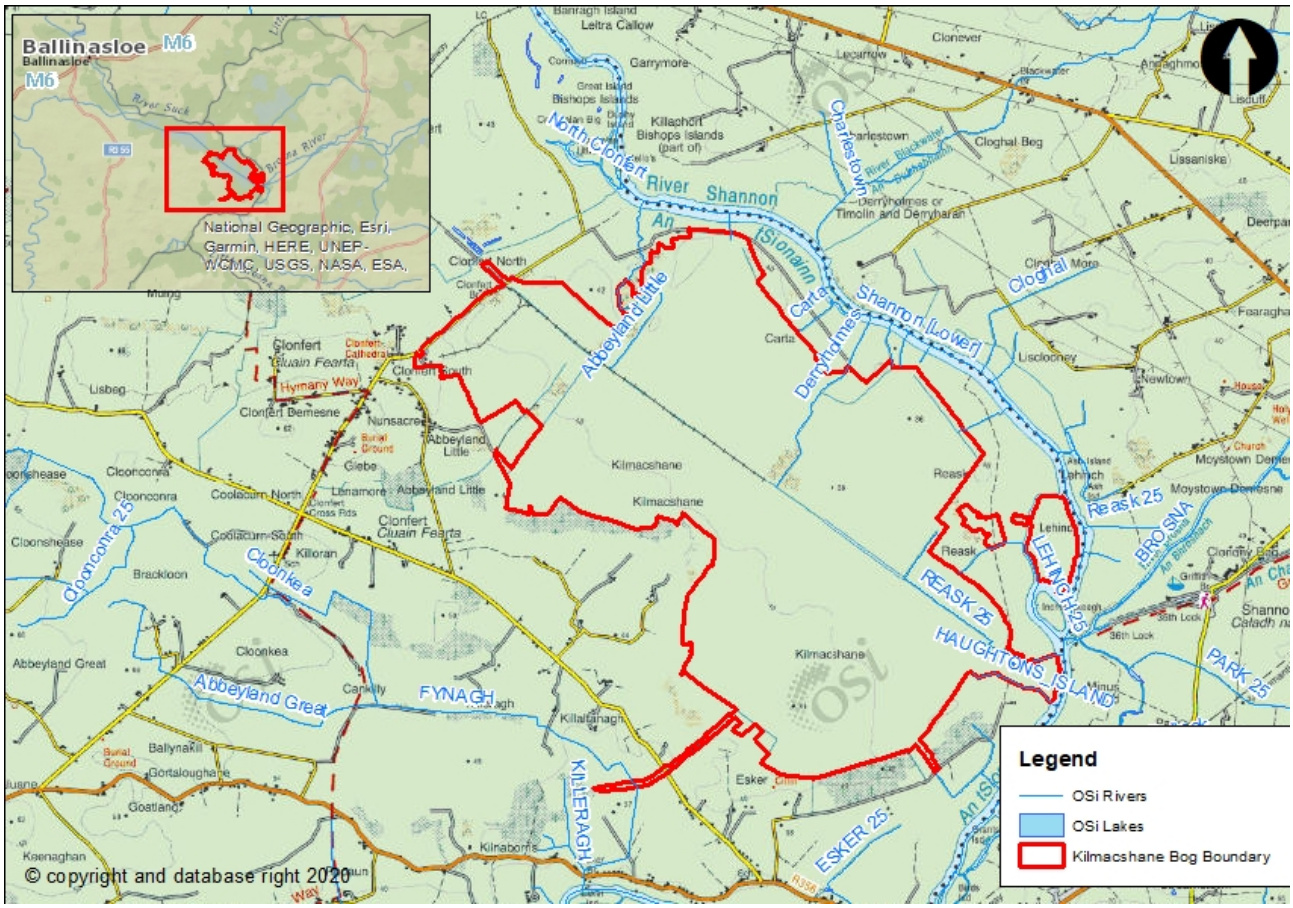

Figure 1.1 Location of Kilmacshane Bog

2 BASELINE ASSESSMENT

Through cessation of peat extraction and implementation of the Kilmacshane Bog rehabilitation plan there is the potential to impact the adjacent land. The extent of the impact will depend on the existing baseline characteristics of the catchments which drain the bog and the adjacent lands.

The purpose of characterising the catchment area is to develop an understanding of how the catchment currently operates and drains. The characterisation also investigates the risks, constraints and opportunities to the operation and drainage.

2.1 Study Area

To characterise the catchments a study area was determined encompassing the total catchment area draining the bog and adjacent lands through the bog. The drainage under the influence of Kilmacshane Bog discharges into external drains or directly into the River Shannon at various locations. In addition to these discharge points there is one inflow location where the adjacent agricultural land drains into Kilmacshane Bog. A review was carried out to delineate the external drains around the bog as presented in Figure 2.1 along with their associated hydrological catchment area.

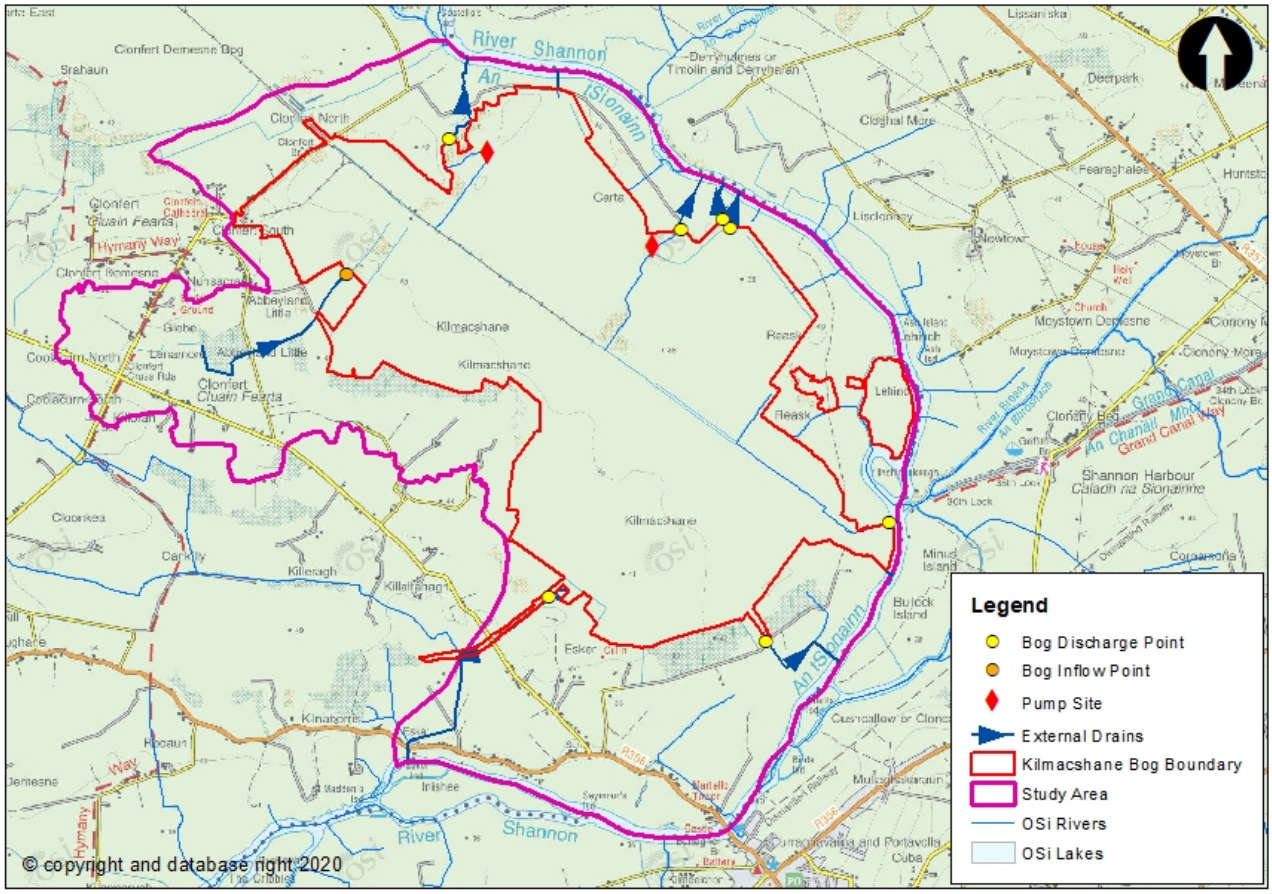

Figure 2.1 Study Area for Kilmacshane Bog

2.2 Catchment Runoff Characterisation

A hydrological analysis was carried out within the study area to delineate the sub catchments of the bog drains and the external drains. The recent Bord na Mona drainage survey was reviewed, and the bog sub-catchments confirmed. Sub-catchments of the external drains were identified using ARC GIS tools. The sub catchments are presented in Figure 2.2.

The FSU catchment characteristics provide an overview of how much rain a catchment receives, how impermeable the catchment is and how quickly the water will runoff the catchment due to topography and drainage. Table 2.1 summarises the FSU catchment descriptors for the sub-catchments identified in Figure 2.2.

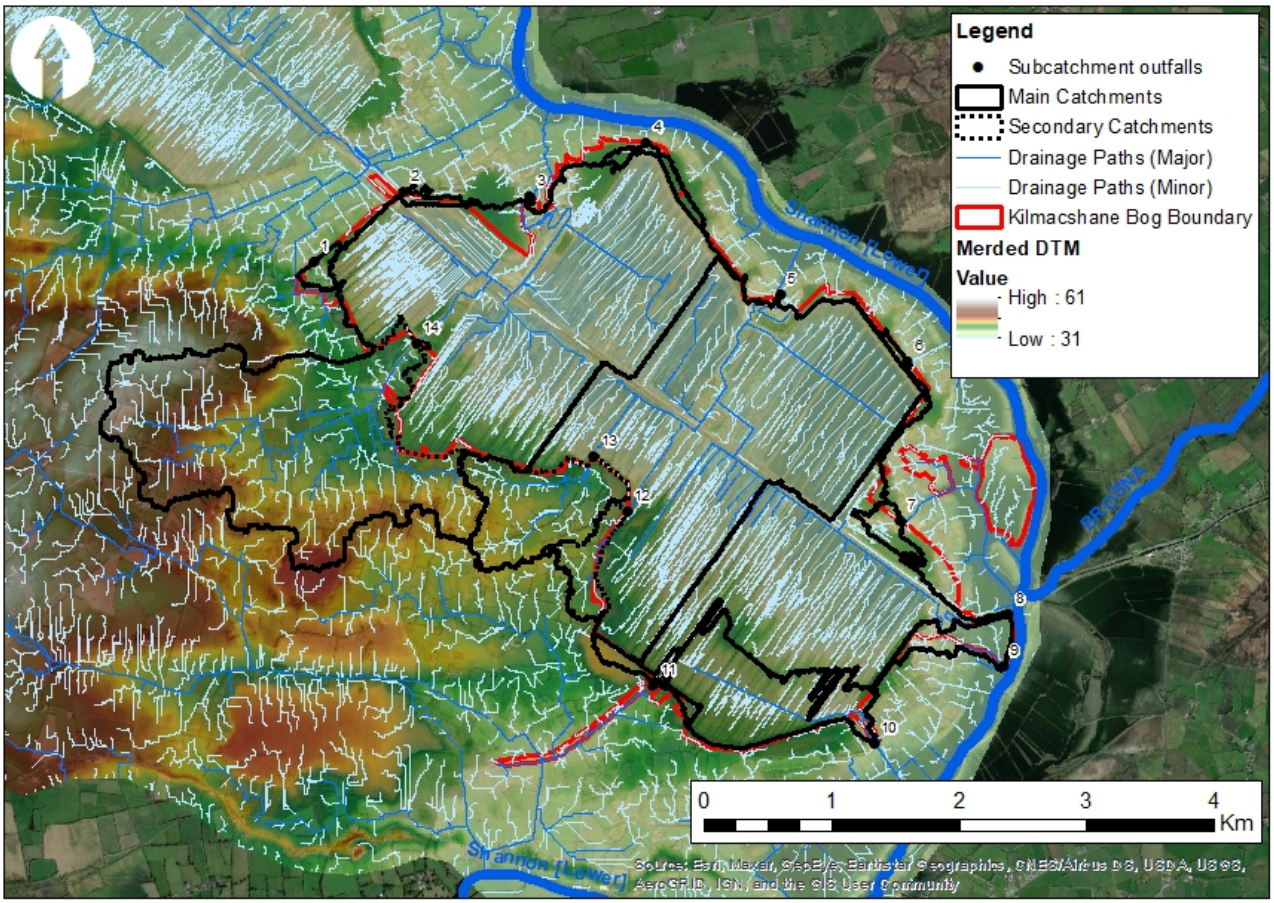

Figure 2.2 Drainage Networks and Sub-Catchments Draining Kilmacshane Bog

There are eleven main sub-catchments and 3 secondary sub catchment draining Kilmacshane Bog and adjacent lands ranging in area from 0.03 km^2 to 7.74 km^2. The catchments are all subject to moderate / low amounts of annual average rainfall. The Baseflow Index for all of the catchments has a range of 0.551-0.674 representing a fairly permeable catchment. The catchments range from very flat to moderately flat.

The Index Flood Flow (Q_{med}) values, which represent the typical peak flood flow which might be anticipated (a 50% chance of being exceeded in any given year), for each of the sub-catchments have been calculated. This is based on two different methods, the Flood Studies Update (FSU) 5 variable equation designed for small and

/ or urbanised catchments in Ireland, and the RPS derived Peat Q_{med} equation, derived in support of the Drainage Management Plan project for SAC sites on behalf of NPWS. Both methods result in very similar Q_{med} values where the proportion of arterial drainage (ARTDRAIN2) is assumed to match the proportion of the catchment managed by Bord na Móna (drained).

Table 2.1 Physical Catchment Descriptors of Sub-Catchments Draining the Bog

Sub-Catchment Number	Area (km^2)	SAAR (mm)	BFI	FARL	ARTDRAIN2	PEAT (%)	S1085 (m/km)	FSU5 Q_{MED} (m^3/s)	Peat Q_{MED} (m^3/s)
1	0.06	895.2	0.561	1	1	100	12.09	**0.027**	0.024
2	0.04	895.2	0.561	1	1	100	5.69	0.015	**0.016**
3	7.74	895.2	0.561	1	0.67	67	2.4	**1.630**	1.482
4	0.08	1045.29	0.673	1	1	100	4.59	0.028	**0.035**
5	5.33	882.7	0.551	1	0.56	56.2	2.52	**1.168**	1.011
6	0.03	1042.42	0.674	1	1	100	11.66	0.014	0.014
7	0.10	866.96	0.562	1	1	100	8.74	**0.038**	0.034
8	2.20	866.96	0.562	1	1	100	0.54	0.336	**0.509**
9	0.20	866.96	0.562	1	0.57	56.5	2.92	**0.057**	0.055
10	0.88	866.96	0.562	1	1	100	2.61	0.213	**0.230**
11	0.96	931.57	0.645	1	1	100	7.04	**0.288**	0.257

2.3 Hydrogeological and Soil Characterisation

Kilmacshane Bog and the surrounding area are underlain by dark limestone and shale and massive unbedded lime-mudstone bedrock which represents a locally important aquifer which is moderately productive in zones. Geological Survey of Ireland (GSI) tracing of karst features has not identified any significant features such as springs, swallow holes or turloughs in close proximity to the bog. Nevertheless the bedrock underlying Kilmacshane bog has potential to facilitate relatively high rates of baseflow / groundwater transfer. The soils covering the catchments are primarily peat, with some mineral alluvium, grey/brown podzolics and peaty gleys outside the extent of the bog. All of these soils would be considered to be moderately impermeable with the exception of the mineral alluvium which is highly permeable.

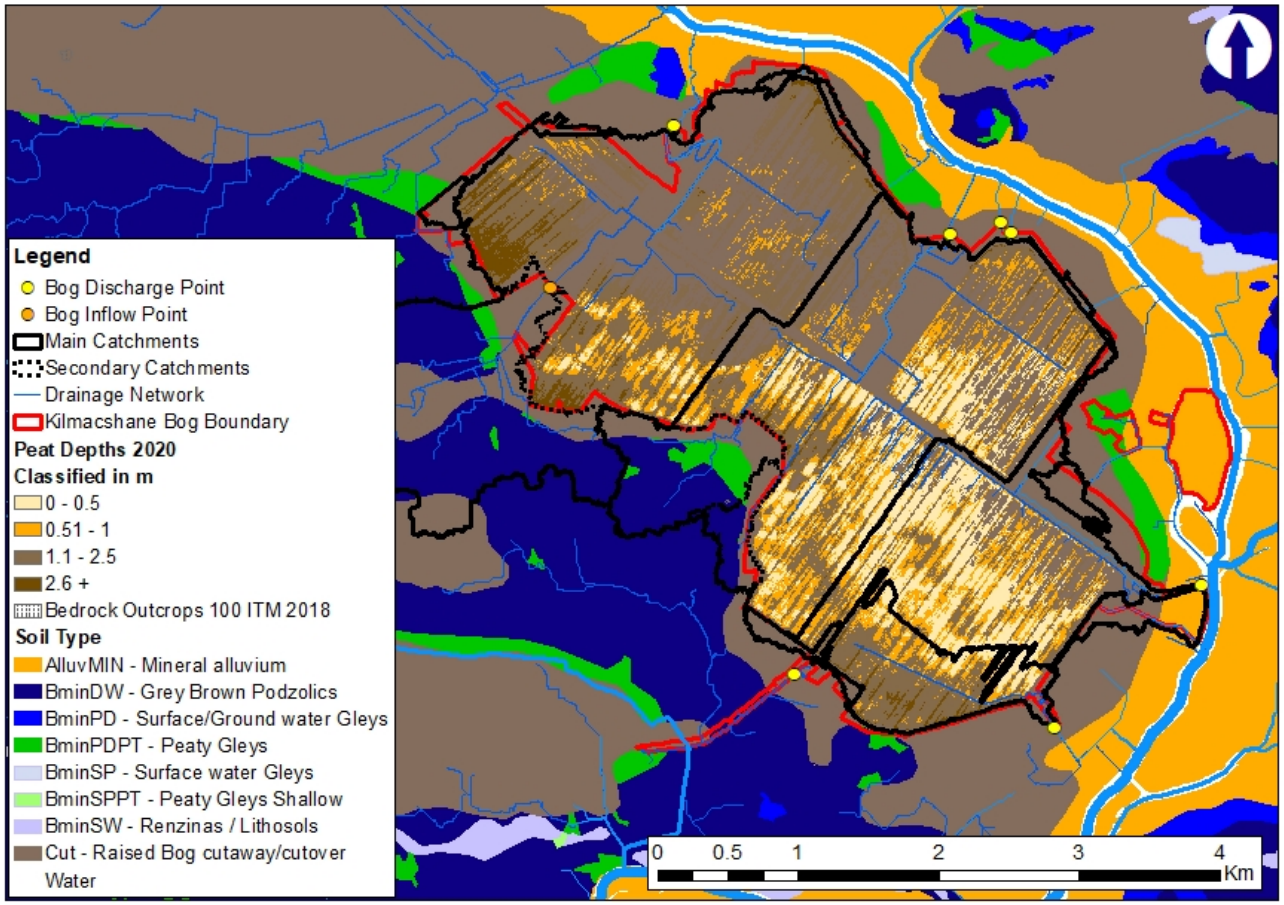

Figure 2.3 Hydrogeological and Soil Characteristics of Kilmacshane Bog

2.4 Morphological and Hydraulic Characterisation

A desk top review was carried out of bog drains and external drains. Morphological and hydraulic features were identified.

The external drains are generally small with gentle bed slopes. Aerial photography shows no signs of erosion or deposition however given that the drains are considered small with gentle bed slopes there would be a risk of deposition, and therefore reduced land drainage efficiency. Risk of deposition would occur where there is

potential for an erosion or debris source from the surrounding land and where there is potential head loss in the channel due to instream features. Figure 2.4 details the reaches of the external drains where there are potential erosion or debris sources and where instream features may facilitate deposition. The figure shows that due to the location of commercial forests, woodlands and disturbed peat in the surrounding lands there are existing potential sediment sources that could enter the external drains. Given the presence of culverts, sharp bends and inflows along the external drains there would be a potential of sediment settling and deposition occurring. The potential for Kilmacshane bog being a sediment source to the external drains is considered low due to the presence of silt ponds at all discharge points and that peat extraction activities have ceased.

A review of the bog drains was carried out. The Bord na Móna drainage survey details the open drains, pipes, settlement silt ponds, pump sumps and discharge points. All known discharge points have a silt pond located upstream which will reduce the amount of peat leaving the bog as water is drained. The drains in the bog have very gentle bed slopes and pass through numerous pipes before discharging from the bog. At two discharge points, pumps currently aid flow out of the bog into the adjacent land. It would be expected that the bog drainage network would be sensitive to drain and pipe alterations and the drain which receives an inflow from the adjacent land, as shown in Figure 2.4, needs careful consideration. A reduction in this drain's capacity has the potential to impact on the agricultural lands that drain into the bog.

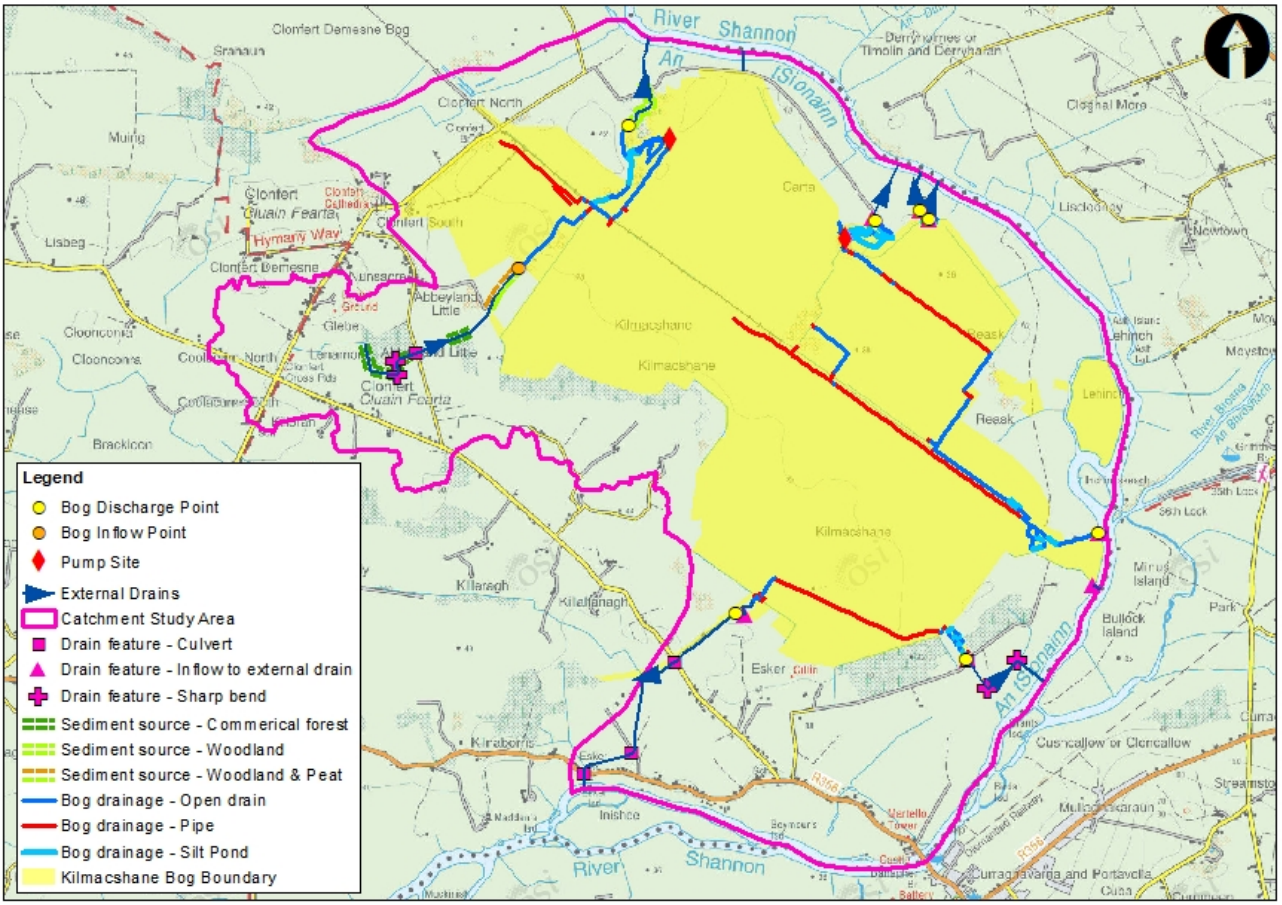

Figure 2.4 Morphological and Hydraulic Characteristics of Kilmacshane Bog and environs

2.5 Land Use Character

The majority of the land within the study area is peat bog and pasture. The remaining areas of the study area consist of less productive agricultural land with natural vegetation. The CORINE land use dataset was used to identify landuse types. This dataset was then reviewed using aerial photography to establish landuse amendments or land use alterations. The review found that additional commercial forests and woodland areas are located in the study area. There are some minor roads and properties located in the study area also.

The pasture land and agricultural land with natural vegetation is mainly used for livestock which provides food production. The commercial forests provide for timber production. The majority of the peat bog outside the Bord na Mona bog shows evidence of being harvested for domestic fuel production. Other areas of peat bog are undisturbed which contribute to carbon storage and biodiversity. The woodland areas are likewise providing carbon storage and biodiversity albeit as a different habitat to the peat bogs. The minor roads within the study area service properties and provide access to the pastures, forests and peat bogs.

In addition to the land use the River Shannon corridor runs adjacent to the Bog.

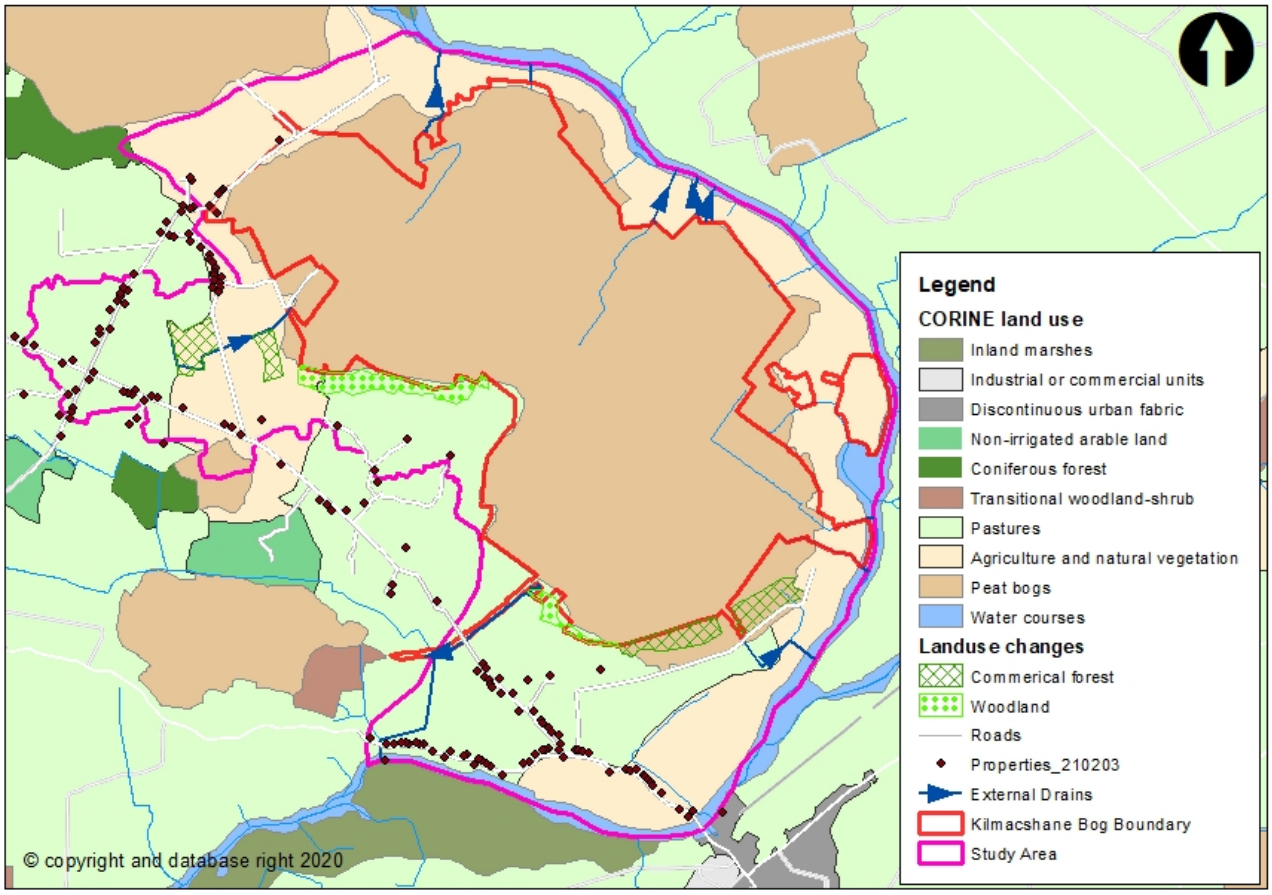

Figure 2.5 Land Use Characteristics of Kilmacshane Bog and environs

2.6 Flood Risk

A number of sources of flood risk information are available, both predicted and simulated, in proximity to Kilmacshane Bog. These include:

- CFRAM Study maps setting out the predicted fluvial 10%, 1% and 0.1% Annual Exceedance Probability (AEP) fluvial flood scenarios for the Shannon River
- GSI predicted groundwater flood maps for high, medium and low probability events
- Mapped fluvial flood extents for the 2009 flood event
- Mapped flood extents for the 2015 flood event (from Sentinel-1 satellite imagery) and a GSI surface water flooding dataset for the same event
- Anecdotal evidence from Bord na Móna

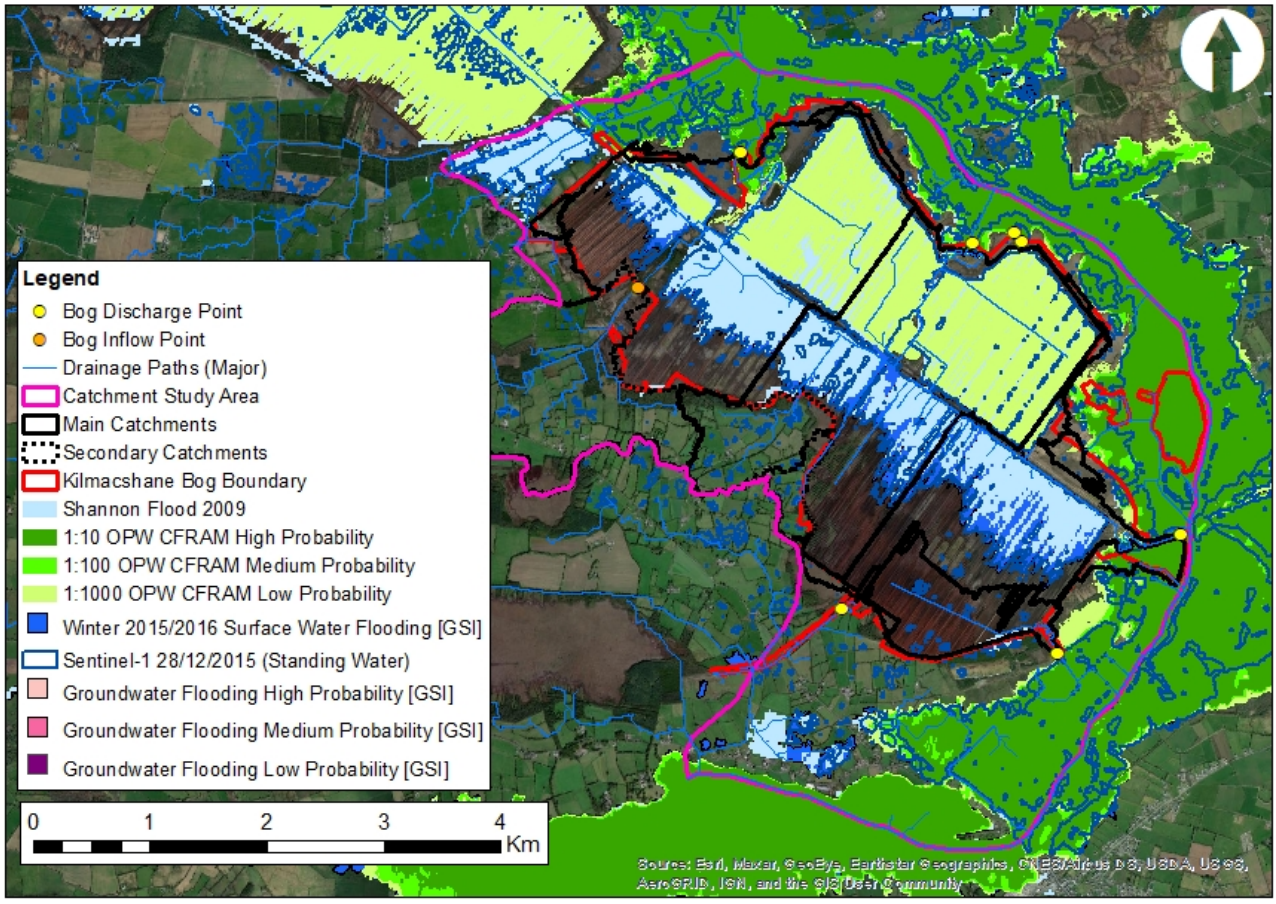

Figure 2.6 Flood Risk at Kilmacshane Bog

The 2009 and 2015 events on the River Shannon were very similar in magnitude with a peak water level of approximately 35.96m OD Malin recorded at the nearby Shannonbridge water level gauging station[1]. These are the largest peak water levels recorded in the 60 year record length at this gauging station and are estimated

[1] https://waterlevel.ie/0000026028/

to have had a return period of just under 1 in 100 years. The mapped flood extents for the 2009 and 2015 events are shown to inundate most of the Kilmacshane site.

The CFRAM Study maps show fluvial inundation of the main peat fields only occurring during a 1 in 1000 year return period event. It should be noted this analysis did not consider the fluvial flood risk from the smaller watercourses which drain to the Shannon or flooding arising from surface water / poor drainage.

Historical anecdotal evidence was reviewed to ascertain if there are any known flooding or drainage issues from these smaller watercourses to the bog or adjacent land. No drainage issues have been identified along the Kilmacshane Bog boundary drains other than that driven by Shannon water levels. Data from the 2015/16 flood event indicates flooding west of the centre of the main peat field and this is consistent with the local knowledge from Bord na Móna operatives familiar with Kilmacshane Bog.

There is no predicted groundwater flooding to the bog indicated on the GSI datasets.

2.7 Summary

The drainage network sub-catchments within Kilmacshane Bog and its environs were used to delineate the study area for the Kilmacshane Drainage Management Plan. The overall catchment area was characterised within the context of hydrology, hydrogeology, morphology, landuse and flood risk.

A detailed drainage network delineation was carried out. Drains within the bog and external drains were identified. The assessment showed that the bog discharges directly to the River Shannon or to drains which flow to the River Shannon.

The catchment area is considered to be relatively small, flat, fairly permeable with a low to moderate annual rainfall. Peak flood flows range from around 0.2 – 0.5 m^3/s per square kilometre (2 – 5 l/s per hectare) for the Q_{med} event to 0.6 – 1.5 m^3/s per square kilometre (6 – 15 l/s per hectare) for the Q_{100} year plus climate change event.

The bedrock within the catchment is limestone, however no karst features were identified in GSI records which could influence groundwater movement and flooding. The soil on top of the bed rock is mainly peat with some other soils in the higher ground. All soil types, with the exception of alluvium on the Shannon floodplain, are relatively impermeable which would restrict transfer of surface water to groundwater and vice versa.

The morphological and hydraulic characteristics of the external drains were assessed. No signs of erosion of deposition could be observed. Areas of deposition risk were identified along each drain. Culverts, bends and inflows were identified as potential factors for sediment deposition. Woodland, commercial forests and bare peat adjacent to the drains were identified as potential sources of sediment. Given that the drains are relatively flat the risk of deposition in the external drains is considered high.

The land use was assessed within the study area. The majority of land is peat bog. Pasture land and less productive agricultural land with natural vegetation make up a significant proportion of the study area also. The land provides important services such as food production, timber production, domestic turf cutting, carbon storage, biodiversity and habitat creation.

Table 2.2 summarises the constraints, risks and opportunities identified as part of the baseline assessment.

Table 2.2 Potential Opportunities / Constraints

Land Parcel / Feature	Risk or Opportunity?	Details
Agricultural land	Constraint	It is important to maintain the productivity of agricultural land surrounding the bog
Peat bog	Constraint	Where turf is still being extracted from other bog adjacent to Kilmacshane Bog conditions should be not be made worse.
Roads	Constraint	Two minor roads are located in the study area providing access to a dwelling, agricultural land and peat bogs. Access to these roads should be maintained.
River Shannon	Constraint	The River Shannon corridor runs adjacent to the bog. No activity should adversely impact this area.
External drains	Risk	Risk of deposition in the drains is considered high due to potential sediment sources in adjacent lands and features within the external drains. External drains may be sensitive to change.
Bog rehabilitation plan	Opportunity	To improve water quality discharging from the bog; stabilisation or improvement in water quality parameters (e.g. suspended solids)
Bog rehabilitation plan	Opportunity	To reduce carbon emissions from the bog and to set bog on a trajectory towards naturally functioning peatlands habitats. Kilmacshane has potential to develop embryonic Sphagnum-rich vegetation that has potential to be a carbon sink.
Bog rehabilitation plan	Opportunity	To improve biodiversity by vegetating bare peat and creating more habitat for flora and fauna.
Bog rehabilitation plan	Opportunity	To reduce runoff and restore a more natural runoff regime, thus contributing to flood risk management.

3 BOG REHABILITATION PLAN

The Kilmacshane Bog rehabilitation plan[2] consists of the following measures as summarised in Table 3.1 and presented in Figure 3.1.

Table 3.1 Kilmacshane Bog rehabilitation measures

Restoration	Description of measures
Deep peat restoration	Berms and field re-profiling (45m x 60m cell) + blocking outfalls and managing overflows+ drainage channels for excess water + Sphagnum inoculation
Deep peat restoration	More intensive drain blocking (max 7/100 m) + blocking outfalls and managing overflows
Dry cutaway restoration	Blocking outfalls and managing water levels with overflow pipes
Dry cutaway restoration	Regular drain blocking (3/100 m) + blocking outfalls and managing water levels with overflow pipes + targeted fertiliser treatment
Wetland creation	Turn off or reduce pumping to re-wet cutaway + blocking outfalls and managing water levels with overflow pipes + Targeted blocking of outfalls within a site
Wetland creation	Turn off or reduce pumping to re-wet cutaway + blocking outfalls and managing water levels with overflow pipes + Targeted blocking of outfalls within a site + constructing larger berms to re-wet cutaway + transplanting Reeds and other rhizomes
Wetland creation	More intensive drain blocking (max 7/100 m), + blocking outfalls and managing overflows + transplanting Reeds and other rhizomes
Other	Maintain silt ponds + reduce pumping regime

[2] For further details see Kilmacshane Bog Cutaway Bog Decommissioning and Rehabilitation Plan 2021 report

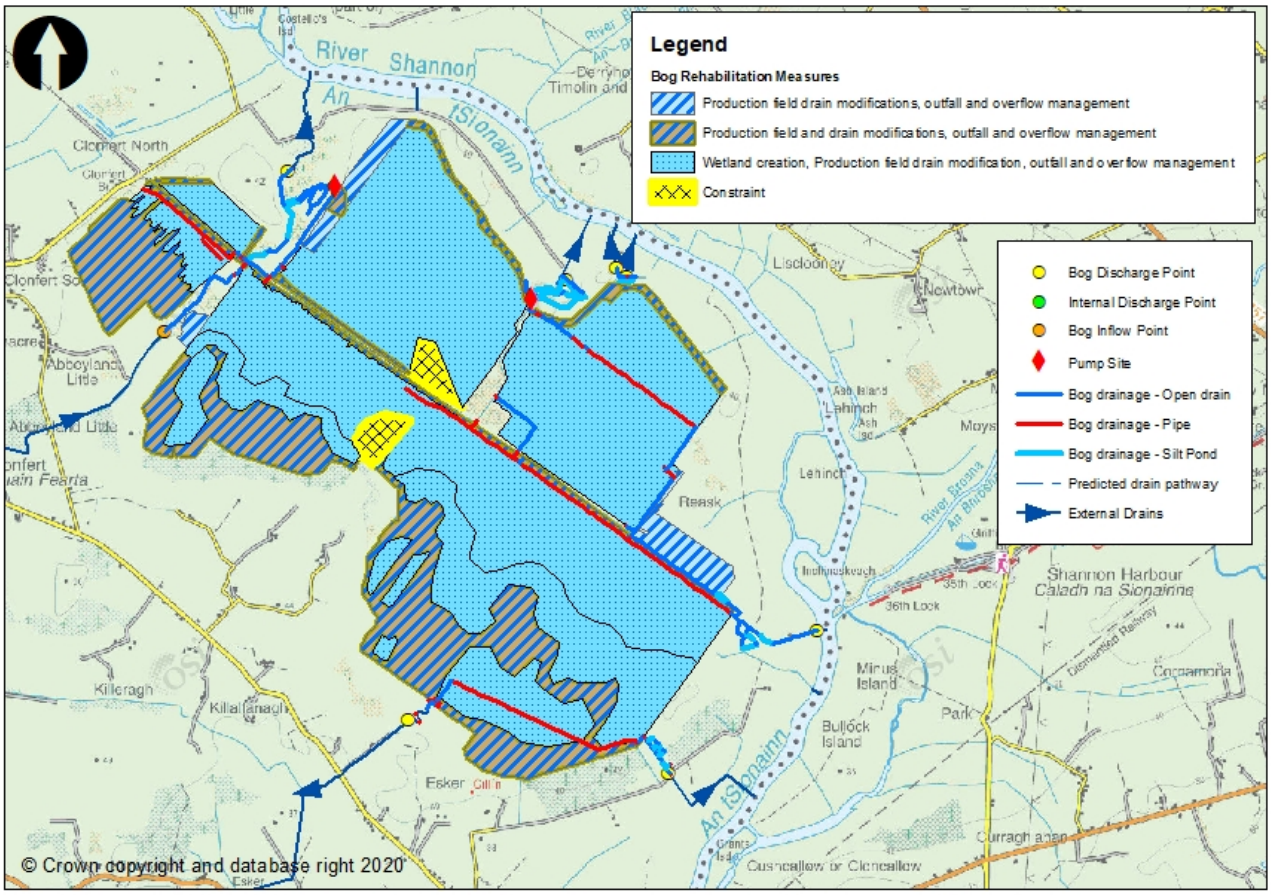

Figure 3.1 Kilmacshane Bog Rehabilitation Plan

Each measure while designed to promote the rehabilitation and re-wetting of the bog will have a potentially positive and/or negative impact on the adjacent land. This section identifies and assesses these potential impacts.

3.1 Impact Screening

Table 3.2 summarises the rehabilitation measures proposed for the Kilmacshane Bog and their potential impact to adjacent land.

Table 3.2 BRP measures proposed at Kilmacshane Bog

BnM rehabilitation measure	Description	Potential Impact	Potential Impact Description
Drain blocking, cell blocking, berm and field re-profiling	Existing production field drains within the bog areas that convey surface water away from the former peat production fields towards the bog discharge points will be modified to reduce conveyance or removed altogether by infilling.	Positive and negative	Reduced runoff from the bog discharge points resulting in less flow in the external drains located downstream. Reduced conveyance at bog inflow point resulting in increased water volume in external drain located

	Surface water runoff through the bog will be slowed allowing the bog to store more water		upstream if conveyance channels through the bog are blocked.
Blocking outfalls	Most production field drain systems drain into a headland pipe running perpendicular to the peat field. This location of the ditch/pipe intersection is known as an outfall. By blocking the outfalls each production field drain will be prevented from operating resulting in the ditch storing water and raising the groundwater level in the bog. This will allow the bog to store more water and bring the groundwater level to the surface.	Positive and negative	Reduced runoff from the bog discharge points resulting in less flow in the external drains located downstream. Raised groundwater levels to the bog surface will create a hydraulic gradient across the bog into the adjacent land. Ground water levels in lands within this hydraulic gradient will potentially rise. The effect will be greatest immediately beside the bog.
Managing overflows with overflow pipes	This measure is usually combined with blocking outfalls which cause groundwater levels to rise. As the bog fills up it will want to overtop at the lowest part of the bog boundary. Overflow pipes control the location this occurs and where the overtopping water is discharged to.	Neutral	The control features will determine the location of the discharge from the bog. However the flow leaving the bog once it is full will be the same as prior to remedial works. Overall the volume of water discharging from the bog will be reduced but will contribute to raised groundwater levels within the bog and potentially within the zone of influence (subject to mitigation).
Drainage channel for excess water	This measure will work in conjunction with the overflow features. Where suitable drainage channels do not exist or are of insufficient capacity along the bog boundary, a new or upgraded drainage channel will be provided. These drainage channels will convey all flows from the bog to suitable watercourses.	Positive	Drainage channels of sufficient capacity will ensure any overtopping water from the bog does not enter adjacent land. Drainage channels will also act as a hydraulic break in groundwater limiting the impact of bog measures to the groundwater in adjacent lands.
Turn off or reduce pumping	Existing pumps that aid discharge flow from the bog would be turned off or reduced to reduce the discharge and promote the rewetting of the bog.	Positive and negative	Reduced runoff from the bog discharge points resulting in less flow in the external drains located downstream. Raised groundwater levels to the bog surface will create a hydraulic gradient across the bog into the adjacent land. Ground water levels in lands within this hydraulic gradient will potentially rise. The effect will be greatest immediately beside the bog.

			Unintended spill points may occur into adjacent land should water levels be allowed to rise.
Sphagnum moss inoculation	This measure will propagate sphagnum moss within the bog. Sphagnum moss will cause bog regeneration as it grows and layers.	Positive	Sphagnum moss can hold up to 10 times its weight in water. As such this measure will store water reducing the runoff from the bog into the exterior drains. This will help retain the external drainage efficiency which adjacent land relies on. This measure may also contribute to runoff reduction and wider catchment FRM goals but in a piecemeal way.
Silt ponds	Existing silt ponds will be maintained to store runoff water from the bog and allow any suspended peat to settle out of the water before it is discharge to the external drains.	Neutral	Maintained capacity from the bog discharge points to the external drains and river located downstream. Maintained quality of water being discharged from the bogs into the external drains or river.
Wetland creation	Areas prone to flooding are designated for wetland creation. Standing water will be allowed to occur resulting in increased water storage. Establishment of reeds and other rhizomes will form part of the wetland creation.	Positive and negative	Reduced runoff from the bog discharge points resulting in less flow in the external drains and river located downstream. Raised groundwater levels to the bog surface will create a hydraulic gradient across the bog into the adjacent land. Land within this hydraulic gradient will potentially rise. The effect will be greatest immediately beside the bog.

3.2 Impact Assessment

Three potential impact sources were identified; groundwater rise, increased runoff from the bog and reduced drainage capacity into the bog. These impact sources have the potential to make the adjacent land wetter and drain less efficiently. An assessment was carried out to delineate the zone of influence resulting from these potential impact sources. Figure 3.2 presents the areas which are at potential risk.

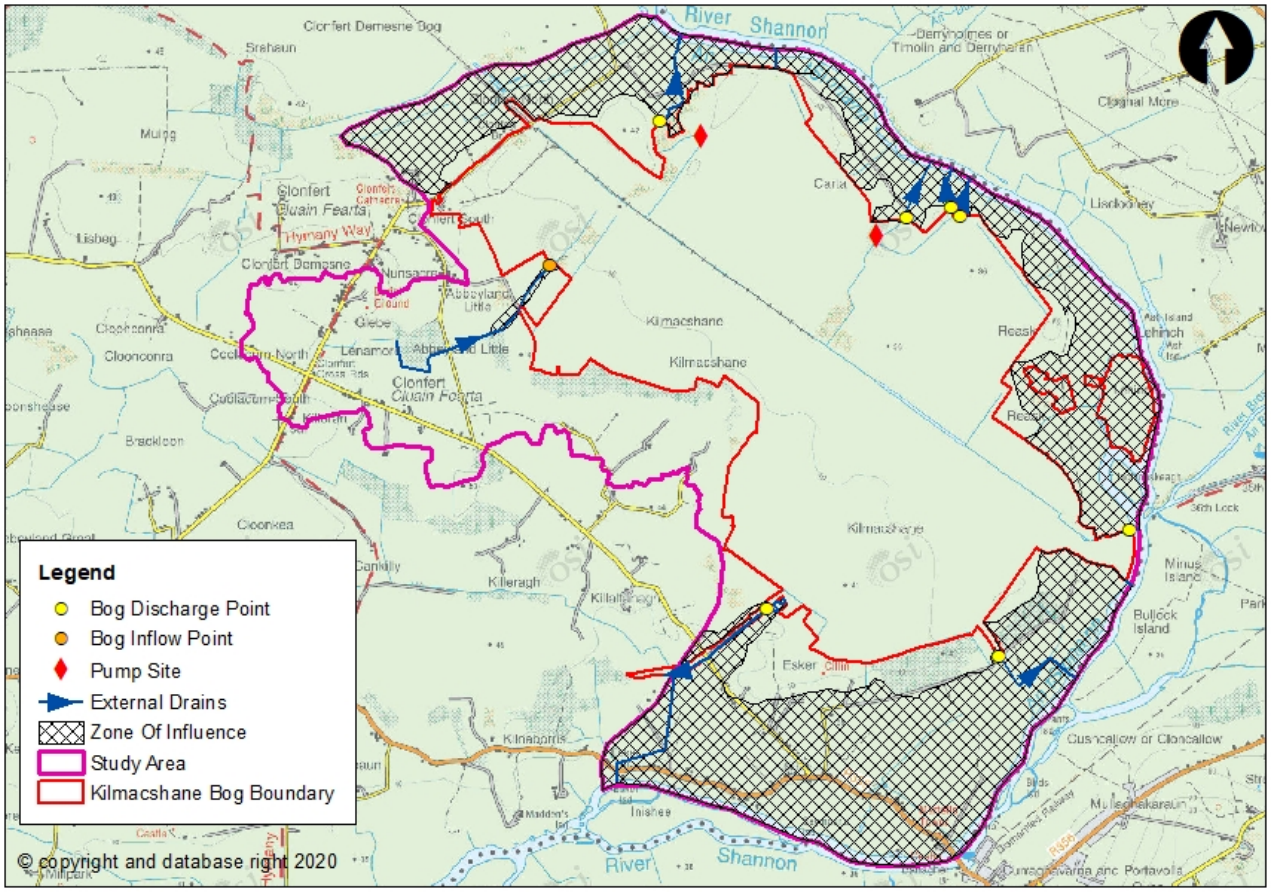

Figure 3.2 Kilmacshane Bog Rehabilitation Plan – Zone of influence

3.2.1 Groundwater Impact

The impact of rehabilitation measures on groundwater levels within and adjacent to the bog is difficult to assess quantitatively in the absence of long term monitoring data and hydro-geological models of the bog. Nevertheless it can be assumed that groundwater levels will rise within the bog itself given that this is an objective of the rehabilitation measures – to restore the hydrological conditions for peat formation. It is assumed that the maximum level which groundwater will reach outside areas zoned as wetland is the surface of the peat fields post-rehabilitation. For areas zoned as wetland the maximum water level will be above surface level as water ponding is promoted through rehabilitation measures.

Groundwater rise in lands adjacent to the Kilmacshane Bog was assessed firstly by estimating the potential rise in groundwater within the bog. The drainage system in the bog is, on average, 1.4m deep. It can be

expected that groundwater could rise by up to 1.4m to bring it to the surface in non-wetland areas. Water level rise in wetland areas is expected to be greater and will be determined by the higher surrounding bog fields or headlands and by the outlet control to the wetland area. As the groundwater rises in the bog a head water difference will be created between the bog and adjacent land forming a hydraulic gradient (see Figure 3.3a and 3.3b). Groundwater will flow across the hydraulic gradient. This flow will be dependent on the porosity of the ground it flows through and the head difference. This will determine the extent of the zone of influence and the area of potentially wetter ground. Where external drains are located in the zone of influence they will act as a hydraulic break or groundwater cut-off and reduce the zone of influence (see Figure 3.3c). This however is dependent on the drain's ability to convey water away. Drains that are inefficient with high water levels (independent from the bog rehabilitation measures) will also raise the groundwater and the adjacent lands to the bog would be wet (see Figure 3.3d). The avoidance of the drain full condition is dependent on maintenance of a positive gravity drainage function of the boundary drains through monitoring and maintenance.

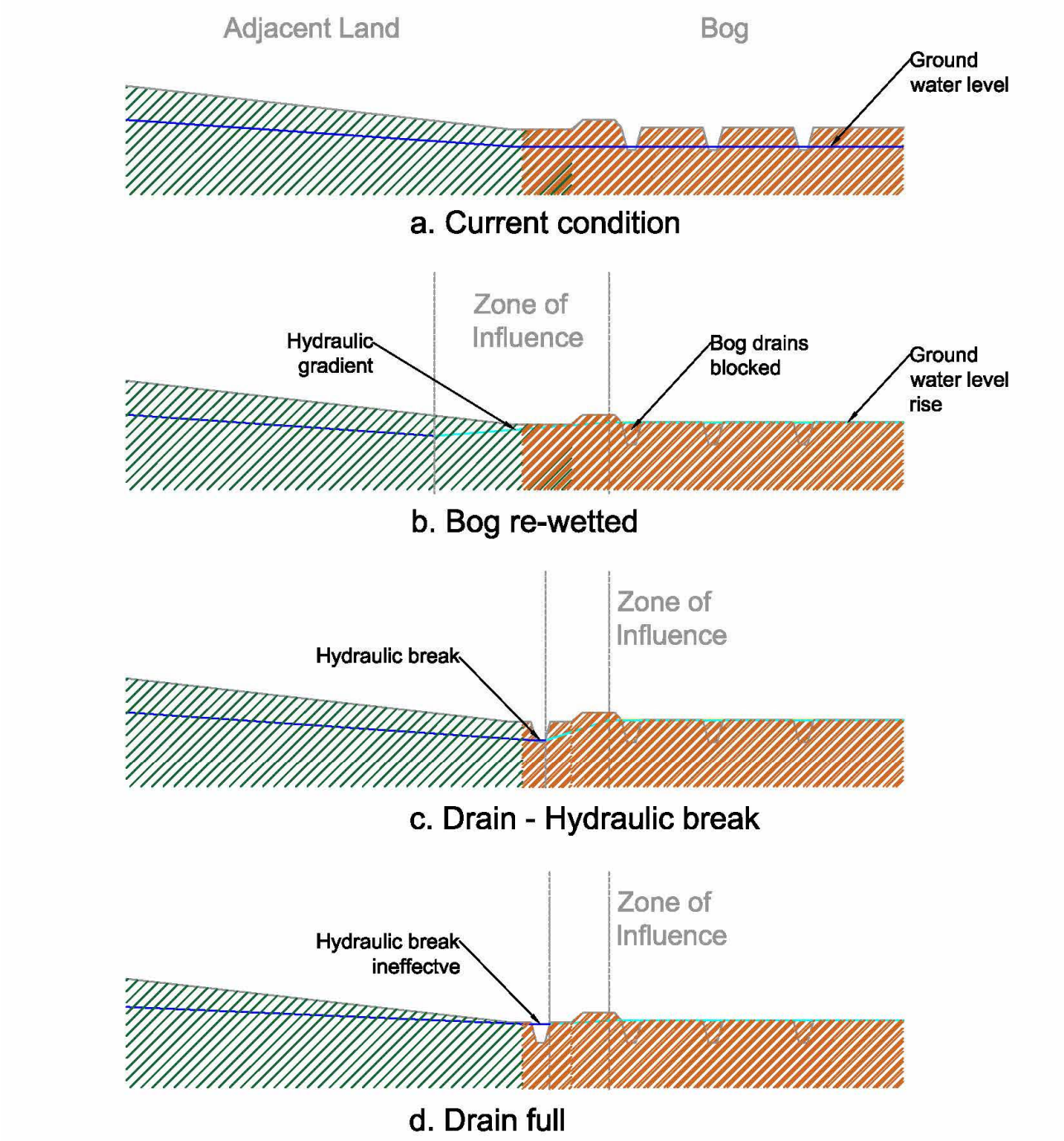

Figure 3.3 Conditions affecting groundwater

A complete survey of the boundary and external drains which provide the groundwater cut-off function to agricultural lands was not available for Kilmacshane Bog. It is assumed that these drains would be able to convey Q_{med} (2 year return period) flows under non-backwater conditions which would be typical of natural watercourses in Ireland. Therefore under non-flood conditions it is expected that the external drains identified around Kilmacshane Bog will act as a hydraulic break to any hydraulic gradient created by bog re-wetting. However there is a risk that should the flow regime in any external drain be changed post rehabilitation that the land adjacent to the drain would become wetter.

There is also a risk that as the bog fills with water and wants to discharge, that unintended discharge locations would occur. A review of the bog boundary was carried out. Potential spill points were identified to the South West of the Westernmost pumped discharge point. Water levels in this area would need to rise significantly before water would spill into the Shannon via the Abbeyland Little. The target water depth in the rehabilitation plan, however, would be much lower than this. The water levels will therefore be regulated by suitable discharge control measures ensuring that no unintended spills occur. The north east boundary of the bog discharges directly in the River Shannon. As such there is little risk to adjacent lands should there be increased flows from the bog owing to elevated groundwater levels. However as previously set out this is based on the ability of the existing boundary drainage network, separating the bog from adjacent lands at a lower level, to provide a positive gravity drainage function in relation to groundwater entering the drain. In other words capacity to convey Q_{med} or 2 year return period flows and a free flow (constantly falling) away from the bog.

3.2.2 Insufficient Drainage

It is a significant concern for adjacent landowners that restoration and rehabilitation measures could lead to localised impacts in terms of reduced drainage leading to flooding of agricultural lands upstream of the bog.

There is one inflow location to Kilmacshane bog (Figure 3.2) which connects to a drain which flows north through the bog. Should this drain's function and capacity deteriorate, low lying parts of the upstream land may reduce in drainage efficiency. This low lying land was identified and included in the zone of influence (see Figure 3.2).

An assessment of the external drains was carried out in chapter 2. Various features were identified that may reduce the drains flow capacity. Culverts, bends, deposition and flooding backwater were identified as potential features that could reduce flow capacity. The drain which serves the lands in question flows into the south west extent of Kilmacshane bog and is currently a mix of open drain with culverted sections. The continued drainage of the lands identified is dependent on the continued performance of this drain and as such its ability to freely drain must be retained.

3.2.3 Increased Runoff

Evidence from bogs that have previously been the subject of restoration measures demonstrates that the measures proposed at Kilmacshane, which are all aimed at reducing runoff and retaining water within the bog, have the effect of reducing the frequency and magnitude of flood events by restoring a more natural hydrological regime. Restoration / rehabilitation has been successfully applied to numerous Bord na Móna bog sites as well as SAC sites such as Clara Bog (East), Raheenmore Bog, Carrownagappul Bog and Lisnageeragh Bog. Elsewhere, the restoration of peatland catchments in numerous sites across the UK, such as Exmoor National Park in Snowdonia, has demonstrated positive flood alleviation following rehabilitation measures. Monitoring found that this occurred as runoff from the moorland was reduced due to increased storage in the peat.

The risk of increased runoff from Kilmacshane Bog is low. All rehabilitation measures being proposed will reduce runoff. However there is a potential that if bog re-profiling is carried out as part of the bog rehabilitation measures that the bog sub-catchments will be modified. Changes in sub-catchments could result in certain

discharge points draining larger areas. This would result in increased flows that could outweigh the effect of the reduced runoff arising from the rehabilitation. This is a moderately low risk at Kilmacshane as the re-profiling of the bog will generally result in the same topographical flow paths, catchment watersheds and discharge locations as in the pre-rehabilitation state. However in the absence of a full pre and post rehabilitation runoff model and in line with a precautionary approach it is prudent that all drainage infrastructure from the bog is fit for purpose and retained such that at a minimum capacity to convey high frequency flood events (Q_{med} or 2 year return period) is provided.

3.3 Potential Risk Areas

The assets that have been identified as being at potential risk from flooding or wetter conditions as described in Table 3.1 are shown in Figure 3.4.

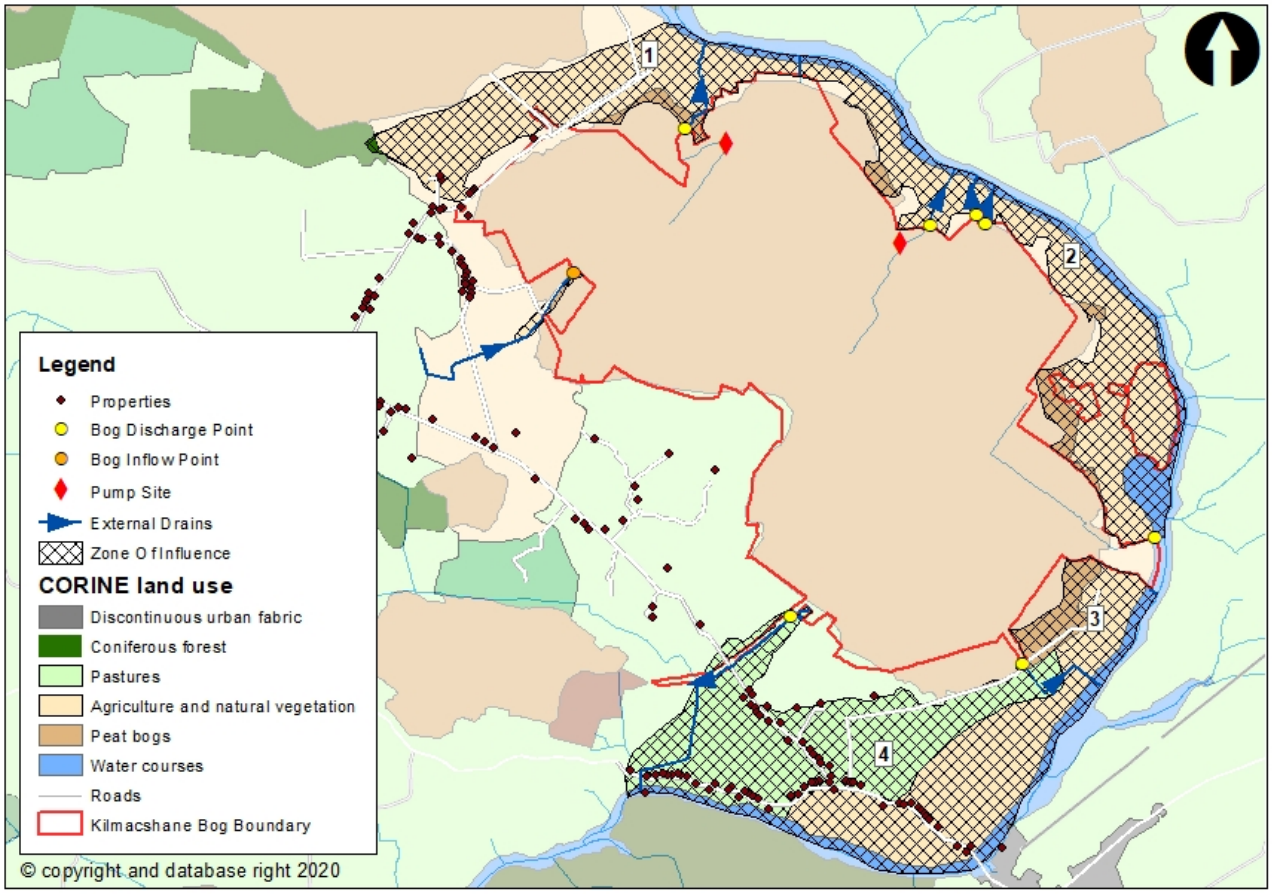

Figure 3.4 Kilmacshane Bog Rehabilitation Plan – Assets at risk

The assets at risk are set out in Table 3.2 along with the vulnerability, based on the current land use, of the asset. It should be noted that the appraisal of the assets at risk is considering the consequences of flooding or wetter conditions, not the likelihood of flooding or wetter conditions occurring.

Table 3.2 Assets at risk

Item	Asset	Vulnerability to flooding and/or wetter conditions
1	Peat and agricultural land with natural vegetation	Low-High vulnerability. Peats can tolerate wetter conditions. Agricultural land would become less productive should it be made wetter.
2	Peat and agricultural land with natural vegetation	Low-High vulnerability. Peats can tolerate wetter conditions. Agricultural land would become less productive should it be made wetter.
3	Peat and agricultural land with natural vegetation	Low-High vulnerability. Peats can tolerate wetter conditions. Agricultural land would become less productive should it be made wetter.
4	Agricultural land and agricultural land with natural vegetation	High Vulnerability. Land would become less productive should it be made wetter.
5	Roads	Low vulnerability. Road level slightly higher than surrounding land. Risk of flooding is low.
6	Properties	Moderate – High Vulnerability. Although the impact of wetter ground conditions or flooding to properties would be considered high, the location of these properties is mostly away from the bog at the limit of the zone of influence or the level of the property is at a higher elevation than the surrounding land. Properties at low elevations are considered high risk. A number of the properties are agricultural sheds which would be more resilient to any potential flood risk.
7	River Shannon	Low Vulnerability. Water quality would reduce with increased sediment entering the River Shannon. Existing silt ponds would continue to manage sediment. Vulnerability is therefore considered low.

In addition to the above risks there is a general low risk that should degradation of the bog boundary occur surface water could be released into adjacent lands.

4 OBJECTIVES

The overarching objective of the Kilmacshane Drainage Management Plan is to facilitate the rehabilitation of bog through management of potential adverse impacts to adjacent land and waterbodies. SMART[3] objectives were developed for the Drainage Management Plan that provides direction for the overarching objective. These objectives consider constraints, risks and opportunities that were identified in chapters 2 and 3 and are detailed as follows:

1. To manage potential groundwater impacts between adjacent land and Kilmacshane bog during and after rehabilitation measures.
2. To retain the current drainage capacity of the agricultural land flowing into Kilmacshane Bog both during and after the rehabilitation measures.
3. To maintain or reduce flows released from the bog at the discharge locations.
4. To reduce sediment entering the River Shannon during and after rehabilitation, these measures are to ensure compliance with current discharge limits in IPC Licence.

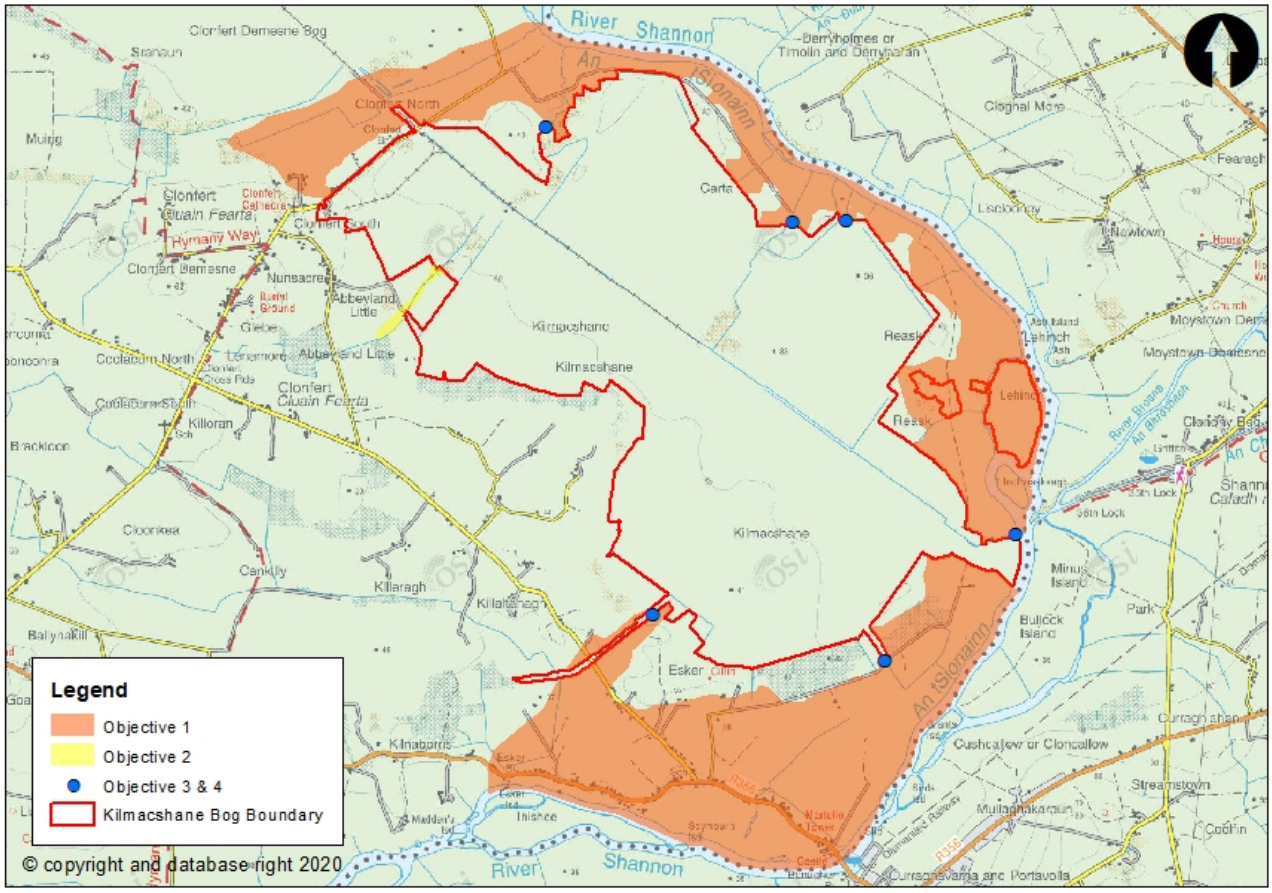

Figure 4.1 Kilmacshane Bog DMP objectives

[3] SMART – Specific, Measureable, Achievable, Relevant, Time bound

5 DRAINAGE MANAGEMENT MEASURES

5.1 Key drainage features

Drainage management measures were identified in relation to the objectives set in chapter 4 and are described below. Objective 1 considers the potential impact to adjacent land from groundwater rise. Objective 2 considers the existing drainage network flowing into and through the bog. Objectives 3 and 4 consider the control mechanisms to flow discharging from the bog.

An assessment was carried out to identify the key drainage features required to meet the objectives set. Figure 5.1 presents these features. For groundwater level rise to be managed between the bog and adjacent land existing drains acting as hydraulic breaks can be used. Many of these drains are located on high ground relative to the inner bog and adjacent lands and will therefore have limited effectiveness in providing a hydraulic break. Alternative mitigation measures are therefore required. To ensure that the land draining into the bog is not impacted the drainage path through the bog will need to be retained. And to ensure that the flow and sediment discharging from the bog is managed the discharge control points will need to be maintained.

Although outside the Bord na Mona bog boundary key external drains were identified. These drains are hydrologically connected to the bog drainage network. While no drainage issues were identified along these external drains, see section 2.4, a risk of sediment deposition was highlighted from sources outside the bog. The maintenance of the existing silt ponds will ensure that the bog will not contribute to an increased risk of sediment deposition arising from rehabilitation. Should this occur drainage from the bog could be impeded and adjacent land could become wetter.

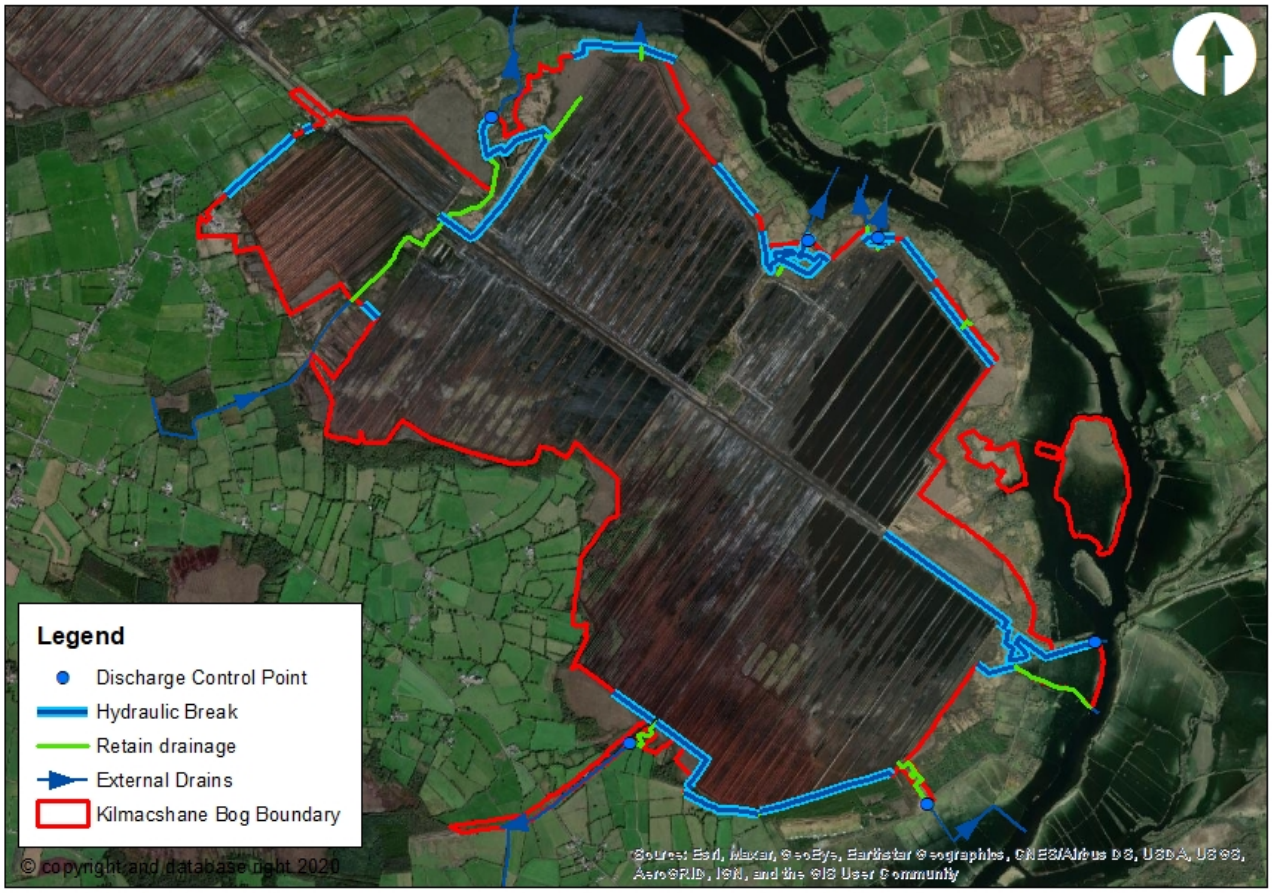

Figure 5.1 Key drainage features for Kilmacshane Bog

When identifying measures to provide the key drainage features a review was carried out of the drains. The review found that there is limited data available for boundary drains to the bog and external drains within the adjacent land. While data is available for internal drains this was found to be limited also. It was therefore required to produce a Drainage Management Plan that could offer a suite of measures whereby the most appropriate measures can be selected based on the level of robustness and on-site observations. The DMP would therefore allow the bog to be managed and adapted as the rehabilitation plan progresses and is retained in the future. The following sections describe the suite of measures that can feasibly be implemented for the Kilmacshane Bog Drainage Management Plan.

5.1.1 Boundary drains

Boundary drains can provide hydraulic breaks between the bog and adjacent land, see Figure 3.3. In most areas of the Kilmacshane Bog there are existing boundary drains albeit located on higher ground to the inner bog and adjacent land. Available information indicates that these drains are suitable to provide hydraulic breaks and can be designated as such and retained in the future. Observing and recording the suitability of the boundary drains is recommended and where they are found to be not functioning as predicted upgrade works will be required. This would involve modification of the drain to make them larger/deeper/wider/steeper. This may be only in specific locations along the drain or an entire reach may require upgrading. Where there is no boundary drain present a new drain can be excavated in order to create the hydraulic break required. In these cases a channel of specified dimensions and slope will be required.

5.1.2 Bog rehabilitation modification

Where a boundary drain is not suitable to act as a hydraulic break or where none exists it may be possible to review the bog rehabilitation plan to provide the required mitigation measure. This can take the form of sacrificing rehabilitation of the last peat field, closest to the adjacent land where an existing field drain could provide the hydraulic break function. The field's drainage network would be retained keeping the groundwater to current conditions and providing a groundwater cut-off in relation to the adjacent land.

In areas zoned as wetland within the rehabilitation plan control of the water levels may be required. Where there is a potential backwater into adjacent lands or where raised water levels could potentially raise ground water on adjacent lands setting a maximum permissible water level may be required.

5.1.3 Internal drain retention

Drains within the bog that include adjacent land within their sub catchment may need to be designated as key drainage features and retained to ensure that the drainage to the adjacent land does not deteriorate.

5.1.4 Maintenance of silt ponds

Existing silt ponds are located upstream of the bog discharge points. They help regulate the flow and level of suspended peat leaving the bog into the external drains and rivers. Bord na Móna have legal responsibility to maintain these silt ponds and ensure their proper functioning capacity under the existing IPC Licence (Ref. P0502-01).

5.1.5 Monitoring

As mentioned above DMP measures were selected based on level of certainty and on-site observations. The most appropriate measure was selected from a suite of measures representing varying levels of intervention. Monitoring of the measure and adjacent land will be required prior, during and after the rehabilitation measures. A monitoring programme can be implemented to observe the impact from the bog rehabilitation to the adjacent land. Monitoring would be observational where the condition of the asset in question is assessed in relation to present day conditions accounting for seasonal variability. Where negative impacts are observed other measures can be implemented that will establish a hydraulic break. Otherwise monitoring should continue until environmental stabilisation.

5.2 Drainage assessment

A review was carried out of the existing drainage networks falling within the key drainage features as shown in Figure 5.1. These drainage networks were reviewed to the confluence with streams in order to identify potential downstream control features.

The estimated flood flows were compared with the hydraulic capacity of each of the control features which are important to the effective performance of the drainage network.

Two methods have been considered for the derivation of the Index Flood flow (Q_{med}) as set out in Section 2.2. There is a high degree of uncertainty in the estimation of flood flows at the small catchment scale and therefore

the larger of the two estimates has been chosen for each sub-catchment in line with a precautionary approach to uncertainty. Flood flows for Q_{med} (50% AEP) and Q_{100} (1% AEP) peak flows for each sub-catchment have been calculated. A generalised growth curve for peat catchments in the midlands has been used, whereby a growth factor of 2.3 has been used to scale up the Q_{med} peak flow to determine the Q_{100} event (100 year return period flood event).

The best projections on the effect of climate change have been applied to determine the Mid-Range Future Scenario (MRFS). This represents a 20% uplift over the present day flood flows.

Table 5.1 Peak Flows in Each Sub-Catchment

Sub Catchment	Q_{med} / 50% AEP	Q_{100} / 1% AEP	Q_{100} / 1% AEP MRFS
1	0.027	0.064	0.076
2	0.016	0.038	0.046
3	1.630	3.846	4.615
4	0.035	0.082	0.099
5	1.168	2.755	3.307
6	0.014	0.034	0.041
7	0.038	0.090	0.108
8	0.509	1.202	1.443
9	0.057	0.134	0.161
10	0.230	0.543	0.652
11	0.288	0.679	0.815

5.2.1 Assessment Points

Assessment Points have been assigned at key / critical points within the drainage network identified in Figure 5.1 as providing a key drainage management function. The location of the Assessment Points is provided in Figure 5.2.

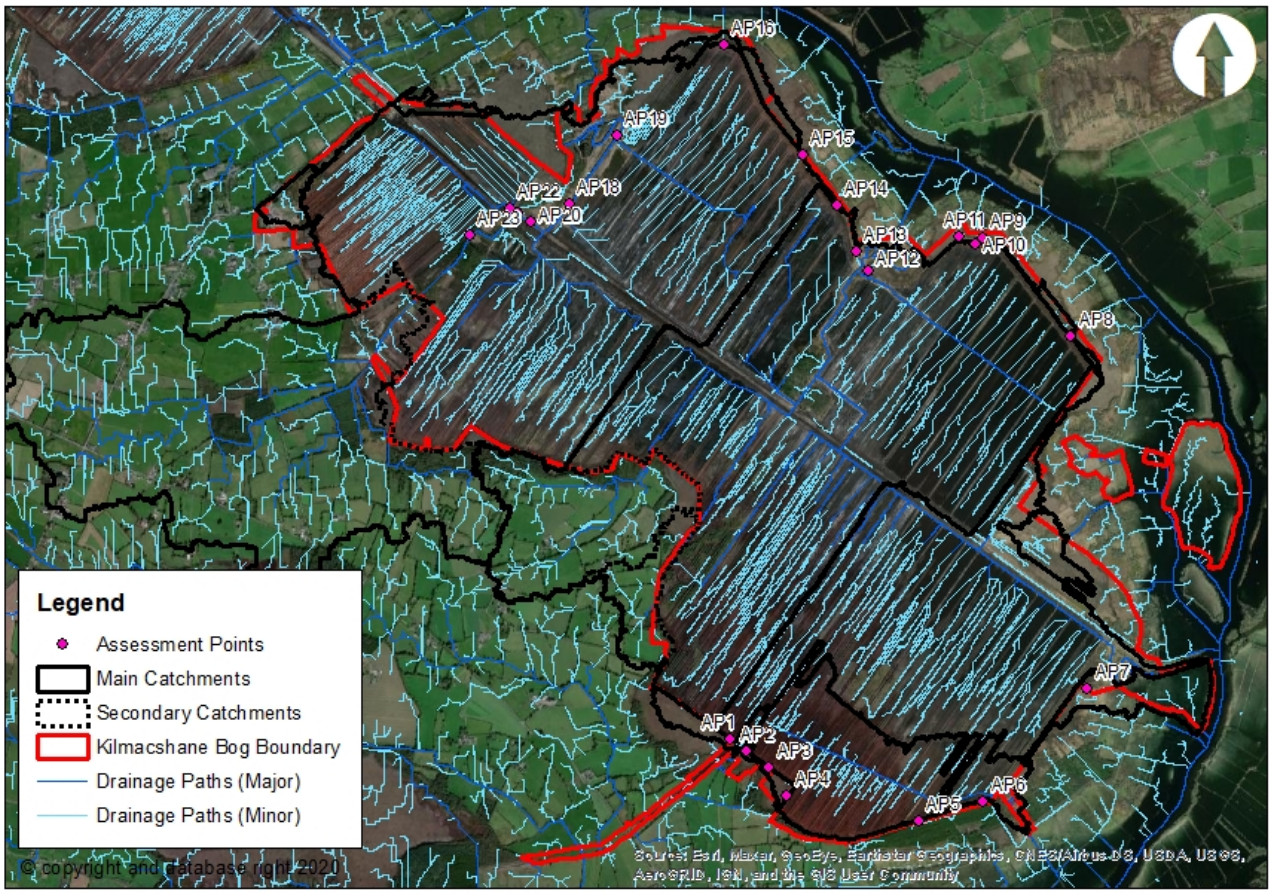

Figure 5.2 Assessment Points at Kilmacshane Bog

5.2.2 Hydraulic Analysis

The peak flows at each Assessment Point (AP) have been compared to the estimated hydraulic capacity of each of the features. A summary of the flood flows that may be generated at each AP along with their likely capacity to convey these flows is summarised below in Table 5.2. Note that capacity issues at an AP may have knock on impacts in terms of flooding for the APs upstream which is not captured in this point by point capacity check.

Table 5.2 AP Capacity

Ref.	Sub-catch.	Feature Type	Flood Flow Range (m^3/s)	Capacity & Recommendations
AP_1	11	Boundary Drain	0.135 - 0.383	Capacity to convey all flood flows.
AP_2	11	Pipe	0.198 - 0.561	No data available. **Check pipe capacity when conditions allow.**
AP_3	11	Boundary Drain	0.166 - 0.470	Capacity to convey QMED flows.
AP_4	11	Boundary Drain	0.018 - 0.052	Capacity to convey flood flows but very shallow.
AP_5	10	Boundary Drain	0.070 - 0.198	Capacity to convey all flood flows.

Ref.	Sub-catch.	Feature Type	Flood Flow Range (m^3/s)	Capacity & Recommendations
AP_6	10	Boundary Drain	0.038 - 0.109	No defined drain at this location. Peat field face bank.
AP_7	8	Boundary Drain	0.073 - 0.207	Very shallow drain at face bank. Capacity to convey QMED.
AP_8	5	Boundary Drain	0.023 - 0.064	Capacity to convey all flood flows.
AP_9	5	Boundary Drain	0.245 - 0.695	No evidence of drain at this location.
AP_10	5	Boundary Drain	0.254 - 0.719	No evidence of drain at this location.
AP_11	5	Boundary Drain	0.039 - 0.111	Capacity to convey QMED flows
AP_12	5	Boundary Drain	0.056 - 0.158	Capacity at QMED. Check for / clear potential constriction at this location.
AP_13	5	Pipe	0.247 - 0.700	No data available. **Check pipe capacity when conditions allow.**
AP_14	5	Boundary Drain	0.009 - 0.025	Capacity to convey all flood flows but may not provide effective hydraulic break due to height above peat field.
AP_15	3	Boundary Drain	0.116 - 0.329	No clearly defined drain at this location. No significant catchment draining to this location.
AP_16	4	Boundary Drain	0.146 - 0.413	Capacity to convey all flood flows.
AP_17	3	Boundary Drain	0.012 - 0.034	Capacity to convey all flood flows but very shallow.
AP_18	3	Boundary Drain	0.256 - 0.725	Capacity to convey all flood flows.
AP_19	3	Boundary Drain	0.566 - 1.603	Capacity to convey all flood flows.
AP_20	3	Boundary Drain	0.081 - 0.228	Capacity at QMED. No fall in drain.
AP_21	3	Pipe	0.714 - 2.023	No data available. **Check pipe capacity when conditions allow.**
AP_22	3	Pipe	0.049 - 0.138	No data available. **Check pipe capacity when conditions allow.**
AP_23	3	Internal Drain	0.703 - 1.991	Capacity at QMED.

5.3 Identification of measures

The review of drain capacities found that most open drains are likely to have sufficient capacity to convey flow away from the bog. They would therefore be suitable to act as hydraulic breaks provided they are maintained with their current estimated carrying capacity. Two reaches of drain were identified as requiring a higher level of intervention. Section 2.6 indicates how all boundary drains appear to be functioning sufficiently with no known drainage issues identified along the drain or in adjacent land. Although there is no survey data for some reaches the anecdotal evidence suggests that the boundary drains identified for retention are functional and can be used as drainage management measures. They would therefore be suitable to act as hydraulic breaks provided they are retained with their current estimated carrying capacity.

While internal and boundary drains were identified for retention to act as hydraulic breaks many are located on relatively high ground and will be limited in their effectiveness. As such DMP measures were identified to

control of water levels in the wetland areas. By ensuring water levels remain below set levels the risk of ground water flow across the bog into adjacent land and subsequent ground water rise would remain low. DMP measures 21 to 24 propose that the maximum water level in the wetland areas is controlled to provide a freeboard of 500mm to the adjacent land draining into the bog. Where it is required to adjust outfalls as part of the rehabilitation measures the invert of the outfall that regulates the maximum water level will not be set higher than 34.0mOD for DMP 21, 22 & 24, and 34.5mOD for DMP measure 23. It should be noted that during extreme flood conditions, that are beyond Bord na Móna's control, water levels in the wetland areas may rise above the invert of the outfalls as they regulate the discharge. If necessary, the proposed wetland areas can be adapted to function as silt control measures before the relevant part of the bog discharges to the Shannon. A review of the internal drains would be required to ensure no drain bypass the wetlands. These measures will keep the water levels sufficiently low in the wetlands so as not to increase the risk of ground water rise in adjacent lands.

DMP measure 2 refers to an internal drain identified for retention to ensure the continued drainage of adjacent lands through the bog.

DMP measure 4 refers to a length of new drain required to ensure that the area excluded from the rehabilitation plan (DMP measure 18) can drain freely from the bog.

DMP measure 10 refers to a reach of boundary drain recommended for upgrade. This drain would act as a hydraulic break but would require deepening in order to function efficiently.

DMP measures 18 - 20 identified areas of bog proposed for rewetting in the rehabilitation plan that are recommended for exclusion. This is due to there being no suitable boundary drain to function as a hydraulic break with the adjacent land and where the adjacent land is level or lower than the bog and as such would be vulnerable to ground water level rise.

DMP measure 26 refers to pumped discharge points which will be turned off as part of the rehabilitation plan. When this occurs, there will be a risk of increased water depths in wetland areas and unintended spill points occurring from the bog. The rehabilitation plan will likely require a new discharge configuration at these locations. The function of discharge points should control the silt and flow from the bog.

The remaining measures are of low intervention consisting of maintaining the existing features or monitoring lands and features.

Table 5.3 and Figure 5.3 details the level of intervention required.

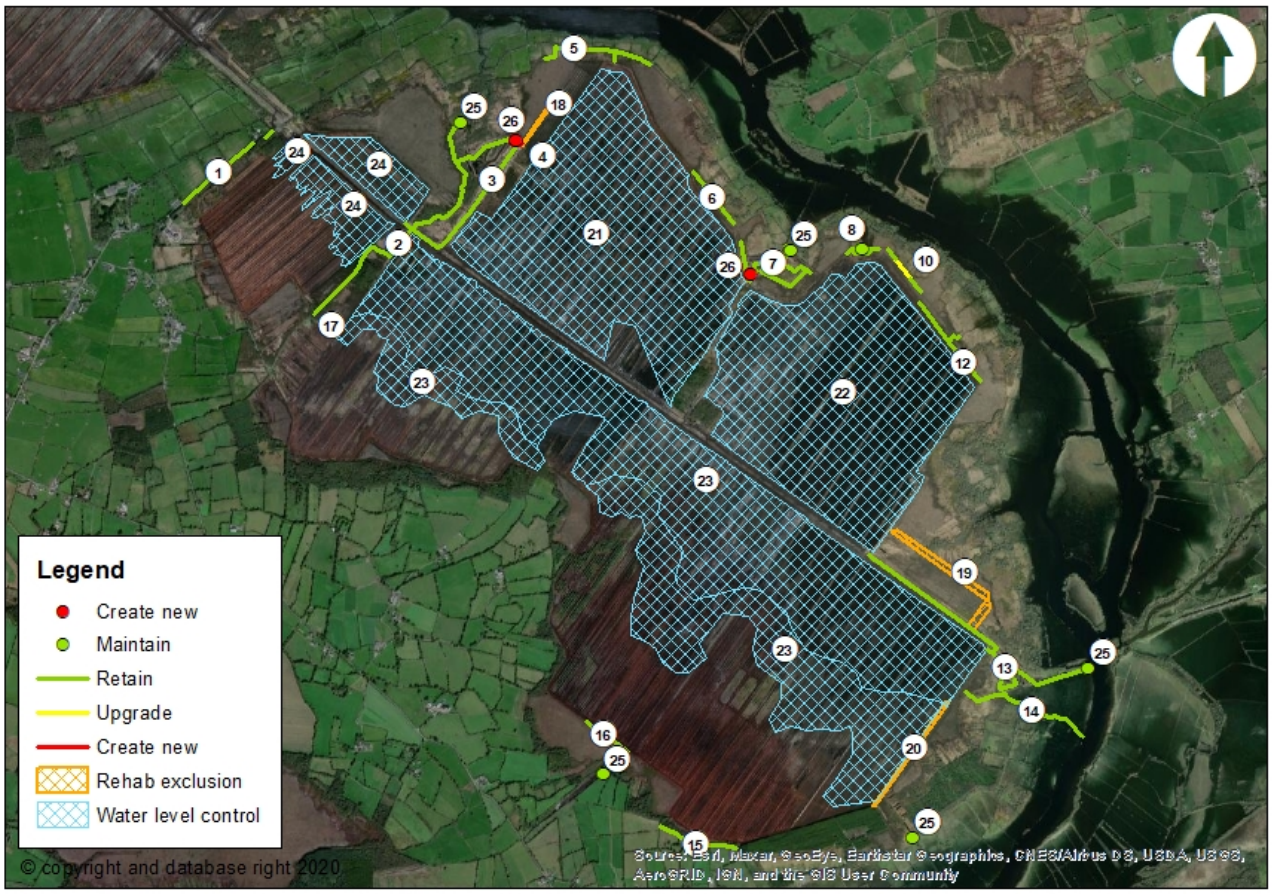

Figure 5.3 DMP measures for Kilmacshane Bog

Table 5.3 Selection of DMP measures

Measures Item	Feature	Function required	Suite of measures Level of intervention			
			Low			High
1	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
2	Internal drain	Drainage of adjacent land	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
3	Internal drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
4	Boundary drain	Hydraulic break	Retain drain	Upgrade drain	Maintain outside bog field	**Create new drain**
5	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
6	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
7	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
8	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
9	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
10	Boundary drain	Hydraulic break	Retain drain	**Upgrade drain**	Maintain outside bog field	Create new drain
11	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
12	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
13	Internal drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain

Measures Item	Feature	Function required	Suite of measures Level of intervention			
			Low			High
14	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
15	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
16	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
17	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
18	Production field and drain	Hydraulic break	-	-	**Exclude from rehabilitation plan**	Create new drain
19	Production field and drain	Hydraulic break	-	-	**Exclude from rehabilitation plan**	Create new drain
20	Production field and drain	Hydraulic break	-	-	**Exclude from rehabilitation plan**	Create new drain
21	Wetland	Water level control	-	**Rehabilitation adaptation**	Exclude from rehabilitation plan	-
22	Wetland	Water level control	-	**Rehabilitation adaptation**	Exclude from rehabilitation plan	-
23	Wetland	Water level control	-	**Rehabilitation adaptation**	Exclude from rehabilitation plan	-
24	Wetland	Water level control	-	**Rehabilitation adaptation**	Exclude from rehabilitation plan	-
25	Silt ponds	Silt and flow control	**Maintain pond**	Upgrade pond	-	-
26	Pump	Flow/silt control	Maintain current pumping regime	Upgrade drain	-	**Create new discharge point**

5.4 Interaction with monitoring plan

As part of the bog rehabilitation plan groundwater level monitors will be installed at Kilmacshane Bog. These monitors will record groundwater levels over the coming months. It will therefore be possible to ascertain if groundwater is rising within the bog following the implementation of the rehabilitation plan.

This data should be considered during the monitoring measures of adjacent land. When groundwater levels are known to be rising within the bog, monitoring of the adjacent land (as described in Section 5.1.5) should take place on a more regular basis to ascertain if impacts to lands outside the bog are observed.

5.5 Residual Risk & Limitations

The level of flood risk to the bog and the surrounding lands has been shown to be low (Section 2.6) generally but with an area in the centre of the bog susceptible to poor drainage and flooding. The impact of the proposed rehabilitation measures will generally be to reduce runoff from the bog but this will lead to increased groundwater levels and surface water flooding in the bog itself. There are unknowns in relation to the post-rehabilitation water levels which will be realised, however the Drainage Management Plan seeks to identify the measures that should provide a hydrological cut off between the bog and the surrounding lands.

As indicated in previous sections there are limitations to the assessments associated with the drainage network both within the bog and outside. Factors such as flow estimations of small catchments, lack of survey data limiting drain capacity estimations and high level definition of soil porosity all contribute to these limitations. Nevertheless the measures recommended represent a pre-cautionary approach based on conservative assumptions.

The DMP measures proposed set a baseline approach however a suite of measures in any given location has been provided. This will allow a reactive approach to be taken if required. Should a measure not be operating efficiently a higher intervention measure can be implemented. This will allow Bord na Móna to identify the most appropriate measure while proceeding with drainage function uncertainties.

5.6 Climate Change Adaptability

There is high uncertainty in relation to the effects of climate change, particularly in how it may manifest in terms of small catchment runoff. Ireland is predicted to have drier summers and wetter winters. The most appropriate guidance in an Irish context can be found in the OPW's Flood Risk Management Climate Change Sectoral Adaptation Plan[4]. For the Mid-Range Future Scenario, representing a central emissions estimate on a 100 year time horizon, it is recommended that allowances for peak flow and rainfall are increased by 20%. If such increases in runoff are realised over the timeframe of establishment of rehabilitation measures this could lead to a perception that bog rehabilitation measures at Kilmacshane Bog are the cause of increased flood risk.

[4] Accessed on 10/12/2020 at https://www.gov.ie/pdf/?file=https://assets.gov.ie/46534/3575554721374f7ab6840ee11b8b066a.pdf#page=1

It is anticipated however that the rehabilitation measures will lead to reduced peak runoff as the water storage function of the bog is increased. This will serve to regulate peak runoff in winter and potentially smooth out the flows in drier periods, essentially acting against the anticipated effects of climate change.

It is therefore anticipated that the bog rehabilitation measures themselves will provide the mitigation of the effects of climate change on runoff and no additional measures will be needed. There are unknowns however in the effectiveness of the rehabilitation measures in this regard and also the severity of climate change impacts. Continued monitoring of the adjacent lands is therefore also crucial to gauge the effectiveness of the BRP measures in mitigating these climate change impacts.

6 SUMMARY OF DRAINAGE MANAGEMENT PLAN

The Drainage Management Plan for Kilmacshane consists of a series of measures to be implemented at different stages of the rehabilitation.

Water level control measures set a maximum permissible water level for each wetland area. This measure is to control the potential ground water level rise in adjacent lands.

Drains within the bog and along its boundary were identified as being key drainage paths or hydraulic breaks in order to mitigate against any potential impacts from the bog rehabilitation measures. The effectiveness of all drains acting as hydraulic breaks is dependent on their ability to convey flow which have been outlined in Section 5.3 and deemed appropriate subject to the measures recommended. Factors such as channel size and slope will determine this along with any downstream feature which may control water levels. The external drains which these boundary drains discharge into are also key drainage features that will affect the operation of the drainage network.

Other measures range from low intervention to high and consist of monitoring, retention of existing features, upgrading features, creating new features and updating the rehabilitation plan. Maintenance of measures are proposed to the silt ponds within the bog to ensure that discharge from the bog and sediment is controlled. This is a legal obligation for Bord na Mona and will continue at all existing silt ponds. Monitoring of adjacent land was included in the plan. The monitoring will observe adjacent bog and woodland for adverse impacts from the bog rehabilitation. Should these impacts be confirmed, higher intervention measures can be implemented to mitigate the impacts. Monitoring measures will therefore be ongoing during and after the bog rehabilitation measures. Continued retention and maintenance of the key drains and silt ponds will also be required after the bog rehabilitation measures. Throughout the process landowner engagement is recommended to ensure both the rehabilitation plan and Drainage Management Plan are understood and to promote collaborative working to manage impacts as they arise.

Table 6.1 Drainage Management Plan

Measures required PRE bog rehabilitation measures	Measures required DURING bog rehabilitation measures	Measures required POST bog rehabilitation measures
Landowner engagement if required via community liaison	Landowner engagement if required via community liaison	Landowner engagement if required via community liaison
Retention of internal and boundary drains (see section 5.1.1)	-	-
Upgrade of boundary drain (see section 5.1.1)	-	-
Creation of new drain (see section 5.1.1)	-	-
-	Wetland water level control (see section 5.1.2)	Wetland water level control (see section 5.1.2)

-	Field bog exclusion from rehabilitation plan (see section 5.1.2)	Field bog exclusion from rehabilitation plan (see section 5.1.2)
-	Upgrade and create new discharge points at pump locations (see section 5.1.3)	-
Monitoring external drains	IF REQUIRED – Consideration of need for higher intervention measures	-
Maintenance of silt ponds (see section 5.1.4)	Maintenance of silt ponds (see section 5.1.4)	Maintenance of silt ponds (see section 5.1.4)
Monitoring of adjacent land (see section 5.1.5)	Monitoring of adjacent land (see section 5.1.5)	Monitoring of adjacent land (see section 5.1.5)
-	-	IF REQUIRED – boundary drain upgrades (see section 5.1.1)
-	-	Retention of key drains and pipes