Lough Neagh Operating Scheme Review

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EXECUTIVE SUMMARY

In the 2015/16 winter period, the UK and Ireland were subject to several major storm events which caused widespread flooding and disruption. Records indicate that Northern Ireland received 695mm of rainfall between November 2015 and February 2016, 162% of the 1971-2000 average for this period. The Armagh Observatory noted that the rainfall recorded in December was the highest since records began in 1838. One such result of these storms was experienced at Lough Neagh, where the water level observed was the highest recorded from 31 years of records.

In response to a recommendation made in the Strong Report "Review of Winter Flooding" (Northern Ireland) 2015-16, RPS were appointed to undertake a review of the Lough Neagh and Lower Bann operating scheme including the sluice gates at Lough Neagh and along the Lower Bann. A hydrodynamic model of the Lough and Lower Bann was constructed in InfoWorks ICM, which was calibrated to the 2015/16 event and verified to an event over the winter of 2009/10. A range of alternative operating schemes were identified and simulated for the 2015/16 event to determine whether another regime would have significantly reduced the flood levels observed over this period.

The results confirmed that any alternative sluice gate motorisation options, to the motorisation followed over the winter of 2015/16, do not afford any significant benefit in reducing water levels in Lough Neagh. The option which offered the greatest reduction in peak flood levels, whilst conforming with the statutory limits within which the Lough level is maintained by DfI Rivers, lowered the level by 19mm. This reduction was deemed insignificant, with the predicted peak level still exceeding the statutory maximum by over 1 metre. The option of allowing the water level to fall below the statutory minimum in anticipation of winter flooding was also assessed and found to provide an insignificant reduction in the flooding experienced. This option would also result in negative environmental impacts to the protected sites which bound the Lough.

A range of other options were assessed and modelled, to quantify the restrictions caused along the Lower Bann by natural and manmade features. It was established that in order to significantly reduce the risk of flooding at Lough Neagh, this would involve the removal of a constriction in the channel at Portna. This option involved the bed level being lowered along a 2 km length of the Lower Bann. To allow this bed reduction the Portna sluice gate and fish pass structure were removed. This ultimately reduced the peak Lough Neagh level by 313mm when compared to the 2015/16 event simulation.

The review concluded that any alternative operation of sluice gates outside that carried out by DfI Rivers would have an insignificant effect on the levels observed. The unusually high levels in the Lough are attributed to the unprecedented rainfall that was received over the winter 2015/16 period in combination with a natural restriction which exists in the network. In order to significantly reduce the peak water level during the simulated events, the restrictions along the Lower Bann would have to be removed, primarily along the identified area near Portna as demonstrated from modelled option outputs. This work would be prohibitively expensive with associated negative environmental impacts and consequently is not considered to be a viable option.

1 INTRODUCTION

1.1 BACKGROUND

The Department for Infrastructure (Rivers) exercises the statutory drainage and flood protection functions arising under the Drainage (Northern Ireland) Order 1973 and other related Statutory Provisions. These provisions include a responsibility for regulation of water levels in Lough Neagh and flows in the Lower Bann under the Lough Neagh and Lower Bann Drainage and Navigation Act (Northern Ireland) 1955 and the Lough Neagh Levels Scheme (1955) (as amended). These water levels are controlled by a system of sluices, gates and weirs.

In winter 2015/16, the statutory bounds within which the water levels in Lough Neagh are to be maintained were exceeded between mid-November 2015 and mid-March 2016. The peak water level in the Lough, taken as the average of four water level gauges, was recorded to be 13.67mOD (Belfast), which is over one metre above the statutory maximum level of 12.6mOD. A series of storm events were experienced over this period. RPS Consulting Engineers were commissioned by DfI Rivers to carry out a review of the Lough Neagh operating scheme in order to meet the aims and objectives as defined in Section 1.2.

1.2 AIMS AND OBJECTIVES

The aims and objectives for this review are as follows:

To develop an understanding of the operation of the structures and flows in the Lower Bann and how they affect the behaviour of Lough Neagh Levels.

Review the performance of the current operating regime and Rivers Agency's management of the Lough Level during winter 2015/16, to ascertain if anything could have been done to lessen the flood risk within the confines of the existing statutory levels.

Consider alternative operating regimes to manage Lough Neagh levels and make recommendations regarding any proposed amendments.

Produce a hydrodynamic model of the Lower Bann and Lough Neagh to replicate the water levels observed in the winter 2015/16 flood events. Validate the model against two other high Lough Neagh water level periods.

The aims and objectives were underpinned by a hydrological and hydraulic analysis which was carried out for the Lough Neagh and Lower Bann network – further information can be found in the accompanying Supplementary Modelling Report (IBE1303Rp0005_Supplementary Report_F01). This document reports on the findings of the review, including results of alternative operating regimes investigated, which made use of the calibrated and verified model. A simulation over winter 2015/16

provided a high water level scenario against which alternative regimes were compared and commented upon. Conditions during 'normal' operating conditions were captured in the simulated periods before and after the high water level periods in the winter 2015/16 event, as well as in the winter 2009/10 event, which was used for model validation.

1.3 PREVIOUS STUDIES AND REPORTS

1.3.1 RPS Study 2006

RPS carried out a study in 2006 to examine ways of improving control of water levels in Lough Neagh and flow in the Lower Bann. This involved a comprehensive hydrological and meteorological study, in which rainfall-runoff hydrological models were linked to a hydraulic model. A number of alternative options to improve the control of water levels in the Lough were assessed. These included the utilisation of additional gauges at the Lough, gauges on rivers draining to the Lough and rainfall/radar data, as well as a range of control strategies from operation 'once per day' to 'fully automated operation'. In addition to these, increasing the capacity at Toome via an overspill weir and the effects of constrictions or increases in flow of tributary rivers were considered.

The study concluded that all options displayed minimal reductions in flood levels. The utilisation of additional gauges to calculate a more representative water level in the Lough was found to be effective in improving the control of water levels in Lough Neagh, where a single water level gauge at Toome was used previously. More regular alteration of gate openings than once daily did little to improve the level control. Options to utilise water level gauges on tributary watercourses and rainfall/radar data were found to produce minor reductions in level but not enough to be cost effective. The 'Toome overspill' and 'control of tributary rivers' options were dismissed as they were found to be unviable.

1.3.2 Review of Winter Flooding (Northern Ireland) 2015-2016

An independent review of the flooding that was experienced in Northern Ireland over the winter 2015/16 was completed in November 2016 (Strong, 2016). This report investigated the following:

- *Consider the causes of the flooding; and*
- *Consider the current management and operating regime to control water levels for Lough Neagh.*

The report listed a number of recommendations following the review of the above, taking on board input from a significant number of stakeholders and interested parties, covering farming, engineering, environment and governance. One of the recommendations was the "procurement of a hydraulic model of Lough Neagh flows, leading to a review of the water levels in Lough Neagh". This report aims to inform this recommendation, in creating a calibrated hydraulic model of Lough Neagh and the Lower Bann, which is capable of determining whether manual operation of control structures along this network could have been done differently, to reduce the flooding experienced at Lough Neagh.

2 OVERVIEW OF STUDY AREA

Lough Neagh is the largest freshwater lake in the British Isles, and the Lower Bann is Northern Ireland's principal system which drains the Lough. Lough Neagh has a catchment area of approximately 4,465 km^2 (excluding the Lough). This catchment includes six major rivers (Maine, Six Mile Water, Upper Bann, Blackwater, Ballinderry and Moyola), as well as two smaller rivers (Crumlin and Glenavy) which drain to the Lough. These watercourses are labelled in Figure 1. Two additional tributaries of the Blackwater and the Upper Bann have been included in the figure (Callan and Cusher), for which flow data was available. This information was incorporated in the hydrological assessment; the hydrological methodology is discussed in Section 3 of the Supplementary Modelling Report (IBE1303Rp0005_Supplementary Report_F01).

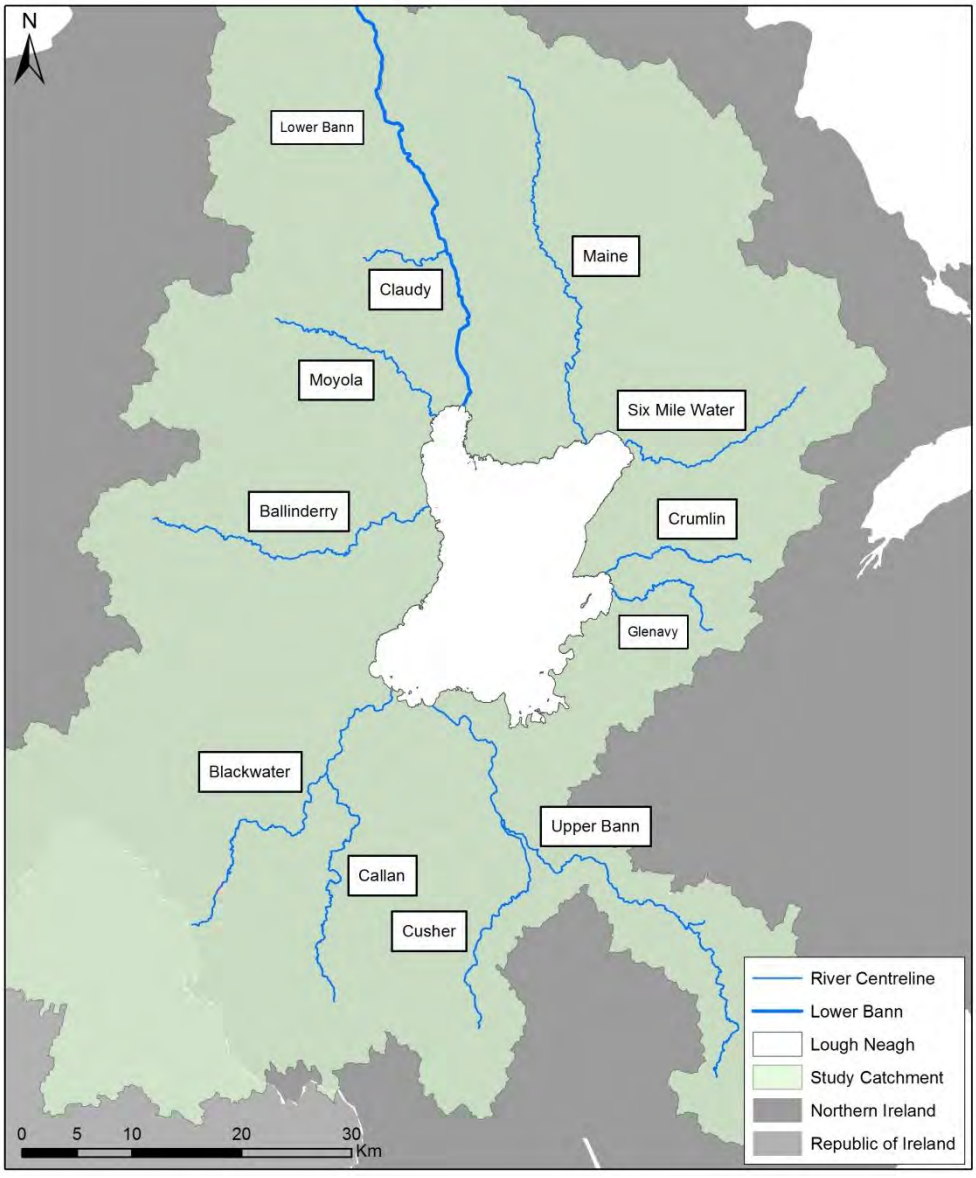


Figure 1: Major Watercourses within Study Catchment

2.1 OPERATING SCHEME AND STATUTORY REGULATIONS

In recent centuries the Lough levels have been subject to change. The first large scale drainage scheme commenced in 1846; this scheme aimed to alleviate flooding and improve navigation. A number of schemes have been adopted since then, which are summarised in Figure 2; this image was sourced from Wood & Smith, 1993. It can be seen that prior to the McMahon Scheme, 'normal' Lough levels were noted to be around 14.8m AOD (Belfast). Since this time the various schemes are found to have lowered the normal levels by approximately 2.3 metres. The extreme fluctuations are suggested to also been reduced significantly, from 3.2 metres to 1 metre.

Table 3.2. Lough Neagh water level fluctuations in m + O.D. Belfast

	Normal	Maximum	Minimum	Extreme fluctuations
Prior to McMahon Scheme 1846–1858	14.8	16.4	not known	c. 3.2
After McMahon Scheme 1860	13.8	14.9	12.8	2.1
After Shepherd Scheme 1942	13.1	13.9	12.3	1.6
After 1952	12.9	13.9	12.3	1.6
After 1959	12.5–12.6	13.1	12.2	0.9
1973–1982*	12.5	13.2	12.2	1.0

Source: Bell (1971) except *.

Figure 2: Lough Neagh Water Level Fluctuations in Relation to Various Schemes and Statutory Legislation (Bell, 1971)

Water levels are currently managed at Lough Neagh and along the Lower Bann by venting flow through sluice gates, which are located at Toome, Portna (Kilrea) and the Cutts (Coleraine). Gate openings are determined by DfI Rivers Area Office staff based in Coleraine. The operation of the gates is based on water level information taken from gauges at Lough Neagh and along the Lower Bann, as well as preceding and forecast weather conditions and from past experience.

Weirs are located along the Lower Bann at Movanagher and Carnroe, which also influence water levels in the network. Figure 3 shows the approximate location of these control structures, along with the location of bridges, along the Lower Bann.

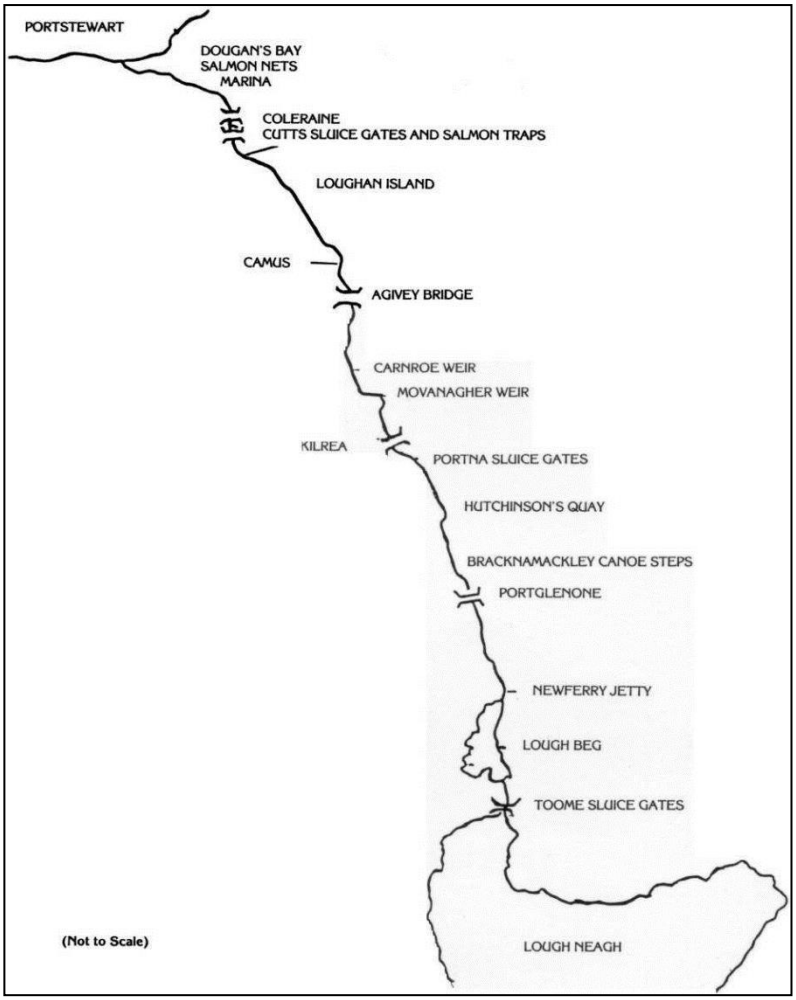


Figure 3: Drawing Indicating Approximate Locations of Control Structures and Bridges Along Lower Bann

DfI Rivers has a statutory responsibility to control water levels in Lough Neagh within a range of 150mm. The water level is to be maintained between 12.45m and 12.60m AOD (Belfast), as far as practicable where rainfall, wind and other natural conditions permit. These limits are a result of the Lough Neagh and Lower Bann Drainage and Navigation Act (NI) 1955, which was brought into effect in 1959. Over the last 15 years the level in the Lough was maintained within the threshold limits approximately 71% of the time. Of the time that the level is exceeded this predominantly occurs over the winter months; the month with the greatest length of time where the limit is not satisfied is January, at 18% of the total time where the Lough was below 12.45m AOD or above 12.6m AOD. A base flow is required in the Lower Bann, which is maintained when all sluice gates are closed via a fish pass.

Additional considerations are taken into account when determining gate openings; including limiting total openings at the Cutts to ensure navigation in the region is not restricted. The Lough level is maintained towards the upper bounds of the statutory limit in the summer, primarily to maintain

the level in Lough Beg downstream, as well as accommodating fishing activities. In the winter, the water level is maintained towards lower bounds to reduce the likelihood of flooding. The green line in Figure 4 is indicative of the target levels across a typical year.

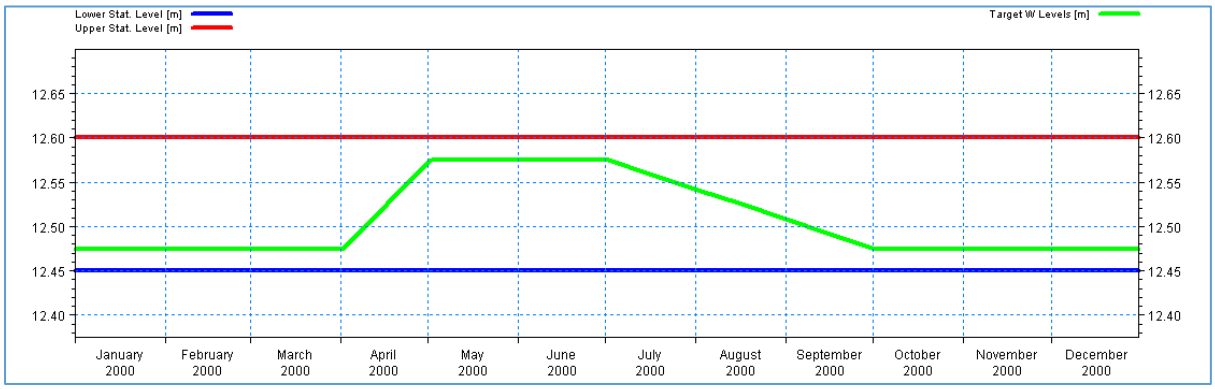


Figure 4: Indication of Seasonal Targets within Statutory Limits for Lough Neagh Water Level to be Maintained

A single set of gate positions is used for a 24 hour period. Gate adjustments commence at 09:00 at Toome and take place over a number of hours; this is due to the time taken to open the gates and the travel period between gates (at Toome, Portna and Coleraine).

2.2 HISTORICAL FLOODING

2.2.1 Winter 2015/16 Event

A sequence of storm events was experienced in Northern Ireland, from the middle of November 2015 through to early February 2016. A total of nine storms (defined by wind only, not rainfall) were named in this period, in addition to one unnamed event, (Table 1). The major flood events experienced in Northern Ireland during this period were associated with storms Barney, Desmond, Frank and the unnamed event (Marsh et al., 2016), which are shown in bold in Table 1.

Table 1: Named Storms in the Winter 2015/16 Period

Name	Date of impact (UK and Ireland)
Abigail	12th – 13th November
Barney	**17th – 18th November**
Clodagh	29th November
Desmond	**5th – 6th December**
Eva	24th December
Frank	**29th – 30th December**
Gertrude	29th January
Henry	1st – 2nd February
Unnamed Event	**3rd – 5th February**
Imogen	8th February

A report reviewing the winter floods in 2015/16 in the UK carried out by the Centre for Ecology and Hydrology indicates return periods for rainfall collected for regions across the UK. These return period estimates are based on monthly rainfall data provided by the Met Office and are compared to the 1971-2000 averages for the respective regions. For a three month period from November 2015, the data indicates the rainfall recorded in Northern Ireland was representative of a <1% annual exceedance probability for this period. Comparing the rainfall recorded to that of the 1971-2000 average indicated 173%, 187% and 147% of the average was received each month from November 2015 onwards (Marsh et al., 2016).

Photos of the flooding along the shoreline of Lough Neagh were sourced from Flood Maps (NI). Figure 5 to Figure 7 were taken on 11th January 2016, 3 days after the peak water level of 13.67m AOD (Belfast) was recorded. DfI Area Engineers provided details of properties and roads which were affected over this period, as well as locations where sandbags were deployed and pumping operations were carried out to avoid property inundation. This information has been provided in Appendix E.



Figure 5: View looking north from motorway crossing on Upper Bann (taken 11th January, 2016)



Figure 6: View looking north from the Ballyneskan Road, to the east of the Upper Bann (taken 11th January, 2016)



Figure 7: View along the east of Lough Neagh, taken west of Glenavy

The average water level variation at Lough Neagh over the winter 2015/16 period is displayed in Figure 8, where the increases in water level can be observed to be as a result of the storms. The highest average water level from the gauges at the Lough was recorded as 13.67m, the highest level recorded at the Lough from 31 years of records.

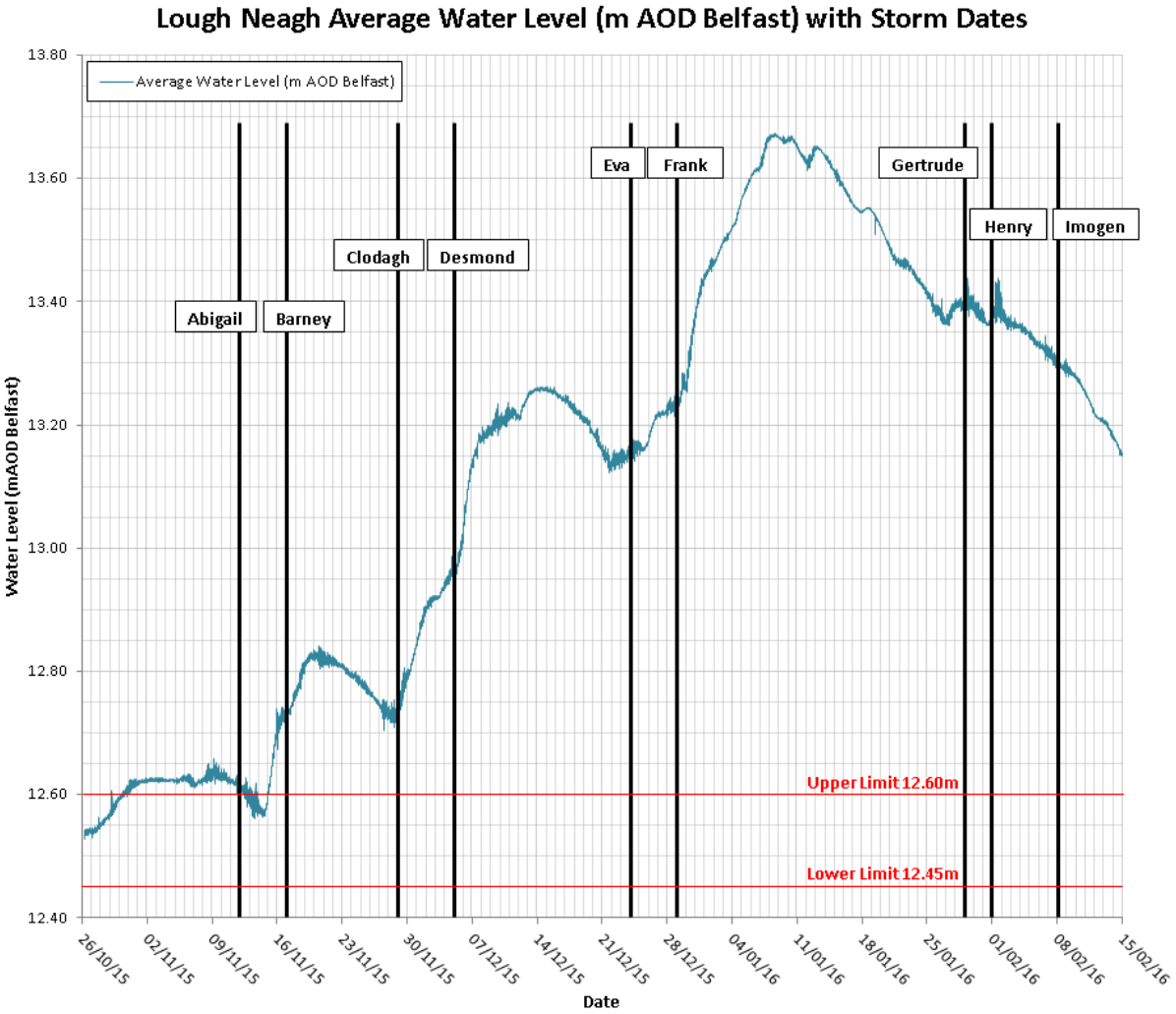


Figure 8: Graph showing water level variation in Lough Neagh and dates of named storm events over winter 2015/16 period

A single site frequency analysis was carried out at gauge locations upstream of Lough Neagh, to develop an understanding of the magnitude of events that were observed in each catchment over the major winter 2015/16 flood events. This made use of the flow data received from DfI Hydrometrics, as well as the National River Flow Archive website. The analysis involved the use of WINFAP, which was utilised to estimate the flood frequency of peak flows observed from gauge data, applying Flood Estimation methods. Although storms Barney, Desmond, Frank and the unnamed event were related to major flood events in Northern Ireland, the highest peak flows in the watercourses entering Lough Neagh were primarily as a consequence of storms Clodagh, Desmond, Henry and Gertrude. A total of 10 gauge stations were assessed; the gauge locations and

contributing catchment areas are presented in Appendix A. The outcome of the assessment is presented in Table 2.

Table 2: Frequency Analysis of Peak Flow During Major Named Storms At Gauges Within Lough Neagh Catchment

Gauge Name	Gauge Reference Number	Clodagh 12th – 13th Nov 2015		Desmond 5th – 6th Dec 2015		Frank 29th – 30th Dec 2015		Gertrude 29th Jan 2016	
		Peak Flow (m^3/s)	AEP*	Peak Flow (m^3/s)	AEP*	Peak Flow (m^3/s)	AEP*	Peak Flow (m^3/s)	AEP*
Antrim	203018	60.64	**85.7%**	85.07	**44.5%**	104.42	**20.6%**	37.44	**99.4%**
Ballinderry Bridge	203012	93.69	**93.7%**	171.99	**7.8%**	126.30	**60.1%**	45.28	**99.9%**
Cidercourt Bridge	203042	31.68	**78.5%**	32.55	**75.2%**	65.04	**7.3%**	11.78	**>100%**
Gambles Bridge	203024	33.42	**93.2%**	44.28	**72.8%**	65.32	**10.3%**	45.18	**70.1%**
Glenone Bridge	203019	23.93	**98.2%**	32.20	**60.5%**	33.29	**53.4%**	20.45	**>100%**
Leap Bridge	203063	16.95	**79.2%**	11.21	**99.1%**	26.78	**16.9%**	8.10	**>100%**
Martins Bridge	203025	28.20	**94.7%**	33.18	**85.3%**	41.67	**6.7%**	33.41	**84.5%**
Maydown Bridge	203010	106.05	**99.5%**	184.67	**4.9%**	148.77	**28.0%**	93.13	**>100%**
Moyallen	203017	52.87	**93.3%**	51.18	**94.6%**	101.93	**6.0%**	58.75	**86.9%**
Moyola	203020	76.90	**95.1%**	98.80	**76.6%**	108.15	**56.6%**	40.76	**99.4%**
Shanes Viaduct	203093	138.64	**99.1%**	221.68	**35.2%**	232.22	**27.5%**	101.67	**>100%**

*Annual Exceedance Probability (AEP) refers the probability of a flood event occurring in a single year

Table 2 indicates the named storm which caused the largest magnitude flows to be observed in the greatest number of catchments was storm Frank; the peak level in Lough Neagh was recorded approximately one week after this storm event. It can be seen that as a consequence of this storm, there were significant peak flows recorded in several catchments. These are indicated by a lower percentage AEP (higher magnitude events are less frequent, therefore have a lower percentage AEP). Where the percentage AEP is greater than 100%, this indicates a more frequent, lower magnitude event which would be expected to occur in any given year.

Table 2 shows that many of the gauges recorded flows with an AEP approximating to 100% (which could be expected in any given year). These flows may not be considered to be significant in terms of flooding when considered in isolation, however, the cumulative effect of all of the large catchments draining to Lough Neagh receiving varying magnitude events several times over a single winter period resulted in the Lough water levels rising to be higher than any level recorded in the last 31 years. Statistically the likelihood of receiving the total of rainfall sustained over the 2015/16 winter was less than a 1% AEP, or greater than a 1 in 100 year event.

2.2.2 Other Significant Flooding Events

The statutory maximum level was also exceeded over the winter period of 2009/10. The maximum level recorded was 13.40m AOD (Belfast). The Lough level exceeded the maximum statutory limit at the start of November 2009 and remained above this level until near the end of December 2009. A number of photos of this event are available on the Flood Maps (NI) website around the Lough; some examples have been included in Figure 9 and Figure 10. This event was used for model verification which is discussed in Section 4.5 of the Supplementary Modelling Report (IBE1303Rp0005_Supplementary Report_F01).



Figure 9: View looking North along River Blackwater at M1 Motorway



Figure 10: View along the west of the Lough taken close to Ballinderry confluence

The water level between October 2009 and January 2010 is displayed in Figure 11. The levels taken were an average taken from water level gauges at Toome, Loughview Road and Oxford Island - the Ardboe point gauge incorporated in the 2015/16 period was not available at this time.

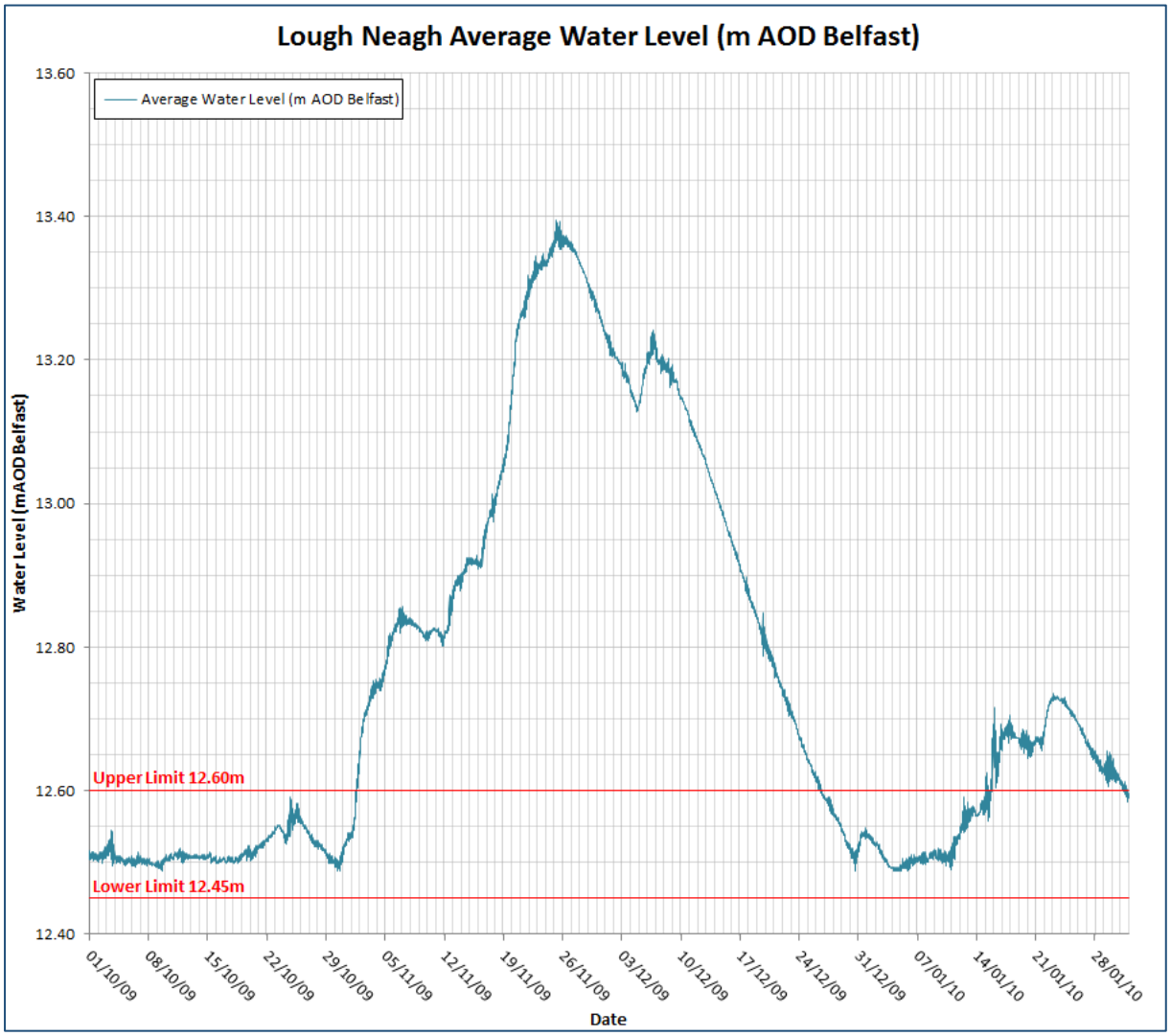


Figure 11: Graph showing water level variation in Lough Neagh over winter 2009/10 period

A frequency analysis was carried out on the gauged portions of the Lough Neagh and Lower Bann catchments, as shown in Table 3. The largest magnitude flow was experienced at the Maydown Bridge gauge, situated along the River Blackwater, indicating a 4.4% annual exceedance probability (AEP) event. At the Glenone Bridge on the Agivey River, the analysis suggests the most significant event experienced over this time represented a less than a 100% AEP event.

Table 3: Frequency Analysis of Peak Flow During Major Named Storms At Gauges Within Lough Neagh Catchment

Gauge Name	Gauge Reference Number	1st Oct 2009 – 31st Jan 2010	
		Peak Flow (m^3/s)	AEP*
Antrim	203018	64.291	**80.6%**
Ballinderry Bridge	203012	164.804	**11.5%**
Cidercourt Bridge	203042	29.553	**85.8%**
Gambles Bridge	203024	49.46	**55.3%**
Glenone Bridge	203019	31.674	**>100%**
Leap Bridge	203063	14.161	**93.5%**
Martins Bridge	203025	40.067	**23.5%**
Maydown Bridge	203010	187.673	**4.4%**
Moyallen	203017	65.987	**73.3%**
Moyola	203020	105.259	**63.7%**
Shanes Viaduct	203093	194.626	**61.8%**

*Annual Exceedance Probability (AEP) refers the probability of a flood event occurring in a single year

2.2.3 Other Flood Events

Photographs of high water levels were available on the Department for Infrastructures Flood Maps NI interactive map-viewer from an event in 1987, but this event was not investigated as part of this study; this event predates the construction of the fish pass at Toome (1992), therefore the hydraulic regime differs from that being assessed in the winter 2015/16 event. No other significant recent flood events outside winter 2015/16 and winter 2009/10 were identified by RPS from searching historic records and local news websites, nor were any identified by DfI Rivers.

3 DATA COLLECTION AND SURVEYS

RPS liaised with DfI Rivers to collect all the available information relevant to the study area. DfI Rivers provided existing InfoWorks ICM models of the 8 watercourses entering Lough Neagh, as well as a model covering the Lower Bann between Agivey Bridge at Kilrea and the coast at Portstewart. Hydrometric data was also sourced for all available level and flow gauges within the study catchment, as well as rainfall data across a range of locations. Historic sluice gate motorisation was passed on by DfI Rivers Area Office Staff for the two simulated winter periods. The complete data collection carried out is included in the Supplementary Modelling Report (IBE1303Rp0005_Supplementary Report_F01).

4 HYDROLOGICAL AND HYDRAULIC ANALYSIS

The aims and objectives of this study required model simulations of the winter 2015/16 event, which was to be calibrated using historic water level data. This required the construction of a hydraulic model of the Lough Neagh – Lower Bann network, along with a hydrological analysis to provide flows to be applied to the model. Model calibration was achieved for the winter 2015/16 event, with verification being provided in the winter 2009/10 period. Further details on the hydrological and hydraulic analysis have been provided in the accompanying Supplementary Modelling Report (IBE1303Rp0005_Supplementary Report_F01).

5 INVESTIGATION OF OPERATING SCHEME OPTIONS

A number of options were assessed to investigate any benefit that may have been afforded from an alternative operating regime for the winter 2015/16 period. These options considered a range of operating regimes, which focus on reducing the peak flooding level, via changes to the motorisation at the three sluice gate locations; reporting on these is presented in Section 5.2. Section 5.1.2 looks at measures outside the operating regime. Potential environmental consequences that may be brought about by the options assessed have also been considered and discussed in Section 5.3.

5.1 OPTION SCREENING

5.1.1 Potential Operating Scheme Options

1. Lower Lough and Lower Bann levels as much as possible by sluice motorisation when statutory limit exceeded.

Model run to simulate all sluice gate structures at Toome, Portna and the Cutts, Coleraine to be open 'clear' as soon as level could not be kept below statutory maximum. The historic water level records at Lough Neagh indicate that from 15th November onwards, the level exceeded the statutory maximum for a duration of 4 months. This option models all sluice gates at Toome, Portna & Coleraine open from 15th November. All gates were open clear at Toome on this date, but not all gates were fully open at Portna and Coleraine.

2. Lower the Lough level ahead of winter floods experienced to 12.45m AOD (lower bound of statutory limit at start of simulation).

Model run to simulate the Lough level to initially be 12.45m AOD at the start of the simulation. This is the lowest level at which the Lough could have been maintained, whilst being within the statutory limits. The starting Lough level was initially set at 12.54m AOD in the calibrated design simulation, which was sourced from observed level gauges and set in the models initial conditions. Option 2 assessed the Lough level being set 90mm lower than was observed, at the lower bound of the statutory limit; this was achieved by altering the initial conditions of the Lough in the model. The gate operation modelled was the same as that carried out for the winter 2015/16 period by DfI Rivers for this simulation, which did not increase the flood risk over the winter 2015/16 period, even when compared with earlier opening of the gates in advance of the storm events, as concluded in Section 5.2.1.1.

3. Lower the Lough levels ahead of winter floods experienced to 12.3m (150mm below lower bound of statutory limit at start of simulation).

Similar to option 2, this option models the Lough level being dropped lower than was observed ahead of the winter 2015/16 storm events. This option assesses the effect on water level when the

Lough is lowered beneath the statutory lower limit; this is outside the current confines that are maintained by DfI Rivers Area Staff. Again, the lowering of the Lough was achieved via the initial conditions in the model. Similar to Option 2, the gate operation modelled was the same as that carried out for the winter 2015/16 period by DfI Rivers for this simulation.

4. Review/sensitivity of flood gate motorisation at Portna during 2015/16 event

Two of four sluice gates at Portna remained closed between 14th October and 21st November 2015 and again between 29th November to 5th December 2015. All gates at Portna were recorded to be clear only between 29th December 2015 to 11th February 2015. In this simulation the flood gates at Portna were left open and clear from the time the Lough levels were recorded to first exceed the statutory maximum (30th October 2015). DfI Operations Staff confirmed gate opening at Portna considers operational water level targets for Portna and the Cutts, and also adopts a staged approach.

5. Impact of weather forecast on winter 2015/16

Similar to Option 1, this option assesses any reduction in levels that might be achieved when gates at all three locations (Toome, Portna and the Cutts, Coleraine) are open, but specifically focussing on the potential response to the weather forecast ahead of storm events in the winter period. As shown in Table 4, sourced from the Alan Strong report, the first storm (Abigail) was named on 10th November 2015. Storm Abigail brought about heavy rain and strong winds across the UK. This option is to simulate all gates to be open from this date onwards, in anticipation of the storm event and associated flow response. DfI Operations Staff confirmed the sources used for the forecast are the Met Office Hazard Manager and long range forecasts, for example the 10 day BBC forecast.

Table 4: Winter 2015/16 Storms, Showing Date Named and Date of Impact

Storm Name	Date named	Date of impact on UK and/or Ireland
Abigail	10 November 2015	12 - 13 November 2015
Barney	16 November 2015	17 - 18 November 2015
Clodagh	28 November 2015	29 November 2015
Desmond	4 December 2015	5 - 6 December 2015
Eva	22 December 2015	24 December 2015
Frank	28 December 2015	29 - 30 December 2015
Gertrude	28 January 2016	29 January 2016
Henry	30 January 2016	1 - 2 February 2016
Imogen	7 February 2016	8 February 2016

5.1.2 Potential Other Options

RPS carried out an assessment of potential options which may provide a benefit in terms of reducing flood levels at Toome, outside of the motorisation of sluice structures or lowering water levels.

5.1.2.1 Removal of 'pinch points' along Lower Bann

Potential restrictions were identified along the channel, most notably at the sluice gates at Portna and further downstream at the weir at Movanagher, where the bed level increases by several metres compared to adjacent sections. A long section of the Lower Bann with structures labelled is provided in Appendix D, which shows the change in bed level. Survey data does not identify the invert of the sluice gates at Portna to be raised significantly above the bed level. To assess the effect these pinch points might be having, the 2015/16 winter period was simulated with a river network where the sluice gates at Portna and the Movanagher and Carnroe weirs were removed.

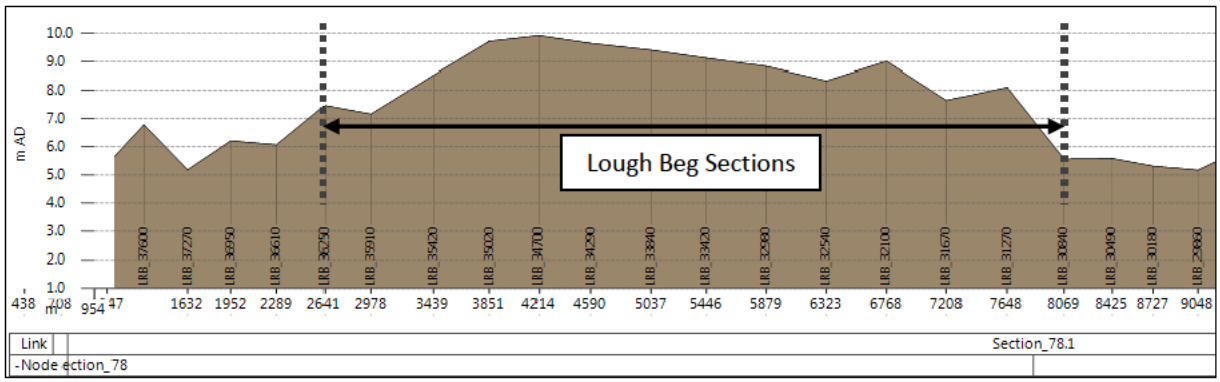
5.1.2.2 Increase capacity of Lower Bann (channels and/or bridges)

In addition to the locations discussed in Section 5.1.2.1, the channel itself is found to restrict the flow along the Lower Bann. The bed level is found to be elevated by around 3 metres for an approximately 2 kilometre reach at Portna starting 1.45 km upstream and ending 0.55 km downstream of the Portna sluice gates). A restriction in this area due to a 'transverse ridge of rock' was noted by John McMahon (of the McMahon Scheme 1846 – 1858) to be a major obstacle in solving the drainage issues for the Lower Bann (McCutcheon, 1984). Part of this historic scheme involved removal of this rock ridge and construction of a weir, which was replaced with sluice gates in the 1930's as part of the Shepard Scheme. Despite removal of material in the mid 1800's, the bed through this section is found to be higher than the adjacent sections upstream and downstream.

To assess what effect the increase in capacity would have had on the peak water levels in Lough Neagh during the 2015/16 winter period, the model was simulated with an altered river network file; the bed level was lowered by around 3 metres along the 2 km length to provide a steady bed slope. This option required the removal of the sluice gates at Portna from the network to achieve the required gradient.

5.1.2.3 Increase capacity through Lough Beg by dredging / excavation

The extended shallow sections at Lough Beg were thought to have an attenuating effect on flows immediately downstream of the Lough, which could be reduced following re-profiling of the channel. Lough Beg is approximately 5km long, and similar to Lough Neagh has a number of environmental designations present, such as Special Protected Area (SPA), Area of Special Scientific Interest (ASSI) and Ramsar. The existing bed level through Lough Beg is presented in Figure 12, which shows the bed to be raised by several metres compared to sections upstream and downstream.



To quantify any benefit derived from dredging/excavation, the existing channel sections were modified to include a 75 metre wide opening with a steady bed slope through the Lough. The bed level in the modified network is presented in Figure 13.

Figure 12: Long Section view along Lough Beg from surveyed sections

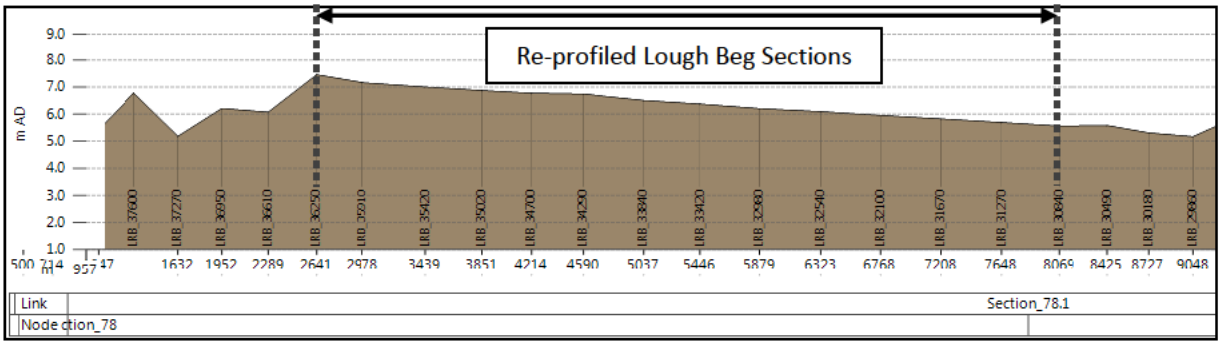


Figure 13: Altered long section in modelled re-profiled sections through Lough Beg

5.1.2.4 Addition of motorised sluices along spill at Toome to allow earlier intervention

This option assesses the impact of having additional capacity at Toome, which could be provided by motorised gates, which would provide the existing levels in a low flow scenario. When the level of the Lough is high it is though this could provide additional flow, in combination with the 5 sluice gates and fish pass. To simulate this, the spill units were altered to include two 20 metre long gates, both of which were lowered by 300mm from the existing level at the spill. These were simulated to be open for the entire model duration by simply modifying the spill unit in the model.

5.2 MODELLED OPTIONS AND DISCUSSION

5.2.1 Modelled Operating Scheme Options

The water level outputs from the option simulations pertaining to the options described in Section 5.1.1 have been included in Appendix B, along with the 2015/16 event simulation which has been included for comparison. A summary has been provided in Table 5 for the reduction in water level achieved for each of the option simulations.

Table 5: Summary of Reductions in Peak Water Level at Lough Neagh for Option Simulations Against 2015/16 Event Simulation

Option	Description	Change in Peak Water Level
1	Lower Lough and Lower Bann levels as much as possible by sluice motorisation when statutory limit exceeded	-7mm
2	Lower the Lough level ahead of winter floods experienced to 12.45m AOD at start of model simulation	-19mm
3	Lower the Lough levels ahead of winter floods experienced to 12.3m AOD at start of model simulation	-53mm
4	Review/sensitivity of flood gate motorisation at Portna	-11mm
5	Impact of weather forecast on winter 2015/16	-9mm

5.2.1.1 Operating Scheme Option Discussion

Options 1, 4 and 5 were found to have a negligible reduction in the peak water level in Lough Neagh. Options 2 and 3 were found to reduce the level slightly, but the water level would still have been significantly higher than the upper bounds of the statutory limit. In Option 2 the water level was initially required to be reduced by 90mm at the start of the simulation; this accounted for only a 19mm reduction in the peak. In Option 3, the water level was required to be lowered by 240mm, putting it 150mm below the minimum statutory level. Despite the level being significantly lowered initially, the peak difference between the modelled and 2015/16 event simulation was calculated to be only 53mm.

The option which was found to be most effective when assessing the winter 2015/16 period was to lower the Lough levels to 12.3m AOD (option 3). The maximum level was calculated to be 13.543m AOD, which is 53mm less than the design simulation against which it was compared. In this scenario the maximum statutory level of 12.6m AOD would have been exceeded by almost 1m. This option differs from the others in that the level would be lowered below the statutory minimum of 12.45m AOD by 150mm. This option would require legislative change with respect to the Lough Neagh (Levels) Scheme 1955.

Within the statutory limits which are to be maintained by DfI Rivers Area Staff the best outcome was Option 2, which reduced the level by 19mm. This is thought to be insignificant in terms of benefits to areas subject to flooding. Maintaining the level at the minimum value of 12.45m would also incur the risk of the water level falling beneath this value, which would present a number of consequences for users and the environment.

An overview of the project and potential options was presented to DfI Rivers Area Staff managing Lough Neagh and the Lower Bann (18/10/17) to receive comments and feedback. DfI Rivers Area Staff confirmed that the operation of gates at Portna is carried out in a staged manner, increasing flows incrementally to reduce any negative effects related to fishing downstream. With all gates open at Toome, DfI Rivers Area Staff stated the Lough could be lowered by approximately 26mm each day (assuming that there are no significant rainfall events). The simulated water level at Lough Neagh was found to correlate strongly with the observed level when the Lough is reducing in level, implying the model is representing the hydraulic regime accurately. The model suggests the value stated by DfI Area Staff is reasonable. There was agreement with all parties that a more defined understanding of the environmental implications would be important should any options be taken forward, in particular for those options considered which involve the Lough level being reduced to near or below the statutory minimum value.

The option outputs indicate that the operation of the gates at Portna does not have a significant effect on the water levels at Lough Neagh. Based on the surveyed cross sections and model outputs, other potential constrictions along the Lough Neagh – Lower Bann network were identified. Simulations in which restrictions in channel capacity are addressed, along with other options, are presented in Section 5.2.2.

In summary, the modelled alternative operation simulations show that the operation over the winter 2015/16 period by DfI Rivers Area Staff was appropriate, with no alternative operation capable of significantly lowering the peak water level observed.

5.2.2 Modelled Potential Other Options

The water level outputs from option simulations pertaining to Section 5.1.2 were compared to the 2015/16 event simulation. A summary has been provided in Table 6 displaying the change in water level for each of the option simulations. The greatest reduction in peak water related to the re-profiling of the channel at Portna at 313mm; the simulated variation in water level for this option is presented in Figure 19 in Appendix B.

Table 6: Summary of Reductions in Peak Water Level at Lough Neagh for Other Option Simulations Against 2015/16 Event Simulation

Option	Description	Change in Peak Water Level
Removal of Pinch Points	Removal of weirs at Movanagher and Carnroe, as well as removal of structures at Portna sluice gates	**+11mm**
Increase capacity of Lower Bann	Lowering of channel bed along Lower Bann near Portna, as well as removal of structures at Portna sluice gates	**-313mm**
Increase capacity through Lough Beg	Re-profiling sections through Lough Beg to increase capacity	**-29mm**
Additional capacity through Toome	Allowing more flow to drain from Lough Neagh via the addition of two movable gates at Toome, allowing the spill to be lowered by 300mm across these gates.	**-5mm**

5.2.2.1 Potential Other Options Discussion

The option which offers the greatest reduction in the peak water level when assessing the winter 2015/16 period was to increase the capacity of the Lower Bann at Portna, where the bed level is naturally raised for approximately 2 kilometres. This option indicated a reduction of 313mm in the peak level observed at Lough Neagh. It was calculated that around 680,000 cubic metres of material would need to be excavated through this section to allow an even bed slope and remove the constriction. The cost of excavating sand / silt material would be approximately £5 million, although the cost per cubic metre of rock material would be expected to be at least 10 times that of fine material. The disposal cost of excavated material is also expected to be an additional £5 million. To maintain levels upstream of this location, it is expected reinstatement of a larger sluice structure would be required to control levels in this portion between the Lough and Portna, which would incur significant cost (estimated at £3m).

Re-profiling of the cross sections through Lough Beg showed an insignificant reduction of 29mm in the peak water levels. This option would require 1.35 million cubic metres of material to be excavated along the 5km long Lough to provide a defined channel with a steady bed slope. The costs associated with the excavation and disposal of this estimated to be in the region of £20m.

The removal of the Portna sluice gate structure and weirs at Movanagher and Carnroe was found to increase the peak slightly at Lough Neagh, by 11mm. The removal of these structures has altered the hydraulic arrangement in these locations which has altered the hydraulic calculations being carried out by the model. It is thought that this small increase is attributed to the tolerances within the hydraulic modelling software calculations, as opposed to the modelled arrangement increasing the likelihood of flood risk in the network. Ultimately this option would offer no reduction in the peak levels at Lough Neagh.

The additional lowered slots along the spill sections at Toome were found to have a negligible effect on water levels, with a 5mm reduction when compared to the 2015/16 simulation. The current

arrangement allows water to drain from Lough Neagh via 5 no. sluice gates and a fish pass. This simulation demonstrates that any additional capacity is minor in comparison to the fish pass in combination to the Toome sluices open clear.

5.3 ENVIRONMENTAL CONSIDERATIONS

5.3.1 Environmental Features at Lough Neagh, Lough Beg and the Lower Bann

Lough Neagh and its shoreline contain a range of environmental designations and protected areas; these include, but are not limited to, Areas of Special Scientific Interest (ASSI), Special Areas of Conservation (SACs), Special Protected Areas (SPAs) and Ramsar sites. There are also protected areas along the Lower Bann, most notably at Lough Beg and at the coast. Maps displaying these areas are provided in Appendix C. Liaison with DfI Conservation Officers provided additional input which is discussed further in Section 5.3.2.

Much of the flora of scientific interest can be found in the swampy wetlands on the fringes of Lough Neagh. A number of rare plant species can be found in these margins around the Lough, which also provide habitat and shelter for rare invertebrate and fish species.

A number of bird species listed in Annex I of the Birds Directive (79/409/EEC) are supported at Lough Neagh, as well as Lough Beg downstream on the Lower Bann. The birds found at Lough Neagh and Lough Beg are associated with open water, shallow lough shore and wet grassland.

It is noted that the flora and fauna at the Lough are directly related to the wetlands on the Lough shore areas, which are directly related to the water level that is maintained within the Lough. The Lough Neagh ASSI citation document states the following would be likely to cause damage to such species:

"Operations or activities which would affect wetlands (including marsh, fen, bog, rivers, streams and open water) e.g.

(i) change in the methods or frequency of routine drainage maintenance;

(ii) modification in the structure of any watercourse;

(iii) lowering of the water table, permanently or temporarily;

(iv) change in the management of bank-side vegetation."

5.3.2 Potential Environmental Impacts Related to Alternative Operations

RPS consulted with DfI Rivers Environmental Officers to assess the environmental impacts of the simulated options and any potential benefits. In the winter 2015/16 event, the maximum water level was noted to be 13.67m AOD, which is significantly higher than the statutory maximum level. The largest reduction in water level peak afforded by alternative operation was assessed to be 19mm, when operating the Lough within statutory limits. As the statutory maximum is exceeded so significantly in each scenario any impacts to the environment were considered by DfI Environmental Officers to be comparable. It was concluded from liaison with DfI Environmental Officers that it is likely any impact on the designation features would not have been avoided in any of the scenarios outlined.

There was concern however as to the consequences of maintaining a lower level in the Lough through the winter period, as brought about by option 2 and 3. It is thought that certainly maintaining the level below the current statutory minimum level would bring about adverse environmental outcomes. Any reduction in Lough level would directly affect the wetland habitats where a number of protected species are found. A detailed Habitats Regulations Assessment would be required to fully analyse the consequences should the statutory limit be lowered (which would be brought about by Option 3). Option 2 maintains the level at the lower bounds of the statutory limit, however by doing this there is an increased likelihood that the water level would fall beneath the lower bound, again sensitive to the same environmental concerns.

Further to the environmental concerns, there would be negative impacts for recreational boating and fishing users of the Lough if it was lowered, as well as commercial fishing interests. A number of quays around the Lough are maintained at a specified depth for boat users, and are dredged when required. Lowering the Lough level would inevitably involve additional dredging at these locations. The Lough levels are maintained at a level which strikes a compromise between a number of stakeholders, which if altered would require significant engagement and consultation with these parties.

5.3.3 Potential Environmental Impacts Related to Other Potential Options

The Lower Bann is designated as a salmonid watercourse, meaning any in channel works would have the potential to cause environmental impacts, specifically relating to the suspension of fines. Several of the options involve in channel excavation or dredging to re-profile channels, which would require further environmental investigation. This may involve the stipulation of appropriate construction techniques to avoid impacts, or restriction of any works altogether.

For options which involve the removal of sluice gates at Portna, this will alter the current water level controls along the Lower Bann. This would directly affect Lough Beg, which relies on flow control downstream at Portna to maintain levels. Similar to Lough Neagh, it is expected that any lowering of the water table would cause environmental damage to Lough Beg. Should alterations be made to the channel it would be imperative that a sluice structure (modified or new) would protect the levels at Lough Beg.

6 STAKEHOLDER CONSULTATION

DfI Rivers and RPS hosted a stakeholder consultation event at which Ulster Farmers Union (UFU) were present (13/11/18). Those in attendance included the deputy president of UFU, as well as the Head of Business Development for DfI Rivers. A presentation was provided by RPS with a subsequent question and answer session, during which time UFU were able to voice any concerns. RPS were able to demonstrate that the assessment carried out was sufficient to address all questions without undertaking further analysis.

There were no additional actions or investigations required as a consequence of stakeholder consultation undertaken.

7 CONCLUSIONS AND RECOMMENDATIONS

RPS carried out a review of the operating scheme at Lough Neagh, with a specific focus on the winter 2015/16 winter period, which saw the Lough rise to its highest level from 31 years of records. A detailed hydraulic analysis was undertaken, in which a hydrodynamic model was produced for the Lough Neagh – Lower Bann network. A hydrological assessment provided flow inputs to the hydraulic model, which made use of historic data from a range of gauging stations situated on the major watercourses in the catchment. The model incorporated motorisation logs of sluice gates at Toome, Portna and Coleraine, as carried out by DfI Rivers Area Staff.

A range of alternative operating scheme options were considered and simulated, to assess any potential benefit during the winter 2015/16 period in terms of reducing the peak flood level in the Lough. Options outside the operating scheme were also investigated and simulated, including section re-profiling and the removal of natural and manmade constrictions in the network.

Based on the hydrodynamic model assessment, it was concluded that any alternative operation of the sluice gates, within the statutory targets, offered an insignificant reduction in the peak level in the winter 2015/16 event. The largest reduction in peak level via alternative operation related to an option which required the Lough level to be lowered below the statutory minimum, which is expected to have negative impacts to the environment and users of the Lough, both commercial and recreational.

Options outside the sluice operation were developed, which identified a constriction at Portna effecting Lower Bann water levels upstream and at Lough Neagh. Re-profiling along this section of the Lower Bann (which also required removal of the Portna sluice gates and fish pass structure) resulted in the largest reduction in the peak level at Lough Neagh at 313mm, compared to the 2015/16 simulation. Ultimately this option is not considered feasible based on environmental and economic grounds. Some of the prohibitive considerations for this option and others have been provided below:

Environmental considerations

- Multiple environmental designations in the network; in particular the shorelines of Lough Neagh and Lough Beg.
- Any alterations in statutory bounds for Lough Neagh and / or Lough Beg likely to require a Habitats Regulations Assessment. This relates to operating Lough Neagh below the statutory minimum of 12.45m AOD, as well as channel re-profiling through Lough Beg and removal of Portna sluice gates, which would affect levels at Lough Beg.
- Channel re-profiling / dredging at Lough Beg would require further environmental screening due to the presence of several environmental designations.
- Channel re-profiling at Portna requires in channel works in a salmonid river. Excavation will likely involve rock removal, as has been identified as a natural restriction at this point.

Economic screening

- Excavation and disposal of bed material at Portna is estimated to be at least £10m.
- Replacement of the existing sluice gates would incur significant costs (estimated at £3m).
- Channel re-profiling at Lough Beg was estimated at £20m.

It is concluded that the drivers behind the high water levels observed in the Lough over the winter 2015/16 period are attributed to the unprecedented sequence of storm events that occurred, in combination with the limited capacity of the Lower Bann due to natural and manmade restrictions. The analysis indicates the flood levels were not exacerbated by the operating regime over the winter 2015/16 period by DfI Rivers Area Staff, with no alternative operation capable of significantly lowering the peak water level observed. Therefore the operation carried out over this period was considered appropriate. Since 2000, the Lough Level has been managed within the statutory limits for 71% of the time. This study indicates that excessive levels at Lough Neagh relating to winter storm events are largely out of the control of DfI Rivers Area Staff. The operation of Lough Neagh is crucial in maintaining levels within the Lough and downstream. If levels fall below the statutory and target thresholds in the Lough Neagh and Lower Bann network, this would have damaging impacts on the environment.

To investigate how DfI Rivers and those at risk may best prepare for flooding from Lough Neagh, it is recommended to investigate a flood forecasting option. Flood forecasting can predict when and where flooding is expected to occur and offer an essential lead in time to allow contingency plans to be put in place. This could involve erection of individual property protection measures, placement of sandbags, pumping to avoid property damage and emergency transportation should flood levels result in roads becoming unpassable. Flood forecasting systems are operational in Great Britain and Ireland, with systems ranging in application and complexity. A flood forecasting system for the Lough Neagh and Lower Bann catchment has the potential to manage expectations of what level Lough Neagh may reach as a consequence of a forecasted rainfall event, or when it may begin to recede after an event. Due to the range of systems available and the specific response of the Lough Neagh and Lower Bann catchment, it is recommended that a scoping study is carried out to appraise options and provide recommendations.

8 BIBLIOGRAPHY

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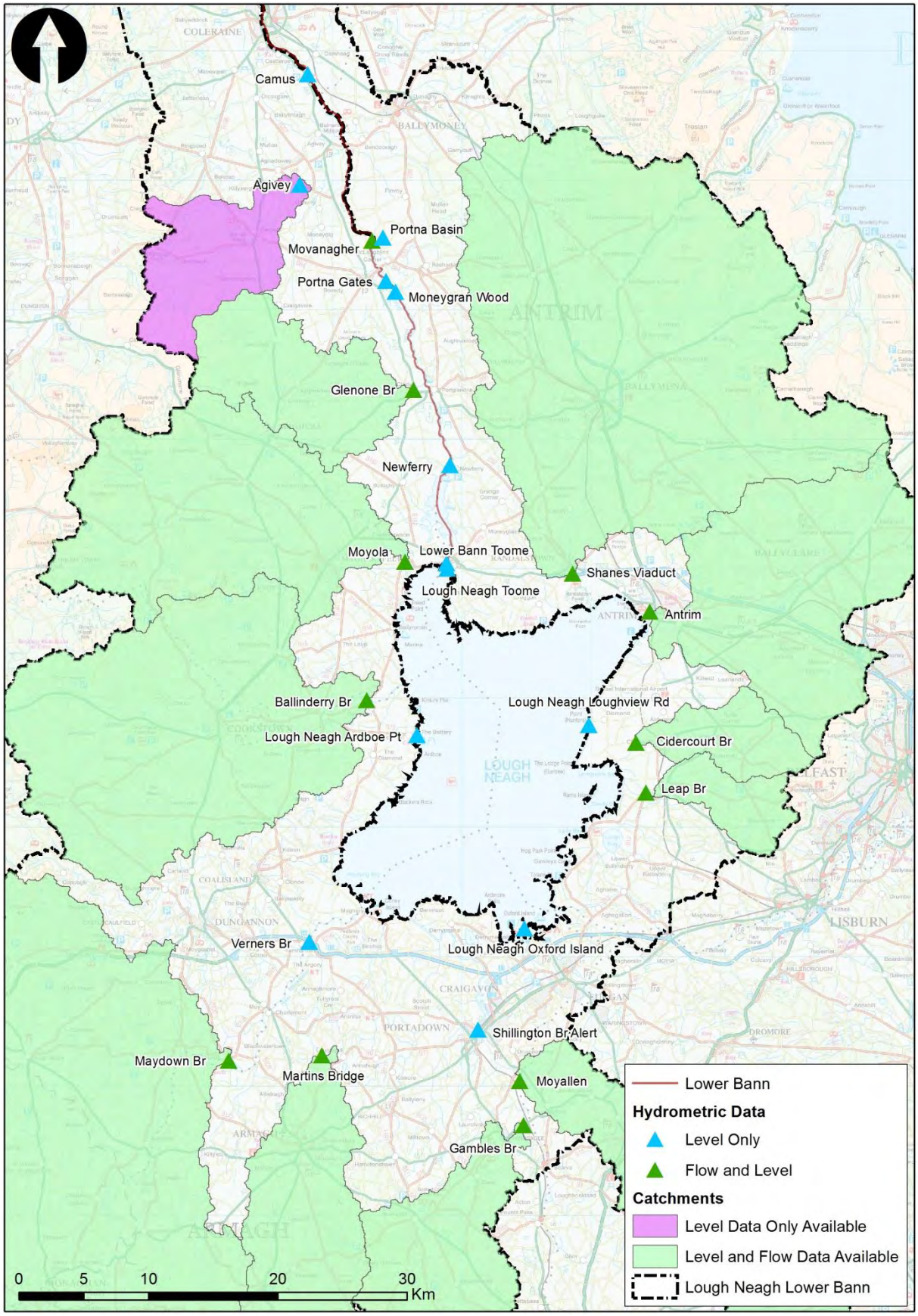
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Appendix A –

Gauge Locations in Lough Neagh and Lower Bann Catchment


Camus
Agivey
Portna Basin
Movanagher
Portna Gates
Moneygran Wood
Glenone Br
Newferry
Moyola
Lower Bann Toome
Lough Neagh Toome
Shanes Viaduct
Antrim
Ballinderry Br
Lough Neagh Ardboe Pt
Lough Neagh Loughview Rd
Cidercourt Br
Leap Br
Verners Br
Lough Neagh Oxford Island
Shillington Br Alert
Maydown Br
Martins Bridge
Moyallen
Gambles Br
0 5 10 20 30
Km
Lower Bann
Hydrometric Data
Level Only
Flow and Level
Catchments
Level Data Only Available
Level and Flow Data Available
Lough Neagh Lower Bann

Appendix B –

Water Level Comparisons at Lough Neagh (Observed, Design and Options)

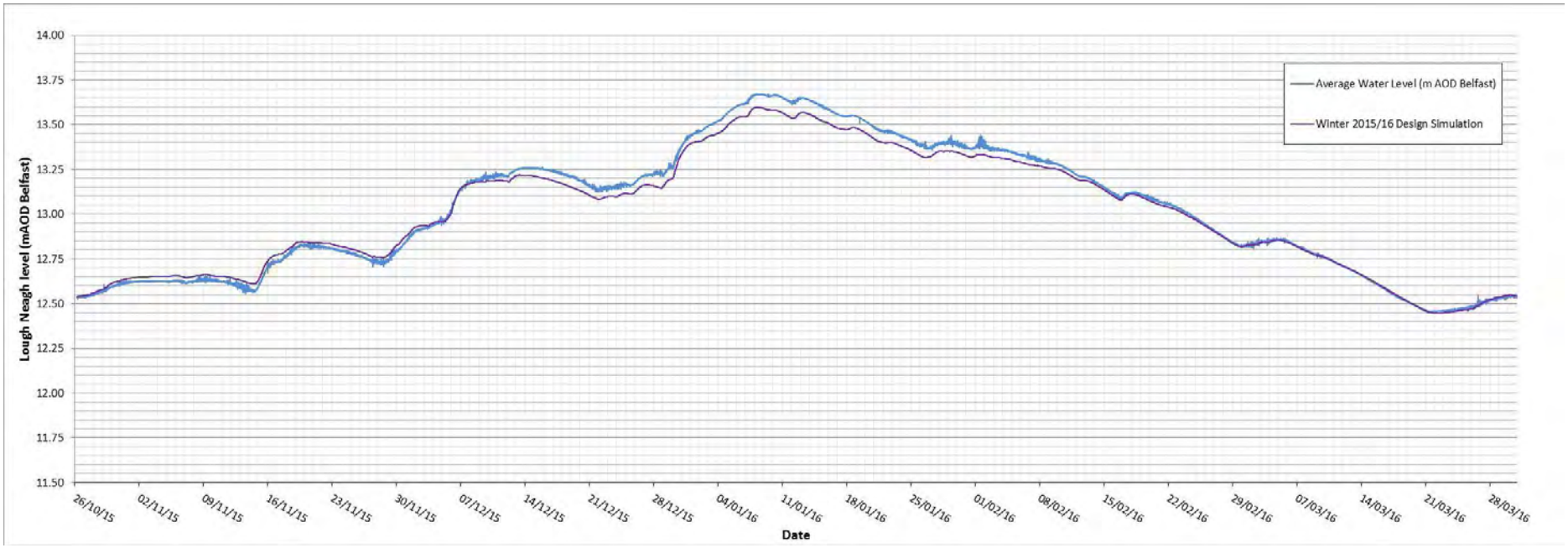


Figure 14: Comparison of Design Simulation and Observed Water Level over Winter 2015/16 Event for Achievement of Model Calibration

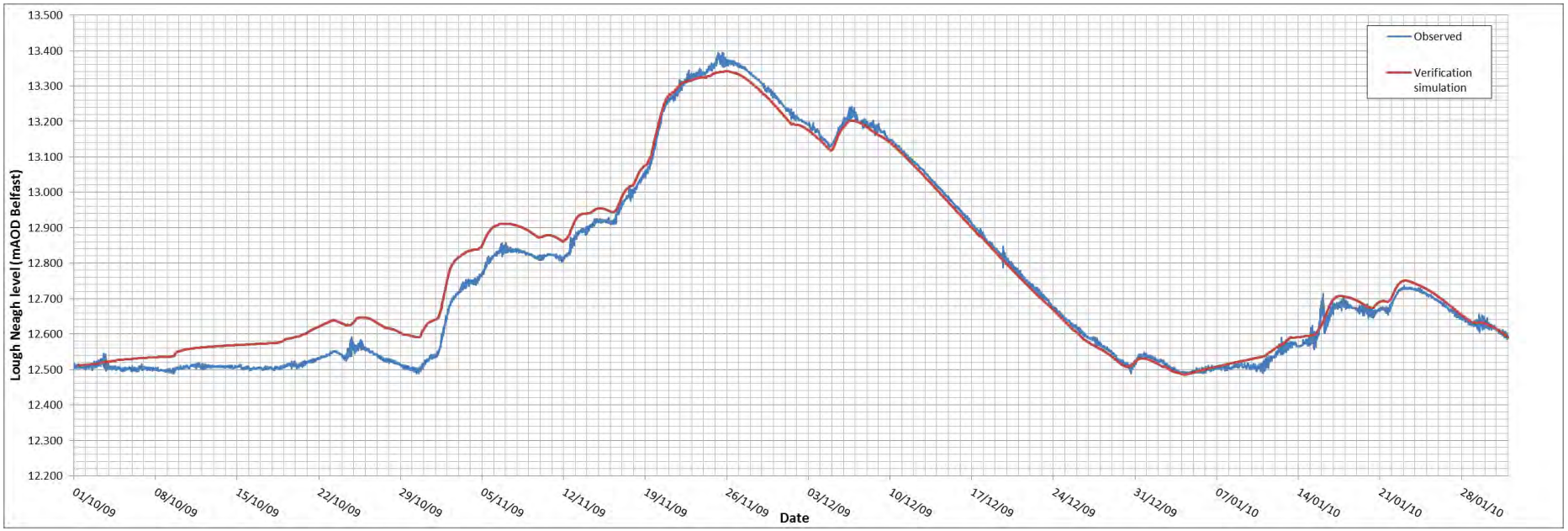


Figure 15: Comparison of Design Simulation and Observed Water Level over Winter 2009/10 Event for Model Verification

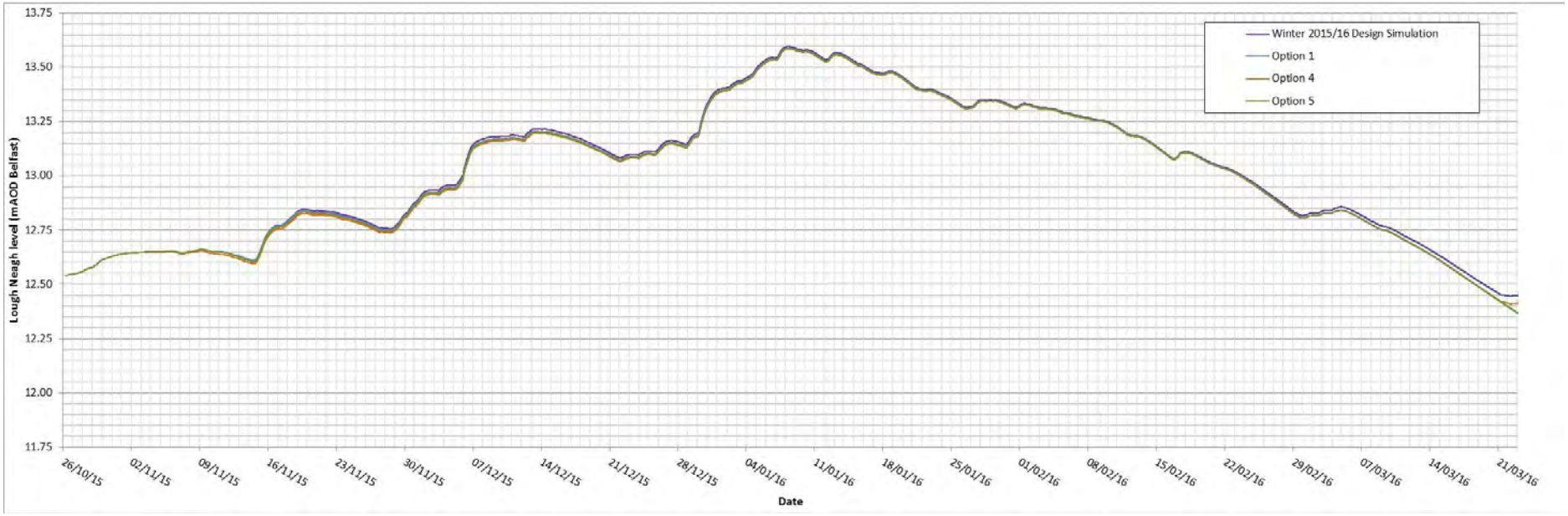


Figure 16: Simulated Option (Option 1, 4 and 5) Water Level Traces Against Design Simulation at Lough Neagh

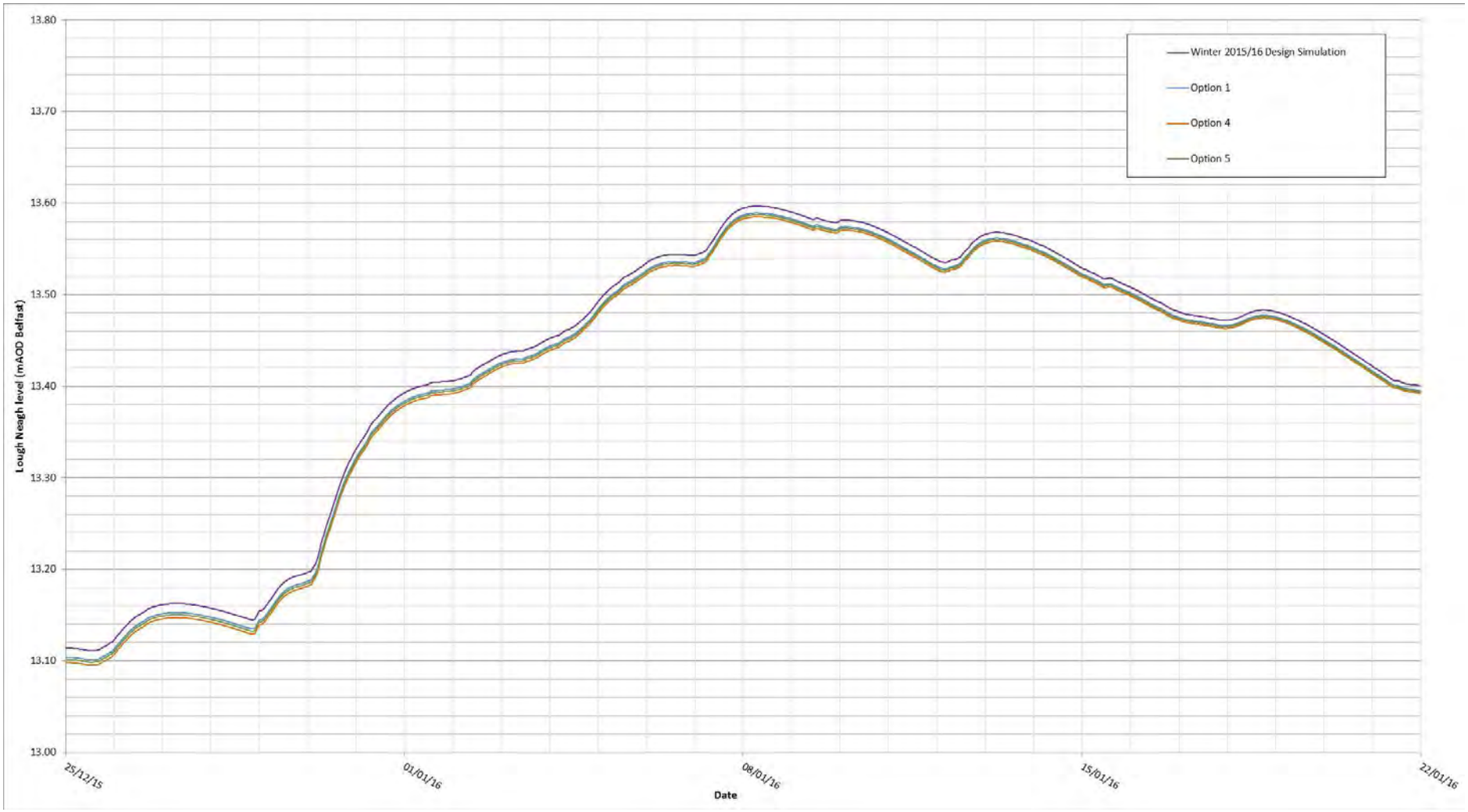


Figure 17: Simulated Option (Option 1, 4 and 5) Water Level Traces Against Design Simulation at Lough Neagh Zoomed in at Peak on 8th January 2016

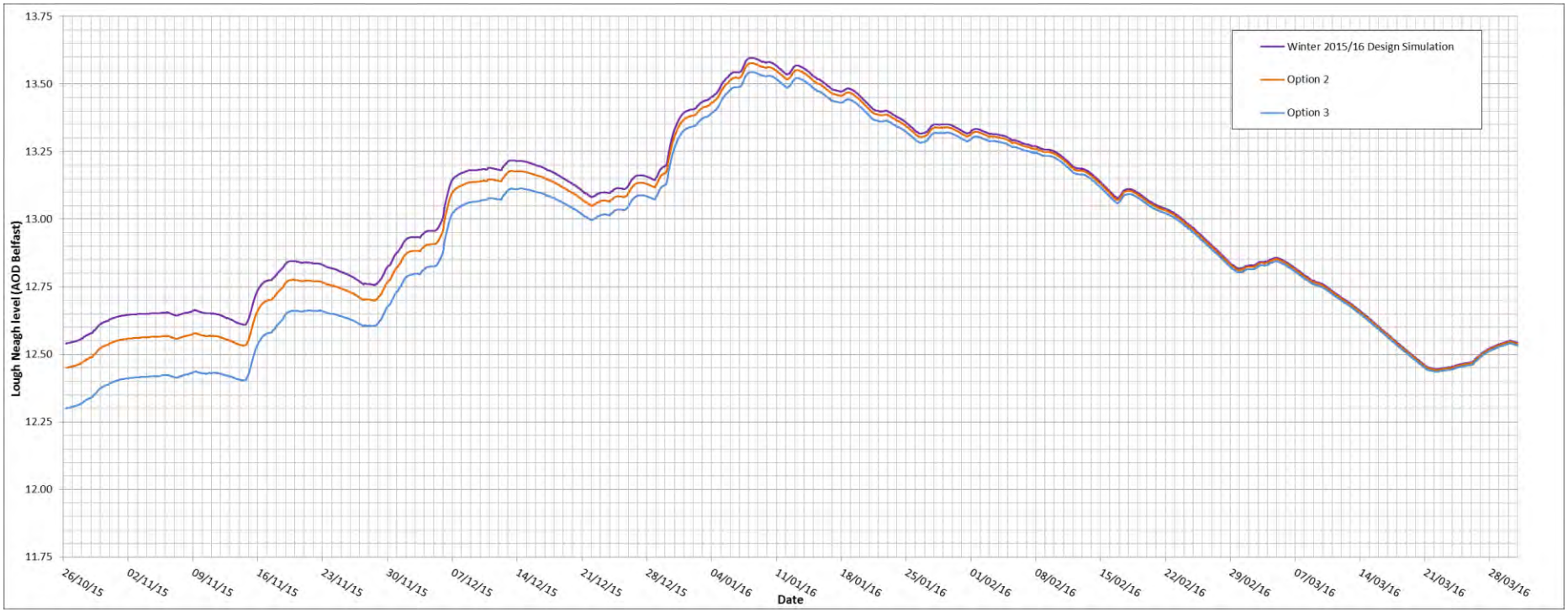


Figure 18: Simulated Option (Option 2 and 3) Water Level Traces Against Design Simulation at Lough Neagh

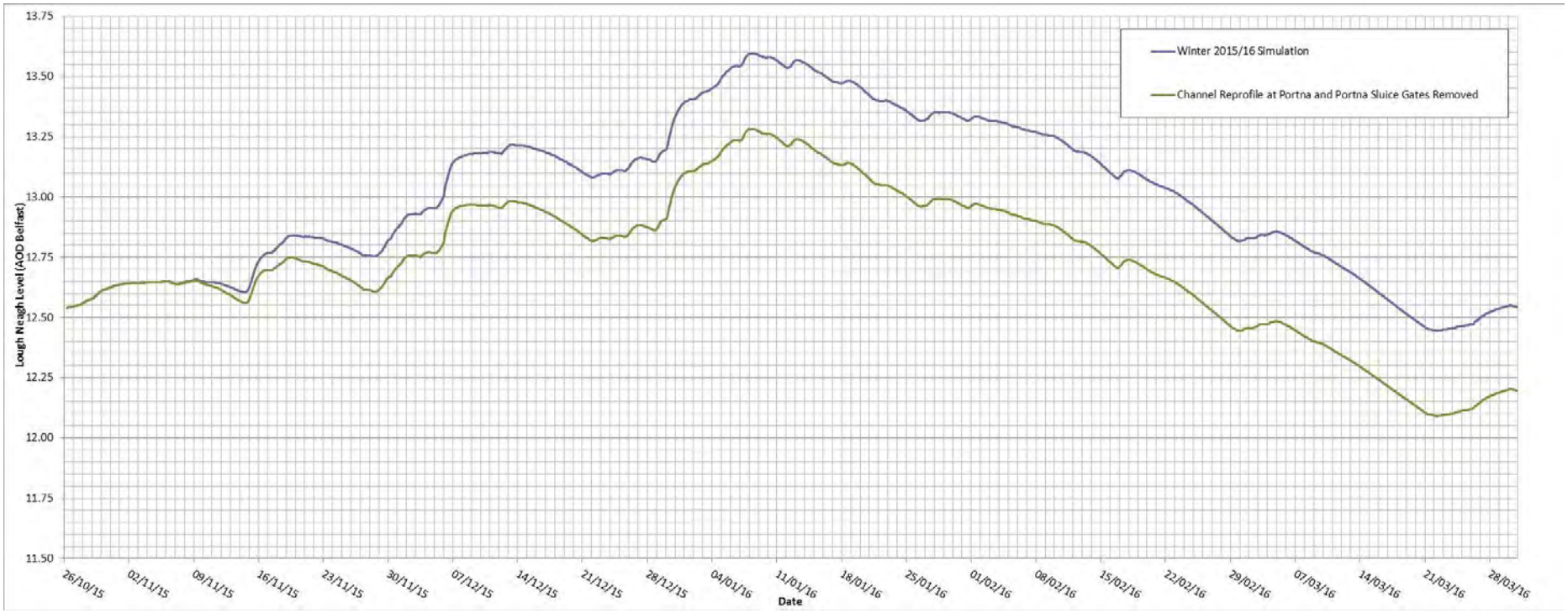
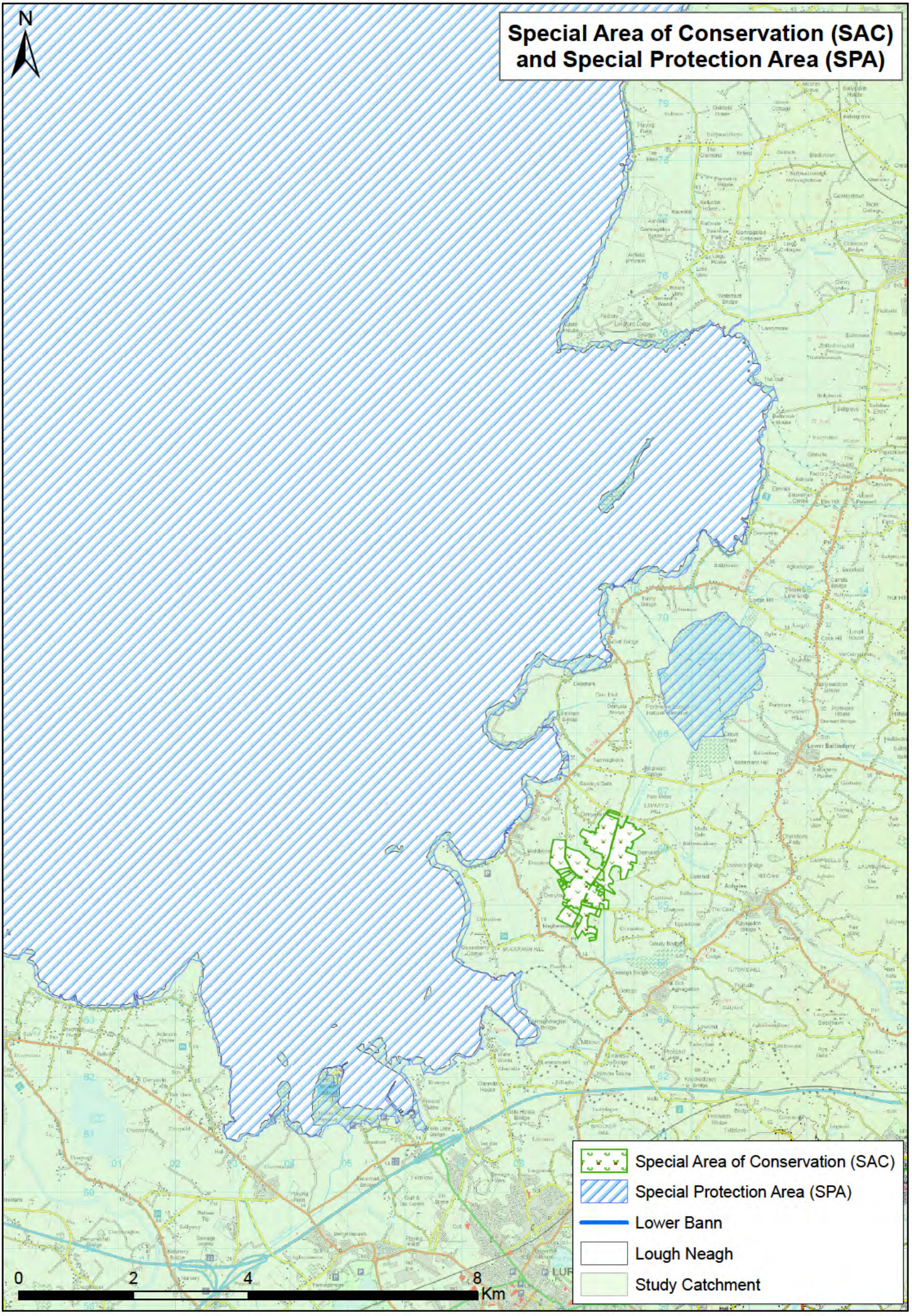


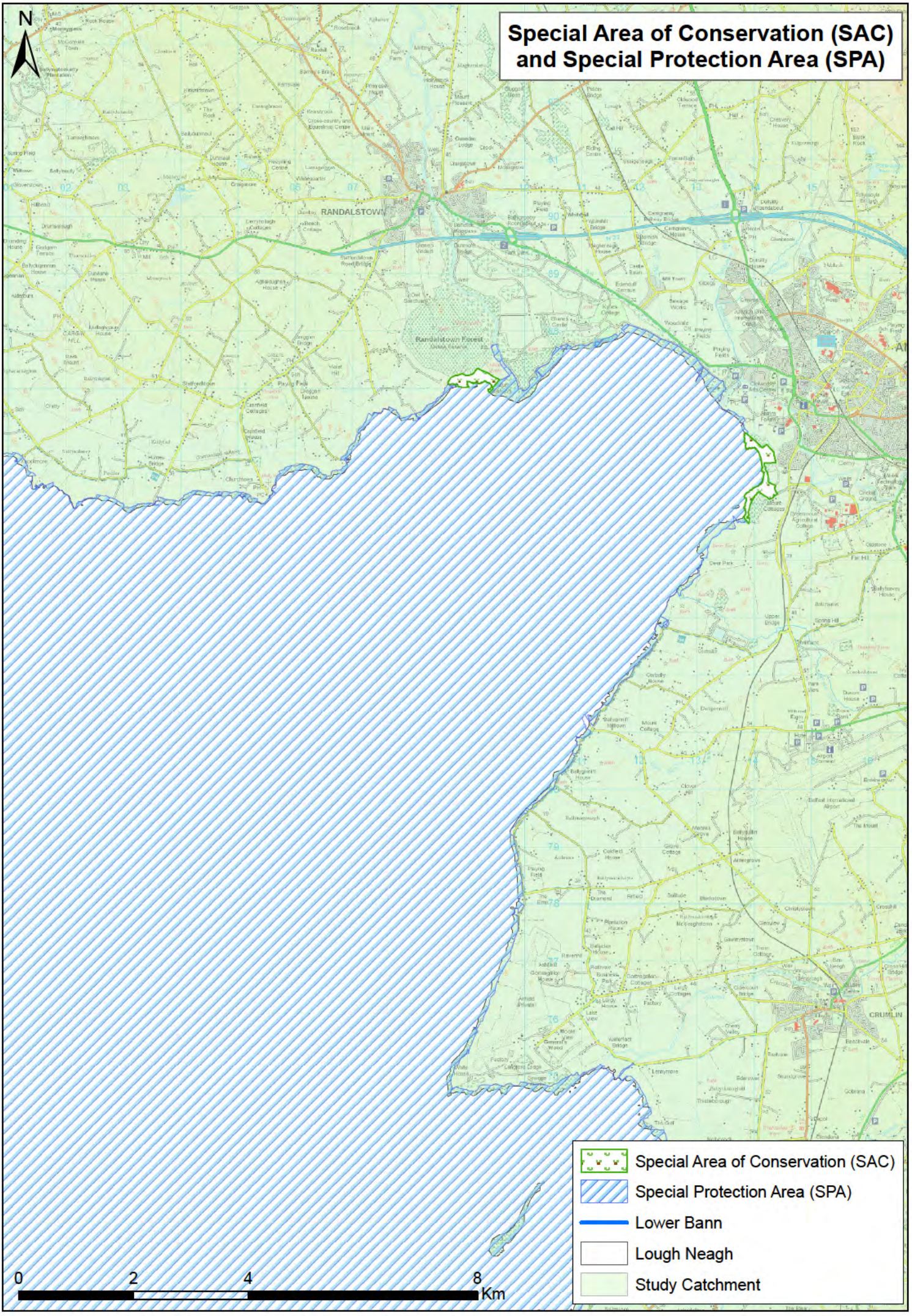
Figure 19: Simulated Alternative Option – Re-profile of Channel through Portna and Associated Removal of Portna Sluice Gates and Fish Pass Against Design Simulation at Lough Neagh

Appendix C –

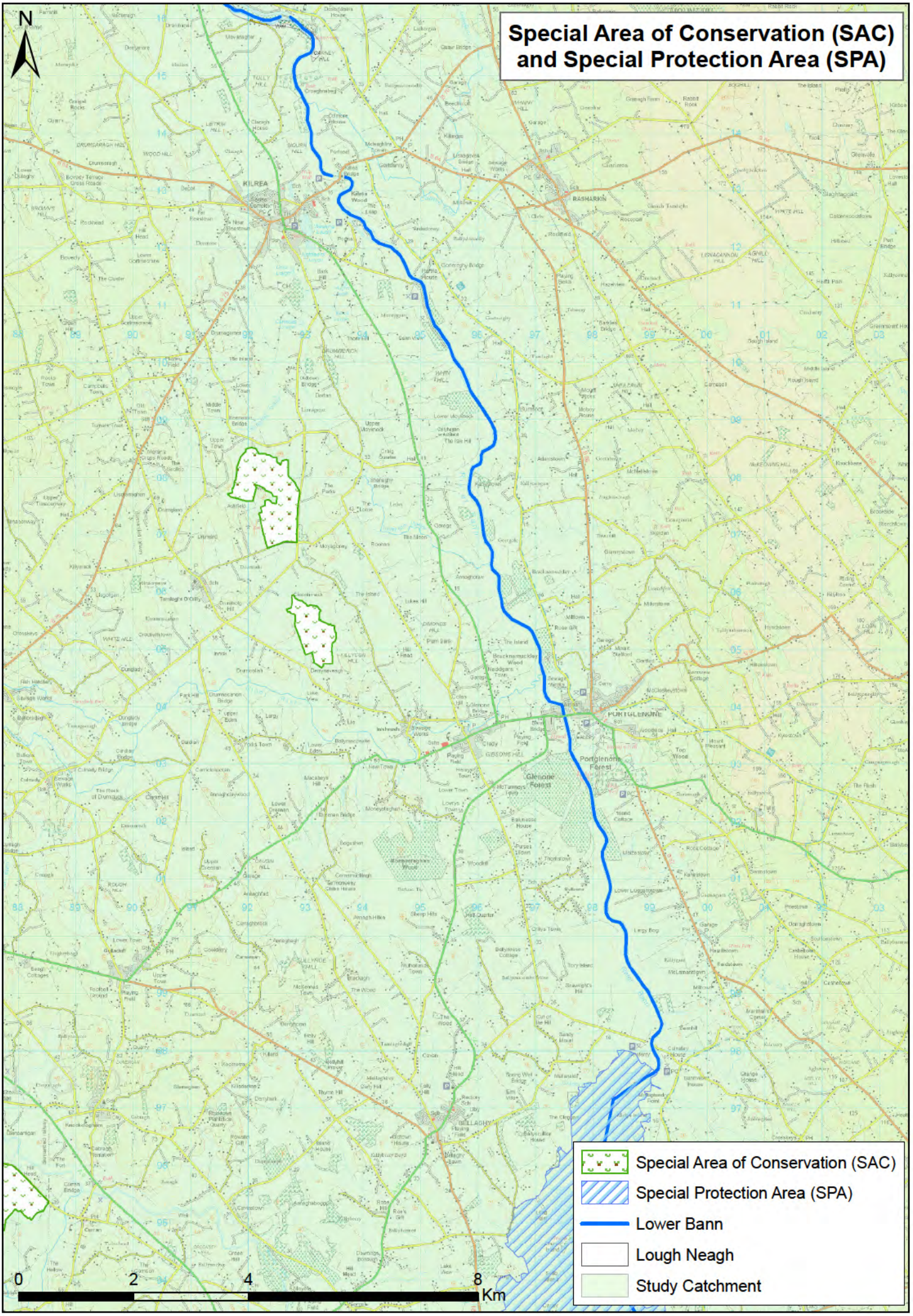
Lough Neagh and Lower Bann Environmental Designations

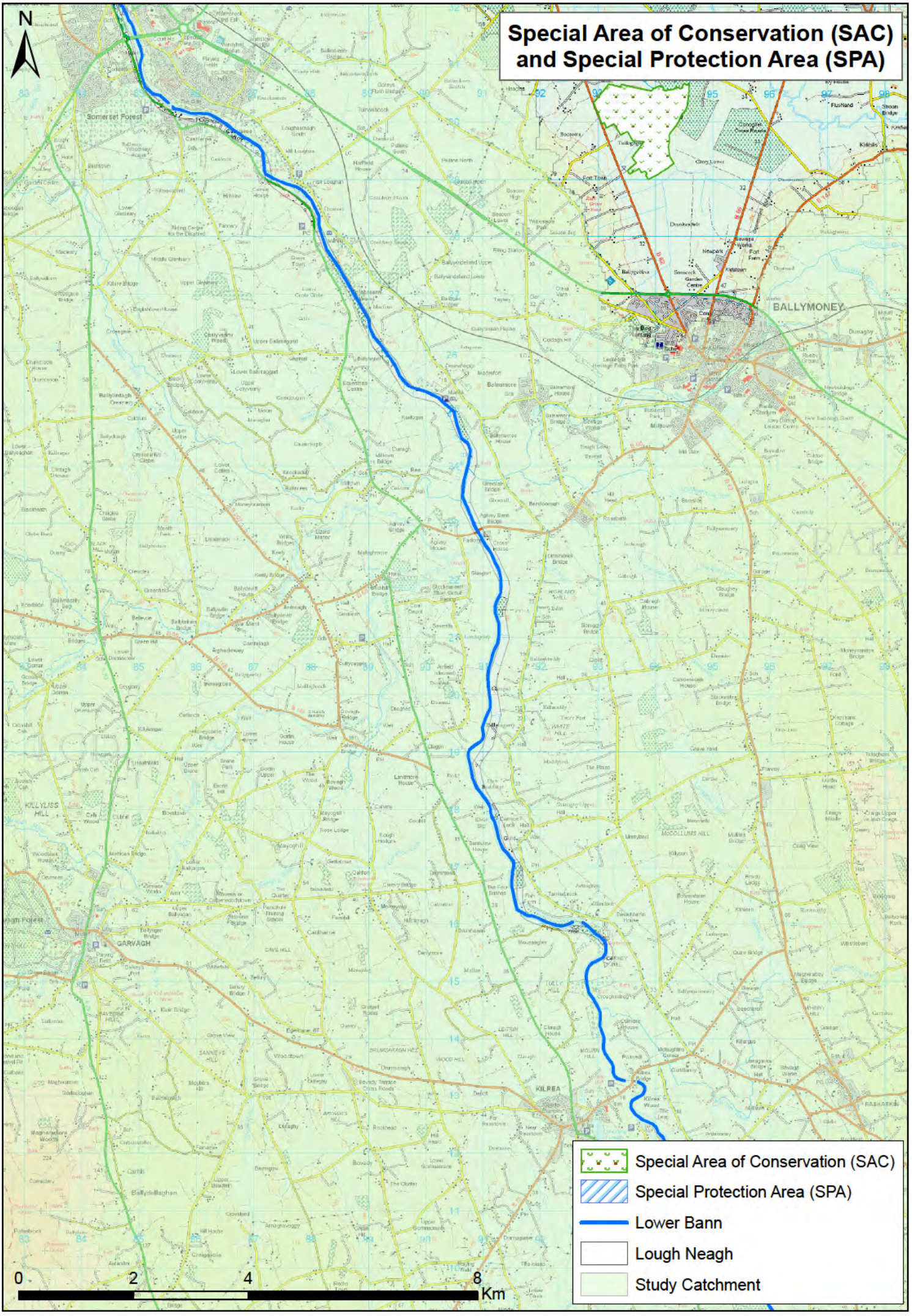

Special Area of Conservation (SAC) and Special Protection Area (SPA)
N
Special Area of Conservation (SAC)
Special Protection Area (SPA)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km


N
Special Area of Conservation (SAC) and Special Protection Area (SPA)
Special Area of Conservation (SAC)
Special Protection Area (SPA)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

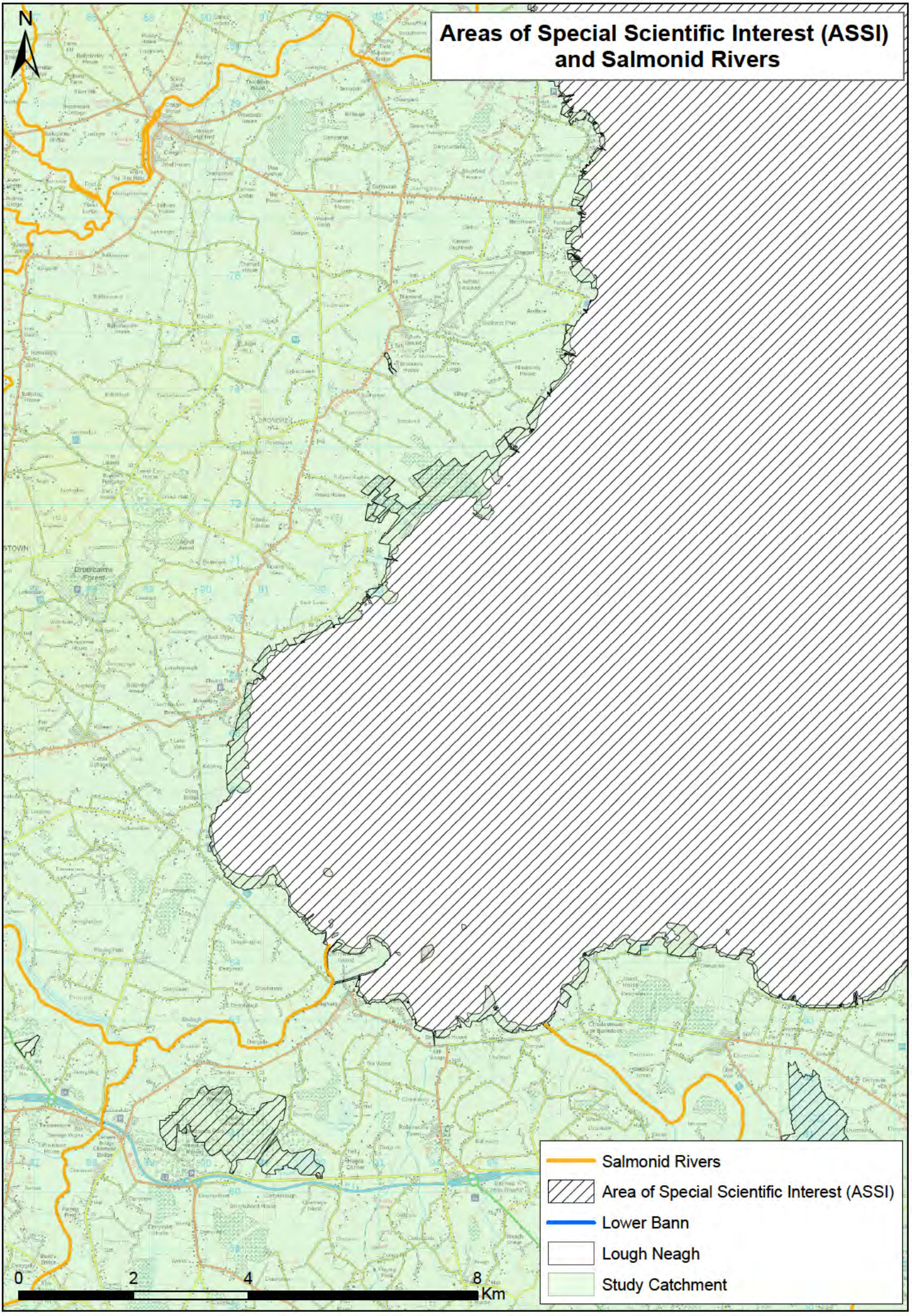

Special Area of Conservation (SAC) and Special Protection Area (SPA)
N
RANDALSTOWN
Randalstown Forest
CRUMLIN
Special Area of Conservation (SAC)
Special Protection Area (SPA)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

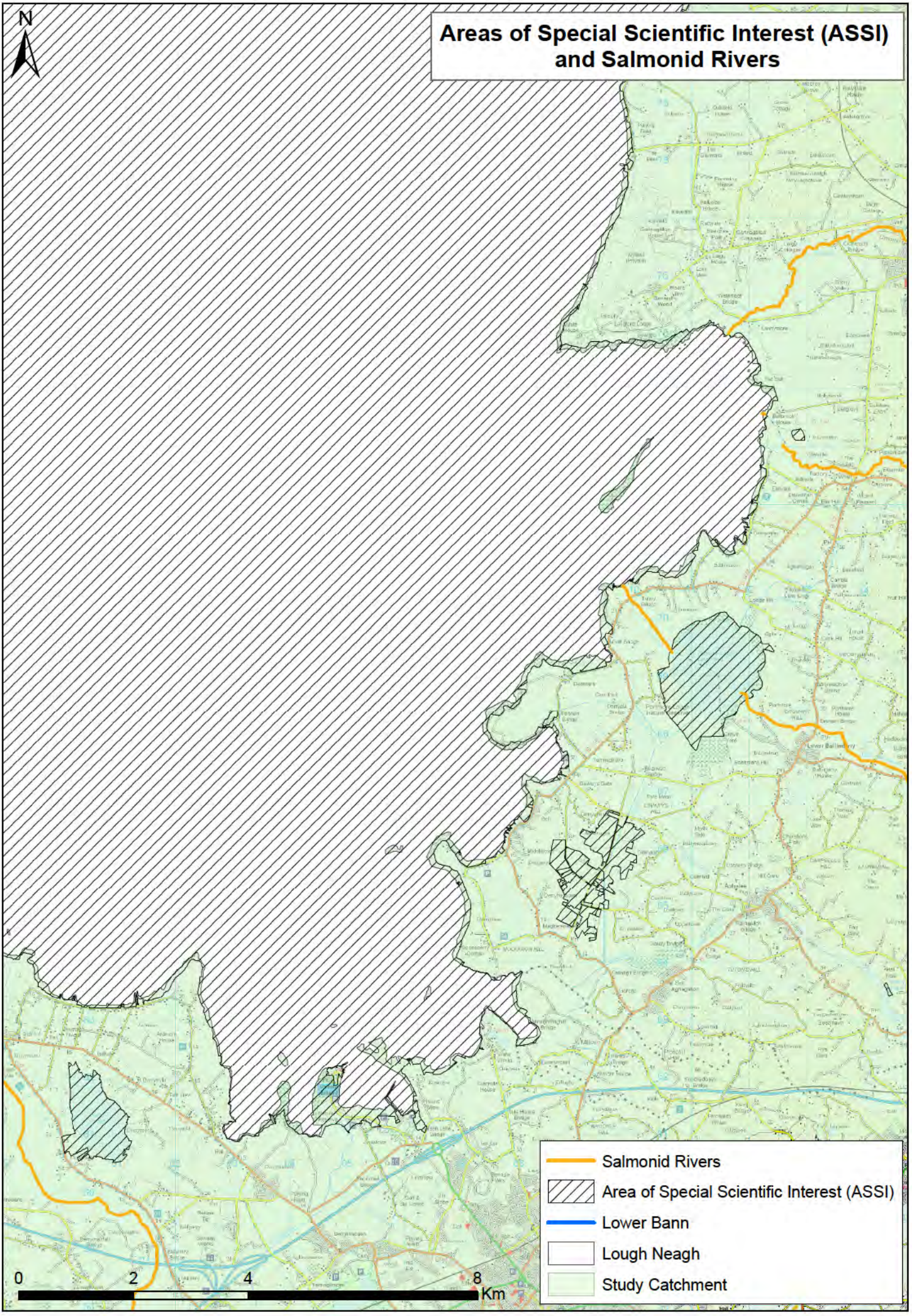

Special Area of Conservation (SAC) and Special Protection Area (SPA)
N
BELLAGHY
CASTLEDAWSON
Special Area of Conservation (SAC)
Special Protection Area (SPA)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

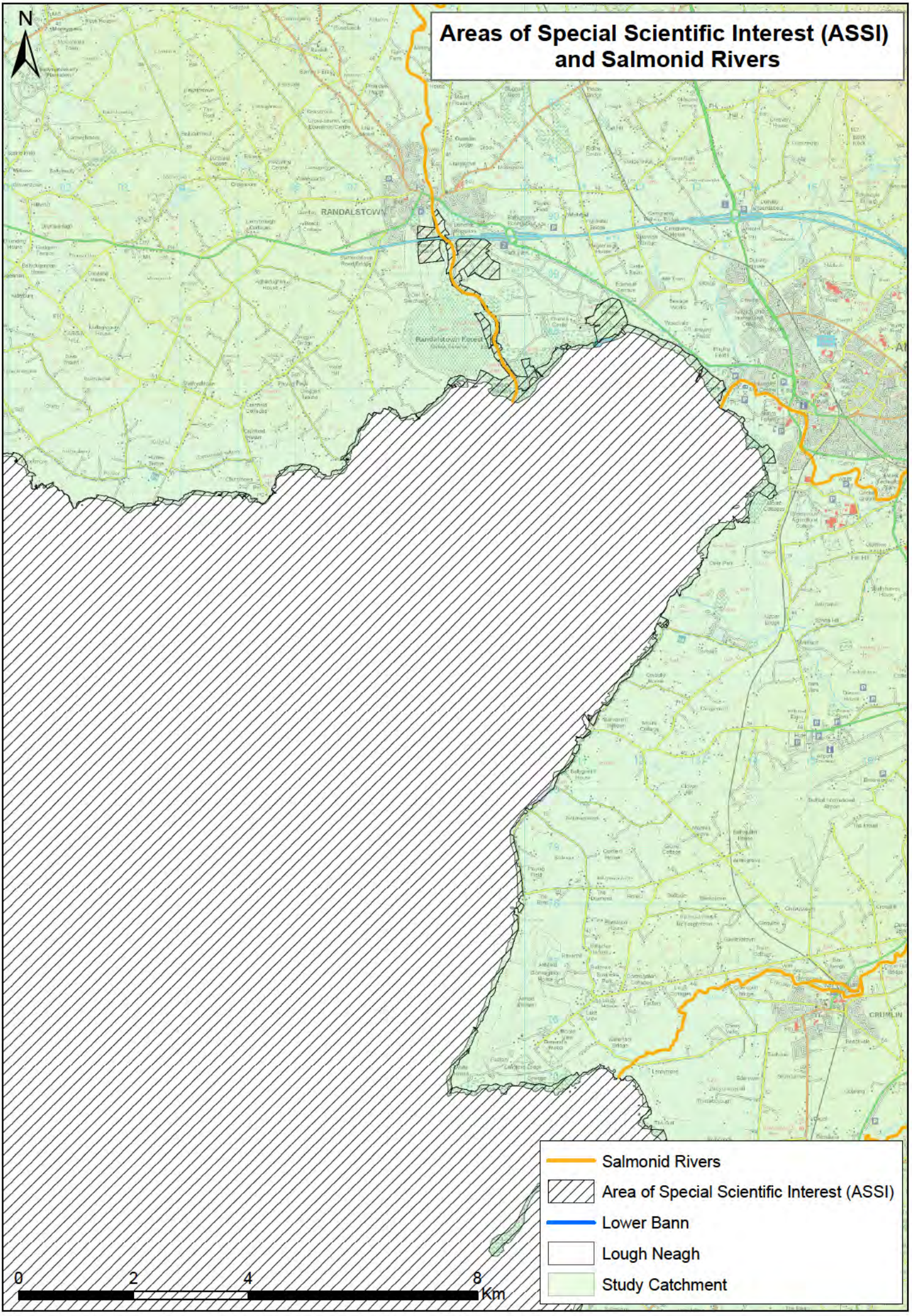

Special Area of Conservation (SAC) and Special Protection Area (SPA)
N
KILREA
RASHARKIN
PORTGLENONE
Portglenone Forest
Glenone Forest
BELLAGHY
Special Area of Conservation (SAC)
Special Protection Area (SPA)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

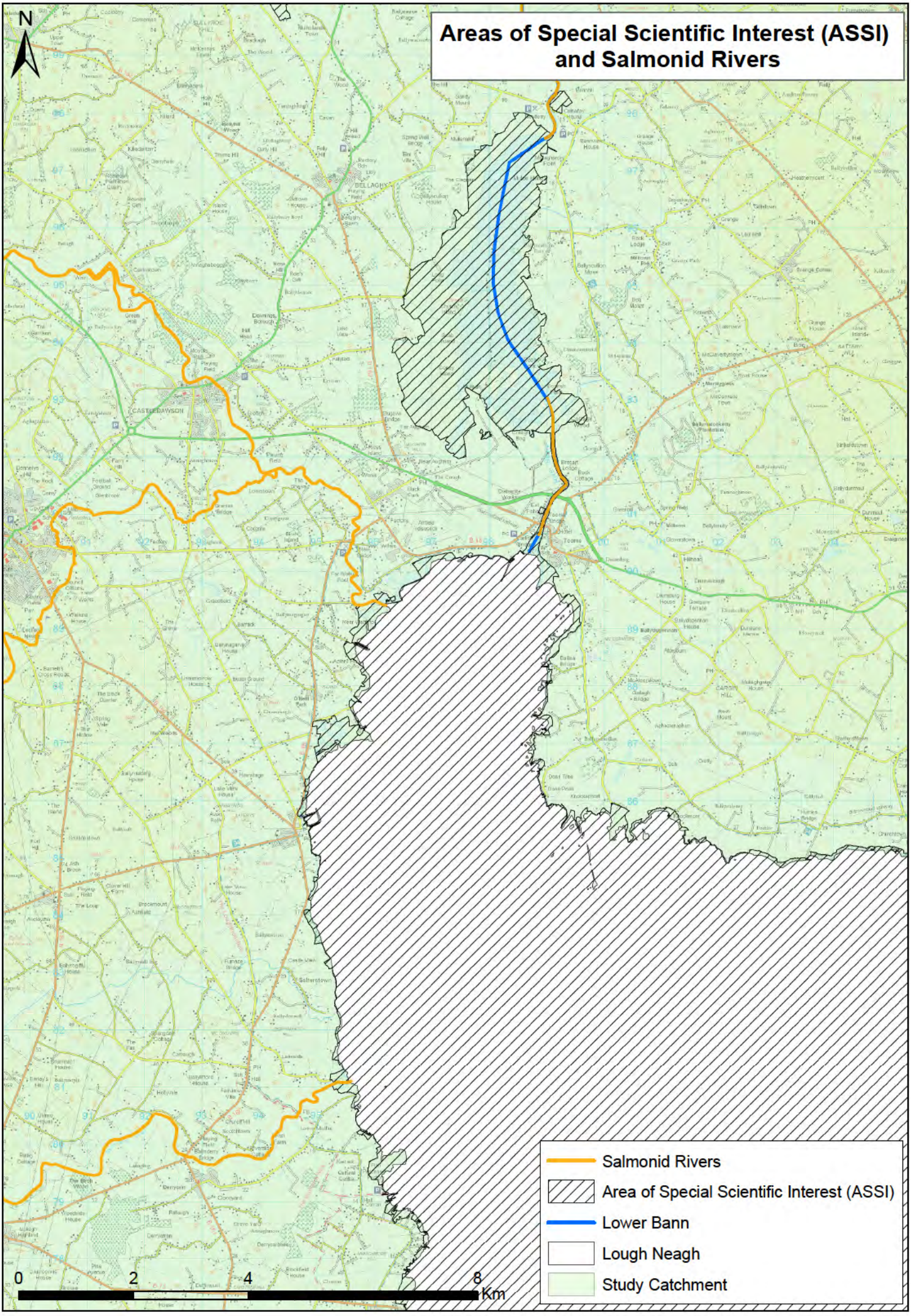

Special Area of Conservation (SAC) and Special Protection Area (SPA)
N
BALLYMONEY
GARVAGH
KILREA
Special Area of Conservation (SAC)
Special Protection Area (SPA)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

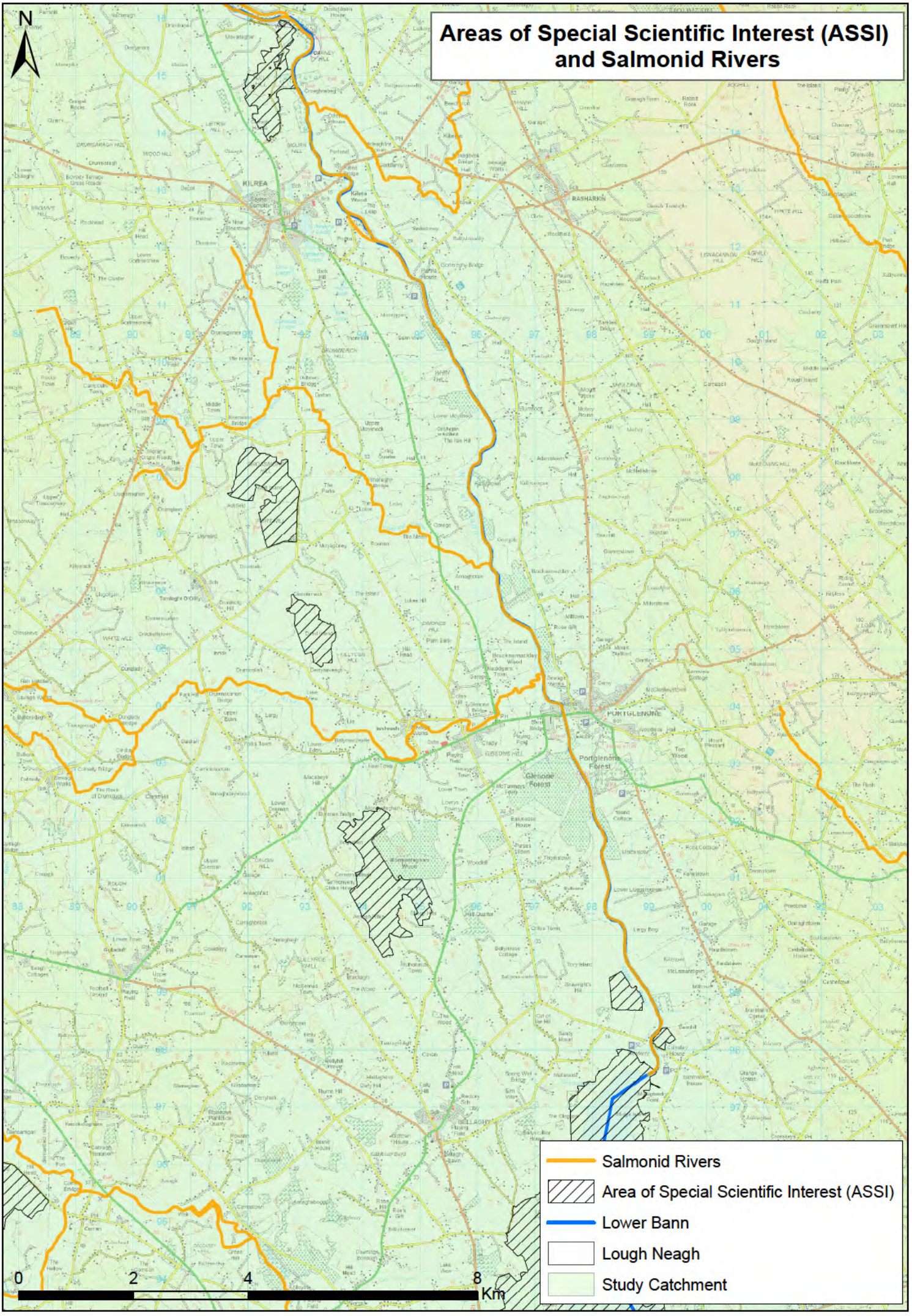

Special Area of Conservation (SAC) and Special Protection Area (SPA)
N
PORTSTEWART
COLERAINE
Downhill Forest
Somerset Forest
Springwell Forest
Coom Forest
KEADY MOUNTAIN
BOYCS MOUNTAIN
Special Area of Conservation (SAC)
Special Protection Area (SPA)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

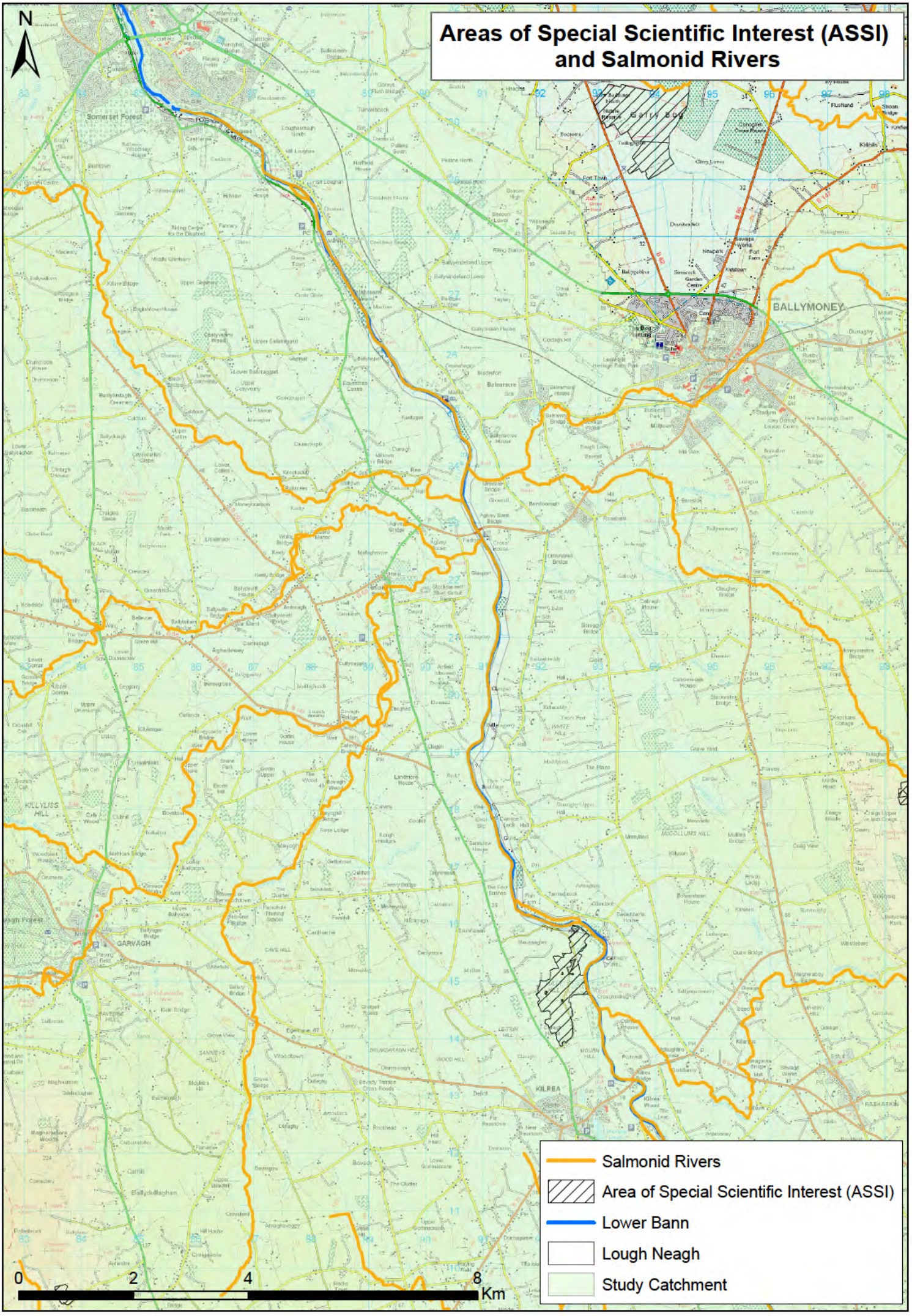

Areas of Special Scientific Interest (ASSI) and Salmonid Rivers
N
Salmonid Rivers
Area of Special Scientific Interest (ASSI)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km


Areas of Special Scientific Interest (ASSI) and Salmonid Rivers
N
Salmonid Rivers
Area of Special Scientific Interest (ASSI)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

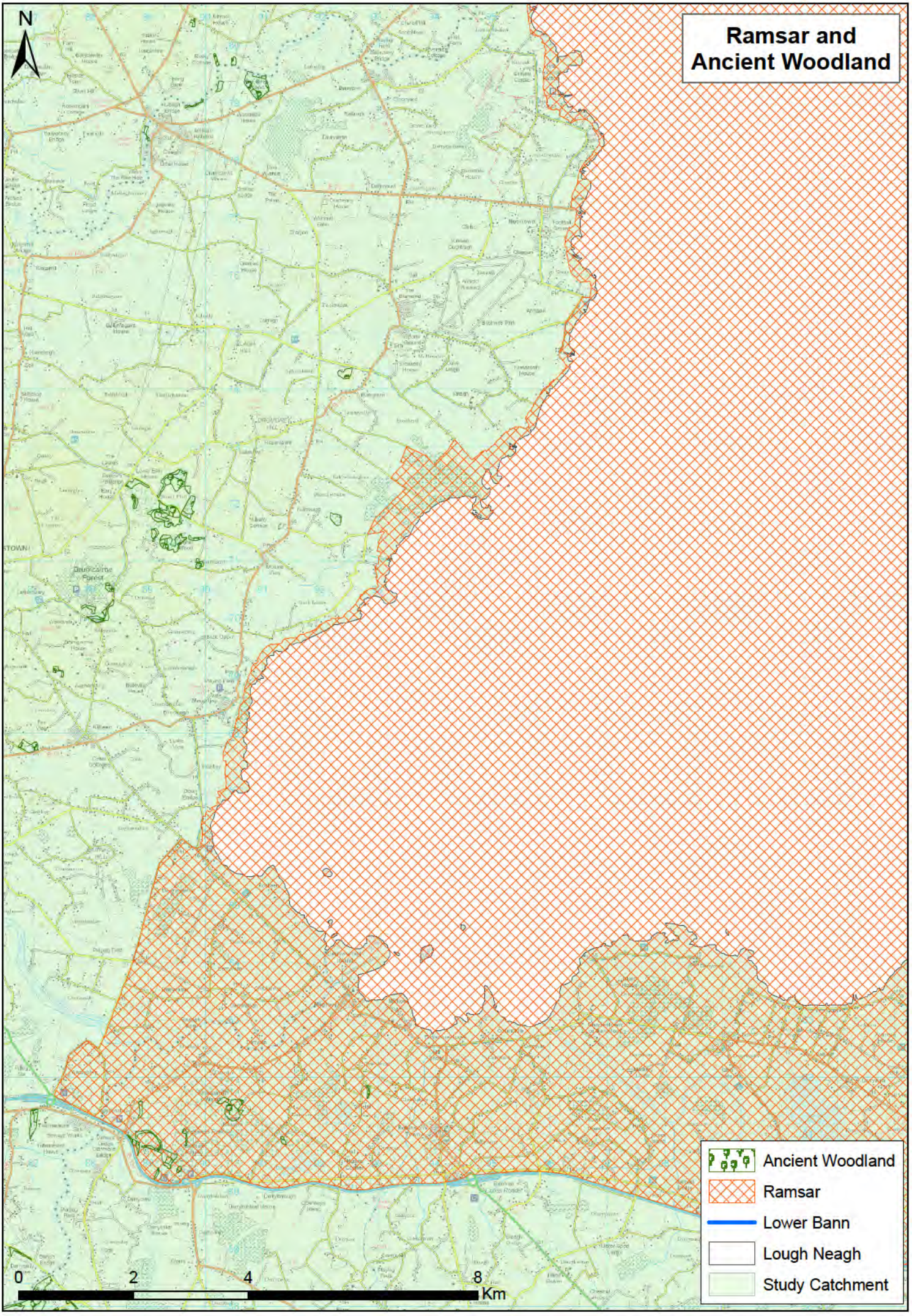

Areas of Special Scientific Interest (ASSI) and Salmonid Rivers
N
RANDALSTOWN
Randalstown Forest
CRUMLIN
Salmonid Rivers
Area of Special Scientific Interest (ASSI)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

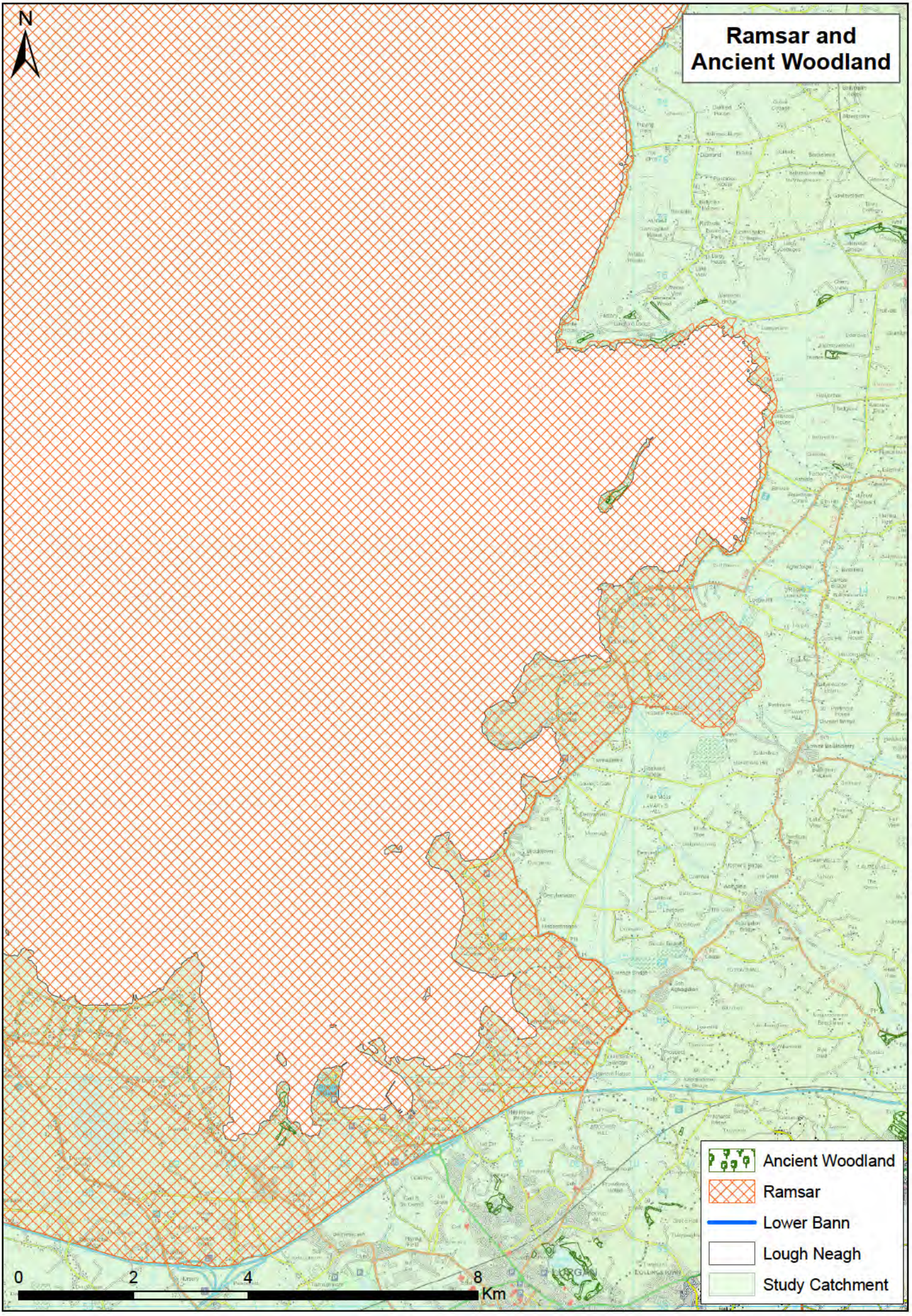

Areas of Special Scientific Interest (ASSI) and Salmonid Rivers
N
Salmonid Rivers
Area of Special Scientific Interest (ASSI)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

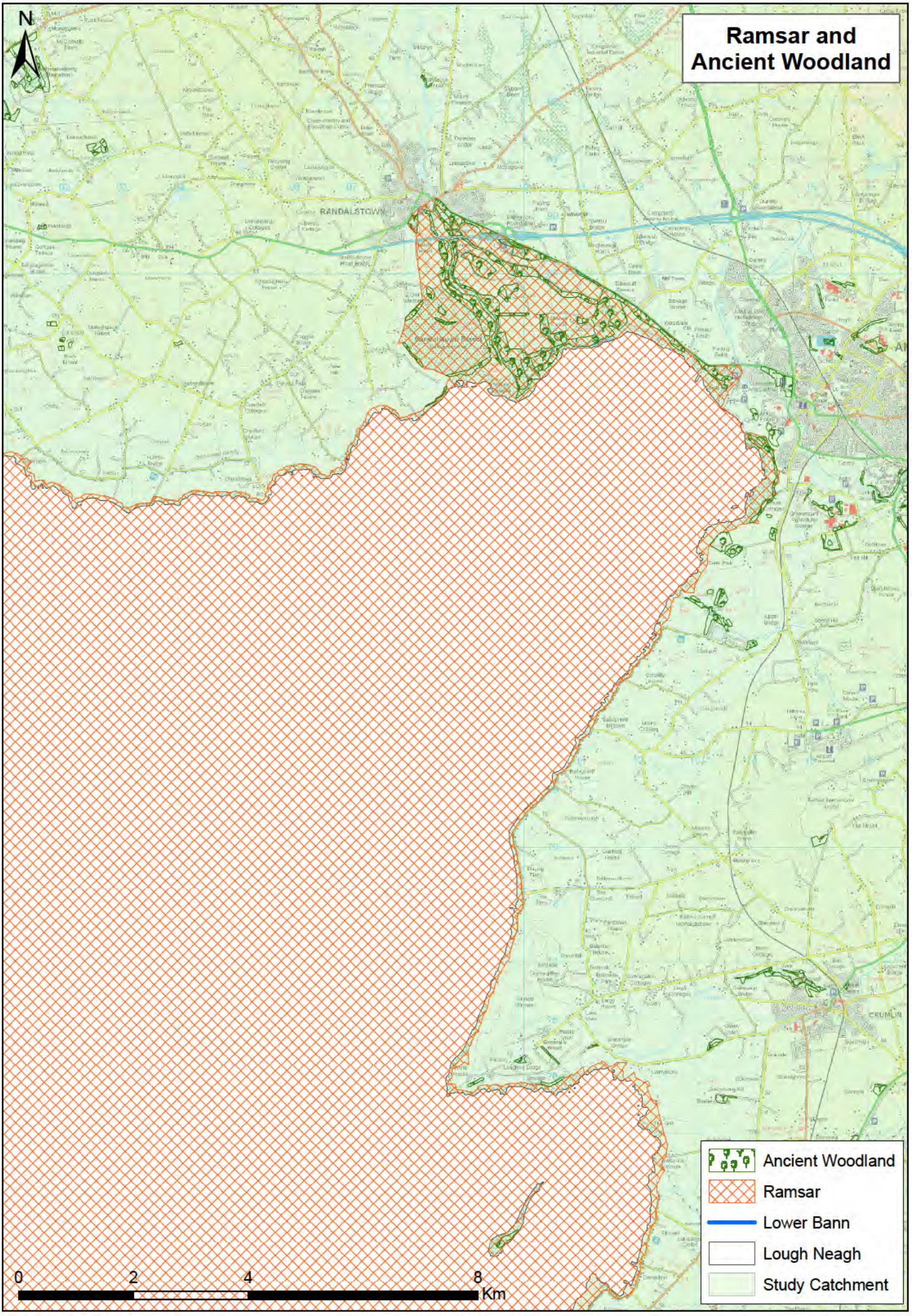

Areas of Special Scientific Interest (ASSI) and Salmonid Rivers
N
KILREA
RASHARKIN
PORTGLENONE
Salmonid Rivers
Area of Special Scientific Interest (ASSI)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

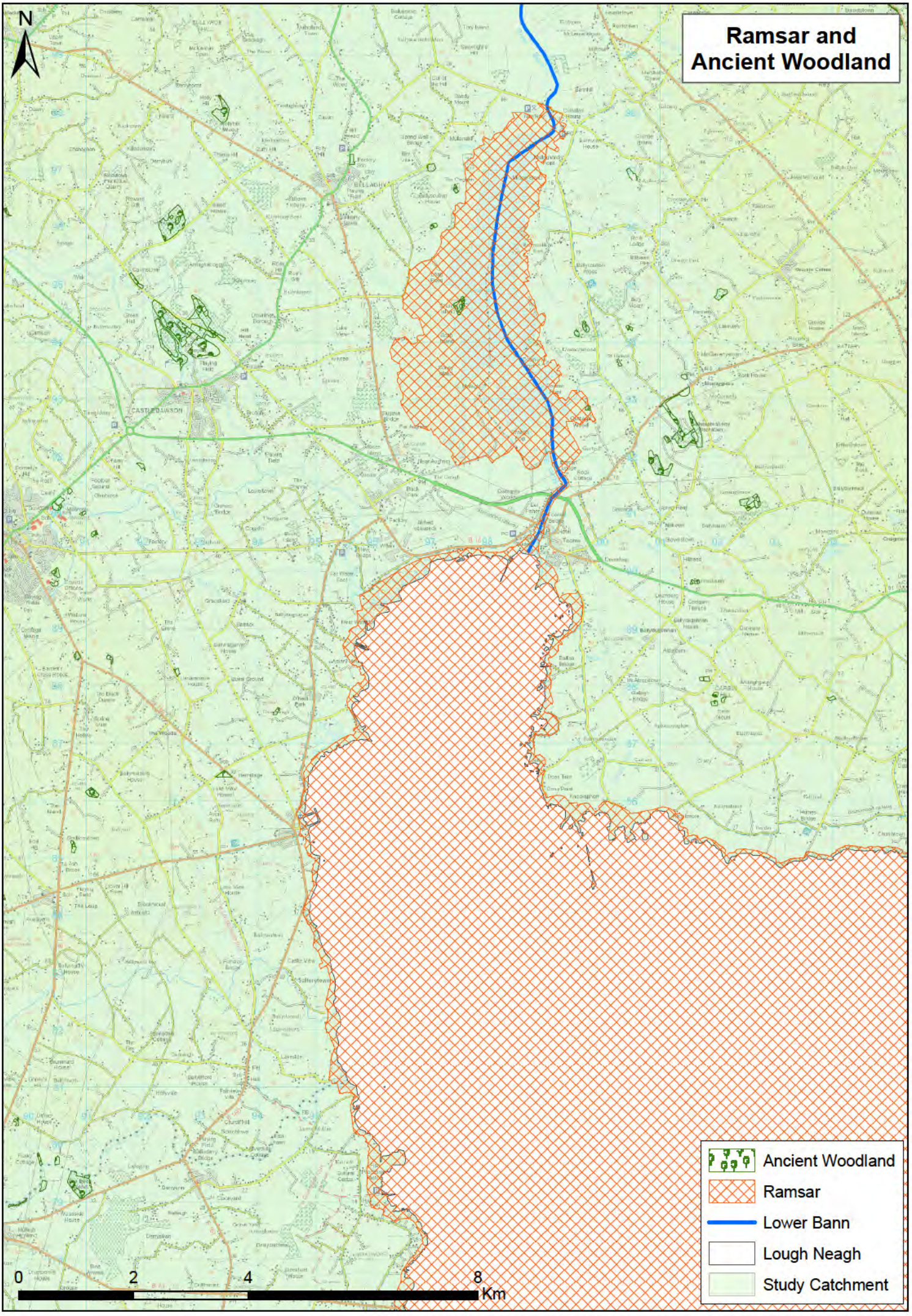

Areas of Special Scientific Interest (ASSI) and Salmonid Rivers
N
BALLYMONEY
KILREA
GARVAGH
Salmonid Rivers
Area of Special Scientific Interest (ASSI)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

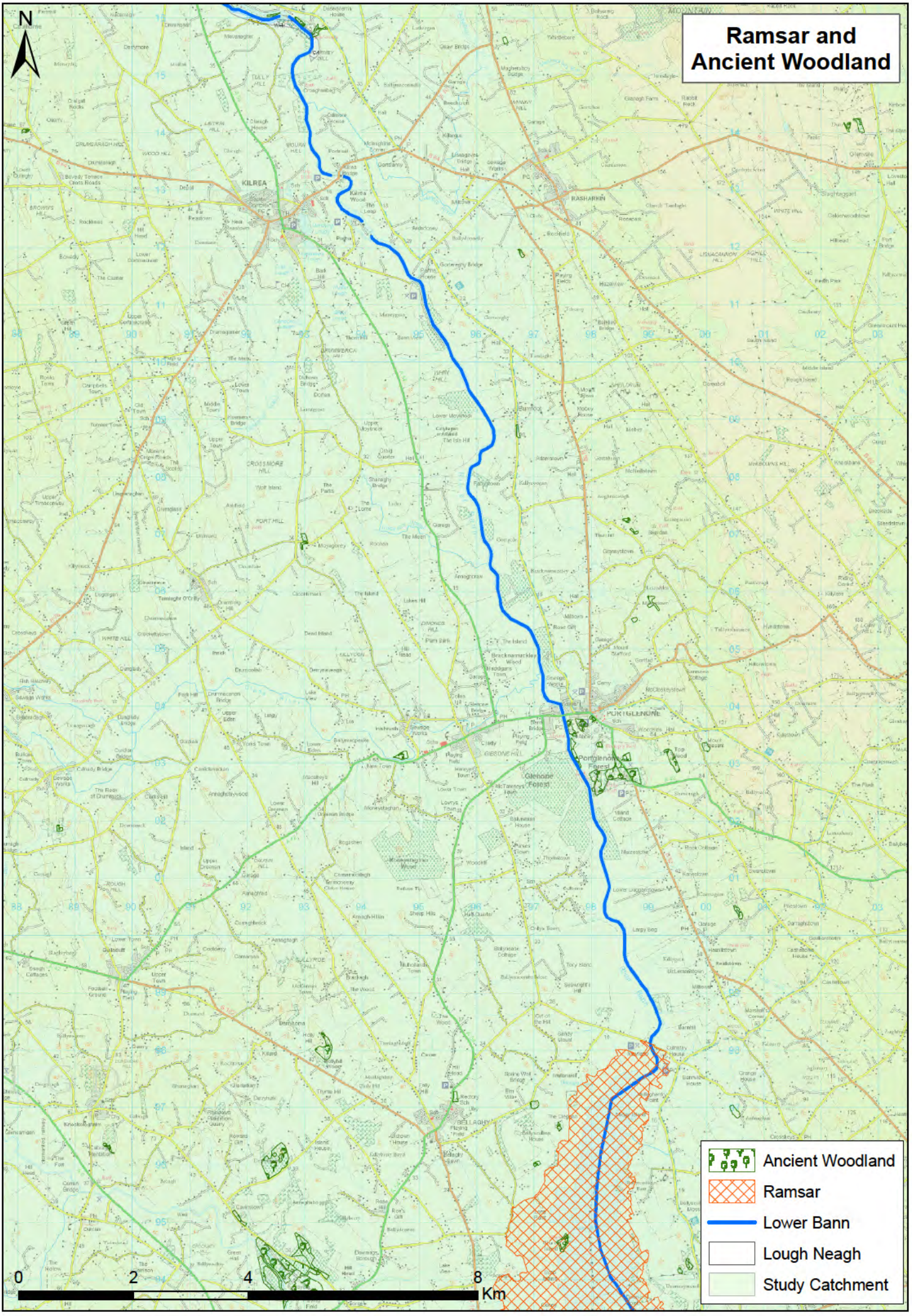

Areas of Special Scientific Interest (ASSI) and Salmonid Rivers
N
Ramore Head
PORTRUSH
PORTSTEWART
COLERAINE
Downhill Forest
Somerset Forest
Springwell Forest
Coom Forest
KEADY MOUNTAIN
BOYCS MOUNTAIN
Salmonid Rivers
Area of Special Scientific Interest (ASSI)
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km

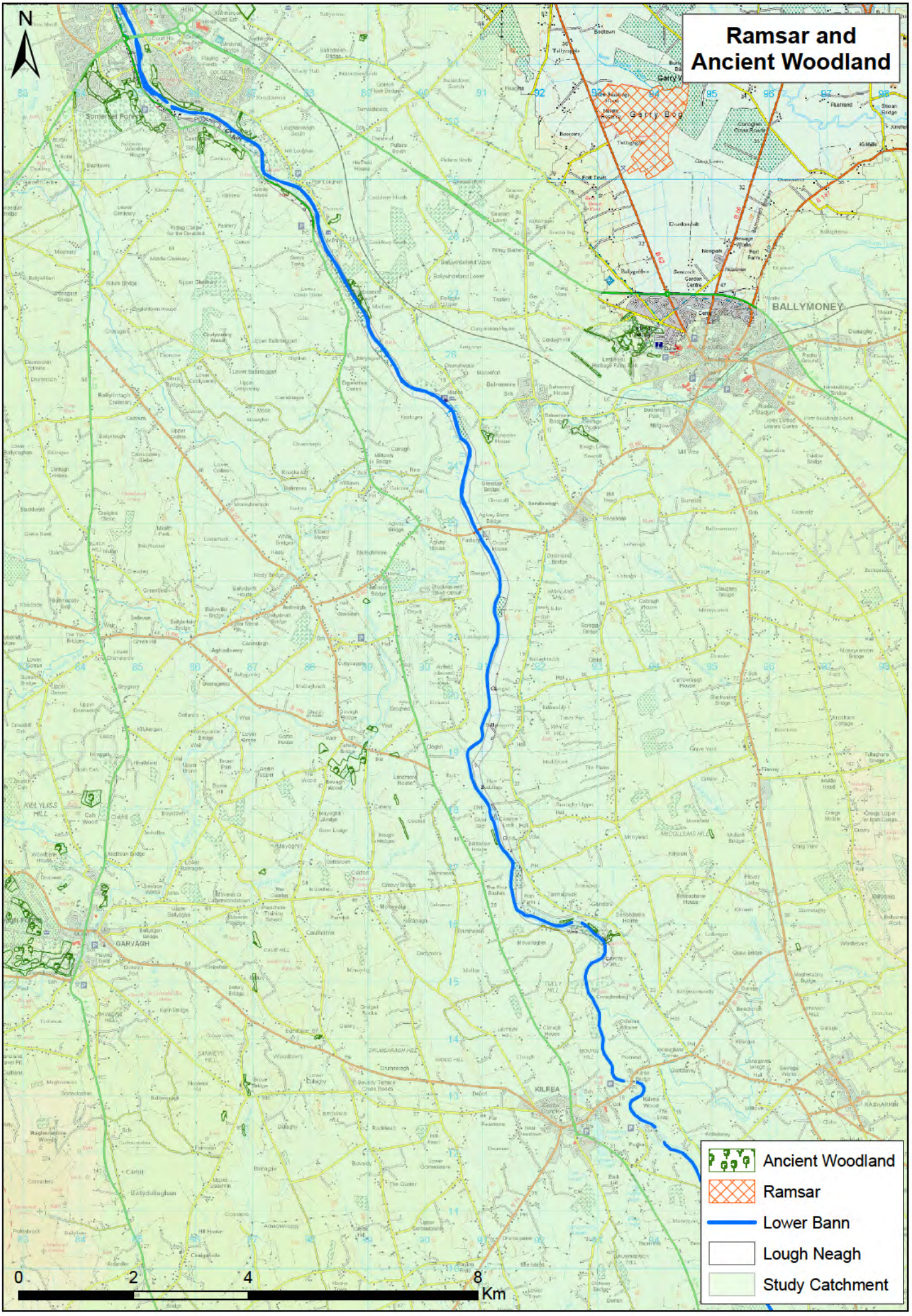

N
Ramsar and Ancient Woodland
Ancient Woodland
Ramsar
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km


N
Ramsar and Ancient Woodland
Ancient Woodland
Ramsar
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km


Ramsar and Ancient Woodland
N
RANDALSTOWN
CRUMLIN
Ancient Woodland
Ramsar
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km


Ramsar and Ancient Woodland
N
Ancient Woodland
Ramsar
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km


Ramsar and Ancient Woodland
N
KILREA
RASHARKIN
PORTGLENONE
Glenone Forest
Ancient Woodland
Ramsar
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km


Ramsar and Ancient Woodland
N
Garry Bog
BALLYMONEY
GARVAGH
KILREA
Ancient Woodland
Ramsar
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km


Ramsar and Ancient Woodland
N
Ramore Head
PORTRUSH
PORTSTEWART
CASTLEROCK
COLERAINE
Downhill Strand
Messenden Temple
The Barmouth
Ballyaghan
Nature Reserve
Dunes
Ringagree Point
Black Rock Blowing Hole
Portstewart Point
Blackcastle Rock
Island Glas
Winkle Island
Little Skerries
Large Skerries
Black Rock
Grange Park Wood
Somerset Forest
BALLYSTRONE HILL
FORMOYLE HILL
Springwell Forest
KEADY MOUNTAIN
Cam Forest
BOYDS MOUNTAIN
Ancient Woodland
Ramsar
Lower Bann
Lough Neagh
Study Catchment
0
2
4
8
Km


Areas of Natural Beauty (AONB)
N
The Skerries
Castle Island
Black Rock
Little Skerries
Large Skerries
West Isle
South Island
Ramore Head
PORTRUSH
Nature Reserve
Ringagree Point
Black Rock
Portstewart Point
PORTSTEWART
The Barmouth
Downhill Strand
Nature Reserve
COLERAINE
Somerset Forest
Grange Park
Springwell Forest
Keady Mountain
Cam Forest
Scon Forest
Boyds Mountain
0
2
4
8
Km
Area of Natural Beauty (AONB)
Lower Bann
Study Catchment

Appendix D –

Long Section of Lower Bann (labelled) with Maximum Flood Elevation in 2015/16 Winter Simulation

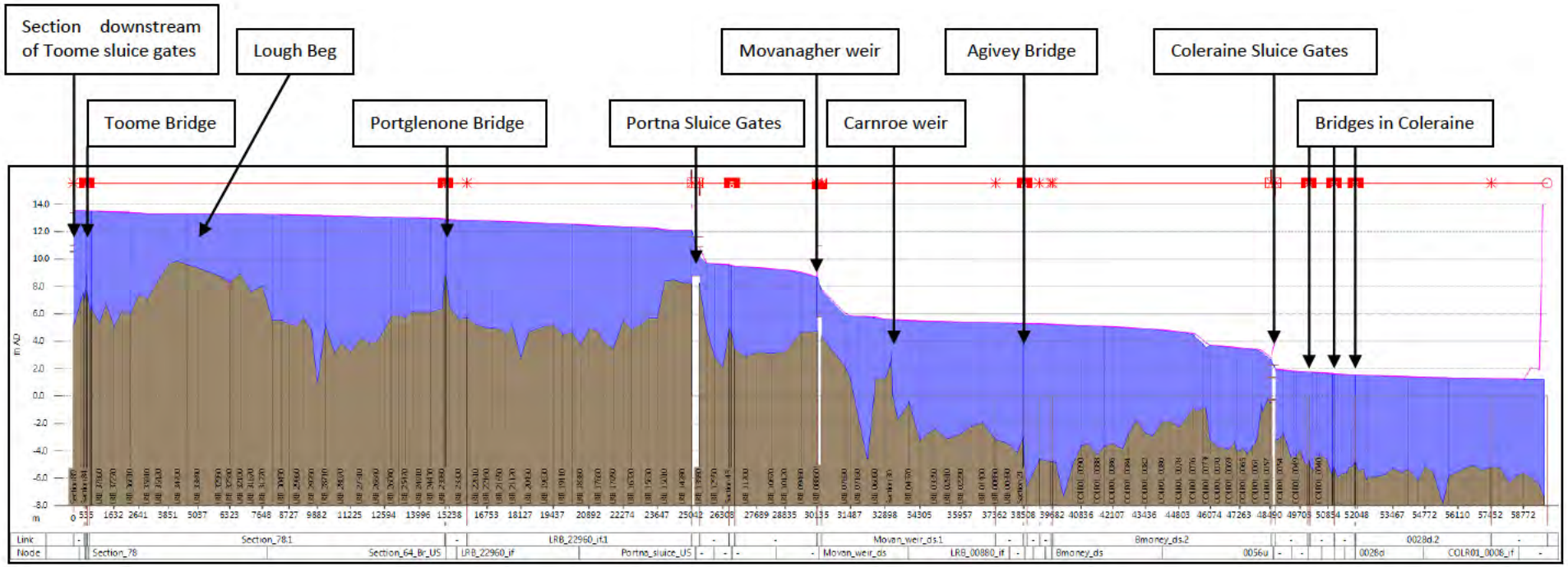


Figure 20: Long Section of Lower Bann, with Structures Labelled and Maximum Flood Elevation in Winter 2015/16 Simulation

Appendix E –

Properties and Roads Affected During 2015/16 Winter Floods

DfI Flooding Records of Winter 2015/16 Flooding

Information was provided by DfI Area Engineers on areas and roads which were affected, as well as areas where DfI Staff were directly involved in deploying sandbags and carrying out pumping to avoid property inundation. The data is presented below:

- Properties where DfI carried out pumping during the Winter 2015/16 are included in the table below:

Address	County	Level from LiDAR (m AOD Belfast)
[redacted], Derrymore, Aghalee	Antrim	13.575
[redacted], Derrymore, Aghalee	Antrim	13.533
[redacted], Lurgan, [redacted] (business premises at Sands Marina and South Shore Marine and Diesel)	Armagh	13.410
[redacted], Muckery, Portadown, [redacted]	Armagh	13.55*
[redacted] Derryall, Portadown, BT62 1UJ	Armagh	13.57*
[redacted], Derrylileagh, Portadown, BT62 1SX	Armagh	13.443
[redacted], Derrylileagh, Portadown, BT62 1SX	Armagh	13.430
[redacted], Derryadd, BT66 6QL	Armagh	13.820*
[redacted], Derrytrasna, Craigavon BT66 6QJ	Armagh	13.550*
[redacted] Derrytresk, Coalisland, BT71 4QW	Tyrone	13.720
[redacted], Derrytresk, Coalisland, BT71 4QW	Tyrone	13.831

*levels taken from national 5m DTM

- A property was sandbagged at [redacted] Derrymore, Aghalee (13.640m AOD).
- Roads affected included the Moss Road, Aghalee, adjacent to property [redacted] (13.605m AOD), on Bartin's Bay Road, adjacent to property [redacted] (13.283m AOD) and the lane access to a property at [redacted] Moss Road (13.510m AOD).