AfterLIFE Hydrology & Vegetation Monitoring Plan

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1 INTRODUCTION

The overall AfterLIFE plan aims to establish how the actions initiated in the living bog project will be continued and developed in the years that follow the end of the project and how the longer-term management of the sites/habitats will be assured. The After-LIFE Plan will build on the lessons learned during the implementation of the project to provide a longer-term dataset that can help quantify the success of the project and provide recommendations for the future management and restoration of other raised bog sites across Ireland.

The main objectives of the After LIFE Plan are to:

1. Continue and propose further actions to contribute to the achievement of 'favourable conservation conditions across the project sites

2. Monitor the long term ecohydrological results in the years following the project restoration works (5-year minimum) to assess whether the restoration works have adequately restored the hydrology for ombrotrophic ecology and whether further measures are required.

3. Maintenance of structures and facilities

4. Dissemination of results

The purpose of this hydrology section is to provide a review of possible AfterLIFE hydrological monitoring activities based on the analysis of results collected by the project thus far combined with data on ecological recovery obtained by the project ecologist. It is anticipated that the ecological response to the hydrological restoration may take several years to respond, it is therefore recommended that ongoing ecological monitoring be conducted so that the overall success of the restoration measures can be assessed. It is recommended that water level monitoring at select locations would continue over this period to supply supplementary data to the ecological response and provide a comprehensive ecohydrology dataset.

Based on the initial findings of the hydrological/ecological datasets, eight sites have been selected as priority sites for continued groundwater level monitoring:

- Ardagullion Bog SAC
- Carrownagappul Bog SAC
- Ferbane Bog SAC
- Moyclare Bog SAC
- Killyconny Bog SAC
- Raheenmore Bog SAC
- Clara Bog SAC
- Carrowbehy Bog SAC

Currently, the living bog project has installed 251 monitoring wells across the 11 project sites, 50 of which are monitored using Solinst Level loggers. This report puts forward recommendations on the continued monitoring of a subset of wells at the eight selected sites. Monitoring at these selected locations in tandem with vegetation monitoring would be particularly beneficial to either

1. Developing a more comprehensive understanding of the long term hydrological and ecological results of restoration or
2. Helping identify any further actions that may be required in the achievement of 'favourable conservation conditions across the project sites

This document will also estimate the time and resources that will be required to maintain/survey these wells and put forward recommendations for sampling frequency based on the initial analysis of the hydrological data collected by the project.

2 SITE RECOMMENDATIONS

2.1 Ardagullion Bog SAC

Ardagullion experienced significant levels of cutover rewetting due to a combination of both peat and plastic dams combined with the installation of the barrier dam along the western cutover. Similarly, several piezometers on the high bog reported improvements in the hydrological supporting conditions across the site. Using the results collected to date, five wells are proposed for ongoing monitoring and are illustrated in Figure 2-1. The selection rationale for each piezometer is detailed in Table 2-1.

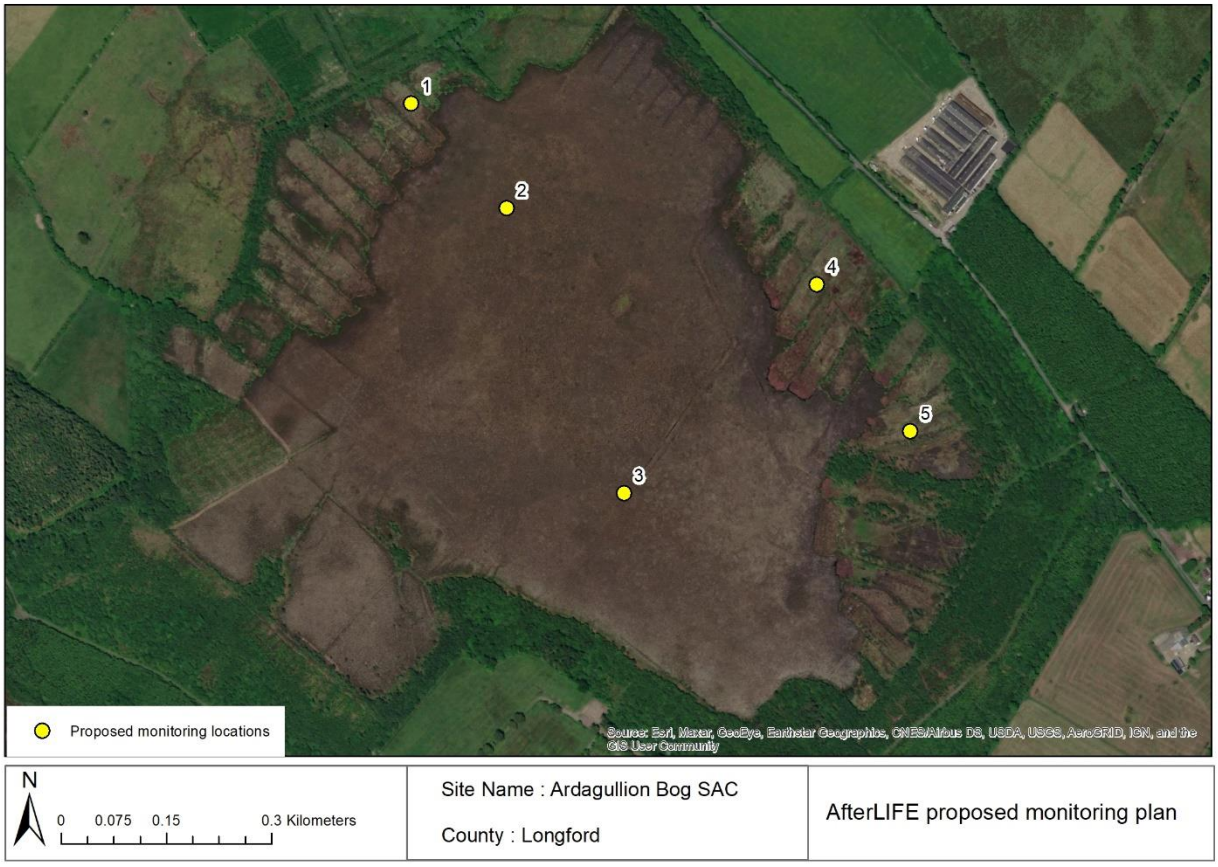

Figure 2-1: Proposed AfterLIFE monitoring locations at Ardagullion Bog SAC

Well code	Existing LIFE well	Distance to existing vegetation monitoring plot (m)	Rationale
1	✓	35	Cutover section that has experienced significant re-wetting. Situated with the modelled area of PFH. Monitoring point can be used to investigate the long term impact of the barrier dam.
2	✓	115	High Bog area that has experienced re-wetting. Currently Sub-Marginal, however, is not situated within the modelled area of DRB. Although the increase in water levels is low compared to some cutover wells, the increase may be critical in that it may achieve the correct conditions for ARB to develop
3	✓	20	High Bog area that has experienced re-wetting. Currently Sub-Marginal and is within the modelled area of DRB. Although the increase in water levels is low compared to some cutover wells, the increase may be critical in that it may achieve the correct
4	✓	35	Cutover section that has experienced significant re-wetting. Situated within a modelled area of PFH.
5	✓	10	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH. Area due to its natural topography is potentially too wet, with pools deeper than 25cm. Assessing the long term implications of this together with vegetation monitoring would be beneficial (e.g. how long does it take these shallow pool areas to be colonised with Sphagnum etc.)

Table 2-1: Details of the selection rationale for AfterLIFE monitoring points on Ardagullion Bog SAC

2.2 Clara Bog SAC

Clara Bog SAC experienced significant re-wetting along the southern cutovers of both Clara-East and Clara-West, with positive results achieved through a combination of peat damming and cell bunding. However, although the living bog achieved positive results on the cutover, Clara Bog SAC is currently suffering from ongoing losses of ARB on the high bog due to subsurface hydrogeological losses (Regan et al. 2019). A proposed solution to halt these ongoing losses is currently under consideration by NPWS and would involve the infilling of drains (and possibly the infilling of an area of the cutover in general) on the southern section of Clara-West. NPWS hydrologist, DR Shane Regan has requested that the current living bog monitoring network be left in place to supplement the existing high bog monitoring network on the site, so the effectiveness of the approach can be studied with greater confidence. The five cutover wells that are proposed to remain are illustrated in Figure 2-2. The selection rationale for each piezometer is detailed in Table 2-2.

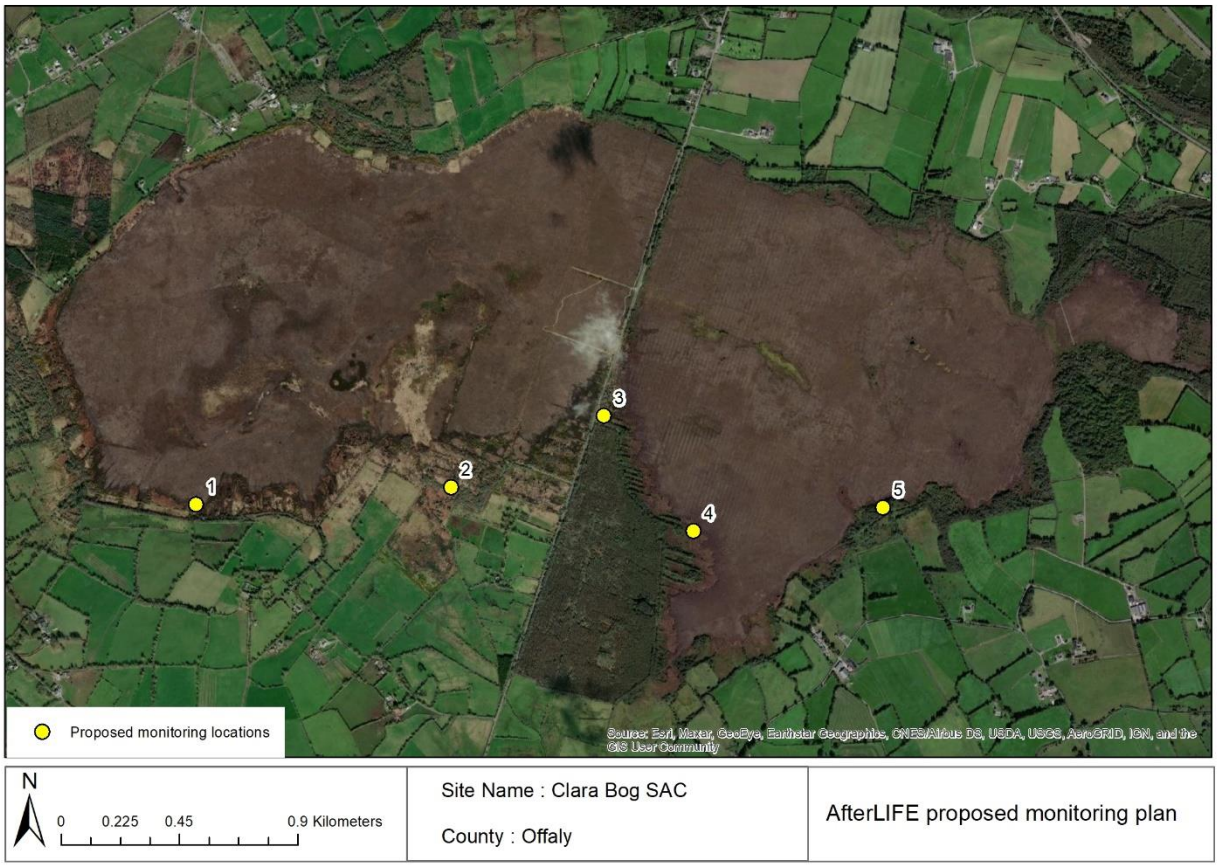

Figure 2-2: Proposed AfterLIFE monitoring locations at Clara Bog SAC

Well code	Existing LIFE well	Distance to existing vegetation monitoring plot (m)	Rationale
1	✓	15	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.
2	✓	120	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH. Located within an area where additional works will be completed to infill drains and halt subsurface losses.
3	✓	15	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.
4	✓	10	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.
5	✓	12	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.

Table 2-2: Details of the selection rationale for AfterLIFE monitoring points on Clara Bog SAC

2.3 Killyconny Bog SAC

Limited hydrological responses were observed on Killyconny Bog SAC, in part due to the timing of the works which were completed near the end of the project and partially due to works already completed on the site in the form of a 1.7km long berm, similar to that installed at Ardagullion Bog SAC, which was installed on the site on the cutover along the western boundary in a number of phases between 2006-10. Additionally, there were several drains along the North and eastern boundary of the site, which were left open due to landowner issues, which limited hydrological improvements in these areas. It is recommended that hydrological monitoring equipment be installed to monitor the impact of not completing these works as part of the living bog project.

As part of a collaborative study, several gas chambers have been installed on the cutover at Killyconny, to understand the greenhouse gas (GHG) fluxes across a range of differing cutover habitats as defined by Smith and Crowley (2020). It is proposed that this GHG study be complemented with loggers from the living bog project so that the GHG fluxes, vegetation composition and hydrological supporting conditions can be compared and contrasted over time. Figure 2-3 shows the locations of the installed GHG measurement chambers, additional piezometers would be required to supplement these readings.

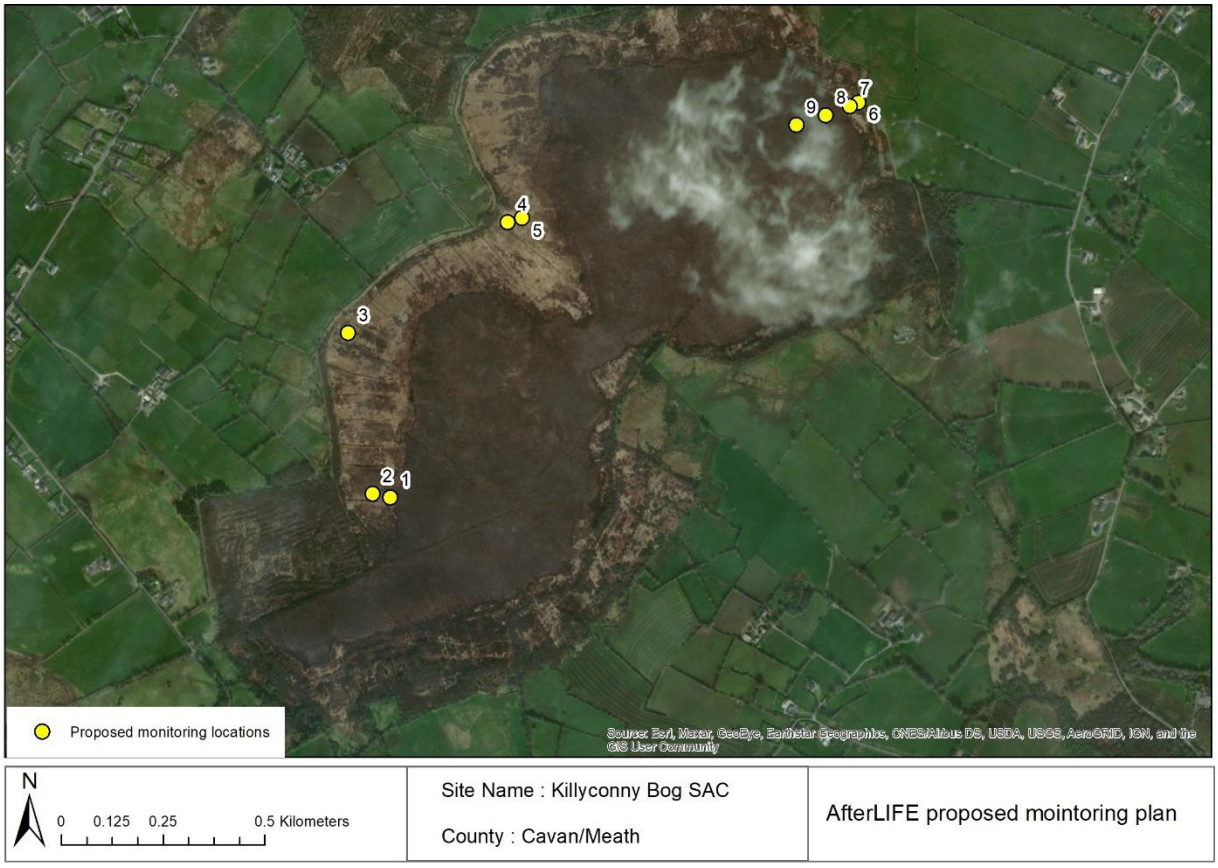

Figure 2-3: Proposed AfterLIFE monitoring locations at Killyconny Bog SAC

Well code	Existing LIFE well	Distance to existing vegetation monitoring plot (m)	Rationale
1	X	N/A	To accompany the GHG chamber installed at this location. Would require new piezometer installed.
2	X	N/A	To accompany the GHG chamber installed at this location. Would require new piezometer installed.
3	X	N/A	To accompany the GHG chamber installed at this location. Would require new piezometer installed.
4	X	N/A	To accompany the GHG chamber installed at this location. Would require new piezometer installed.
5	X	N/A	To accompany the GHG chamber installed at this location. Would require new piezometer installed.
6	X	N/A	To investigate the impact of drains remaining open and establish a baseline for future works.
7	X	N/A	To investigate the impact of drains remaining open and establish a baseline for future works.
8	X	N/A	To investigate the impact of drains remaining open and establish a baseline for future works.
9	X	N/A	To investigate the impact of drains remaining open and establish a baseline for future works.

Table 2-3: Details of the selection rationale for AfterLIFE monitoring points on Killyconny Bog SAC

2.4 Carrownagappul Bog SAC

Carrownagappul experienced significant levels of cutover rewetting due to a combination of restoration measures, such as peat and plastic dams, sandwich dams, contour bunding, tree removal and stump flipping. Similarly, several piezometers on the high bog reported improvements in the hydrological supporting conditions across the site due to actions completed by the living bog project, with the project ecologist also noting ongoing improvements on the high bog, hypothesised to be partially as a result of continued recovery from earlier restoration efforts on the site (in the mid-2000s) and partially as a result of Living Bog works. Using the results collected to date, six wells are proposed for ongoing monitoring and are illustrated in Figure 2-4. The selection rationale for each piezometer is detailed in Table 2-4. Additionally, a logger will be added to the existing flume at Carrownagappul to provide long term flow records at the site.

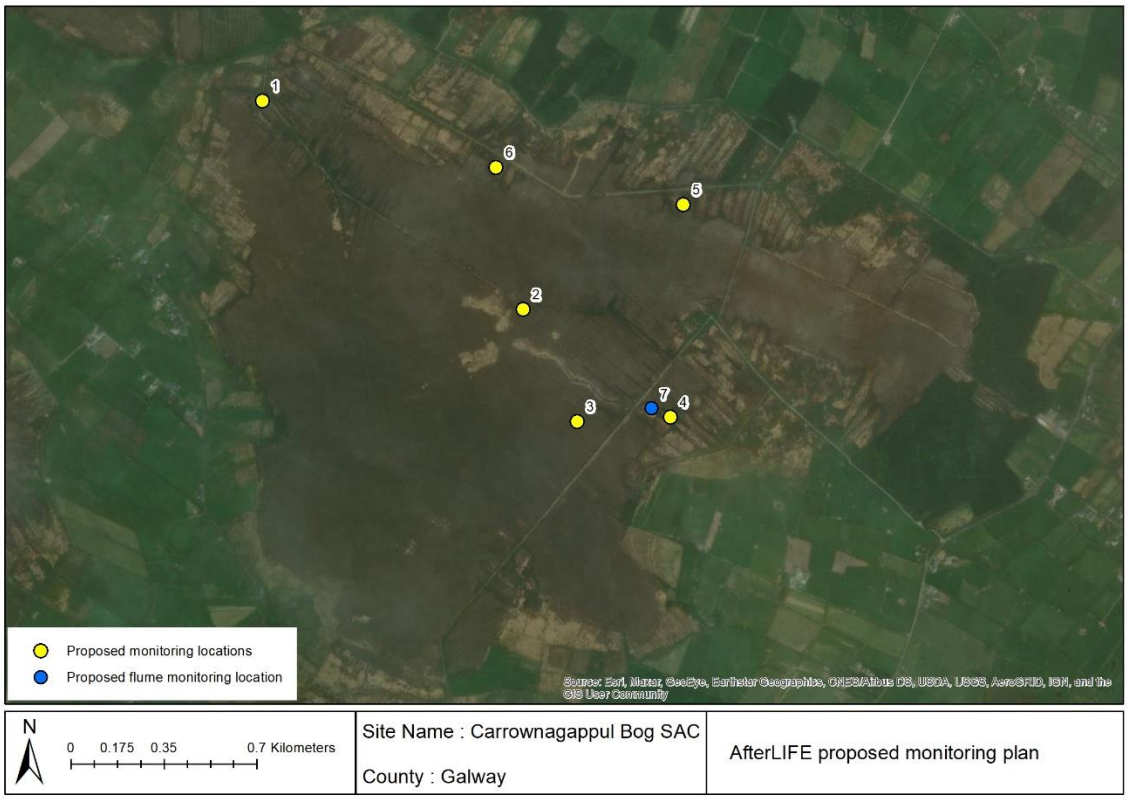

Figure 2-4: Proposed AfterLIFE monitoring locations at Carrownagappul Bog SAC

Well code	Existing LIFE well	Distance to existing vegetation monitoring plot (m)	Rationale
1	✓	5	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.
2	X	10	High Bog area that has experienced re-wetting. Currently Marginal, however, is situated within the modelled area of DRB. Project ecologist noted a positive response in the area. New piezometer required in area.
3	✓	120	High Bog area, currently Sub-Marginal and is situated with the modelled area of DRB. Area did not re-wet as modelled, further investigation required.
4	✓	40	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.
5	✓	15	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.
6	X	5	Cutover section that has experienced significant re-wetting. Not currently within an area of modelled PFH, however project ecologist has noted a positive response. New piezometer required in area.
7	✓	N/A	Flume monitoring point – existing stilling well in place.

Table 2-4: Details of the selection rationale for AfterLIFE monitoring points on Carrownagappul Bog SAC

2.5 Raheenmore Bog SAC

Raheenmore Bog SAC was one of the project sites on which positive results were not widely observed. Although re-wetting was observed in some southern and eastern sections of cutover due to peat damming, these were spatially limited and not considered to be representative of widely hydrological restoration across the site.

The project ecologist noted a reduction in ARB on the high bog (from 2011 to 2016) which suggests that the supporting hydrological conditions are worsening on the site. A potential hypothesis for this is that large drains situated to the East and the North of Raheenmore, which were left open due to unresolved issues with landowners are having ongoing hydrogeological impacts on the bog. This is supported by the data from the living bog project which shows hydraulic gradients increasing from the centre of the bog towards these drains. It is recommended to support the conservation objectives of the site that these drains should be blocked and that ongoing liaison with landowners should be perused.

To monitor the current ongoing losses and provide a baseline from which the success of future restoration measures can be studied and quantified. It is recommended that two transects continue to be monitored on Raheenmore Bog SAC as illustrated in Figure 2-5. This would require the additional instrumentation of piezometers as detailed in Table 2-5.

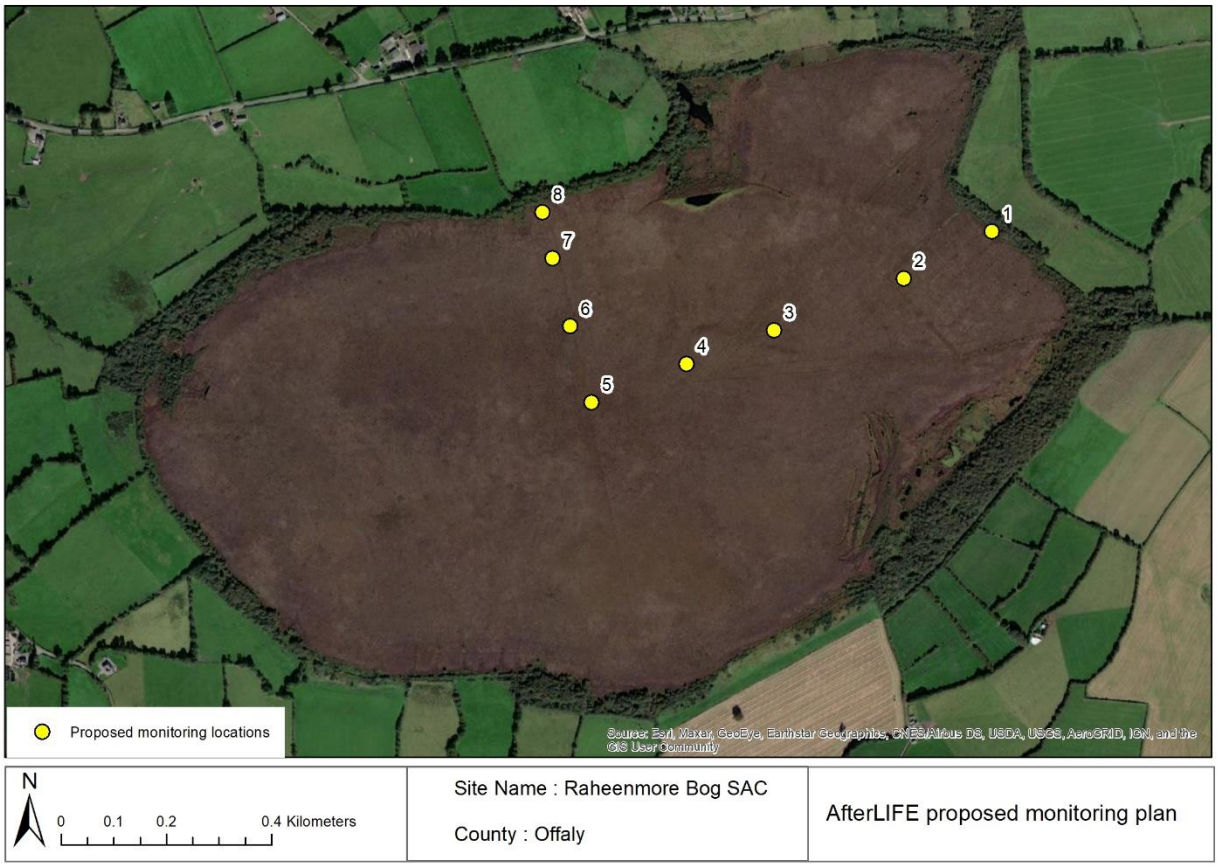

Figure 2-5: Proposed AfterLIFE monitoring locations at Raheenmore Bog SAC

Well code	Existing LIFE well	Distance to existing vegetation monitoring plot (m)	Rationale
1	✓	N/A	Transect to investigate ongoing subsurface losses. Would require an additional deep piezometer.
2	✓	N/A	Transect to investigate ongoing subsurface losses. Shallow & deep piezometer pair already installed.
3	✓	N/A	Transect to investigate ongoing subsurface losses. Shallow & deep piezometer pair already installed.
4	X	N/A	Transect to investigate ongoing subsurface losses. Would require installation of shallow & deep piezometer pair.
5	✓	N/A	Transect to investigate ongoing subsurface losses. Shallow & deep piezometer pair already installed.
6	X	N/A	Transect to investigate ongoing subsurface losses. Would require installation of shallow & deep piezometer pair.
7	X	N/A	Transect to investigate ongoing subsurface losses. Would require installation of shallow & deep piezometer pair.
8	X	N/A	Transect to investigate ongoing subsurface losses. Would require installation of shallow & deep piezometer pair.

Table 2-5: Details of the selection rationale for AfterLIFE monitoring points on Raheenmore Bog SAC

2.6 Ferbane/Moyclare Bog SAC

Both Ferbane Bog SAC and Moyclare Bog SAC experienced significant levels of rewetting as a result of a combination of both peat and plastic damming works. Moyclare was noted as a site where cutover re-wetting was particularly successful and Ferbane was highlighted as a site on which high bog re-wetting was most successful based on the hydrological data collected to date. Given the close proximity of the two sits to one another, they have been included as one area for the purposes of collecting hydrological data. Using the results collected to date, four wells on Moyclare Bog SAC and 3 wells on Ferbane Bog SAC are proposed for ongoing monitoring and are illustrated in Figure 2-6. The selection rationale for each piezometer is detailed in Tables 2-6 and 2-7.

Figure 2-6: Proposed AfterLIFE monitoring locations at Moyclare Bog SAC and Ferbane Bog SAC

Well code	Existing LIFE well	Distance to existing vegetation monitoring plot (m)	Rationale
1	✓	20	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.
2	✓	5	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.
3	✓	5	High Bog area that has experienced re-wetting. Currently Sub-Marginal and is within the modelled area of DRB. Although the increase in water levels is low compared to some cutover wells, the increase may be critical in that it may achieve the correct
4	✓	15	Cutover section that has experienced significant re-wetting. Situated with a modelled area of PFH.

Table 5-6: Details of the selection rationale for AfterLIFE monitoring points on Moyclare Bog SAC

Well code	Existing LIFE well	Distance to existing vegetation monitoring plot (m)	Rationale
1	✓	10	High Bog area that has experienced re-wetting. Currently Sub-Marginal and is within the modelled area of DRB
2	✓	5	High Bog area that has experienced re-wetting. Currently Sub-Marginal and is within the modelled area of DRB
3	✓	5	High Bog area that has experienced re-wetting. Currently Sub-Marginal and is within the modelled area of DRB

Table 2-7: Details of the selection rationale for AfterLIFE monitoring points on Ferbane Bog SAC

2.7 Carrowbehy Bog SAC

Several drains along the eastern boundary of the site were left open due to landowner issues, which limited hydrological improvements in these areas. It is recommended that hydrological monitoring equipment be installed to monitor the impact of not completing these works as part of the living bog project. Using the results collected to date, four wells on Carrowbehy Bog SAC are proposed for ongoing monitoring and are illustrated in Figure 2-6. The selection rationale for each piezometer is detailed in Tables 2-10.

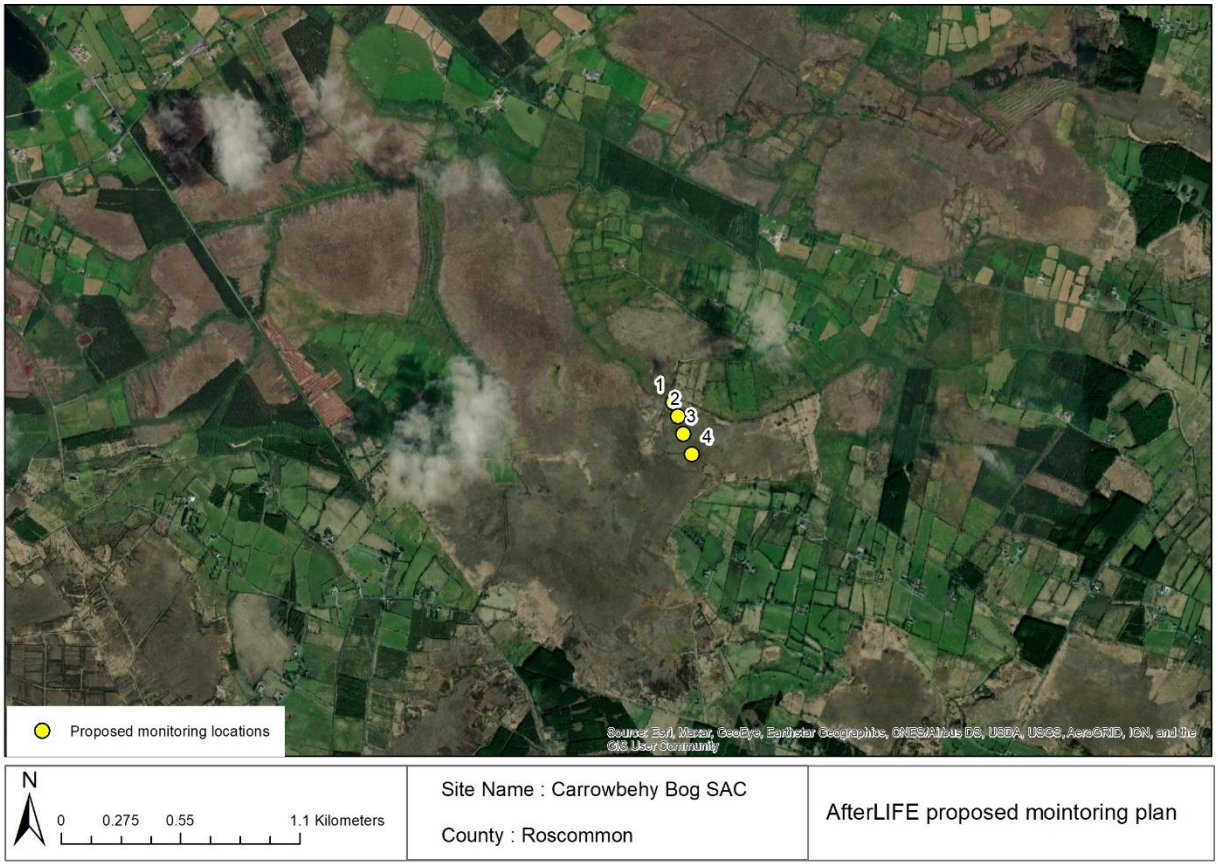

Figure 2-7: Proposed AfterLIFE monitoring locations at Carrowbehy Bog SAC

Well code	Existing LIFE well	Distance to existing vegetation monitoring plot (m)	Rationale
1	X	N/A	To investigate the impact of drains remaining open and establish a baseline for future works.
2	X	N/A	To investigate the impact of drains remaining open and establish a baseline for future works.
3	X	N/A	To investigate the impact of drains remaining open and establish a baseline for future works.
4	X	N/A	To investigate the impact of drains remaining open and establish a baseline for future works.

Figure 2-8: Details of the selection rationale for AfterLIFE monitoring points on Carrowbehy Bog SAC

3 VEGETATION MONITORING

Vegetation monitoring of *The Living Bog* sites will continue into the future. The NPWS has a well-established high bog monitoring programme that runs in six-year cycles. Four *Living Bog* sites (Clara, Raheenmore, Derrinea and Mongan) are due to be monitored as part of the Raised Bog Monitoring 2021-24 programme in which a total of 31 SAC and NHA bogs are to be surveyed using the standard NPWS ecotope mapping techniques. High bog monitoring quadrats will also be revisited at this time. Additionally, these four *Living Bog* sites together with another ten raised bog SACs are to make up the raised bog National Ecosystem Monitoring Network (co-ordinated by the Environmental Protection Agency), sites on which the levels of atmospheric nitrogen deposition will be monitored.

Future NPWS Raised Bog Monitoring Programmes will also now need to include an element of cutover habitat surveying since the conservation objectives of raised bog SACs now include achieving a specific area of ARB (or at least peat-forming habitat) on the cutover. Cutover monitoring plots can be re-visited during these surveys.

However, in the shorter term (ca 5 years) in order to aid the overall understanding of the impacts of the project's restoration, a number of sites will be selected for full ecotope, cutover habitat, high bog quadrat and full species releves survey with surveys to be undertaken in ca 2025-26. The sites selected are from those that are to have continued hydrological monitoring so that datasets can be combined for a more holistic analysis. The following sites are suggested:

1. Carrownagappul Bog
2. Ardagullion Bog
3. Ferbane Bog
4. Moyclare Bog
5. Killyconny Bog

Ecotope surveys will follow the methodology described by Fernandez *et al*. (2014), based on raised Bog ecotope vegetation community complexes developed by Kelly and Schouten (2002). Cutover habitat surveys will use the classification system developed by Smith and Crowley (2020). To aid the mapping, high resolution aerial photography of these sites will be undertaken prior to surveys commencing in 2025. The monitoring transects on Carrownagappul, Ardagullion and Killyconny are also to be repeated. The methodology (i.e. survey of 30 vegetation plots) used to describe the western cutover on Killyconny by Crowley *et al.* (2021) should also be repeated to characterise how the restoration of that site is progressing. The number of monitoring plots on each of the sites is shown in Table 3.1 with a total of 185 plots across the five sites. These are 4m x 4m plots. This does not include the monitoring plots along the transects on Ardagullion (44 plots, each 2m x 2m), Carrownagappul track transect (12 plots, each 2m x 2m) and Killyconny (27 plots, each 5m x 5m) or the 30 vegetation plots (2m x 2m) undertaken across the western Killyconny cutover to characterise its vegetation. Thus, the total number of plots to be resurveyed is 298.

Table 3.1 Number of Monitoring plots on The Living Bog sites to be resurveyed as part of the AfterLIFE plan.

Site Code/Name	Monitoring Quadrats on HB	Monitoring Releves on cutover	Total Number of MQ's/MR's
000006 Killyconny Bog	9	14	23
000575 Ferbane Bog	12	16	28
000581 Moyclare Bog	14	25	39
001242 Carrownagappul Bog	26	38	64
002341 Ardagullion Bog	8	23	31
TOTAL NUMBER OF MONITORING PLOTS	**69**	**116**	**185**

4 MONITORING RECOMMENDATIONS

During the LIFE project, RPS staff collected water levels on a monthly basis. This included the manual dipping of 251 wells across the 11 project sites. The process took a team of two-people approximately 4 days to complete (8 personnel days). A full download of the loggers was not completed on a monthly basis, however, when incorporated in the process (every 6 months), the manual dipping and downloading process could be completed by a team of two people in 5 days (10 personnel days). Of the 251 wells installed as part of the LIFE project, a subset of 45 wells have been put forward to be monitored as part of this proposal. It is anticipated that this would take a team of two people 3 days (6 personnel days) to monitor going forward. Table 3.1 below details the envisaged sampling round based on the experience of collecting data for the living bog project.

Cycle Day	Site Groups
1	Killyconny
1	Ardagullion
1	Raheenmore
2	Ferbane
2	Moyclare
2	Clara
3	Carrownagappul
3	Carrowbehy

It is recommended that these loggers be downloaded on a yearly continuous basis, although the loggers have a memory that can record data for the entire period if the sample frequency is lowered, it is not recommended that data be left on the devices for this period, as technical issues can be common. During the living bog project, several data gaps exist due to various issues, completing downloads on a yearly basis allowed for these issues to be identified early and resolved. Leaving a larger gap between downloads increases the risk of associated data losses. Downloading at a lower monthly resolution will increase the associated cost of managing the data.

Currently, the loggers are set to measure water levels every 15mins. The initial datasets coming from the Living Bog project suggests that this resolution is too high based on the daily fluctuations observed in the wells. It is recommended that this figure is reduced to a reading every 6 hours. This will also extend the battery life of the loggers, which is finite and cannot be replaced, helping ensure the loggers will last for the duration of the AfterLIFE project.

The last download of the loggers on the living bog project was completed in June 2021. This means that the loggers will run out of memory during the summer of 2022. Once a final plan has been agreed, it is recommended that the re-distribution of the loggers be treated as a priority to optimise the process and ensure no data gaps will exist.

5 REFERENCES

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