HYDROLOGY RESULTS ON THE EU LIFE FUNDED "LIVING BOG PROJECT" 2017-2022

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1.1 Overview of methodology

A detailed methodology for the installation of the piezometer/phreatic monitoring network, the monitoring schedule and subsequent data analysis.

1.1.1 Phreatic network

Due to the limited availability of resources, the number of phreatic wells and their location was optimised to support the main aim of the hydrology network in assessing the impact of proposed works on the hydrological regime of the site. Strategic selection of the location(s) for the deployment of the phreatic monitoring network on each site was carried out following prudent consideration of the following parameters.

1.1.1.1 Restoration potential

Modelled restoration potential examined to assist in the identification and selection of areas of both high bog and cutover bog of suitable topographic conditions such that they may be supportive of the development of Active Raised Bog (ARB) and potential peat-forming habitats (PFH) following restoration. As it is in these areas that the greatest effects of restoration stand to be made, it stands to reason that by positioning the phreatic monitoring network with a bias towards these areas that the greatest opportunity exists in quantifying the effectiveness of restoration measures. It is however also important to note that an understanding of how these models were developed and where they are likely to perform poorly is also important (e.g., a model suggesting good restoration potential within an inactive flush caused by increased vertical losses is very unlikely to be restored to a condition of Active Raised Bog following restoration).

1.1.1.2 Ecotope mapping

High bog ecotope maps were examined to identify areas in which the model suggests a high potential for ARB growth but are not currently classified as ARB. It is anticipated that these are the areas in which the largest increase in water table elevation will be observed post-restoration. The placement of phreatic wells within areas of central or sub-central ecotopes (ARB) was not a priority owing to the existing conditions of high water tables close to the surface, year-round associated with these particular ecotopes. Therefore, increases in water-table height because of proposed works are generally not anticipated in these areas (unless significant drain-blocking is proposed nearby which may result in improved habitat quality (Note: Hydrological monitoring nests deployed in these areas may have use in informing other hydrological monitoring tasks).

1.1.1.3 Drains/measures nearby due to be blocked

In line with the requirements of the National Raised Bog Special Areas of Conservation (SAC) Management Plan 2017-2022, draft restoration plans were developed for each of the 11 SAC bogs included in this LIFE project. These plans are founded in hydrological science and recommend the implementation of a suite of measures, bespoke to each site and intended to achieve measurable and quantifiable results in line with the site-specific conservation objectives.

As predominantly ombrotrophic systems (precipitation-fed), hydrological processes are key drivers of raised bog ecology and as such, specific hydrological conditions must exist in support of the continued development of Active Raised Bog (ARB), including consistent near-to-surface mean water levels free from excessive seasonal fluctuation. The use of modelling informed by field observations and multiple datasets (including elevation data derived from IFSAR and much higher resolution LiDAR), enabled areas of high restoration potential to be identified. Comparing these areas to the existing drainage network highlighted opportunities where specific and targeted intervention in existing flow characteristics may offer the best and most favourable conditions for modification of the local hydrological regime, such that a more natural condition be returned to the SAC bog, supporting active peat formation.

In areas where extensive proposed intervention coincided with projections of significant generation of the most favourable conditions for active peat formation, positioning of phreatic wells near proposed works allowed for ongoing monitoring to inform dynamic adaptation of the plan and for direct quantification of the methods. If limited responses are observed in areas where significant drain blockage occurred and suitable topographic conditions exist, it again may suggest sub-surface features and provide an indication of locations where further hydrological monitoring nests could be installed to monitor 3-D flow.

1.1.1.4 Flow paths

Flow paths (modelled from high-resolution LiDAR) within catchments under the influence of each bog were examined to provide an indication of primary flow accumulations and combined with existing drainage densities to indicate within which areas the greatest potential for re-wetting was likely to be observed. Although flow paths were previously consulted in the creation of high bog and cutover restoration potential models, these models utilise thresholds of contributing catchment area and surface slope, thus by reviewing flow paths at this stage it was possible to sense check the models by providing an assessment of the probability of modelled potential becoming ARB/PFH. For instance, larger contributing catchment areas are known to influence the model by increasing the predicted probability of successful restoration, meaning modelled restoration potential may be unreasonable. Additionally, uncertainties in flow path delineation and the knowledge that post-restoration flow paths will change by an unknown extent will impact the accuracy of the modelled outputs.

1.1.1.5 Consultation with Project ecologist

The project ecologist (William Crowley) was consulted on the proposed locations prior to installation. The project ecologist's knowledge of each site and its current vegetation composition maps provided an indication of the areas that show a high potential to re-wet after drain blocking.
Additionally, consultation with the project ecologist suggested proposed phreatic locations within proximity to installed ecological quadrats, which are used to monitor ecological change as a result of drain blockage; in this case, the proposed location of the phreatic could be altered to move it closer to the quadrat, this will enable a direct comparison between ecology and hydrology to be made which can then be extrapolated to the wider site.

1.1.1.6 Control points

Several control points were included to characterise the hydrology in areas where the above features are not present (e.g., areas with limited restoration potential modelled, areas of little contributing catchment area etc). As limited impacts on water levels are anticipated following restoration these control points could be manually measured to provide an indication of the baseline and post-restoration hydrological regime.

The results can be directly compared to the results collected from the automated phreatic wells to verify the selection rationale outlined in this report.

1.1.2 Piezometer network

The piezometers were installed at deeper levels on the high bog within the sites. The piezometers are constructed of 28 mm internal diameter HDPE solid pipe connected to a perforated PVC piezometer point. The purpose of the piezometers is to monitor the spatial distribution of pressure gradients within a site. Data from the piezometers assist in understanding the 3-dimensional flow regimes within the bog.

These points were selected using judgement sampling according to the following criteria:

1. Higher weights were assigned to central and sub-central ecotypes as the hydrology in these areas represented conditions required to support Active Raised Bog (ARB) under pre-restoration equilibrium conditions.
2. Design separation distance between piezometer nests, higher weights were assigned to areas that maintained maximum separation distances.

The orientation of the intersecting piezometer nest transects was selected to maximise gradients of ecology and DRB and Non-DRB points.

1.2 Phreatic/piezometer installation

Phreatic surface monitoring was conducted by the installation of 2m long (where sufficient peat depth allowed) PVC pipe (of internal diameter of 32mm) into the uppermost strata of the peat, with the bottom 1.5m of each pipe screened (perforated) and installed below the surface, leaving 0.5m of ‘stick-up’ above the surface to allow easy identification by survey teams in the low-visibility associated with typical weather conditions common to these regions of Ireland. Each install was suitably protected against the ingress of peat particulates in the screened portion using an appropriate geo-textile ‘sock’ and from the introduction of precipitation through the top of the piezometer by a bright yellow cap (also for the purposes of aiding identification). Installation was carried out with the use of coring equipment to manually drill pilot holes for each pipe to sufficient depth such that no screened portion of pipe remained above ground, thus ensuring a reliable gauge of the true phreatic surface less the influence of interfering surface water and/or precipitation.

The installation of the deeper piezometer network followed the same methodology, however utilising an initial core sample to determine peat depth and underlying substrate condition. This process enabled bespoke off-site construction of individual pipes for each location, ensuring reduced wastage and faster installation on-site by fewer personnel, carrying less material. As with the phreatic monitoring network PVC pipe (32mm ID) was utilised, however unlike the 1.5m screened section used to capture the phreatic surface, a 0.5m screened interval was utilised at the bottom/tip of the pipe. Again, these pipes were suitably protected from peat particulate and precipitation ingress with the use of geo-textile sock and PVC caps, respectively. Installation utilised the same pilot-hole methodology applied to the phreatic network, using the base of peat/ beginning of the substrate recorded by initial exploratory coring survey, the bottom/tip of the pipe was placed approximately 0.25-0.5m above the base of peat. This was to minimise the impacts that the transitional zone, which contains a mixture of peat and substrate material, may have on permeability

and groundwater flow. Each piezometer pipe was placed approximately 0.5m away from the neighbouring phreatic pipe, forming a ‘nest’ such that the hydraulic gradient for each location could be calculated. Figure 1-1 illustrates a piezometer and phreatic pipe ‘nest’ installed on Moyclare Bog, the photograph also shows its close proximity to an ecological quadrat that was used to compare the hydrology and ecology data.

Figure 1-1: A Piezometric and Phreatic ‘nest’ installed near to, but not within, an ecological quadrat on Moyclare Bog SAC, Co. Offaly (000581).

1.3 Water level monitoring

All wells had manual water table measurements taken on a monthly basis. Automated pressure transducers were also installed to achieve high-resolution water table data, however, due to the limited availability of resources, these were only employed on a subset of the total number of wells. A review of the proposed phreatic network was undertaken, and priority wells were selected to contain leveloggers based on their potential to illustrate the greatest re-wetting potential.
In the selected wells, a Solinst Levelogger Junior Edge, Model 3001, was installed to record high temporal resolution water-level variations at fifteen-minute intervals. The loggers have an accuracy of 0.05% of the full scale (or 0.5cm). The accuracy of the leveloggers was ensured by comparing automated results to manual measurements. Routine (monthly) static water level readings, recorded using a manual dip-meter, permitted comparison with records generated by data loggers and, where necessary, correction of automated data where deviations from manual records occurred. These routine monthly measurements were also conducted in all wells across all sites.

Barologgers were installed on 4 sites to record changes in atmospheric pressure, which was required to correct the water-level data generated by fully submerged (non-vented) pressure transducers. The barometric readings recorded by the loggers used are accurate over a 30km radius which allowed for these 4 strategically located barologgers to record atmospheric pressure for all 11 SAC sites.

Raw pressure data collected from the submerged water level loggers were corrected by removing background atmospheric pressure and calibrated using manual water levels to construct hydrographs and summarised using water-table depth-duration curves. Duration curves or water table characteristic curves are derived by calculating the percentage of time that the water table is above a certain depth in a particular vegetation community (Grootjans and ten Klooster 1985). This approach enables water table characteristics to be effectively summarised and interpreted more rapidly than from groundwater hydrographs. The curves prove particularly useful for comparing and contrasting hydrological conditions for identifying seasonal contrasts and comparing results pre/post-restoration.

2 OVER-ALL COMPARISON

This section aims to provide a general overview and discussion of the results, examining the various hydrological datasets and interoperating results to provide an indication of the overall success of the restoration measures deployed and where additional work may be required. Individual site characterisation is detailed in Section 4. The methodology applied, grouped various areas of the bog together defined by their modelled restoration potential (described in section 1.1.1.1) on both the high bog and cutover area. The D90 value is generated from statistical analysis of the water level hydrographs to determine the 90th percentile or the value that the water level is at or above for 90% of the monitoring period and allows for quantitative analysis of the water level results to be completed. The D90 values are illustrated using a series of box and whisker plots, before and after restoration, as presented in Figure 2-1 to Figure 2-6.

2.1 Cutover Bog

2.1.1 Modelled PFH areas

Figure 2-1, summarises the summer D90 values collected pre and post-restoration from all wells situated within the modelled areas of Peat Forming Habitat (PFH), located on cutover bog, across the 11 project sites. In total 49 phreatic wells were located within this zone. A 20cm target zone is highlighted (by a dashed black line) to illustrate the target water level that restoration aims to achieve to create the correct hydrological conditions required to promote the return of ARB/PFH.

As shown, prior to restoration the majority of D90 values obtained fell below the 20cm target zone with the upper limit of the interquartile range equal to the 20cm target level and the median level located at 28cm below ground level. Post restoration there was a significant increase in the water level with the interquartile range fully situated within the target zone. Importantly the median level post-restoration was at ground level, highlighting the success of the measures.

It must be noted that post-restoration, the minimum whisker line, is still below the target zone, which highlights that restoration was not successful in restoring peat-forming conditions in all modelled PFH areas (as discussed in section 2.8 at Mongan Bog SAC); however, hydrological conditions have improved overall. These areas should be investigated further to understand why restoration was not as successful so lessons can be incorporated into future restoration projects.

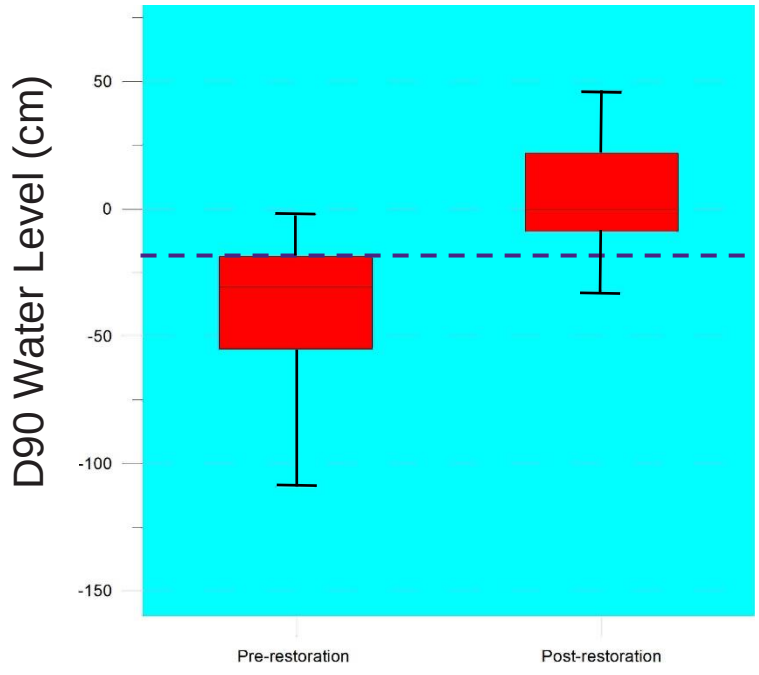

Figure 2-1: Box and whisker plot summarising the D-90 values for piezometers located in modelled PFH in cutover areas pre and post-restoration

2.1.2 Modelled non-PFH areas

Figure 2-2, summarises the D90 values pre and post-restoration from all the wells situated within cutover areas that were not modelled as likely to become peat-forming habitats. In total 13 phreatic wells were located within this zone. A 20cm target zone is highlighted (by a dashed black line) to illustrate the target water level that restoration aims to achieve to create the correct hydrological conditions required to promote the return of ARB/PFH.

As shown, prior to restoration, all of the D90 values obtained were beneath the 20cm target zone. With the median level situated at 42cm and the lower limit of the interquartile range observed as greater than 1m. This indicates prior to restoration these areas were particularly dry, which not only will have contributed to the lack of peat-forming vegetation in these areas but will have resulted in wider environmental issues such as the oxidation of peat, which in turn results in the release of carbon dioxide which contributes to climate change.

Post restoration there was a significant increase in the water level with the upper limit of the interquartile range rising close to the ground surface and the median level rising to 21cm, and the upper limit rising to the ground surface. The lower limit of the interquartile range was observed to increase to 54cm, which although still significantly below the target level, this represents a large increase from that observed level's pre-restoration and will result in reduced carbon emissions.

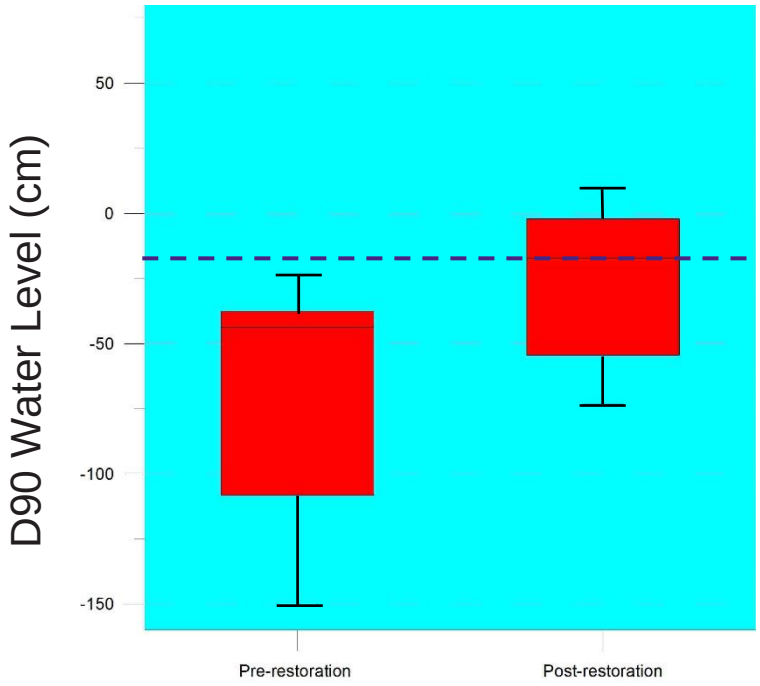

Figure 2-2: Box and whisker plot summarising the D-90 values for piezometers located in areas where PFH in cutover areas pre and post restoration

2.1.3 Control areas

Figure 2-3, summarises the D90 values collected pre and post-restoration from all the wells situated within areas where restoration was not completed, hence acting as controls. In total 13 phreatic wells were located in this zone. A 20cm target zone is highlighted (by the dashed black line) to illustrate the target level that restoration aims to achieve to create the correct hydrological conditions required to promote the return of ARB/PFH.

As shown, there was a negligible increase in water levels observed with the median water level remaining consistent at 47cm and limited variation in the interquartile range. The results suggest that in these control areas where restoration was not completed water levels remained consistent. This is a significant finding as it highlights that the results observed in Section 2 and in Figure 2-1 and Figure 2-2 were due to the works completed by the project and not due to variations in climatic factors such as increased rainfall or reduced evapotranspiration.

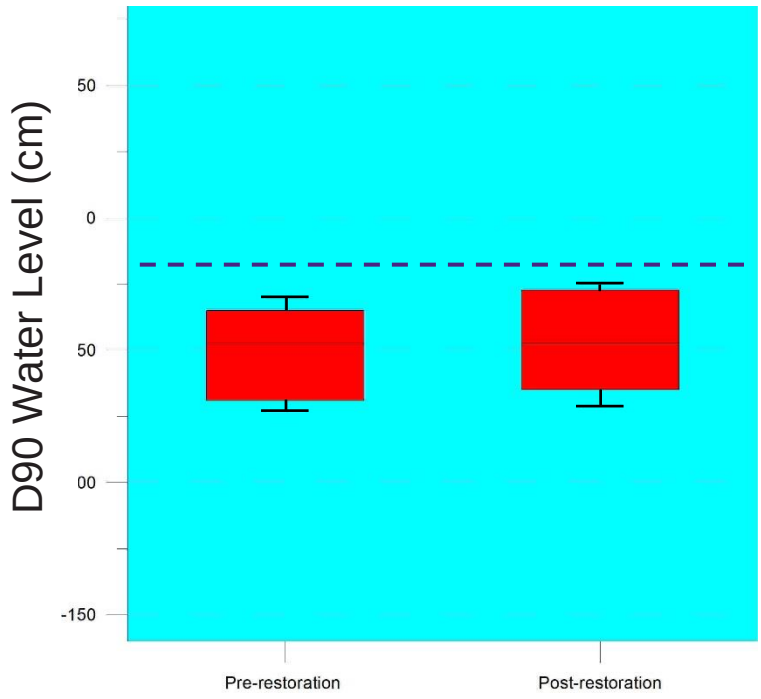

Figure 2-3: Box and whisker plot summarising the D-90 values for piezometers located in areas where PFH in cutover areas pre and post restoration

2.2 High Bog areas

2.2.1 Areas of ARB

Figure 2-4, summarises the D90 values collected pre and post-restoration from all the wells situated within areas that are currently categorised as ARB on the High Bog. In total 24 phreatic wells were located in this zone. A 20cm target zone is highlighted (by the dashed black line) to illustrate the target level that restoration aims to achieve to create the correct hydrological conditions required to promote the return of ARB/PFH.

The majority of restoration measures did not take place in the vicinity of these wells and were focused in areas of DRB and supporting high bog, however, analysing these wells would provide an indication of the impact that wider site measures would have on current areas of ARB. As presented, there is a significant increase in the median values from 16cm to 9cm and an increase in the interquartile range, suggesting improvements in the hydrological regime in ARB areas across the project due to restoration.

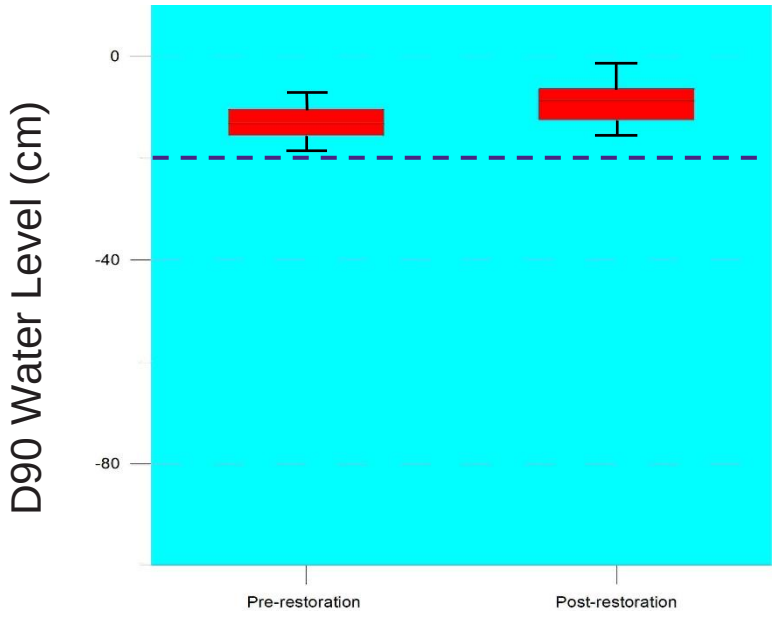

Figure 2-4: Box and whisker plot summarising the D-90 values for piezometers located in areas where PFH in cutover areas pre and post-restoration

2.2.2 Modelled ARB areas – Degraded Raised Bog (DRB)

Figure 2-5, summarises the D90 values collected pre and post-restoration from all the wells situated within areas that are currently modelled as DRB on the High Bog. In total 29 phreatic wells were located in this zone. A 20cm target zone is highlighted (by the dashed black line) to illustrate the target level that restoration aims to achieve to create the correct hydrological conditions required to promote the return of ARB/PFH.

As shown, prior to restoration the majority of D90 values obtained fell below the 20cm target zone with the upper limit of the interquartile range at 19cm, slightly above the 20cm target level and the median level located at 28cm below ground level. Post restoration there was a significant increase in the water level with the interquartile range fully situated within the target zone. The median level rose to approx. 16cm. As shown the data suggests that restoration within areas of DRB were generally very successful.

It must be noted that post-restoration, the minimum whisker line, is still below the target zone, which highlights that restoration was not successful in all these areas. These areas should be investigated further to understand why a restoration was not successful so lessons can be incorporated into future restoration projects.

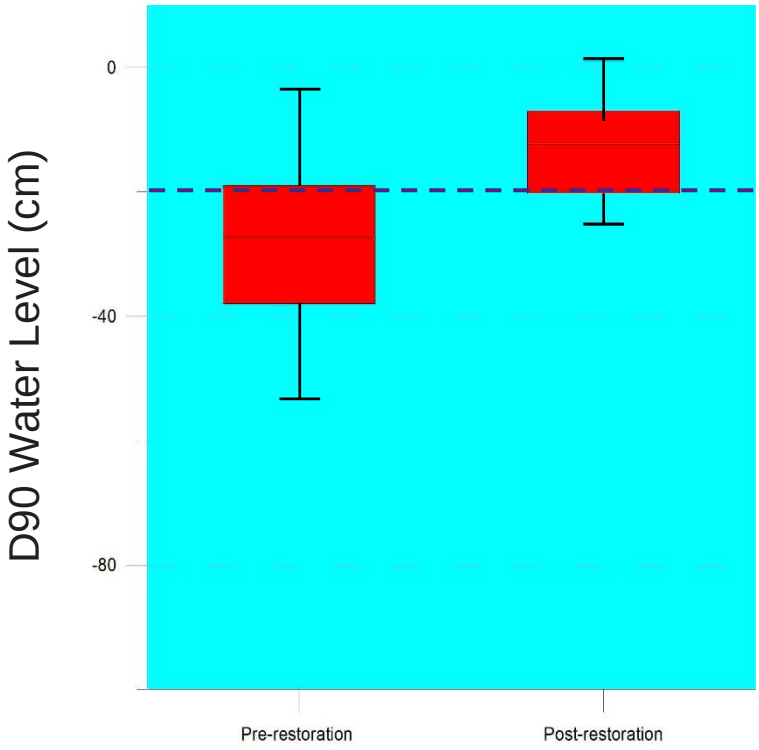

Figure 2-5: Box and whisker plot summarising the D-90 values for piezometers located in areas where PFH in cutover areas pre and post restoration

2.2.3 Areas of supporting high bog

Figure 2-6, summarises the D90 values collected pre and post-restoration from all the wells situated within areas of supporting high bog, where ARB is not present and DRB has not been modelled. The data has been split further with a) wells situated less than 50m from drains that were blocked and b) wells situated more than 50m from drains that were blocked. In total 36 were situated in category “a” areas and 5 wells were situated in category “b” areas. A 20cm target zone is highlighted (by the dashed black line) to illustrate the target level that restoration aims to achieve to create the correct hydrological conditions required to promote the return of ARB/PFH.

As shown, prior to restoration, in both areas, the interquartile ranges were located below the target level. However, post-restoration there was a noticeable improvement in the water levels in areas less than 50m from drains, with the interquartile range fully within the target zone. In monitoring wells located further than 50m from drains, there was a limited response noted, however as only 5 monitoring wells were located in this zone the results are not fully conclusive.

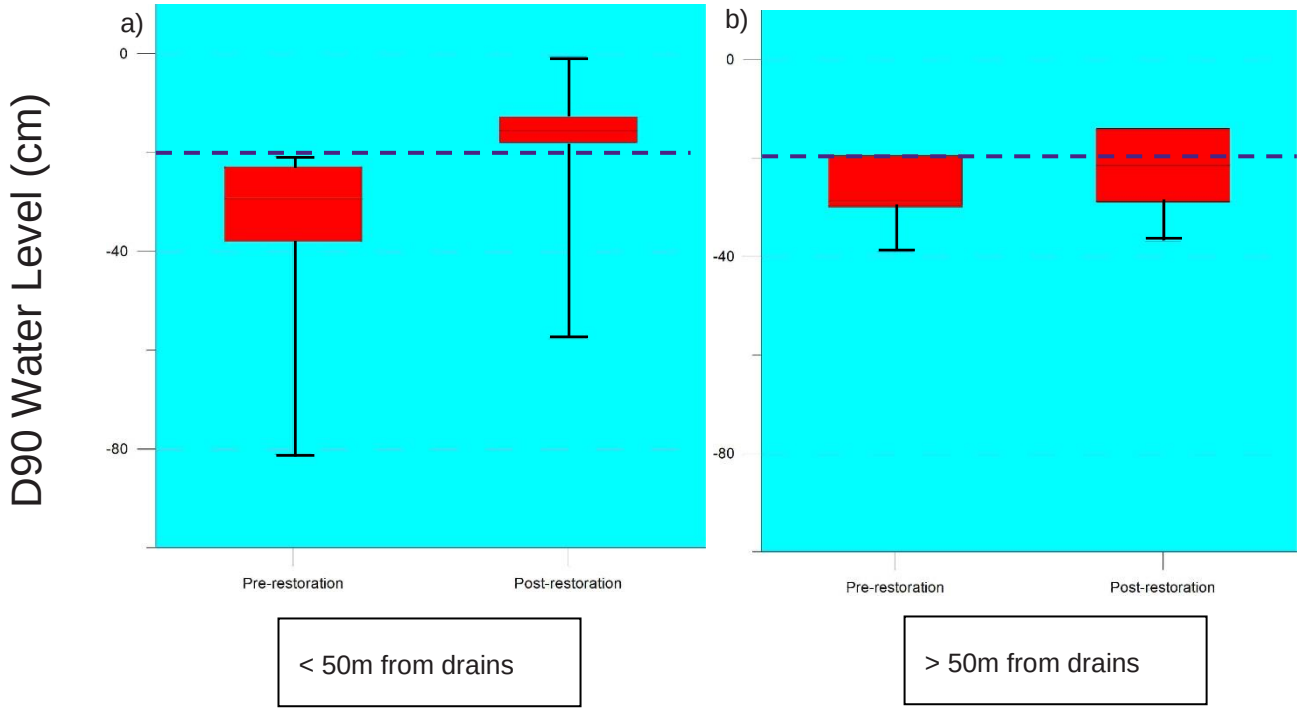

Figure 2-6: Box and whisker plot summarising the D-90 values for piezometers located in areas where PFH in cutover areas pre and post restoration

2.3 Discussion

The hydrology monitoring results presented in this report suggest that the restoration measures implemented as part of the Living Bog Project were successful in improving the supporting hydrological conditions across large areas of the twelve project sites. Critically water levels in most of these areas, have risen to within 20cm of the ground surface, which is the target level required for peat-forming vegetation to re-establish (Cushnan 2018). The limited variation observed in control plots highlights the fact that the positive results observed were as a direct result of the actions undertaken by the Living Bog Project and not as a result of climatic variables or seasonal/yearly variations.

Data obtained from areas modelled as PFH and DRB, showed the largest increases in water level height when comparing pre/post-restoration data, this suggests that the ecohydrological model currently used to estimate restoration potential and calculate ARB/PFH targets in Ireland, was largely successful at predicting the areas of the bog that would rewet as a result of restoration. This is a significant finding; it currently isn't cost-effective to monitor every area of these sites and going forward it may not be cost-effective to install the detailed hydrological monitoring network that the Living Bog Project installed. the results from this project demonstrate the benefits of using the modelling approach to predict areas of greatest restoration potential, which ensures restoration resources are appropriately targeted to areas of greatest potential in future.

The water level results collected by the project in areas outside the modelled areas of PFH and DRB, also improved significantly, although not to the same extent as those within modelled areas. In 50% of the wells within these areas, the target value of a D90 vale within 20cm of the ground surface was reached, indicating that the model used to estimate restoration success potentially underpredicts the total area that will successfully re-wet as a result of restoration. The model was originally calibrated using limited datasets, the information collected from the Living Bog Project should be used to re-calibrate this model and improve upon it to provide a more accurate indication of the ARB/PFH habitats achievable in Ireland through restoration. Additionally, even in the wells that did not meet the 20cm target, significant re-wetting occurred, in some examples increasing the water table height up by 60cm. Although this may not directly lead to PFH forming in these areas, it will result in wider ecosystem benefits such as reduced carbon emissions.

The wells situated within areas of ARB were installed to monitor the impact site wide measures would have on areas that currently have the correct hydrological conditions for peatland. Limited restoration works were completed directly in these areas, with measures focused on areas of DRB and supporting high bog downstream. Hydrological improvements were observed within ARB areas, with a moderate increase in the D90 values observed. Although longer-term data is required, this potential indicates that the drain blocking completed on areas of DRB and supporting high bog is having positive impacts in areas of ARB by making them more resilient to water table drawdown. This may prove important in the future as climate change influences weather patterns across Ireland and influences the amount of rainfall these sensitive ecosystems receive. In addition, it is possible that minor improvements in hydrological conditions observed in these areas are indicative of a change of conditions that support sub-central ecotope to that which will support central ecotope. There is not enough data to prove this hypothesis statistically significant, however, follow-up ecological surveys of the area will determine if the extent of central ecotope has increased, which can be attributed to the minor improvements noted in the hydrological monitoring in these areas.

3 INDIVIDUAL SITE CHARACTERISATION

Individual characterisation of the 11 monitored Living Bog sites will outline the hydrogeological setting, the deployed monitoring network, data obtained and consequent results of hydrological analysis, forming a methodology by which to assess the efficacy of restoration efforts.

3.1 Ardagullion Bog SAC

3.1.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests Ardagullion Bog SAC and adjacent lands to be underlain by a singular lithographic unit referred to as Visean basinal 'Calp' (Figure 3-1). This typically denotes a non-homogenous unit, often comprising fine shales, interbedded and intermixed with calcareous material/spar and in this region is associated with moderately productive (locally), low vulnerability aquifer units. As such, contributions to in-channel flows from processes of groundwater recharge are thought to be small and localised.

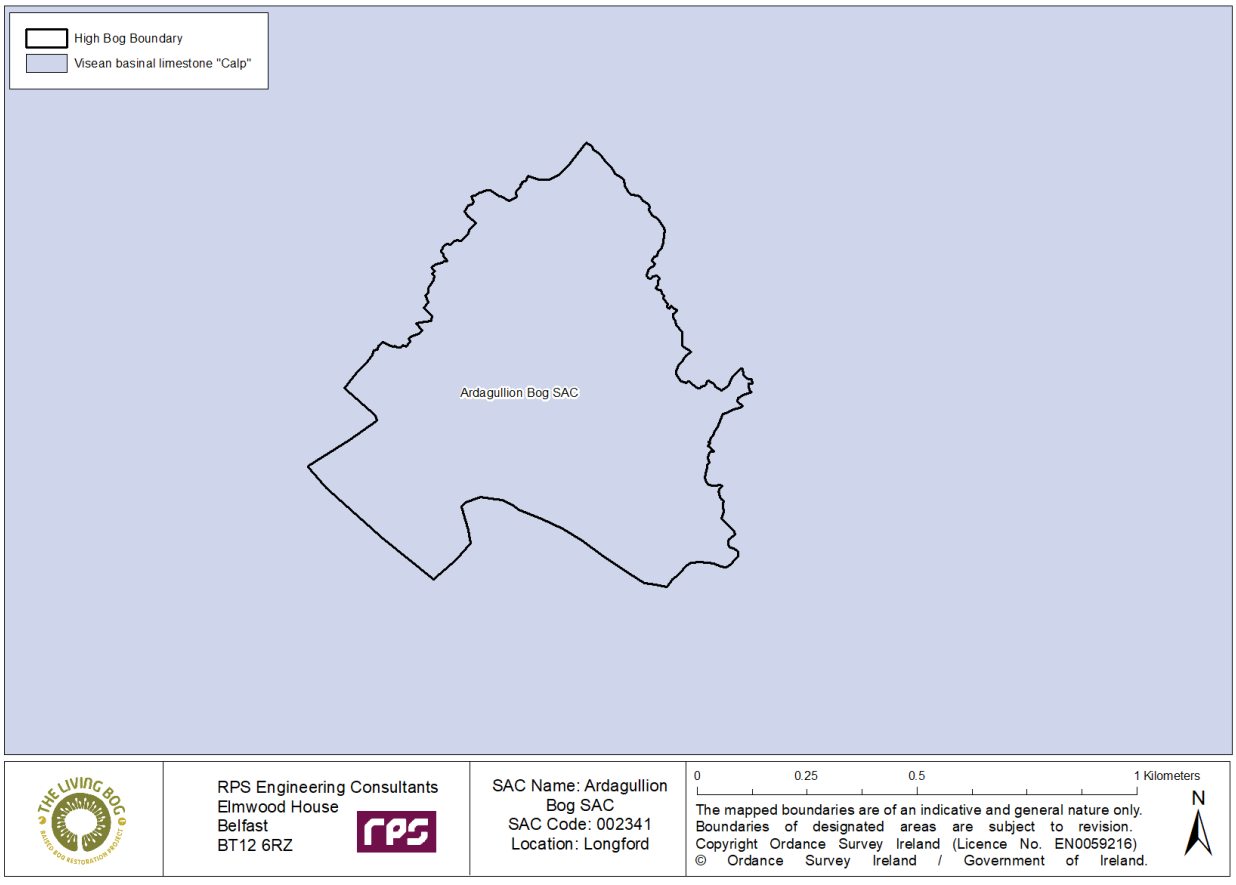

Figure 3-1: Simplified geology of Ardagullion Bog SAC 'High bog' and adjacent lands.

3.1.2 Ecotope map

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-2). During the last monitoring survey (2018) it was noted, that Ardagullion Bog SAC consists of 9.07 ha of Active Raised Bog (ARB) consisting of areas of central, sub-central and active flush.

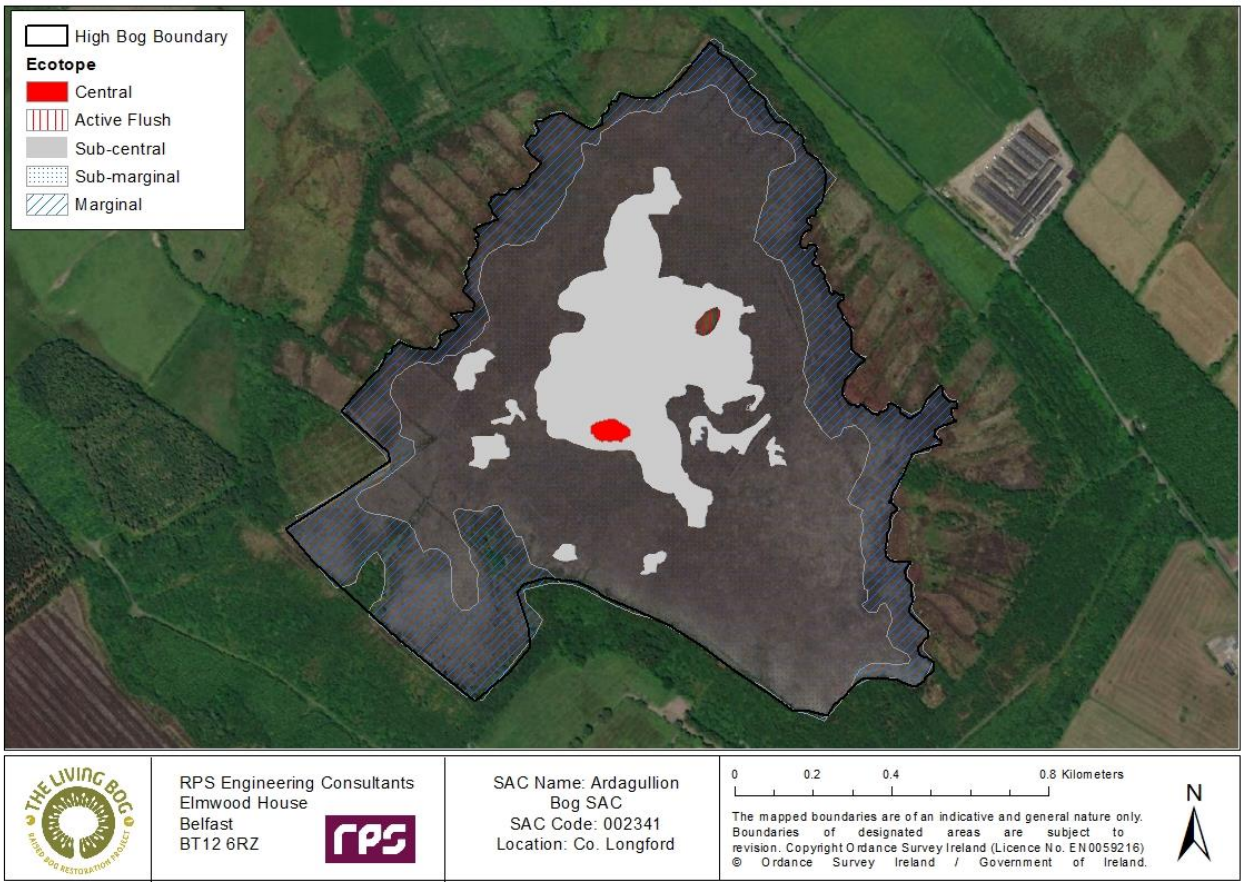

Figure 3-2: Ecotope mapping carried out for Ardagullion Bog SAC.

3.1.3 Proposed restoration plan

The restoration plan for Ardagullion Bog SAC (Figure 3-3) identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat forming (ARB) habitat. Overall, the installation of peat dams was recommended across 12.24km of channels both on the high bog and cutover. Additionally, due to suitable topography located on the western cutover of Ardagullion Bog SAC, enhanced measures in the form of 650m of marginal bunding with integrated flow control in the form of weirs was recommended.

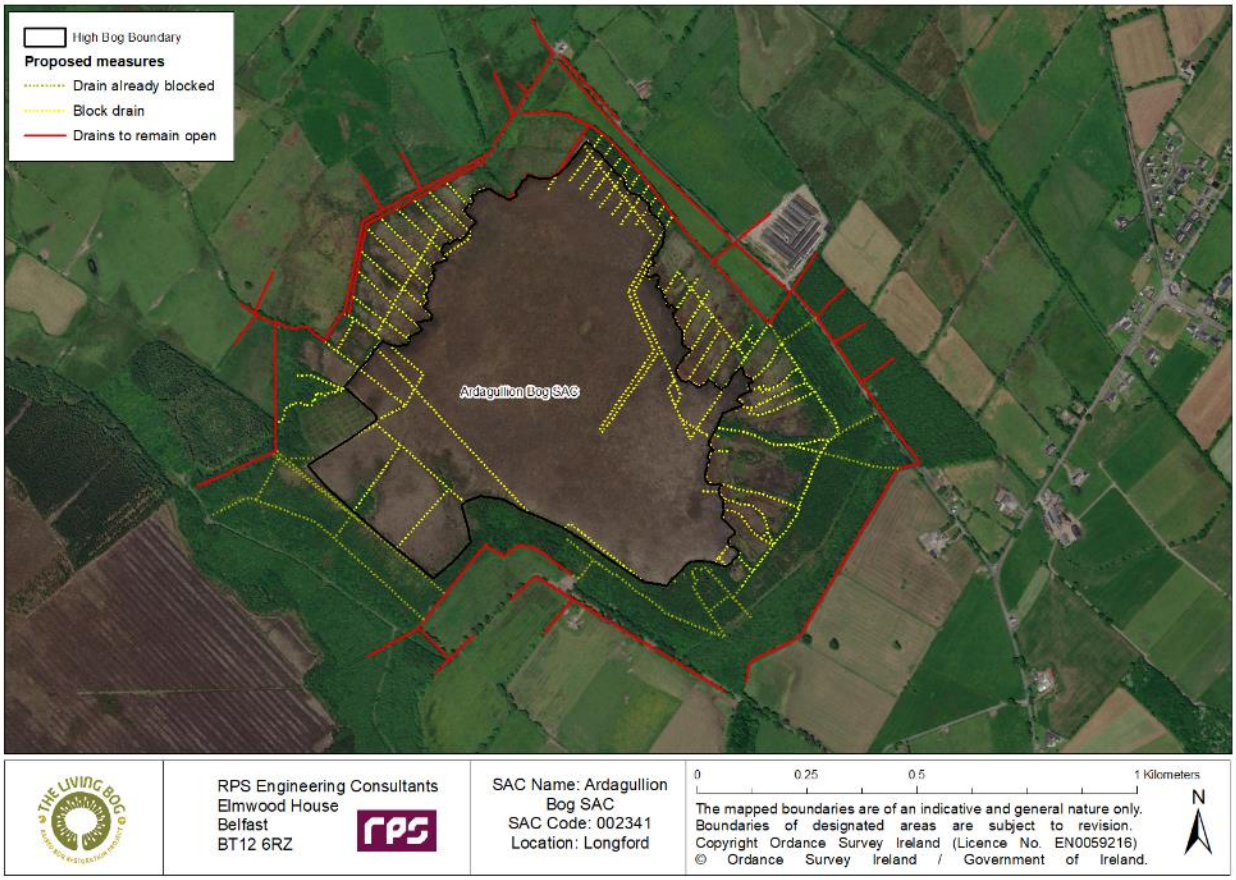

Figure 3-3: Restoration measures specified in support of hydrological goals.

3.1.4 Restoration potential

Eco-hydrological modelling of the restoration potential of Ardagullion Bog SAC, excluding current areas mapped as ARB, suggested as much as 9 ha of habitat had the potential to be positively impacted by restoration works, with 2.7 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 6.3 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-4).

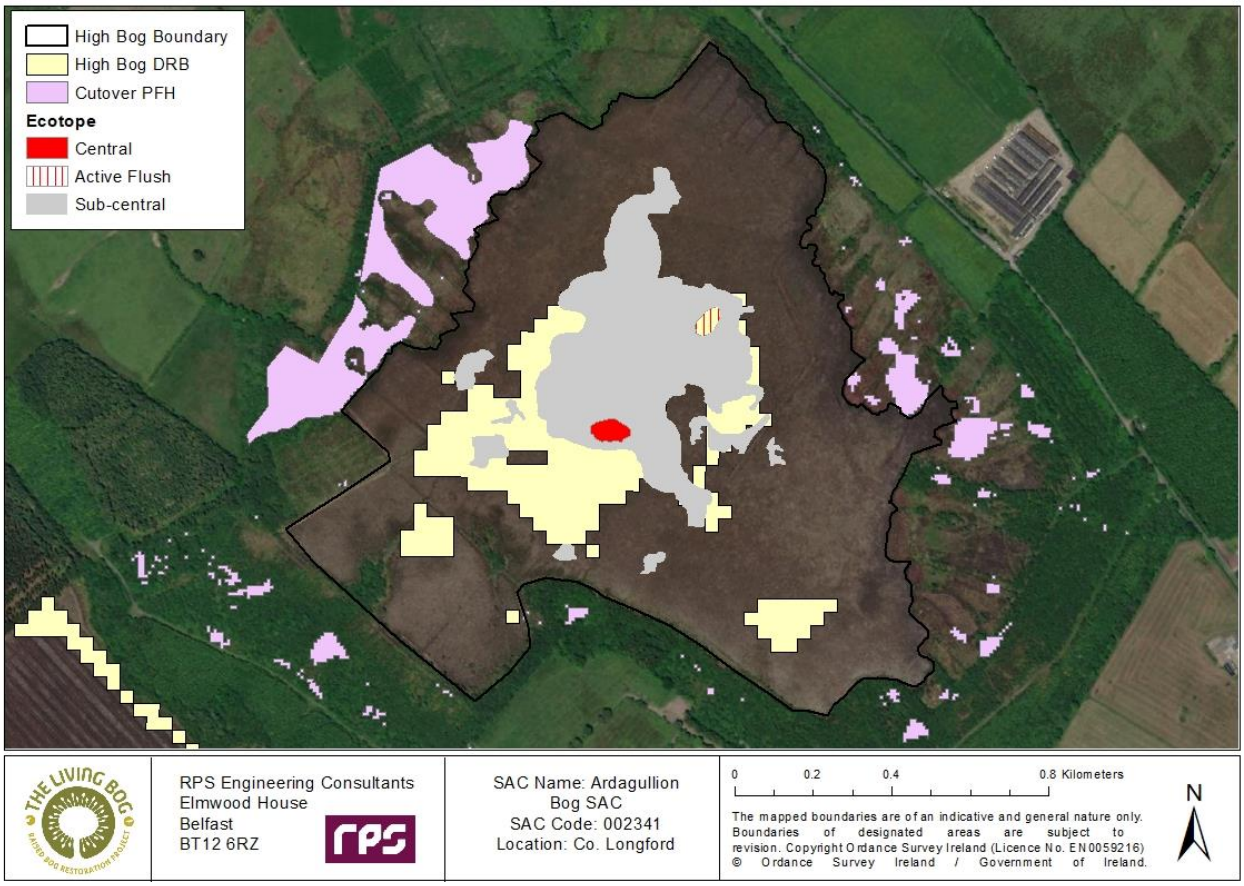

Figure 3-4: Restoration potential of Ardagullion Bog SAC as outlined by eco-hydrological modelling.

3.1.5 Deployed monitoring network

A monitoring network comprising a mixture of 36 shallow phreatic wells and deeper piezometric wells (Figure 3-5) was subsequently installed in 2017 on Ardagullion Bog SAC. On the high bog, 12 phreatic wells were installed accompanied by 20 deep piezometers in order to monitor vertical hydraulic gradients. On the cutover, 4 phreatic wells were installed. A total of 12 water level loggers were spread amongst the wells. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic. Loggers were set to automatically record levels at 15-minute intervals, the data was downloaded on a quarterly basis. A barometric logger was also located on this site and was installed to monitor changes in atmospheric pressure, subsequently used to barometrically correct the levelogger data.

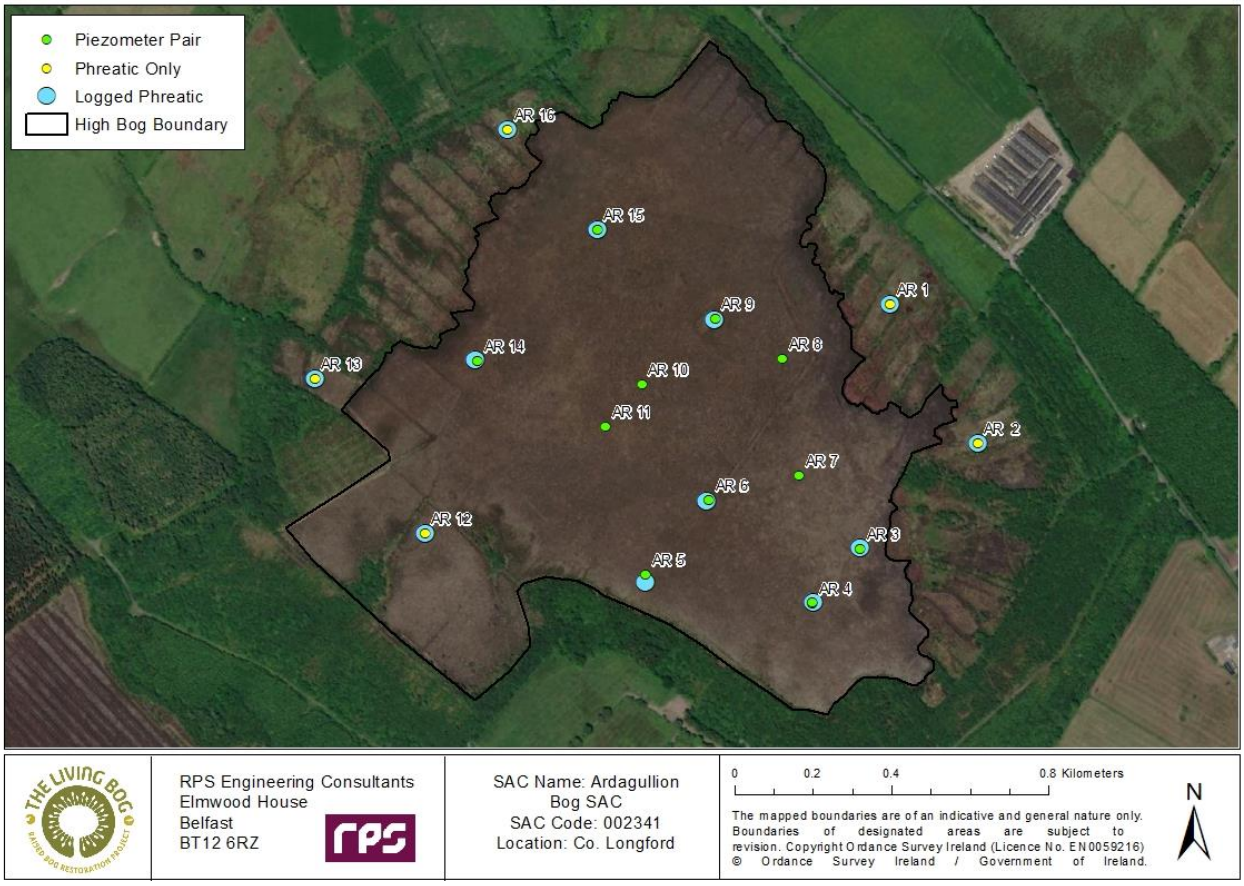

Figure 3-5: Hydrological monitoring network installed and operating on Ardagullion Bog SAC.

3.1.6 General field observations

Owing to regular site visits RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. For instance, in the Eastern cutover in the vicinity of wells AR 1 and AR 2, the ground surface has become significantly wetter following restoration with pools forming close to the main drain in both areas with the local the topography contributing to the rapid changes in hydrology. On the western cutover, a similar impact was observed over a large area upstream of the weir-regulated bund, here the water table rose to the surface and remained there year-round. The design of the bund had been modified to alleviate concerns of landowners, as a result, the south-western corner of this cutover is currently outside the scope of the project in an area where restoration was not undertaken, therefore observations made in this area could be used as control monitoring to quantify the impact of restoration on the site.

Figure 3-6 : Rewetting observed on Ardagullion Bog, where the water table came up to the surface throughout the year

On the high bog, conditions remain similarly wet and soft underfoot throughout the monitoring period, with limited changes observed however areas close to the main high bog drains did become noticeably wetter following restoration. However, given water table levels are generally closer to the ground surface in high bog areas anyway, hydrological changes are more difficult to observe visually than widespread rewetting of very dry cutover areas.

3.1.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Ardagullion SAC are presented with all supplementary results provided in Appendix A.

3.1.7.1 Eastern Cutover

In a bid to evaluate and quantify the effects of restoration measures, both AR 1 and AR were placed in regions of high restoration potential in cutover bog (Figure 3-7), east of the high bog.

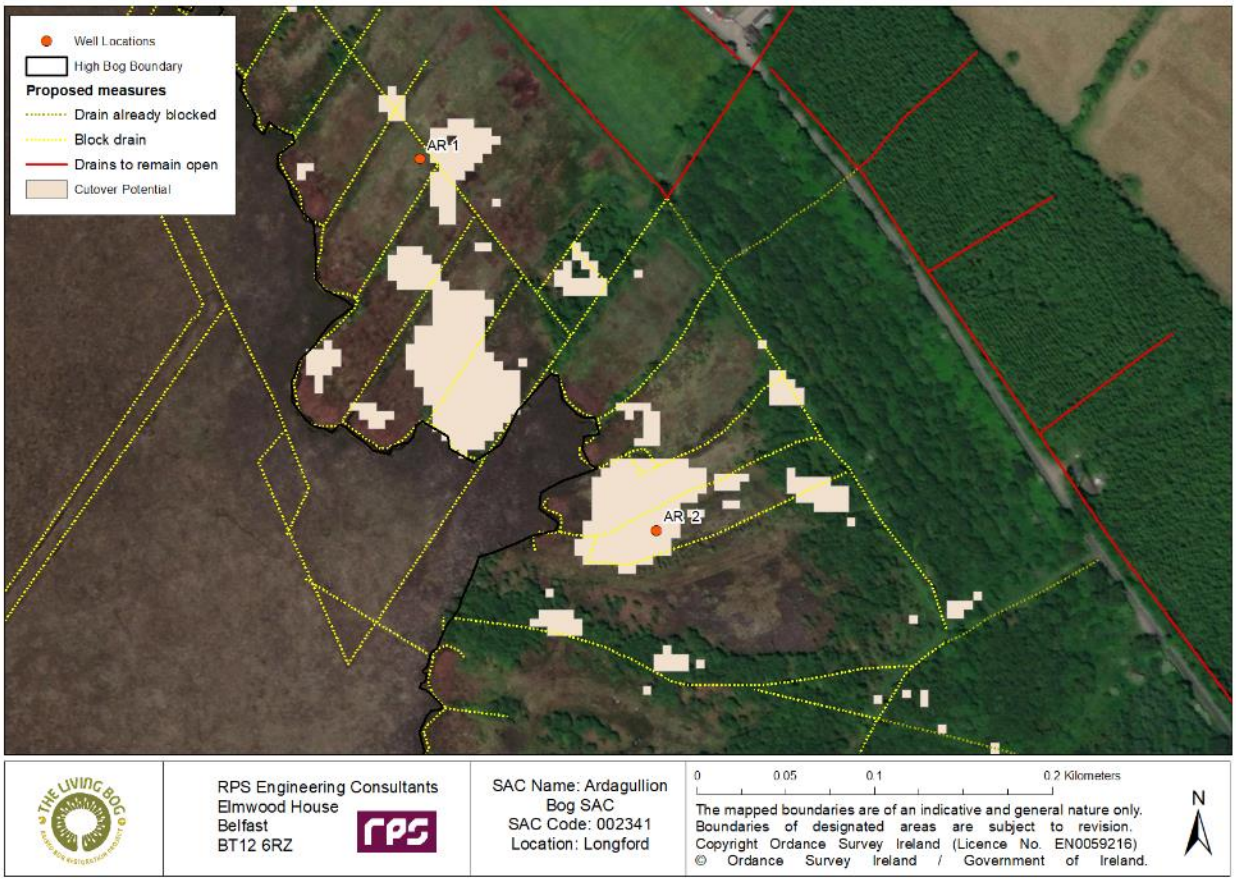

Figure 3-7: Location of wells AR 1 & AR on the eastern cutover at Ardagullion Bog SAC

Figure 3-8 – Figure 3-11 illustrate results from the hydrological monitoring points located on the Eastern cutover at Ardagullion Bog SAC. Figure 3-8 presents the hydrograph at AR1, as demonstrated the water table fluctuated extensively in the year of data recorded prior to restoration, dropping lower than 40cm below ground surface in the summer dry period (April – October) of 2018. For the most part, water levels remained predominantly beneath ground surface, rising above surface on only a limited number of occasions. Conversely, following restoration water levels rose and stayed consistently at or above ground surface for the majority of the remainder of the record length, dipping below but staying close to surface between December 2019 and April 2020, and again between March and August 2021. Owing to a technical issue a data gap exists between March and November 2020 in this record, however, consulting the manual

record (Figure 3-9) for the same well during this period reveals water levels remained consistent with no significant drawdowns or rises observed.

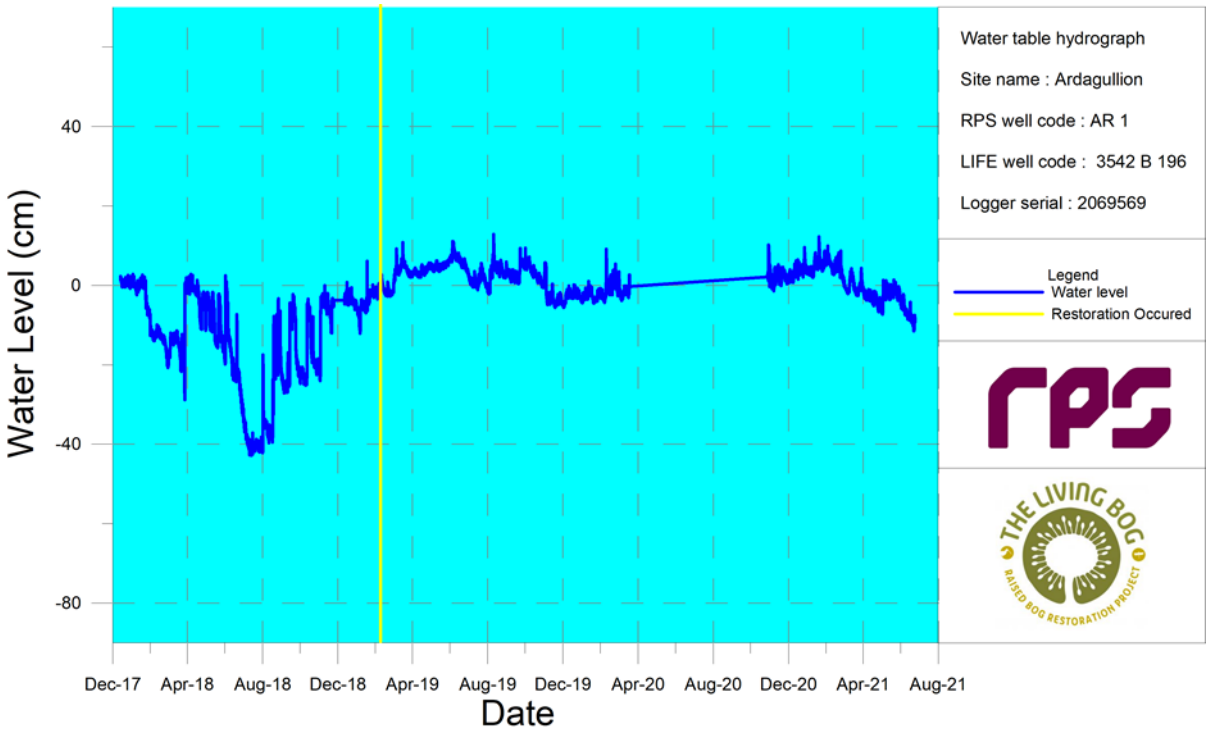

Figure 3-8: Level logger data recorded between December 2017 and August 2021 at well AR 1, Ardagullion Bog SAC.

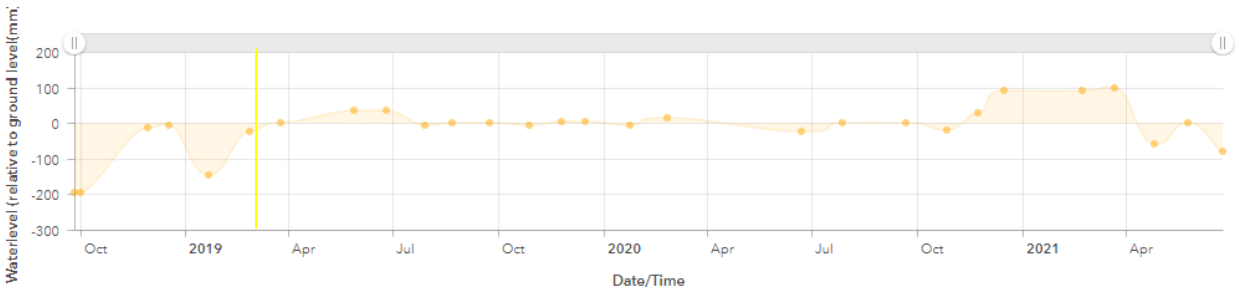

Figure 3-9: Hydrograph of manual water levels AR 1, Ardagullion Bog SAC.

Figure 3-10 presents data obtained from the levelogger at AR 2, as demonstrated the results exhibit a clear positive change in water level following the completion of site-wide works in early 2019. Baseline data recorded prior to restoration showed the water table consistently below the ground surface. Water level measurements as low as 30 cm beneath ground surface coincided with extended periods of dry weather, confirmed by the daily precipitation record at the nearby Met Eireann Ballymore (Granard) rainfall station. Following site-wide completion of works in early 2019 water levels rose significantly at this location, staying consistently between 40-60 cm above ground surface for the remainder of the post-restoration record period. Data stopped being recorded in early 2021 due to technical issues with the installed logger.

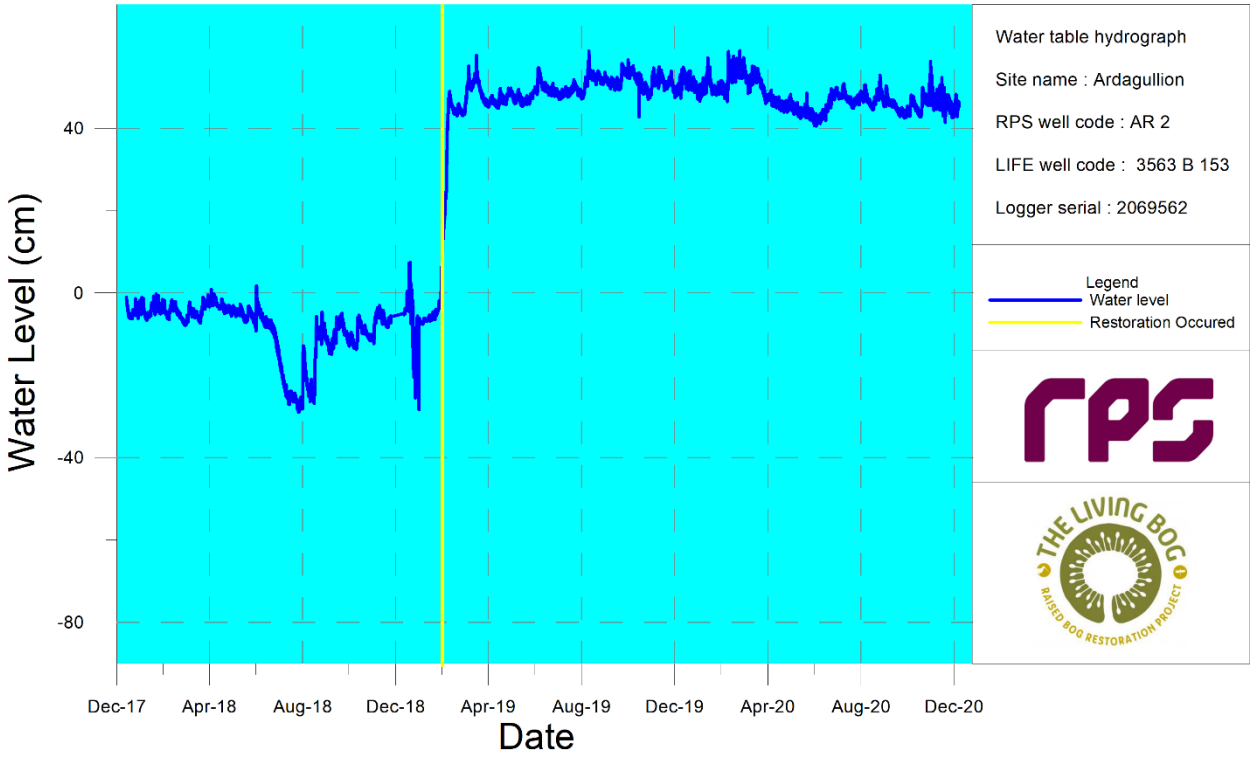

Figure 3-10: Level logger data recorded between December 2017 and August 2021 at well AR 2, Ardagullion Bog SAC.

Water table duration curves were generated at each location monitored to show WL before and after restoration over the same time period of an annual hydrological cycle, in this case, April-October in 2018, 2019, and 2020. This format has been used as it is concise and clear for the reader and the data can be used to easily interpret min/max and percentile values. Figure 3-11 illustrates the duration curves generated from the data obtained from AR 2. The duration curves indicate a clear difference between water levels pre (2018) and post (2019/20) restoration. With a difference of 71cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

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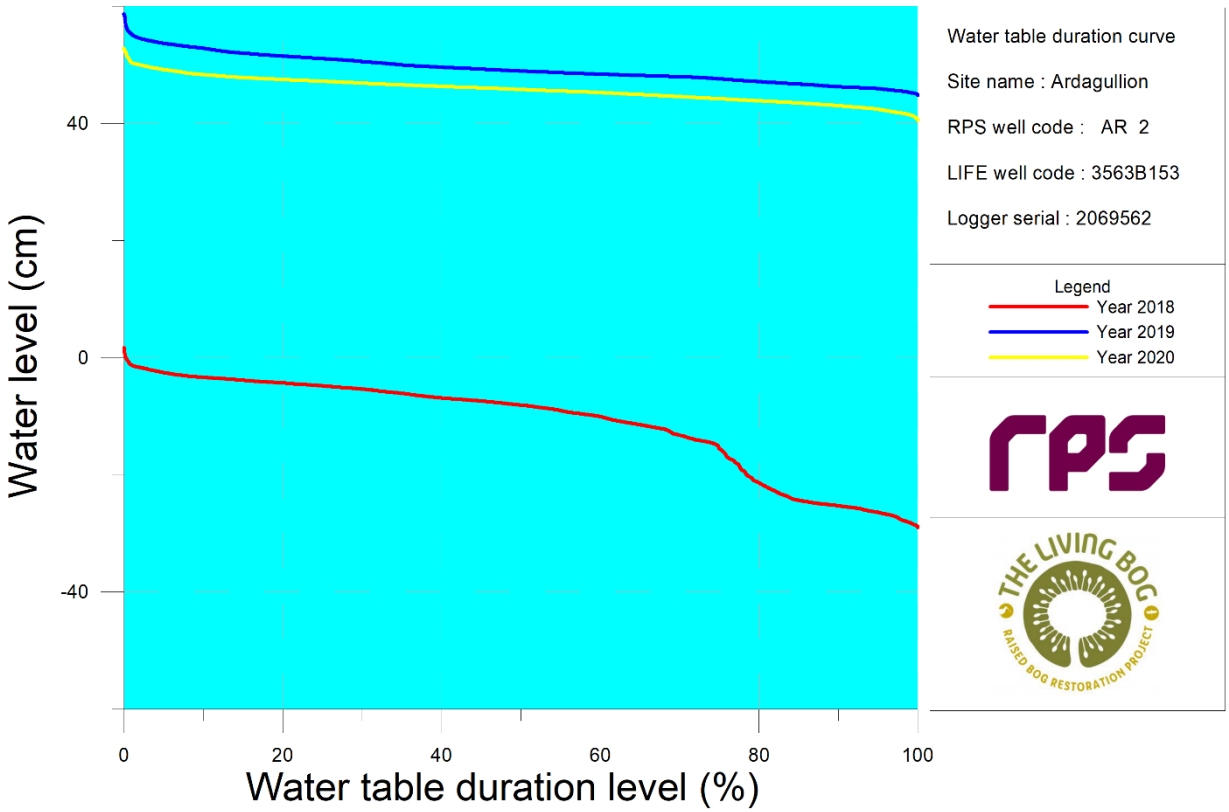

Figure 3-11: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well AR 2, Ardagullion Bog SAC.

3.1.7.2 Western cutover

In a bid to evaluate and quantify the effects of restoration measures, both AR 13 and AR 16 were placed in regions of high restoration potential, that were modelled to re-wet after the construction of a peat barrier dam on the western cutover bog of Ardagullion. Figure 3-12 illustrates the area modelled to re-wet and the location of the two piezometers. However, as access for local landowners would have been affected, the design of the barrier dam was altered, which resulted in AR 13 being located in an area where restoration measures would not be completed. The landowner permitted access for the installation and ongoing monitoring of this well throughout the project which allowed it to act as a control, where the impact of not completing restoration could be studied to better understand the results of restoration works on water level fluctuations, independent of climatic variables.

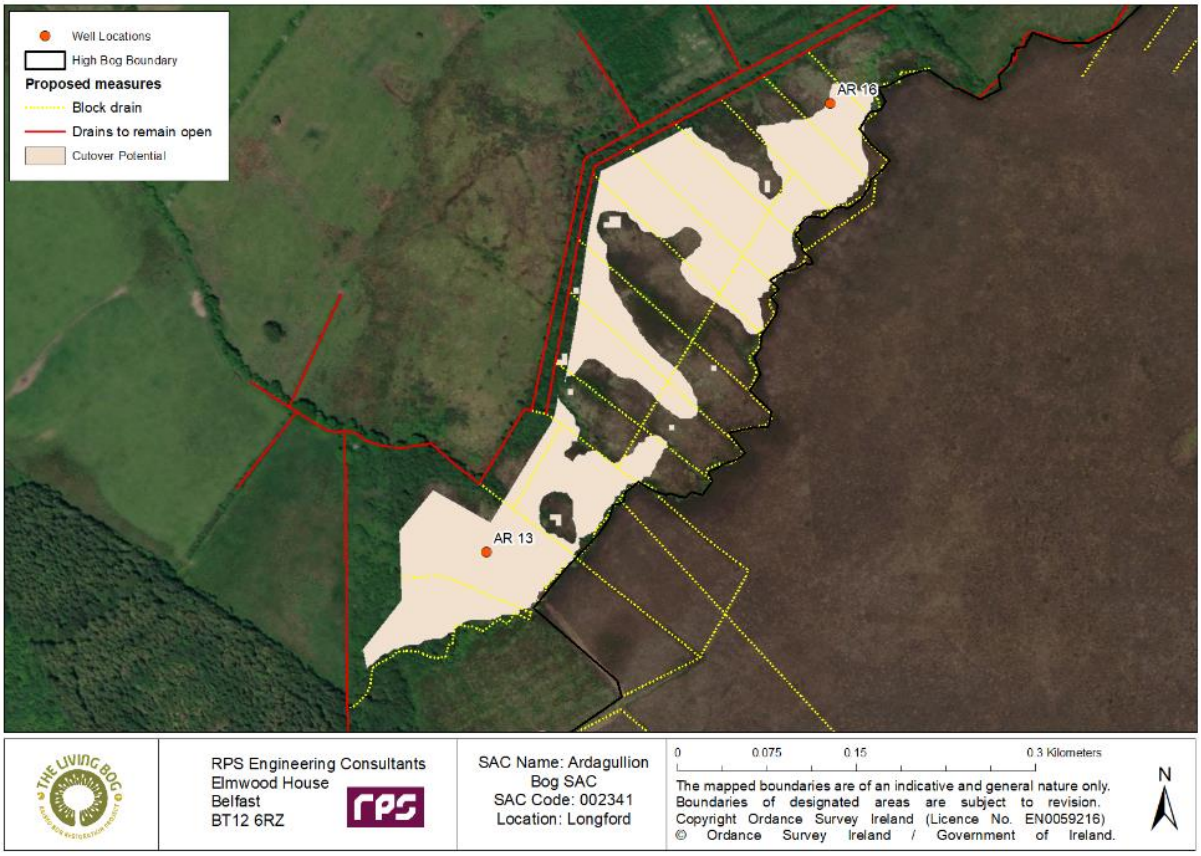

Figure 3-12: Location of wells AR 13 & AR 16 on the western cutover at Ardagullion Bog SAC.

Figure 3-13 – Figure 3-16 illustrate results from the hydrological monitoring points located on the Western cutover at Ardagullion Bog SAC. Figure 3-13 presents the hydrograph at AR13, as demonstrated, a minor increase in water level is notable when comparing the period March 2018 to March 2019 against the period March 2019 to March 2020. However, a major drawdown occurs in the summer of 2020, with water levels dropping to close to the maximum depth recorded prior to restoration works. Figure 3-14 illustrates the duration curves generated from the data obtained from AR 13. As shown, there is limited variation between the water levels for 50% of the duration level. Small variations can be observed in the duration levels which can be attributed to differences in climatic conditions. Overall this highlights the impact of not completing

restoration in this area. It also confirms that the positive results observed in other areas of the site can be attributed to the restoration works and aren't simply as a result of variations in climatic conditions.

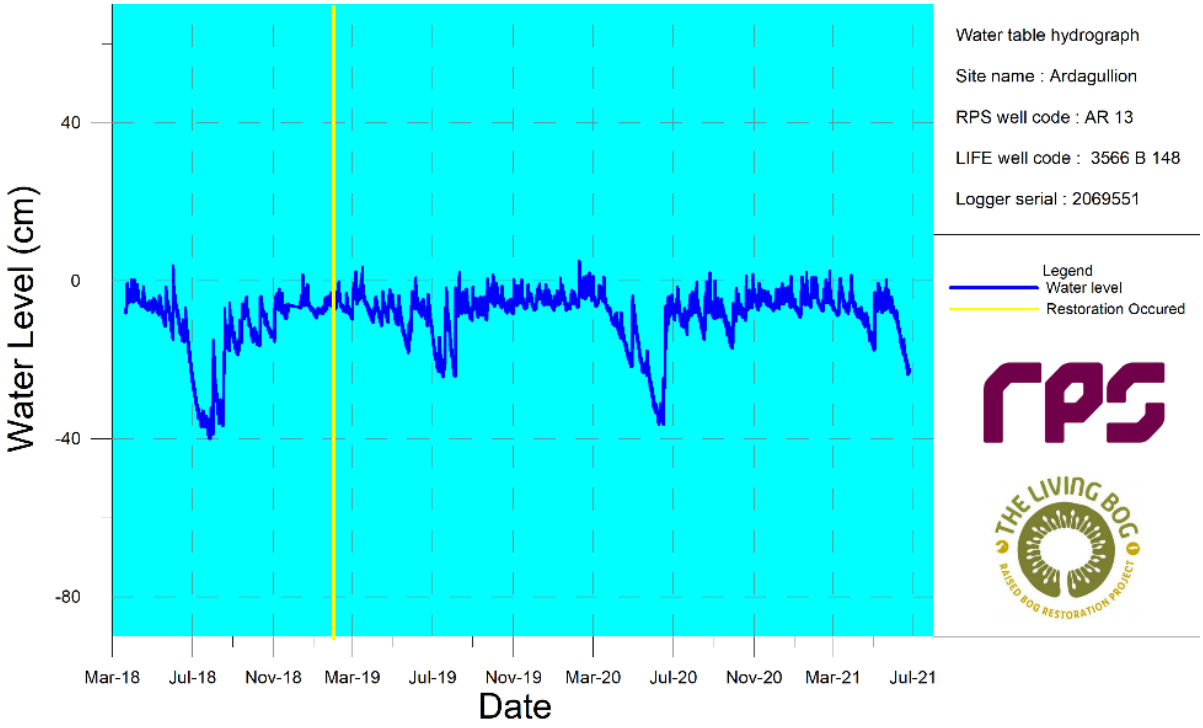

Figure 3-13: Level logger data recorded between May 2018 and July 2021 at well AR 13, Ardagullion Bog SAC.

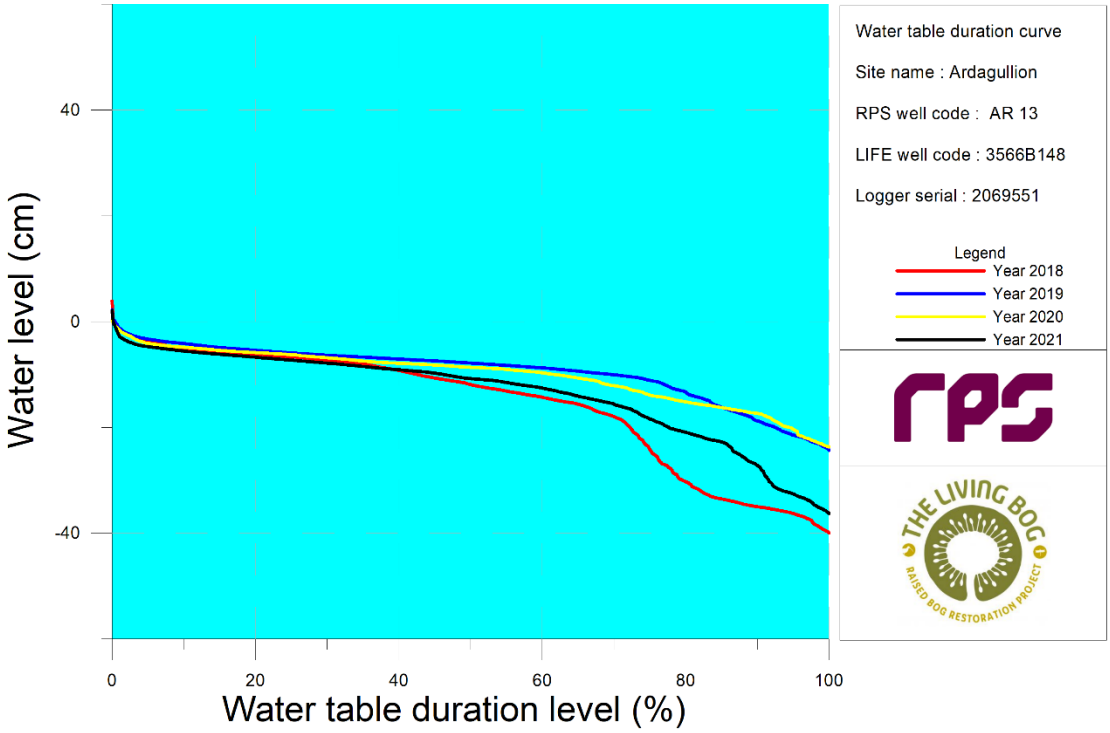

Figure 3-14: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well AR 13, Ardagullion Bog SAC.

Figure 3-16 presents data obtained from the levelogger at AR 16, as demonstrated the data indicates a positive response to completion of restoration measures, with a clear and consistent water level rise. In the summer prior to restoration (2018), the water table fluctuated extensively, dropping lower than 50cm below ground surface. Conversely, following restoration water levels rose and stayed consistently at or above ground surface for the majority of the remainder of the record length. Most notably, the capacity for significant drawdown appears to have been reduced following the successful completion of restoration, in the two years of data following restoration only two periods of significant drawdown are evident, with the greatest of the two occurring in 2020, briefly lowering the water level to approximately 3 cm below ground surface before rapidly rebounding to pre-drawdown levels.

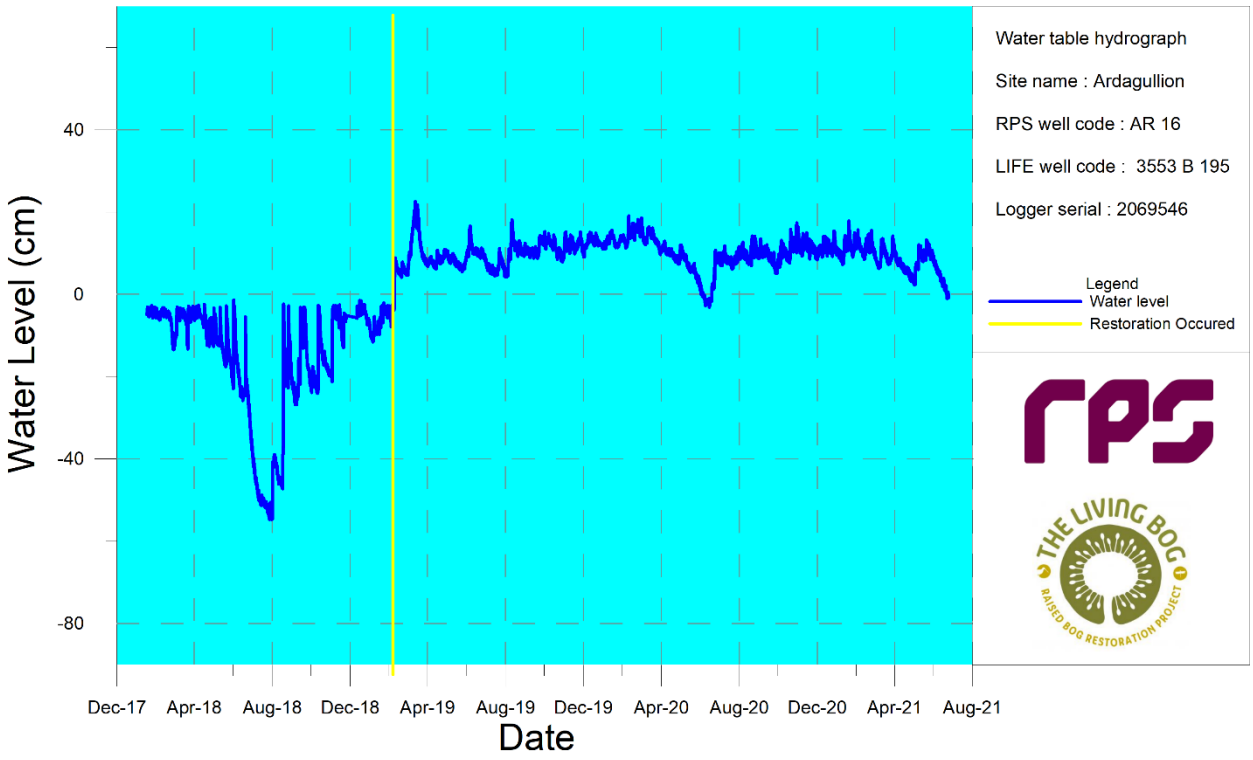

Figure 3-15: Level logger data recorded between May 2018 and July 2021 at well AR 16, Ardagullion Bog SAC.

Figure 3-16 illustrates the duration curves generated from the data obtained from AR 16. Results appear similar to those of the phreatic wells on the eastern cutover, there is a clear increase in the duration level in the two years post-restoration. Comparison of the data obtained from this well, to that collected from AR13 (Figure 3-13 & Figure 3-14) highlights the success of restoration in the area as opposed to the baseline measurements where no restoration was completed.

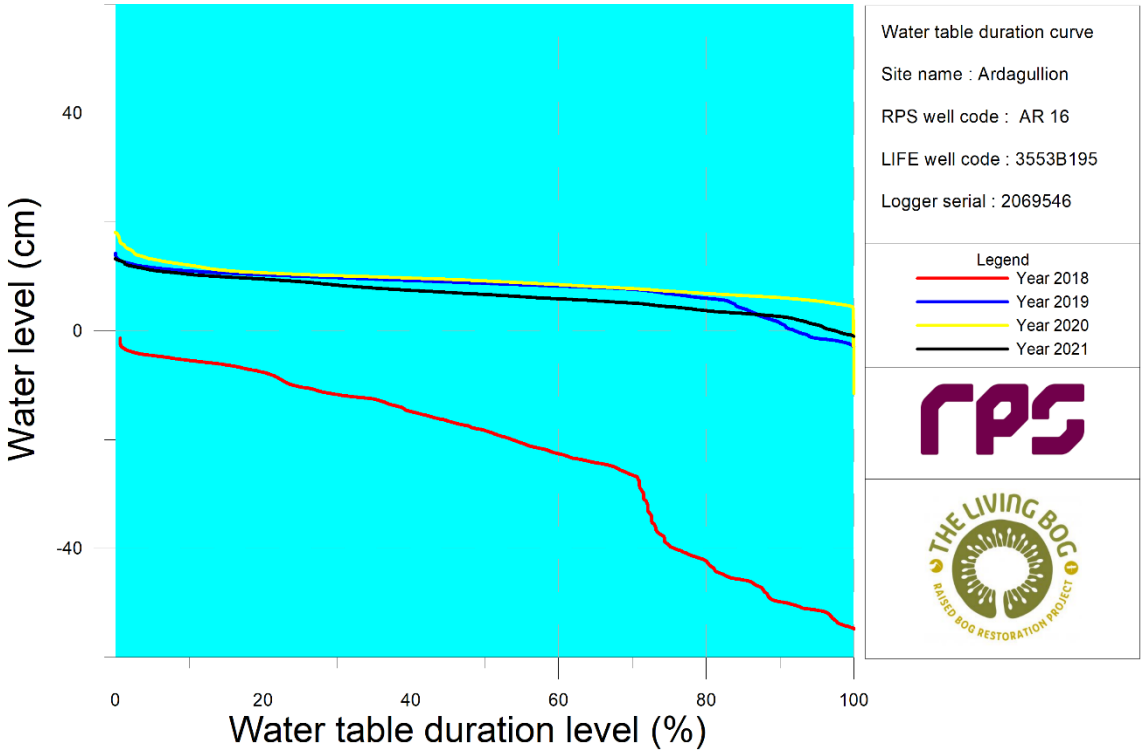

Figure 3-16: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well AR 16, Ardagullion Bog SAC.

3.1.7.3 High Bog

To investigate the impact restoration measures would have on the high bog at Ardagullion Bog SAC, piezometers were located in areas currently defined as Active raised bog (ARB), Degraded Raised Bog (DRB) and areas of supporting high bog. Figure 3-17, shows the location of the high bog monitoring network at Ardagullion Bog, SAC.

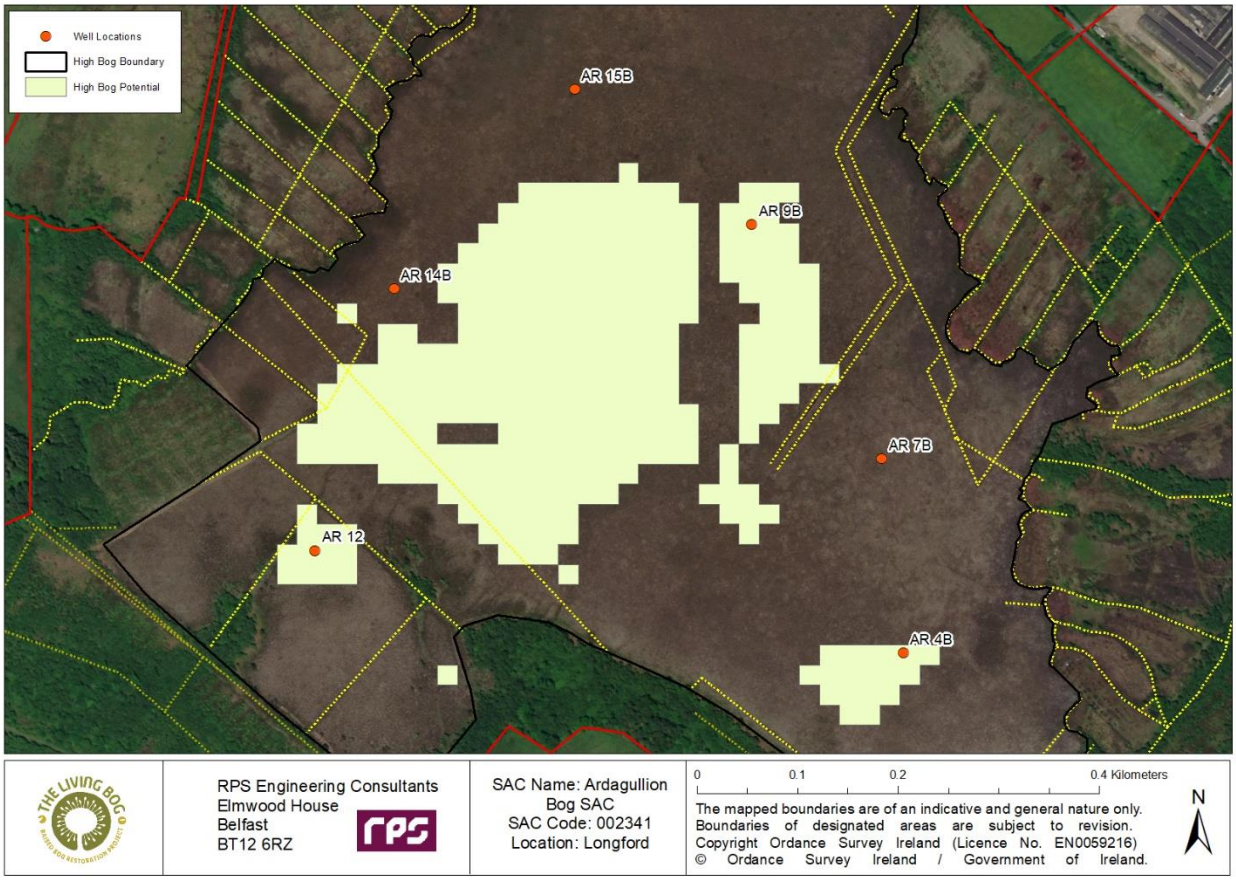

Figure 3-17: Location of wells AR 9 & AR 12 on the High Bog at Ardagullion Bog SAC.

Overall, modest responses to drain blocking was observed on the High Bog compared to cutover areas. Water levels in ARB areas were observed close to the bog surface and remained so throughout the study, as expected. Limited fluctuations were also noted in areas of DRB or supporting high bog and it is recommended that longer-term data is collected to investigate the impact of drain blocking over time. Data obtained from AR 12 can be used to demonstrate the negligible variation in water levels observed pre/post restoration on the high bog at Ardagullion Bog SAC which was representative of a majority of monitoring points on the high bog. Data observed by AR 12 (Figure 3-18) shows a limited response to the completion of restoration works when compared to pre-restoration levels. The water table duration curves for data collected from AR12 (Figure 3-19) present similar results for the pre-restoration summer dry period in 2018 and the same period in 2020 and partly again in 2021.

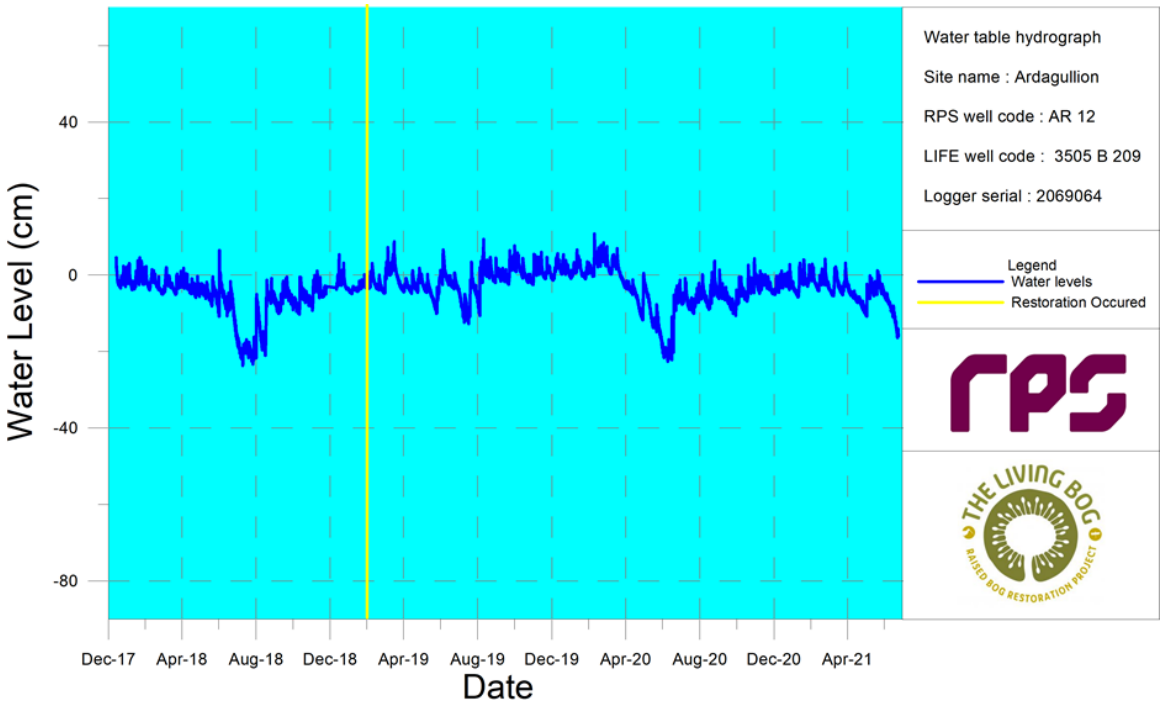

Figure 3-18: Level logger data recorded between December 2017 and August 2021 at well AR 12, Ardagullion Bog SAC.

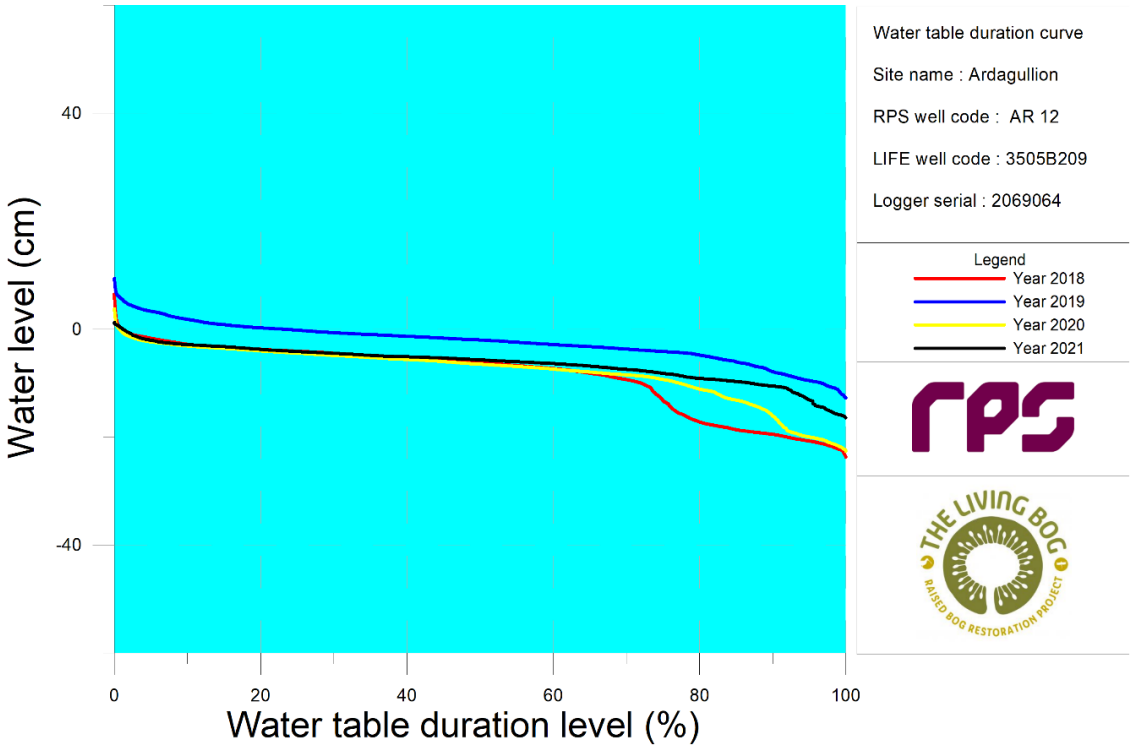

Figure 3-19: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well AR 12, Ardagullion Bog SAC.

Reiterating the observations of change (or lack thereof) in visible condition noted on the high bog at Ardagullion Bog SAC, no change in condition is evident in the water level at AR 7 (Figure 3-20) across the record period of September 2018 – July 2021. A similar case is true of data recorded at AR 14 (Figure 3-21) and AR 15 (Figure 3-22). It is important to note that water levels at these locations were already close to the surface and for the most part within the desired range to support active raised bog. It is likely that the restoration measures will provide these areas with additional resilience to ensure water levels do not decline too far in drought years.

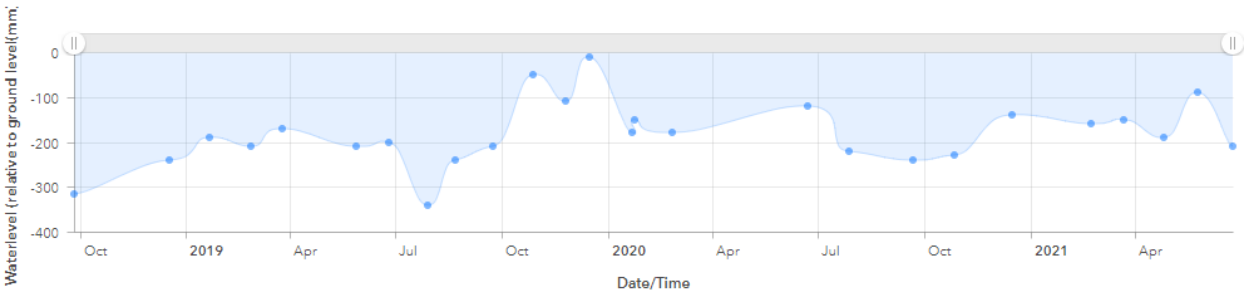

Figure 3-20: Hydrograph of manual monthly water levels AR 7, Ardagullion Bog SAC.

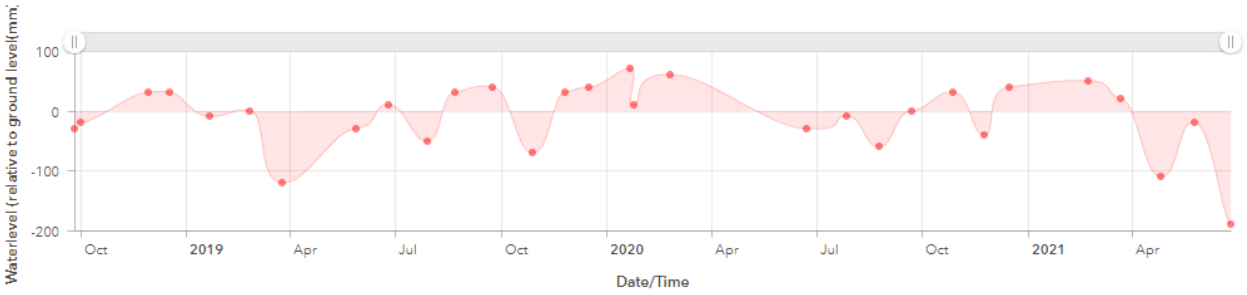

Figure 3-21: Hydrograph of manual monthly water levels AR 14, Ardagullion Bog SAC.

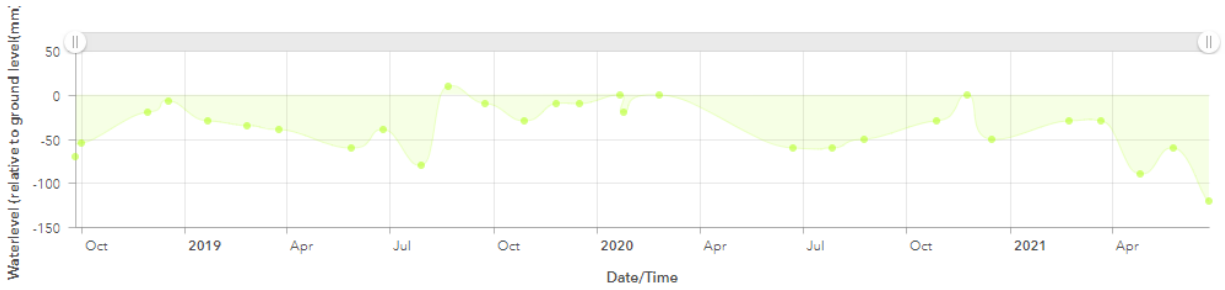

Figure 3-22: Hydrograph of manual monthly water levels AR 15, Ardagullion Bog SAC.

However, data observations from well AR 9 (Figure 3-23) on the northern sector of the high bog showed a clear and apparent increase in water level is evident across the recording period, with water levels trending closer to the surface, Furthermore, the post-restoration data shows a more consistent water level, with fewer fluctuations, most notably severe drawdown events are reduced significantly. This is especially evident when analysing the rebound effect of the water level in the summer 2018 dip versus the summer 2020 dip. Figure 3-24, illustrates the duration curves generated from the data obtained from AR 9. The duration curves indicate a minor but clear difference between water levels pre (2018) and post (2019/20) restoration. With a difference of 8cm between the annual D90 values pre-post restoration. Overall, this highlights minor improvements in the hydrological conditions and longer-term monitoring should be completed.

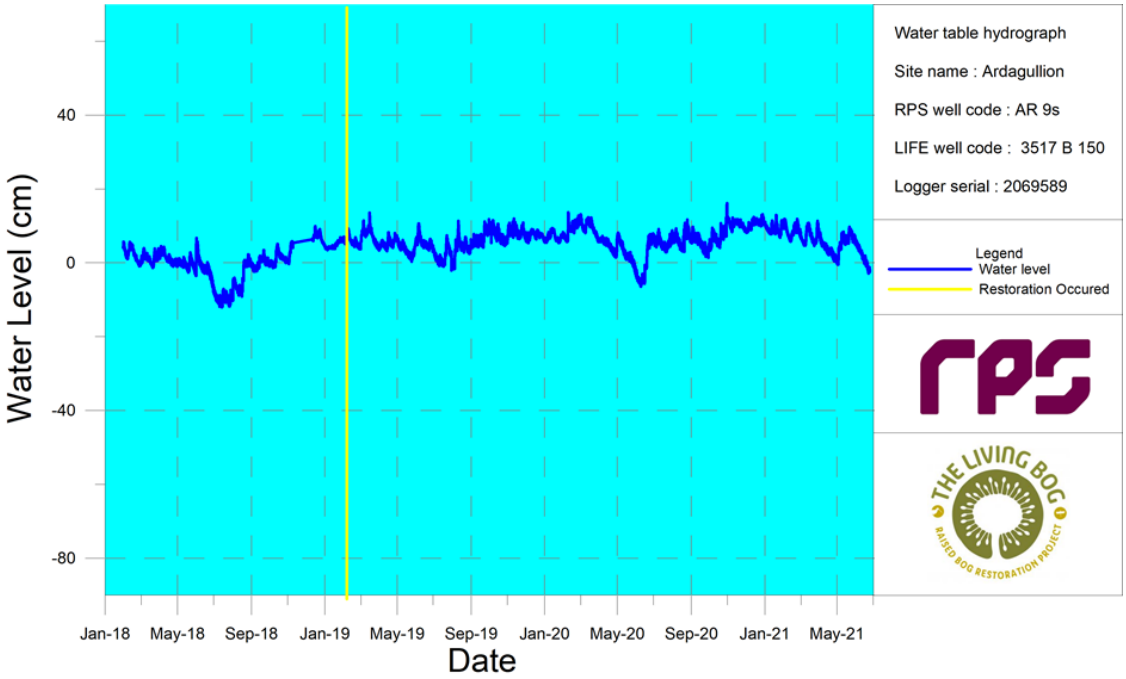

Figure 3-23: Level logger data recorded between January 2018 and June 2021 at well AR 9, Ardagullion Bog SAC.

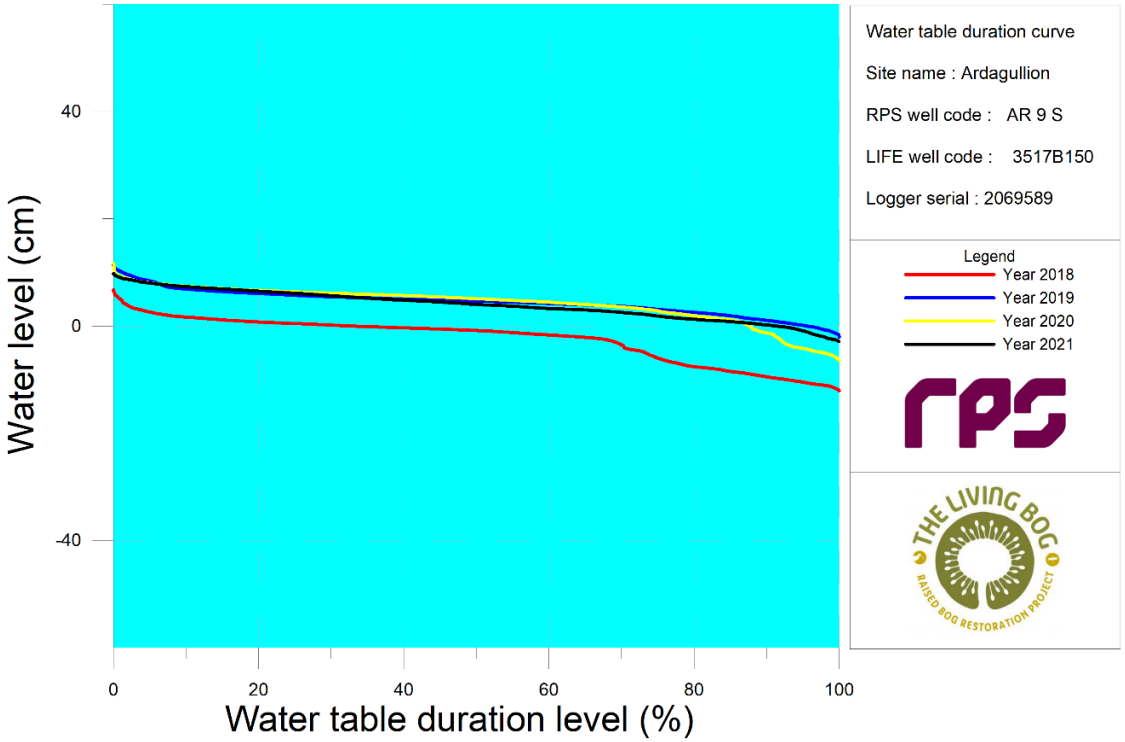

Figure 3-24: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well AR 9, Ardagullion Bog SAC.

3.1.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in the majority of wells between pre-restoration levels (2018) and post-restoration levels (2020[1]) (Table 3.1), although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration. The largest increases were noted in all cutover wells apart from AR13 in which restoration was not completed. On the high Bog, limited changes were noted, with the water level remaining consistent. There was a notable increase at AR9, which was installed in an area of sub-central ecotope close to an area where drain blocking occurred.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Ardagullion	AR1	Cutover	Non-PFH	-40.12	-2.00
Ardagullion	AR13	Cutover	Non-PFH	-35.01	-27.21
Ardagullion	AR16	Cutover	PFH	-49.81	6.097
Ardagullion	AR2	Cutover	PFH	-25.26	46.27
Ardagullion	AR11-S	High Bog	ARB	-12.27	-12.75
Ardagullion	AR12	High Bog	Supporting High Bog	-19.48	-16.09
Ardagullion	AR14-S	High Bog	Supporting High Bog	-13.12	-17.40
Ardagullion	AR15-S	High Bog	Supporting High Bog	-15.59	-12.21
Ardagullion	AR3-S	High Bog	Supporting High Bog	-39.04	-36.87
Ardagullion	AR4-S	High Bog	ARB	-15.53	-13.72
Ardagullion	AR5-S	High Bog	Supporting High Bog	-28.81	-28.94
Ardagullion	AR6-S	High Bog	ARB	-15.39	-13.87
Ardagullion	AR8-S	High Bog	DRB	-26.84	-23.8
Ardagullion	AR9-S	High Bog	ARB	-9.483	-1.27

Table 3.1: 90th Percentile water levels at Ardagullion Bog SAC, pre- and post-restoration.

[1] Post-restoration 90th percentile water level for AR 1 calculated from 2019 data due to an incomplete 2020 record.

3.2 Carrowbehy Bog SAC

3.2.1 Geological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests Carrowbehy/Caher Bog SAC (primarily known as Carrowbehy Bog SAC) and adjacent lands to be underlain by a singular lithographic unit referred to as the 'Marine shelf facies' (Figure 3-25). Comprised of interbedded calcareous shales and limestone, this unit is known as a moderately productive and regionally-important aquifer unit. With a calcareous and interbedded nature, heavy karstification is noted, however low permeability peat subsoils act to confine and thus reduce aquifer vulnerability in the immediate area of the high bog. Groundwater contributions are therefore uncertain.

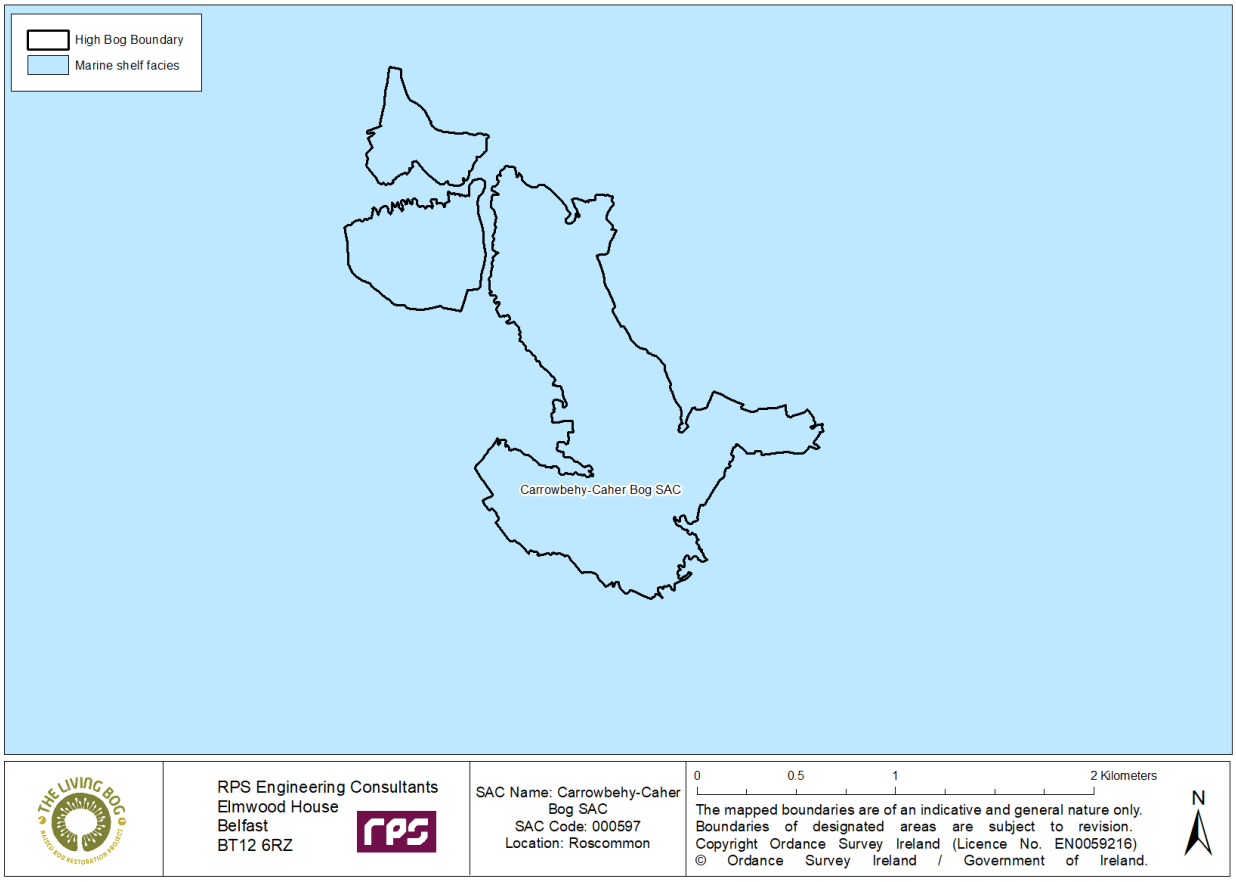

Figure 3-25: Simplified geology of Carrowbehy/Caher Bog SAC 'High bog' and adjacent lands.

3.2.2 Ecotope map

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-26). During the last monitoring survey (2018) it was noted, that Carrowbehy Bog SAC consists of 72.84 ha of Active Raised Bog (ARB) consisting of areas of central, sub-central and active flush.

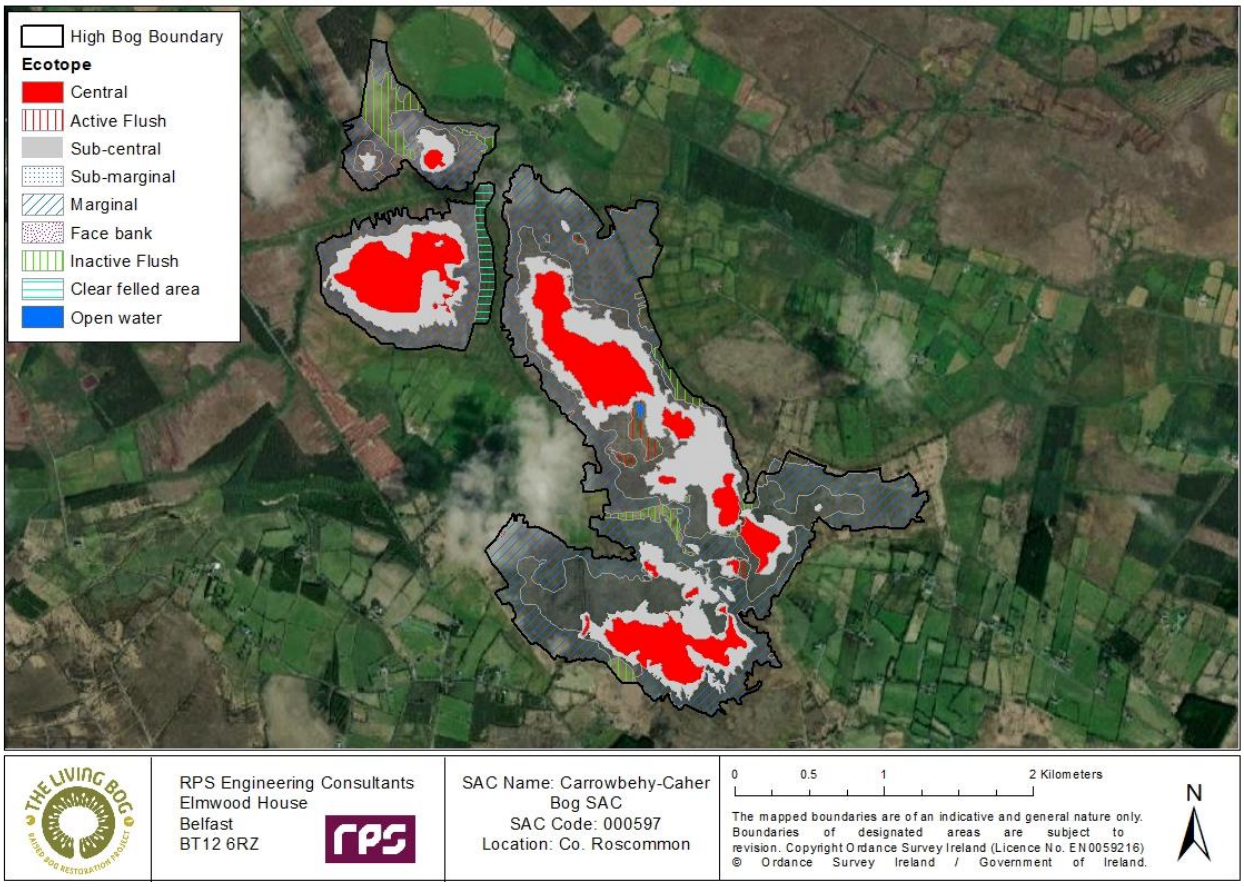

Figure 3-26: Ecotope mapping carried out for Carrowbehy/Caher Bog SAC.

3.2.3 Proposed restoration plan

The restoration plan for Carrowbehy/Caher Bog SAC (Figure 3-27) identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat forming (ARB) habitat. Overall, the installation of peat dams was recommended across 19.82km of channels both on the high bog and cutover.

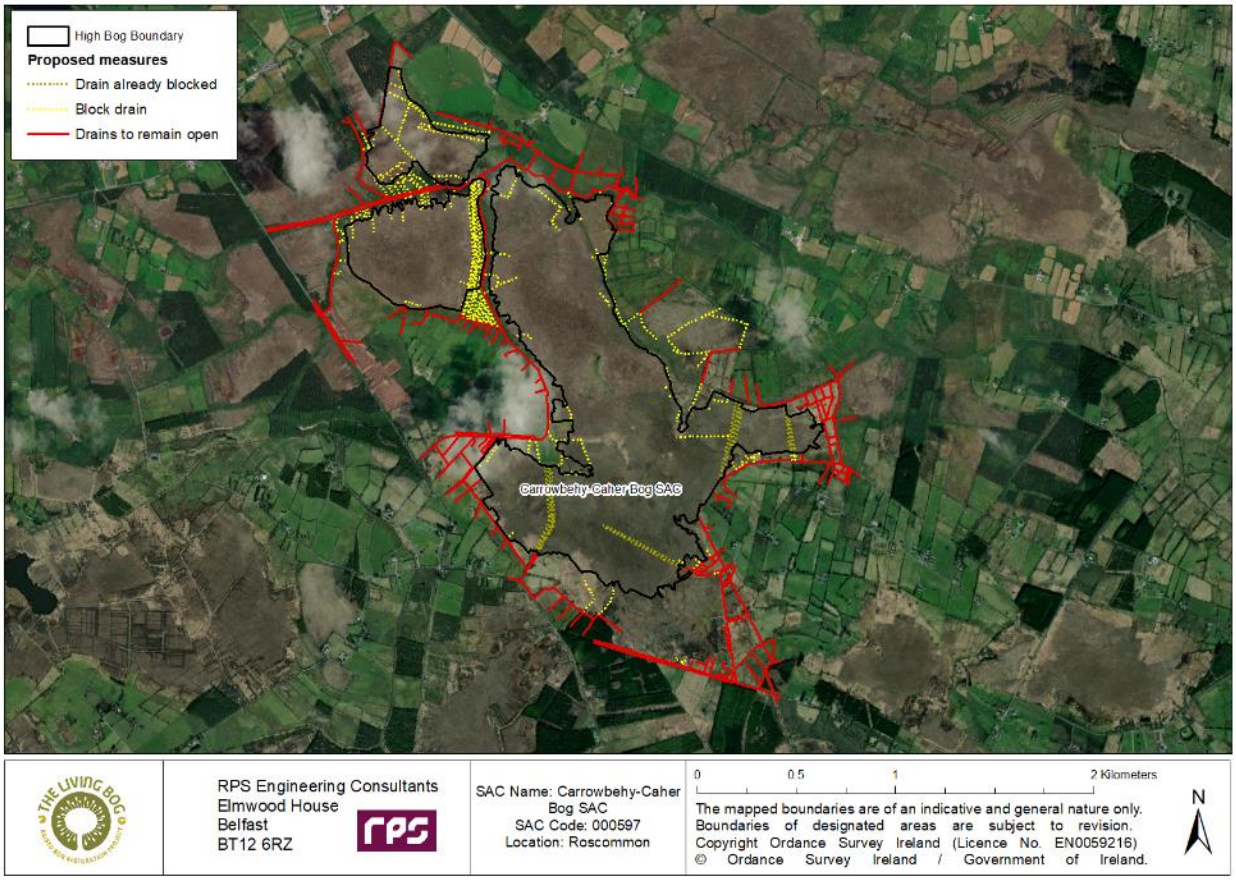

Figure 3-27: Restoration measures specified in support of hydrological goals.

3.2.4 Restoration potential

Eco-hydrological modelling of the restoration potential on Carrowbehy Bog SAC, excluding current areas mapped as ARB, suggested as much as 22.4 ha of habitat had the potential to be positively impacted by restoration works, with 17.8 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 4.6 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-28).

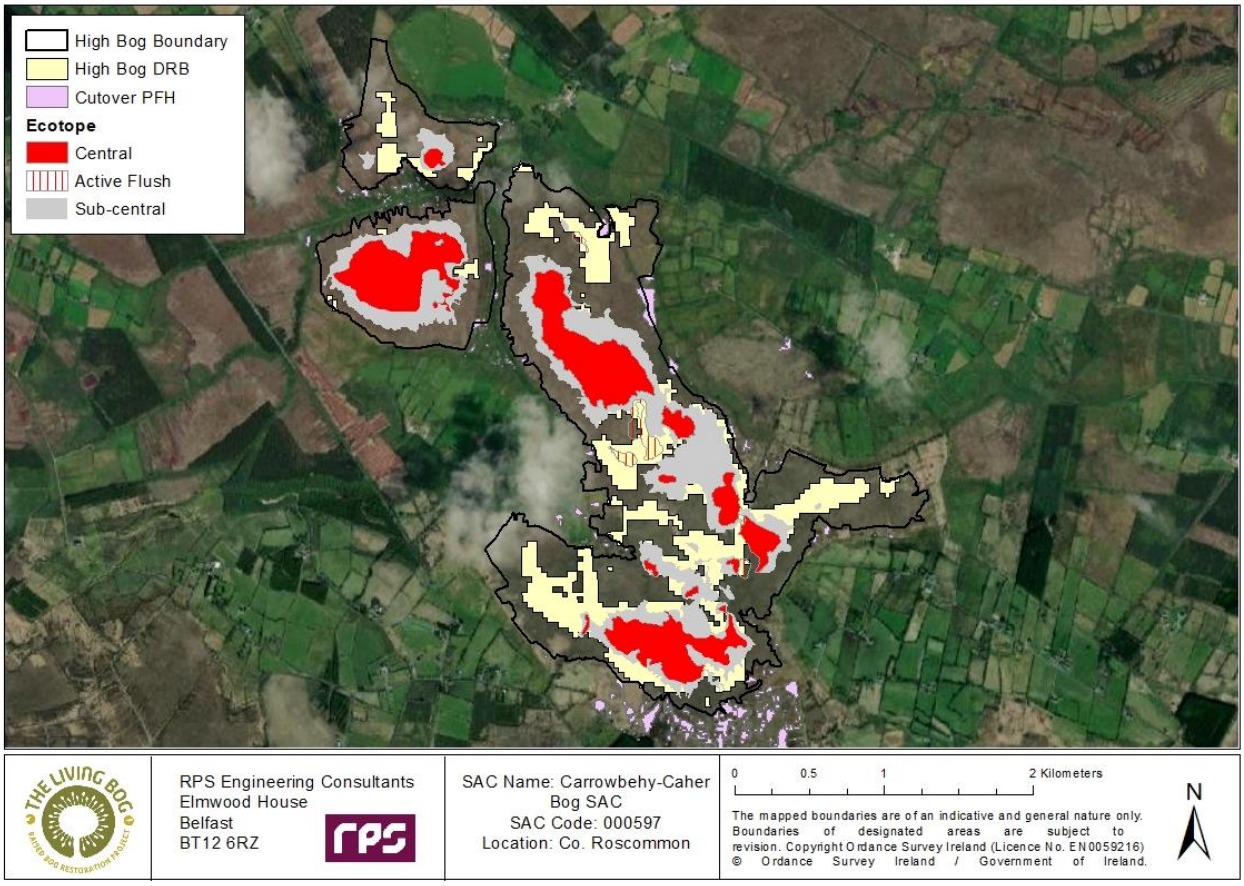

Figure 3-28: Restoration potential of Carrowbehy/Caher Bog SAC.

3.2.5 Deployed monitoring network

A monitoring network comprising a mixture of 29 shallow phreatic wells and deeper piezometric wells (Figure 3-29) was subsequently installed on Carrowbehy Bog SAC. On the high bog, 12 phreatic wells were installed accompanied by 9 deep piezometers in order to monitor vertical hydraulic gradients. On the cutover, 8 phreatic wells were installed. A total of 3 water level loggers were spread amongst the wells. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic. Loggers were set to automatically record levels at 15-minute intervals, the data was downloaded on a quarterly basis. A barometric logger was also located on this site and was installed to monitor changes in atmospheric pressure, subsequently used to barometrically correct the levelogger data.

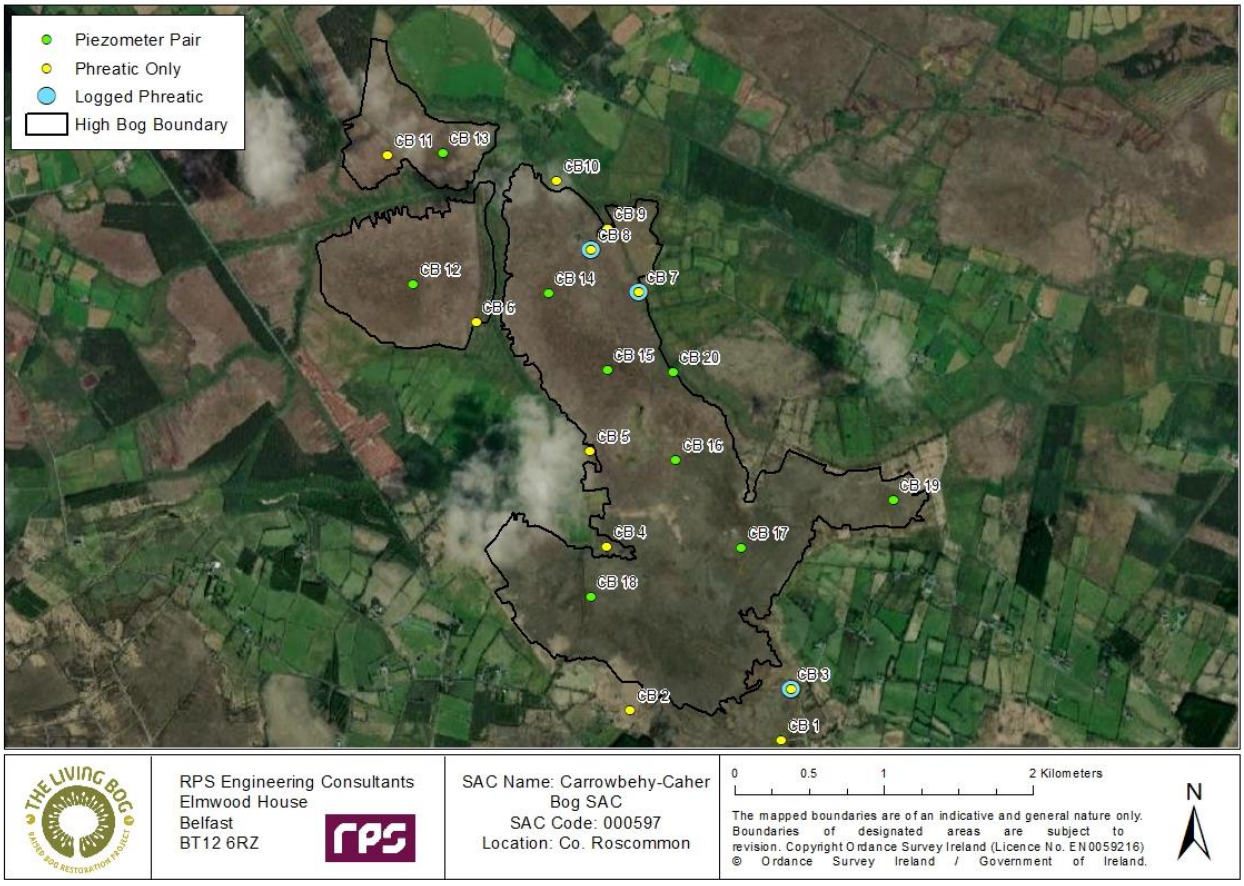

Figure 3-29: Hydrological monitoring network installed and operating on Carrowbehy/Caher Bog SAC.

3.2.6 General field observations

Owing to regular site visits RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. For instance, in the Southern cutover, limited observations were made in the area surrounding CB1 and CB3 which were generally wet all year round, suggesting the conditions for PFH may already have been in existence. The area surrounding CB2 re-wetted significantly post-restoration with the area becoming unsuitable for further surveying as the water depth restricted access suggesting measures were successful in the area.

Several drains could not be blocked across the site due to agreements not being reached with landowners. These areas remained dry throughout the study and should be prioritised for future restoration works if an agreement can be reached with the landowner. Drain blocking was partially completed in the vicinity of CB7, with significant rewetting observed, however the monitoring equipment at this location was subsequentially vandalised and pulled from the ground. The logger was found, and a partial dataset was recovered.

A large proportion of the high bog was already defined as ARB and was considerably wet underfoot (Figure 3-30). given water table levels are generally closer to the ground surface in high bog areas anyway, hydrological changes are more difficult to observe visually than widespread rewetting of very dry cutover areas. Rewetting, in close proximity to drains, could be observed on the high bog near nests CB20 and CB18.

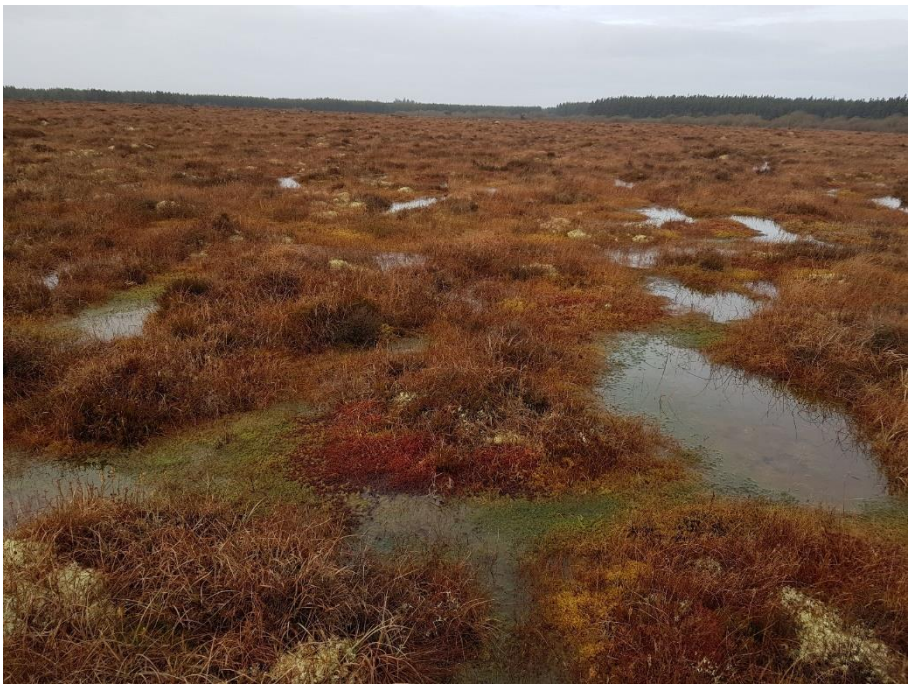

Figure 3-30: High bog at Carrowbehy. Large portions of the high bog were defined as ARB and remained wet throughout the year

3.2.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Carrowbehy SAC are presented with all supplementary results provided in Appendix A.

3.2.7.1 Western cutover

In a bid to evaluate and quantify the effects of restoration measures, both CB 7 and CB 8 were placed in regions of high restoration potential in cutover bog (Figure 3-31), east of the high bog in areas where significant drain blocking was proposed.

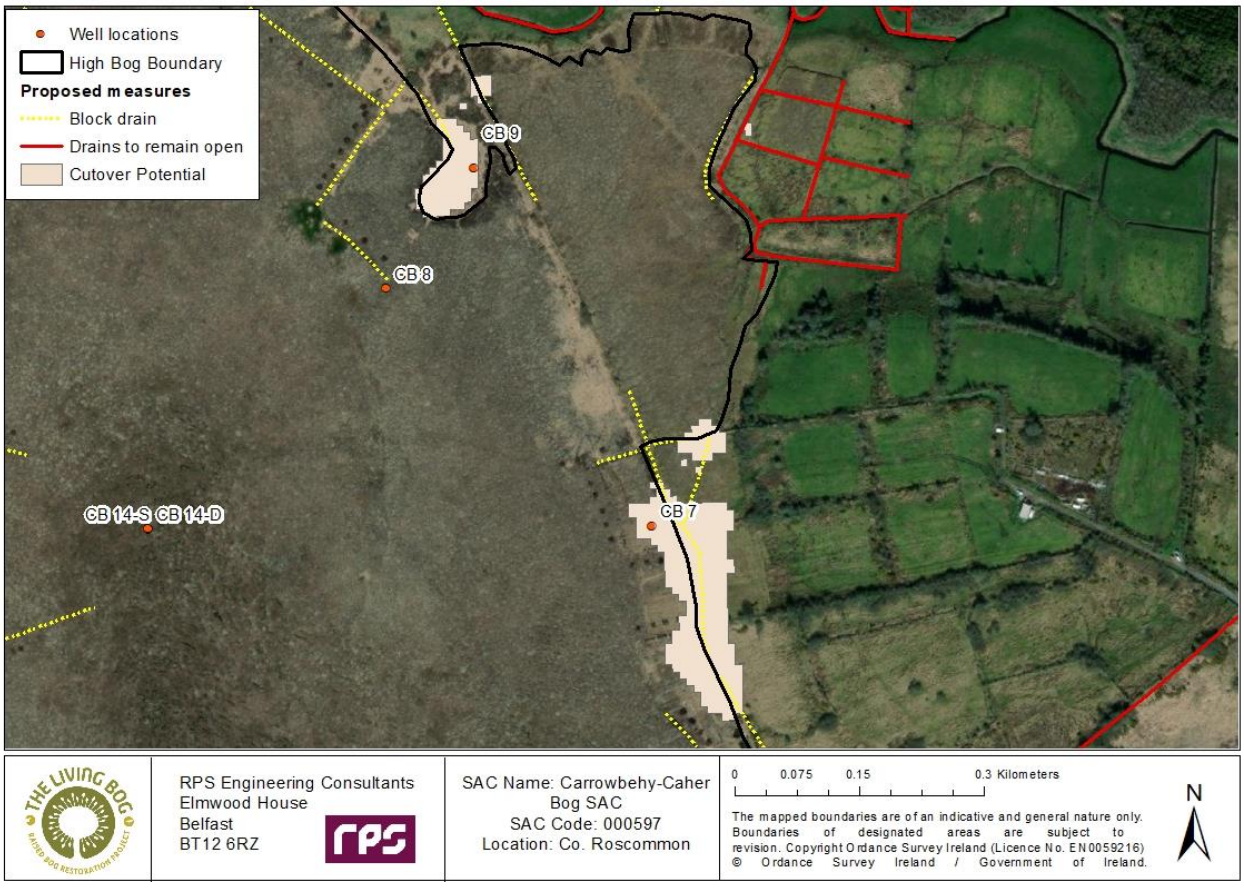

Figure 3-31: Location of wells CB 7 & CB 8 on the eastern cutover at Carrowbehy Bog SAC

Figure 3-32 – Figure 3-34 illustrate results from the hydrological monitoring points located on the Western cutover at Carrowbehy Bog SAC. Figure 3-32 presents the hydrograph at CB 7, as demonstrated the water table in the area was already relatively close to the surface during the winter period, with fluctuations up to 25cm of the ground surface in the summer dry period (April – October) of 2019. Following restoration, there was a notable increase in the water level, with the water table remaining within the top 10cm of the surface in the summer dry period (April – October) of 2020. Data could not be recorded past this period due to the data logger being removed by a local farmer but monthly field visits confirmed that this area remained saturated throughout the duration of the project. Overall, results suggest that restoration was successful in the area and extended beyond the extent modelled as PFH.

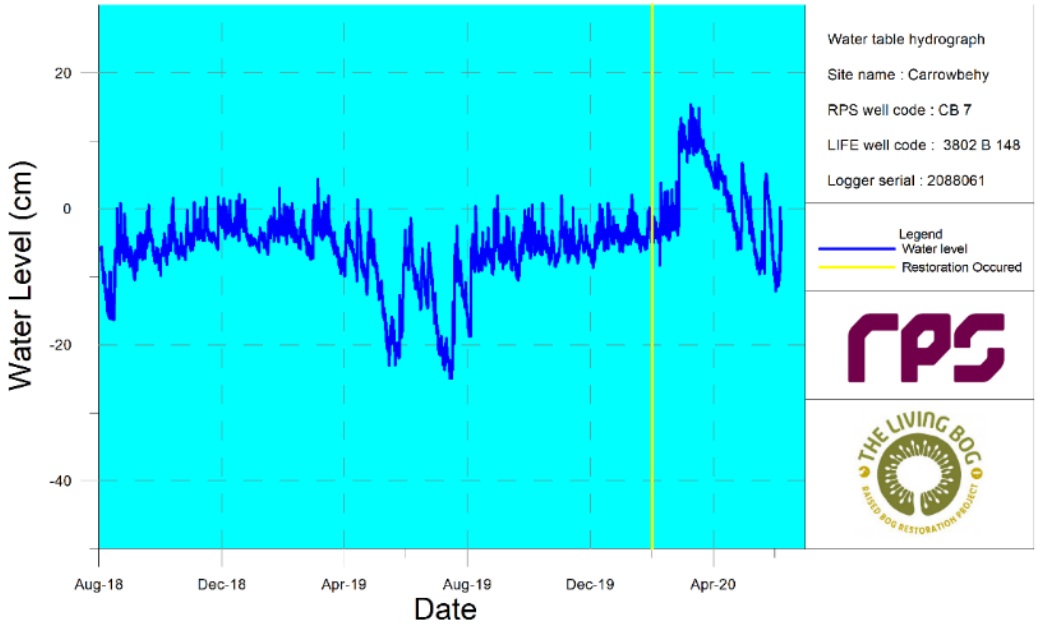

Figure 3-32: Level logger data recorded between December 2017 and August 2021 at well CB 7, Carrowbehy Bog SAC.

Figure 3-33 presents the hydrograph at CB 8. This well was located in an area of PPFH, however, due to ongoing issues with landowners, restoration works could not be completed on the drains close to the well during the project. Baseline data recorded prior to restoration completed in other areas of the site showed the water table consistently below the ground surface. Water level measurements as low as 40 cm beneath the ground surface coincided with extended periods of dry weather during the summer dry period (April – October) of 2019. Post completion of the site restoration measures, a major drawdown occurs in the summer of 2020, with water levels dropping to close to the maximum depth recorded prior to completion of restoration works on other areas of the site. Figure 3-34 illustrates the duration curves generated from the data obtained from CB 8. As shown, there is limited variation between the water levels which highlights the impact of not completing restoration in this area. Overall this confirms that the positive results observed in other areas of the site can be attributed to the restoration works and aren't simply as a result of variations in climatic conditions.

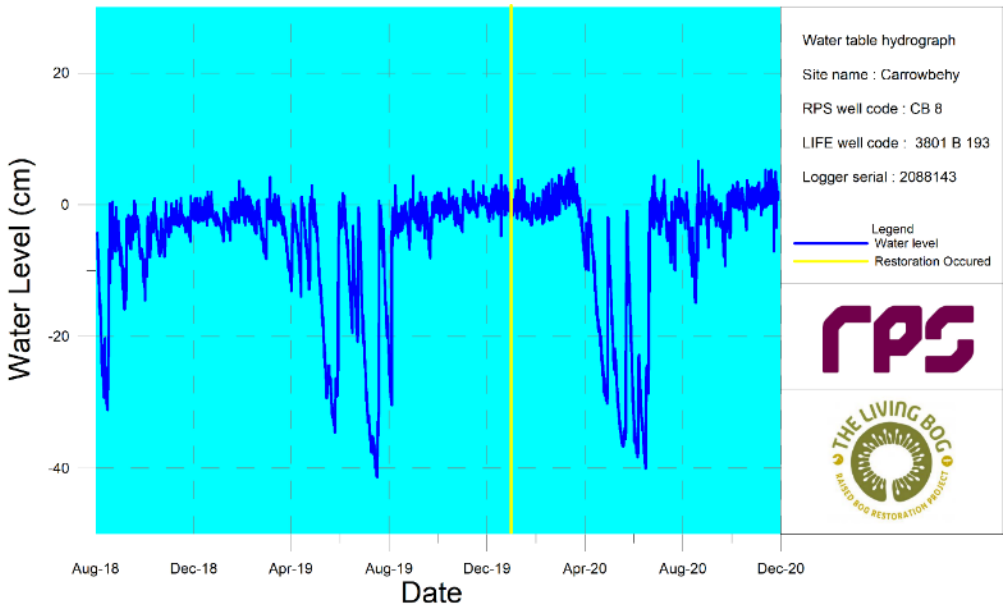

Figure 3-33: Level logger data recorded between August 2018 and December 2020 at well CB 8, Carrowbehy Bog SAC.

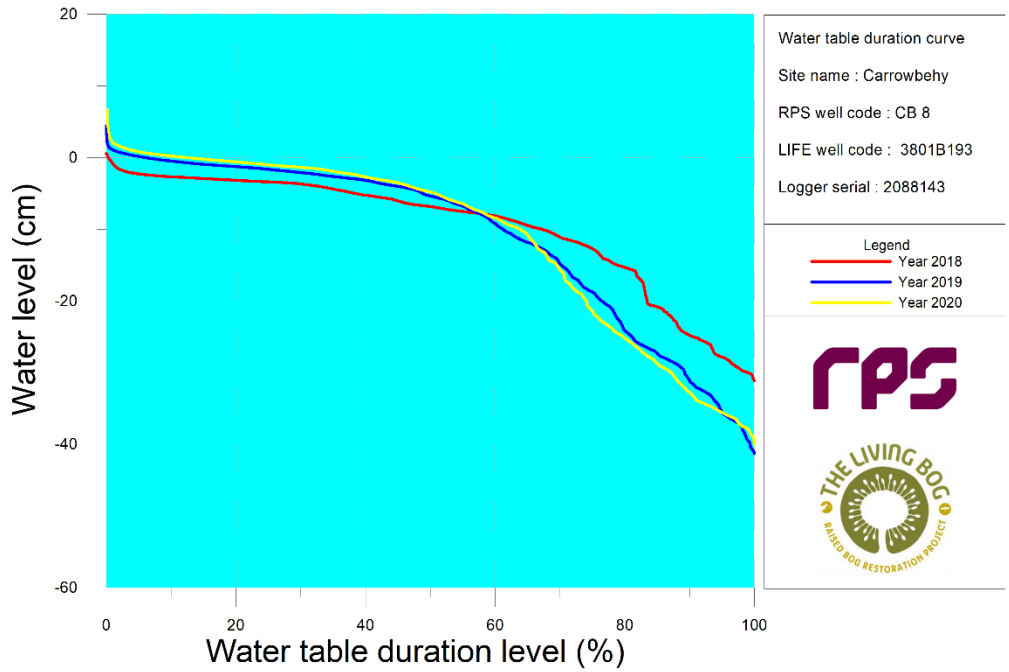

Figure 3-34: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well CB 8, Carrowbehy Bog SAC.

3.2.7.2 Southern Cutover

In a bid to evaluate and quantify the effects of restoration measures, CB 1 and CB 2 were placed in regions of high restoration potential in cutover bog (Figure 3-35), South of the high bog.

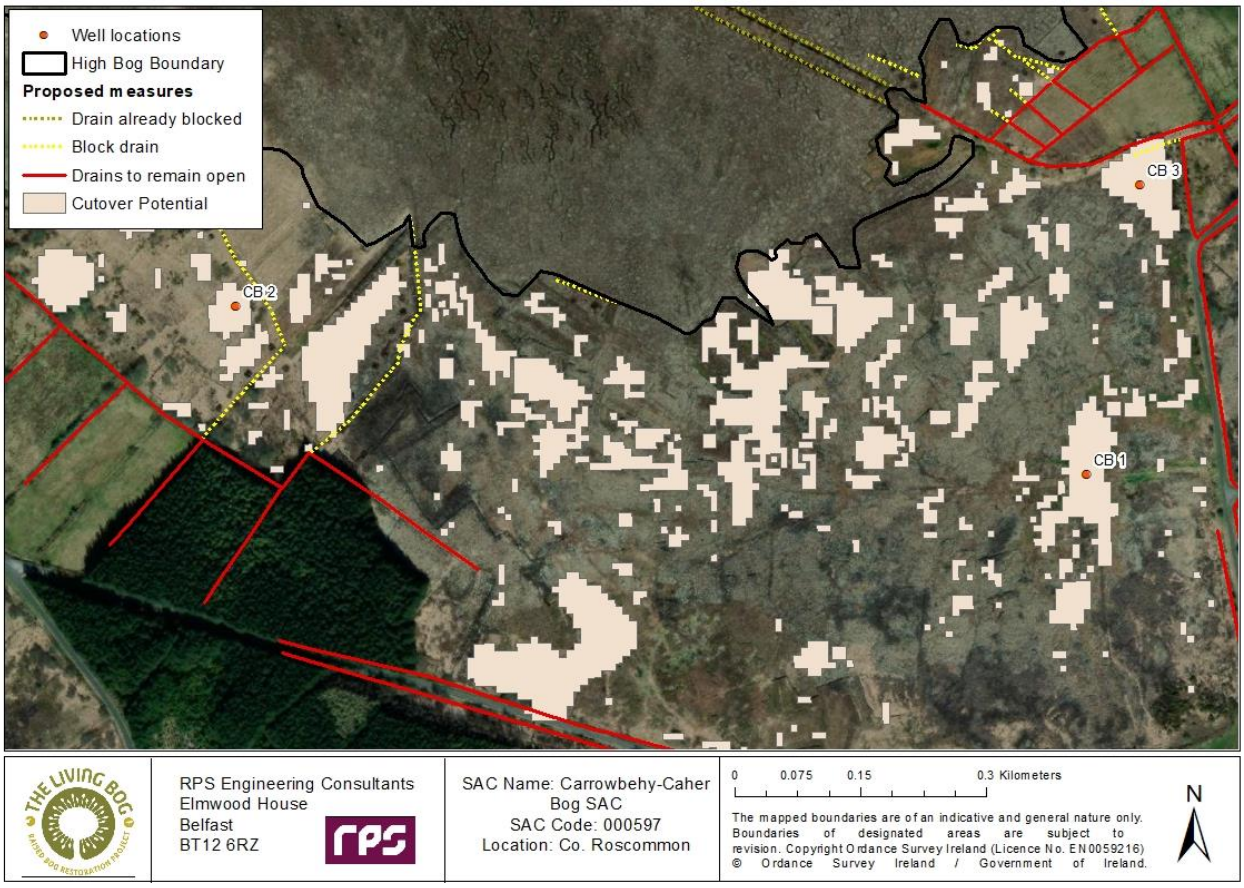

Figure 3-35: Location of wells CB 1 & CB2 on the Southern cutover at Carrowbehy Bog SAC

Figure 3-36 and Figure 3-37 illustrate results from the hydrological monitoring points located on the Southern at Carrowbehy Bog SAC. Figure 3-36 presents the hydrograph at CB 1, as demonstrated the water table remained relatively close to the surface throughout the monitoring period, remaining within 10cm of the surface throughout the year. A minor improvement was noted post restoration where the water table remained predominately above ground after restoration, which may be indicative of an established greater resilience to water table drawdown in the area post-restoration.

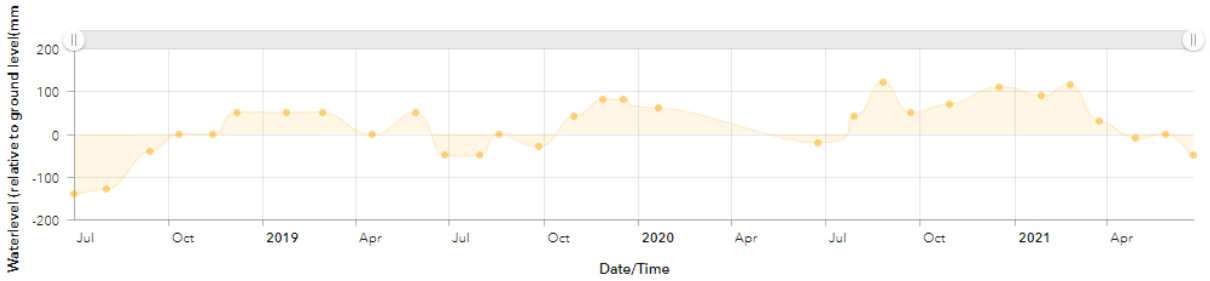

Figure 3-36: Hydrograph of manual monthly water levels CB 1, Carrowbehy Bog SAC.

Figure 3-37 presents the hydrograph at CB 2, as demonstrated prior to restoration the water table remained relatively close to the surface, remaining within 10cm of the surface throughout the year. Following site-wide completion of works in early 2019 water levels rose significantly at this location, with the monitoring equipment becoming inaccessible due to flood waters. An estimated value of 25cm above ground was selected based on a visual inspection of the monitoring well, highlighting the success of the measures in the area. Generally, within this area, the re-wetting expanded over a larger area than that predicted by the restoration model.

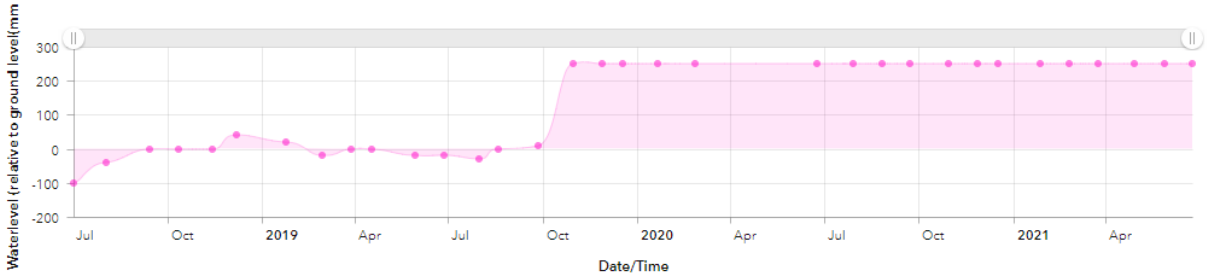

Figure 3-37: Hydrograph of manual monthly water levels CB 2, Carrowbehy Bog SAC.

3.2.7.3 High Bog

To investigate the impact restoration measures would have on the high bog at Carrownehy Bog SAC, piezometers were located in areas currently defined as Active raised bog (ARB), Degraded Raised Bog (DRB) and areas of supporting high bog. Figure 3-38, shows the location of the high bog monitoring network at Carrowbehy Bog, SAC.

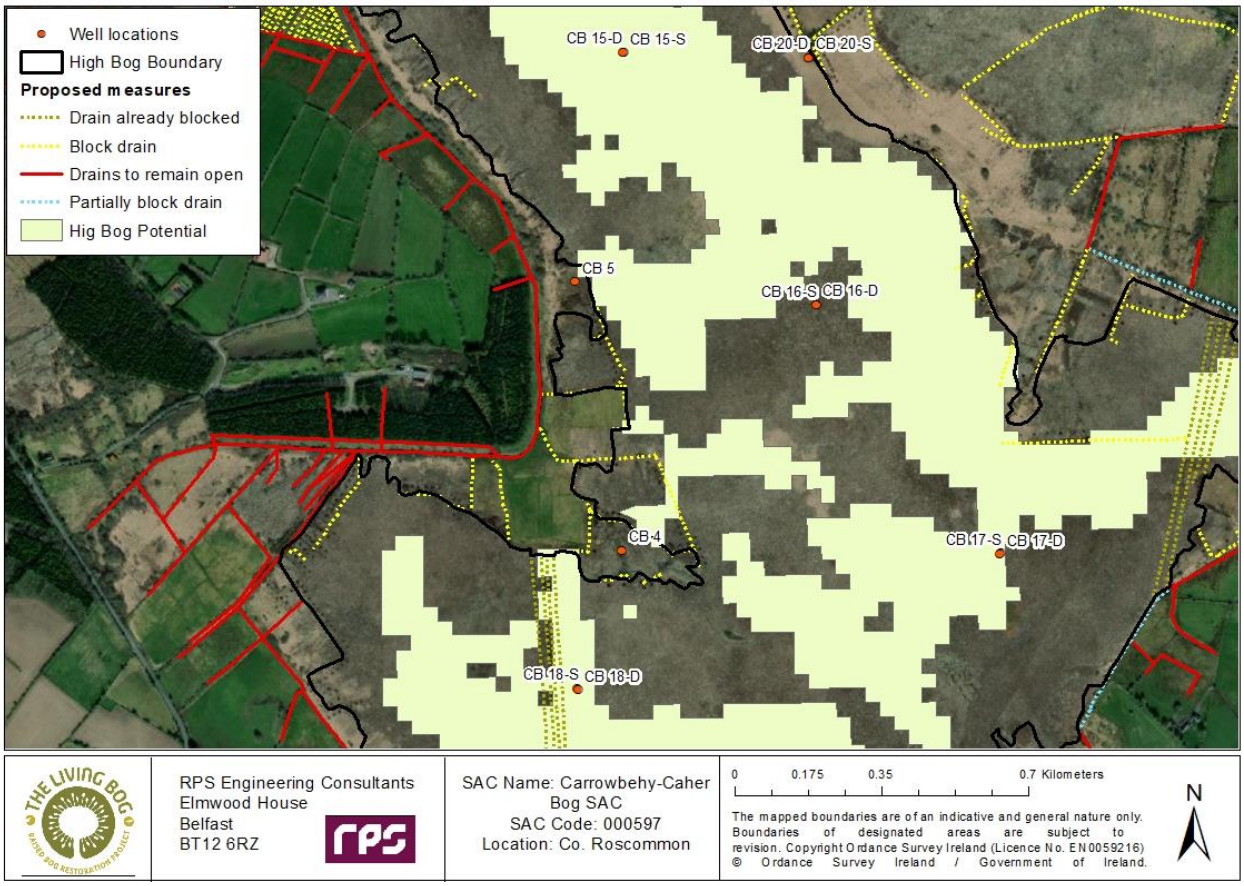

Figure 3-38: Location of wells on the High Bog at Carrowbehy Bog SAC

Overall, modest responses to drain blocking was observed on the High Bog compared to cutover areas. Water levels in ARB areas were observed close to the bog surface and remained so throughout the study, as expected. Carrowbehy Bog SAC had a large proportion of ARB compared to other sites. Data obtained from CB 15 can be used to demonstrate the minor variations in water levels observed pre/post restoration on the high bog at Carrowbehy Bog SAC which was representative of a majority of monitoring points. Data observed by CB 15 (Figure 3-39) shows a limited response to the completion of restoration works when compared to pre-restoration levels. However, data observations from well CB 18 (Figure 3-40) on the south western sector of the high bog showed a clear and apparent increase in water level is evident across the recording period, with water levels trending closer to the surface. This monitoring location was close to an area of high bog drain blocking. Furthermore, the post-restoration data shows a more consistent water level, with fewer fluctuations, most notably severe drawdown events are reduced significantly. This is

especially evident when analysing the rebound effect of the water level in the summer 2018 dip versus the summer 2020 dip.

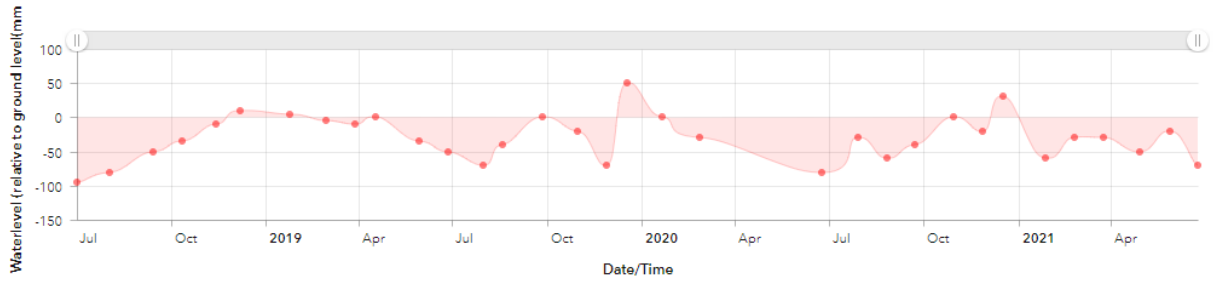

Figure 3-39: Hydrograph of manual monthly water levels CB 15, Carrowbehy Bog SAC.

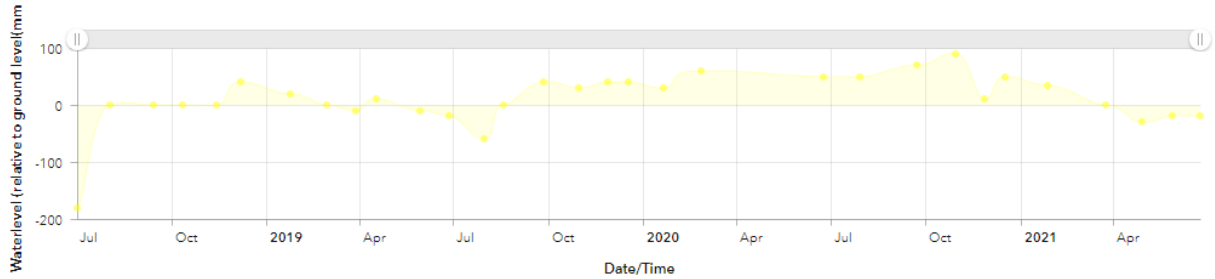

Figure 3-40: Hydrograph of manual monthly water levels CB 18, Carrowbehy Bog SAC.

3.2.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.2). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration The largest increases were noted in all cutover wells. Significant changes were observed on the high bog with multiple wells in areas designated as DRB or Supporting High Bog now displaying a post-restoration hydrological regime capable of supporting ARB.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Carrowbehy	CB1	Cutover	PFH	-13.8	-0.2
Carrowbehy	CB10	Cutover	Non-PFH	-86.8	-54.4
Carrowbehy	CB2	Cutover	PFH	-8.8	25
Carrowbehy	CB20-S	Cutover	PFH	-19.2	11.5
Carrowbehy	CB3	Cutover	PFH	-26.276	7.8
Carrowbehy	CB4	Cutover	PFH	-14.4	5
Carrowbehy	CB5	Cutover	PFH	-14.8	-4.8
Carrowbehy	CB6	Cutover	PFH	-45.8	20.8
Carrowbehy	CB7	Cutover	PFH	-20.195	-8.002
Carrowbehy	CB9	Cutover	Non-PFH	-49.6	-49.4
Carrowbehy	CB11	High Bog	DRB	-27.6	-17.7
Carrowbehy	CB12-S	High Bog	ARB	-10	-5.9
Carrowbehy	CB13-S	High Bog	ARB	-18.6	-15.4
Carrowbehy	CB14-S	High Bog	ARB	-13.8	-9
Carrowbehy	CB15-S	High Bog	ARB	-9.2	-7.4
Carrowbehy	CB16-S	High Bog	ARB	-16.6	-9.5
Carrowbehy	CB17-S	High Bog	Supporting High Bog	-9.8	-3.8
Carrowbehy	CB18-S	High Bog	DRB	-19	-3.7
Carrowbehy	CB19-S	High Bog	Supporting High Bog	-13	-6.4

Table 3.2: 90th percentile water levels at Carrowbehy Bog SAC, pre- and post-restoration.

3.3 Carrownagappul Bog SAC

3.3.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests Carrownagappul Bog SAC and adjacent lands to be underlain predominantly by the rocks of the marine shelf facies – interbedded calcareous shales and karstified limestones – this unit is known as a moderately productive and regionally-important aquifer unit, whilst to the East, a minor portion of the site is underlain by Visean basinal “calp” – a non-homogenous unit of fine shales, interbedded and intermixed with calcareous material/spar and in this region is associated with moderately productive (locally), low vulnerability aquifer units.

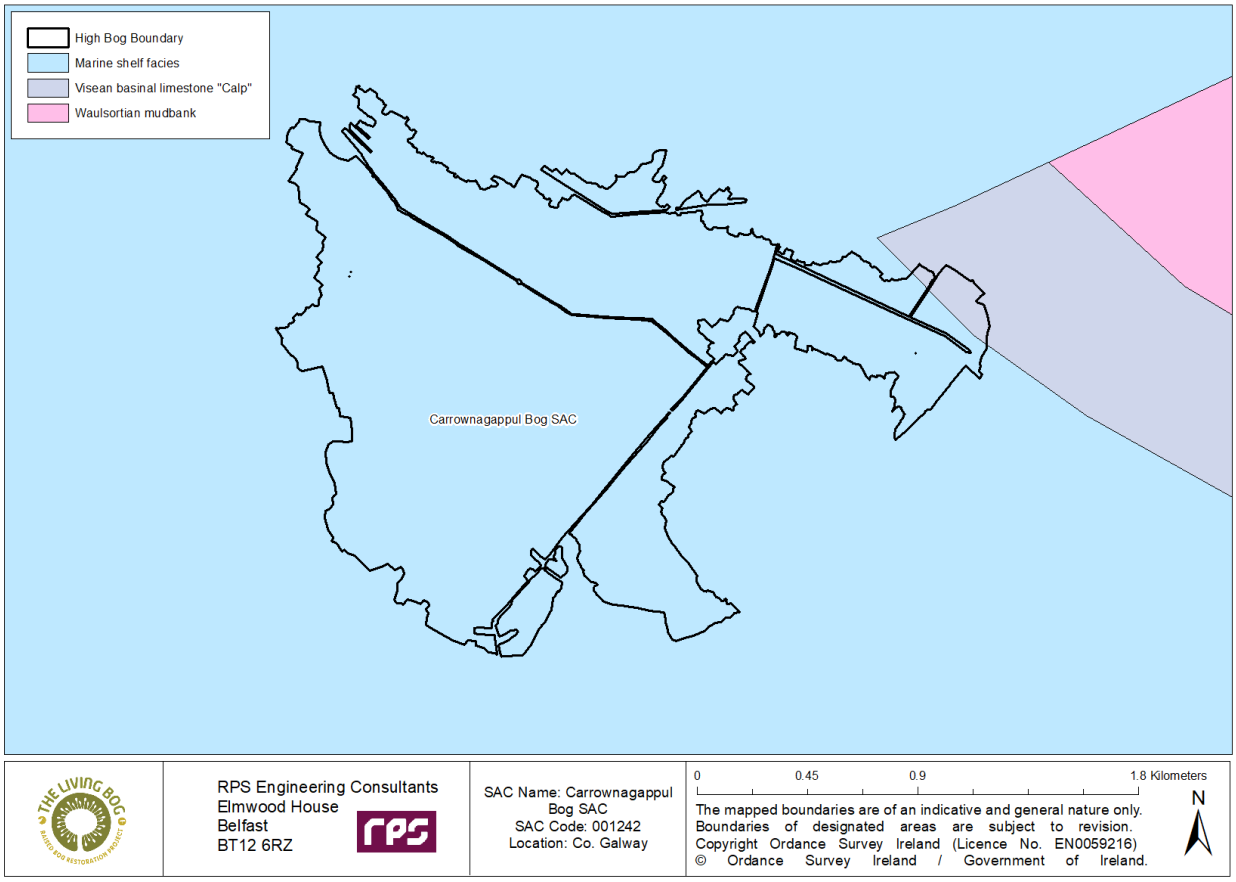

Figure 3-41: Simplified geology of Carrownagappul Bog SAC 'High bog' and adjacent lands.

3.3.2 Ecotope map

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-42). During the last monitoring survey (2018) it was noted, that Carrownagappul Bog SAC consists of 45.28 of Active Raised Bog (ARB) consisting of areas of central, sub-central and active flush.

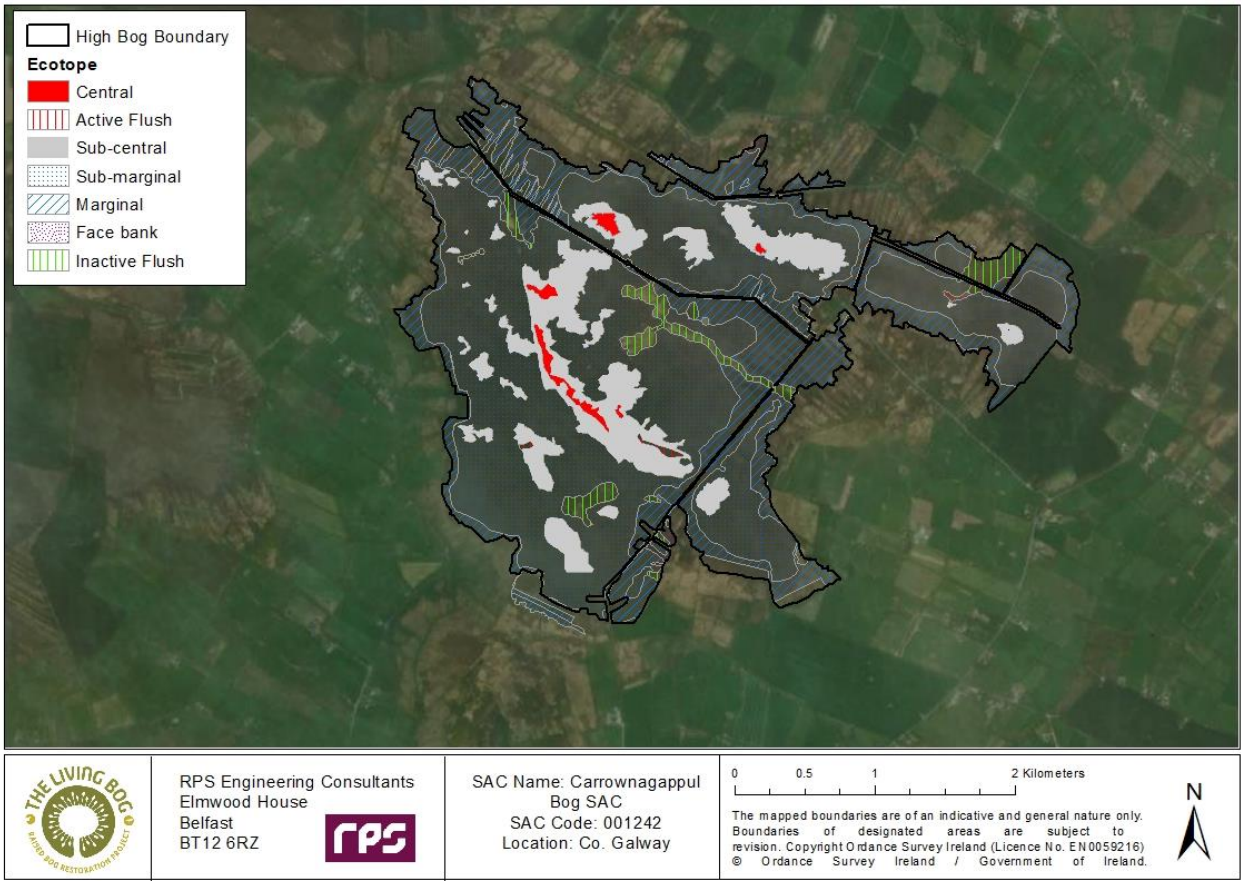

Figure 3-42: Ecotope mapping carried out for Carrownagappul Bog SAC.

3.3.3 Proposed restoration plan

The restoration plan for Carrownagappul Bog SAC identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat forming (ARB) habitat. Overall, the installation of peat dams was recommended across 46.63km of channels both on the high bog and cutover.

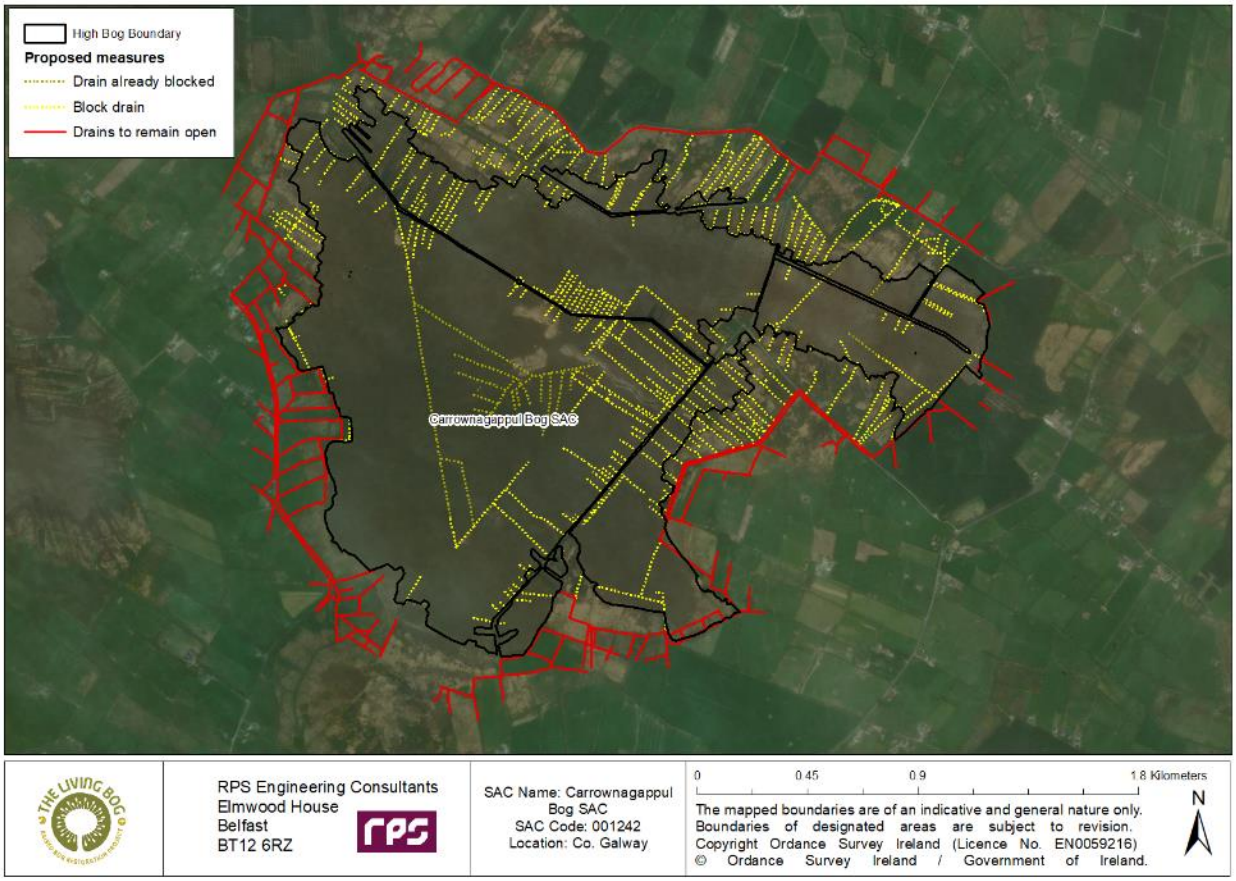

Figure 3-43: Restoration measures specified in support of hydrological goals.

3.3.4 Restoration potential

Eco-hydrological modelling of the restoration potential on Carrownagappul Bog SAC, excluding current areas mapped as ARB, suggested as much as 41.8 ha of habitat had the potential to be positively impacted by restoration works, with 36.5 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 5.3 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-44).

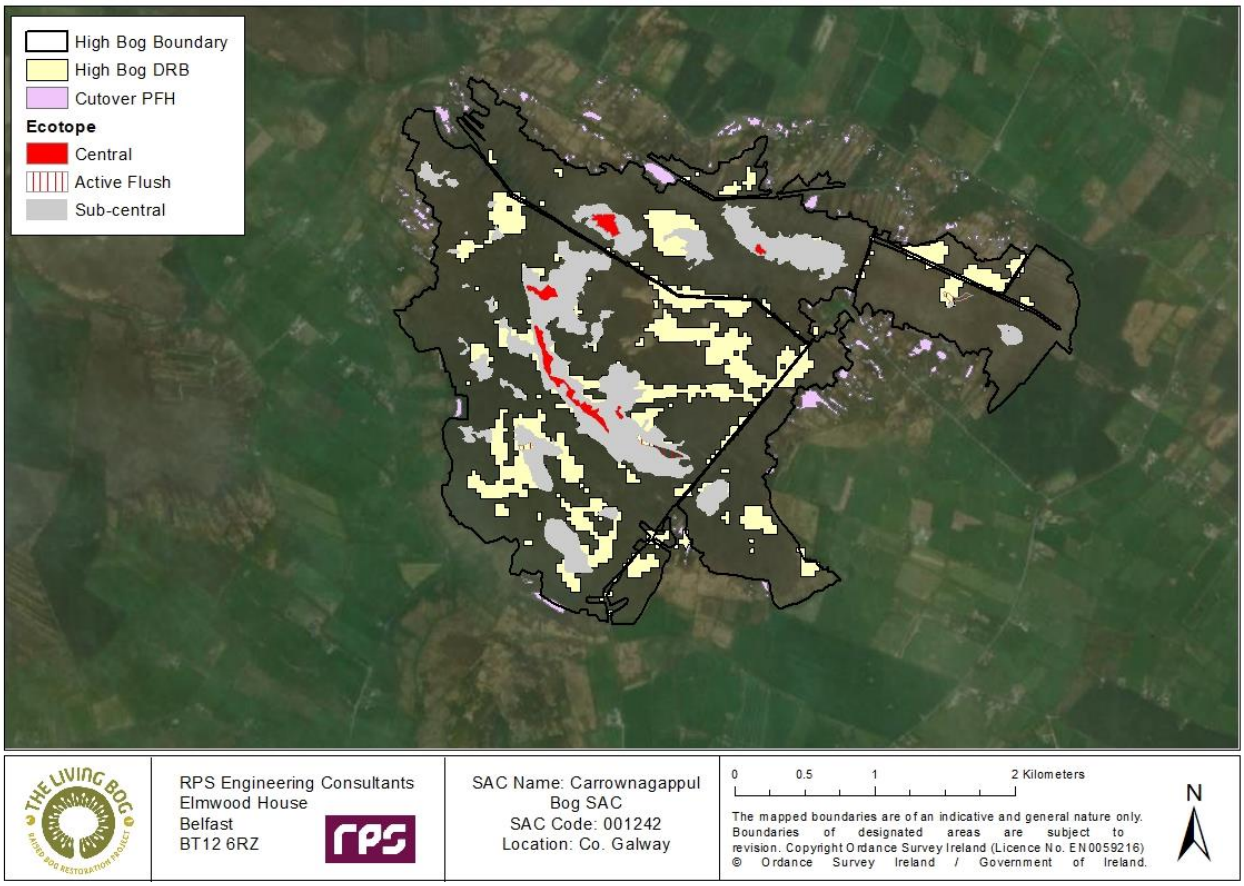

Figure 3-44: Restoration potential of Carrownagappul Bog SAC as outlined by eco-hydrological modelling.

3.3.5 Deployed monitoring network

A monitoring network comprising a mixture of 36 shallow phreatic wells and deeper piezometric wells (Figure 3-45) was subsequently installed on Carrownagappul Bog SAC. On the high bog, 15 phreatic wells were installed accompanied by 12 deep piezometers to monitor vertical hydraulic gradients. On the cutover, 9 phreatic wells were installed. A total of 6 water level loggers were spread amongst the wells. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic, whilst those equipped with loggers were set to automatically record levels in 15-minute intervals, and downloaded on a quarterly basis. A barometric logger was also located on the site and was installed to monitor changes in atmospheric pressure and used to barometrically correct the water logger data.

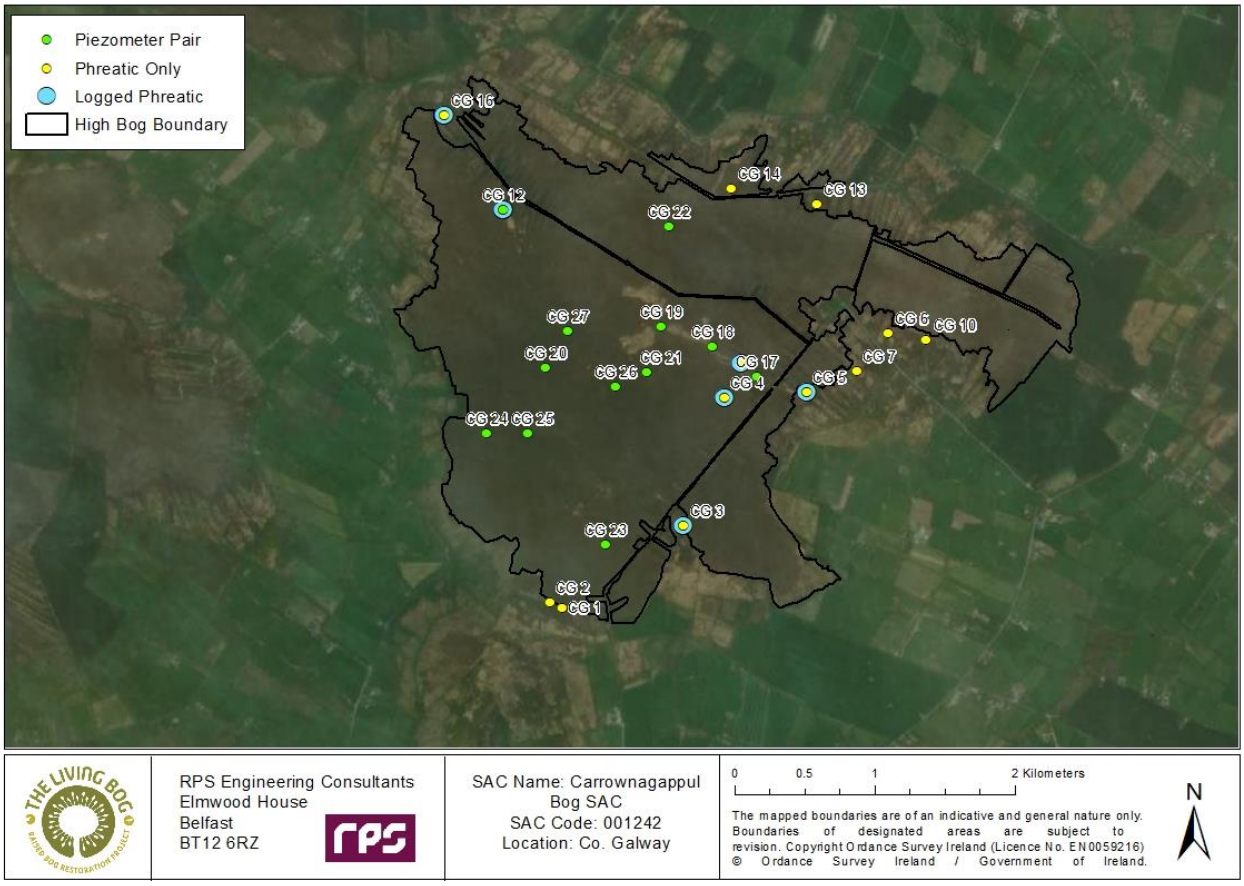

Figure 3-45: Hydrological monitoring network installed and operating on Carrownagappul Bog SAC.

3.3.6 General field observations

On account of regular periodic site visits, RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. Carrownagappul was a large complex site, with a range of drain blocking methods trialled and differing results observed. In general, significant re-wetting was observed on cutover areas. Close to CG 5, where sandwich dams were used to effectively block large drains, with a large contributing catchment, significant re-wetting occurred (Figure 3-46). Noticeably the total area that re-wetted was significantly larger than that anticipated by the ecohydrological model.

Figure 3-46: Cutover at Carrownagappul Bog SACwhere significant rewetting was observed

On the high bog, given water table levels are generally closer to the ground surface anyway, hydrological changes are more difficult to observe visually than widespread rewetting of very dry cutover areas. However, significant re-wetting was observed in areas close to drains that were blocked. Although no baseline measurements were available, areas of Carrownagappul Bog SAC that were previously restored as part of an earlier restoration programme were very wet underfoot and difficult to transverse suggesting the measures in these areas had been successful.

Due to the observed flat topography and numerous drains closely spaced together, enhanced measures in the form of cell bunding were trialled to the North of the site. Although no hydrological monitoring equipment was installed in the vicinity of these bunds, significant re-wetting was observed during site walkovers post-construction. Similarly, positive results in the area where stump flipping was trialled indicated initial success. In these areas, ecological monitoring should be conducted to report on the overall success of the measures as part of the AfterLIFE programme.

3.3.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Carrownagappul SAC are presented with all supplementary results provided in Appendix A.

3.3.7.1 Eastern Cutover

In a bid to evaluate and quantify the effects of restoration measures, both CG3 and CG 5 were placed in regions of high restoration potential in cutover bog (Figure 3-47).

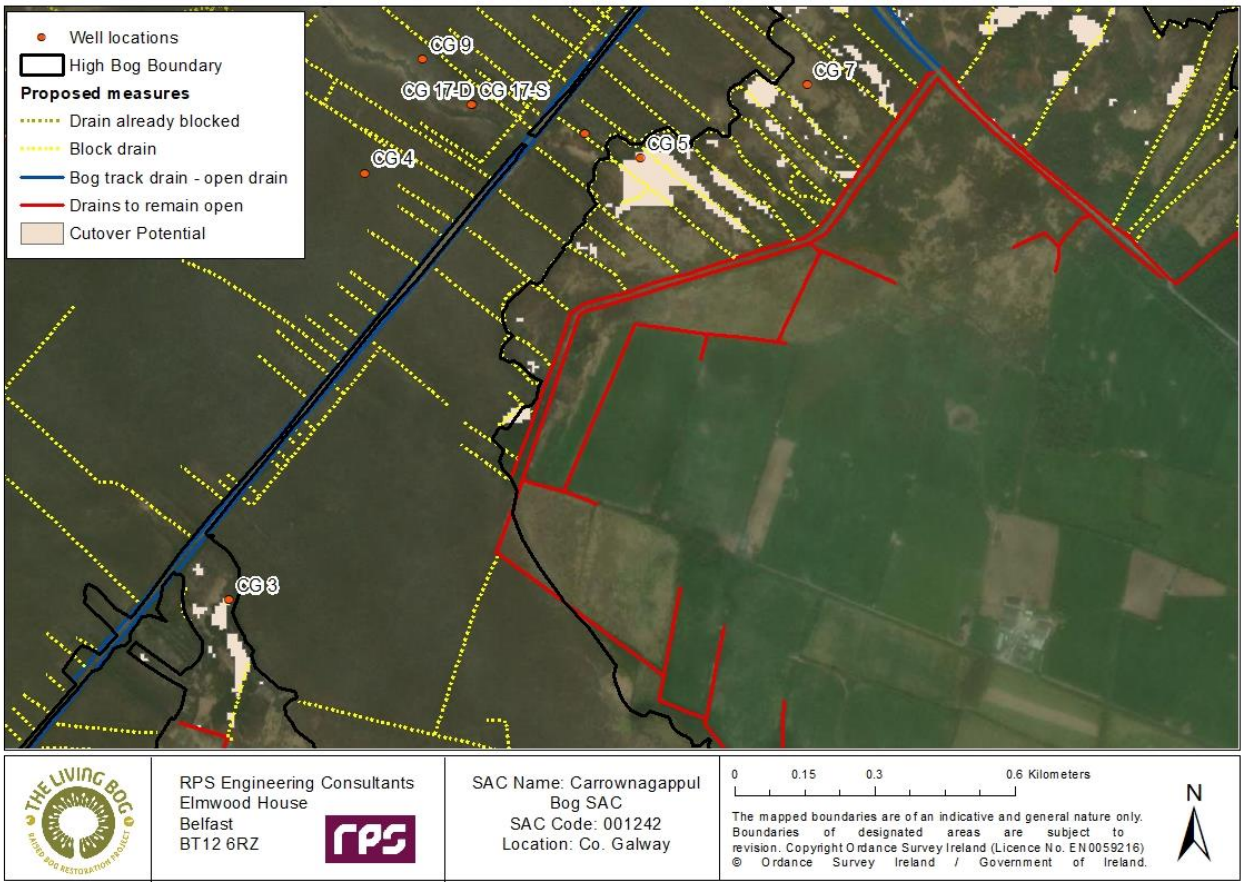

Figure 3-47: Location of wells CG3 & CG5 on the eastern cutover at Carrownagappul Bog SAC

Figure 3-48 – Figure 3-51 illustrate results from the hydrological monitoring points located on the eastern cutover at Carrownagappul Bog SAC. Figure 3-48 presents the hydrograph at CG 3, as demonstrated, prior to restoration the water table was already at the ground surface, however, this is predominantly due to it being situated in a localised hollow. Following restoration, water levels rose to approximately 40cm and stayed consistently above ground surface for the majority of the remainder of the record length. Most notably, the capacity for significant drawdown appears to have been reduced following the successful completion of restoration, with the water table remaining above ground surface during the summer period (April – October) in 2019 and 2020. However, there is a notable drop in water level in 2020, site observations indicated that this was due to a dam failing which reduced the overall water level in the area. Although the

water table remained above the ground surface, this is an important finding as it indicates that the effect of restoration may reduce over time and may indicate that highlight the importance of ongoing maintenance. This monitoring location will continue to be monitored as part of the afterLIFE proposals to assess the long-term impacts in this area and if needed make recommendations for maintenance measures to be implemented.

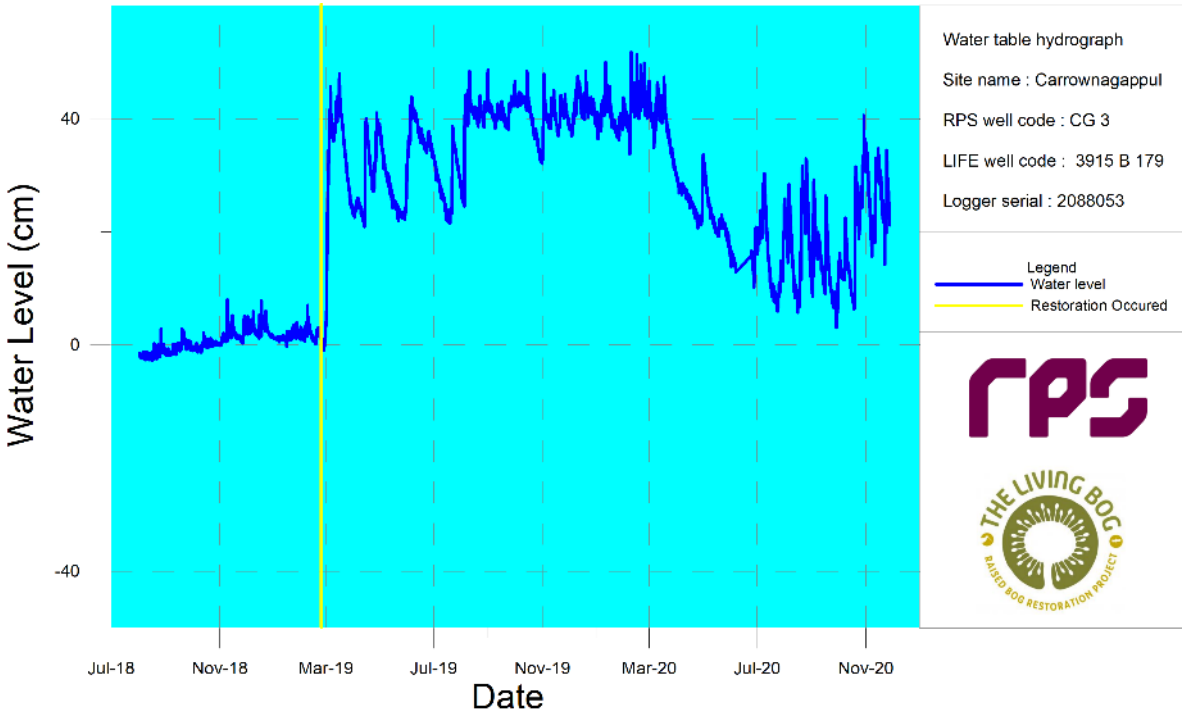

Figure 3-48: Level logger data recorded between December 2017 and August 2021 at well CG 3, Carrownagappul Bog SAC.

Water table duration curves were generated at each location monitored to show WL before and after restoration over the same time period of an annual hydrological cycle, in this case, April-October in 2018, 2019, and 2020. This format has been used as it is concise and clear for the reader and the data can be used to easily interpret min/max and percentile values. Figure 3-49 illustrates the duration curves generated from the data obtained from CG 3. The duration curves indicate a clear difference between water levels pre (2018) and post (2019/20) restoration. With a difference of 40cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area. The 2021 duration curve highlights the effect of the dam failure downstream of CG 3 and the need for continued observation to ensure the water level does not drop further.

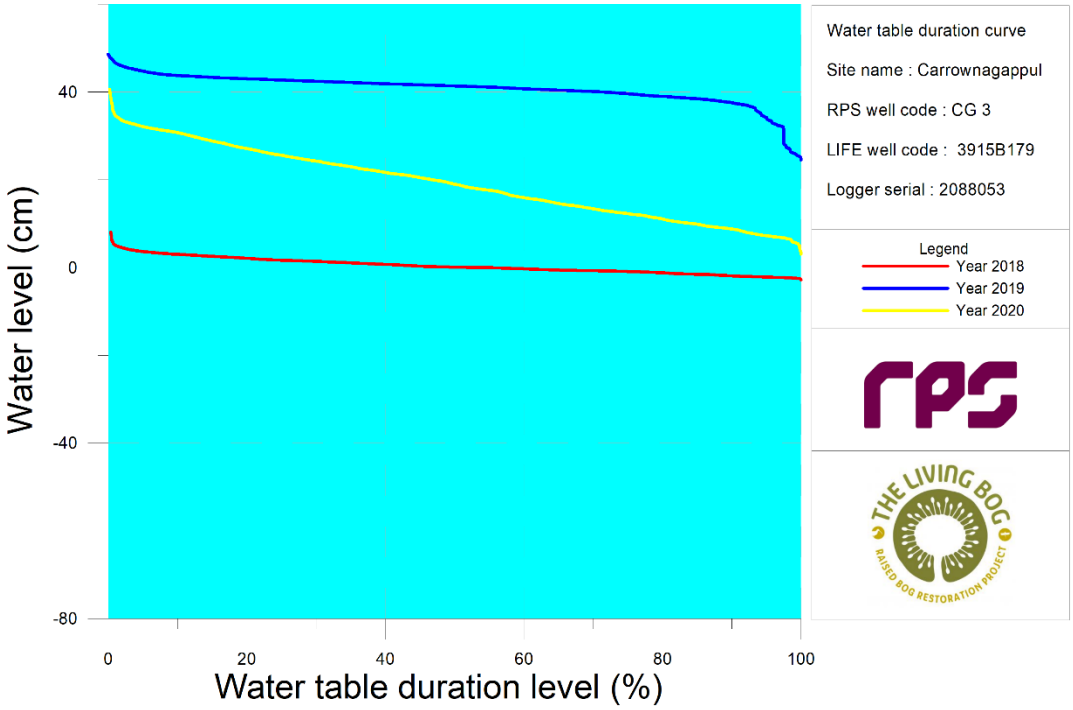

Figure 3-49: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well CG 3, Carrownagappul Bog SAC.

Figure 3-50 presents data obtained from the levelogger at CG 5, as demonstrated the data indicates a positive response to completion of restoration measures, with a clear and consistent water level rise. In the summer prior to restoration (2018), the water table fluctuated extensively, dropping lower than 15cm below ground surface. Conversely, following restoration water levels rose and stayed consistently at or above 30cm of the ground surface for the majority of the remainder of the record length. Most notably, the capacity for significant drawdown appears to have been reduced following the successful completion of restoration, in the two years of data following restoration, the water table did not drop below the ground surface. Figure 3-51 illustrates the duration curves generated from the data obtained from CG 5. The duration curves indicate a clear difference between water levels pre (2018) and post (20/20) restoration. With a difference of 40cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

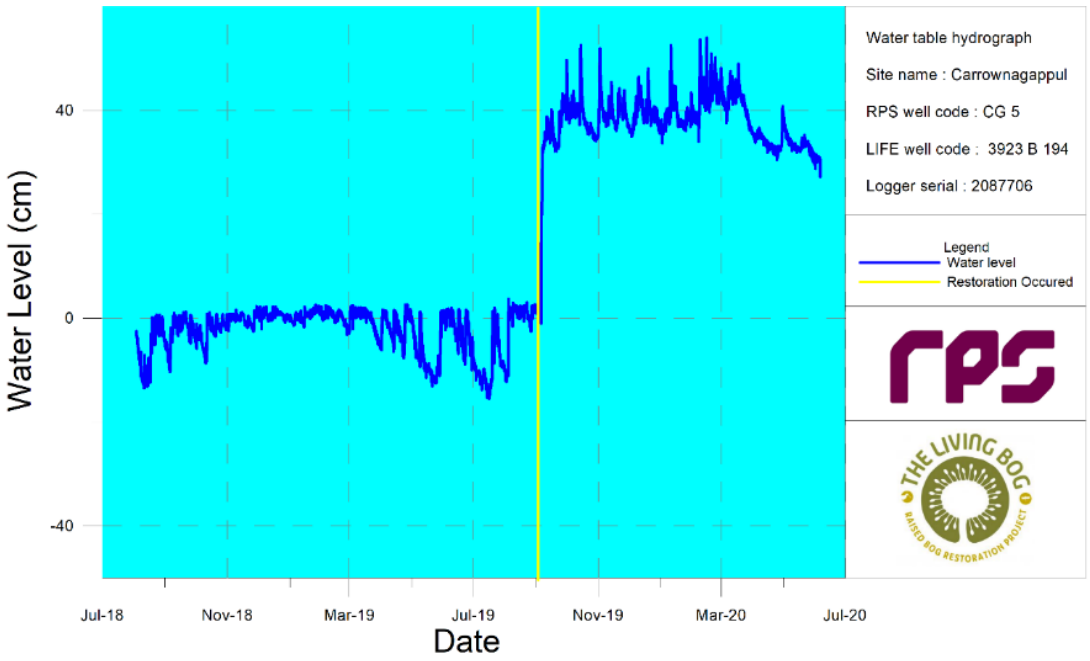

Figure 3-50: Level logger data recorded between August 2018 and June 2020 at well CG 5, Carrownagappul Bog SAC.

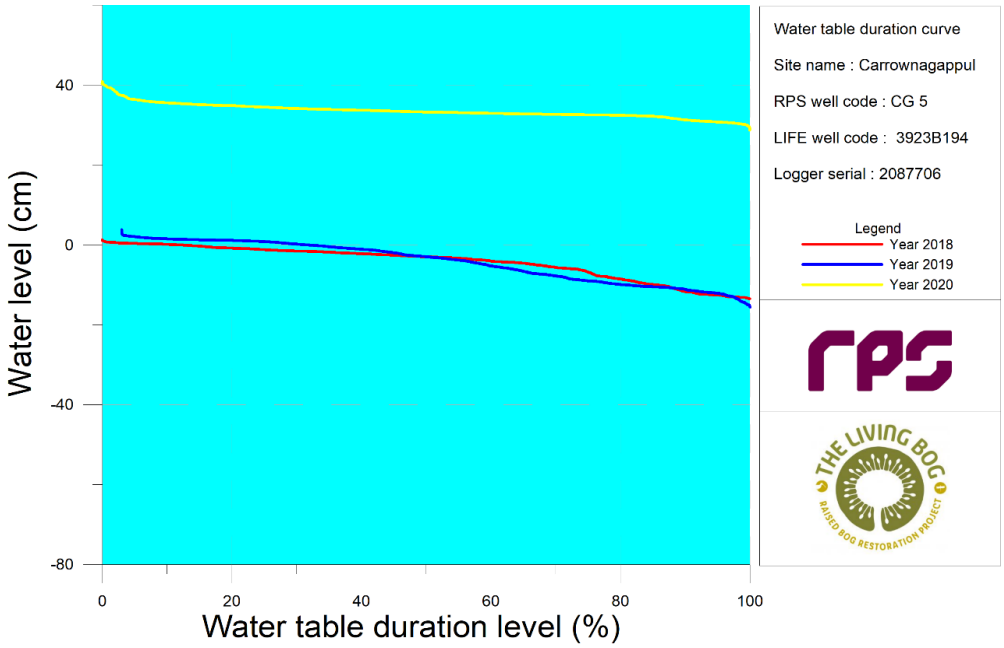

Figure 3-51: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well AR 2, Ardagullion Bog SAC

3.3.7.2 High Bog

To investigate the impact restoration measures would have on the high bog at Carrownagappul SAC, piezometers were located in areas currently defined as Active raised bog (ARB), Degraded Raised Bog (DRB) and areas of supporting high bog. Figure 3-52, shows the location of a proportion of the high bog monitoring network at Carrownagappul bog, SAC.

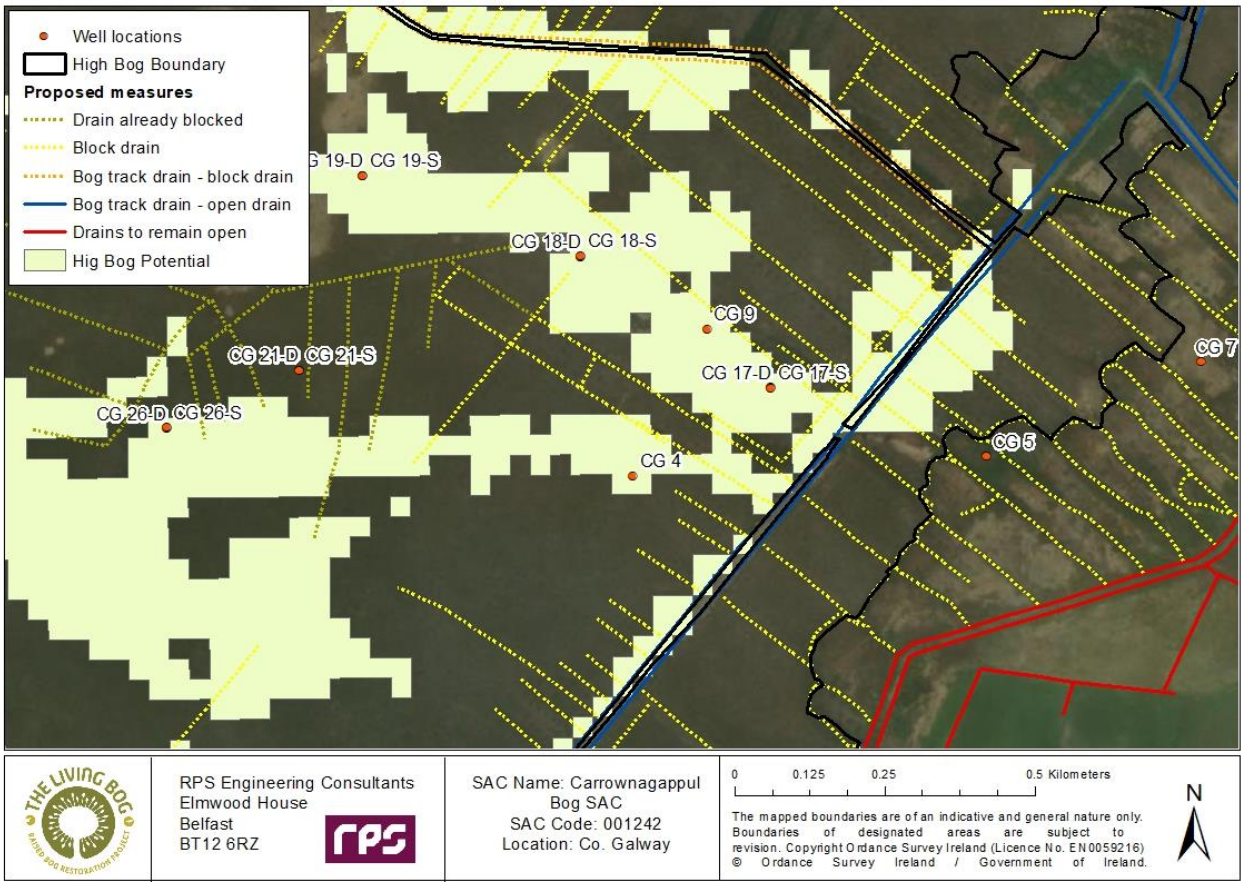

Figure 3-52: Location of wells on the High Bog east of the site at Carrownagappul Bog SAC.

Overall, modest responses to drain blocking was observed on the High Bog compared to cutover areas. Water levels in ARB areas were observed close to the bog surface and remained so throughout the study, as expected. A range of observations were made on the high, with all wells indicating some improvements in hydrology, however, some wells reported a minor improvement of 1-2cm with others reporting larger improvements of 10-15cm. Data obtained from CG 9 (Figure 3-53) can be used to demonstrate a well where minor improvements in hydrology were observed pre/post restoration on the high bog at Carrownagappul Bog SAC. Data observed by CG 4 (Figure 3-54) shows a larger response to the completion of restoration works when compared to pre-restoration levels. A complicating factor to consider is the impact that the previous restoration may have on the results, with moderate increases observed in areas already blocked. However, even within these areas, water levels did rise, indicating that restoration on a site wide level can still impact these areas several years post-restoration.

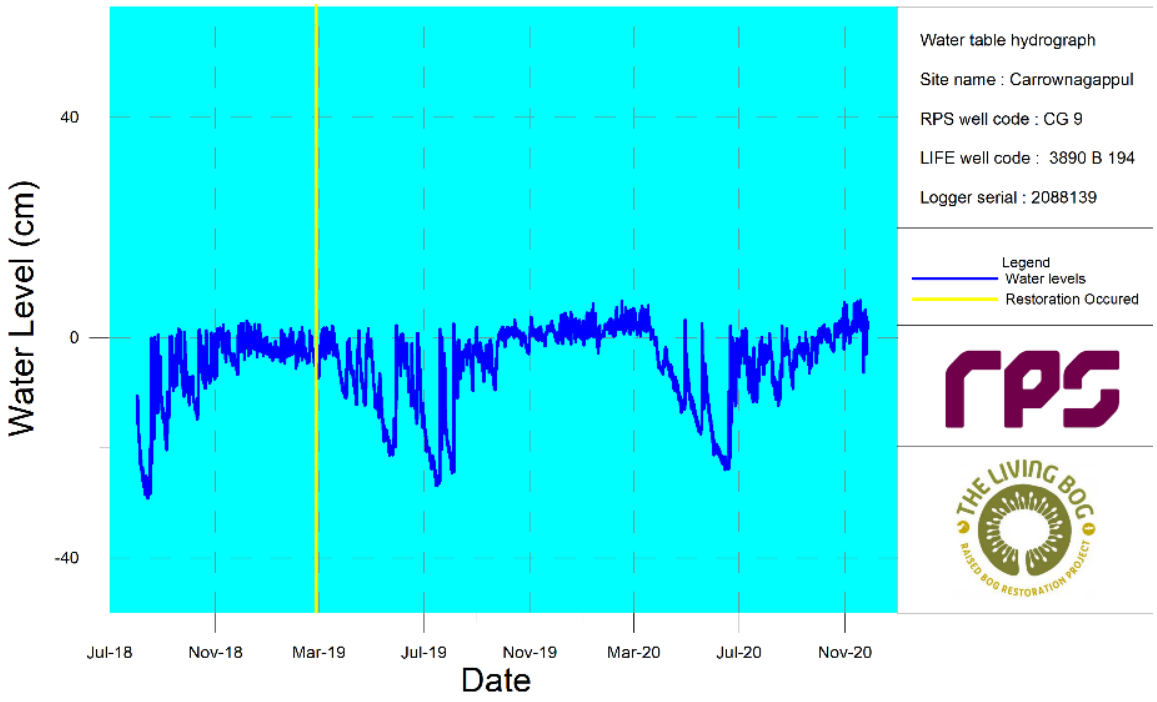

Figure 3-53: Level logger data recorded between August 2017 and June 2021 at well CG 9, Carrownagappul Bog SAC.

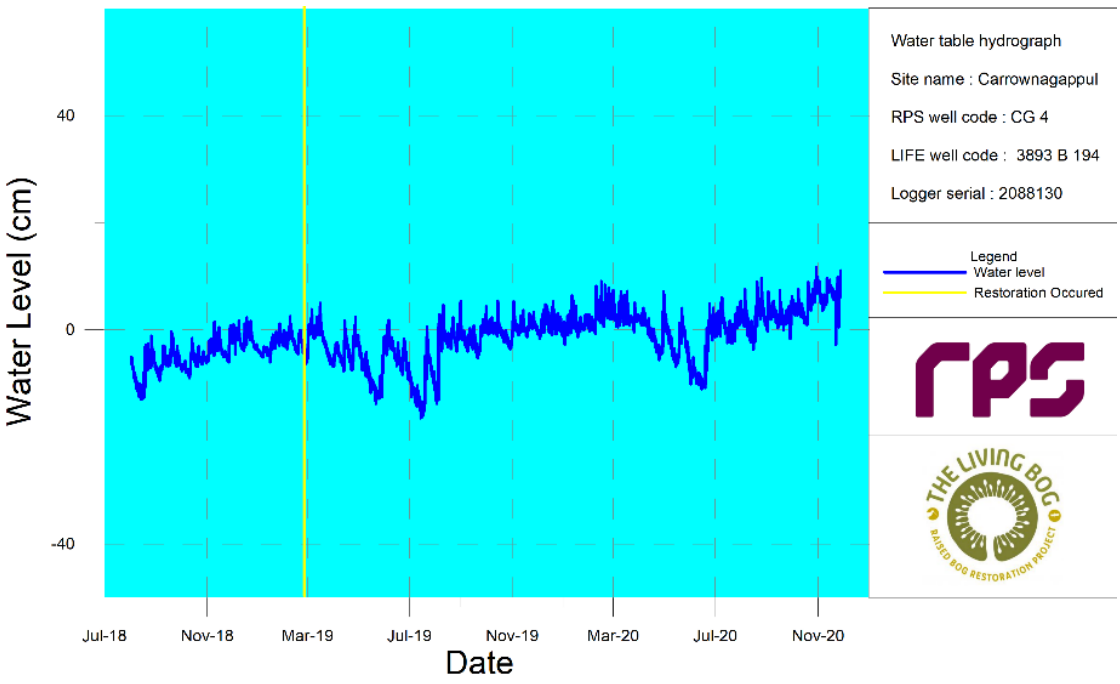

Figure 3-54: Level logger data recorded between August 2017 and June 2021 at well CG 4, Carrownagappul Bog SAC.

3.3.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.3Table 3.1). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration The largest increases were noted in all cutover wells. Significant changes were observed on the high bog with multiple wells in areas designated as DRB or Supporting High Bog now displaying a post-restoration hydrological regime capable of supporting ARB.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Carrownagappul	CG1	Cutover	PFH	-18.60	-5.20
Carrownagappul	CG10	Cutover	PFH	-7.70	25.00
Carrownagappul	CG11	Cutover	PFH	-12.60	-0.80
Carrownagappul	CG12-S	High Bog	DRB	-36.64	-24.90
Carrownagappul	CG13	Cutover	Non-PFH	-23.30	-9.40
Carrownagappul	CG14	High Bog	Supporting High Bog	-13.90	-13.50
Carrownagappul	CG16	Cutover	PFH	-17.74	36.24
Carrownagappul	CG17-S	High Bog	DRB	-41.60	-16.80
Carrownagappul	CG18-S	High Bog	DRB	-38.60	-8.60
Carrownagappul	CG19-S	High Bog	Supporting High Bog	-22.90	-13.80
Carrownagappul	CG2	Cutover	PFH	-20.30	-4.80
Carrownagappul	CG20-S	High Bog	ARB	-10.40	-6.40
Carrownagappul	CG21-S	High Bog	Supporting High Bog	-14.00	-5.40
Carrownagappul	CG22-S	High Bog	DRB	-3.20	1.10
Carrownagappul	CG23-S	High Bog	DRB	-18.20	-0.80
Carrownagappul	CG24-S	High Bog	ARB	-14.60	-9.00
Carrownagappul	CG25-S	High Bog	ARB	-11.20	-6.70
Carrownagappul	CG26-S	High Bog	ARB	-7.00	-4.70
Carrownagappul	CG27-S	High Bog	Supporting High Bog	-15.60	-11.10
Carrownagappul	CG3	Cutover	PFH	-2.20	23.50
Carrownagappul	CG4	High Bog	DRB	-11.18	-7.02
Carrownagappul	CG5	Cutover	PFH	-11.65	31.32
Carrownagappul	CG6	Cutover	PFH	-16.60	25.00
Carrownagappul	CG7	Cutover	Non-PFH	-18.20	-10.60
Carrownagappul	CG9	High Bog	DRB	-26.49	-15.20

Table 3.3: 90th percentile water levels at Carrownagappul Bog SAC, pre and post-restoration.

3.4 Clara Bog SAC

3.4.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests Clara Bog SAC High bog be underlain by rocks of the Waulsortian mudbank unit, whilst to the West courceyan limestones are the primary lithographic unit with marine shelf facies to the east. This typically denotes, a non-homogenous unit, often comprising pale-grey, crudely bedded or massive limestone. This unit is known as a moderately productive and regionally-important aquifer unit, however low permeability peat subsoils act to confine and thus reduce aquifer vulnerability in the immediate area of the high bog. Groundwater contributions are therefore uncertain. Groundwater upwelling is noted as a significant issue at the site (Regan 2019)

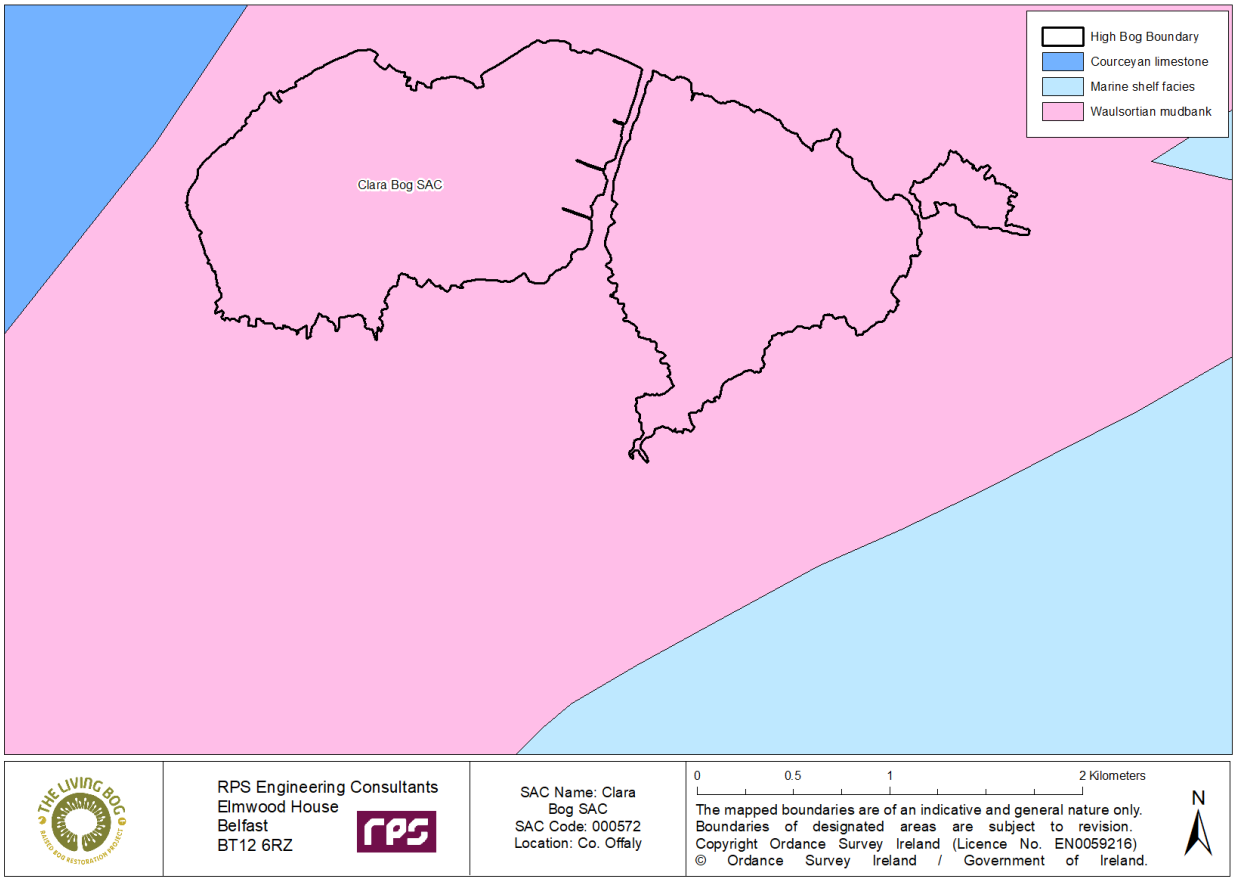

Figure 3-55: Simplified geology of Clara Bog SAC.

3.4.2 Ecotope map

Ecotope mapping is a powerful tool for categorising differing types of habitats found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-56). During the last monitoring survey (2018) it was noted, that Clara Bog SAC consists of 94.71 of Active Raised Bog (ARB) consisting of areas of central, sub-central and active flush.

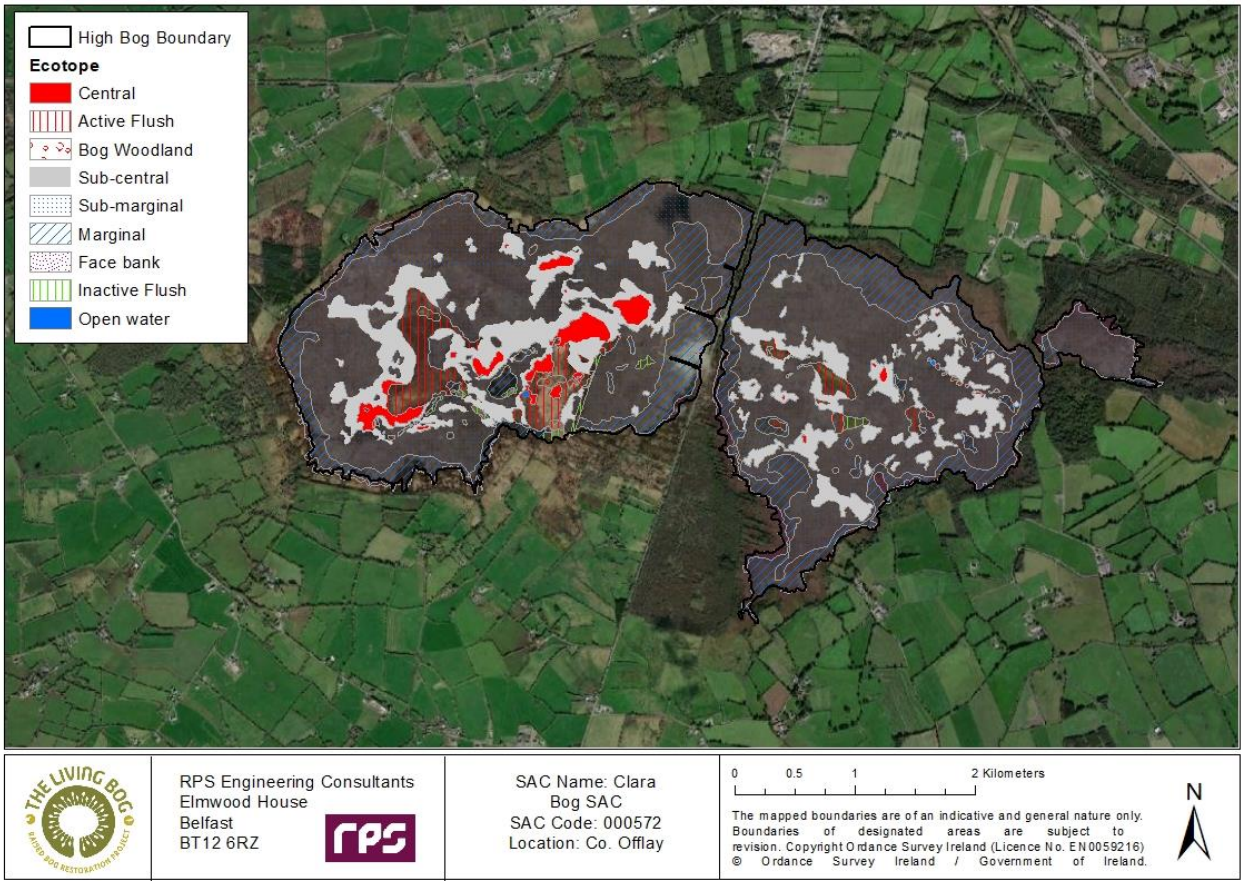

Figure 3-56: Ecotope mapping carried out for Clara Bog SAC.

3.4.3 Proposed restoration plan

The restoration plan for Clara Bog SAC identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat forming (ARB) habitat. Overall, the installation of peat dams was recommended across 26.37 km of channels both on the high bog and cutover.

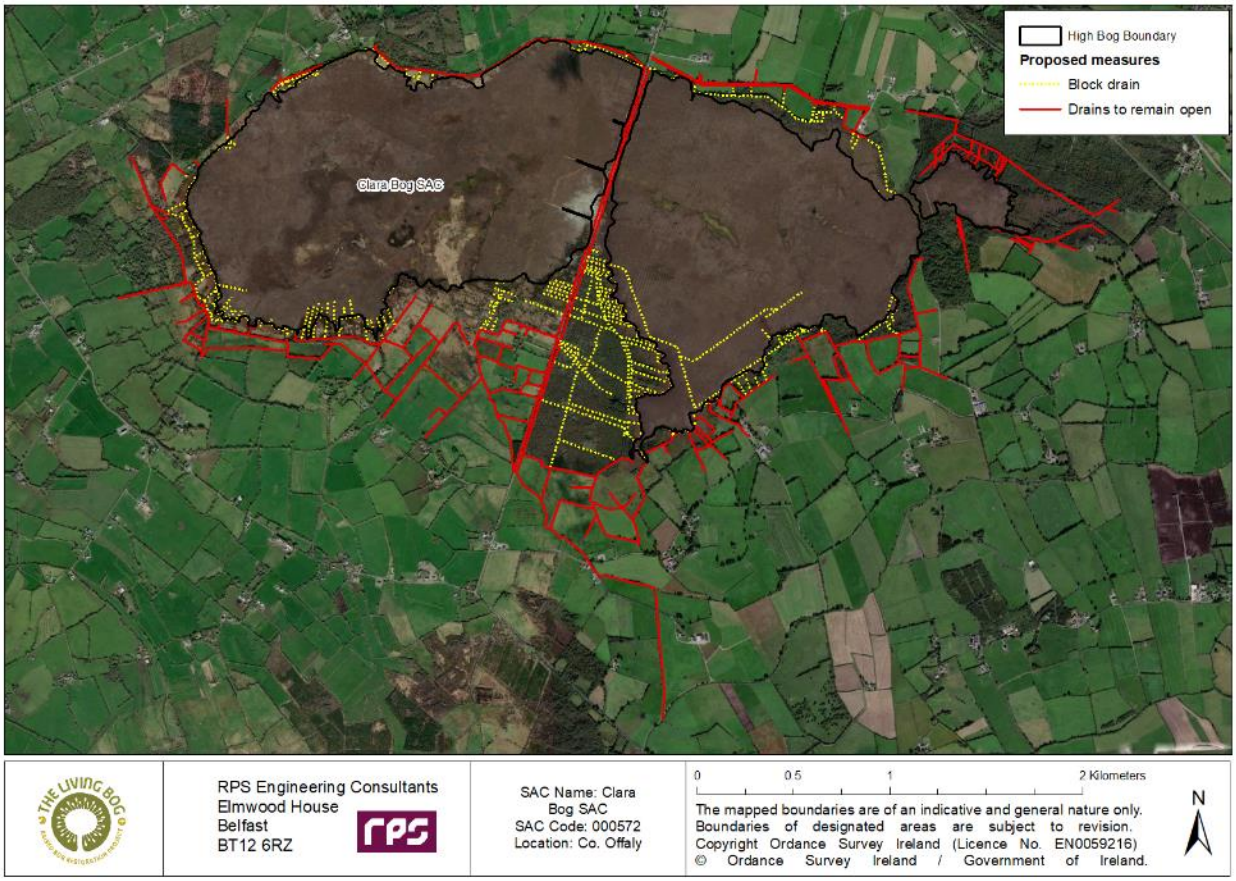

Figure 3-57: Restoration measures specified in support of hydrological goals.

3.4.4 Restoration potential

Eco-hydrological modelling of the restoration potential on Clara Bog SAC, excluding current areas mapped as ARB, suggested as much as 68.2 ha of habitat had the potential to be positively impacted by restoration works, with 61.3 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 6.9 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-58)

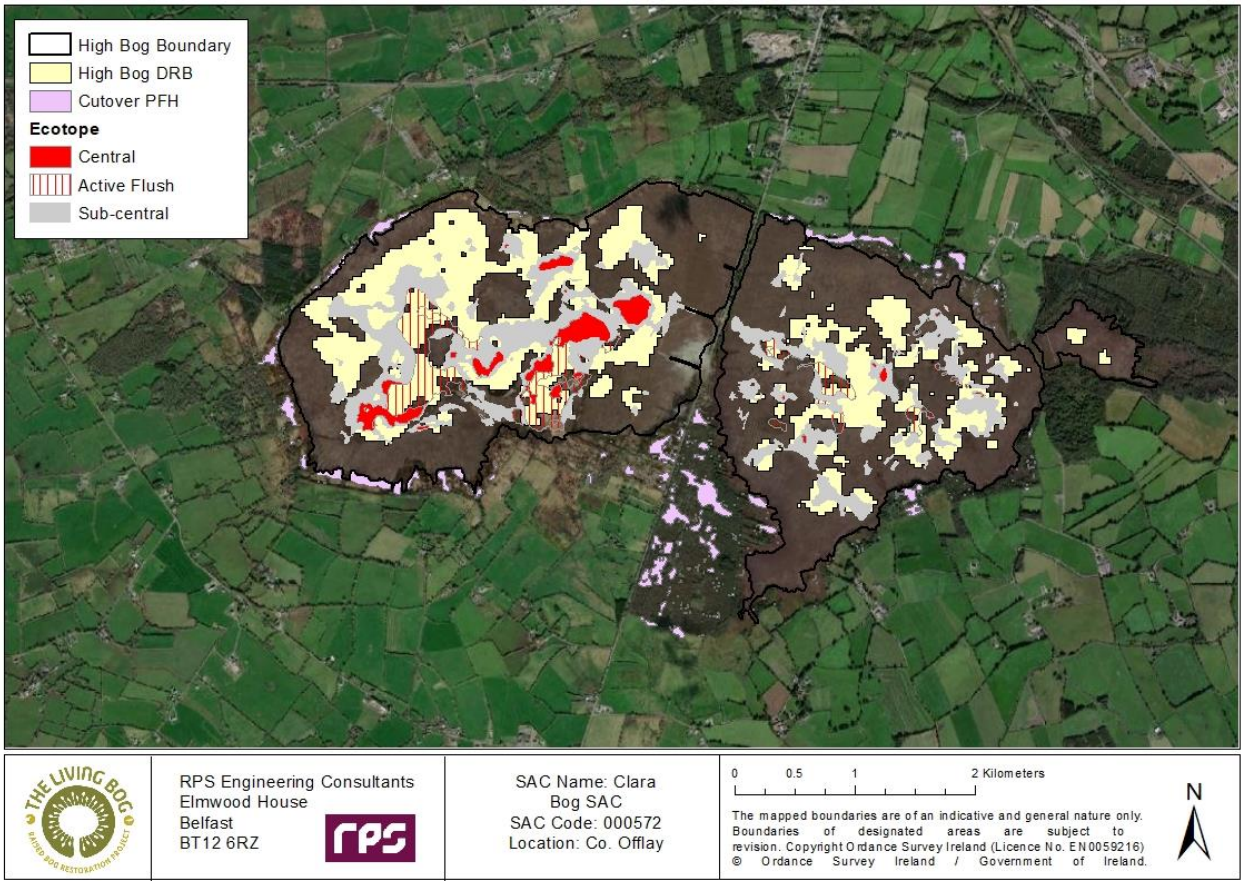

Figure 3-58: Restoration potential of Clara Bog SAC as outlined by eco-hydrological modelling.

3.4.5 Deployed monitoring network

A monitoring network comprising a mixture of 9 shallow phreatic wells (Figure 3-59) was subsequently installed on Clara Bog SAC. On the high bog, 2 phreatic wells were installed, no deep wells were installed due to the breadth of knowledge already obtained in this field by various academic researchers. On the cutover, 8 phreatic wells were installed. A total of 2 water level loggers were spread amongst the wells. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic, whilst those equipped with loggers were set to automatically record levels in 15-minute intervals and downloaded on a quarterly basis. Water level readings were barometrically corrected using the barometric logger installed on the nearby site of Moyclare Bog SAC, located approx. 17km away.

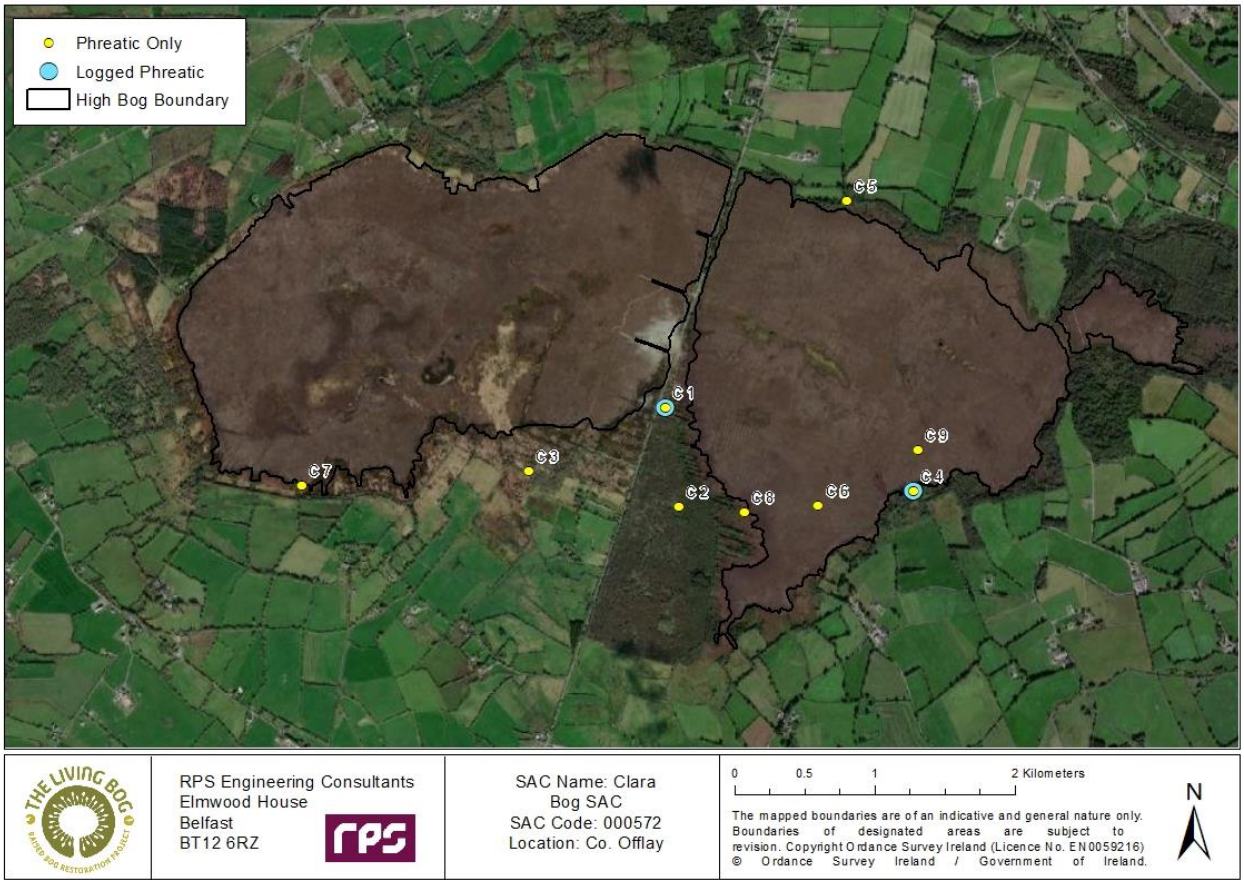

Figure 3-59: Hydrological monitoring network installed and operating on Clara Bog SAC.

3.4.6 General field observations

On account of regular periodic site visits, RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. On Clara West, on the southern section of cutover, large-scale re-wetting was observed, with shallow pools of water forming that covered a large area throughout the year (Figure 3-60), even during the drier summer periods. Noticeably, this re-wetting area expanded over a larger area than anticipated by the ecohydrological model. Similar observations were noted on the southern cutover of Clara East, where re-wetting was noted in the vicinity of C4 and C8, however, this was more localised and confined to topographic low points. Some localised flooding of adjacent land was reported on Clara west, due to several drains flowing from farmland into cutover areas. Secondary works were completed in the area to lower the water levels in adjacent lands outside the SAC while maintaining the benefits obtained by the drain blocking within the site.

Figure 3-60: Cutover at Clara Bog where significant rewetting was observed

In the South Eastern section of the cutover on Clara West, infilling of drains was proposed as a means of limiting the ongoing impact of upwelling groundwater, which is well documented (Regan 2019) as having an ongoing impact on the high bog by causing subsidence and on-ongoing habitat loss. Unfortunately, this work could not be completed as the practicalities of completing this action are not yet unknown. Ongoing consultation with academics is occurring, to develop a methodology which will allow this work to be completed in future. However, the limited works that could be completed in the area, through the installation of peat dams, in the vicinity of C3, proved effective with large rewetting observed.

On the high bog, limited works were proposed as large-scale drain blocking had been conducted previously as part of earlier restoration measures. Site walkover surveys suggested the restoration measures were completed to a high standard across the site, as referenced in the raised bog best practice guidance (Mackin et al, 2017).

3.4.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Clara Bog SAC are presented with all supplementary results provided in Appendix A.

3.4.7.1 Southern Cutover

In a bid to evaluate and quantify the effects of restoration measures, wells C1, C 3, C 4 and C 7 have been placed in regions of high restoration potential in cutover bog (Figure 3-61), south of the high bog.

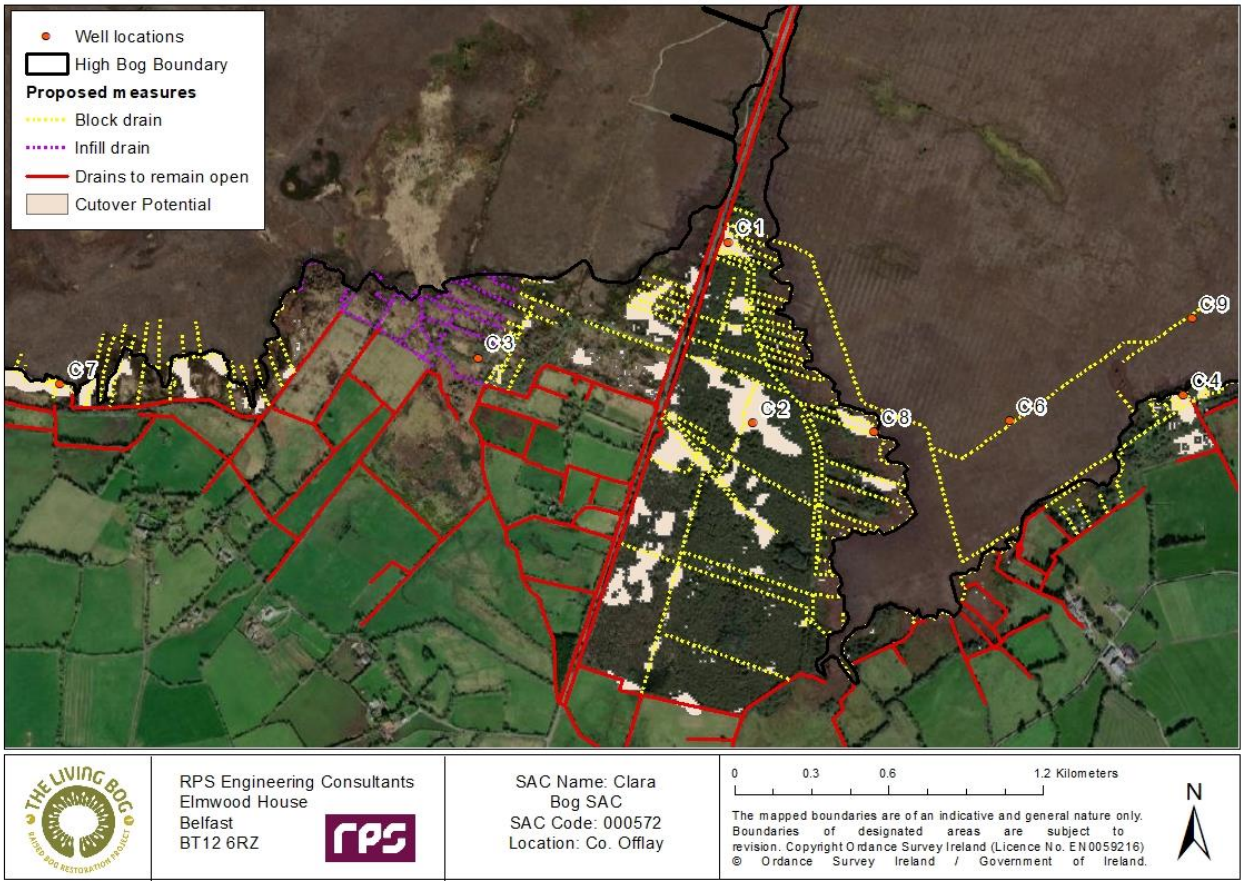

Figure 3-61 Location of wells C 1, C 3, C 4, and C 7 on the southern cutover in Clara Bog SAC

Figure 3-62 – Figure 3-67 illustrate results from the hydrological monitoring points located on the eastern cutover at Clara Bog SAC. Figure 3-61 shows the location of the hydrological monitoring points located on the central cutover at Clara Bog SAC. Figure 3-62 presents the hydrograph at C1, as demonstrated the water table fluctuated extensively in the year of data recorded prior to restoration, dropping lower than 30cm below ground surface in the summer dry period (April – October) of 2018. For the most part, water levels remained predominantly beneath ground surface, rising above surface on only a limited number of occasions. Conversely, following restoration water levels rose and stayed consistently at or above ground surface for the majority of the post-restoration recording period. Water levels occasionally fell below the ground surface with levels falling to just below -10cm during the summer dry period of 2021.

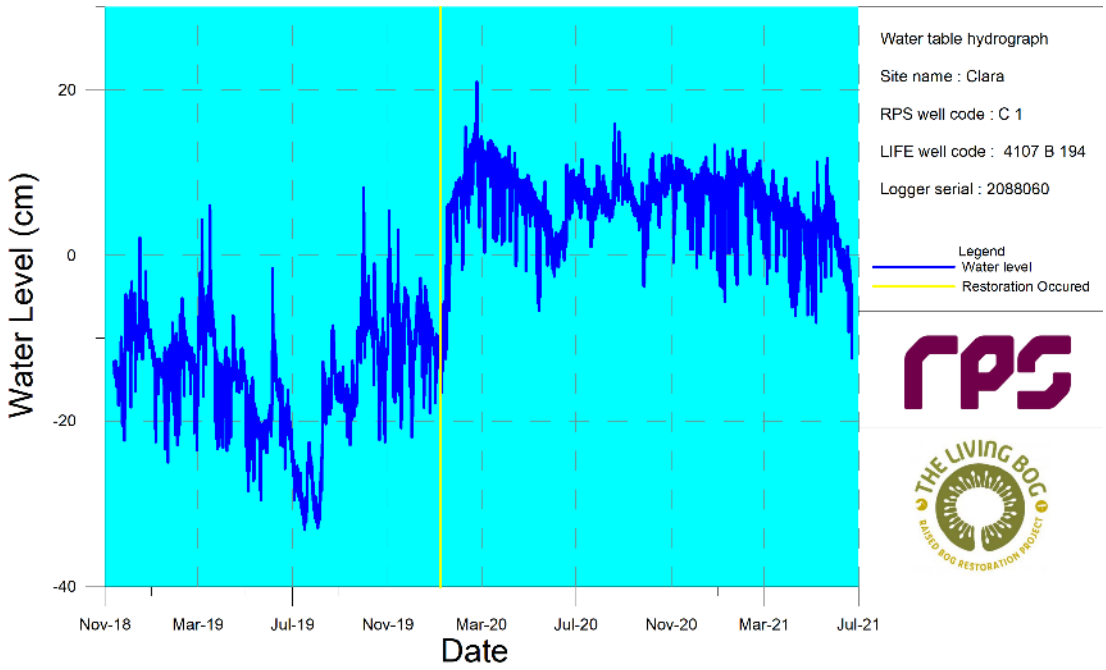

Figure 3-62 Level logger data recorded between November 2018 and August 2021 at well C 1, Clara Bog SAC.

Water table duration curves were generated at each location monitored to show water levels before and after restoration over the same time period of an annual hydrological cycle, in this case, April-October in 2018, 2019 and 2020. This format has been used as it is concise and clear for the reader and the data can be used to easily interpret min/max and percentile values. Figure 3-63 illustrates the duration curves generated from the data obtained from C 1. The duration curves indicate a clear difference between water levels pre (2019) and post (2020/21) restoration. With a difference of 26cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

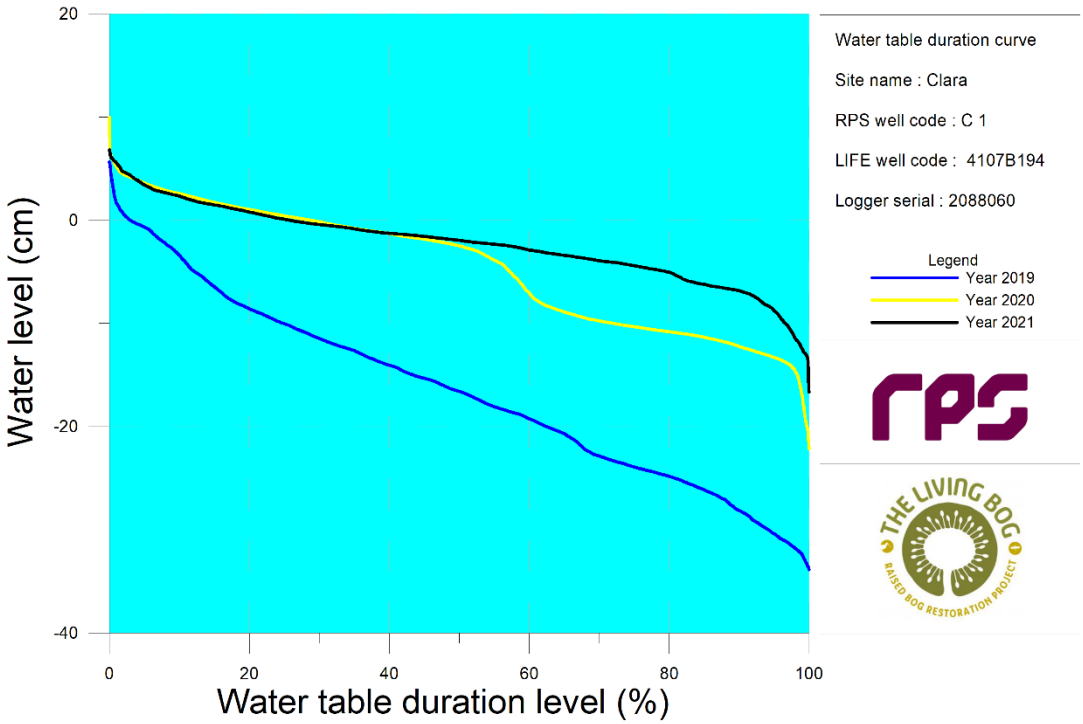

Figure 3-63 Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well C 1, Clara Bog SAC.

Figure 3-64 presents the hydrograph at C4, as demonstrated the water table fluctuated extensively in the year of data recorded prior to restoration, dropping lower than 30cm below ground surface in the summer dry period (April – October) of 2019. For the most part, water levels remained predominantly beneath ground surface, rising above surface on only a limited number of occasions. Conversely, following restoration water levels rose and remained consistently close to or above ground surface for the majority of the post-restoration recording period. Water levels fell to just below -20cm on a limited number of occasions during the summer dry period of 2020.

Manual records from wells C 3 (Figure 3-65) and C 7 (Figure 3-66) reinforce the results obtained from the logger data at well C 4. Both wells show a considerable improvement in water levels post-restoration and remain above ground surface for the entirety of the post-restoration period.

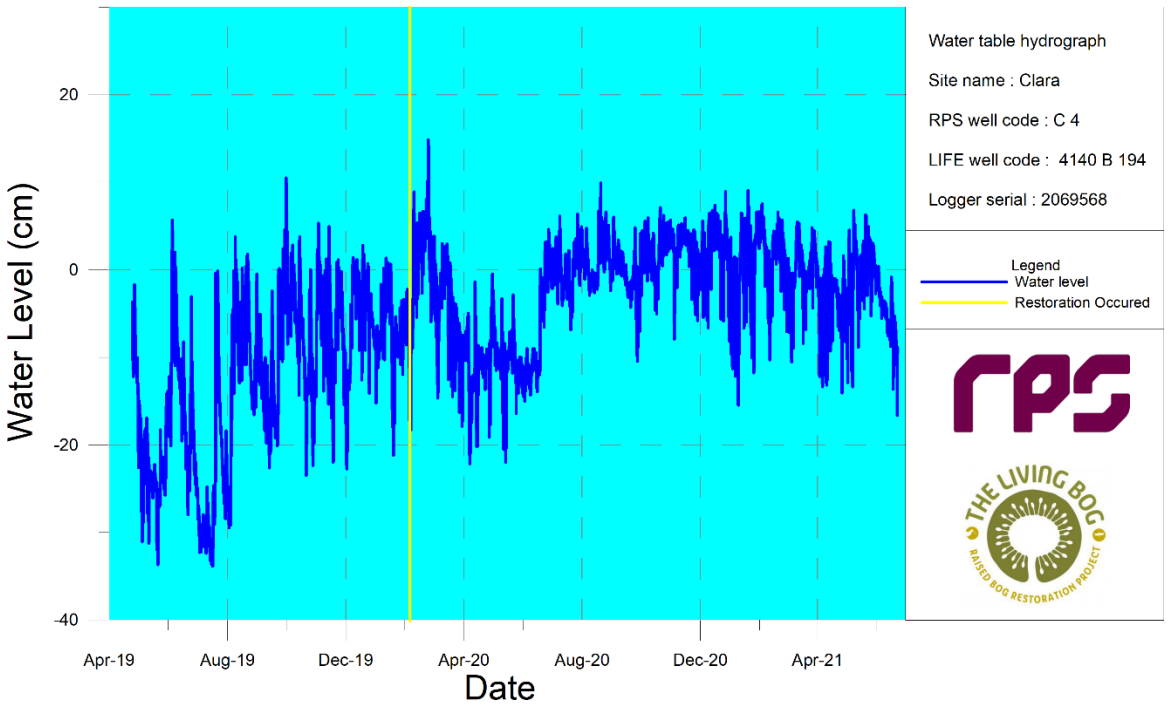

Figure 3-64: Level logger data recorded between April 2019 and August 2021 at well C 4, Clara Bog SAC.

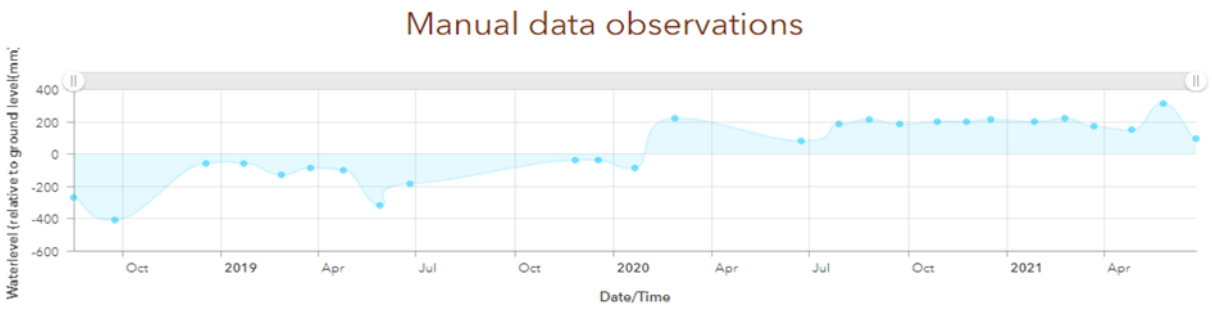

Figure 3-65: Hydrograph of manual monthly water levels C 3, Clara Bog SAC

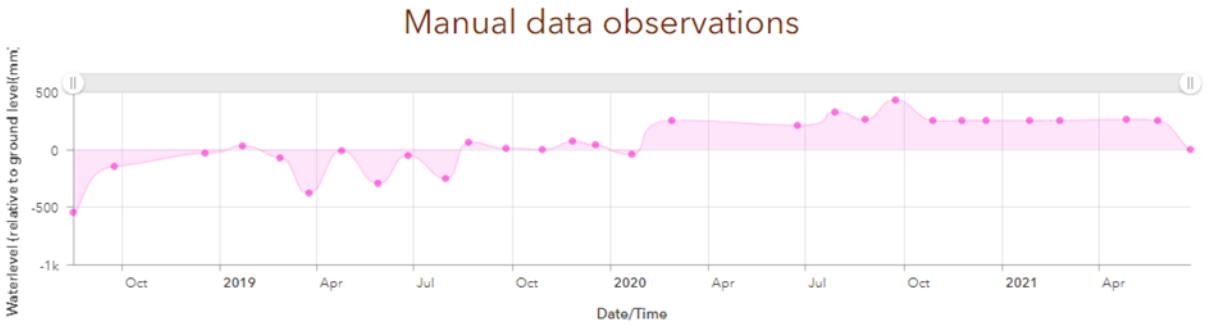

Figure 3-66: Hydrograph of manual monthly water levels C 7, Clara Bog SAC

Water table duration curves were generated at each location monitored to show water levels before and after restoration over the same time period of an annual hydrological cycle, in this case, April-October in 2018, 2019 and 2020. This format has been used as it is concise and clear for the reader and the data can be used to easily interpret min/max and percentile values. Figure 3-67 illustrates the duration curves generated from the data obtained from C 4. The duration curves indicate a clear difference between water levels pre (2019) and post (2020/21) restoration. With a difference of 41cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

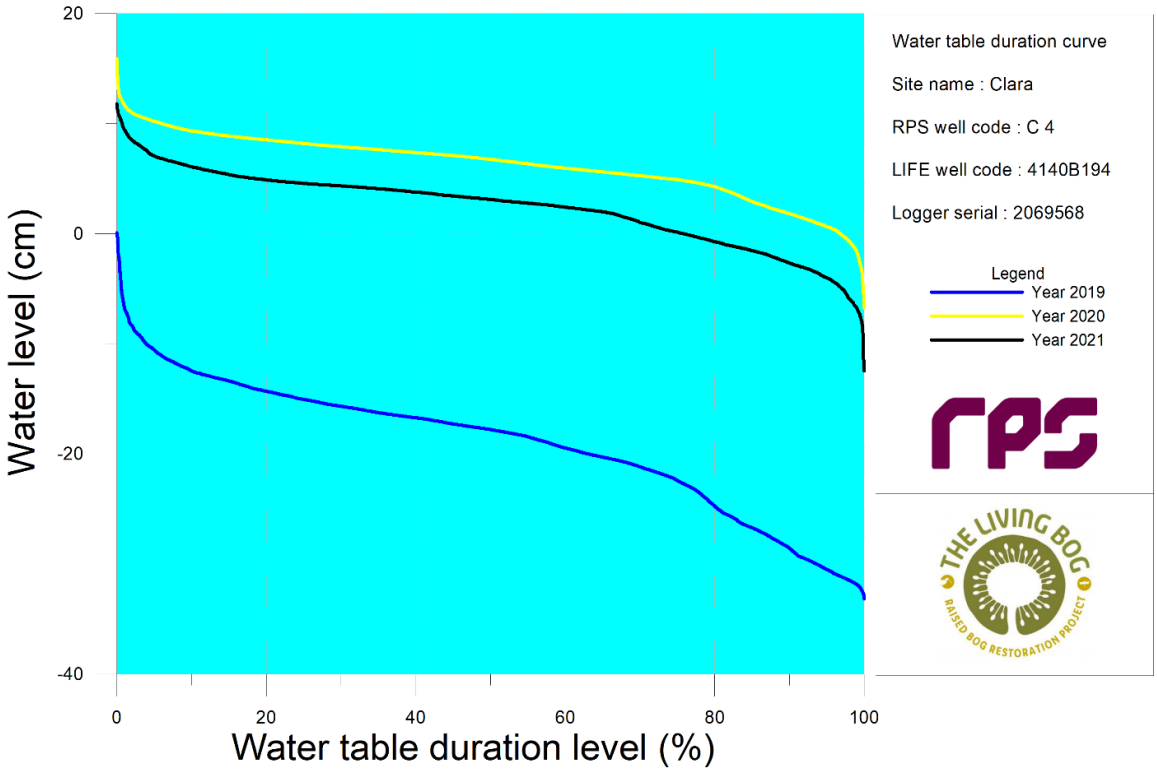

Figure 3-67 Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well C 4, Clara Bog SAC.

3.4.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.4). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration The largest increases were noted in all cutover wells ere PFH was modelled.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Clara	C1	Cutover	PFH	-28.13	-12.23
Clara	C2	Cutover	PFH	-49.00	-2.60
Clara	C3	Cutover	Non-PFH	-39.60	11.00
Clara	C4	Cutover	PFH	-39.00	1.82
Clara	C7	Cutover	PFH	-50.60	22.00
Clara	C8	Cutover	PFH	-62.80	-1.00
Clara	C6	High Bog	ARB	-16.20	-4.60
Clara	C9	High Bog	ARB	-12.60	-8.60

Table 3.4: 90th percentile water levels at Clara Bog SAC, pre and post-restoration.

3.5 Ferbane Bog SAC

3.5.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests the 'High bog' of Ferbane Bog SAC to be underlain entirely by the waulsortian mudbank group of rocks, whilst to the south-east a combination of courceyan limestone and rocks of the Navan group are predominant. This typically denotes, a non-homogenous unit, often comprising pale-grey, crudely bedded or massive limestone. This unit is known as a moderately productive and regionally-important aquifer unit, however low permeability peat subsoils act to confine and thus reduce aquifer vulnerability in the immediate area of the high bog. Groundwater contributions are therefore uncertain.

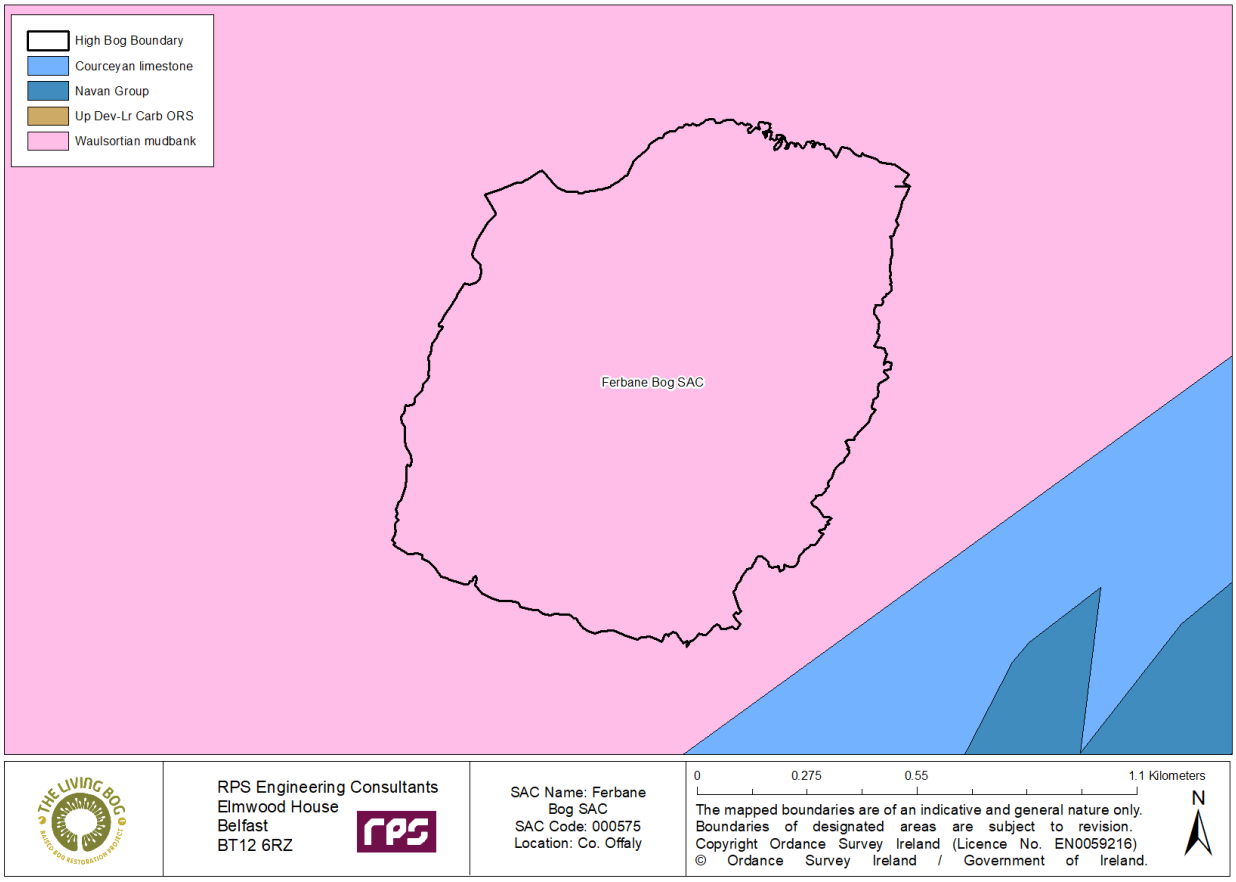

Figure 3-68: Simplified geology of Ferbane Bog SAC

3.5.2 Ecotope map

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-69). During the last monitoring survey (2018) it was noted, that Ferbane Bog SAC consists of 36.88ha of active raised bog (ARB) consisting of areas of central and sub-central ecotope.

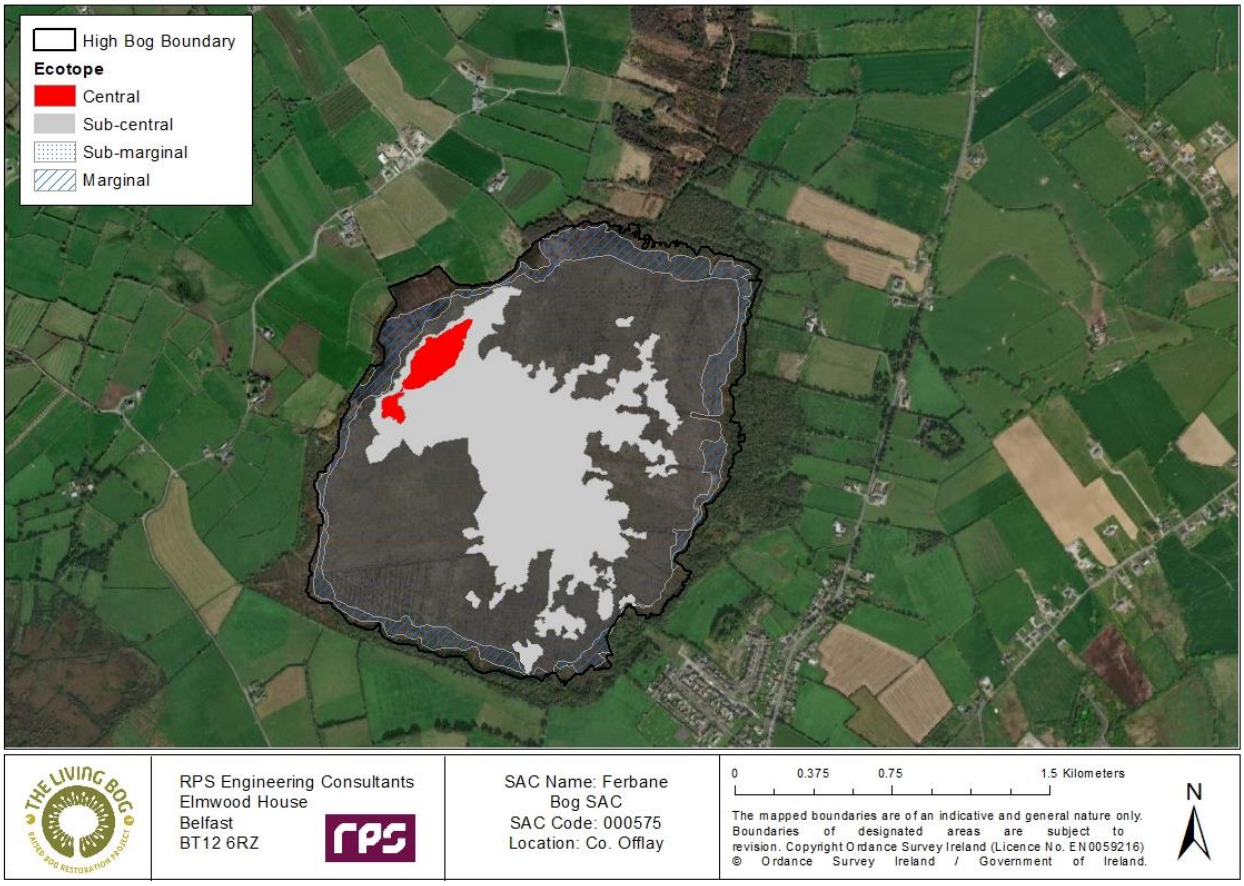

Figure 3-69: Ecotope mapping carried out for Ferbane Bog SAC

3.5.3 Proposed restoration plan

The restoration plan for Ferbane Bog SAC (Figure 3-70) identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat forming (ARB) habitat. Overall, the installation of peat dams was recommended across 21.63 km of channels both on the high bog and cutover.

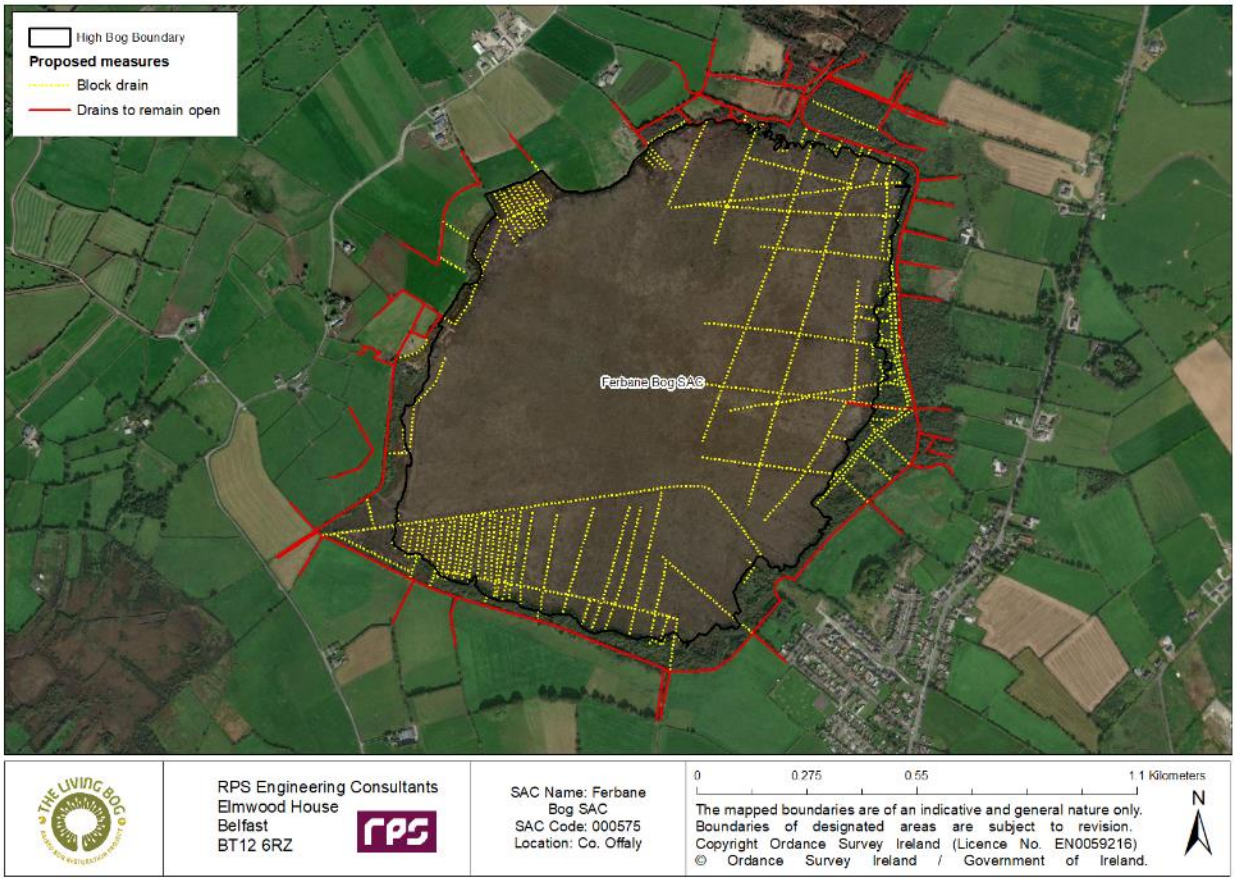

Figure 3-70: Restoration measures specified in support of hydrological goals.

3.5.4 Restoration potential

Eco-hydrological modelling of the restoration potential on Ferbane Bog SAC, excluding current areas mapped as ARB, suggested as much as 11.9 ha of habitat had the potential to be positively impacted by restoration works, with 10.9 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 1 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-71).

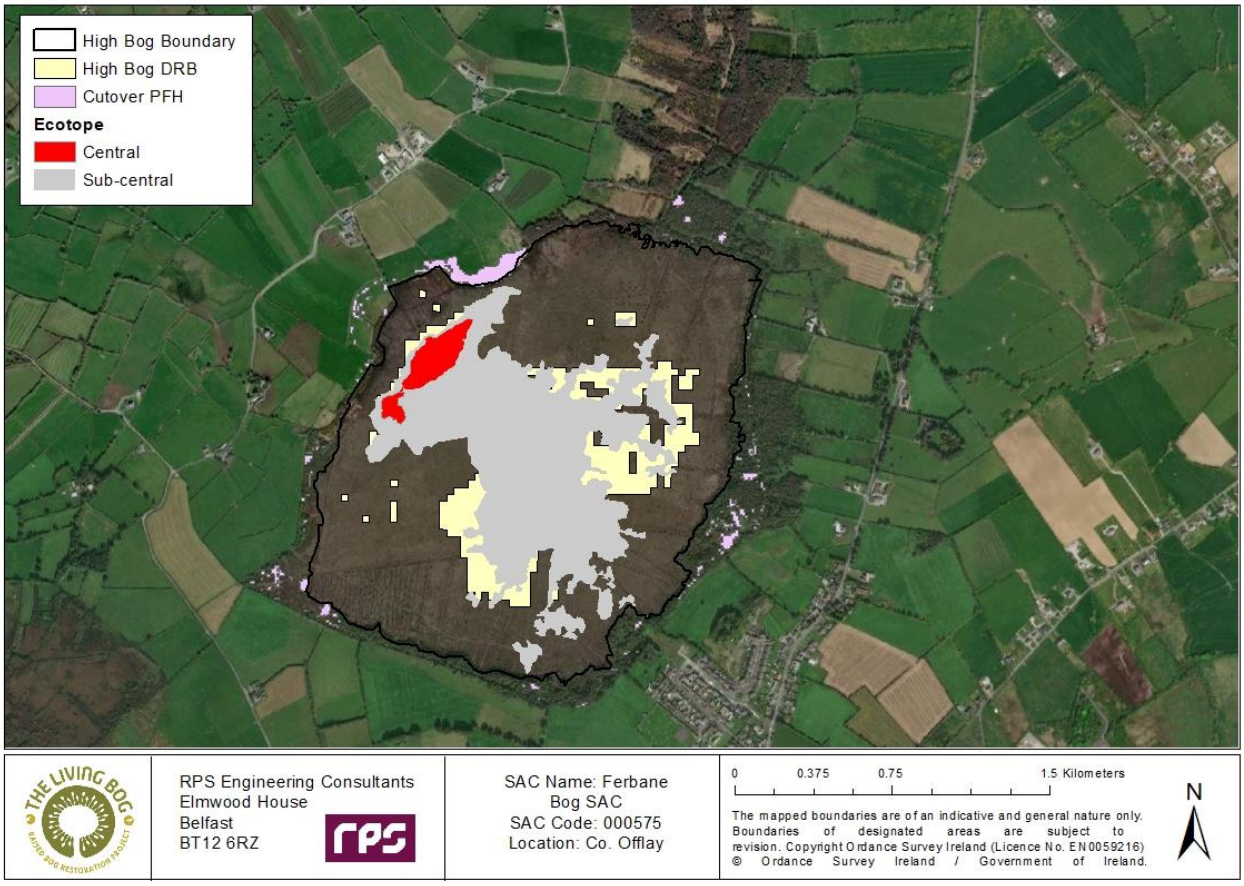

Figure 3-71. Restoration potential of Ferbane Bog SAC as outlined by eco-hydrological modelling.

3.5.5 Deployed monitoring network

A monitoring network comprising a mixture of 15 shallow phreatic wells and deeper piezometric wells (Figure 3-72) was subsequently installed on Ferbane Bog SAC. On the high bog, 8 phreatic wells were installed, accompanied by 3 deep piezometers to monitor vertical hydraulic gradients. On the cutover, 4 phreatic wells were installed. A total of 3 water level loggers were spread amongst the wells. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic, whilst those equipped with loggers were set to automatically record levels in 15-minute intervals, and downloaded on a quarterly basis. Water level readings were barometrically corrected using the barometric logger installed on the nearby site of Moyclare Bog SAC, located approximately 2.5km away.

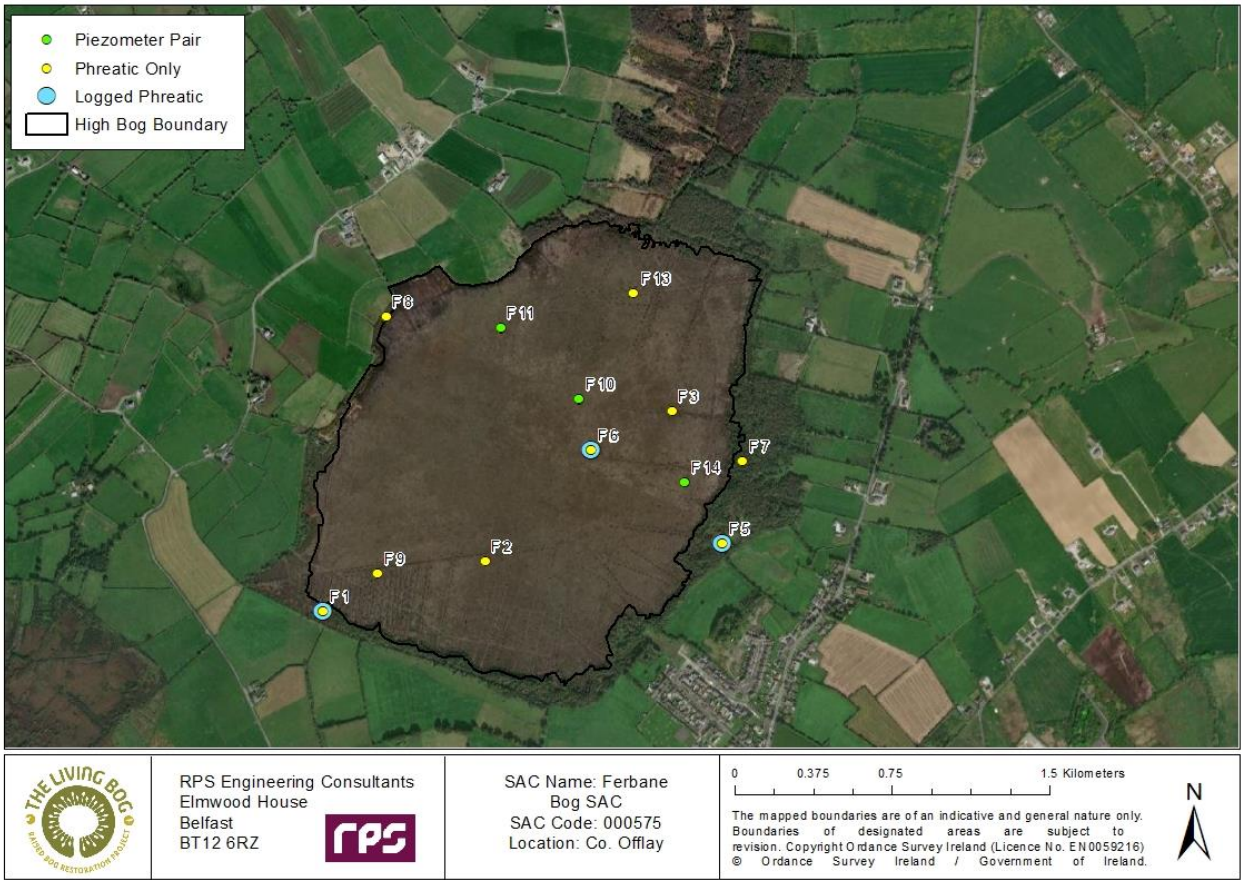

Figure 3-72: Hydrological monitoring network installed and operating on Ferbane Bog SAC.

3.5.6 General field observations

Owing to regular site visits RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. Ferbane Bog SAC was the Living Bog project site with the most intense network of deep high bog drains. Post restoration, significant re-wetting was achieved on the high bog in all areas across the site and was noticeable underfoot while walking the high bog. In the area around wells, F2, F9 and F14 in particular the bog surface has been noted to be soft under foot and the water table has become visible at the surface all year-round.

Limited restoration measures were employed on the Eastern cutover due to the presence of mature forestry, however, partial blocking was completed by installing plastic dams at key locations, this significantly raised the water levels in drains within this area, however, ecological monitoring of the area will be required to determine the impact of this in the coming years as part of the AfterLIFE plan. On the Southern cutover, in the vicinity of well F1, the area has become inaccessible for measurements during wetter periods due to significant rewetting post-restoration. Observations from a distance have estimated the water table at 30cm or more above the ground surface. While F1 is accessible during the drier months the cutover surface typically remains submerged throughout the year (Figure 3-73).

Figure 3-73: Cutover at Ferbane Bog SAC where significant rewetting was observed

3.5.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Ferbane SAC are presented with all supplementary results provided in Appendix A.

3.5.7.1 The Southern Cutover

In a bid to evaluate and quantify the effects of restoration measures, F 1 has been placed in regions of high restoration potential in cutover bog (Figure 3-74), south of the high bog.

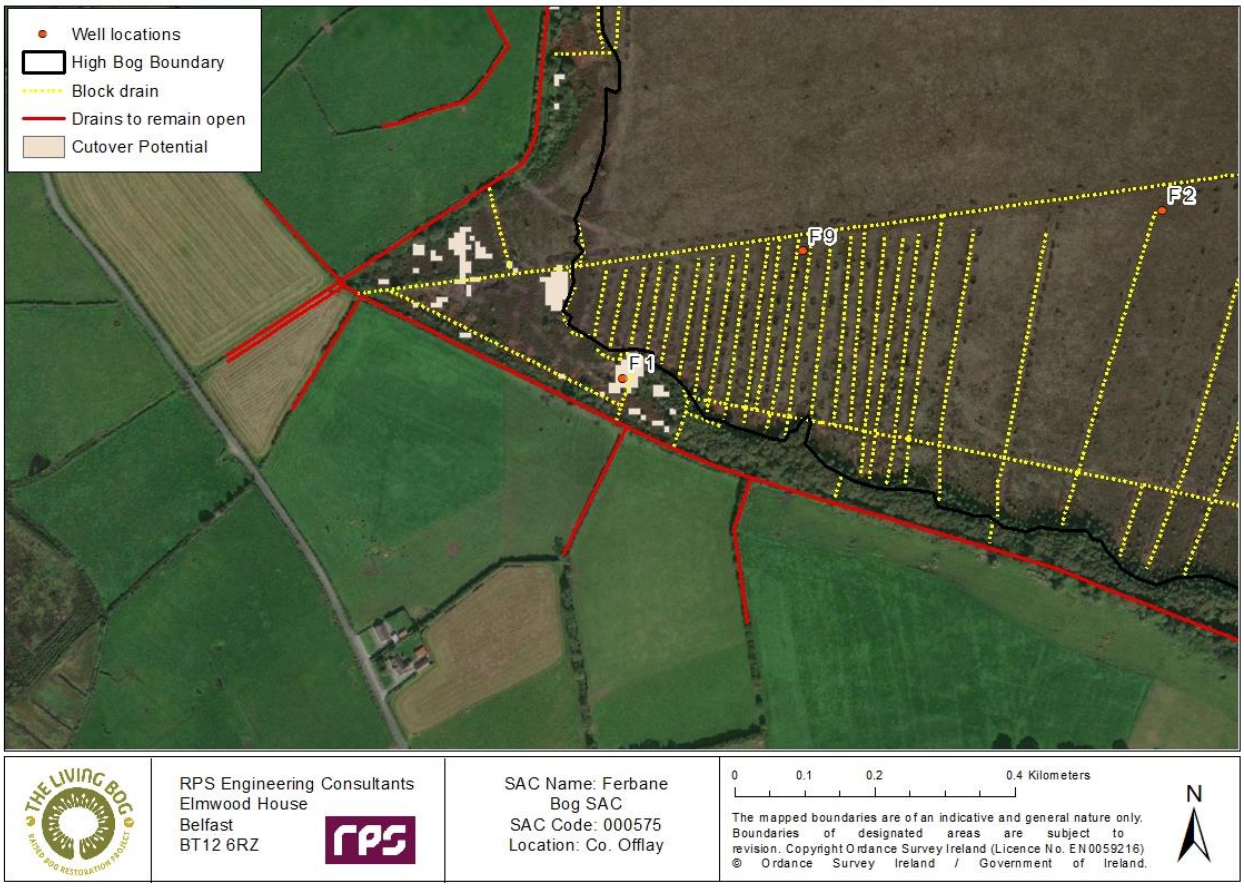

Figure 3-74 Location of well F 1 on the southern cutover of Ferbane Bog SAC

Figure 3-74 shows the location of the hydrological monitoring point located on the southern cutover at Ferbane Bog SAC. Data obtained from the level logger installed at F1 (Figure 3-75) demonstrates a positive change in water levels following the completion of site-wide works in September 2019, with water levels entering the peat-forming habitat zone in 2021. Prior to restoration, water levels recorded in F1 were very low, particularly between the months of August 2018 and October 2018 were water levels dropped 100cm below the ground surface. Water levels remained beneath the ground surface, fluctuating around the -40cm mark. Conversely, following restoration water levels rose and stayed consistently at or above the ground surface until the late spring and early summer of 2020, at which stage water levels gradually dropped to 40cm below the ground surface. Owing to a technical issue a considerable data gap exists between June 2020 and February 2021 in this record, however, consulting the manual record (Figure 3-76) for the same

well during this period reveals water levels remained consistently above the ground surface with no significant drawdowns. When logger recording resumed after February 2021 water levels had risen to over 30cm above the ground surface. Levels fluctuated above and below the ground surface for the remaining recording period, never falling below -40cm and never rising above 40cm of the ground surface.

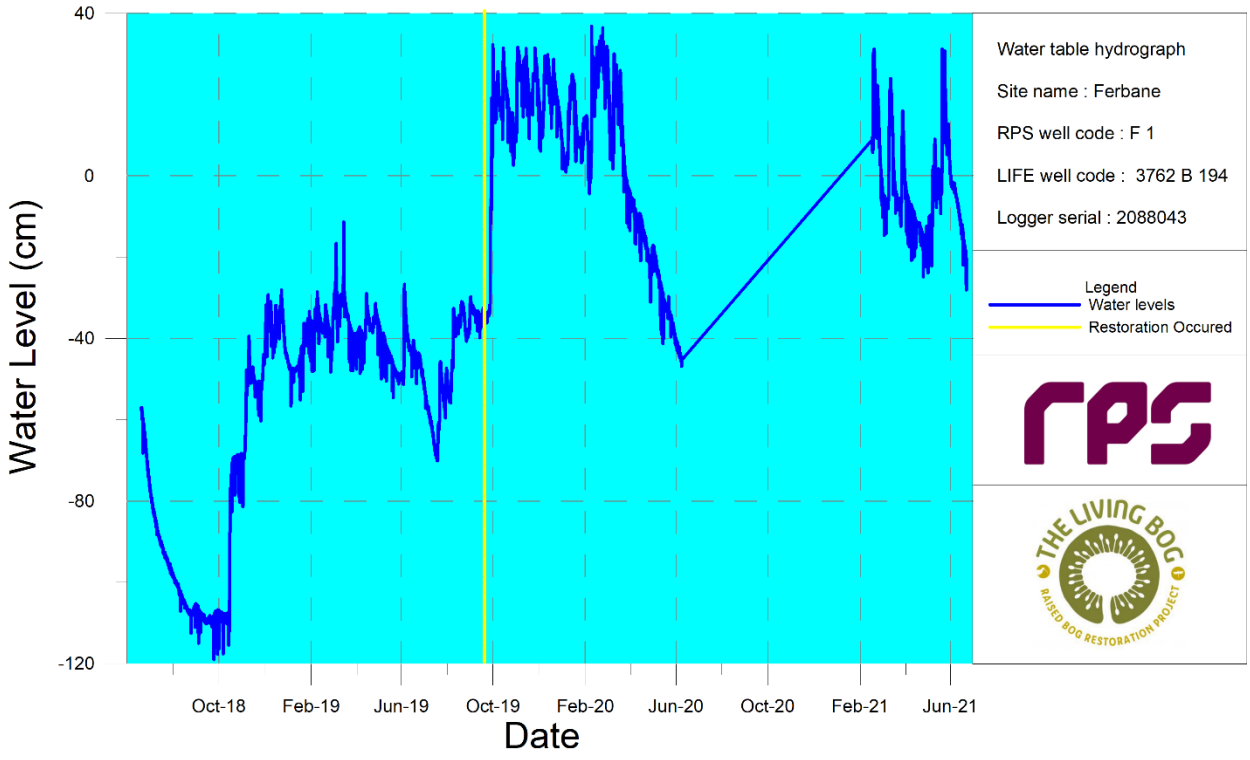

Figure 3-75: Level Logger data recorded between June 2018 and June 2021 at well F1, Ferbane Bog SAC.

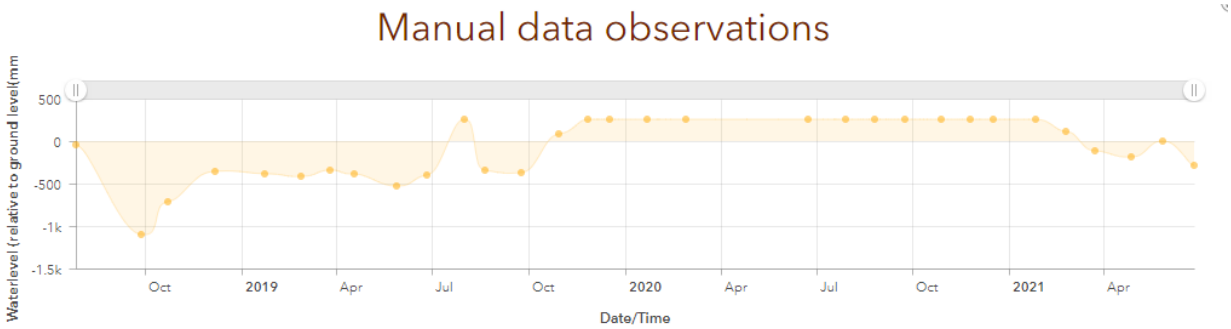

Figure 3-76. Hydrograph of manual water levels F1, Ferbane Bog SAC

Water table duration curves have been generated at each location monitored to show water levels before and after restoration over the same time period of an annual hydrological cycle, in this case, April-October in 2018, 2019, 2020 and 2021. This format has been used as it is concise and clear for the reader and the data can be used to easily interpret min/max and percentile values. Figure 3-77 illustrates the duration

curves generated from the data obtained from F 1. The duration curves indicate a clear difference between water levels pre (2018) and post (2019, 2020 and 2021) restoration. With a difference of 40cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

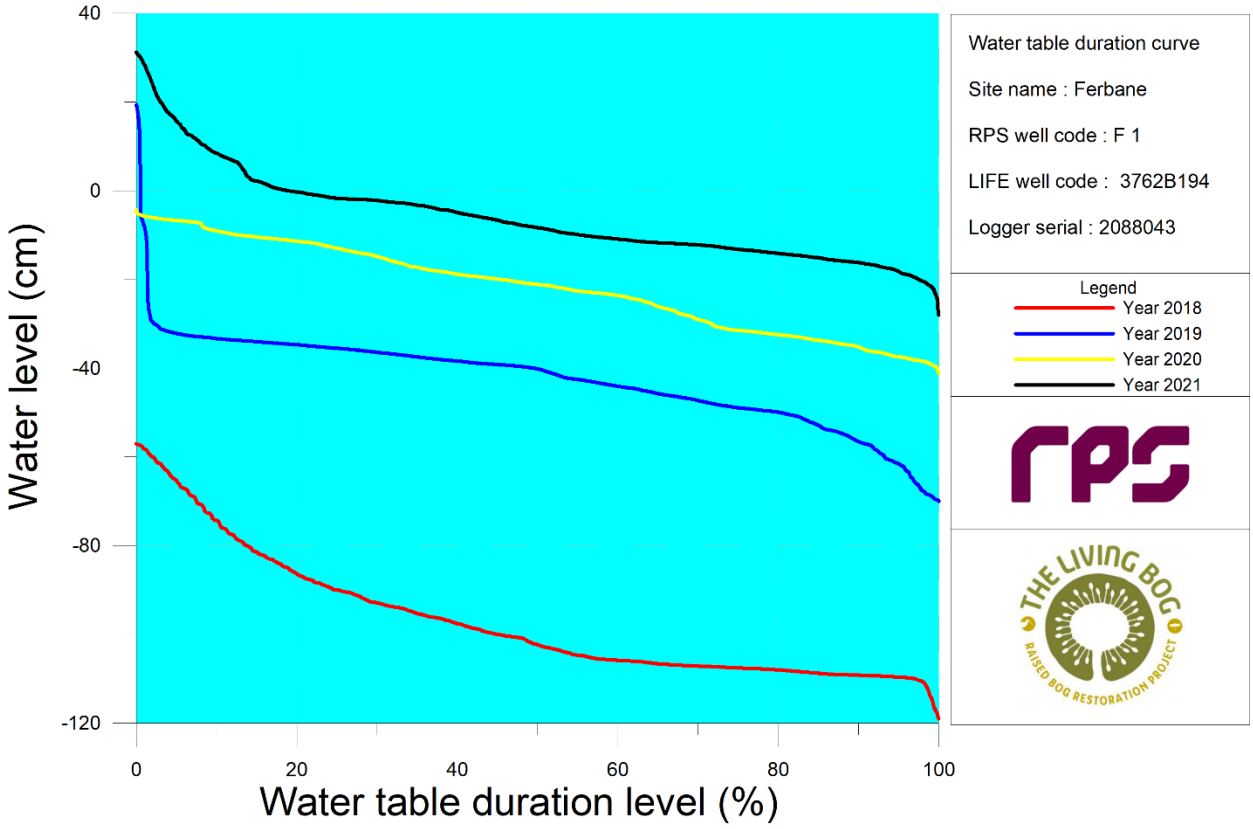

Figure 3-77. Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well F1, Ferbane Bog SAC.

3.5.7.2 The Eastern Cutover

In a bid to evaluate and quantify the effects of restoration measures, F 5 was placed in a region of high restoration potential in cutover bog (Figure 3-78), east of the high bog.

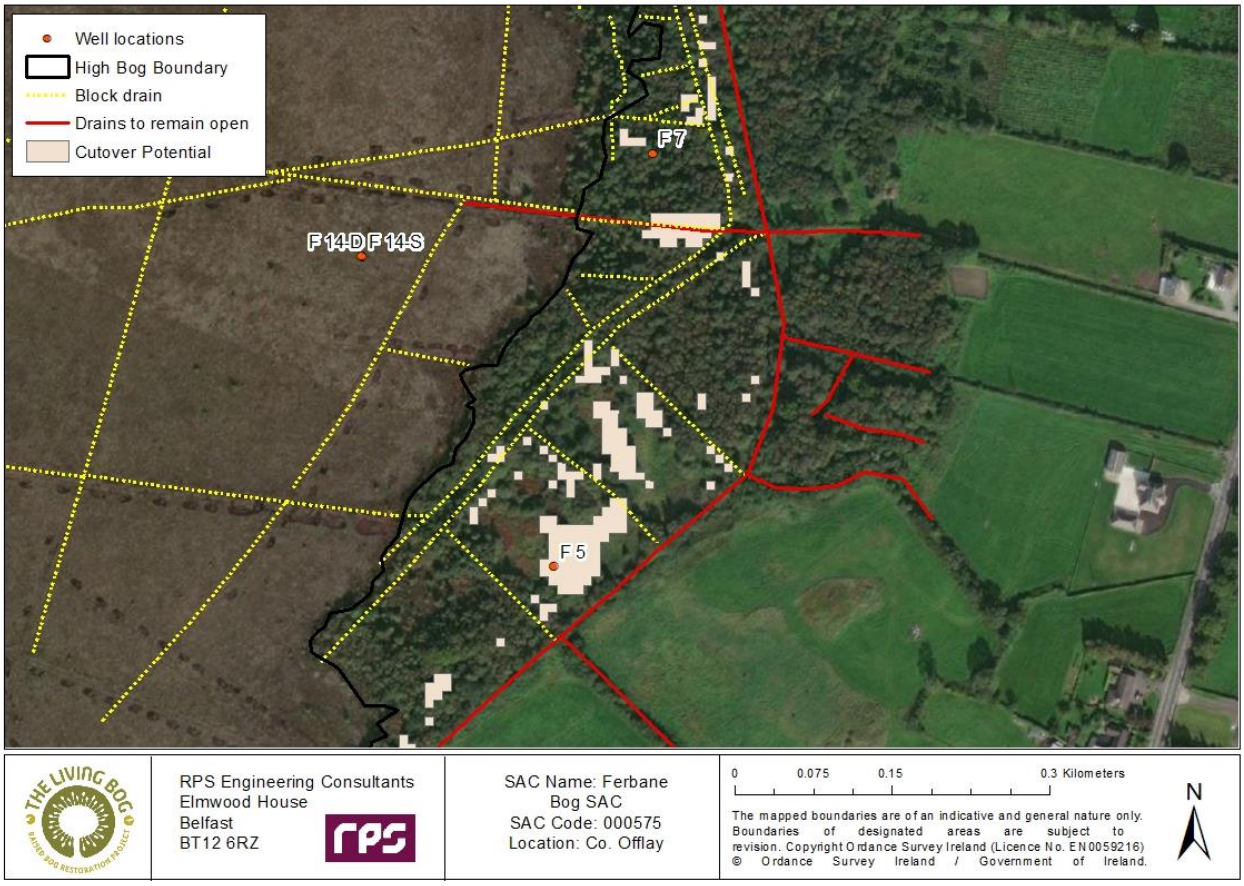

Figure 3-78 Location of wells F 5 and F 7 on the eastern cutover of Ferbane Bog SAC

Figure 3-78 shows the location of the hydrological monitoring points located on the eastern cutover at Ferbane Bog SAC. Data obtained from the level logger installed at F5 shows an improvement in hydrology with water levels rising after the completion of site-wide restoration works (Figure 3-79). This is also seen in the manual data for the same well, with water levels rising but remaining low throughout the recording period (Figure 3-80). Levels did not reach and consistently remain in the peat-forming habitat zone. Prior to restoration works water levels generally fluctuated between -40cm and 5cm, with exceptions during the summer periods of 2018 and 2019, where water levels fell to just below -80cm and -45cm respectively. Post restoration water levels continued to fluctuate between -40cm and 5cm of the ground surface, but with notable exceptions in June 2018 when water levels dropped to just under -50cm and again in June 2021 when water levels dropped to just under -40cm. The improvements in hydrology can also be seen in the duration curve generated for this well (Figure 3-81), with clear increases from 2018 and slight variation between 2019, 2020 and 2021.

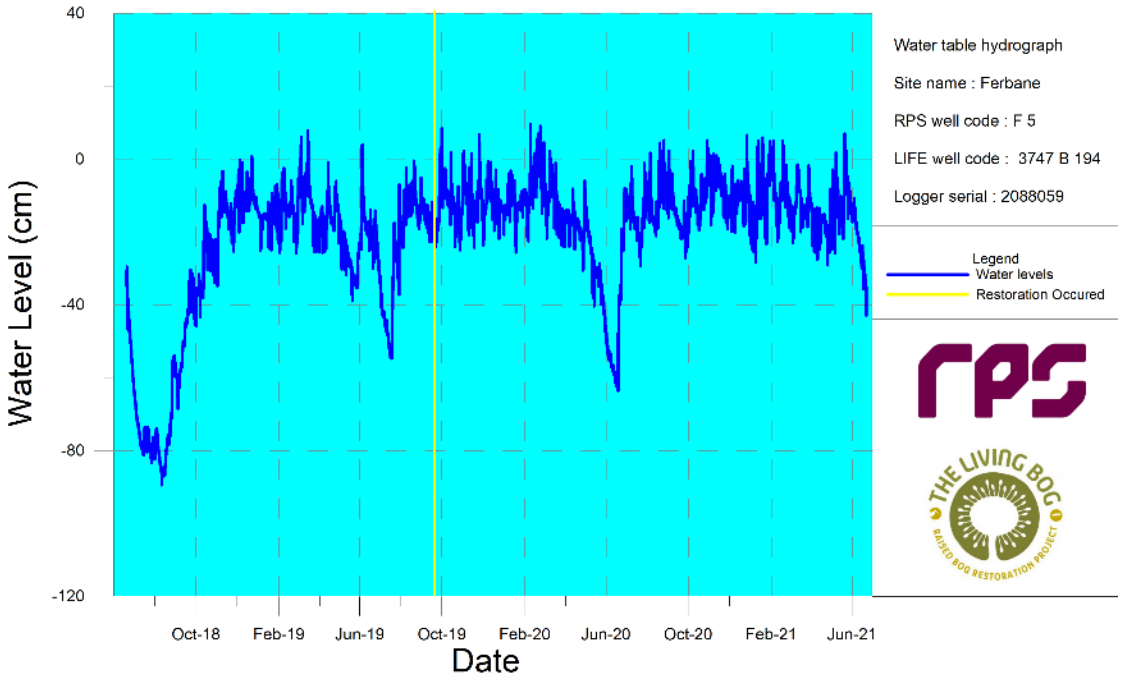

Figure 3-79 Level Logger data recorded between June 2018 and June 2021 at well F5, Ferbane Bog SAC.

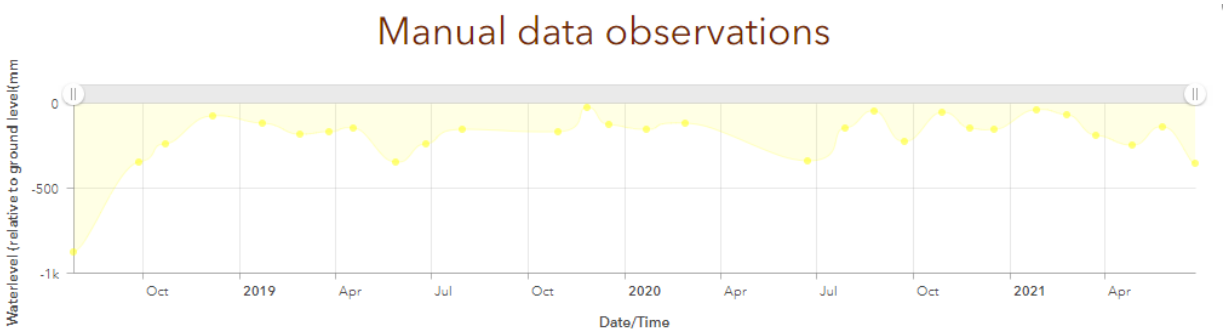

Figure 3-80 Hydrograph of manual water levels F5, Ferbane Bog SAC

Figure 3-81 Illustrates the duration curves generated from the data obtained from F 5. The duration curves indicate a clear difference between water levels pre (2018) and post (2019, 2020 and 2021) restoration. With a difference of 57cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

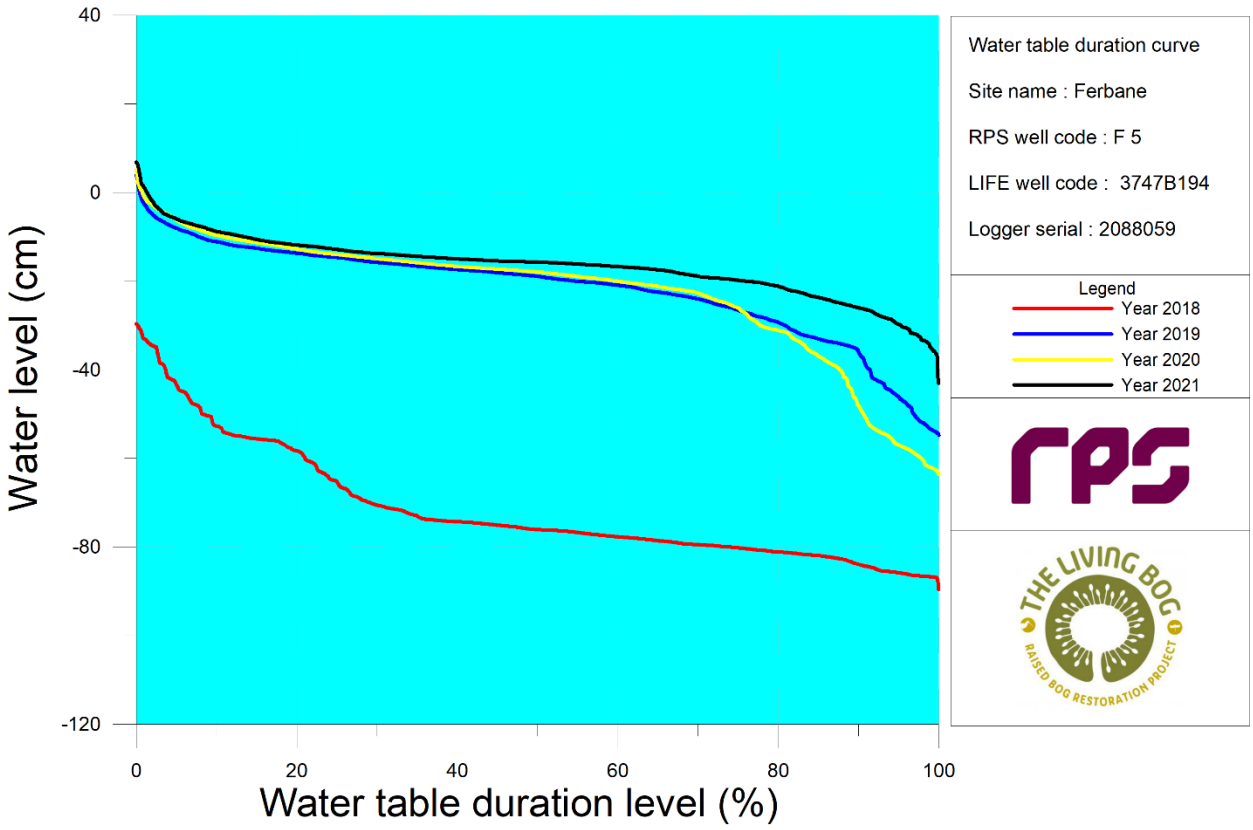

Figure 3-81 Level Logger data recorded between June 2018 and June 2021 at well F5, Ferbane Bog SAC

3.5.7.3 The High Bog

In a bid to evaluate and quantify the effects of restoration measures, F 2, F 3, F 6 and F 10 were placed in regions of high restoration potential on the high bog (Figure 3-82).

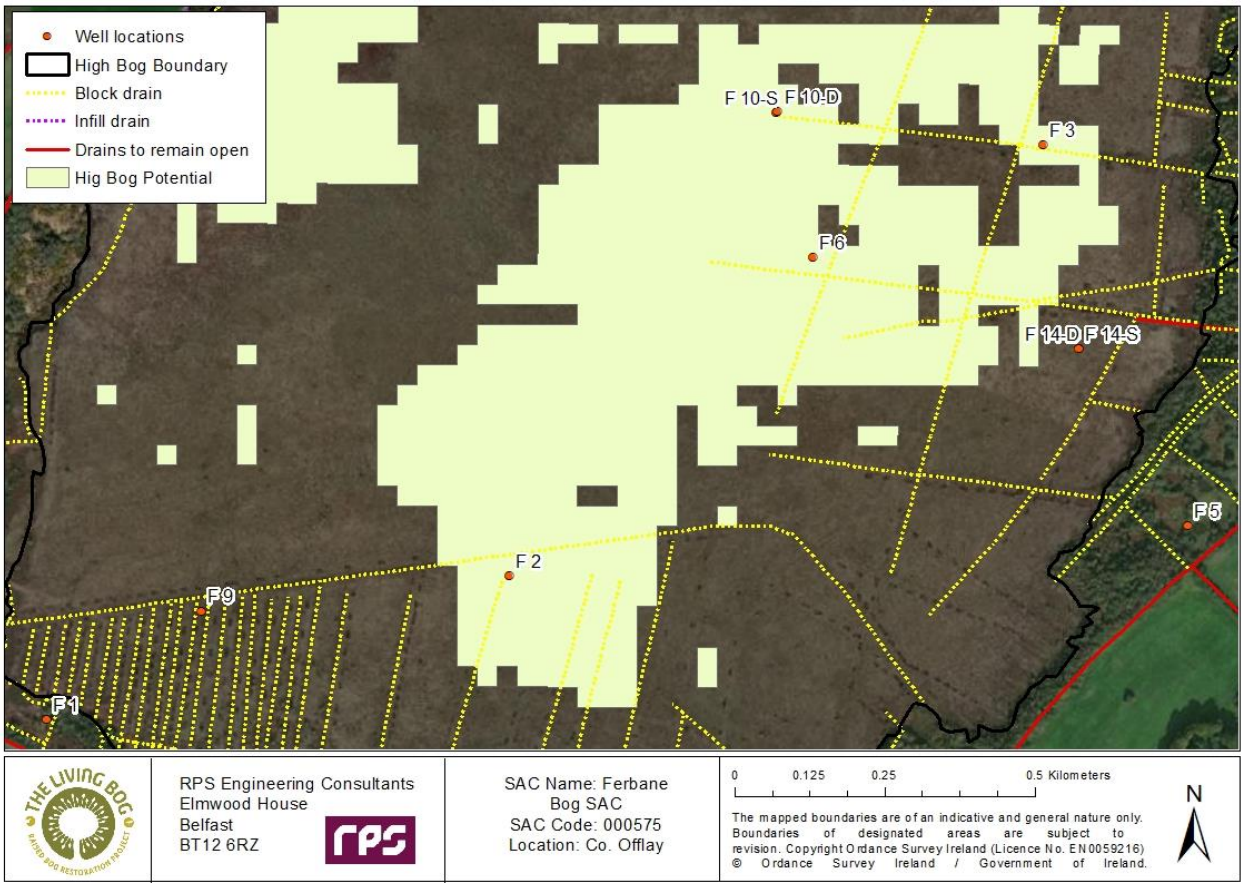

Figure 3-82 Location of wells F 2, F 3 F 6 and F 10 on the high bog at Ferbane Bog SAC

Figure 3-82 shows the location of the hydrological monitoring points located on the high bog at Ferbane Bog SAC. Data obtained from F6 demonstrates the slight variation in water levels pre and post-restoration on the high bog at Ferbane Bog SAC. The trends seen in this well were similarly observed across most piezometers installed on the high bog at this site. Data recorded by the level logger installed at F6 (Figure 3-83) shows moderate signs of improvement to an area that was already in good condition after the completion of restoration works. This is also reflected in the manual data observations of the same well (Figure 3-85). The duration curve (Figure 3-84) generated for this well also demonstrates the slight hydrological improvement, with post-restoration water levels (2019, 2020 and 2021) remaining above the pre-restoration levels (2018).

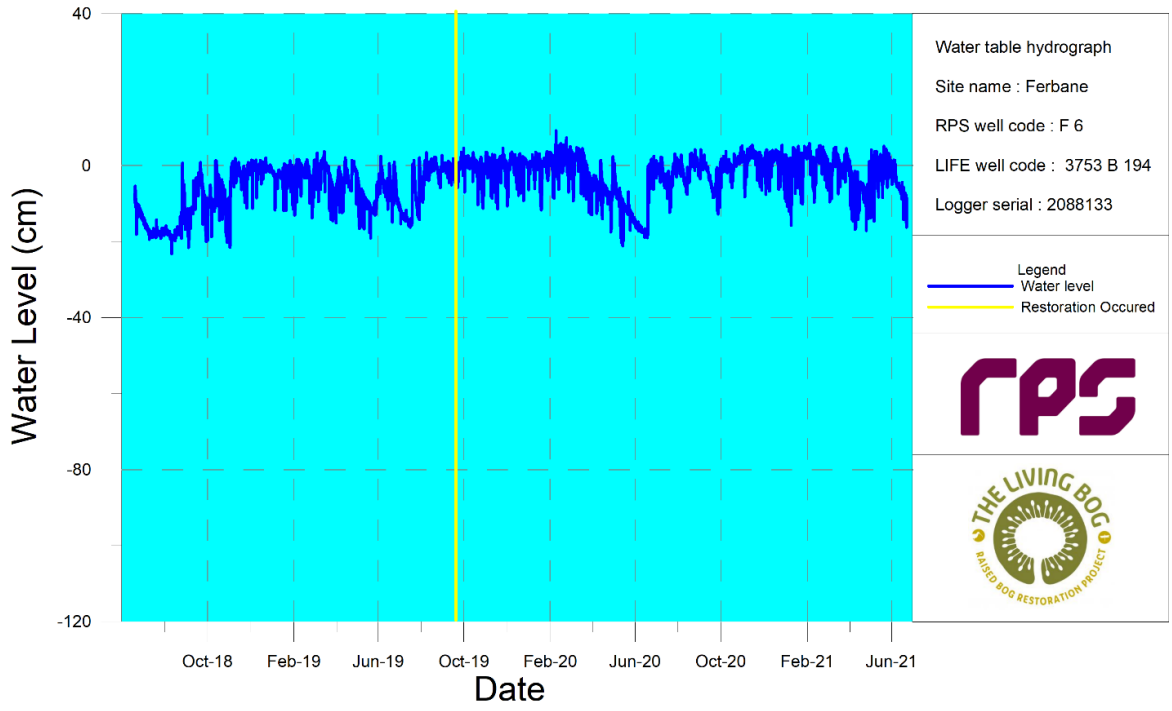

Figure 3-83 Level Logger data recorded between June 2018 and June 2021 at well F 6, Ferbane Bog SAC.

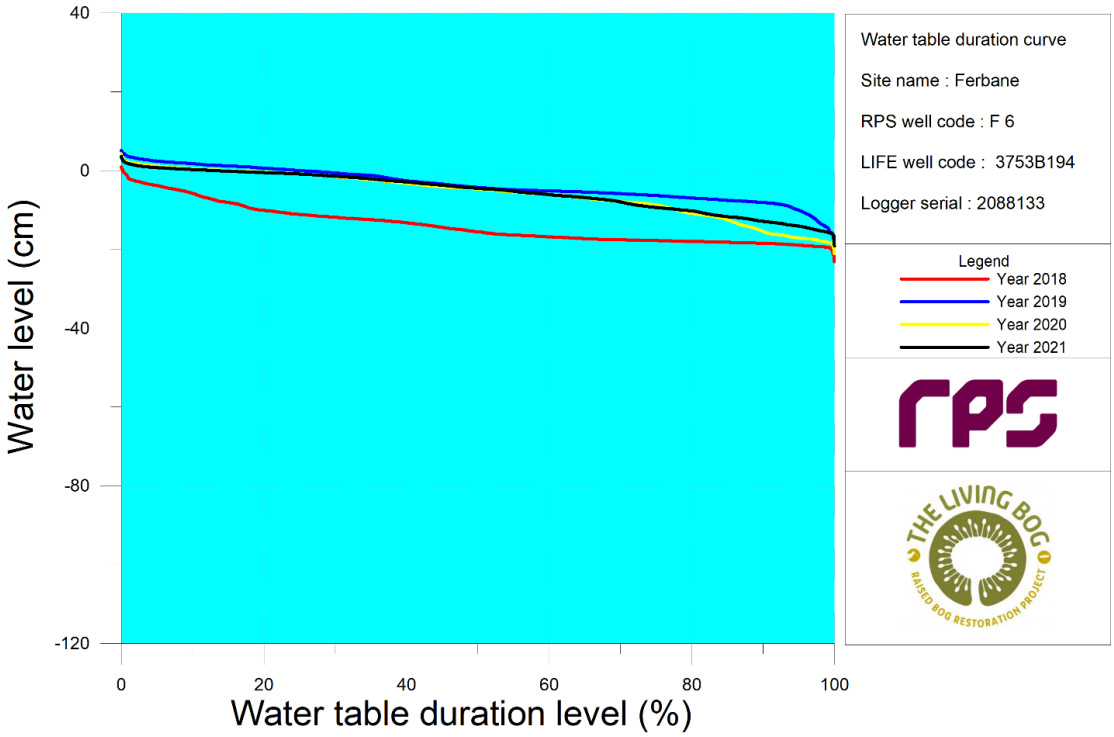

Figure 3-84 Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well F 6, Ferbane Bog SAC.

Figure 3-84 Illustrates the duration curves generated from the data obtained from F 6. The duration curves display a slight improvement in post-restoration water levels (2019, 2020 and 2021). With a difference of 10cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

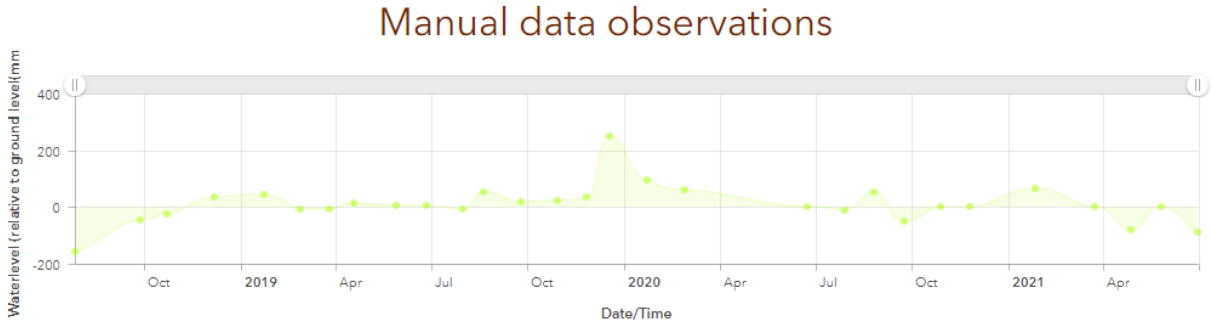

Figure 3-85 Hydrograph of manual water levels at well F6, Ferbane Bog SAC

Manual data observations collected from wells F 2 and F 3 (Figure 3-86-Figure 3-87) demonstrate the positive response of hydrology to restoration. Post restoration water levels rose into the peat-forming habitat zone and stayed at this level for the remainder of the recording period.

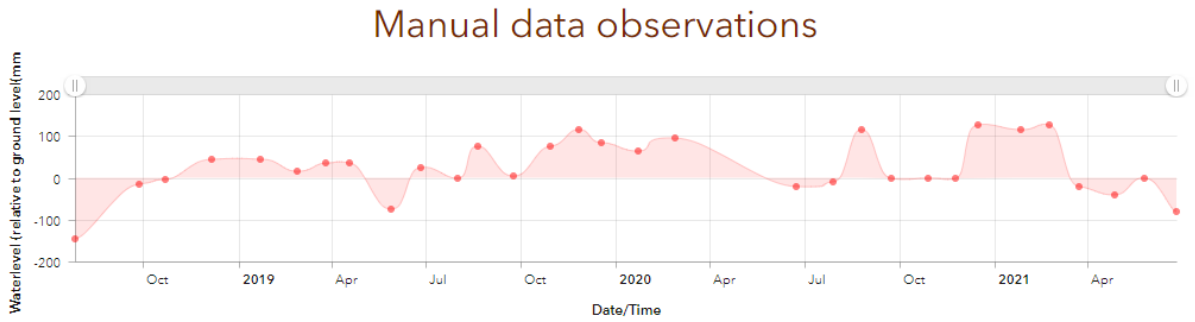

Figure 3-86 Hydrograph of manual monthly water levels F 2, Ferbane Bog SAC

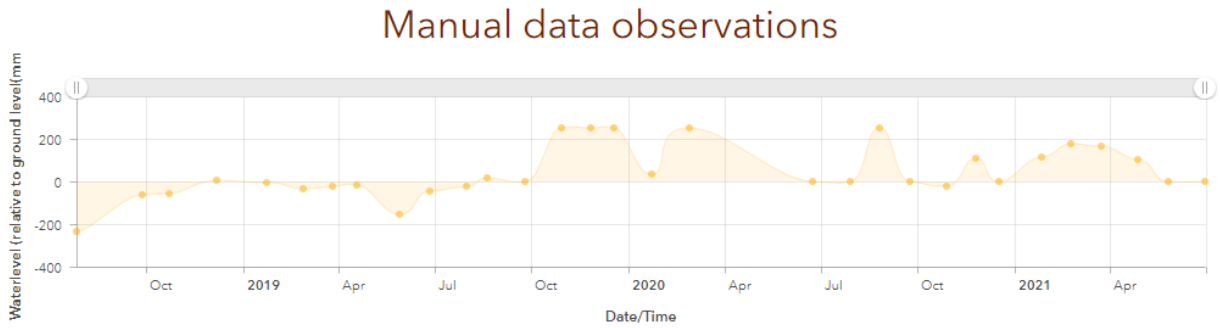

Figure 3-87 Hydrograph of manual water levels F3, Ferbane Bog SAC

Wells F11-S (Figure 3-88) and F13 (Figure 3-89), are both situated on the supporting high bog outside areas of high restoration potential. Manual data observations for these wells show positive responses to restoration works. Prior to restoration, the intensive & deep drainage network in the north of Ferbane high bog had reduced the water table below the levels needed for active raised bog. Post-restoration

measurements taken at both F11-S and F13 indicate that the hydrological conditions necessary to promote the formation of ARB have been achieved.

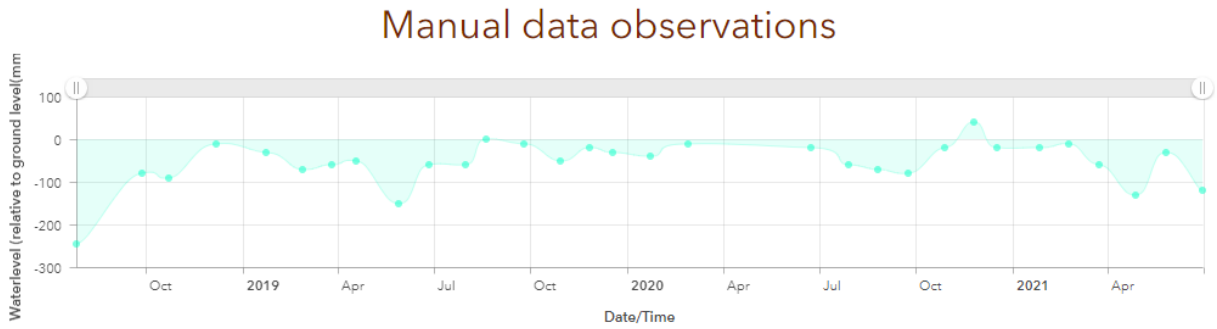

Figure 3-88 Hydrograph of manual water levels F11, Ferbane Bog SAC

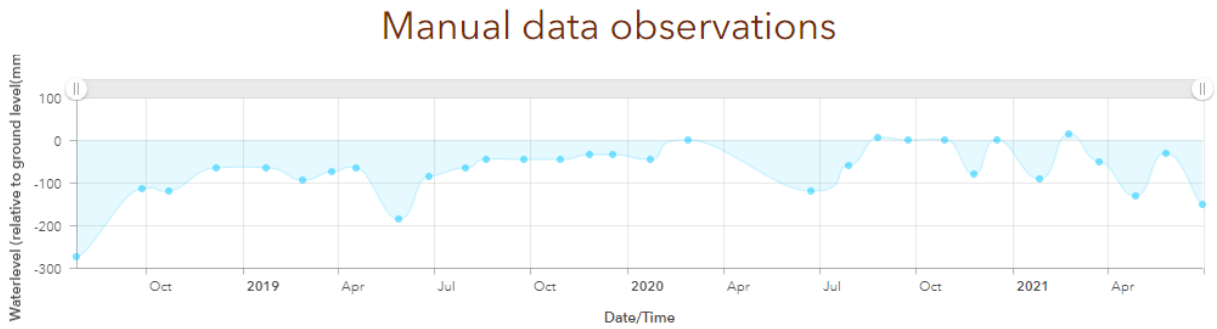

Figure 3-89: Hydrograph of manual water levels F13, Ferbane Bog SAC

3.5.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.5Table 3.1). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration The largest increases were noted in all cutover wells. Significant changes were observed on the high bog with multiple wells in areas designated as DRB or Supporting High Bog now displaying a post-restoration hydrological regime capable of supporting ARB.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Ferbane	F10-S	High Bog	ARB	-14.25	-8.00
Ferbane	F11-S	High Bog	Supporting High Bog	-22.85	-12.80
Ferbane	F13	High Bog	Supporting High Bog	-25.90	-14.60
Ferbane	F14-S	High Bog	DRB	-21.00	-7.00
Ferbane	F15-S	High Bog	ARB	-11.10	-8.80
Ferbane	F1	Cutover	PFH	-56.50	16.20
Ferbane	F2	High Bog	DRB	-13.20	-1.70
Ferbane	F3	High Bog	DRB	-21.80	0.00
Ferbane	F5	Cutover	PFH	-83.90	-26.02
Ferbane	F6	High Bog	DRB	-18.44	-8.11
Ferbane	F7	Cutover	Non-PFH	-150.00	-73.20
Ferbane	F8	Cutover	Non-PFH	-68.40	-18.70
Ferbane	F9	High Bog	Supporting High Bog	-27.0	-0.70

Table 3.5: 90th percentile water levels at Ferbane Bog SAC, pre- and post-restoration.

3.6 Garriskil Bog SAC

3.6.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests Garriskil Bog SAC and adjacent lands to be underlain entirely by Visean basinal “calp”. This typically denotes a non-homogenous unit, often comprising fine shales, interbedded and intermixed with calcareous material/spar and in this region is associated with moderately productive (locally), low vulnerability aquifer units. As such, contributions to in-channel flows from processes of groundwater recharge are thought to be small and localised.

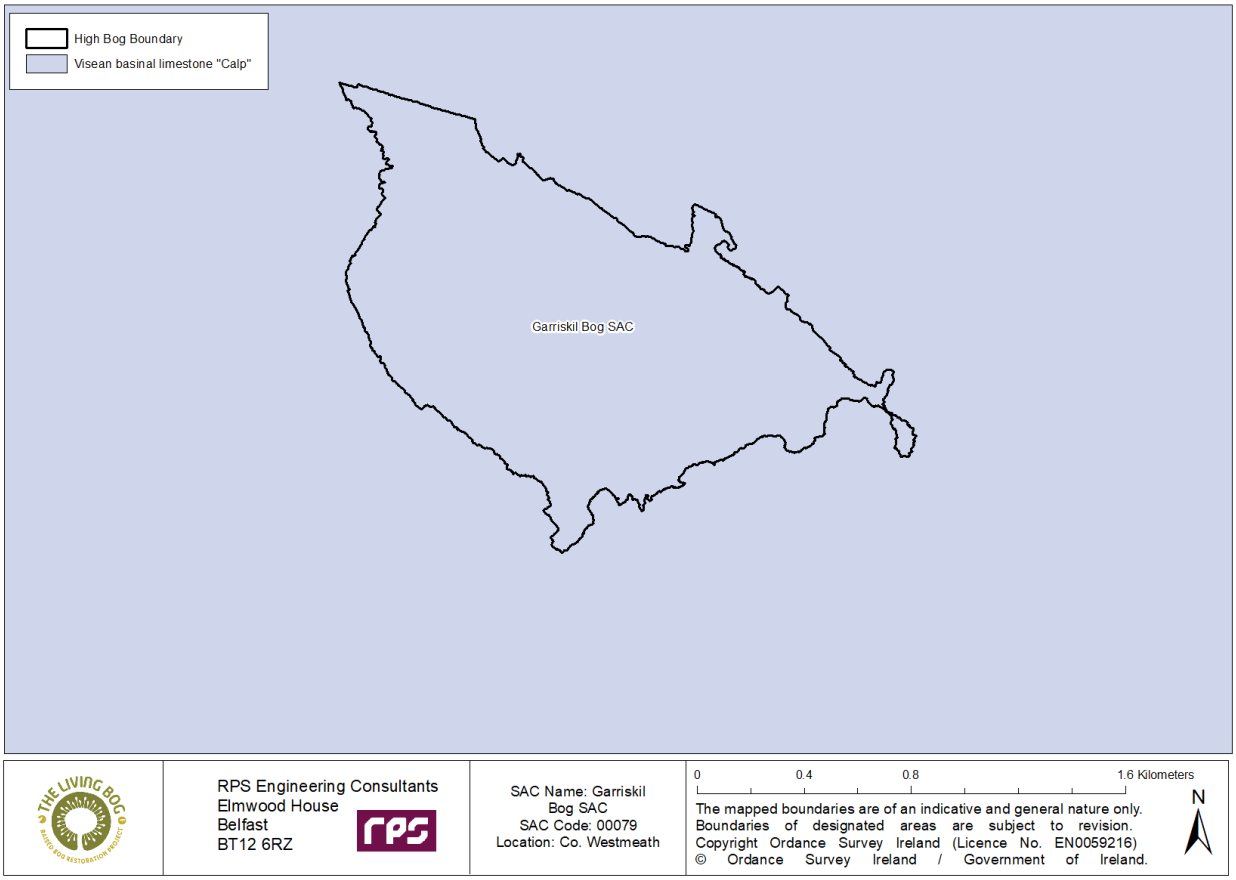

Figure 3-90: Simplified geology of Garriskil Bog SAC.

3.6.2 Ecotope mapping

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-91). During the last monitoring survey (2018) it was noted, that Garriskil Bog SAC consists of 65.68 ha of Active Raised Bog (ARB) consisting of areas of central, sub-central and active flush.

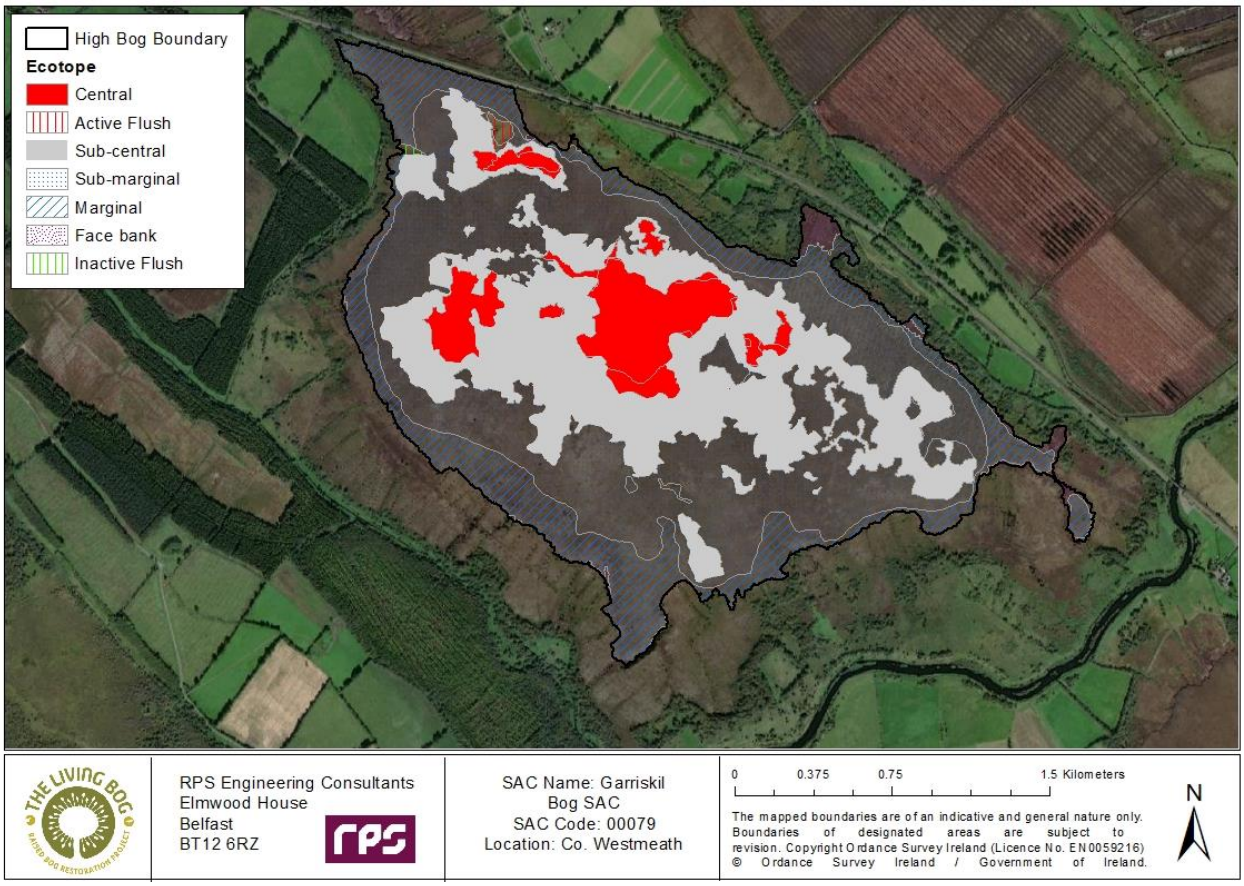

Figure 3-91: Ecotope mapping carried out for Garriskil Bog SAC.

3.6.3 Proposed restoration plan

The restoration plan for Garriskil Bog SAC (Figure 3-92) identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat forming (ARB) habitat. Overall, the installation of peat dams was recommended across 14.61 km of channels both on the high bog and cutover.

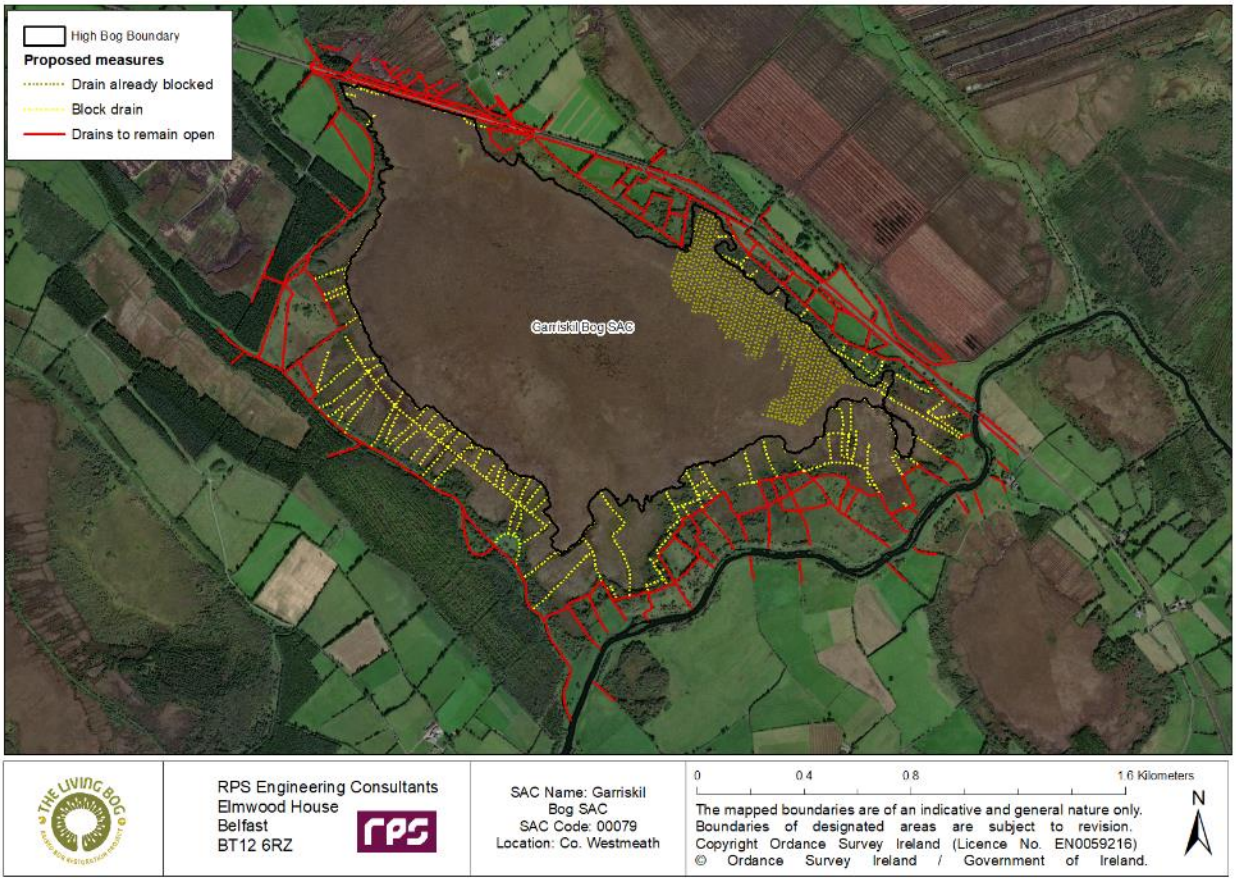

Figure 3-92: Restoration measures specified in support of hydrological goals.

3.6.4 Restoration potential

Eco-hydrological modelling of the restoration potential on Garriskil Bog SAC, excluding current areas mapped as ARB, suggested as much as 34 ha of habitat had the potential to be positively impacted by restoration works, with 31.6 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 2.4 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-93)

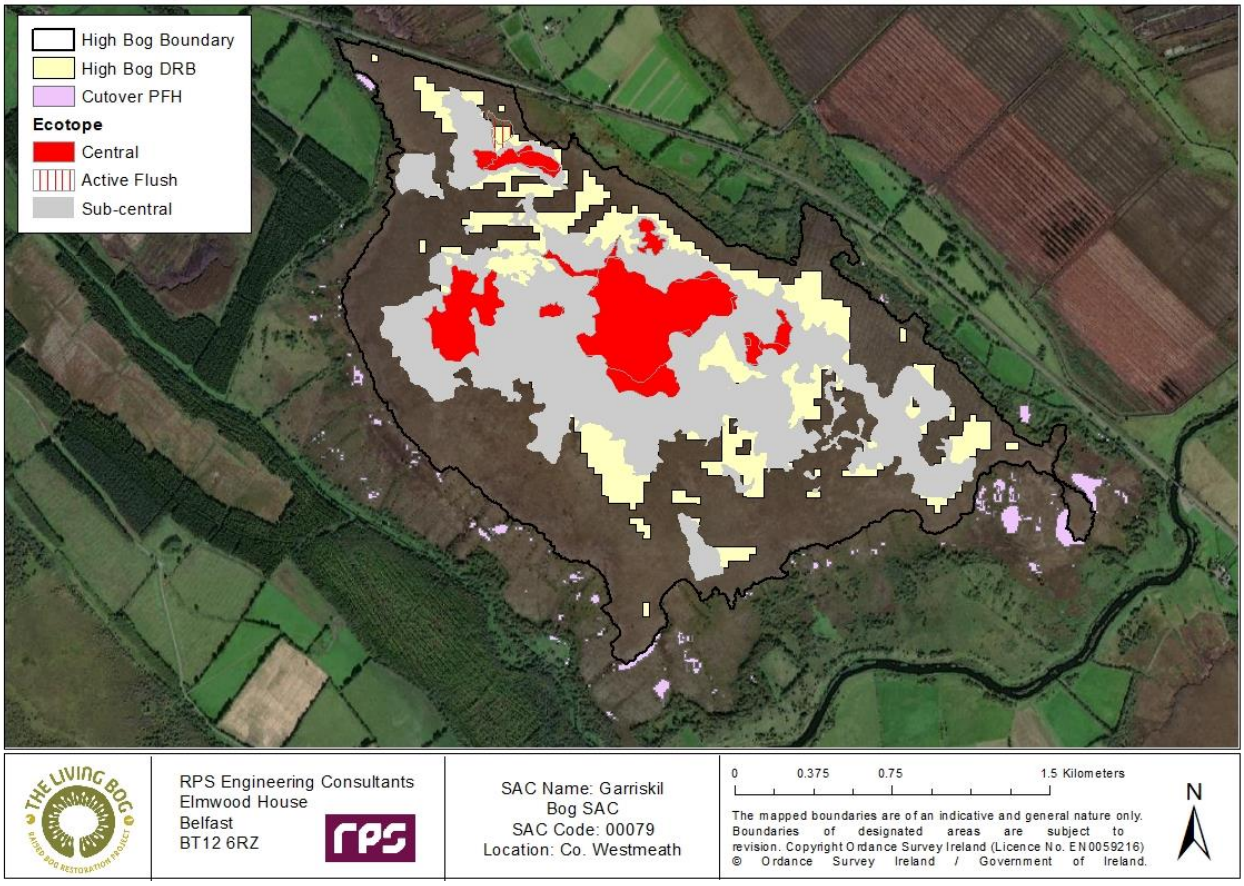

Figure 3-93: Restoration potential of Garriskil Bog SAC as outlined by eco-hydrological modelling.

3.6.5 Deployed monitoring network

A monitoring network comprising a mixture of 18 shallow phreatic wells (Figure 3-94) was subsequently installed on Garriskil Bog SAC. On the high bog, 7 phreatic wells were installed, accompanied by 7 deep piezometers to monitor vertical hydraulic gradients. On the cutover, 4 phreatic wells were installed. A total of 3 water level loggers were spread amongst the wells. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic, whilst those equipped with loggers were set to automatically record levels in 15-minute intervals and downloaded on a quarterly basis. Water level readings were barometrically corrected using the barometric logger installed on the nearby site of Ardagullion Bog SAC, located approx. 8.5km away.

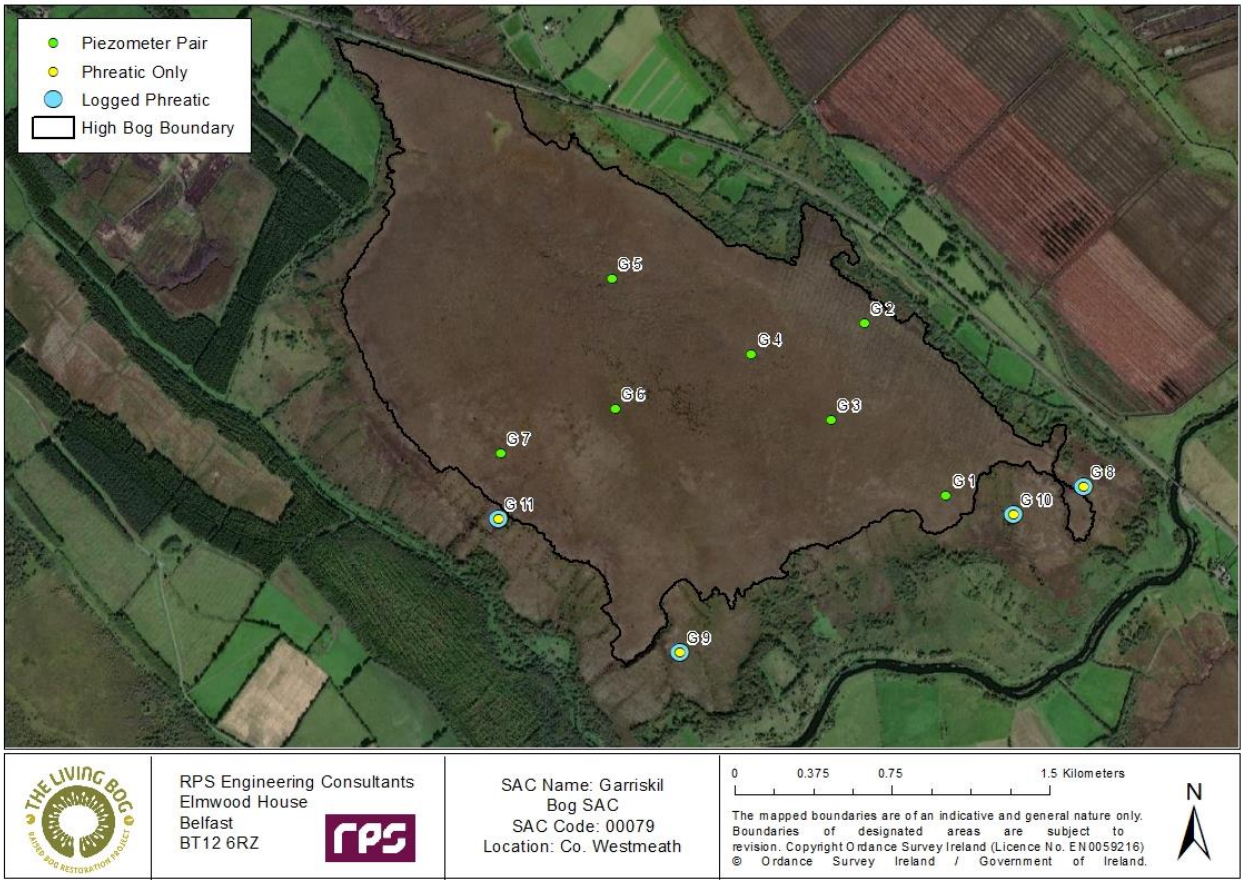

Figure 3-94: Hydrological monitoring network installed and operating on Garriskil Bog SAC.

3.6.6 General field observations

On account of regular periodic site visits, RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. The majority of cutover restoration took place on the Southern and Eastern cutovers, in both areas the ground surface has become significantly wetter following restoration with pools forming close to the main drains and across wider areas of cutover in both areas, with the local the topography contributing to the rapid changes in hydrology. A large drain to the Southeast of the site, was a major outflow from the site, with a considerable contributing catchment. After restoration measures were completed, re-wetting could be observed to backup into the site that extended along the main facebank and surrounding drains. (Figure 3-95).

Figure 3-95: Cutover at Garriskil Bog SAC where significant rewetting was observed

A large proportion of the high bog was already defined as ARB and was considerably wet underfoot. Given water table levels are generally closer to the ground surface in high bog areas anyway, hydrological changes are more difficult to observe visually than widespread rewetting of very dry cutover areas. Rewetting, in close proximity to drains, could be observed on the high bog.

3.6.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Garriskil Bog SAC are presented with all supplementary results provided in Appendix A.

3.6.7.1 The Eastern Cutover

In a bid to evaluate and quantify the effects of restoration measures, wells G 8 and G10 were placed in regions of high restoration potential in the eastern cutover of Garriskil Bog SAC (Figure 3-96).

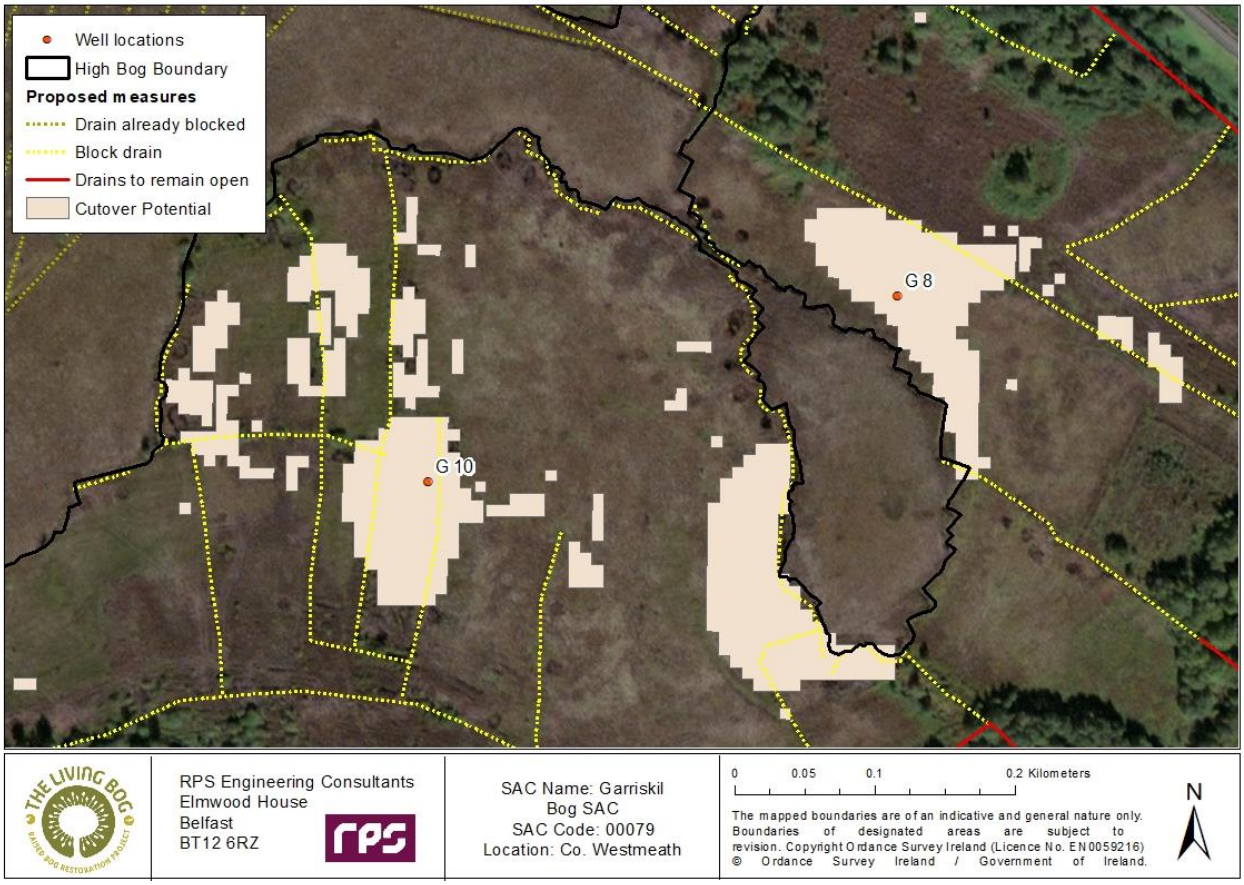

Figure 3-96 Location of wells G 8 and G10 on the eastern cutover of the Garriskal Bog SAC

Data obtained from the level logger installed at F 8 (Figure 3-97) demonstrates a positive change in water levels following the completion of site-wide works in November 2018, with water levels entering and remaining in the peat-forming habitat zone during the majority of the post-restoration period. Prior to restoration, water levels recorded in G 8 were at or above the ground surface in the winter months, however in the summer of 2018 significant falls in water level, to as low as -80cm, were observed. During the post-restoration period, some sharp drops in water level can be observed as seen during the June-August period in 2020. However, the size of the drop in water level has been significantly reduced falling to -45cm. The manual data records for G 8 (Figure 3-98) display similar improvements in hydrology with water levels rising significantly and remaining within the peat-forming habitat zone for the entirety of the post-restoration period. The positive change in water levels is also reflected in the duration curve generated (Figure 3-99).

Clear improvements were observed post-restoration, with a difference of 64cm between the annual pre-post restoration D90 values. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

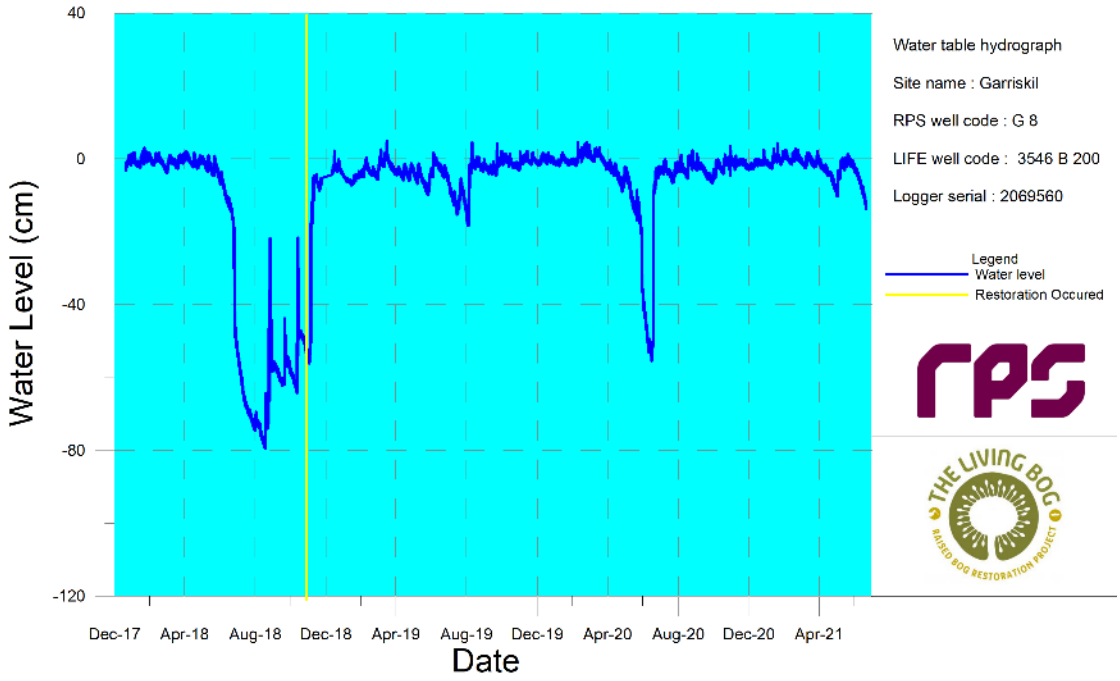

Figure 3-97 Level Logger data recorded between December 2017 and June 2021 at well G 8, Garriskal Bog SAC.

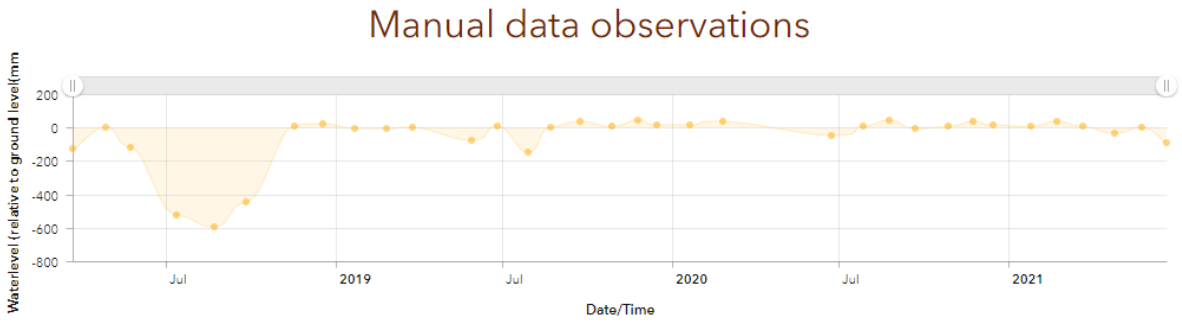

Figure 3-98 Hydrograph of manual monthly water levels G 8, Garriskill Bog SAC

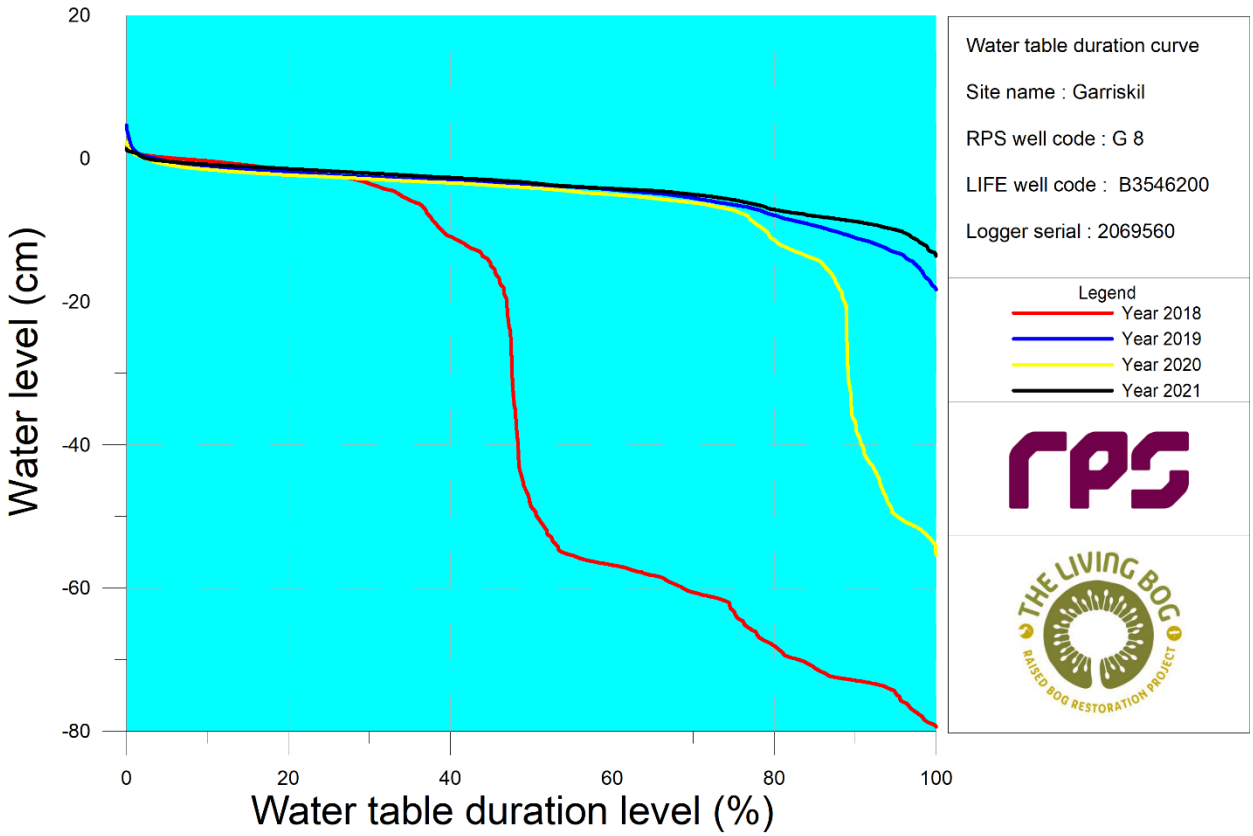

Figure 3-99 Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well G 8, Garriskal Bog SAC.

Data obtained from the level logger installed at G 10 (Figure 3-101) demonstrates a positive change in water levels following the completion of site-wide works in November 2018, with water levels entering and remaining in the peat-forming habitat zone during the majority of the post-restoration period. For the entirety of the pre-restoration period, water levels recorded in G 10 were consistently below ground level, falling to as low as -60cm in the summer of 2018. Water levels rose significantly after restoration, remaining within the peat-forming habitat zone for the majority of the remaining recording period, excluding the period of May to July when water levels fell to -30cm below the ground surface.

The manual data records for G 10 (Figure 3-101) display similar improvements in hydrology with water levels rising significantly and remaining within the peat-forming habitat zone for the entirety of the post-restoration period. The positive change in water levels is also reflected in the duration curve generated (Figure 3-102), with clear improvements pre and post-restoration. With a difference of 49cm between the pre-post restoration annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

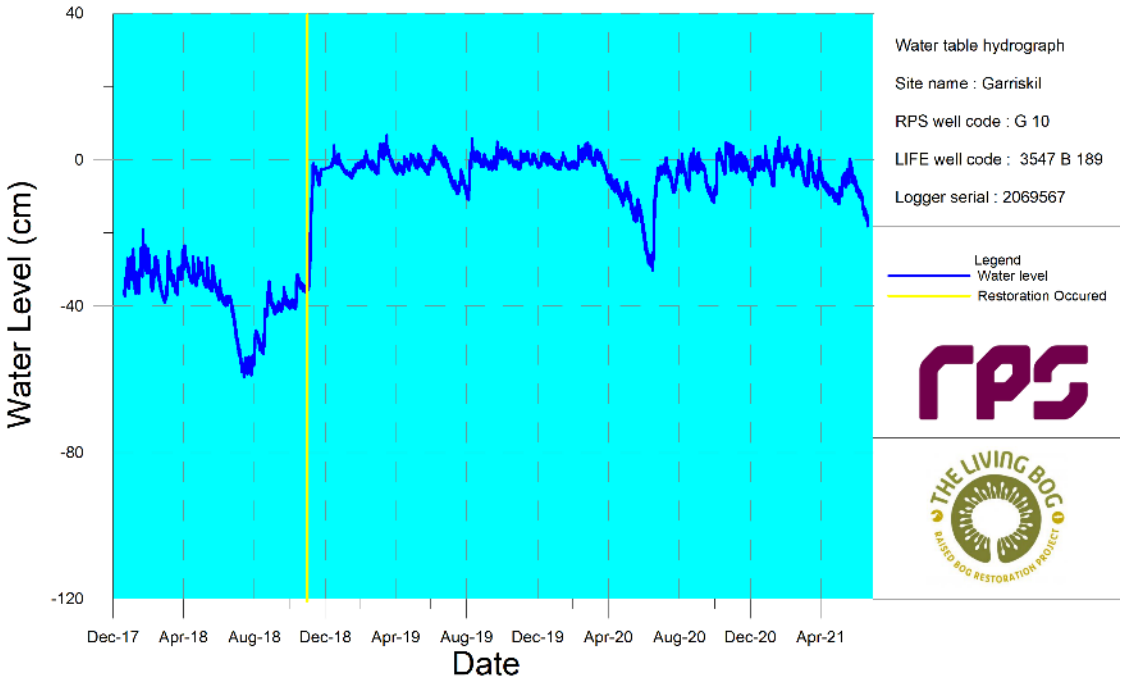

Figure 3-100 Level Logger data recorded between December 2017 and June 2021 at well G 10, Garriskal Bog SAC.

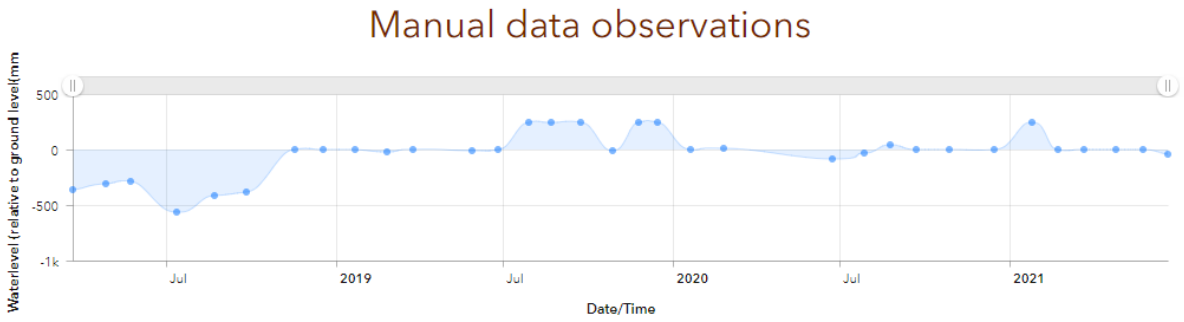

Figure 3-101 Hydrograph of manual monthly water levels G 10, Garriskill Bog SAC

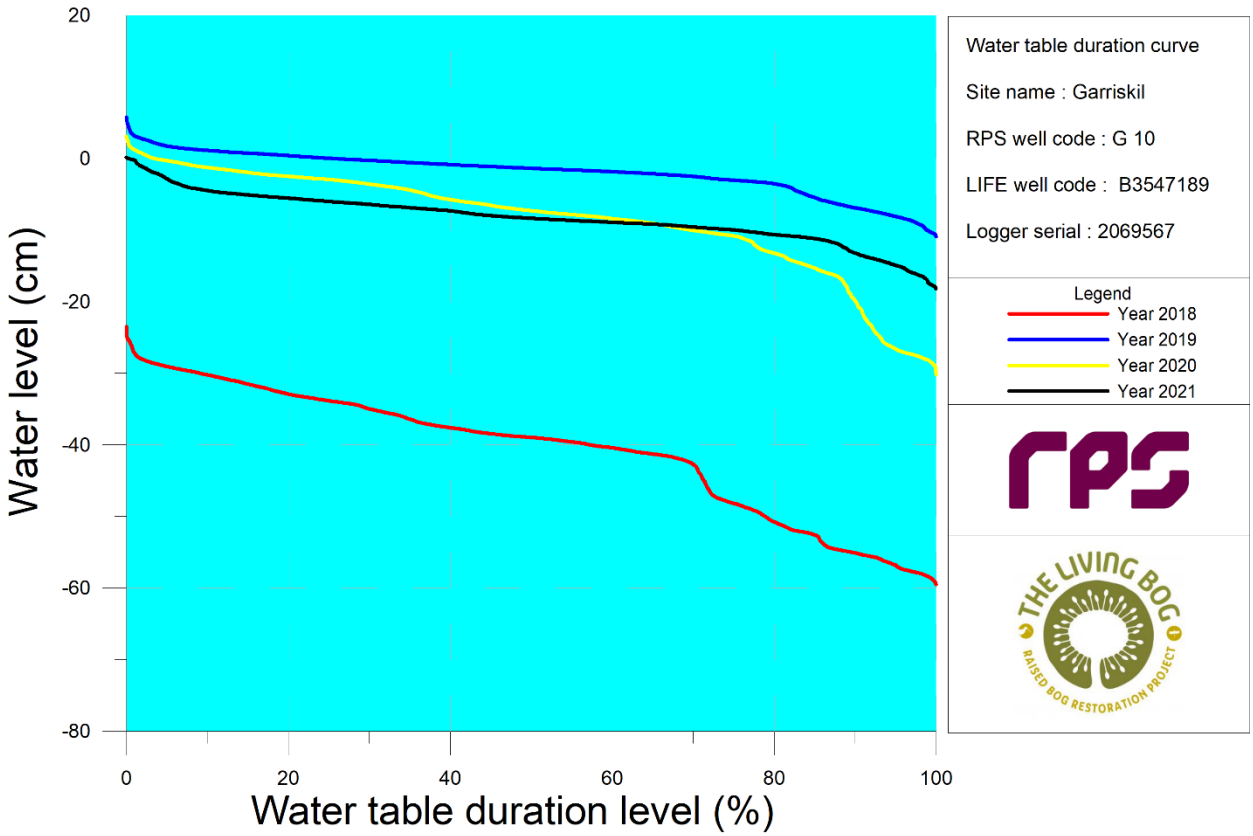

Figure 3-102 Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well G 10, Garriskal Bog SAC.

3.6.7.2 The Southern Cutover

In a bid to evaluate and quantify the effects of restoration measures, wells G 9 and G 11 were placed near regions of high restoration potential in the eastern cutover of Garriskil Bog SAC (Figure 3-103), however, were not located within the modelled boundary.

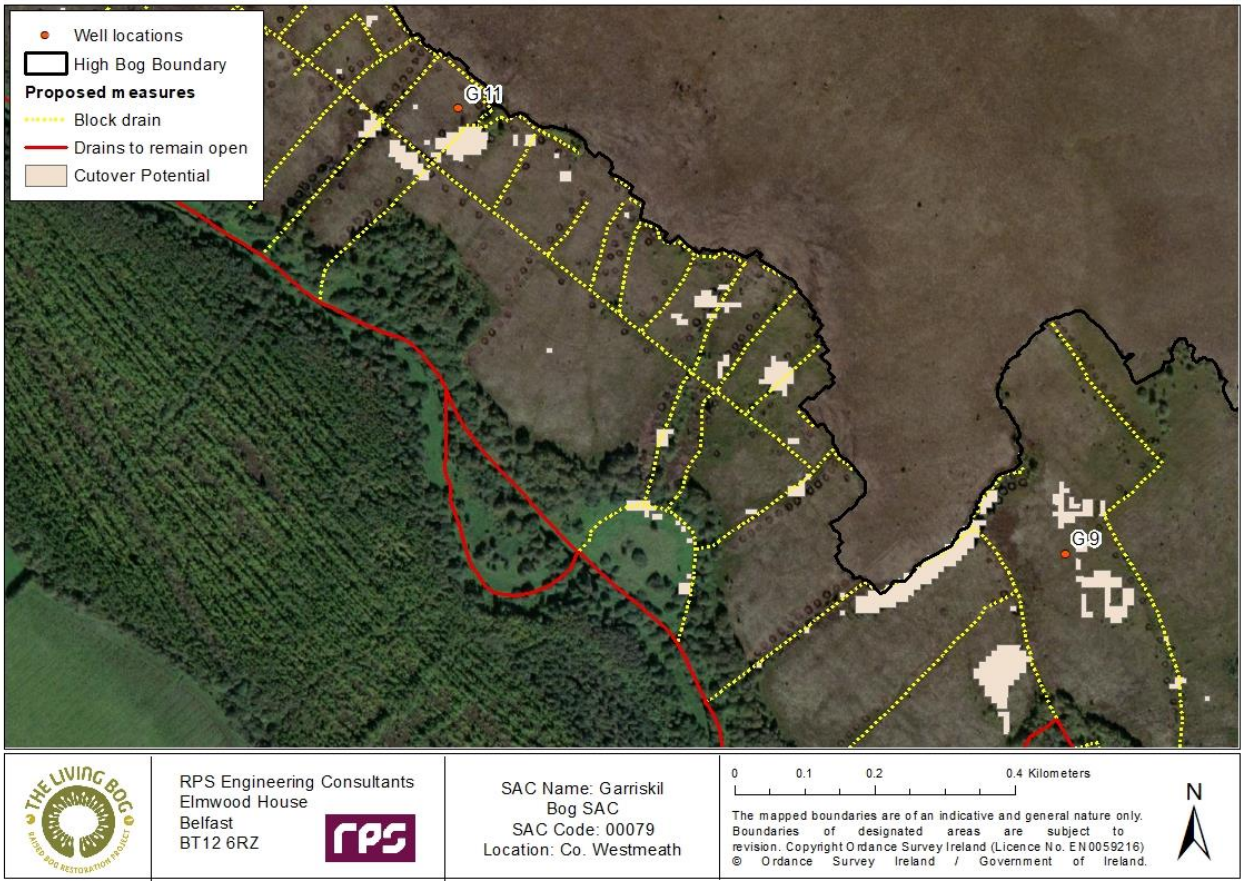

Figure 3-103 Shows the location of wells G 9 and G 11 on the southern cutover of Garriskil bog SAC

Data obtained from the level logger installed at G 9 (Figure 3-104) demonstrates a minor but positive change in water levels following the completion of site-wide works in November 2018. Prior to restoration, water levels recorded in G 9 fluctuated at or above the ground surface in the winter months, however water levels experienced significant falls to below -40cm between April and September of 2018. After restoration water levels remained around the surface level for the remainder of the recoding period. Several sharp falls can be observed in July/August of 2019 and 2020 but these drops are not as sharp as those observed prior to restoration, falling to just under -30cm.

The manual data records for G 9 (Figure 3-105) display similar improvements in hydrology post restoration with water levels rising and never dropping to levels observed prior to restoration. The slight positive change in water levels is also reflected in the duration curve generated (Figure 3-106). Clear improvements were observed post-restoration, with a difference of 16cm between the pre-post restoration annual D90 values. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

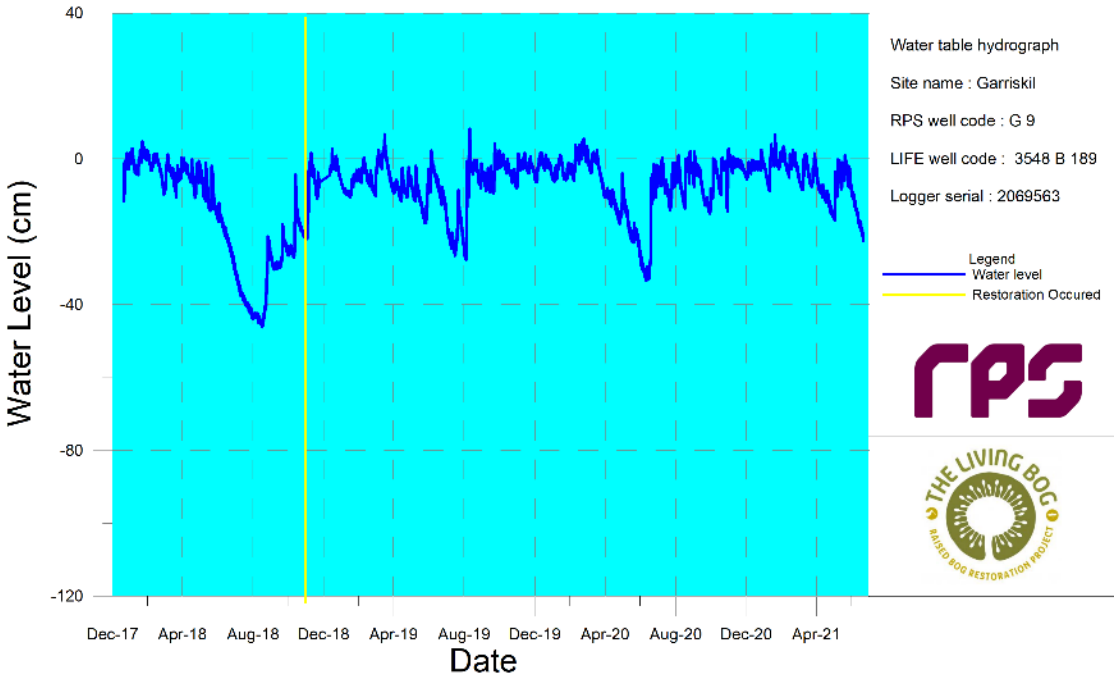

Figure 3-104 Level Logger data recorded between December 2017 and June 2021 at well G 9, Garriskal Bog SAC.

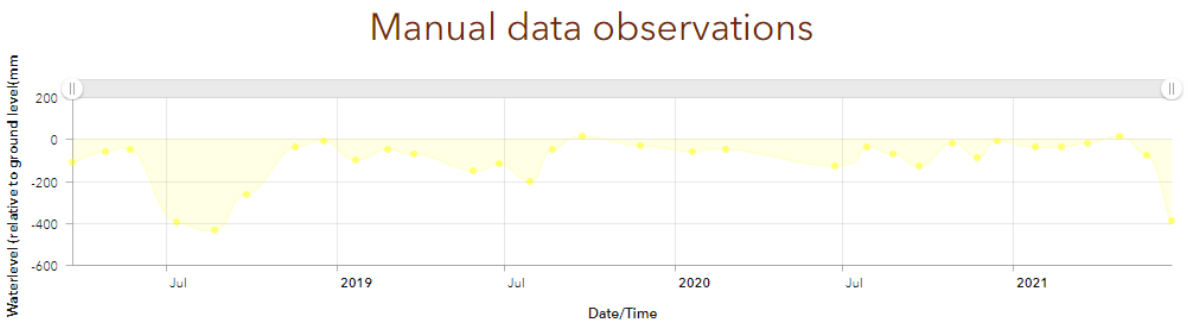

Figure 3-105 Hydrograph of manual monthly water levels G 9, Garriskill Bog SAC

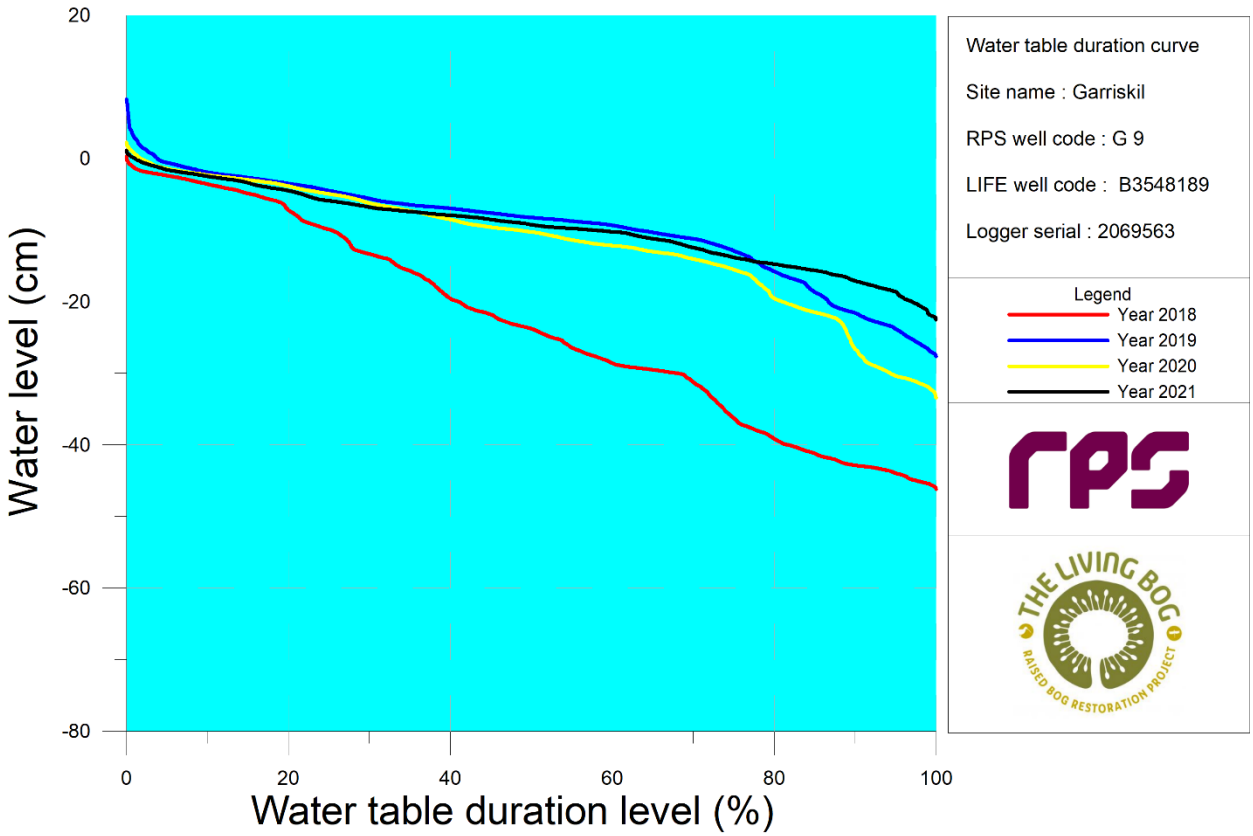

Figure 3-106 Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well G 9, Garriskal Bog SAC.

Data obtained from the level logger installed at G 11 (Figure 3-107) demonstrates a slight positive change in water levels following the completion of site-wide works in November 2018. Prior to restoration, water levels recorded in G 11 fluctuated close to the ground surface in the winter months, however, water levels experienced significant falls to -40cm between April and September of 2018. After restoration water levels remained closer to the surface compared to the pre-restoration levels for the remainder of the recoding period. Several slight falls can be observed in July/August of 2019 and 2020 but these drops are not as sharp as those observed in the prior to restoration, falling to just under -20cm.

The manual data records for G 11 (Figure 3-109) display similar improvements in hydrology post restoration with water levels rising and never dropping to levels observed prior to restoration. The positive change in water levels is also reflected in the duration curve generated (Figure 3-109). Clear improvements were observed post-restoration, with a difference of 21cm between the pre-post restoration annual D90 values. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area and potentially highlights that the model is currently underpredicting the potential extent in these areas.

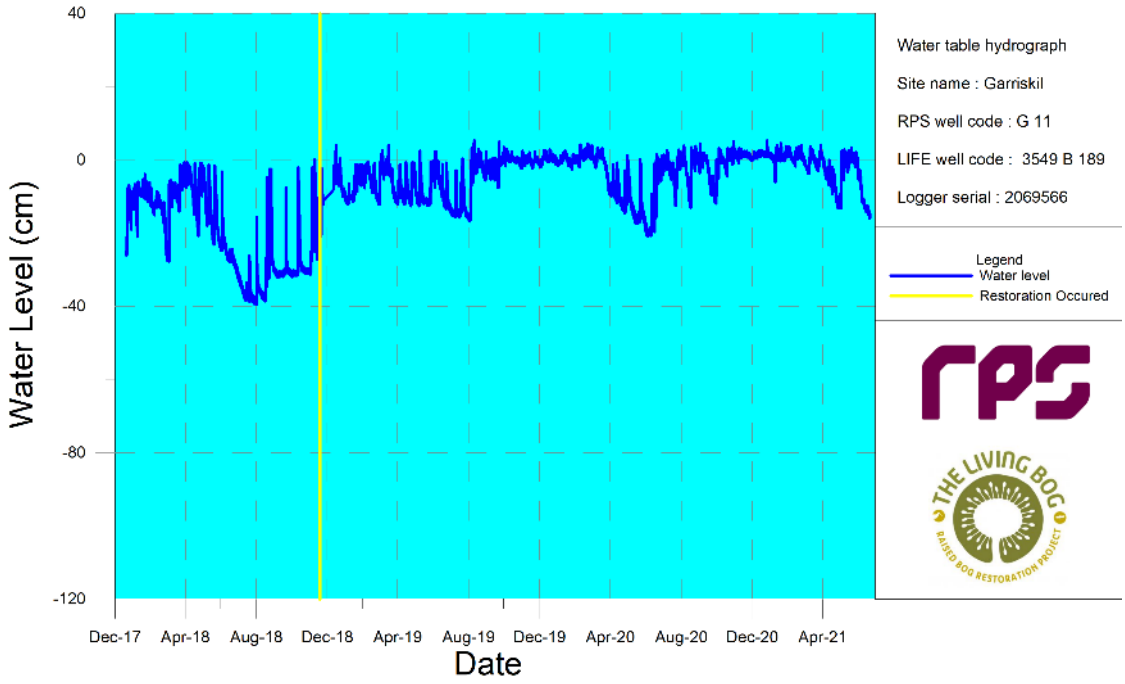

Figure 3-107 Level Logger data recorded between December 2017 and June 2021 at well G 11, Garriskal Bog SAC.

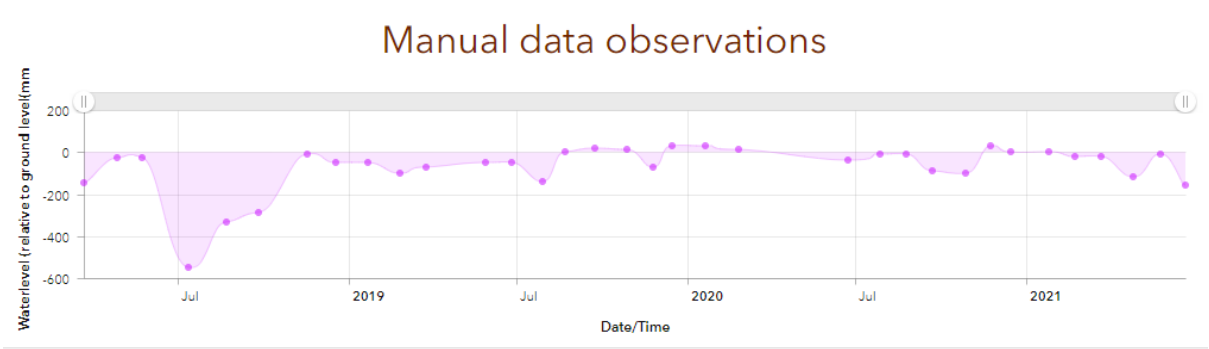

Figure 3-108 Hydrograph of manual monthly water levels G 11, Garriskil Bog SAC

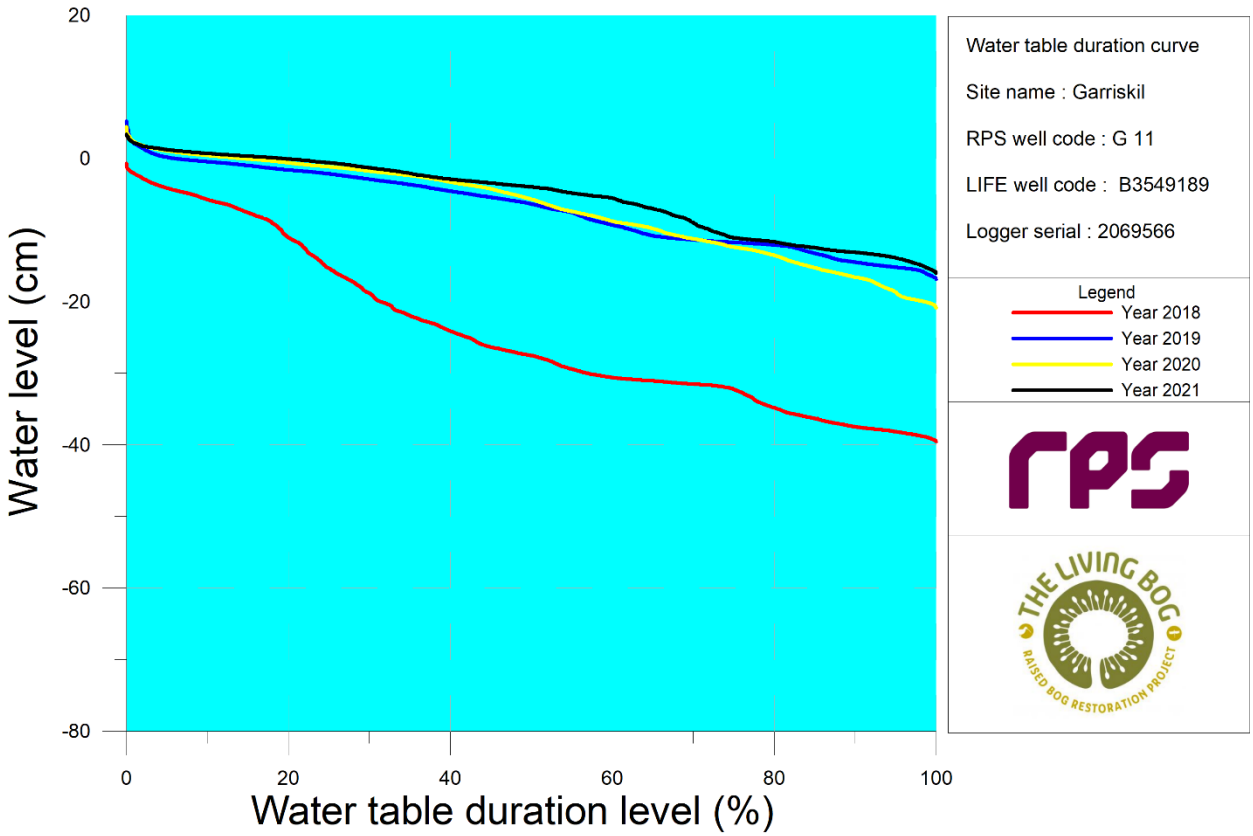

Figure 3-109 Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well G 11, Garriskal Bog SAC.

3.6.7.3 High Bog

In a bid to evaluate and quantify the effects of restoration measures, wells G 4S, G 5S, and G 6S were placed in regions of high restoration potential on the high bog of Garriskil Bog SAC (Figure 3-110).

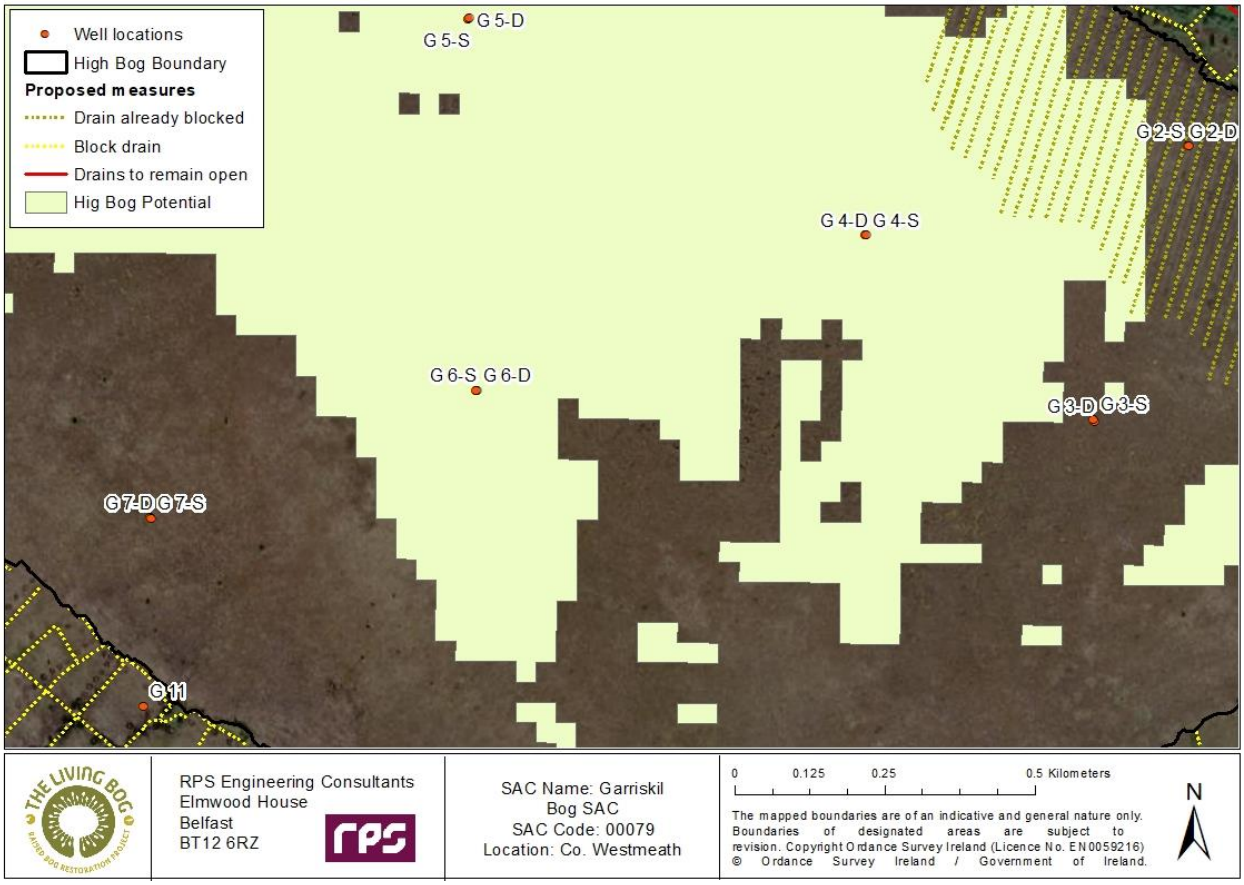

Figure 3-110 Shows the location of wells G 2S, G 3S, G 4S, G 5S, G 6S and G 7S on the high bog of Garriskil Bog SAC

The data obtained from the manual records at well G 4S (Figure 3-110) indicate slight improvement. Post restoration water levels rose and fluctuated around the ground surface. Water levels never fell to levels recorded prior to restoration. Similar results can be seen in well G 5S (Figure 3-112), with a slight positive change in water levels. However, at this well, the observed positive changes are on a smaller scale Data records at well G 6S (Figure 3-113) indicate that this area did not see a positive change in hydrology as a result of restoration measures as demonstrated by the similar trend in the summers pre and post-restoration. It must be taken into account that this area was already in good hydrological condition prior to restoration.

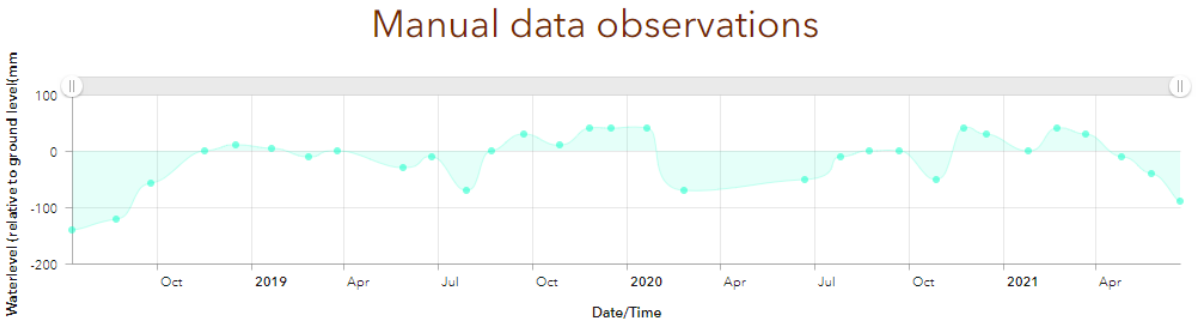

Figure 3-111 Hydrograph of manual monthly water levels G 4S, Garriskill Bog SAC

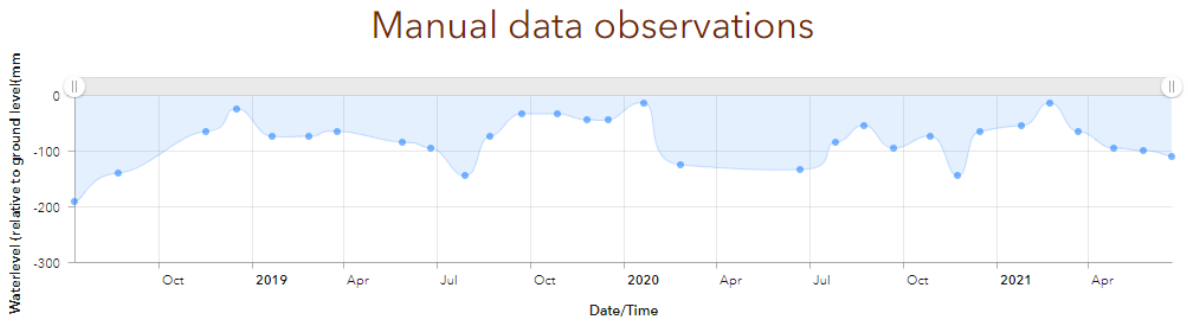

Figure 3-112 Hydrograph of manual monthly water levels G 5S, Garriskill Bog SAC

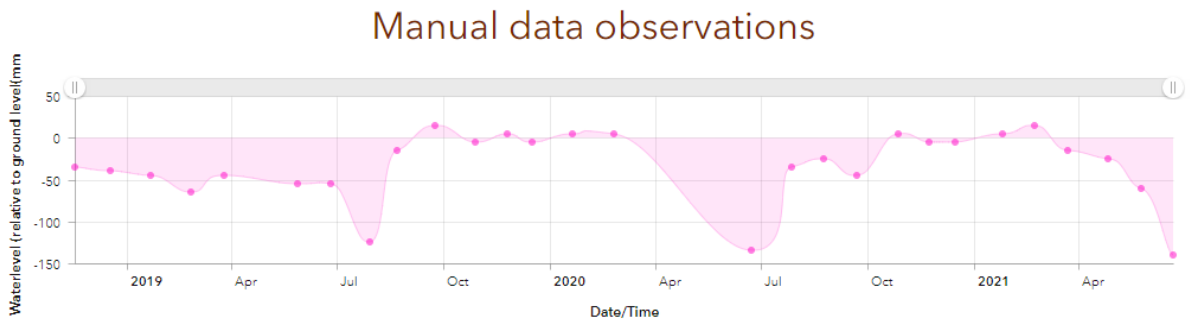

Figure 3-113 Hydrograph of manual monthly water levels G 6S, Garriskill Bog SAC

3.6.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.6). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration The largest increases were noted in all cutover wells. Significant changes were observed on the high bog with multiple wells in areas designated as DRB or Supporting High Bog now displaying a post-restoration hydrological regime capable of supporting ARB.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Garriskil	G10	Cutover	PFH	-55.08	-6.90
Garriskil	G11	Cutover	Non-PFH	-37.46	-16.57
Garriskil	G8	Cutover	PFH	-72.88	-8.78
Garriskil	G9	Cutover	Non-PFH	-42.84	-26.60
Garriskil	G1-S	High Bog	DRB	-38.38	-23.00
Garriskil	G2-S	High Bog	DRB	-26.21	-11.00
Garriskil	G3-S	High Bog	DRB	-26.04	-9.70
Garriskil	G4-S	High Bog	ARB	-13.70	-8.00
Garriskil	G5-S	High Bog	ARB	-18.60	-12.50
Garriskil	G6-S	High Bog	DRB	N/A	N/A
Garriskil	G7-S	High Bog	DRB	-34.52	-12.90

Table 3.6: 90th percentile water levels at Garriskil Bog SAC, pre and post-restoration.

3.7 Killyconny Bog SAC

3.7.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests Killyconny Bog SAC and adjacent lands to be underlain entirely by amalgamated Silurian sandstones, greywacke and shales (Figure 3-114). This typically denotes a non-homogenous unit, often comprising green-grey, medium to thickly bedded, coarse and very fine-grained Tae greywackes, with dark grey, thinly bedded, poorly graded, quartzose fine sandstone to siltstone units and in this region is associated with generally unproductive (locally), low vulnerability aquifer units. As such, contributions to in-channel flows from processes of groundwater recharge are thought to be negligible apart from small, localised areas.

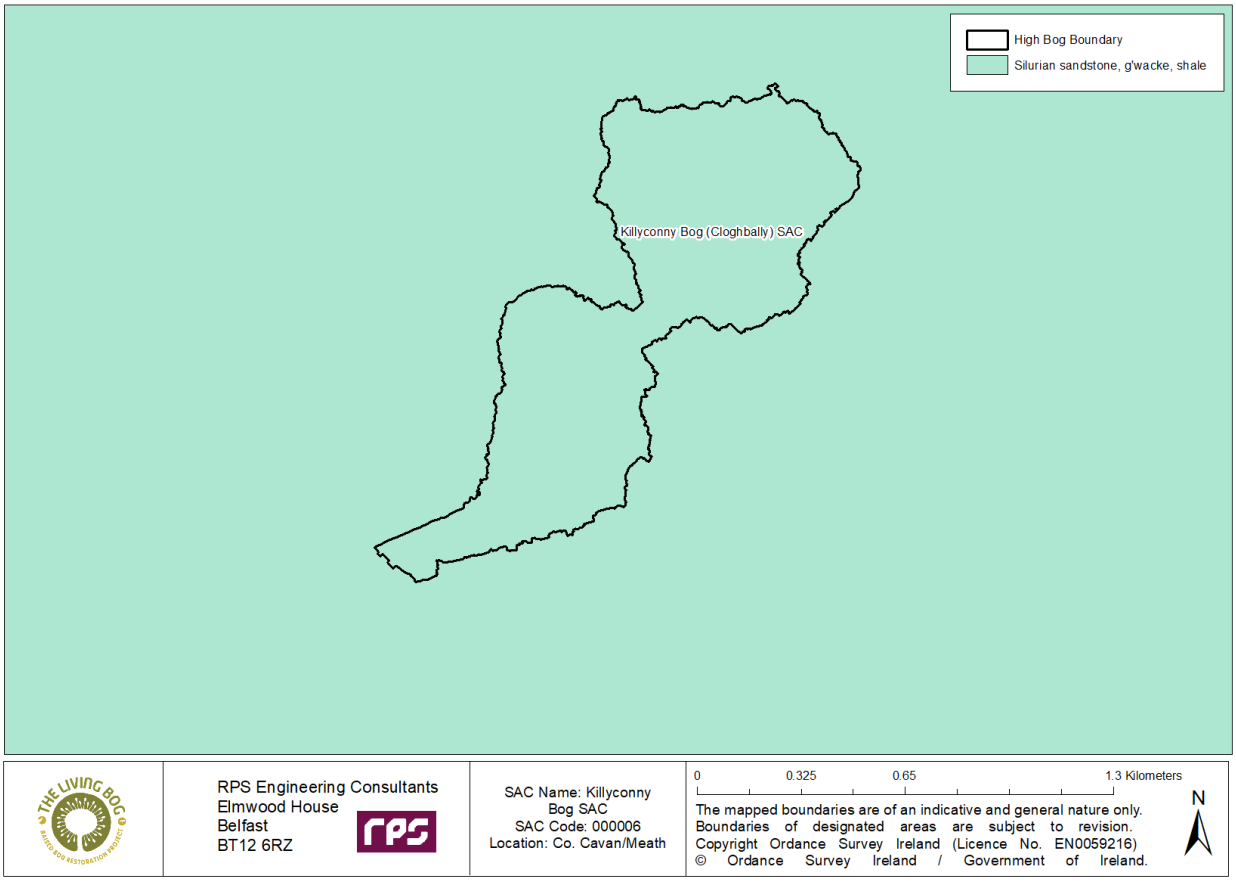

Figure 3-114: Simplified geology of Killyconny Bog SAC.

3.7.2 Ecotope map

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-115). During the last monitoring survey (2018) it was noted, that Killyconny Bog SAC consists of 3.91 ha of Active Raised Bog (ARB) consisting of areas of central and sub-central.

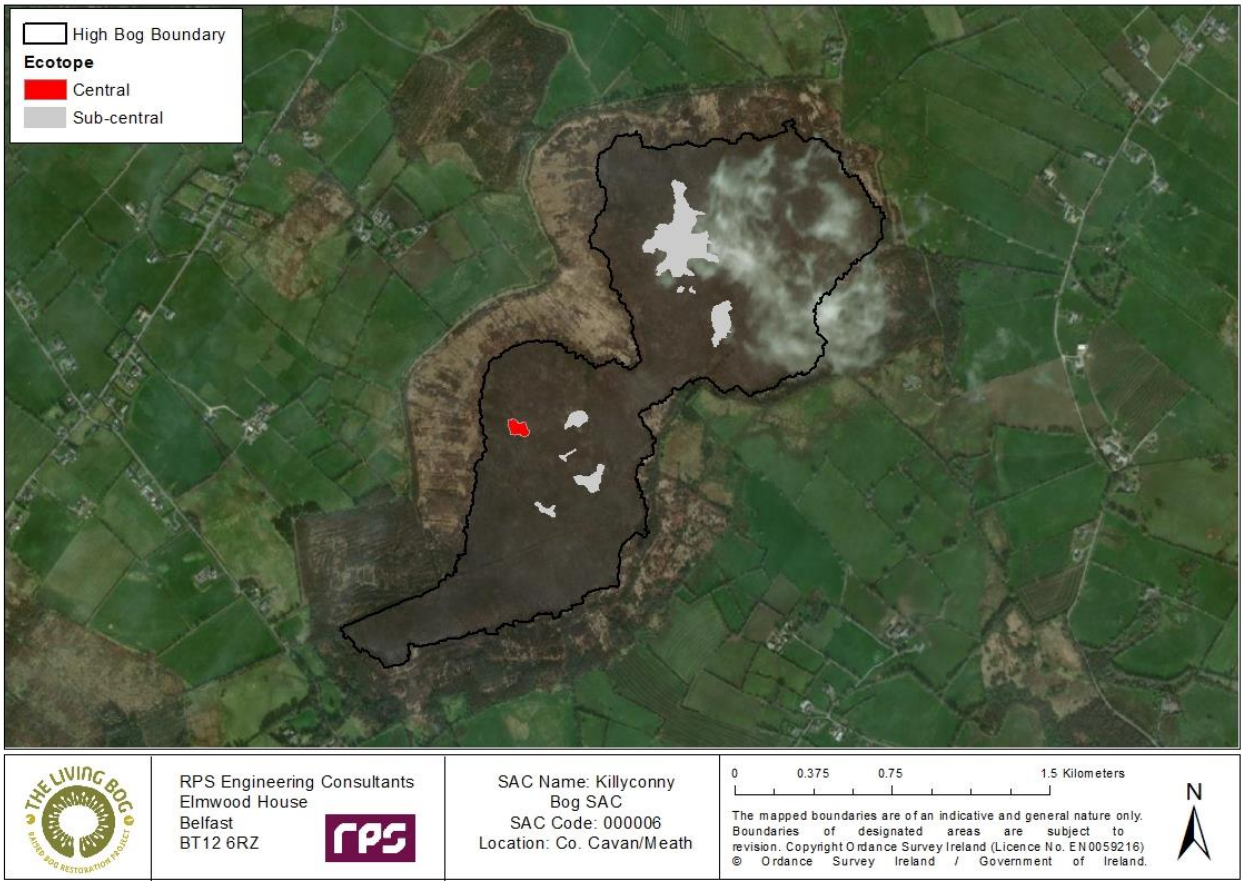

Figure 3-115 Ecotope mapping carried out for Killconny Bog SAC

3.7.3 Proposed restoration plan

The restoration plan for Killyconny Bog SAC identified functional drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. To combat surface flows on the high bog and adjacent cutover bog, the installation of peat dams (reinforced with plastic as required) was recommended across 12.39km of channels both on the high bog and cutover.

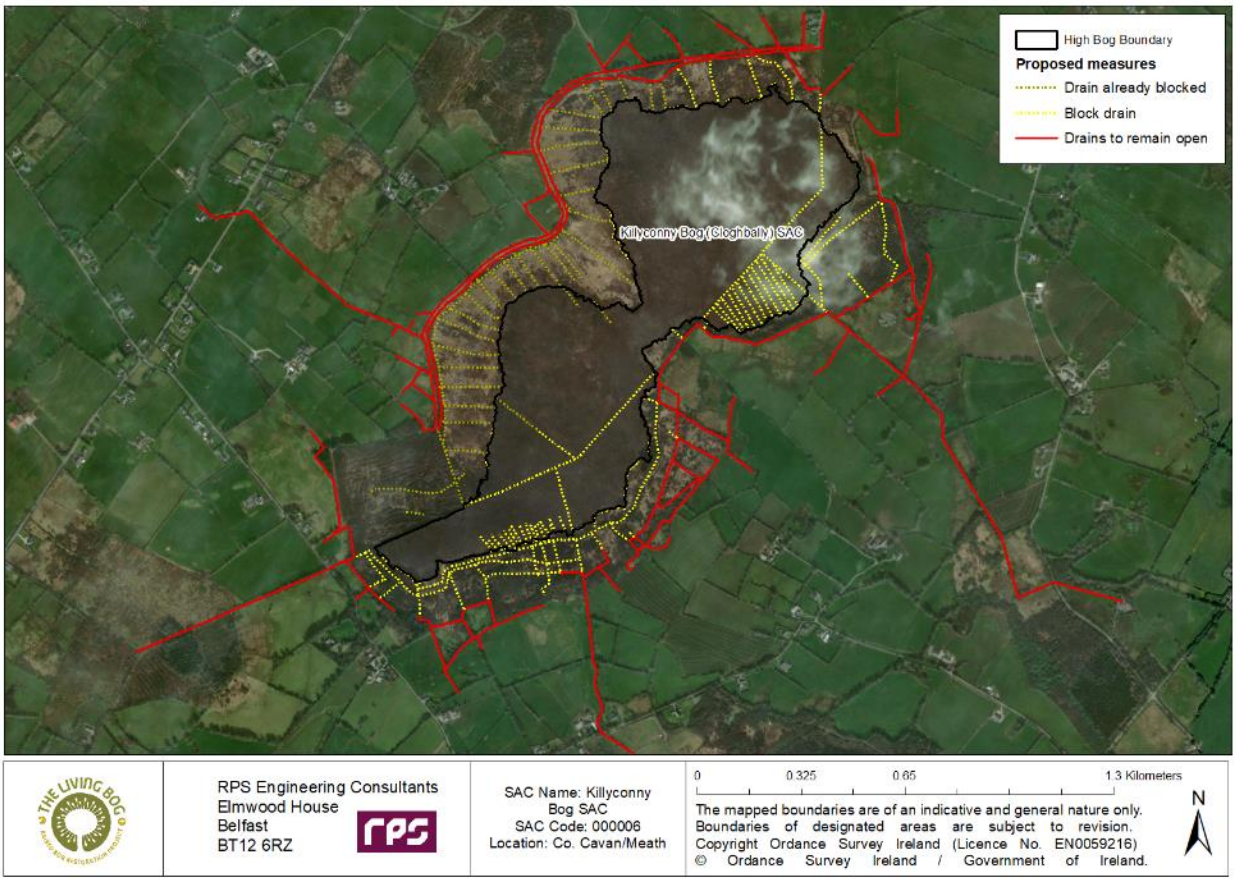

Figure 3-116 Restoration measures specified in support of hydrological goals.

3.7.4 Restoration potential

Eco-hydrological modelling of the restoration potential on Killyconny Bog SAC, excluding current areas mapped as ARB, suggested as much as 9.3 ha of habitat had the potential to be positively impacted by restoration works, with 4.8 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 4.5 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-117).

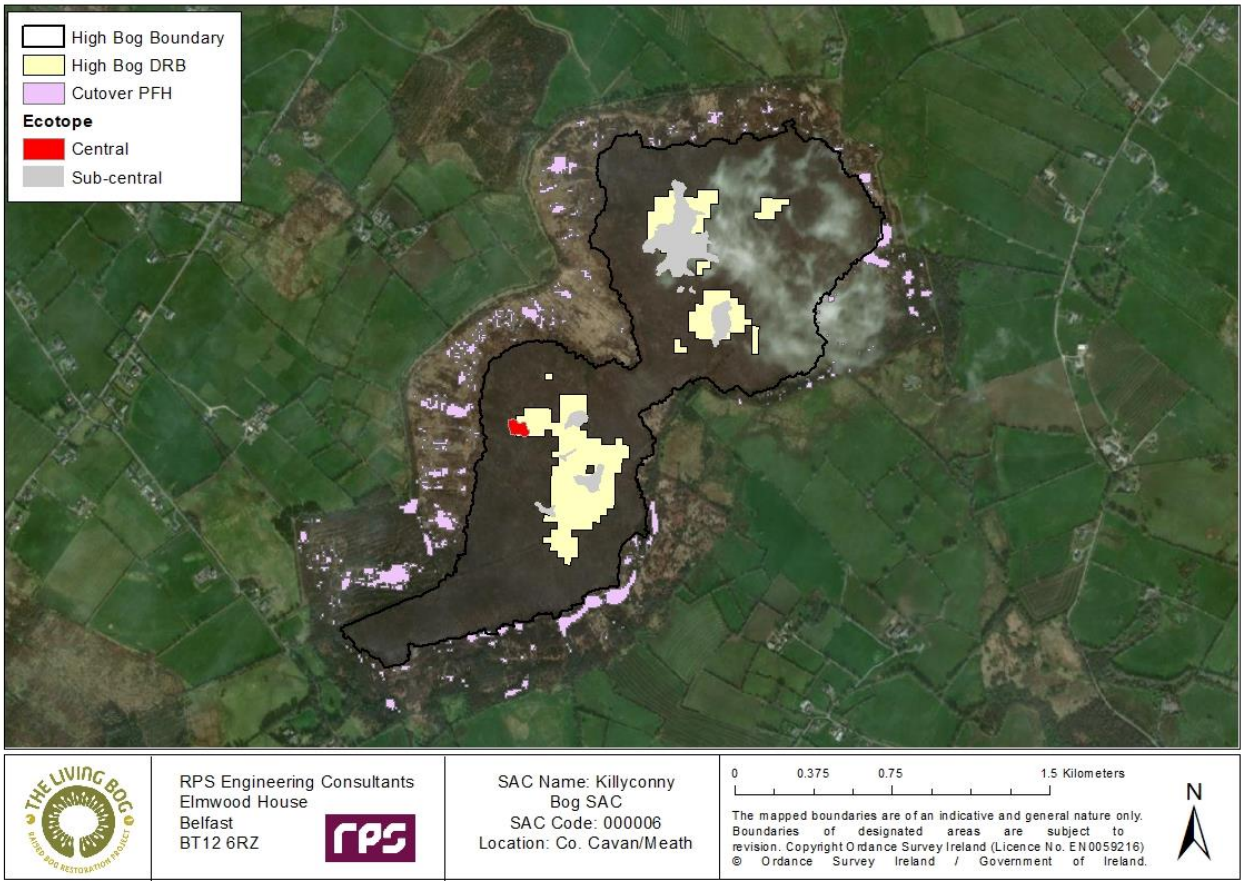

Figure 3-117 Restoration potential of Killyconny Bog SAC as outlined by eco-hydrological modelling.

3.7.5 Deployed monitoring network

A monitoring network comprising a mixture of 26 shallow phreatic wells (Figure 3-118) was subsequently installed on Killyconny Bog SAC. On the high bog, 10 phreatic wells were installed, accompanied by 8 deep piezometers to monitor vertical hydraulic gradients. On the cutover, 8 phreatic wells were installed. A total of 4 water level loggers were spread amongst the wells. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic, whilst those equipped with loggers were set to automatically record levels in 15-minute intervals and downloaded on a quarterly basis. A barometric logger was also located on the site and was installed to monitor changes in atmospheric pressure and used to barometrically correct the water logger data, however, a technical error meant a lot of this data could not be used. Water level readings were barometrically corrected using the barometric logger installed on the nearby site of Ardagullion Bog SAC, located approx. 36km away.

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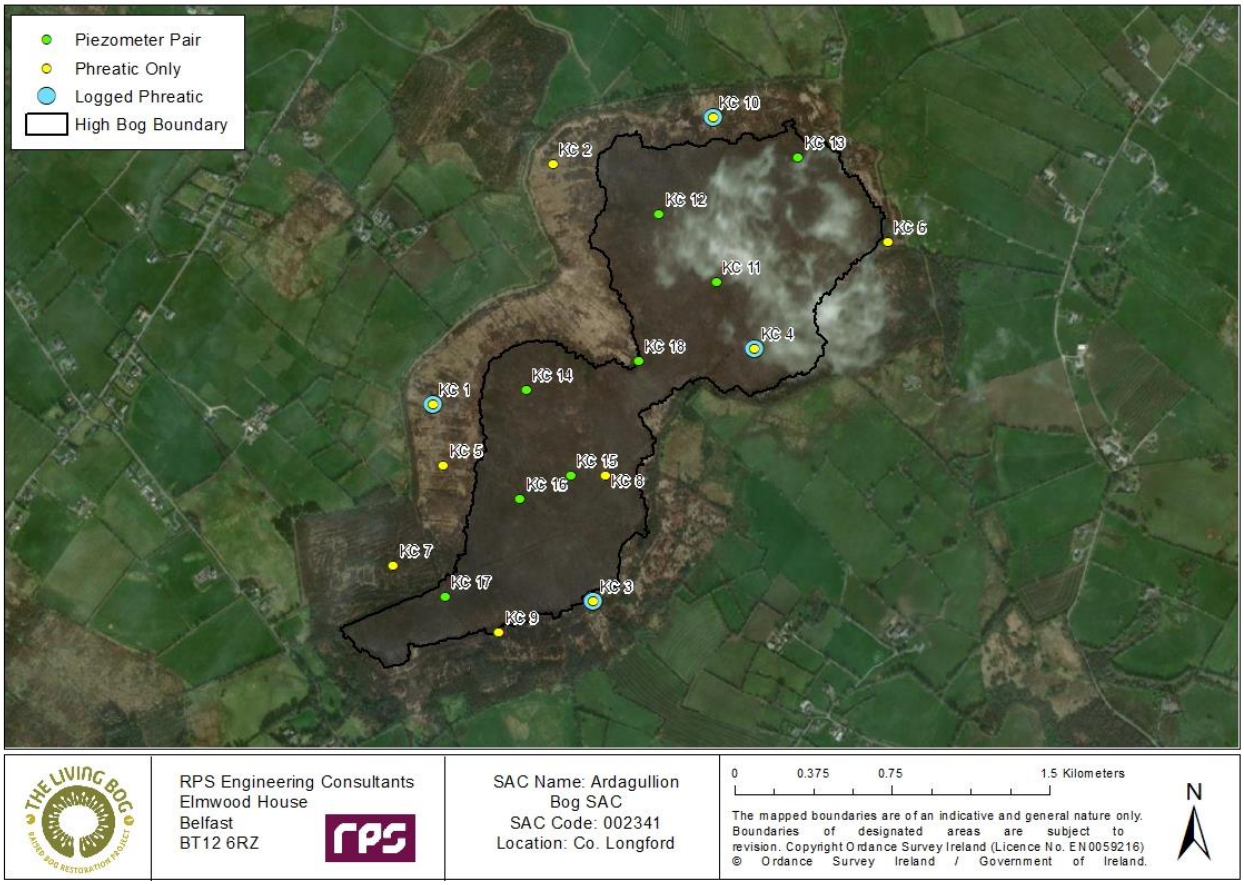


Figure 3-118 Hydrological monitoring network installed and operating on Killyconny Bog SAC.

3.7.6 General field observations

Owing to regular site visits, RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. For instance, on the western cutover, significant re-wetting was evident from a barrier dam installed as part of an earlier restoration project. However, re-wetting was mainly confined to localised topographic low points, with higher areas remaining dry. To increase the effectiveness of measures in the area, cell bunding was trialled in three separate zones. Although no hydrological monitoring equipment was installed in the vicinity of these bunds, significant re-wetting was observed during site walkovers post-construction. Ecological monitoring should be conducted to report on the overall success of the measures as part of the AfterLIFE programme.

Figure 3-119: Rewetting observed on Killyconny Bog SAC, in cell bunds where the water table came up to the surface throughout the year

Notably, an overspill weir, which was constructed from timber during the installation of the original barrier dam started to show signs of failure and there was concern that this may fail in the near future, undoing the positive re-wetting work that had been achieved. A steel weir was retrofitted into the barrier dam and the old timber weir was decommissioned. The same design level was set to maintain the positive results currently observed in this section of cutover (Crowley & Smith 2002). A large drain on the South-Eastern cutover and another drain on the North-Eastern cutover could not be blocked due to agreements with landowners not being reached. These areas remained dry throughout the study and should be prioritised for future restoration works if an agreement can be reached with the landowner.

3.7.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Killyconny Bog SAC are presented with all supplementary results provided in Appendix A.

3.7.7.1 The Cutover

In a bid to evaluate and quantify the effects of restoration measures, wells KC 5 and KC 10 were placed in regions of high restoration potential in the cutover on Killyconny Bog SAC (Figure 3-120).

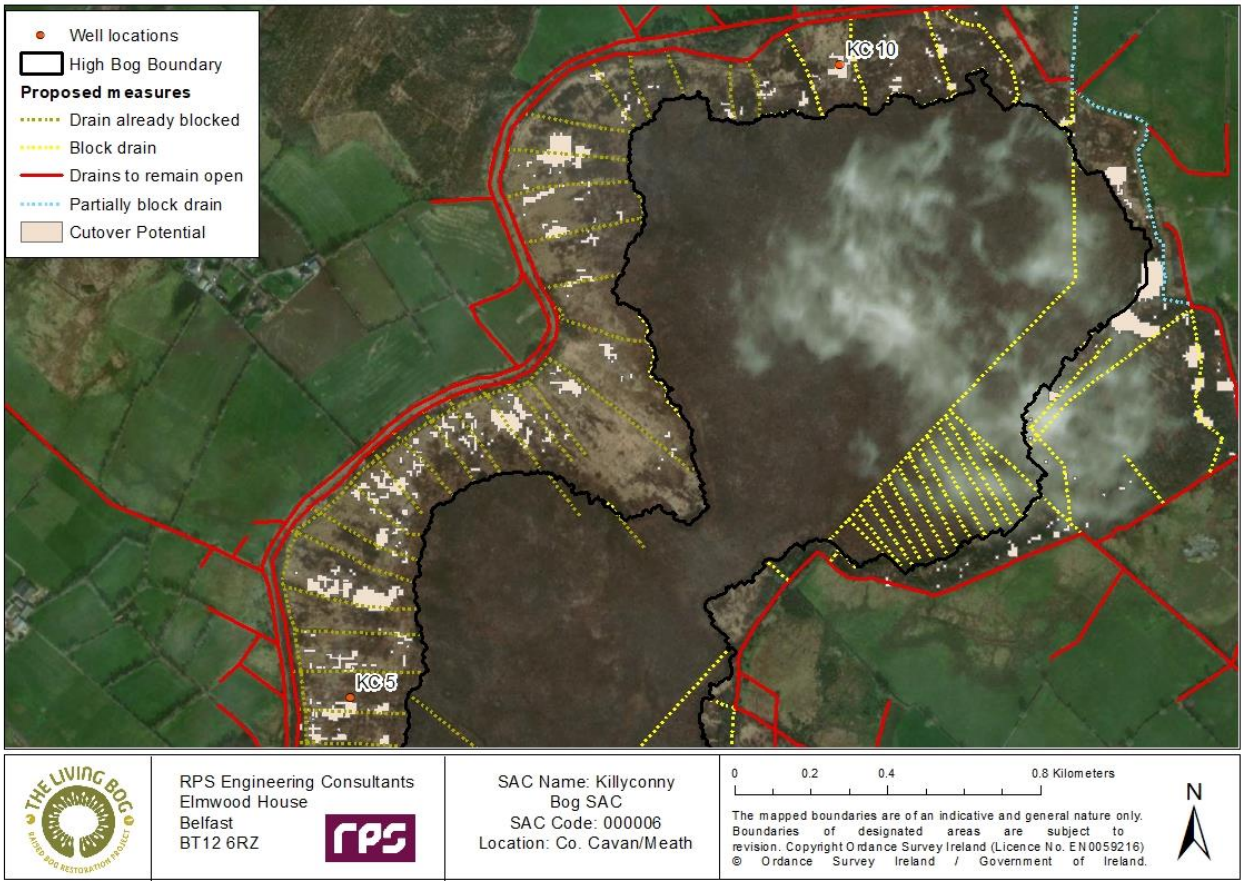


Figure 3-120 Location of wells KC 5 and KC 10 on the southern cutover in Killyconny Bog SAC

Figure 3-122 – Figure 3-125 illustrate results from the hydrological monitoring points located on the cutover at Killyconny Bog SAC. Figure 3-121 presents the hydrograph of manual monthly water levels at KC5 which demonstrates that the water table in the area was already at or above the surface predominately due to the impact of the barrier dam installed as part of an earlier restoration programme.

Contrastingly Figure 3-122 presents the hydrograph at KC10, as demonstrating the water table fluctuated extensively in the year of data recorded prior to restoration, dropping lower than 40cm below ground surface in the summer dry period (April – October) of 2018-19. For the most part, water levels remained predominantly beneath ground surface, rising above surface on a limited number of occasions. Following

restoration water levels rose and stayed consistently at or above ground surface for the majority of the remainder of the record length, dipping 40cm below the ground surface during the summer dry period of 2020 and dipping 20cm below the ground surface during the summer dry period of 2021.

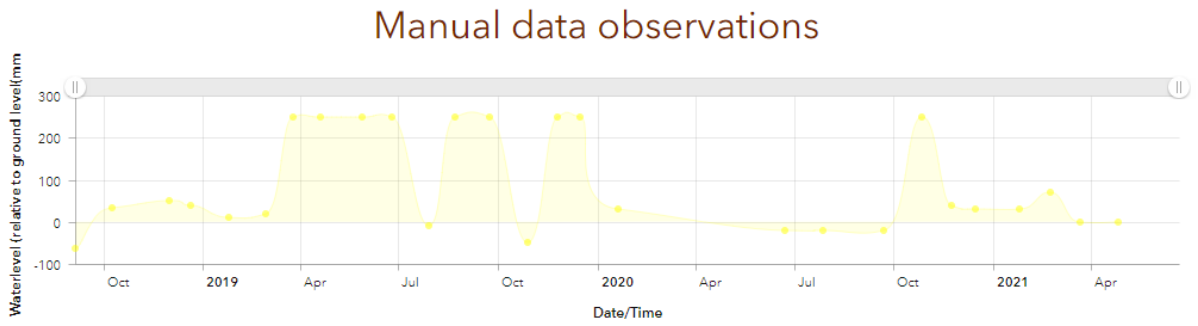


Figure 3-121 Hydrograph of manual monthly water levels K 5, Killyconny Bog SAC

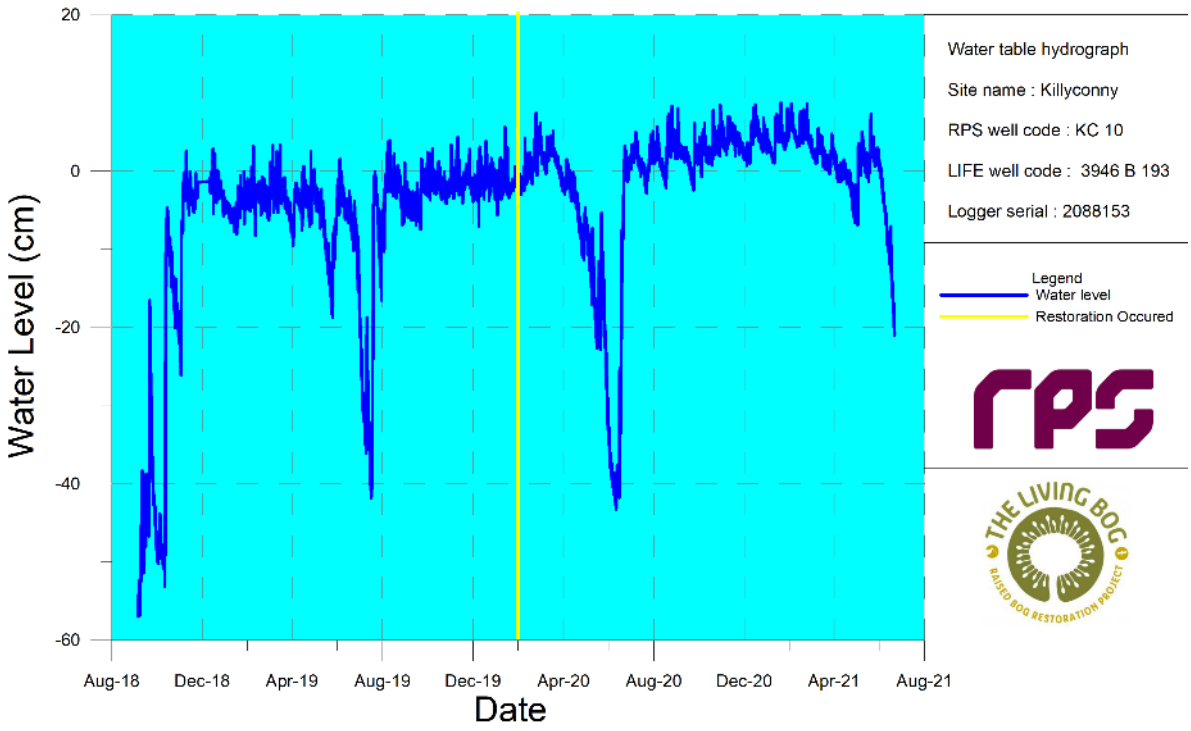


Figure 3-122: Level logger data recorded between August 2018 and August 2021 at well KC 10, Killyconny Bog SAC.

Manual measurements of water table depth obtained from KC10 (Figure 3-123) do not show similar results to that indicated from the logger data, with the water table rising to the surface in the winter of 2018/2019 and remaining there throughout the duration of the project. This highlights the importance of logger data and how sporadic manual measurements can miss large drawdown events.

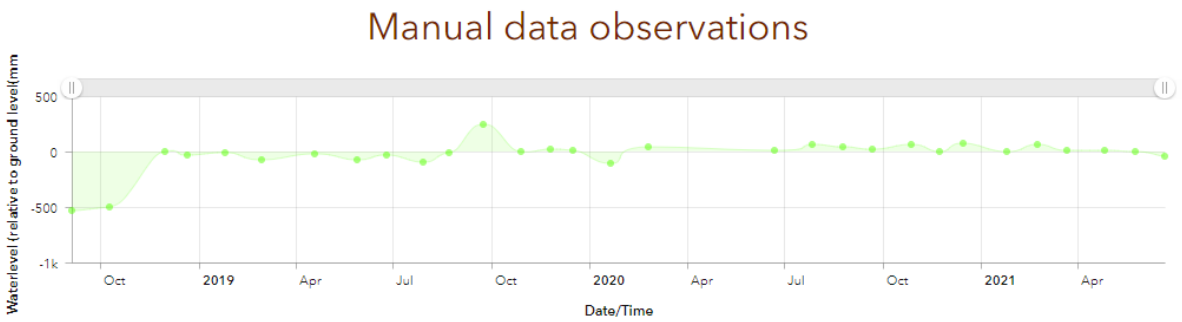


Figure 3-123: Hydrograph of manual monthly water levels KC 10, Killyconny Bog SAC.

3.7.7.2 High Bog

To investigate the impact restoration measures would have on the high bog at Killyconny Bog SAC, piezometers were located in areas currently defined as Active raised bog (ARB), Degraded Raised Bog (DRB) and areas of supporting high bog. Figure 3-124, shows the location of the high bog monitoring network at Killyconny bog SAC.

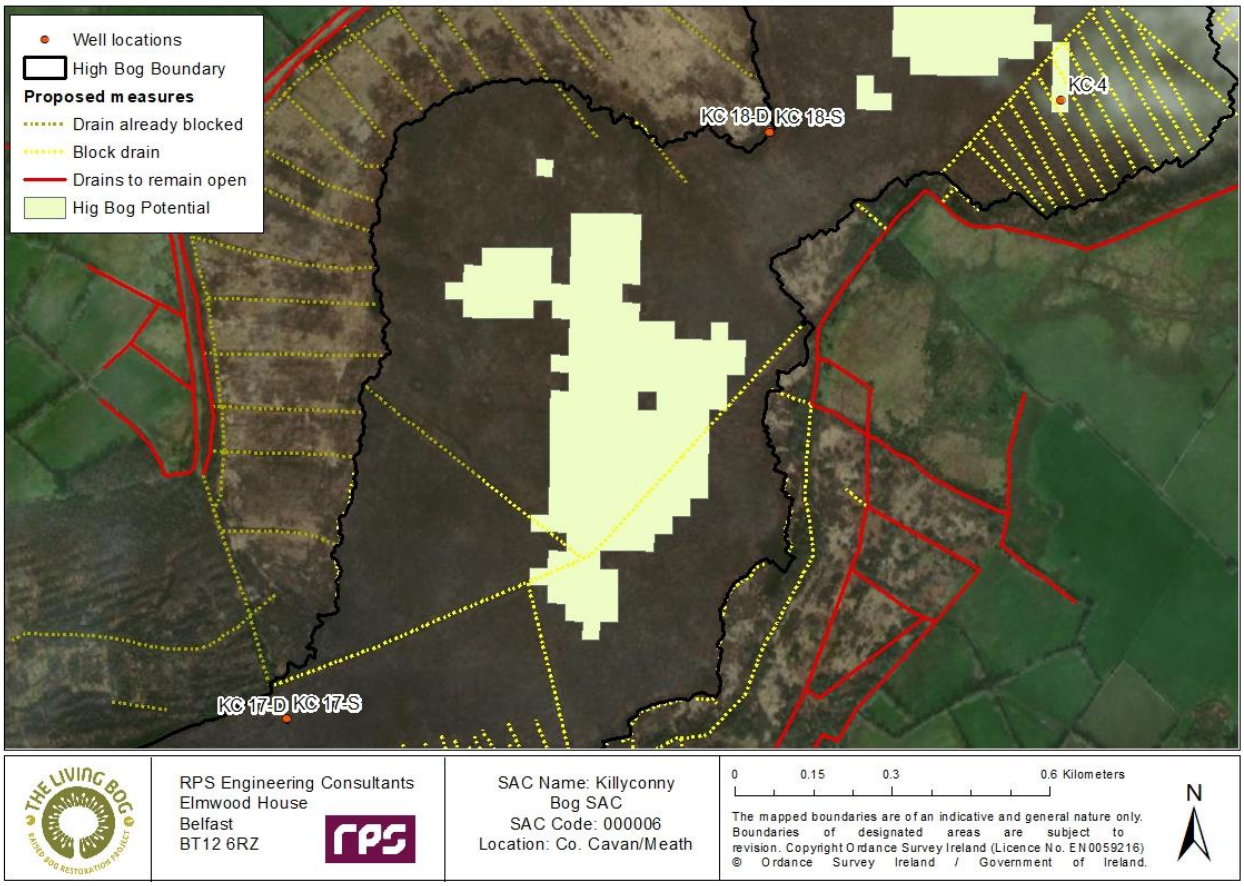


Figure 3-124 Location of well KC 4 on the high bog in Killyconny Bog SAC

Overall, modest responses to drain blocking was observed on the High Bog compared to cutover areas.. Water levels in ARB areas were observed close to the bog surface and remained so throughout the study, as expected. Limited fluctuations were also noted in areas of DRB or supporting high bog and it is recommended that longer-term data is collected to investigate the impact of drain blocking over time. Data obtained from KC 4 can be used to demonstrate the negligible variation in water levels observed pre/post-restoration on the high bog at Killconny Bog SAC which was representative of a majority of monitoring points on the high bog. Data observed by KC 4 (Figure 3-125) shows a limited response to the completion of restoration works when compared to pre-restoration levels. The manual record (Figure 3-126) for the same well during this period reveals water levels remained consistent with no significant drawdowns or rises observed. The water table duration curves for data collected from KC 4 (Figure 3-127) present similar results for the pre-restoration summer dry period in 2019 and the same period in 2020 and partly again in 2021.

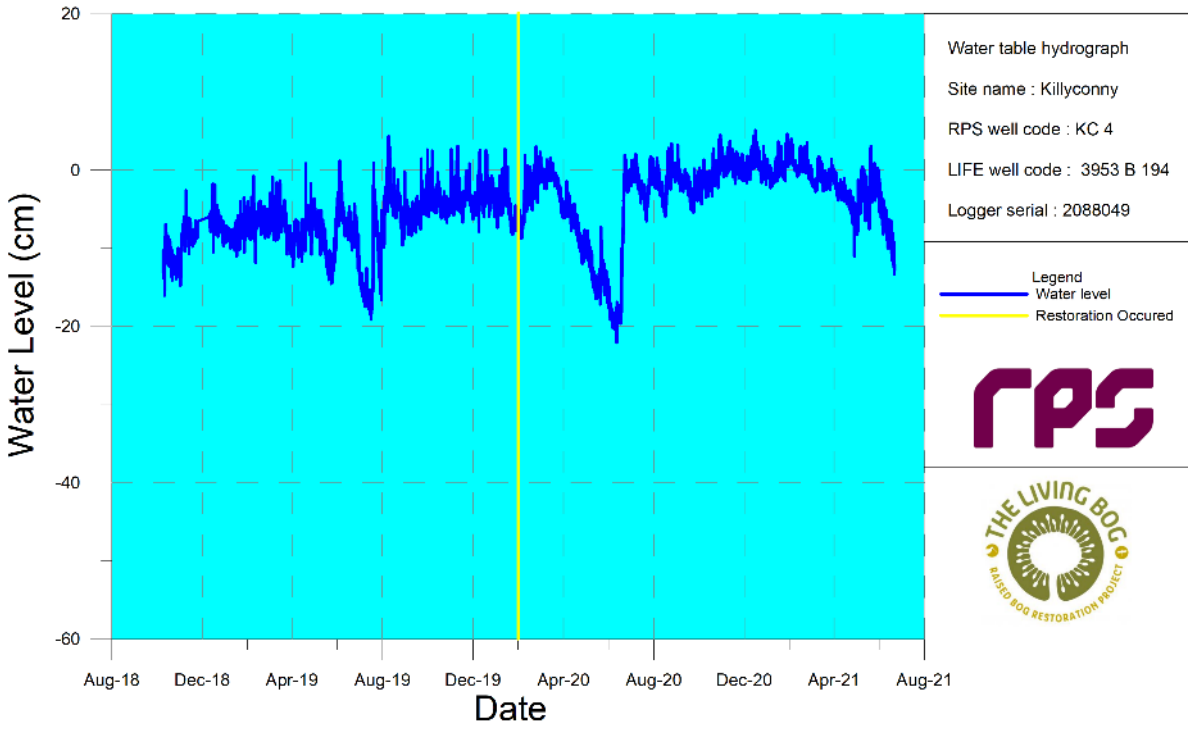


Figure 3-125: Level logger data recorded between August 2018 and August 2021 at well KC 4, Killyconny Bog SAC.

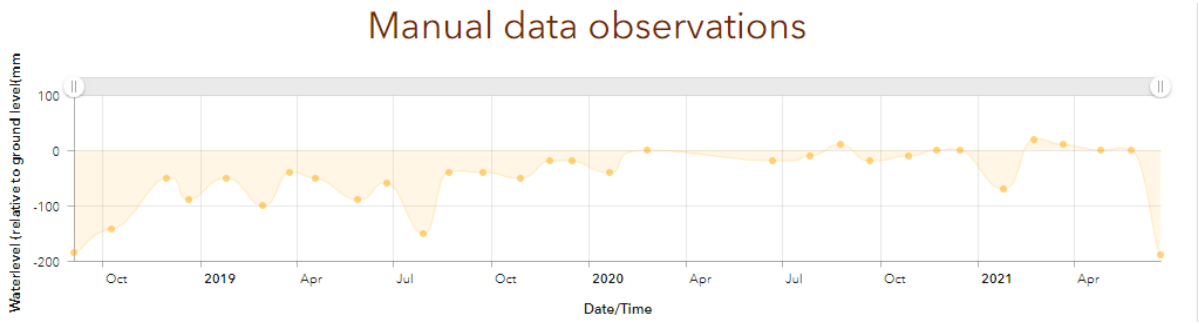


Figure 3-126: Hydrograph of manual monthly water levels KC 4, Killyconny Bog SAC

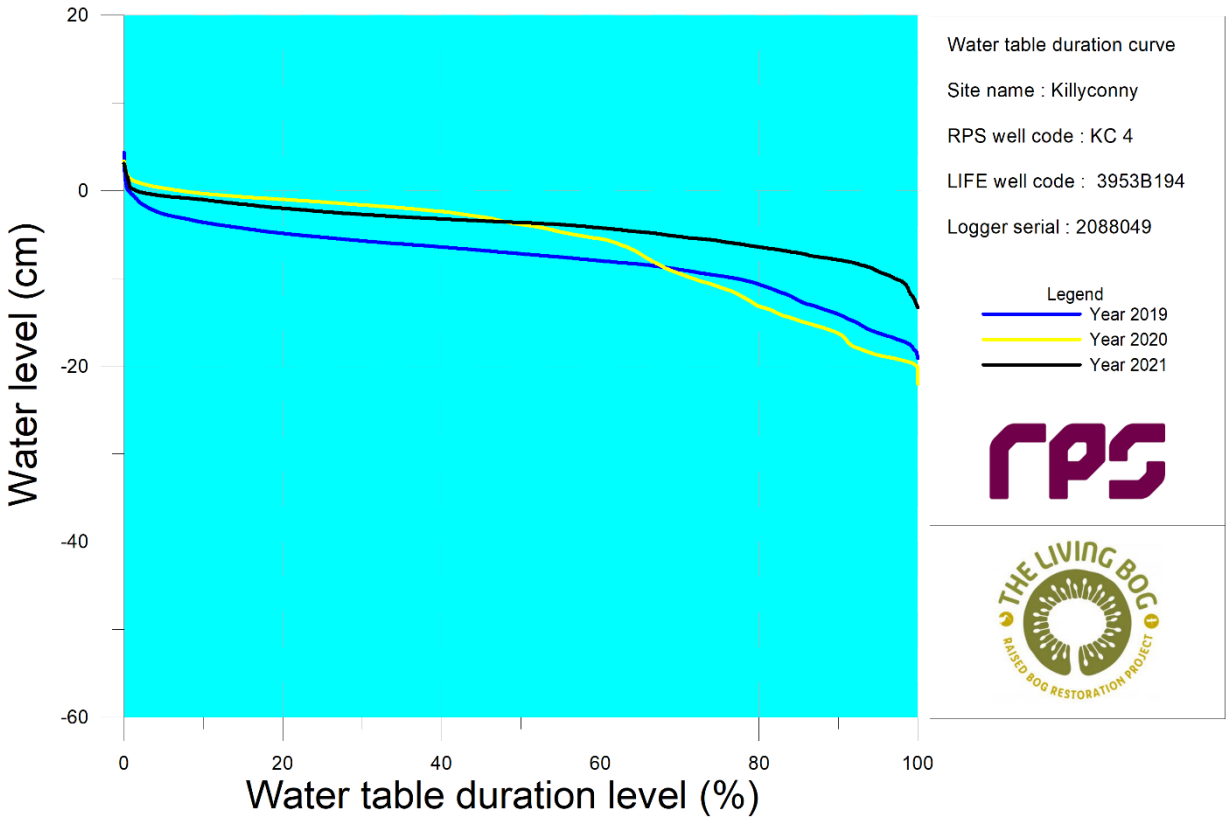


Figure 3-127: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well KC 4, Killyconny Bog SAC

3.7.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.6). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration. The largest increases were noted in all cutover wells. Significant changes were observed on the high bog with multiple wells in areas designated as DRB or Supporting High Bog now displaying a post-restoration hydrological regime capable of supporting ARB.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Killyconny	KC1	Cutover	PFH	-25.3	-3.2
Killyconny	KC10	Cutover	PFH	-53.7	-25.6
Killyconny	KC11-S	High Bog	Non-PFH	-24.9	-19.4
Killyconny	KC12-S	High Bog	DRB	-18.1	-21.6
Killyconny	KC13-S	High Bog	Non-PFH	-23.9	-17.7
Killyconny	KC14-S	High Bog	Non-PFH	-13.1	-12.2
Killyconny	KC15-S	High Bog	PFH	-13.2	-23.6
Killyconny	KC16-S	High Bog	Non-PFH	-25.6	-22.4
Killyconny	KC17-S	High Bog	Non-PFH	-34.98	-19
Killyconny	KC18-S	High Bog	DRB	-25.4	-27
Killyconny	KC2	Cutover	PFH	-29	0.7
Killyconny	KC3	Cutover	PFH	-28.6	-15.2
Killyconny	KC4	High Bog	PFH	-18.6	0
Killyconny	KC5	Cutover	PFH	-6.3	-44.8
Killyconny	KC6	Cutover	PFH	-66.1	-17
Killyconny	KC8	High Bog	PFH	-20.3	1.2
Killyconny	KC9	Cutover	PFH	-30.2	0

Table 3.6: 90th percentile water levels at Killyconny Bog SAC, pre and post-restoration.

3.8 Mongan Bog SAC

3.8.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests Mongan Bog SAC 'High bog' to be underlain entirely by courceyan limestones, whilst a small portion of adjacent lands to the south are also underlain by rocks of the Navan group (Figure 3-128). This typically denotes a non-homogenous unit, often comprising of irregularly bedded and nodular bedded argillaceous bioclastic limestones (wackestones and packstones), interbedded with fossiliferous calcareous shales and in this region is associated with moderately productive (locally), low vulnerability aquifer units. As such, contributions to in-channel flows from processes of groundwater recharge are thought to be small and localised

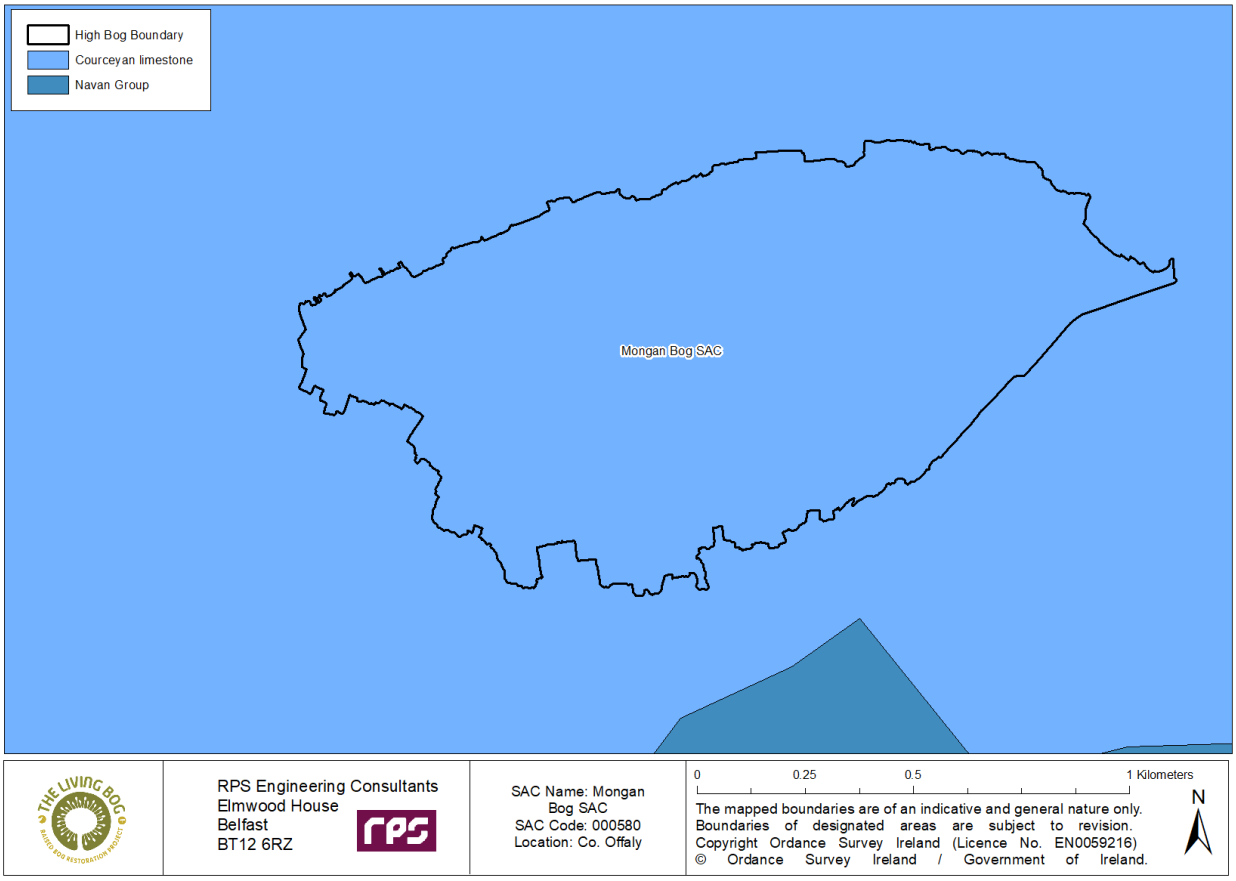


Figure 3-128: Simplified geology of Mongan Bog SAC.

3.8.2 Ecotope Map

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-129). During the last monitoring survey (2018) it was noted, that Mongan Bog SAC consists of 49.13 ha of Active Raised Bog (ARB) consisting of areas of central and sub-central ecotopes.

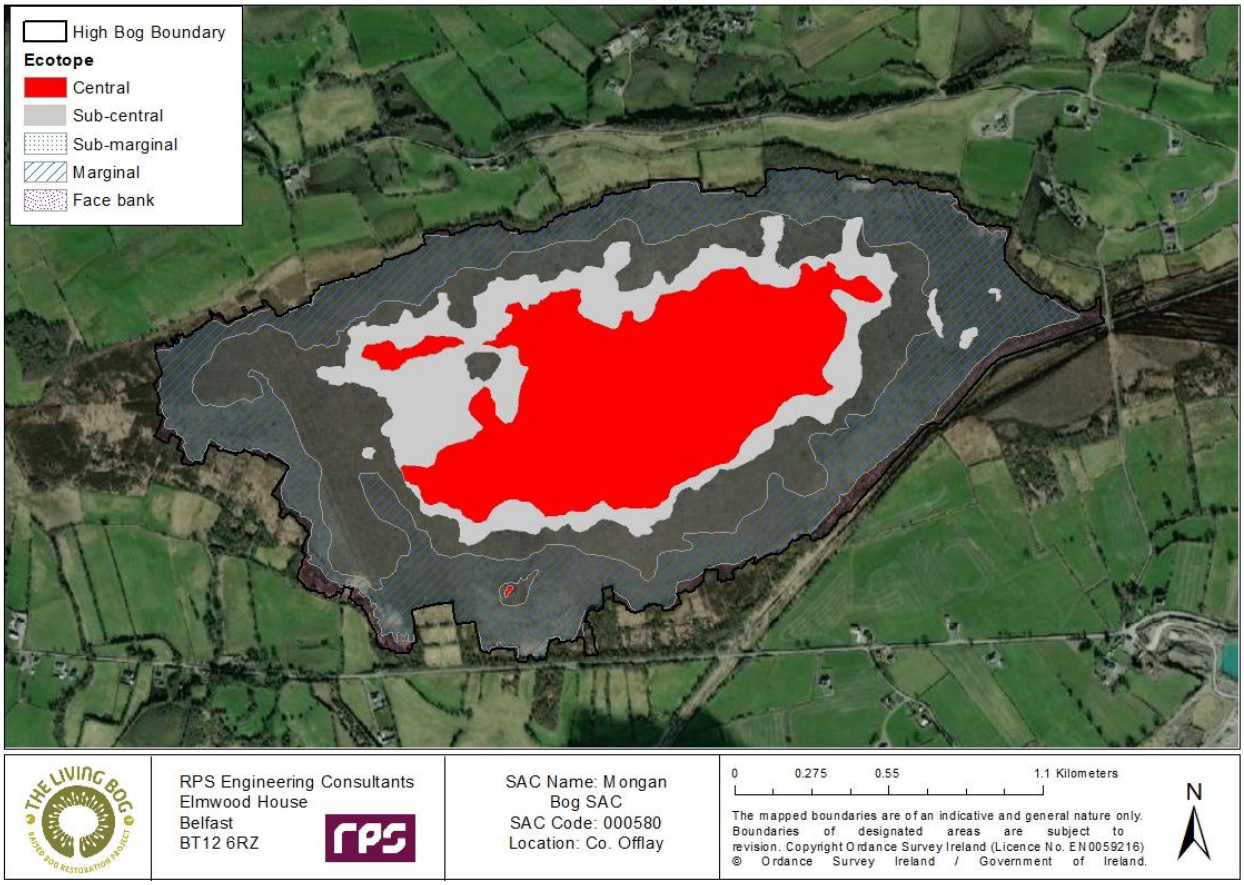


Figure 3-129 Ecotope mapping carried out for Mongan Bog SAC.

3.8.3 Proposed restoration plan

The restoration plan for Mongan Bog SAC (Figure 3-130) identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat forming (ARB) habitat. Overall, the installation of peat dams was recommended across 5.6 km of channels both on the high bog and cutover.

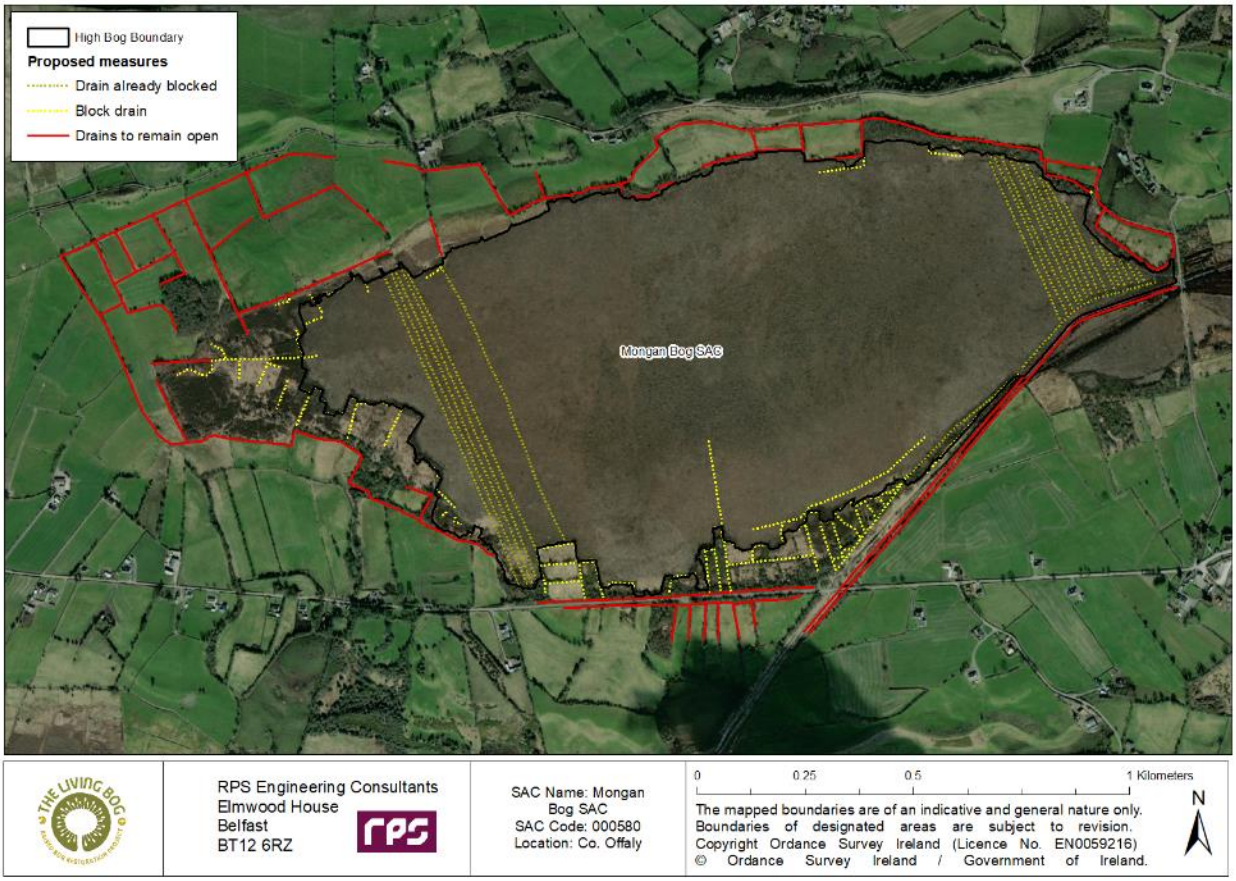


Figure 3-130: Restoration measures specified in support of hydrological goals.

3.8.4 Restoration potential

Eco-hydrological modelling of the restoration potential on Mongan Bog SAC, excluding current areas mapped as ARB, suggested as much as 14.5 ha of habitat had the potential to be positively impacted by restoration works, with 10.4 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 4.1 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-131).

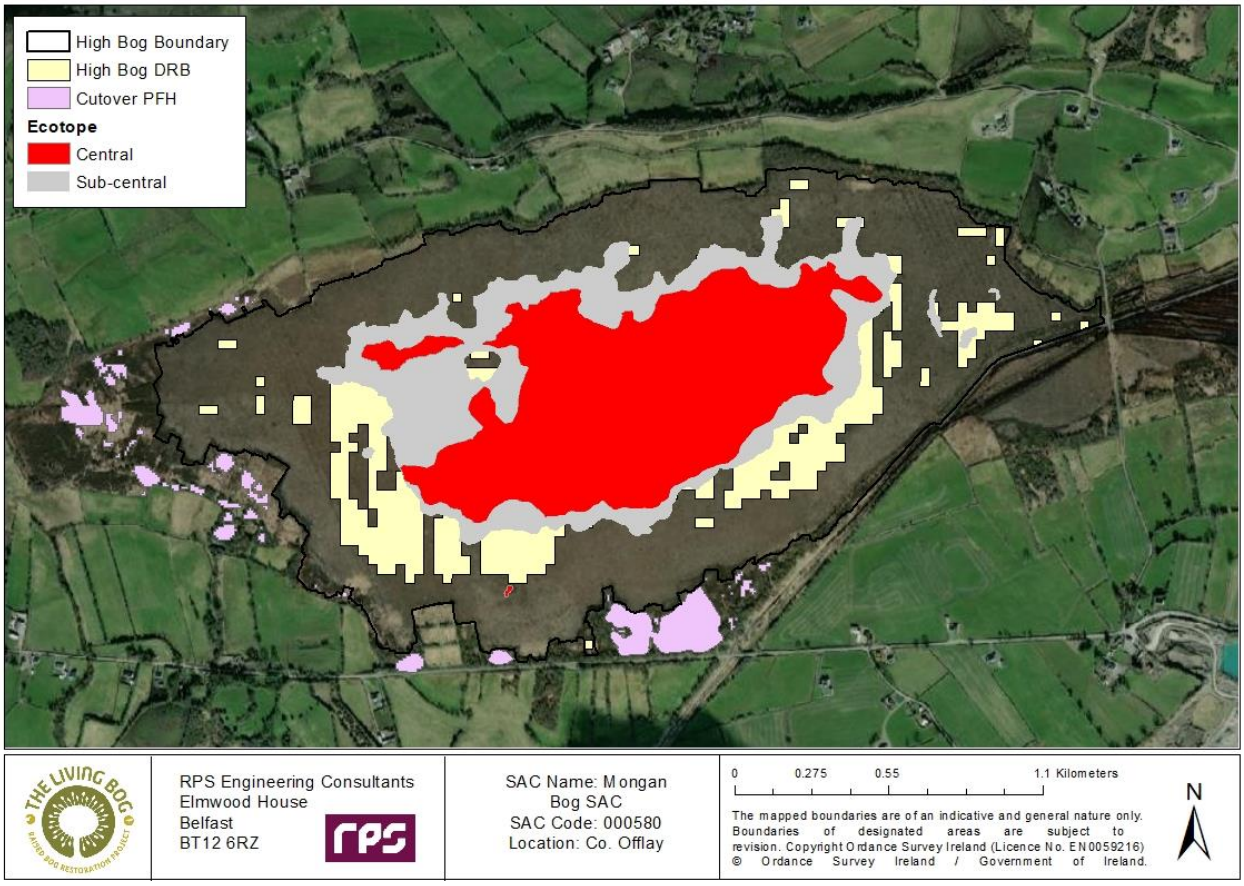


Figure 3-131: Restoration potential of Mongan Bog SAC as outlined by eco-hydrological modelling.

3.8.5 Deployed monitoring network

A monitoring network comprising a mixture of 17 shallow phreatic wells and deeper piezometric wells (Figure 3-132) was subsequently installed on Mongan Bog SAC. On the high bog, 5 phreatic wells were installed accompanied by 5 deep piezometers to monitor vertical hydraulic gradients. On the cutover 7 phreatic wells were installed. 2 water level loggers were installed at wells M 13 and M 1. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic. Loggers were set to automatically record levels at 15-minute intervals, the data was downloaded on a quarterly basis. Water level readings were barometrically corrected using the barometric logger installed on the nearby site of Moyclare Bog SAC, located approx. 7.5km South-East of the site.

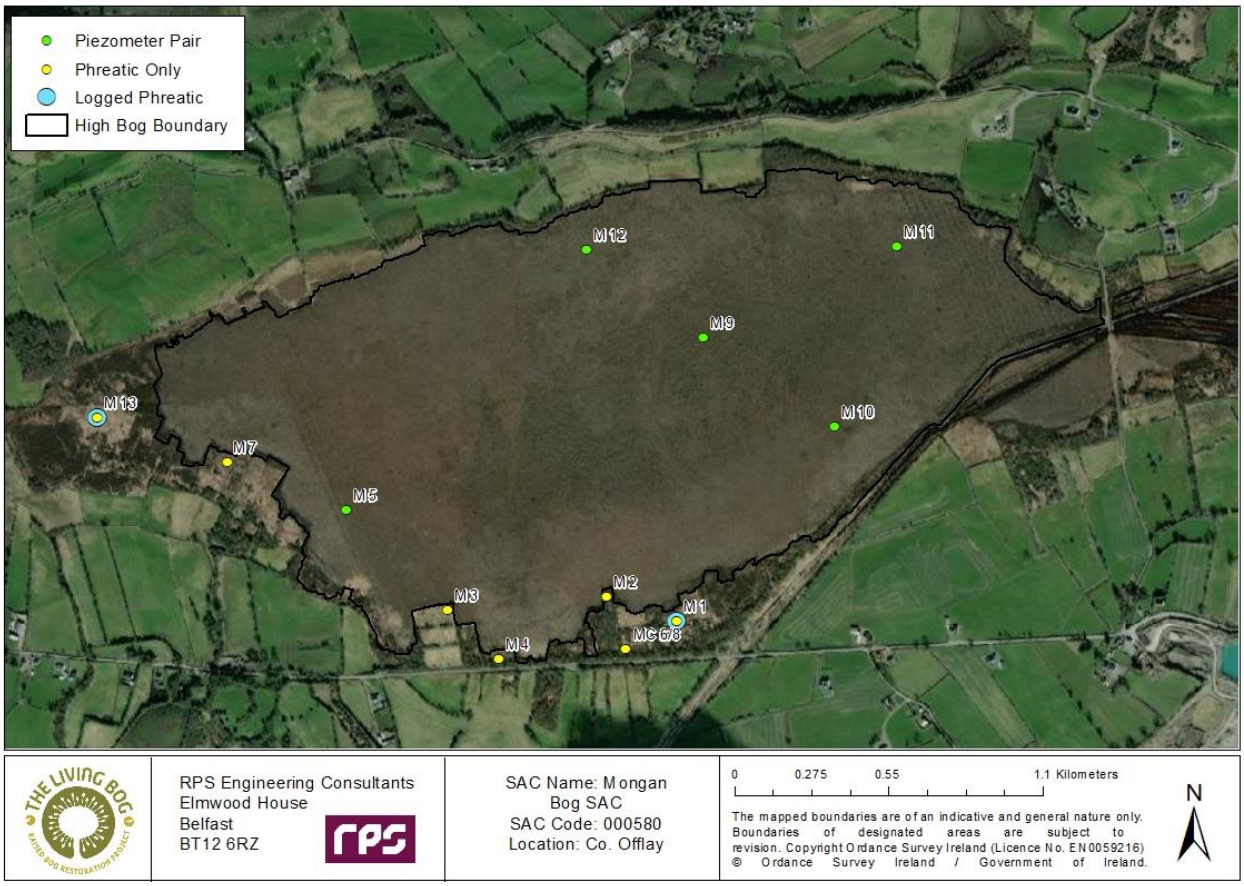


Figure 3-132: Hydrological monitoring network installed and operating on Mongan Bog SAC.

3.8.6 General field observations

Owing to regular site visits RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. For instance, in the Southern cutover in the vicinity of all hydrological monitoring locations, the ground surface has become significantly wetter following restoration with pools forming close to the main drain in both areas with the local the topography contributing to the rapid changes in hydrology (Figure 3-133). It was noted that excess water was pooling on this southern cutover, especially during the winter months. A report on this issue has been submitted to The Living Bog team, with ongoing discussion with stakeholders on the best approach to rectify the problem. On the Western cutover, a similar impact was observed over a large area where the water table rose to the surface and remained there year-round.

Figure 3-133: Rewetting observed on Mongan Bog SAC, where the water table came up to the surface throughout the year

On the high bog, conditions remain similarly wet and soft underfoot throughout the monitoring period, with limited changes observed however areas close to the main high bog drains did become noticeably wetter following restoration. However, given water table levels are generally closer to the ground surface in high bog areas anyway, hydrological changes are more difficult to observe visually than widespread rewetting of very dry cutover areas.

3.8.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Mongan Bog SAC are presented with all supplementary results provided in Appendix A.

3.8.7.1 Western Cutover

In a bid to evaluate and quantify the effects of restoration measures, both M7 and M13 were installed in regions of high restoration potential in cutover bog (Figure 3-134), West of the high bog itself.

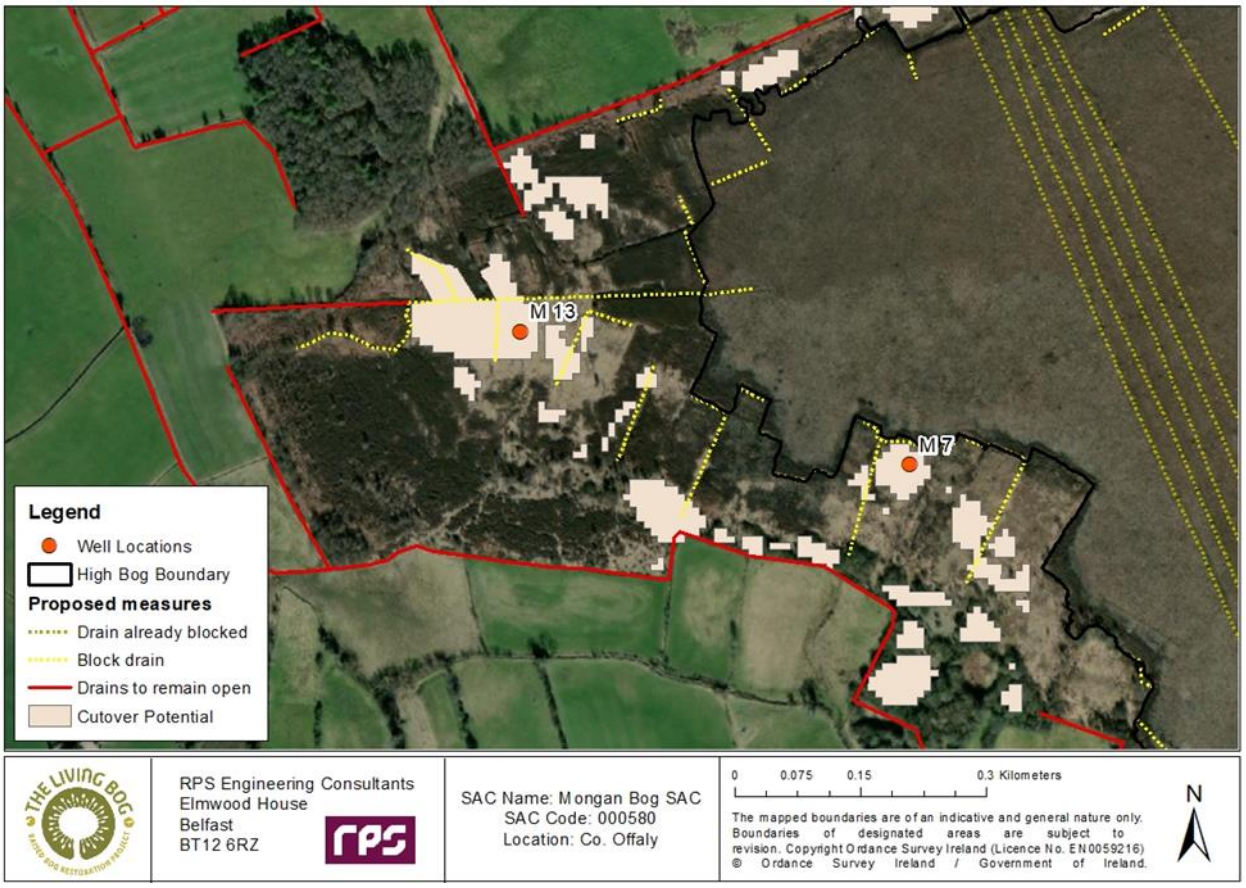


Figure 3-134: Location of wells M7 and M13 on the Western cutover at Mongan Bog SAC.

In the data recorded prior to restoration, water levels at well M13 (Figure 3-135) were observed to be a considerable depth below the ground surface. The water table remained consistently low, dropping to more than 120cm below the ground surface in the autumn period of 2018. Conversely, following restoration water levels rose and stayed consistently at or above ground surface for the majority of the remainder of the record length, dipping below but staying close to surface in the summer months of 2019, 2020 and 2021. The logger data is corroborated by the manual record collected from M13, (Figure 3-136). Water levels are shown to be at or near the ground surface for the majority of the year with levels dipping below the ground surface in the summers of 2019, 2020 and 2021.

Manual measurements of water table depth obtained from M7 (Figure 3-137) exhibit a clear positive change in water level following restoration work carried out in November 2018. Completion of trial works on this

area of cutover resulted in the dramatic increase in water level from -250 cm below the surface up to an 'at-surface' condition, dipping to -40 cm beneath surface in the dry periods of summer 2019 and 2020, and dipping further to – 90 cm in the summer of 2021.

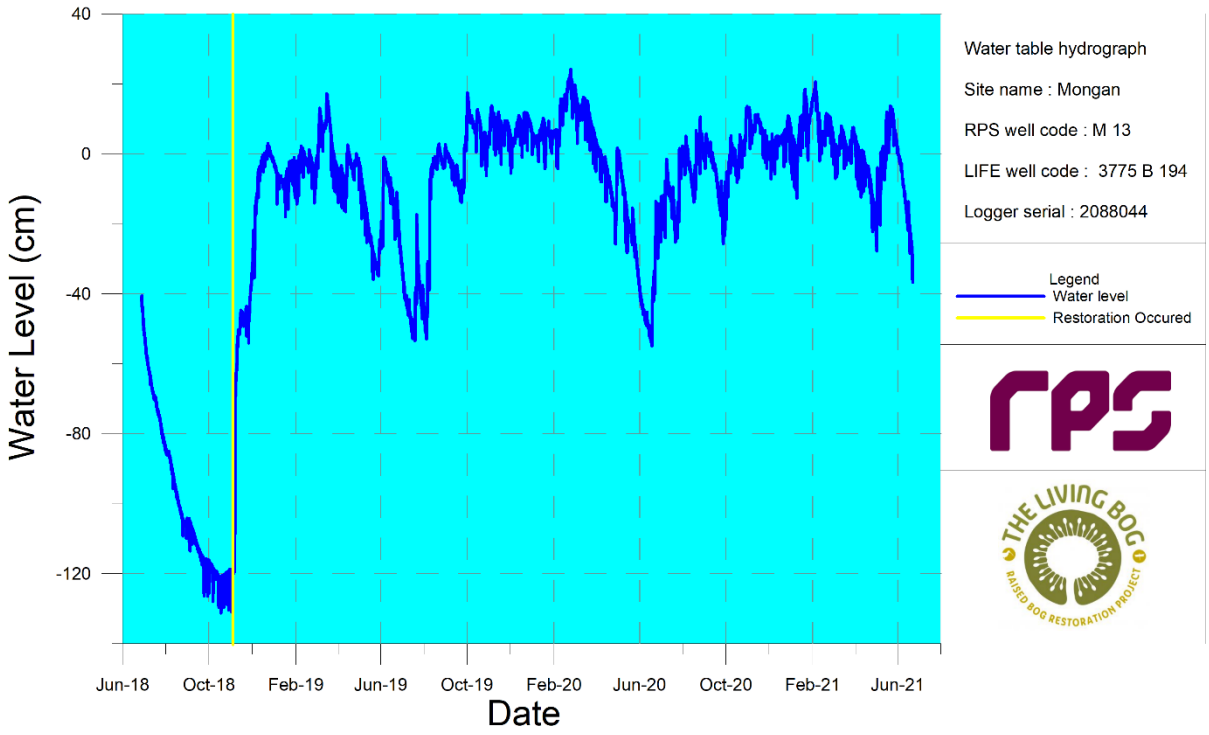


Figure 3-135: Level logger data recorded between June 2018 and June 2021 at well M13, Mongan Bog SAC.

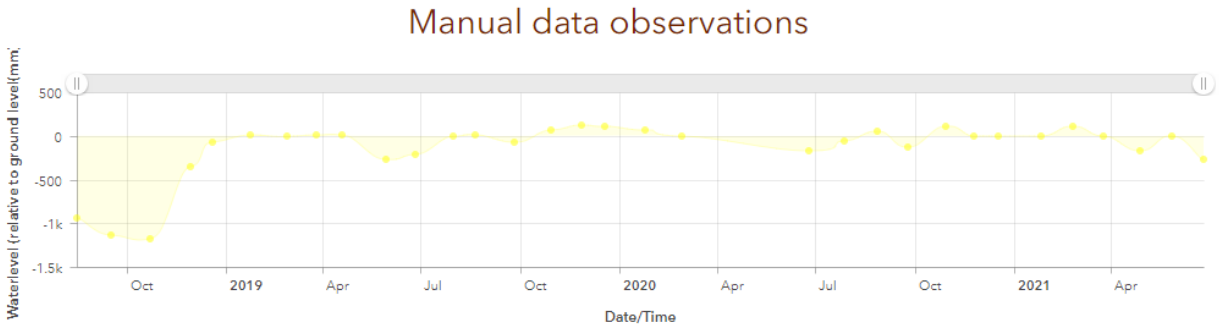


Figure 3-136: Hydrograph of manual water levels M13, Mongan Bog SAC.

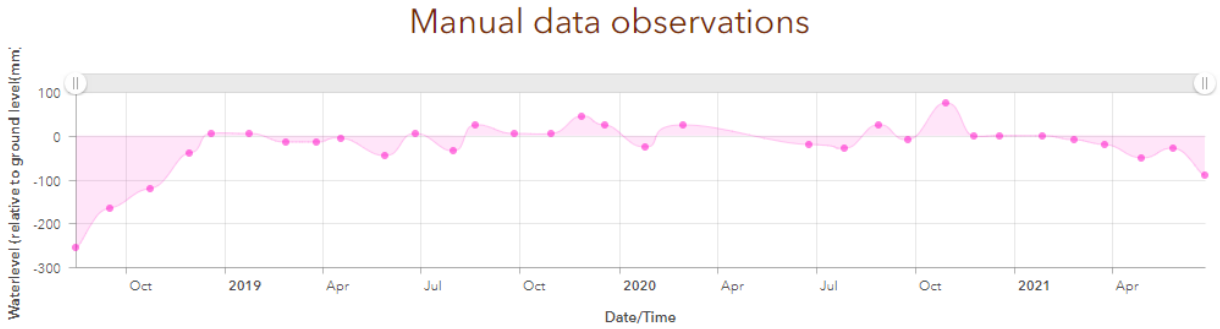


Figure 3-137: Hydrograph of manual water levels M7, Mongan Bog SAC.

3.8.7.2 Southern Cutover

In a bid to evaluate and quantify the effects of restoration measures, M1, M2, M3, M4, M6 and M8 were placed in regions of high restoration potential in cutover bog (Figure 3-138), south of the high bog.

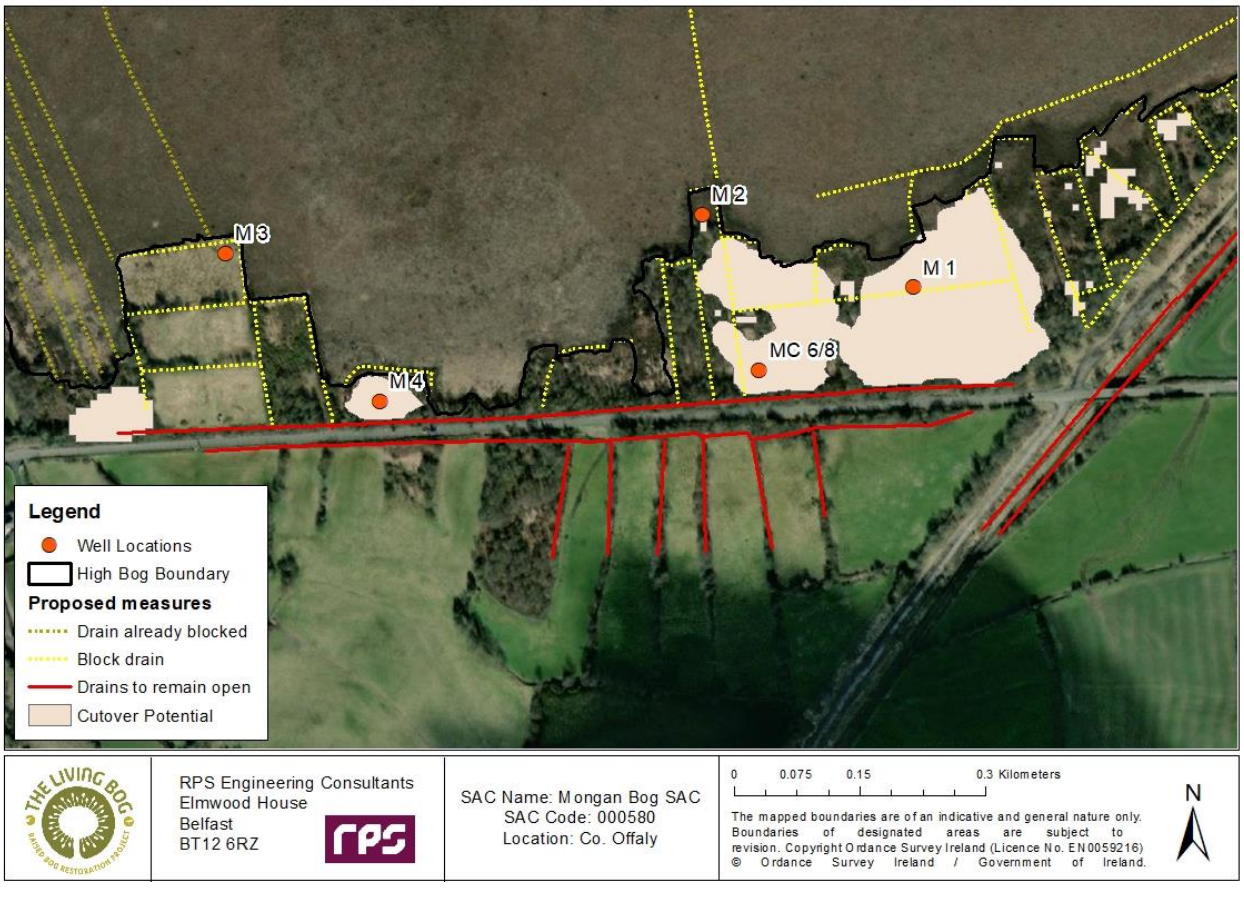


Figure 3-138: Location of wells M1, M2, M3, M4, M6 and M8 on the southern cutover at Mongan Bog SAC.

In the period prior to restoration, water levels remained steady and low never rising above -35 cm and never going below -80 cm. Following restoration, in November 2018 water levels rose to surface level. Throughout the remainder of the recording period, water levels remained considerably higher than pre-restoration

levels, fluctuating between a high of 30cm above surface level and never going -40 cm below surface level (Figure 3-139)

The rise in water level is also reflected in the manual dipping data for wells M2 (Figure 3-140) and M3 (Figure 3-141). Well, M2 shows a large increase in water level post-restoration, rising from -350 cm below surface level in September 2019 to 100 cm above the ground surface in January 2019. Water levels remain above the surface level for the majority of the survey period only falling slightly below surface level in June 2019 and June 2021.

Well, M3 also demonstrated a large increase in water level post restoration rising from -600 cm in October 2018 to surface level in January 2019. Water levels fluctuated between just above surface level and -200cm, never dropping below -200cm throughout the recording period.

Wells M 2 and M 3 were not predicted to have a high potential for restoration using the ecohydrological model, however, data from manual dipping suggests that this area is responding well to the rehabilitation measures implemented.

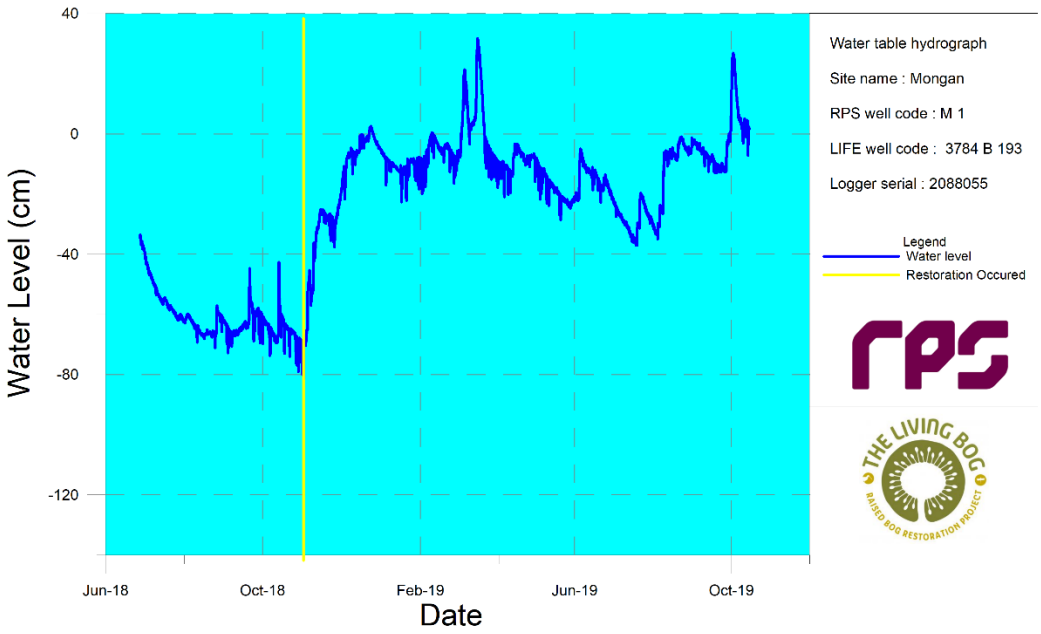


Figure 3-139: Level logger data recorded between June 2018 and October 2019 at well M1, Mongan Bog SAC.

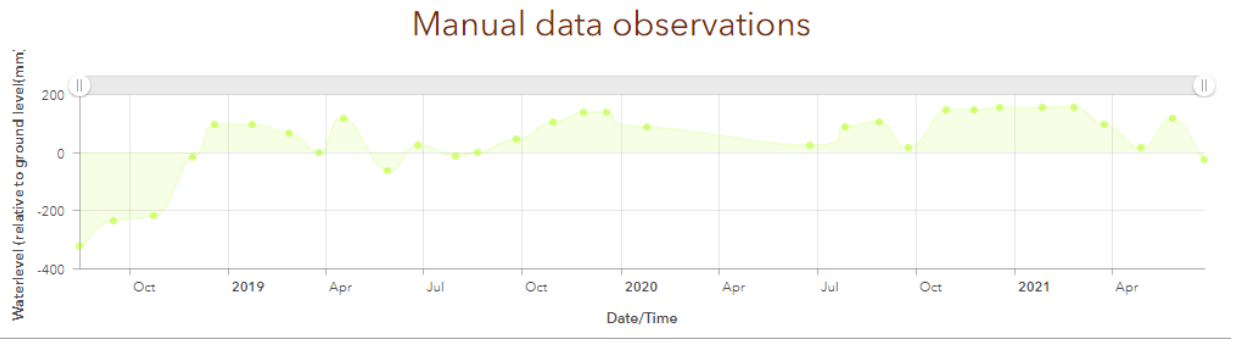


Figure 3-140: Hydrograph of manual water levels M2, Mongan Bog SAC.

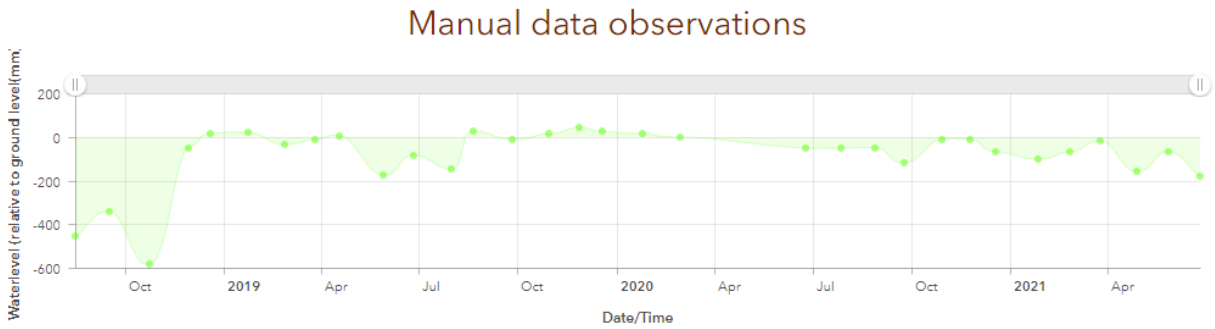


Figure 3-141: Hydrograph of manual water levels M3, Mongan Bog SAC.

3.8.7.3 High Bog

Wells M 9 and M 10 were placed in regions of high restoration potential on the high bog of Mongan. Wells M 12 and M 11 were installed on the high bog but outside of areas of high restoration potential. Monthly manual water level data recorded in wells M 9, M 10 and M11 will assist in the quantification and assessment of restoration measures applied to Mongan Bog SAC (Figure 3-142).

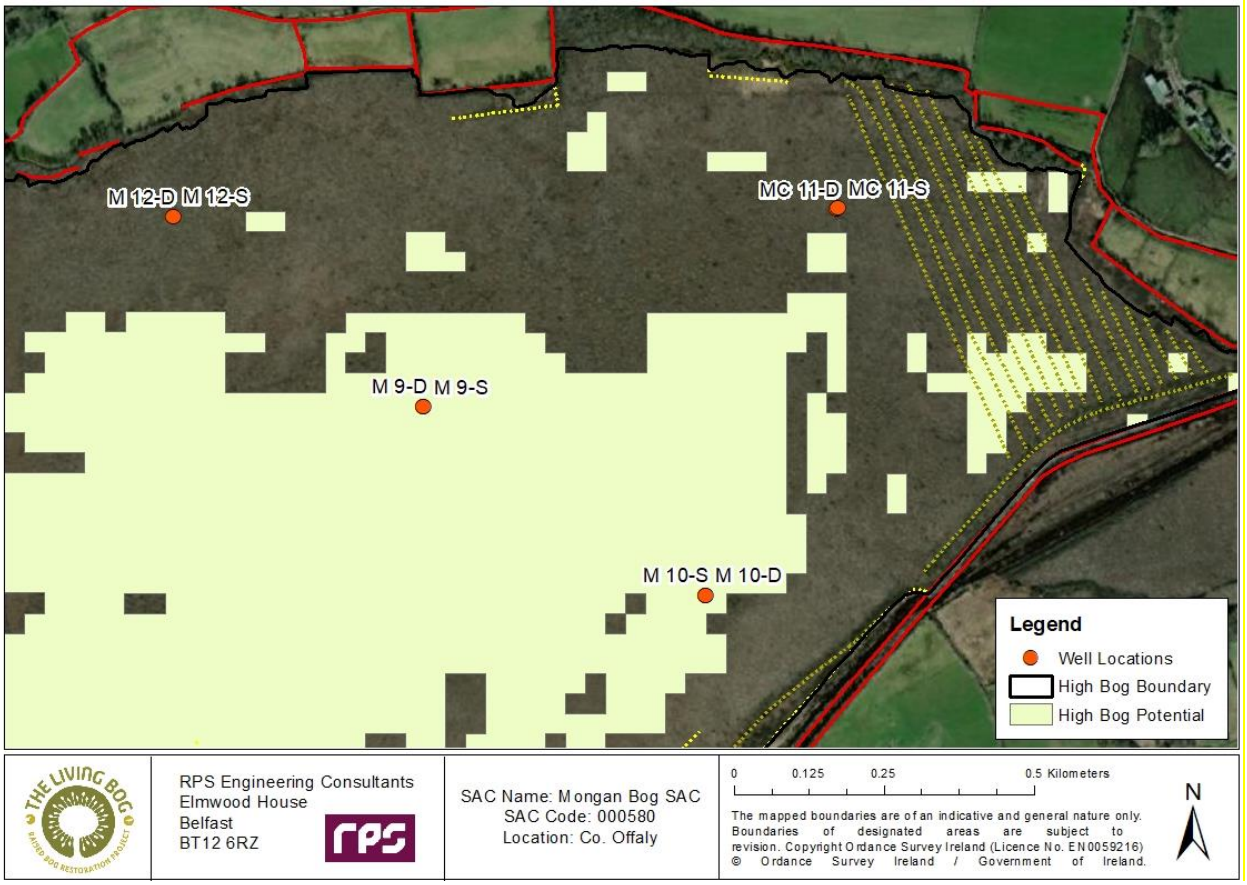


Figure 3-142: Location of wells M9, M10, and M11 on the High Bog at Mongan Bog SAC.

Overall, modest responses to drain blocking was observed on the High Bog compared to cutover areas. Water levels in ARB areas were observed close to the bog surface and remained so throughout the study, as expected. Limited fluctuations were also noted in areas of DRB or supporting high bog and it is recommended that longer-term data is collected to investigate the impact of drain blocking over time. Data obtained from M 9, M 10, and M 11 can be used to demonstrate the negligible variation in water levels observed pre/post-restoration on the high bog at Mongan Bog SAC which was representative of a majority of monitoring points on the high bog.

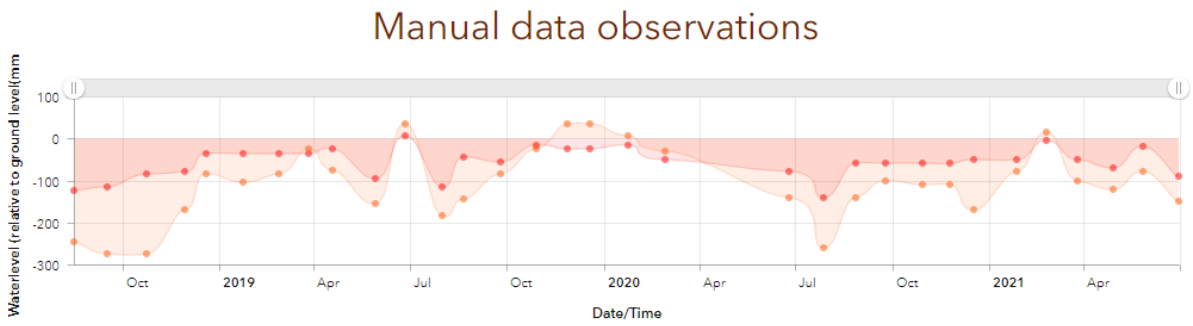


Figure 3-145: Hydrograph of manual monthly water levels M 9S (red) and M 9D (orange), Mongan Bog SAC

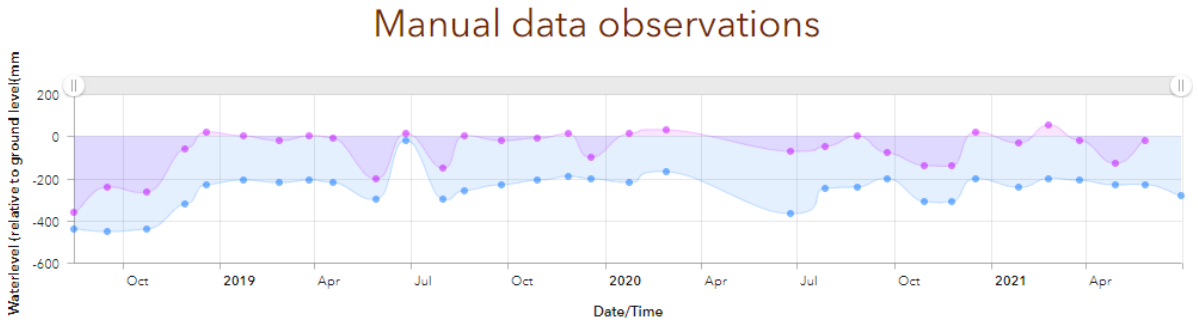


Figure 3-144: Hydrograph of manual monthly water levels M 10S (purple) and M 10D (blue), Mongan Bog SAC

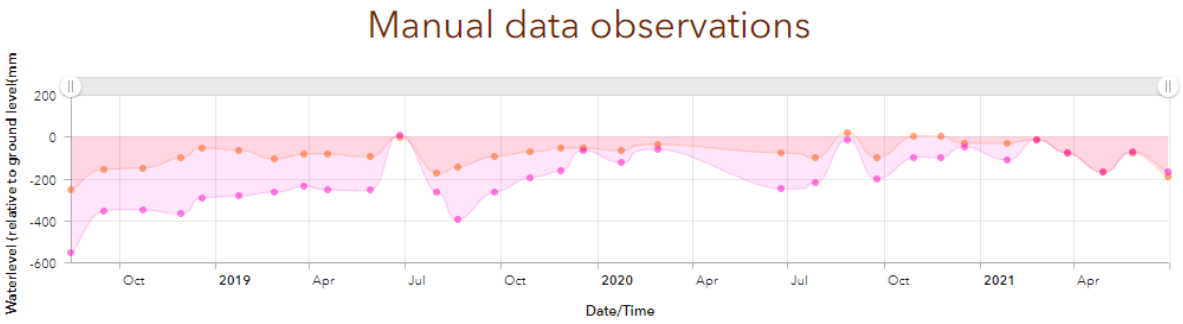


Figure 3-143: Hydrograph of manual monthly water levels M 11S (orange) and M 11D (pink), Mongan Bog SAC

3.8.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.7). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration The largest increases were noted in all cutover wells. Significant changes were observed on the high bog with multiple wells in areas designated as DRB or Supporting High Bog now displaying a post-restoration hydrological regime capable of supporting ARB.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Mongan	M1	Cutover	PFH	-64.89	-19.80
Mongan	M10-S	High Bog	DRB	-34.80	-11.90
Mongan	M11-S	High Bog	Supporting High Bog	-24.50	-18.60
Mongan	M12-S	High Bog	Supporting High Bog	-19.50	-14.00
Mongan	M13	Cutover	PFH	-104.60	-18.62
Mongan	M2	Cutover	Non-PFH	-31.60	1.80
Mongan	M3	Cutover	Non-PFH	-44.40	-17.60
Mongan	M4	Cutover	PFH	-59.45	-19.00
Mongan	M5-S	High Bog	Supporting High Bog	-20.90	-16.20
Mongan	M6	Cutover	PFH	-87.80	25.00
Mongan	M7	Cutover	PFH	-24.60	-2.70
Mongan	M9-S	High Bog	ARB	-12.40	-12.20

Table 3.7: 90th percentile water levels at Mongan Bog SAC, pre and post-restoration.

3.9 Moyclare Bog SAC

3.9.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests the 'High bog' of Moyclare Bog SAC to be underlain entirely by the waulsortian mudbank group of rocks, whilst to the south-east a combination of courceyan limestone and rocks of the Navan group are predominant. This typically denotes, a non-homogenous unit, often comprising pale-grey, crudely bedded or massive limestone. This unit is known as a moderately productive and regionally-important aquifer unit, however low permeability peat subsoils act to confine and thus reduce aquifer vulnerability in the immediate area of the high bog. Groundwater contributions are therefore uncertain.

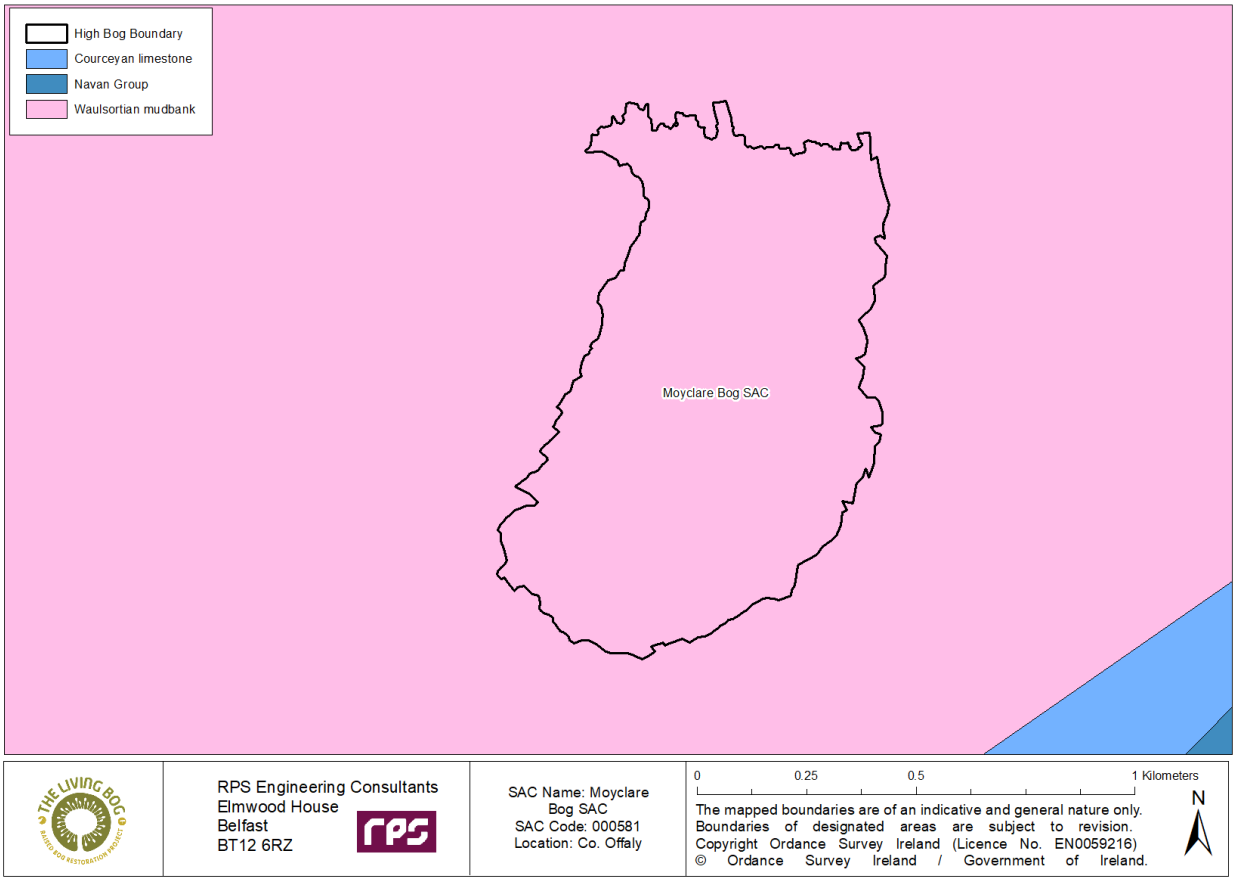


Figure 3-146: Simplified geology of Moyclare Bog SAC.

3.9.2 Proposed restoration plan

The restoration plan for Moyclare Bog SAC (Figure 3-147) identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat forming (ARB) habitat. Overall, the installation of peat dams was recommended across 15.93 km of channels both on the high bog and cutover.

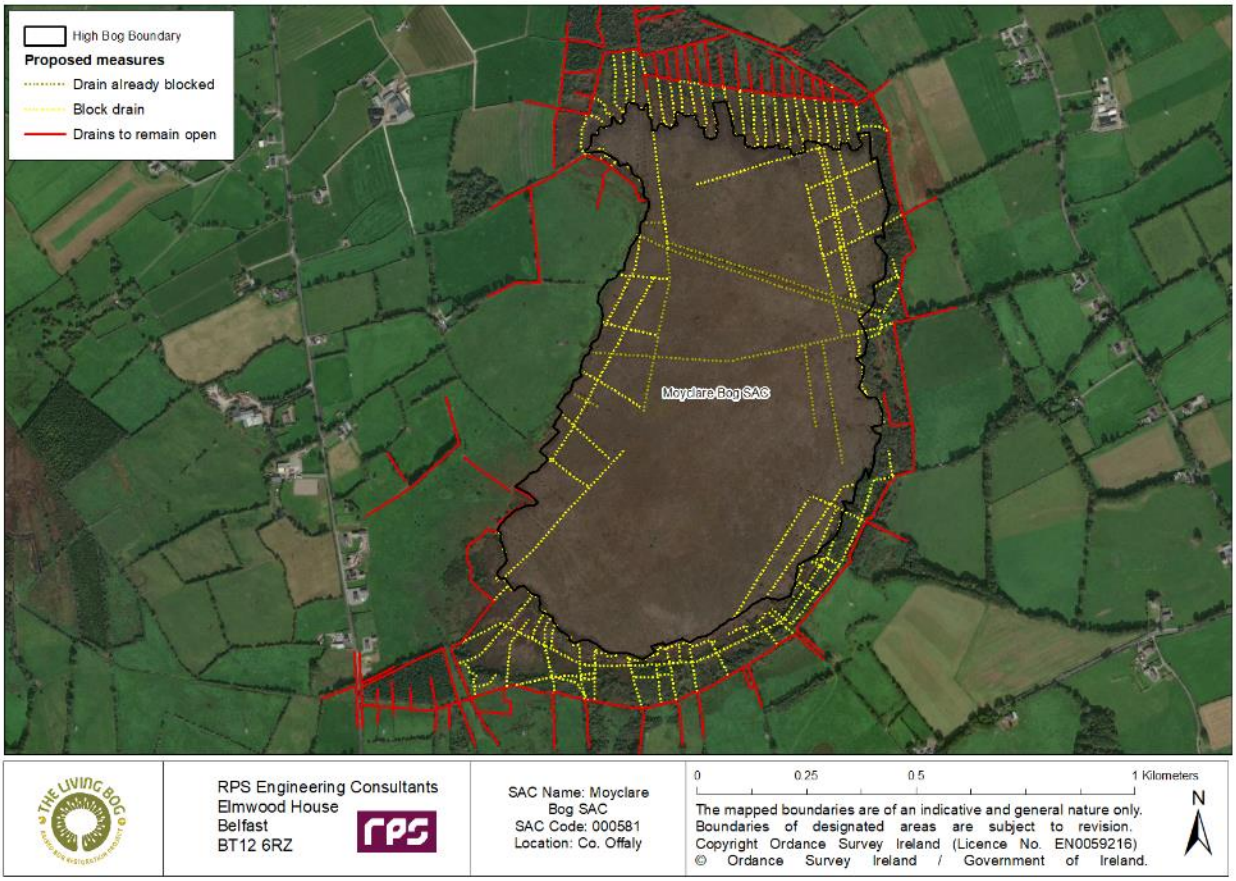


Figure 3-147: Restoration measures specified in support of hydrological goals.

3.9.3 Restoration potential

Eco-hydrological modelling of the restoration potential on Moyclare Bog SAC, excluding current areas mapped as ARB, suggested as much as 12.8 ha of habitat had the potential to be positively impacted by restoration works, with 8.3 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 4.5 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-148).

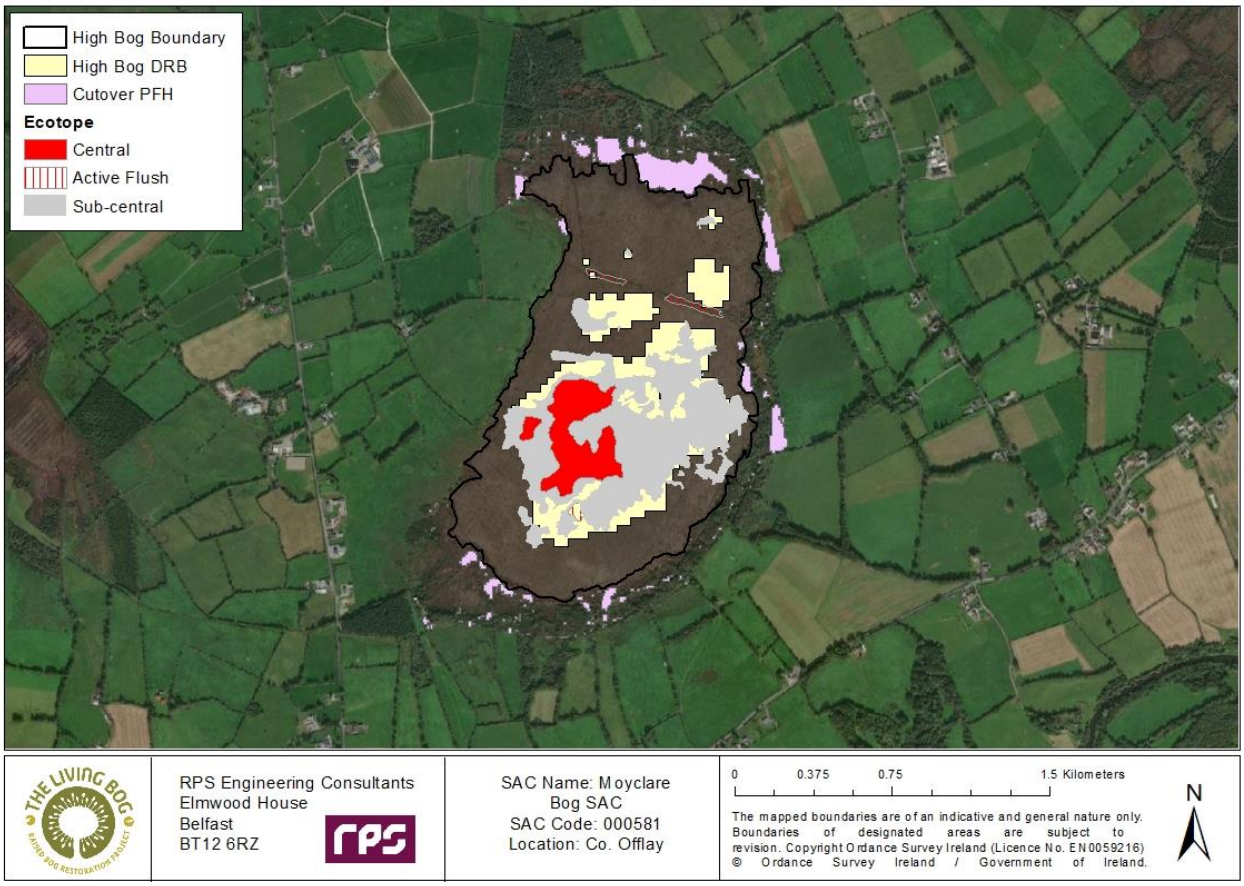


Figure 3-148: Restoration potential of Moyclare Bog SAC as outlined by eco-hydrological modelling.

3.9.4 Ecotope map

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-149). During the last monitoring survey (2018) it was noted, that Moyclare Bog SAC consists of 23.18 ha of Active Raised Bog (ARB) consisting of areas of central, sub-central and active flush.

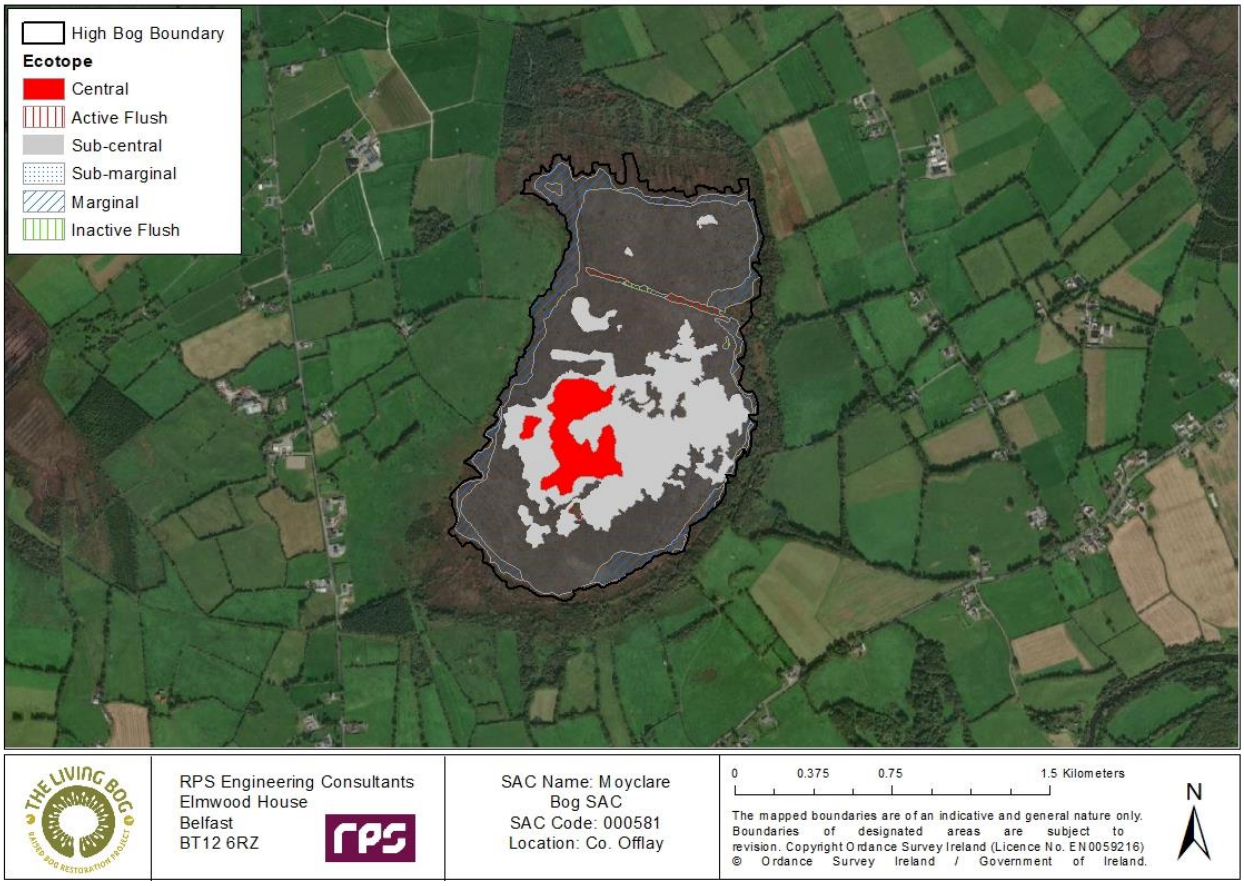


Figure 3-149: Ecotope mapping carried out for Moyclare Bog SAC

3.9.5 Deployed monitoring network

A monitoring network comprising a mixture of 29 shallow phreatic wells and deeper piezometric wells (Figure 3-13247) was subsequently installed on Moyclare Bog SAC. On the high bog, 12 phreatic wells were installed accompanied by 9 deep piezometers to monitor vertical hydraulic gradients. On the cutover 8 phreatic wells were installed. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic. Loggers were set to automatically record levels at 15-minute intervals, the data was downloaded on a quarterly basis. Water level readings were barometrically corrected using the barometric logger installed on the nearby site of Moyclare Bog SAC, located approx. 7.5km South-East of the site.

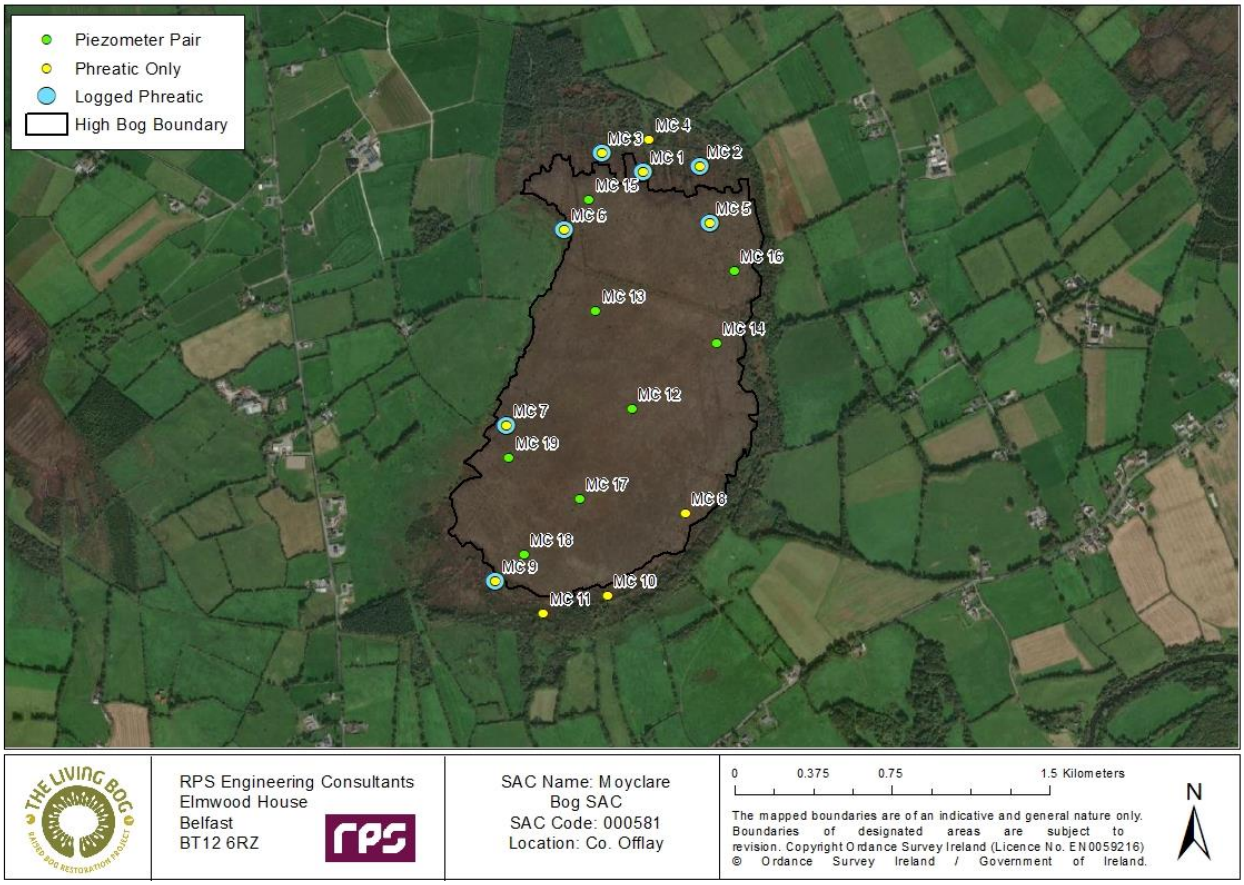


Figure 3-150: Hydrological monitoring network installed and operating on Moyclare Bog SAC.

3.9.6 General field observations

Owing to regular site visits RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. On the Northern cutover, large-scale re-wetting was observed when the drains were blocked, with a shallow pool of shallow water covering a large area throughout the year, even during the drier summer periods (Figure 3-148). This observation led to an amendment to the original restoration plan and the proposed barrier dam proposed on the northern cutover was deemed unnecessary as the natural topography of the area was considered sufficient to maintain water levels at the desired level close to the ground surface. Similar observations were noted on the southern cutover where re-wetting was noted, however, this was more localised and confined to topographic low points.

Figure 3-148: Cutover at Moyclare Bog SAC where significant rewetting was observed

On the high bog, re-wetting was noted close to drains that were blocked, in particular in the North-Western and the South Eastern section of the bog. However, widespread re-wetting of the high bog post restoration was not immediately evident from walkover surveys alone. No impacts on adjacent lands were noted on Moyclare Bog SAC post-restoration. Site walkover surveys suggested the restoration measures were completed to a high standard across the site, as referenced in the raised bog best practice guidance (Mackin et al, 2017).

3.9.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Moyclare Bog SAC are presented with all supplementary results provided in Appendix A.

3.9.7.1 Northern cutover

Figure 3-151 illustrates the location of MC1 and MC4. Both wells were situated in the Northern cutover section approximately 90m from each other. MC1 was located in an area in which the model predicted successful restoration and MC4 was located, as a control, in an area where a hydrological response to restoration was not predicted. Figure 3-152 illustrates the hydrograph obtained from each well, As shown, prior to restoration (February 2019) both wells reported water levels significantly below ground level in the summer of 2018, with the level reaching a maximum of -80cm at MC1 and -150cm at MC4. Once the restoration was completed, there was a significant increase in water level at MC1 where the water level rose above the surface to a maximum level of +18cm, notably the water level at this location never dropped below ground level again even during the drier summer periods.

AT MC4 the water level continued to fluctuate post-restoration, rising in the winter period and decreasing during the summer period. Unlike MC1 it never rose above the ground surface. Comparing maximum water level depths from these two wells indicates that there is a significant increase in the observable water table in the area due to restoration.

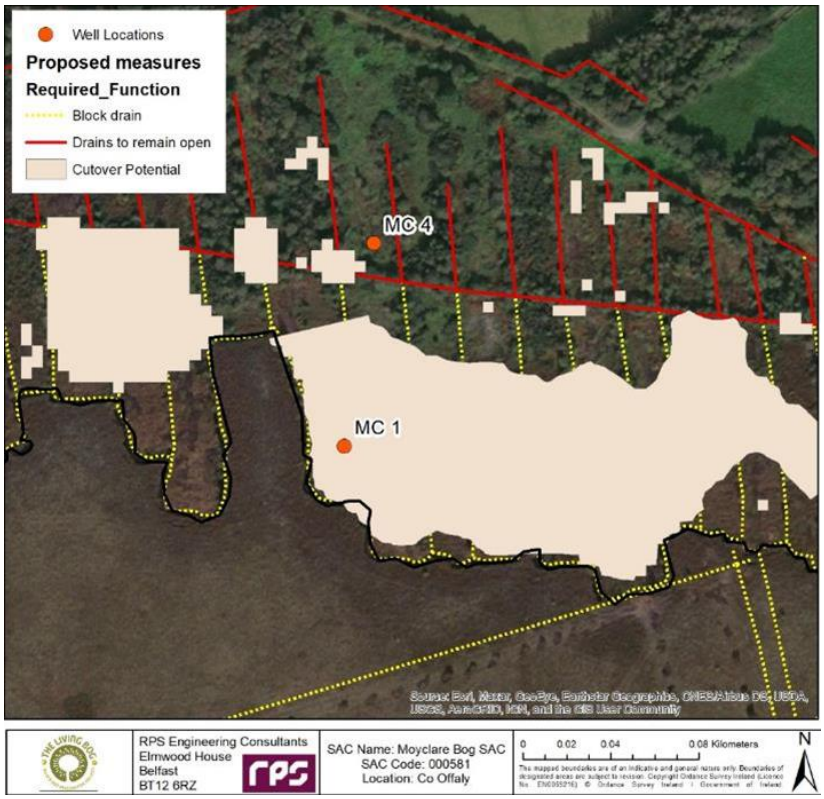


Figure 3-151: Map highlighting the location of MC1 and MC4. MC1 was located within the modelled area of restoration potential and MC4 outside of the area in an area where restoration measures were not implemented.

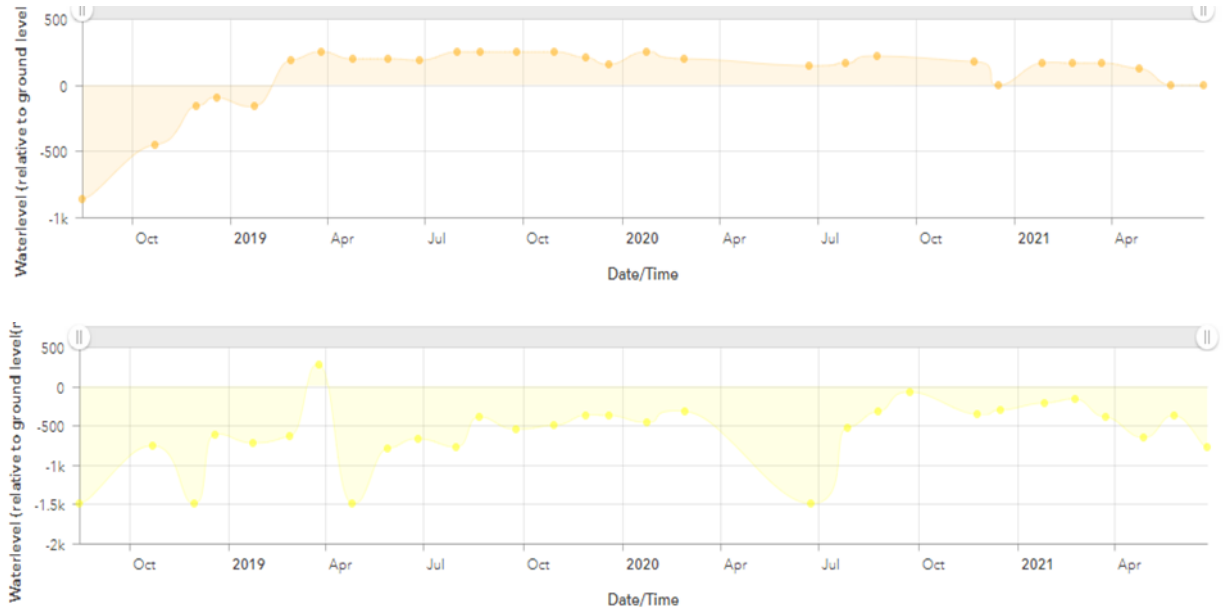


Figure 3-152: Manual hydrographs from the Northern cutover section on Moyclare, comparing a) MC1 (3692B194) and b) MC4 (3663B155).

Figure 3-153 illustrates the high-resolution water level logger data collected from MC1. The data indicate a strong response to drain-blocking which occurred in February 2019, with an immediate increase in water level above the ground surface. A maximum water table depth of -82cm was detected in the summer of 2018. The water never dropped below the ground surface after restoration apart from briefly during the summer of 2020 when it reached -2cm, highlighting the success of restoration measures in the area surrounding MC1.

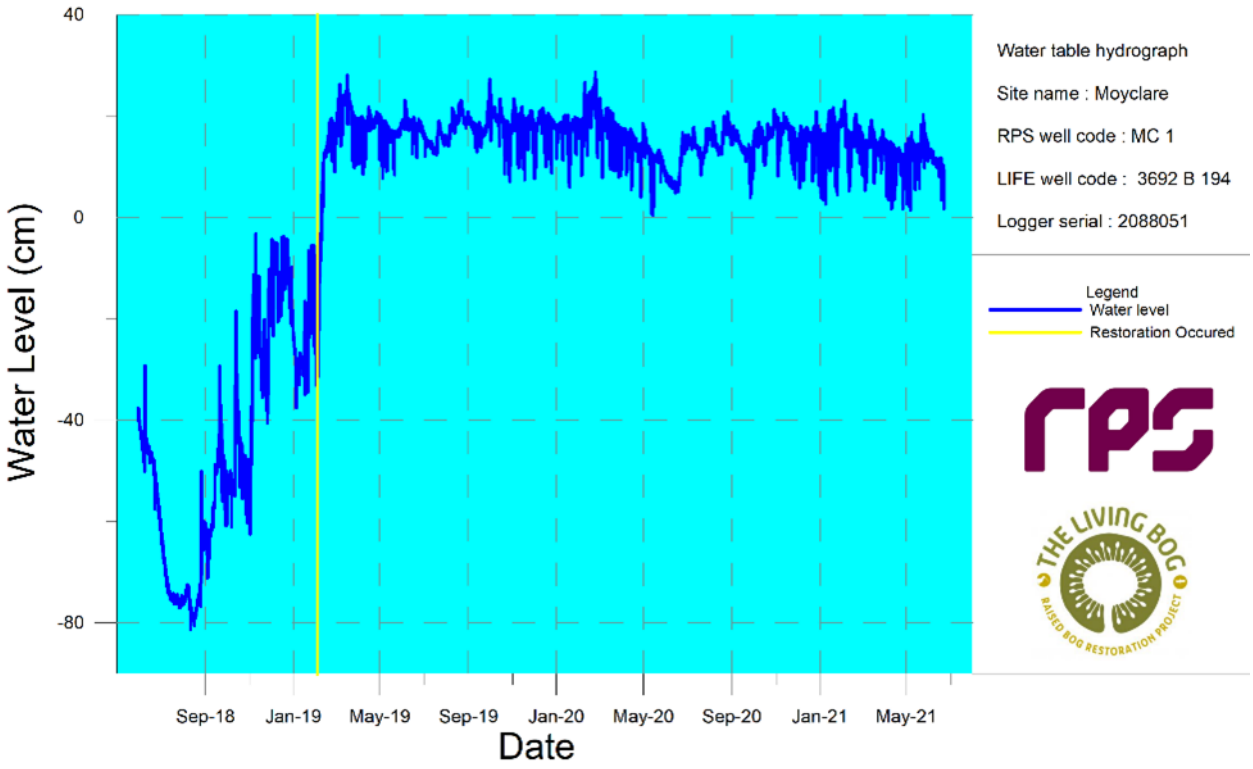


Figure 3-153: Hydrograph from MC1, highlighting the rapid increase in water level post-restoration

3.9.7.2 Southern cutover

Figure 3-154 illustrates the locations of MC9 and MC 11. Both wells were situated in the Southern cutover section approximately 140m from each other. MC9 was located in an area in which the model predicted successful restoration and MC11 was located, as a control, in an area where a hydrological response to restoration was not predicted. Figure 3-155 illustrates the hydrographs created using manual data. As shown, prior to restoration (March 2019) both wells reported water levels significantly below ground level, with the level reaching a maximum of -55cm at MC1 and -130cm at MC4.

Once the restoration was completed, there was a significant increase in water level at MC9, where the water level rose to -5cm. Importantly the water table only increased once restoration occurred and did not rise during the winter period (October 2018 – February 2019), indicating that the rewetting was a direct result of restoration and not seasonal impacts. The water table was maintained close to the surface for the remainder of the monitoring period. At MC11 the water level continued to fluctuate, rising in the winter period and decreasing during the summer period. Unlike MC9 it never rose above the ground surface. Comparing maximum water level depths from these two wells indicates that there is a significant increase in the observable water table due to restoration.

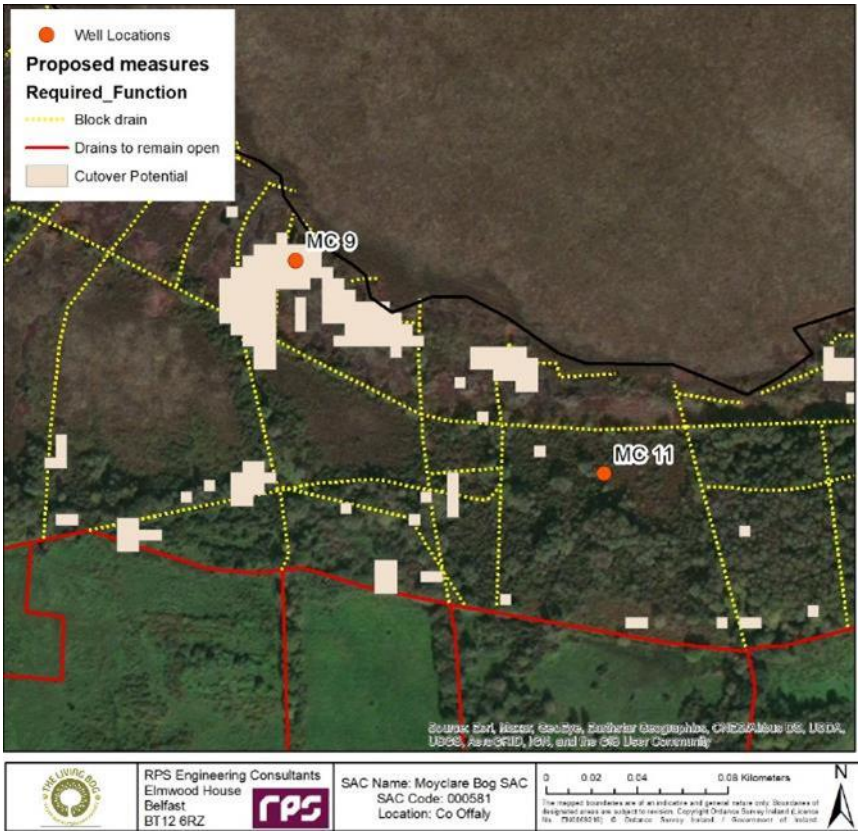
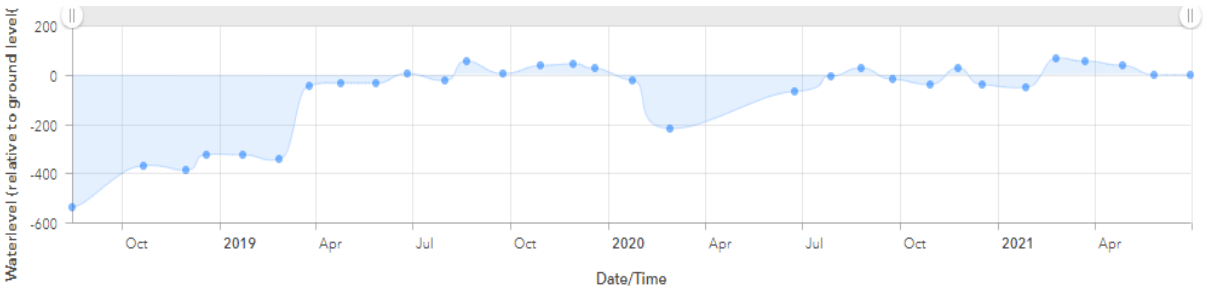


Figure 3-154: Map highlighting the location of MC9 and MC11. MC9 was located within the modelled area of restoration potential and MC11 outside of the area in an area where restoration measures were implemented was heavily overgrown and restoration potential was not anticipated



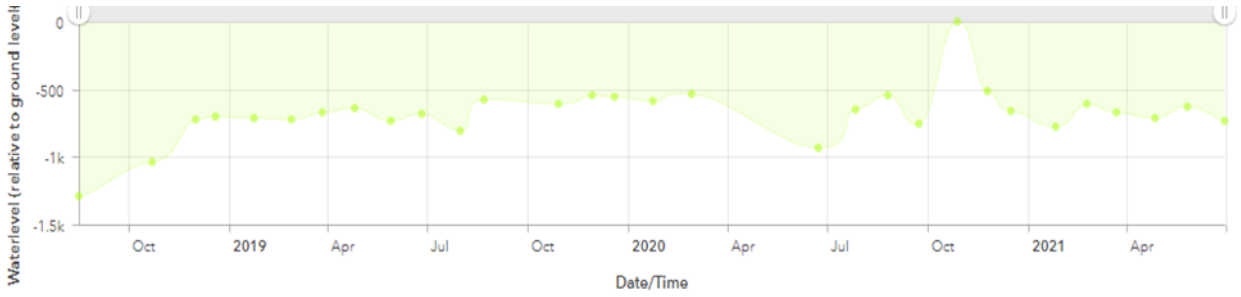


Figure 3-155: Manual hydrographs from Southern cutover section on Moyclare, comparing a) MC9 (3673B194) and b) MC11 (3676B194).

Figure 3-156 illustrates the high-resolution water level logger data collected from MC9, similarly to MC1 there was an immediate response to drain blocking in the area with the water level increasing from approx. -40cm to the ground surface during a three week period. The water level in this area did fluctuate below and above ground level throughout the remaining monitoring period but did not reach similar levels experience pre-restoration, with the water table remaining within the top 20cm of the ground surface.

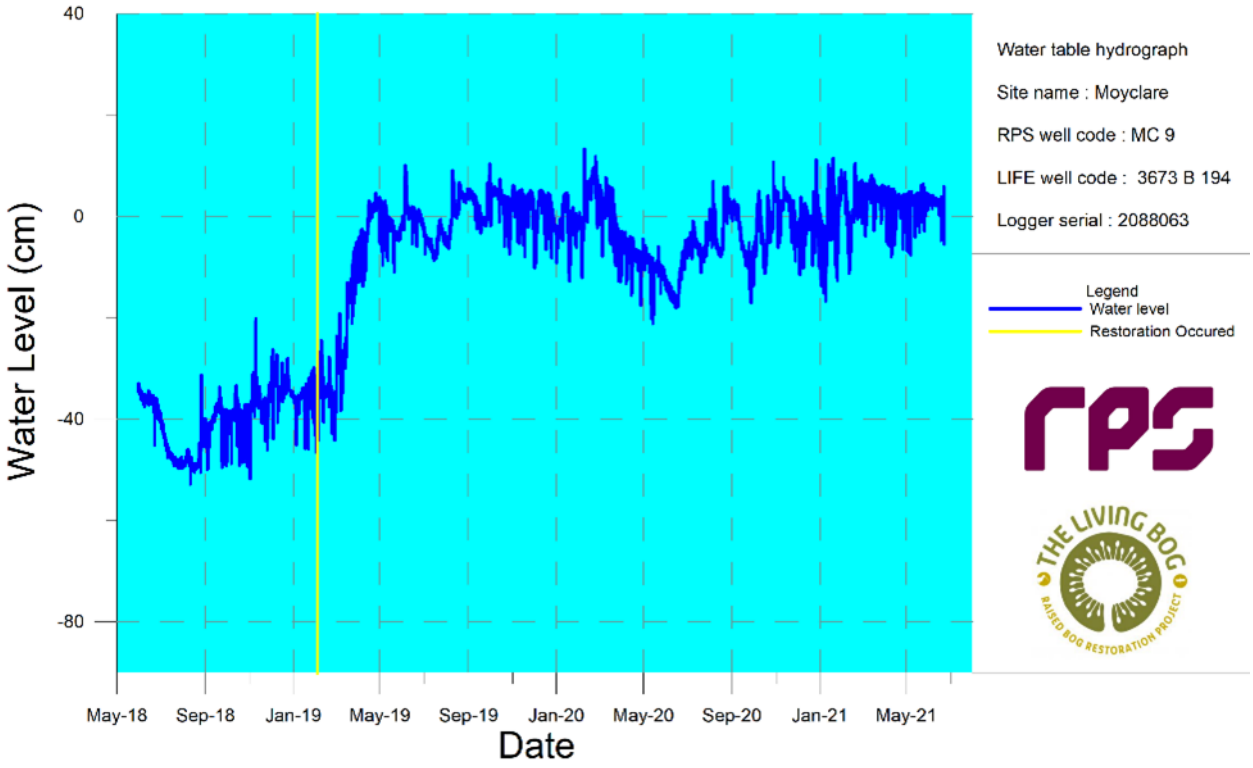


Figure 3-156 Hydrograph from MC9, highlighting the rapid increase in water level post-restoration

3.9.7.3 Western cutover

Figure 3-157 illustrates the location of MC6, which is situated on the Western cutover. MC6 was located in an area in which the model predicted successful restoration. Figure 3-158 illustrates the hydrograph created using manual data collected from MC6. As shown, the water table did increase slightly from the lowest level of -50cm recorded in July 2018, however, the water table continued to fluctuate throughout the monitoring period, suggesting restoration had not been successful in this area.
Significant flow was noted in the marginal drain to the west of the modelled area, which was kept open to protect adjacent farmland. Results suggest this marginal drain controlled the water level in this cutover area, keeping it lower than anticipated. Future modelling of restoration potential on other sites could potentially consider this and modify targets where areas of modelled restoration potential are located close to open marginal drains. Such data can also be used to justify the potential for land purchase or further rewetting under future restoration schemes which may expand outside the immediate area of the SAC.

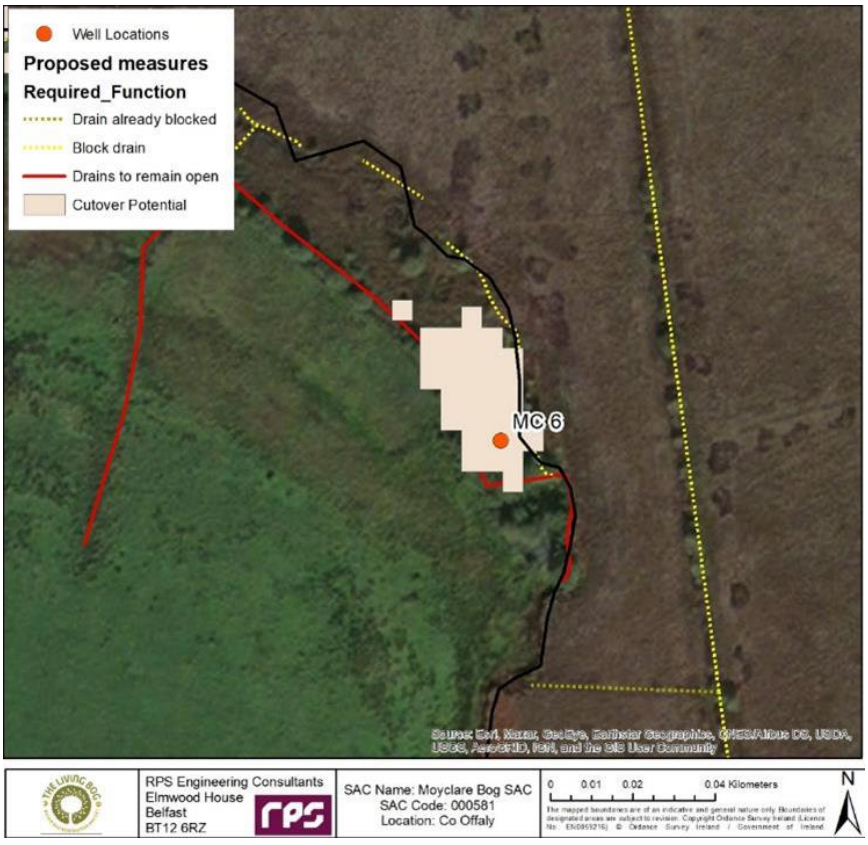


Figure 3-157: Map highlighting the location of MC6 which was located within an area of modelled restoration potential. Drains were blocked along the facebank but a marginal drain to the West was kept open to protect adjacent land.

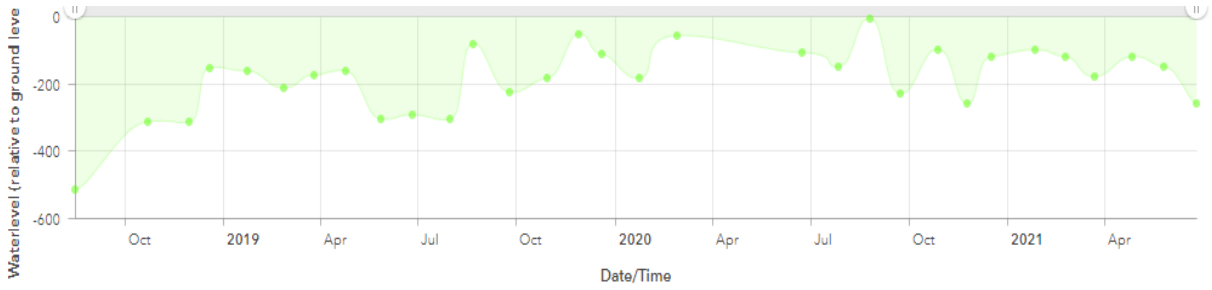


Figure 3-158 Manual hydrograph from the western cutover on Moyclare at MC6 (3365B154)

Figure 3-159 illustrates the high-resolution water level logger data collected from MC6, as shown the water table showed limited impact on restoration, with water levels continuing to fluctuate in the continuing summer periods. However, although continued fluctuations were observed, there was a notable improvement in the maximum water table depth. In the summer of 2018, a maximum water table depth of -57cmmm was recorded. The water table did not reach similar levels post-restoration, reaching a maximum level of -41cm in the summer of 2019 and 2020. This suggests that the restoration measures did have an impact but wasn't enough to raise the water table close to the ground surface for a continuous period.

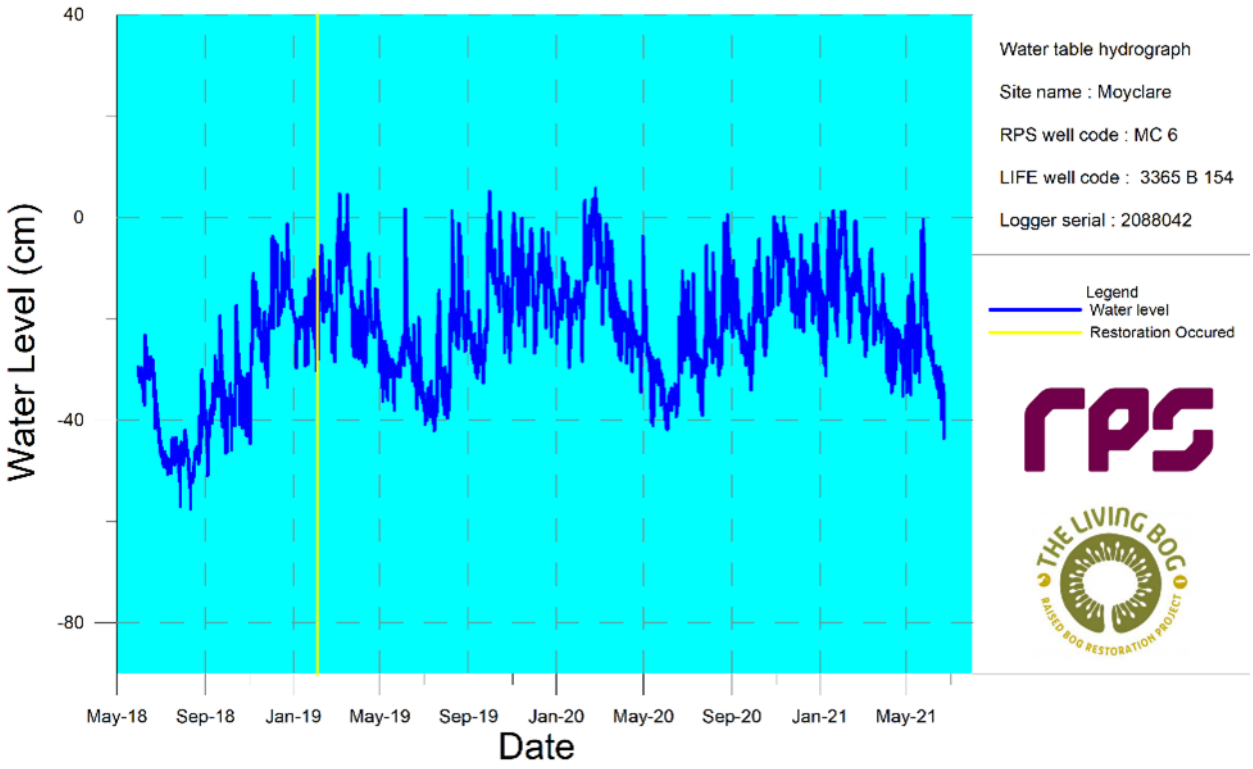


Figure 3-159: Hydrograph from MC6, highlighting the continued fluctuation in water level post-restoration

3.9.7.4 High bog

Figure 3-160 illustrates the location of MC8, located in the south-eastern section of high bog. The phreatic was not located in an area of modelled restoration potential, however, drains were blocked in close proximity to the monitoring station. Figure 3-161 illustrates the hydrograph created using manual data collected from MC8. As shown restoration in this area had a positive impact. Pre-restoration a maximum water table depth of -39cm was recorded. Post restoration the water level did not drop below -15cm. This potentially suggests that although restoration potential was not predicted in the area, the correct hydrological conditions have been met to allow for Active Raised Bog to be returned. Further analysis comparing data to vegetation composition in the area is required to determine the full impact, which if shows a similar positive impact, potentially indicates that the modelled restoration potential calculated for the high bog undercalculated the total area which benefited from restoration measures.

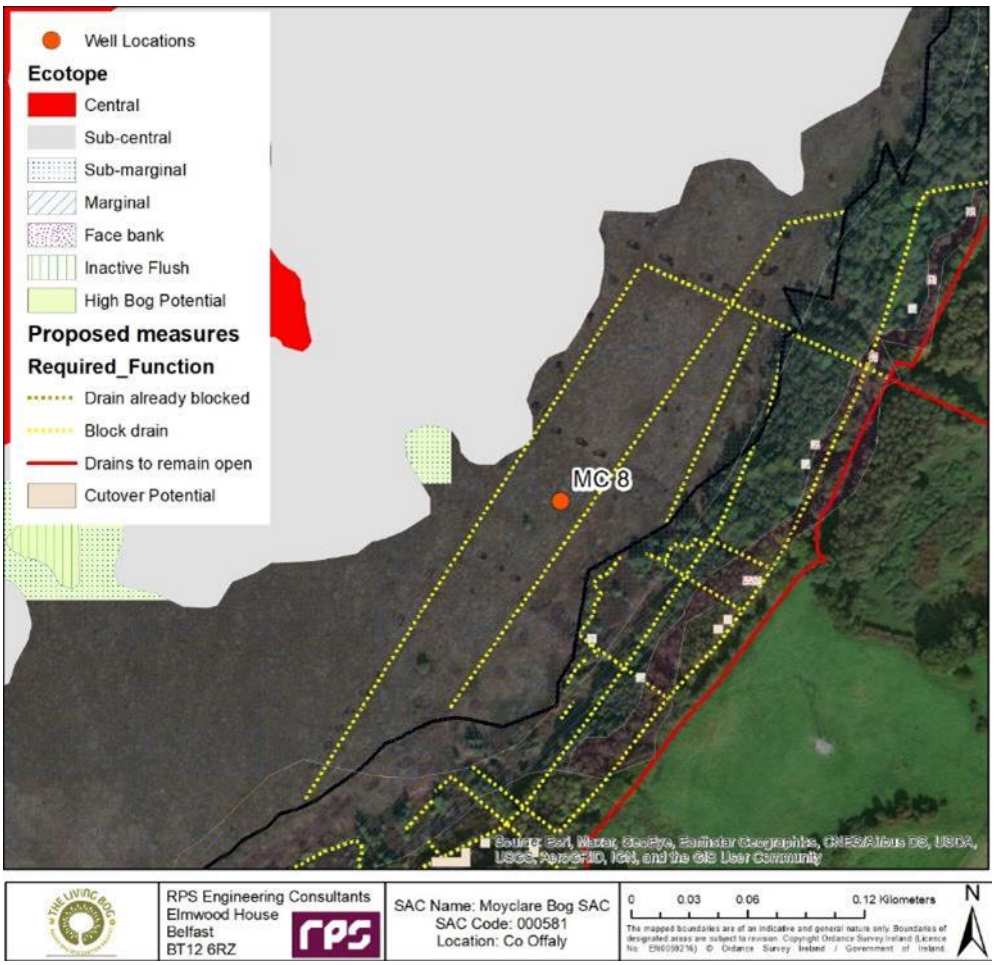


Figure 3-160: Map highlighting the location of MC8 which was located on the high bog in an area of marginal ecotope. The phreatic was not located in an area of modelled restoration potential, however, drains were blocked in close proximity to the monitoring station.

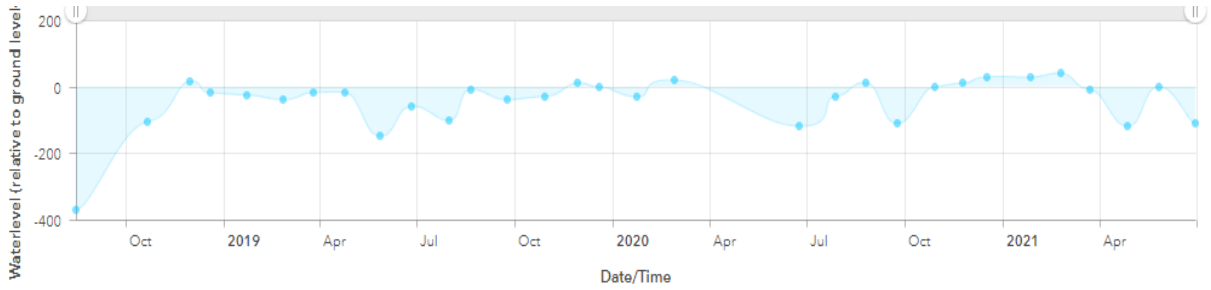


Figure 3-161 Manual hydrographs from MC8 (3365B154), a phreatic located within the South Eastern section of the high bog of Moyclare.

3.9.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.8Table 3.1). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration The largest increases were noted in all cutover wells. Significant changes were observed on the high bog with multiple wells in areas designated as DRB or Supporting High Bog now displaying a post-restoration hydrological regime capable of supporting ARB.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Moyclare	MC1	Cutover	PFH	-76.29	14.60
Moyclare	MC10	Cutover	PFH	-33.00	15.00

Moyclare	MC11	Cutover	Non-PFH	119.00	-72.60
Moyclare	MC2	Cutover	PFH	-27.26	27.09
Moyclare	MC3	Cutover	PFH	-33.54	-9.15
Moyclare	MC4	Cutover	No works	-73.00	-65.00
Moyclare	MC6	Cutover	PFH	-44.67	-32.64
Moyclare	MC9	Cutover	PFH	-48.99	-14.04
Moyclare	MC12-S	High Bog	DRB	-38.00	-20.20
Moyclare	MC13-S	High Bog	DRB	-53.50	-17.10
Moyclare	MC14a-S	High Bog	DRB	-40.00	-20.20
Moyclare	MC14b-S	High Bog	Supporting High Bog	-30.00	-21.50
Moyclare	MC15-S	High Bog	Supporting High Bog	-44.00	-18.00
Moyclare	MC16-S	High Bog	Supporting High Bog	-38.00	-16.00
Moyclare	MC17-S	High Bog	DRB	-33.00	-21.40
Moyclare	MC18-S	High Bog	Supporting High Bog	-29.00	-15.50
Moyclare	MC19-S	High Bog	Supporting High Bog	-31.00	-15.00
Moyclare	MC5	High Bog	Supporting High Bog	-29.32	-17.98
Moyclare	MC7	High Bog	Supporting High Bog	-45.08	-24.54
Moyclare	MC8	High Bog	Supporting High Bog	-37.00	-12.50

Table 3.8: 90th percentile water levels at Moyclare Bog SAC, pre and post-restoration.

3.10 Raheenmore Bog SAC

3.10.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests Raheenmore Bog SAC and adjacent lands to be underlain by a singular lithographic unit referred to as Visean basinal ‘Calp’ (Figure 3-162). This typically denotes a non-homogenous unit, often comprising fine shales, interbedded and intermixed with calcareous material/spar and in this region is associated with moderately productive (locally), low vulnerability aquifer units. As such, contributions to in-channel flows from processes of groundwater recharge are thought to be small and localised.

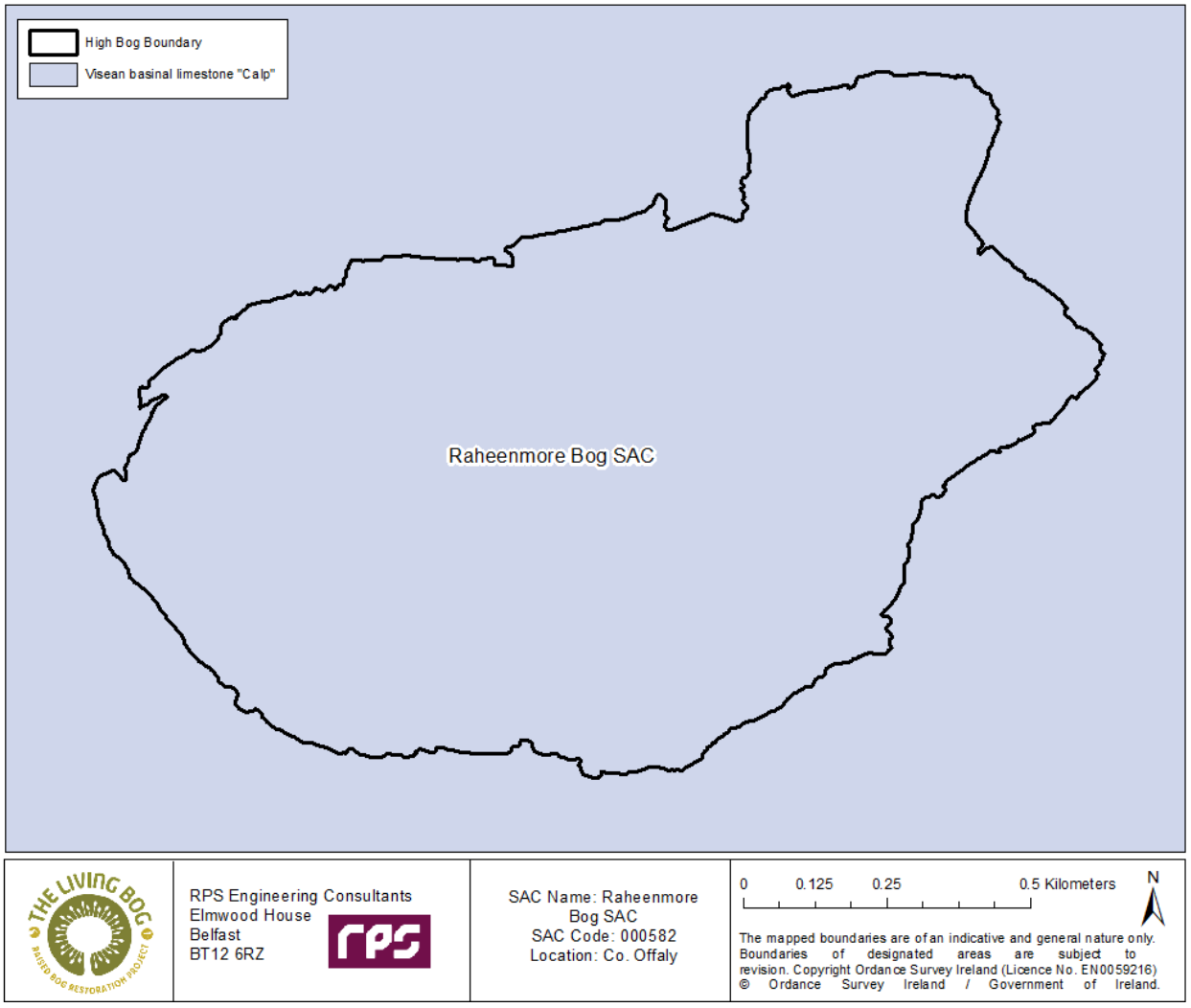


Figure 3-162: Simplified geology of Raheenmore Bog SAC.

3.10.2 Ecotope map

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-163). During the last monitoring survey (2018) it was noted, that Rahennmore Bog SAC consists of 45.79 ha of Active Raised Bog (ARB) consisting of areas of central, sub-central and active flush.

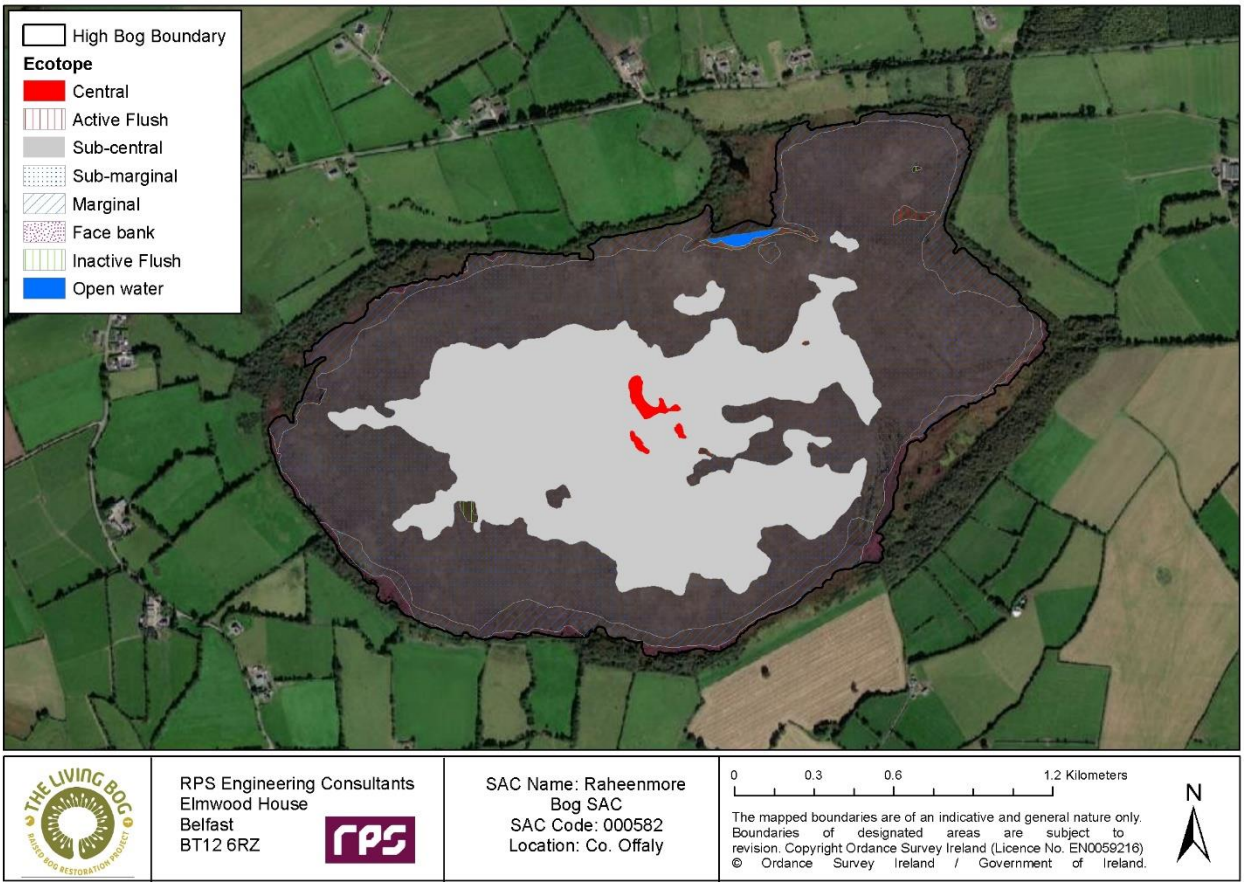


Figure 3-163 Ecotope mapping carried out for Raheenmore Bog SAC

3.10.3 Proposed restoration plan

The restoration plan for Raheenmore Bog SAC (Figure 3-164) identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat-forming (ARB) habitat. Overall, the installation of peat dams was recommended across 4.97 km of channels both on the high bog and cutover.

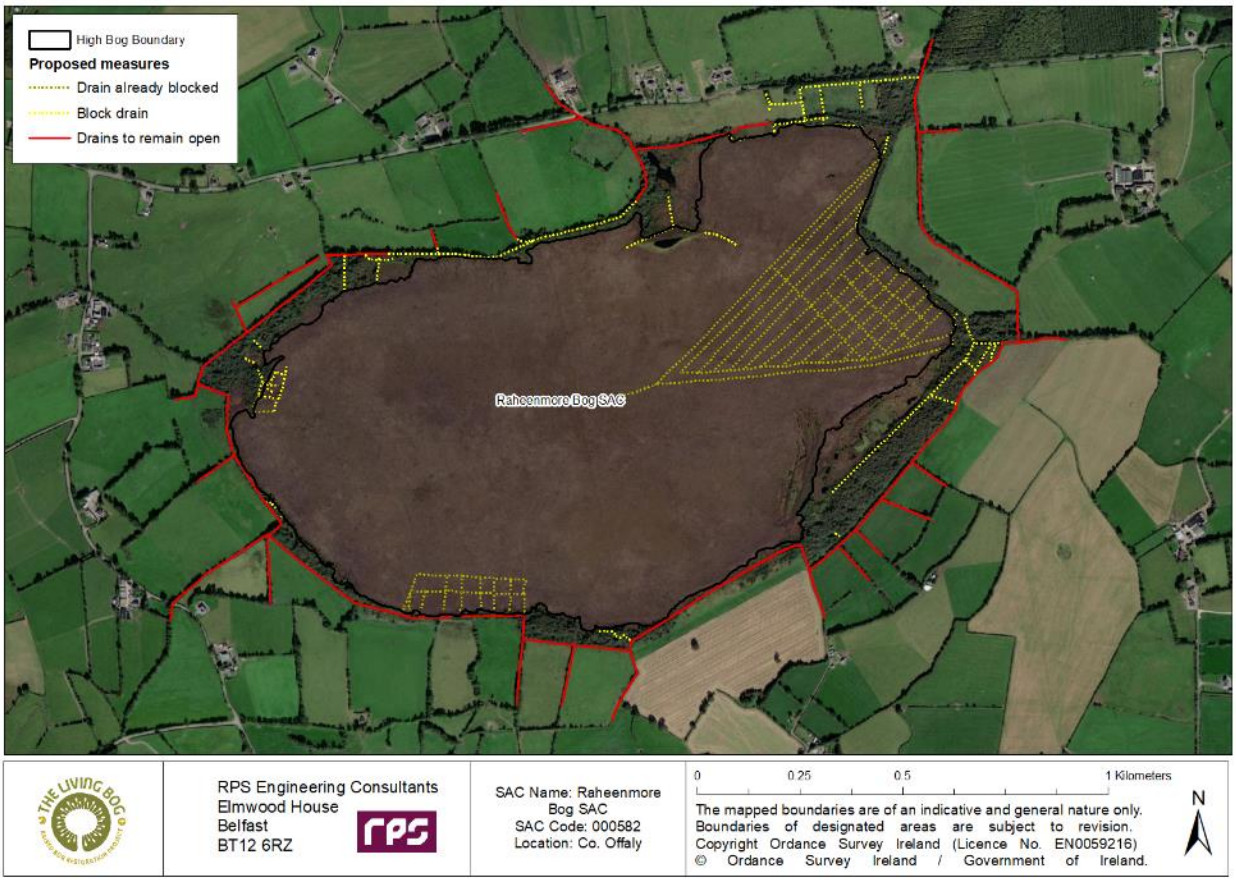


Figure 3-164 Restoration measures specified in support of hydrological goals.

3.10.4 Restoration potential

Eco-hydrological modelling of the restoration potential on Raheenmore Bog SAC, excluding current areas mapped as ARB, suggested as much as 17.7 ha of habitat had the potential to be positively impacted by restoration works, with 16.4 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 1.3 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-165).

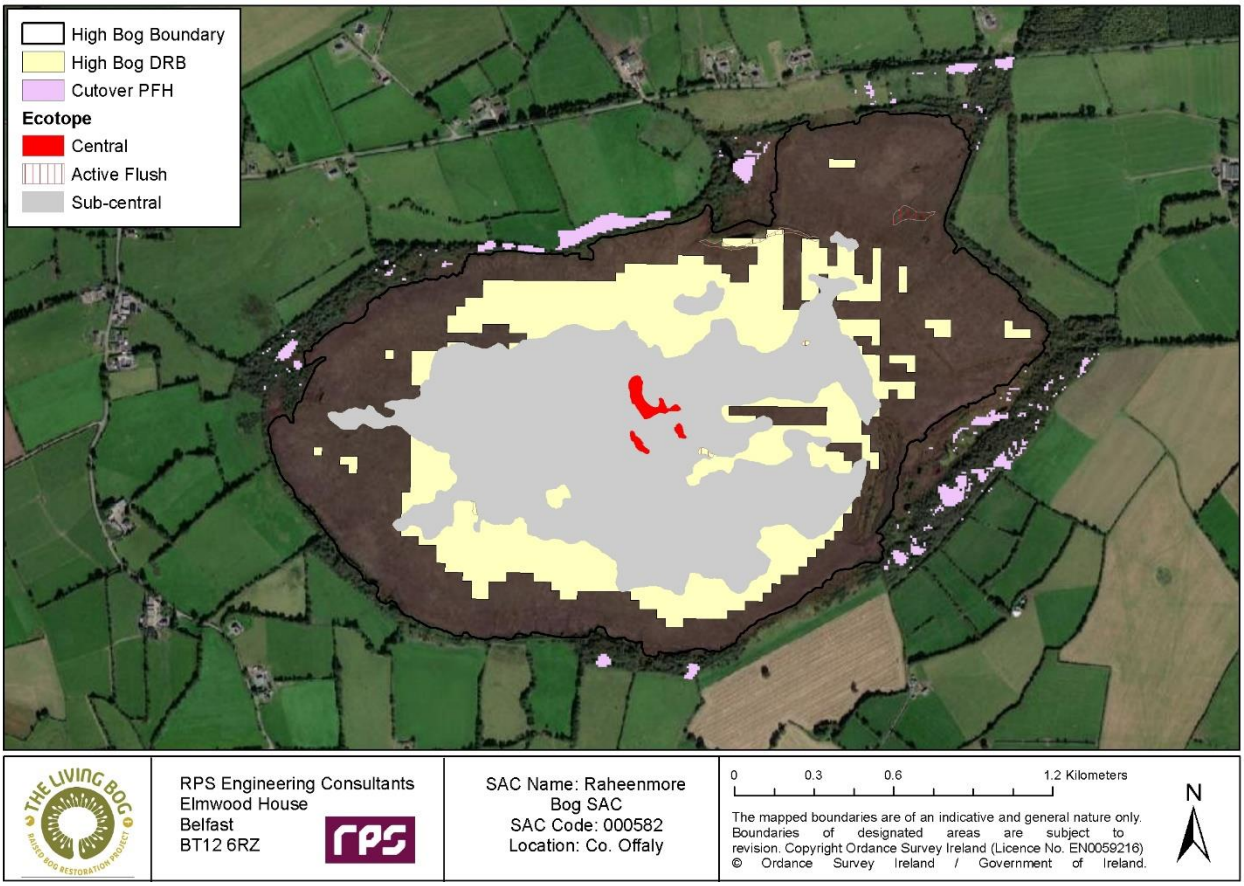


Figure 3-165 Restoration potential of Raheenmore Bog SAC as outlined by eco-hydrological modelling.

3.10.5 Deployed monitoring network

A monitoring network comprising a mixture of 13 shallow phreatic wells (Figure 3-166) was subsequently installed on Raheenmore Bog SAC. On the high bog, 6 phreatic wells were installed, accompanied by 5 deep piezometers to monitor vertical hydraulic gradients. On the cutover, 2 phreatic wells were installed. A total of 2 water level loggers were spread amongst the wells. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic. Two wells were

equipped with loggers which were set to automatically record levels in 15-minute intervals, downloaded on a quarterly basis. Water level readings were barometrically corrected using the barometric logger installed on the nearby site of Moyclare Bog SAC, located approx. 35km East of the site.

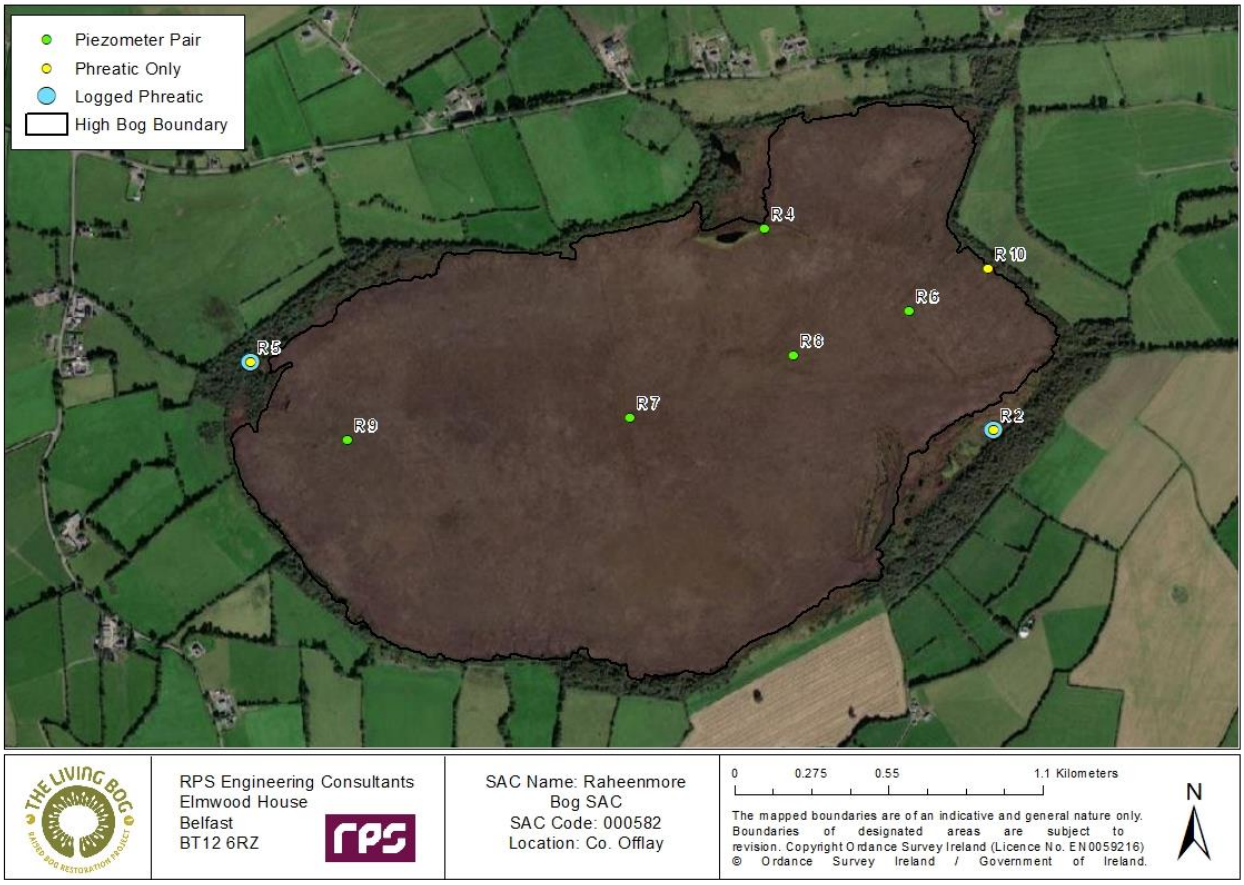


Figure 3-166: Hydrological monitoring network installed and operating on Raheenmore Bog SAC.

3.10.6 General field observations

Owing to regular site visits RPS survey teams are well placed to contribute anecdotal evidence based on conditions observed in the field. For instance, in the Southern cutover, limited observations were made in the area surrounding R2 which was generally wet all year round, suggesting the conditions for PFH may already have been in existence. The area surrounding R 5 re-wetted significantly (Figure 3-167), post-restoration with localised rewetting observed, which was indicative in general of pockets across the cutover on Raheenmore Bog SAC. A large drain along the Eastern boundary could not be blocked due to landowner issues, this drain is hypothesised to have ongoing impacts on the high bog as documented in the project

vegetation monitoring results (Crowley & Smith 2002) and should be prioritised for future restoration works if agreement can be reached with the landowner.

Figure 3-167: Cutover at Raheenmore Bog SAC where significant rewetting was observed

On the high bog, conditions remain similarly wet and soft underfoot throughout the monitoring period, with limited changes observed however areas close to the main high bog drains did become noticeably wetter following restoration. However, given water table levels are generally closer to the ground surface in high bog areas anyway, hydrological changes are more difficult to observe visually than widespread rewetting of very dry cutover areas.

3.10.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Raheenmore Bog SAC are presented with all supplementary results provided in Appendix A.

3.10.7.1 Western cutover

In a bid to evaluate and quantify the effects of restoration measures, R5 was placed in a region of high restoration potential on the cutover, (Figure 3-168) West of the high bog.

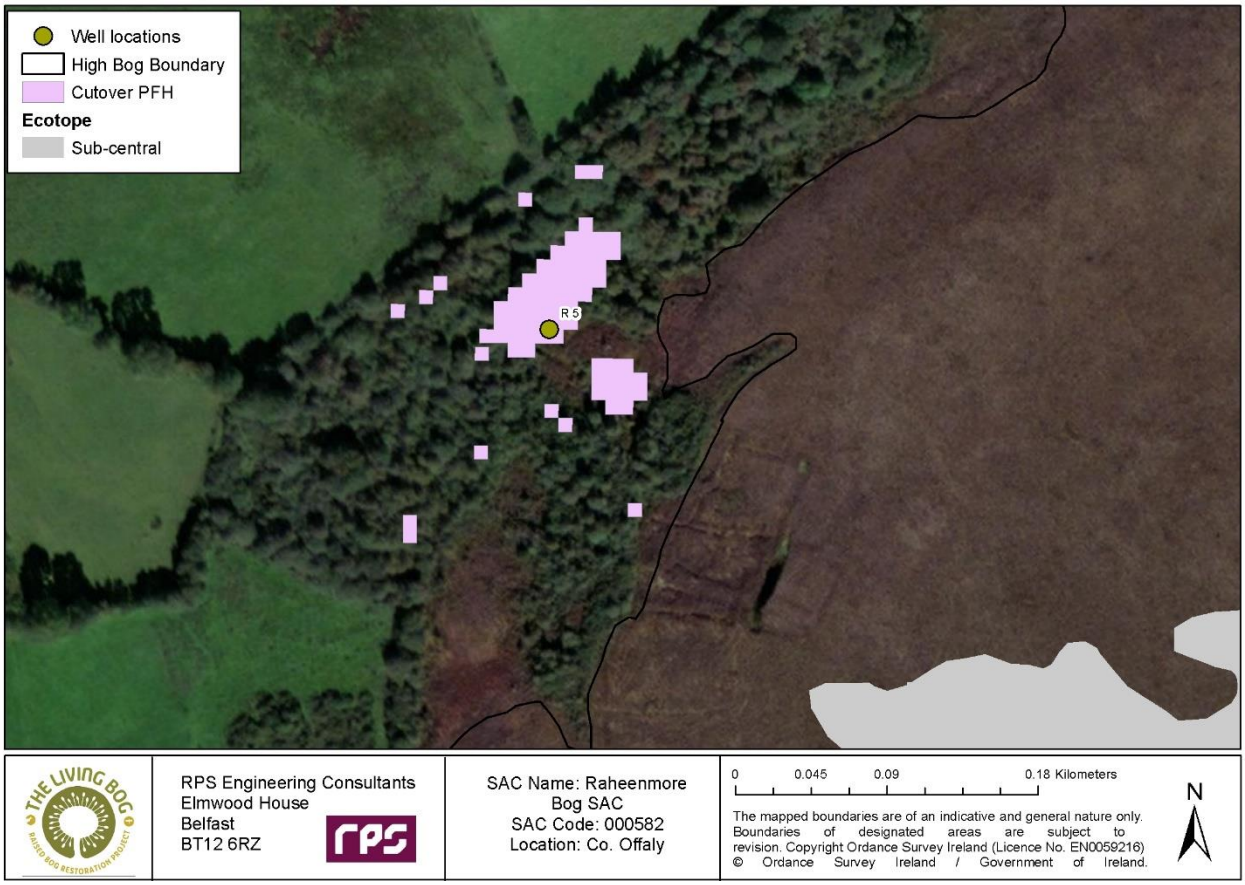


Figure 3-168: Location of well R5 on the western cutover at Raheenmore Bog SAC

Figure 3-169– Figure 3-171 illustrate results from the hydrological monitoring points located on the Western cutover at Raheenmore Bog SAC. Figure 3-168 presents the hydrograph at R5, as demonstrated the water table fluctuated extensively in the year of data recorded prior to restoration, dropping lower than 30cm below ground surface in the summer dry period (July) of 2018. For the most part, water levels remained predominantly beneath ground surface, rising above surface on only a limited number of occasions. Conversely, following restoration water levels rose and stayed consistently at or above ground surface for the majority of the remainder of the record length, dipping below but staying close to surface between April 2019 and July 2021. The manual record (Figure 3-170) for the same well during this period reveals water levels remained consistent with no significant drawdowns or rises observed.

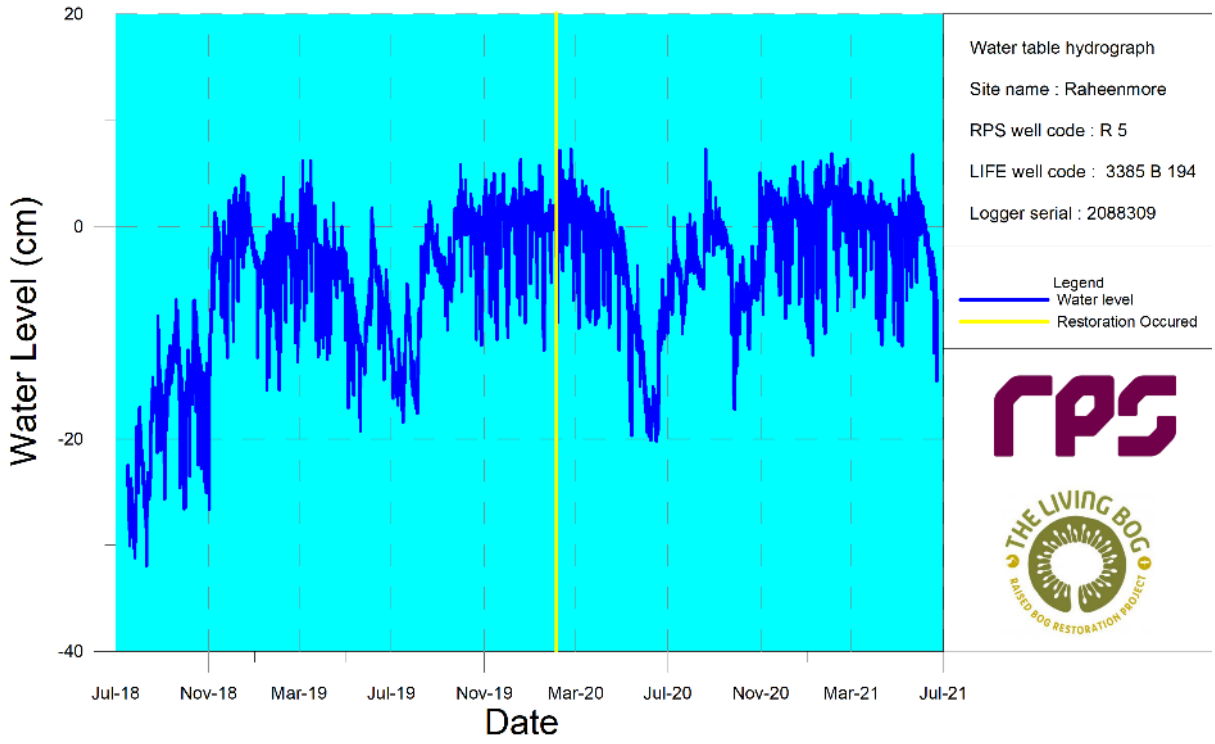


Figure 3-169: Level logger data recorded between July 2018 and July 2021 at well R 5, Raheenmore Bog SAC.

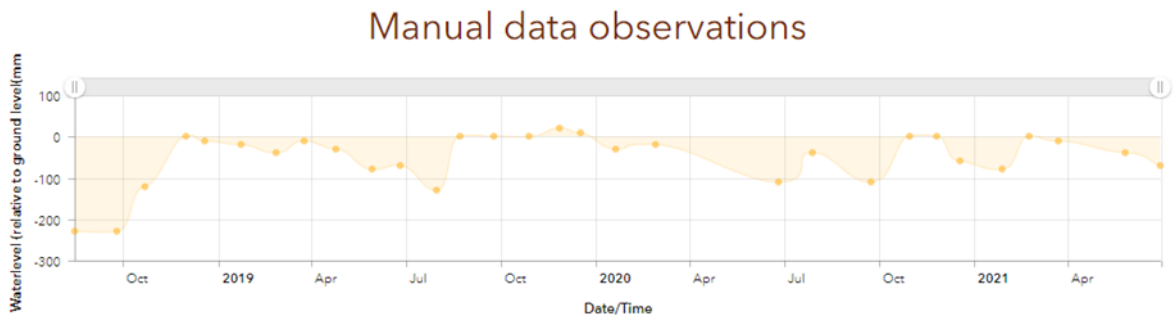


Figure 3-170 Hydrograph of manual monthly water levels R 5, Raheenmore Bog SAC

Water table duration curves were generated at each location monitored to show WL before and after restoration over the same time period of an annual hydrological cycle, in this case, April-October in 2018, 2019, 2020 and 2021. This format has been used as it is concise and clear for the reader and the data can be used to easily interpret min/max and percentile values. Figure 3-171 illustrates the duration curves generated from the data obtained from R5. The duration curves indicate a clear difference between water levels pre (2018) and post (2020) restoration. With a difference of 12.38cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

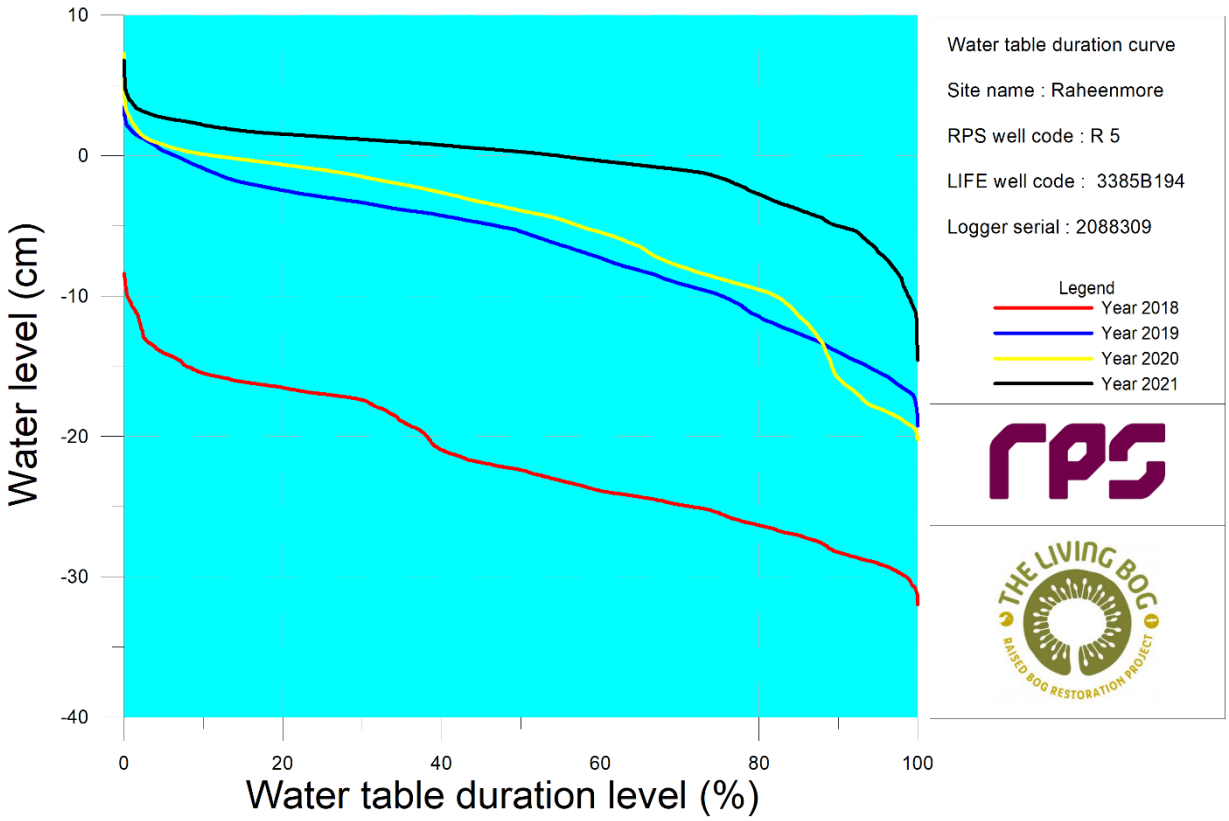


Figure 3-171: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well R5, Raheenmore Bog SAC.

3.10.7.2 Southern Cutover

In a bid to evaluate and quantify the effects of restoration measures, R2 has been placed in a region of high restoration potential in cutover bog (Figure 3-172), east of the high bog.

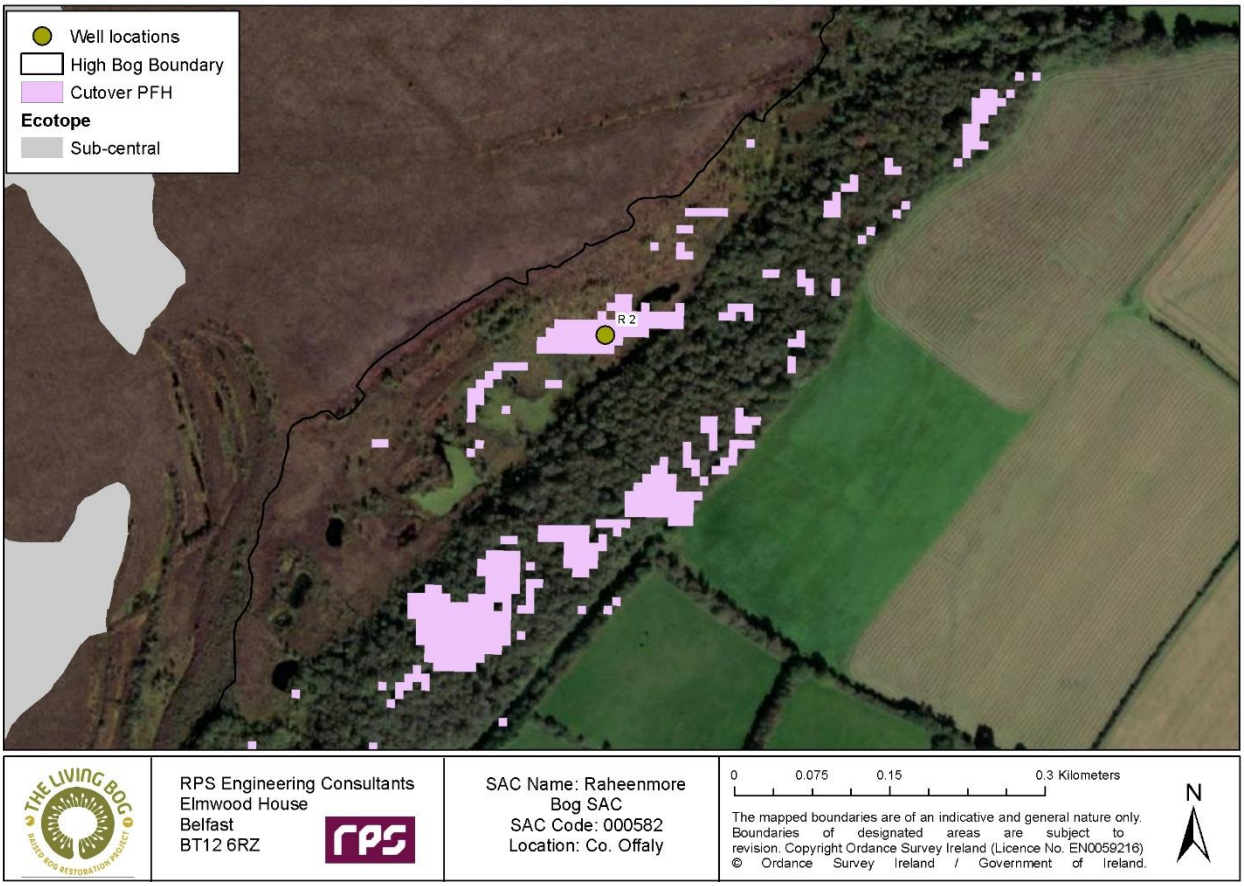


Figure 3-172: Location of well R2 on the eastern cutover at Raheenmore Bog SAC

Figure 3-179 – Figure 3-181 illustrate results from the hydrological monitoring points located on the Eastern cutover at Raheenmore Bog SAC. Figure 3-173 presents the hydrograph at R2, as demonstrated the water table in the area was already relatively close to the surface during the winter period, with fluctuations up to 15cm of the ground surface in the summer dry period (April – October) of 2018. Following restoration, there was a notable increase in the water level, with the water table fluctuating to -15cm less often during the summer dry period (April – October) of 2020 and similar activity occurring through to the summer dry period of 2021. The manual record (Figure 3-174) for the same well during this period reveals water levels remained consistent with only one significant drawdown post-restoration in July 2020.

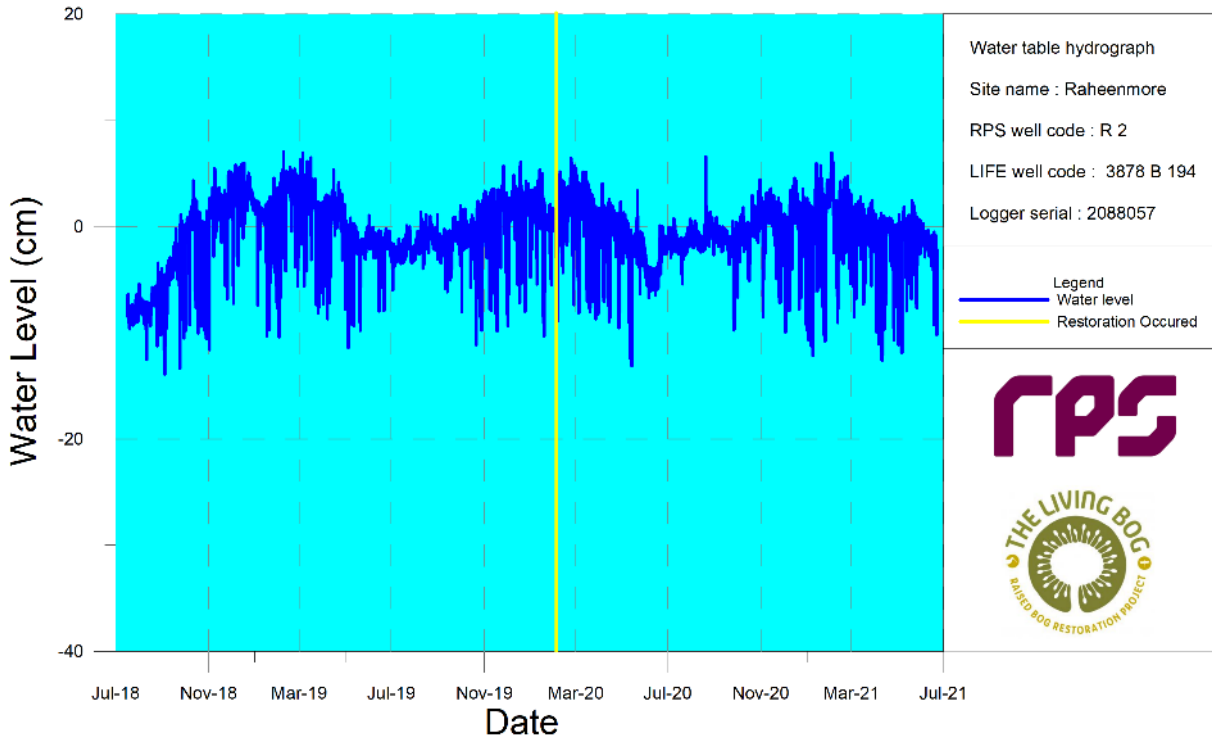


Figure 3-173: Level logger data recorded between July 2018 and July 2021 at well R2, Raheenmore Bog SAC.

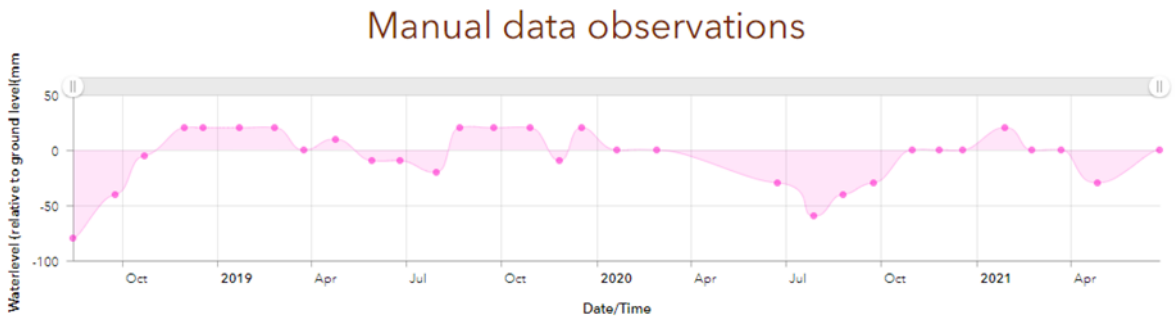


Figure 3-174 Hydrograph of manual monthly water levels R 2, Raheenmore Bog SAC

Figure 3-175 illustrates the duration curves generated from the data obtained from R2. The duration curves indicate a clear difference between water levels pre (2018) and post (2020-21) restoration. With a difference of 2.2cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

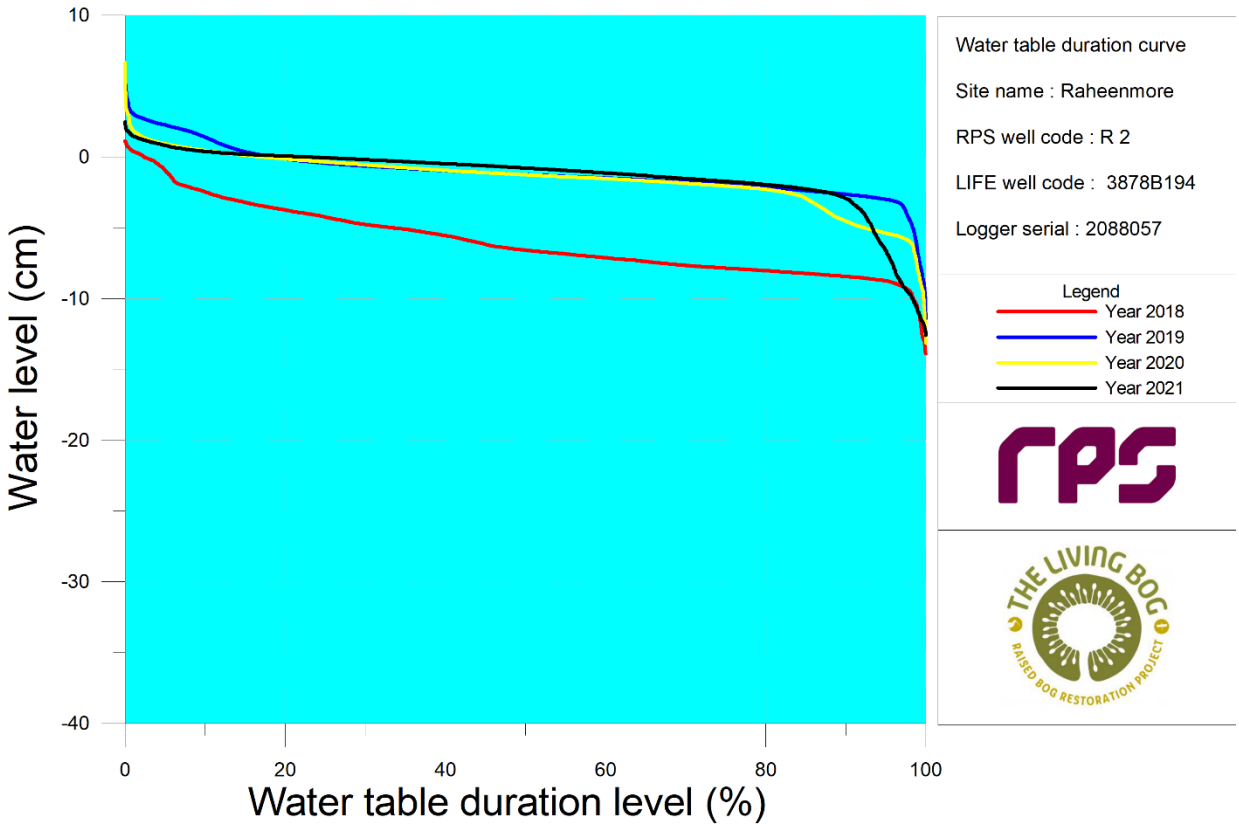


Figure 3-175: Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well R2, Raheenmore Bog SAC.

3.10.7.3 High Bog

To investigate the impact restoration measures would have on the high bog at Raheenmore Bog SAC, piezometers were located in areas currently defined as Active raised bog (ARB), Degraded Raised Bog (DRB) and areas of supporting high bog. Figure 3-176, shows the location of the high bog monitoring network at Raheenmore bog, SAC.

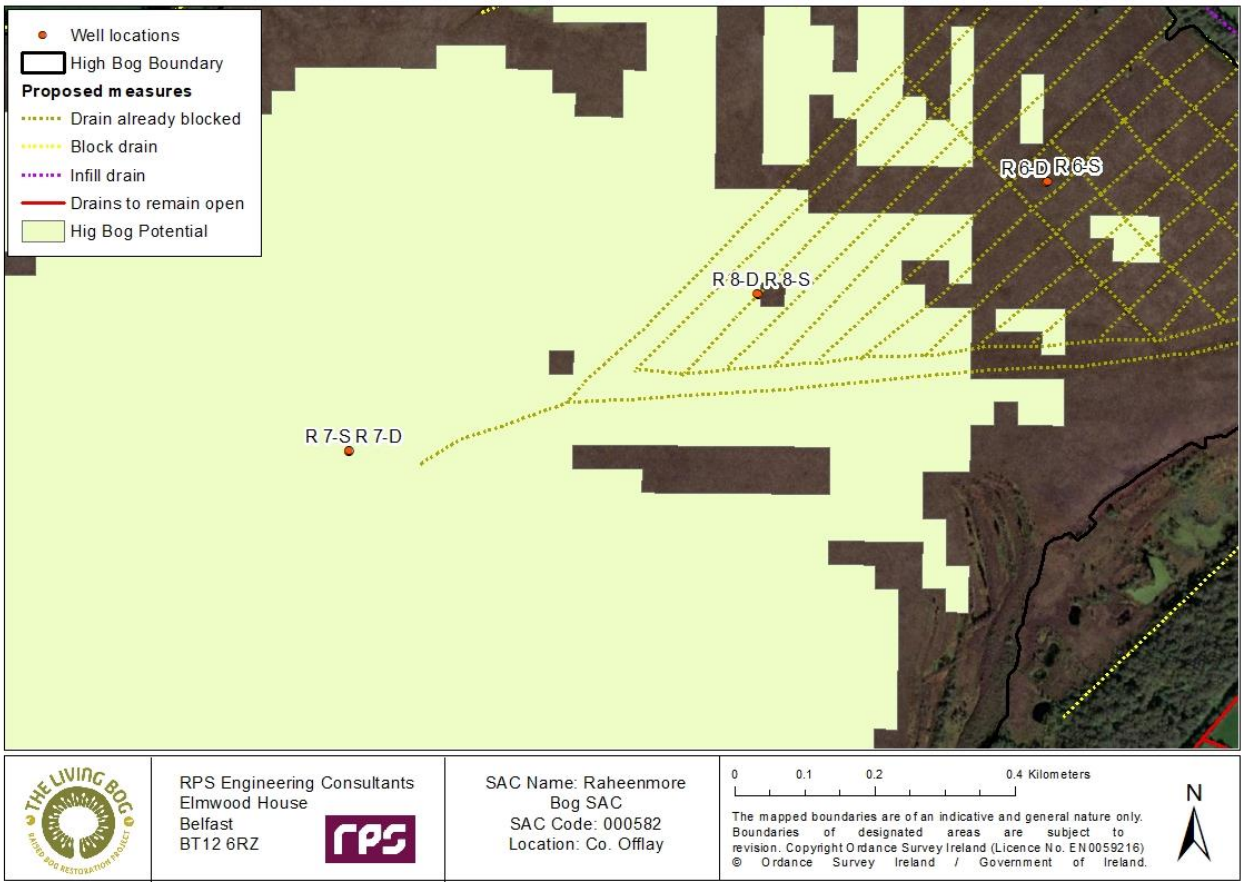


Figure 3-176: Location of well R6-8 on the high bog in Raheenmore Bog SAC

Overall, modest responses to drain blocking was observed on the High Bog compared to cutover areas. Water levels in ARB areas were observed close to the bog surface and remained so throughout the study, as expected. Limited fluctuations were also noted in areas of DRB or supporting high bog and it is recommended that longer-term data is collected to investigate the impact of drain blocking over time. Manual data obtained from R6s, R7s and R8s (Figure 3-177-Figure 3-179) can be used to demonstrate the negligible variation in water levels observed pre/post-restoration on the high bog at Raheenmore bog SAC. Notably, post-restoration water levels fluctuated above the ground surface more often.

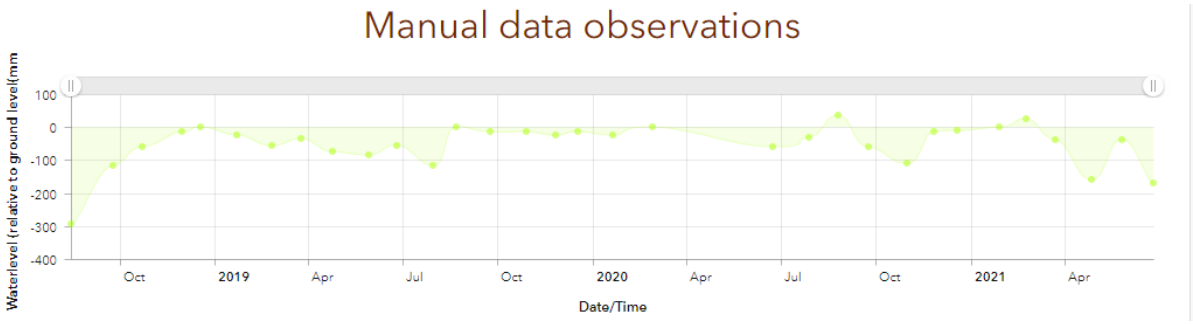


Figure 3-177 Hydrograph of manual monthly water levels R 6S, Raheenmore Bog SAC

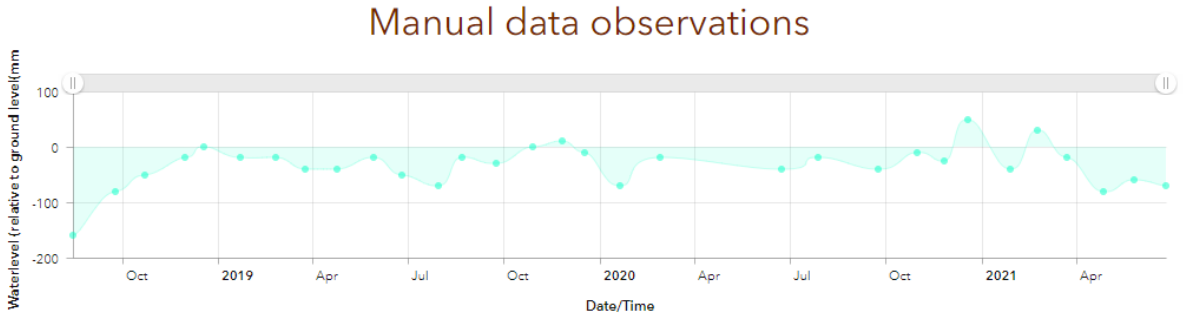


Figure 3-178 Hydrograph of manual monthly water levels R 7S, Raheenmore Bog SAC

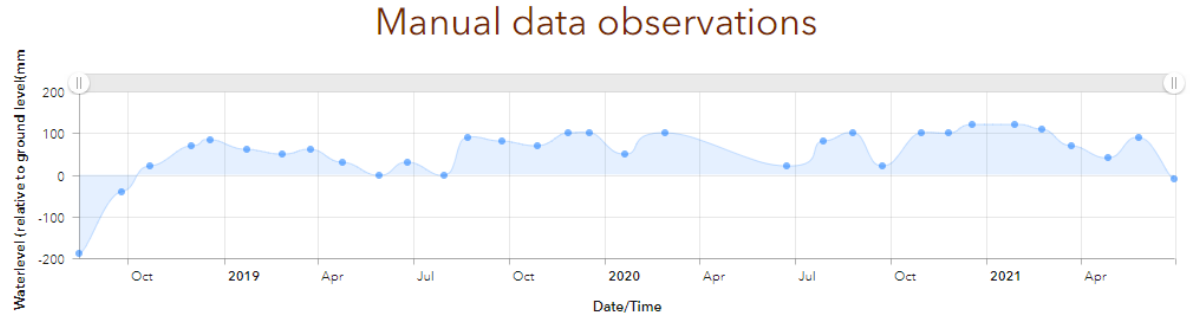


Figure 3-179 Hydrograph of manual monthly water levels R 8S, Raheenmore Bog SAC

3.10.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.9). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration The largest increases were noted in all cutover wells. Significant changes were observed on the high bog with multiple wells in areas designated as DRB or Supporting High Bog now displaying a post-restoration hydrological regime capable of supporting ARB.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Raheenmore	R10	High Bog	Supporting High Bog	-81.00	-57.50
Raheenmore	R2	Cutover	PFH	-7.60	-5.40
Raheenmore	R4-S	High Bog	DRB	-7.40	-7.00
Raheenmore	R5	Cutover	PFH	-28.25	-15.80
Raheenmore	R6-S	High Bog	DRB	-27.70	-16.80
Raheenmore	R7-S	High Bog	ARB	-15.20	-7.00
Raheenmore	R8-S	High Bog	ARB	-17.50	2.00
Raheenmore	R9-S	High Bog	ARB	-17.40	-4.20

Table 3.9: 90th percentile water levels Raheenmore Bog SAC, pre and post-restoration.

3.11 Sharavogue Bog SAC

3.11.1 Hydrogeological setting

Consultation of Geological Survey Ireland (GSI) 1:500,000 bedrock mapping suggests the 'High bog' of Sharavogue Bog SAC to be underlain entirely by the waulsortian mudbank group of rocks, whilst to the west a combination of courceyan limestone and rocks of the Navan group are predominant. This typically denotes, a non-homogenous unit, often comprising pale-grey, crudely bedded or massive limestone. This unit is known as a moderately productive and regionally-important aquifer unit, however low permeability peat subsoils act to confine and thus reduce aquifer vulnerability in the immediate area of the high bog. Groundwater contributions are therefore uncertain.

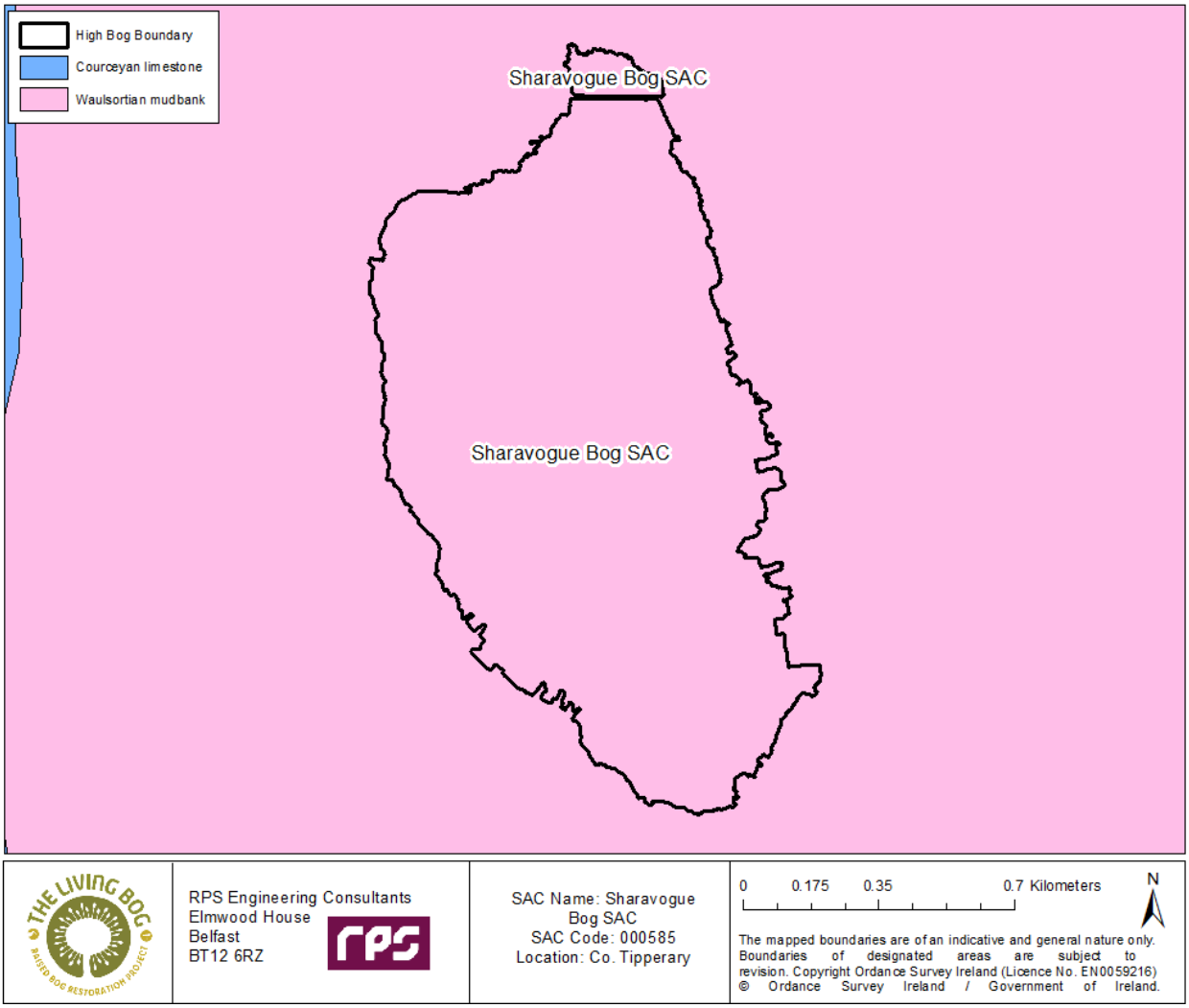


Figure 3-180: Simplified geology of Sharavogue Bog SAC.

3.11.2 Ecotope mapping

Ecotope mapping is a powerful tool for categorising differing types of habitat found on the high bog, providing a methodology for and quantification of targeted restoration on the high bog (Figure 3-181). During the last monitoring survey (2018) it was noted, that Sharavogue Bog SAC consists of 25.78 ha of Active Raised Bog (ARB) consisting of areas of sub-central and Active Flush.

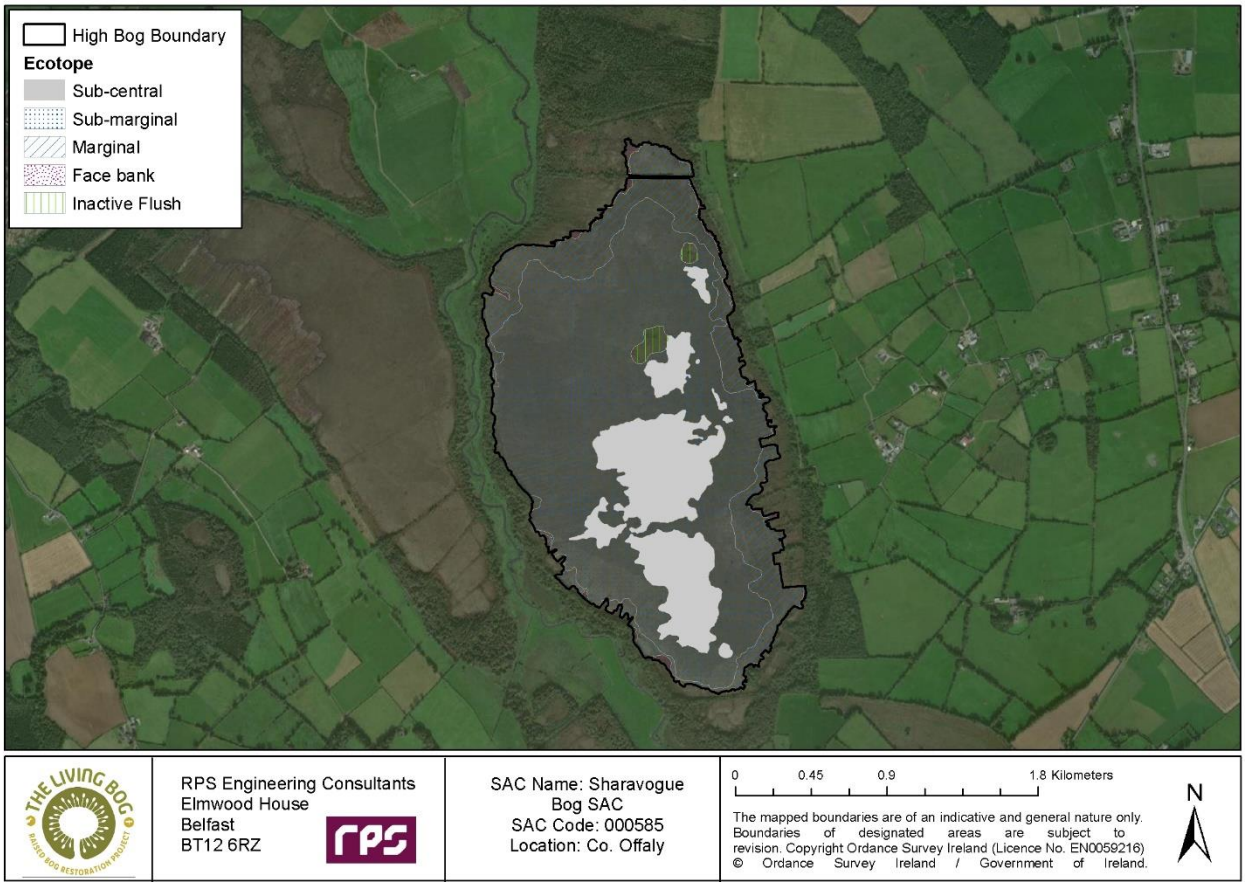


Figure 3-181 Ecotope mapping carried out for Sharavogue Bog SAC

3.11.3 Proposed restoration plan

The restoration plan for Raheenmore Bog SAC (Figure 3-182) identified operational drains on the high bog which impacted on the hydrological function of the bog by facilitating and expediting surface flow. Similarly, several areas of adjacent cutover surrounding the bog were identified as opportunities for reducing ongoing subsidence of the high bog, whilst simultaneously contributing to an overall increase in the percentage of active peat-forming (ARB) habitat. Overall, the installation of peat dams was recommended across 5.54 km of channels both on the high bog and cutover.

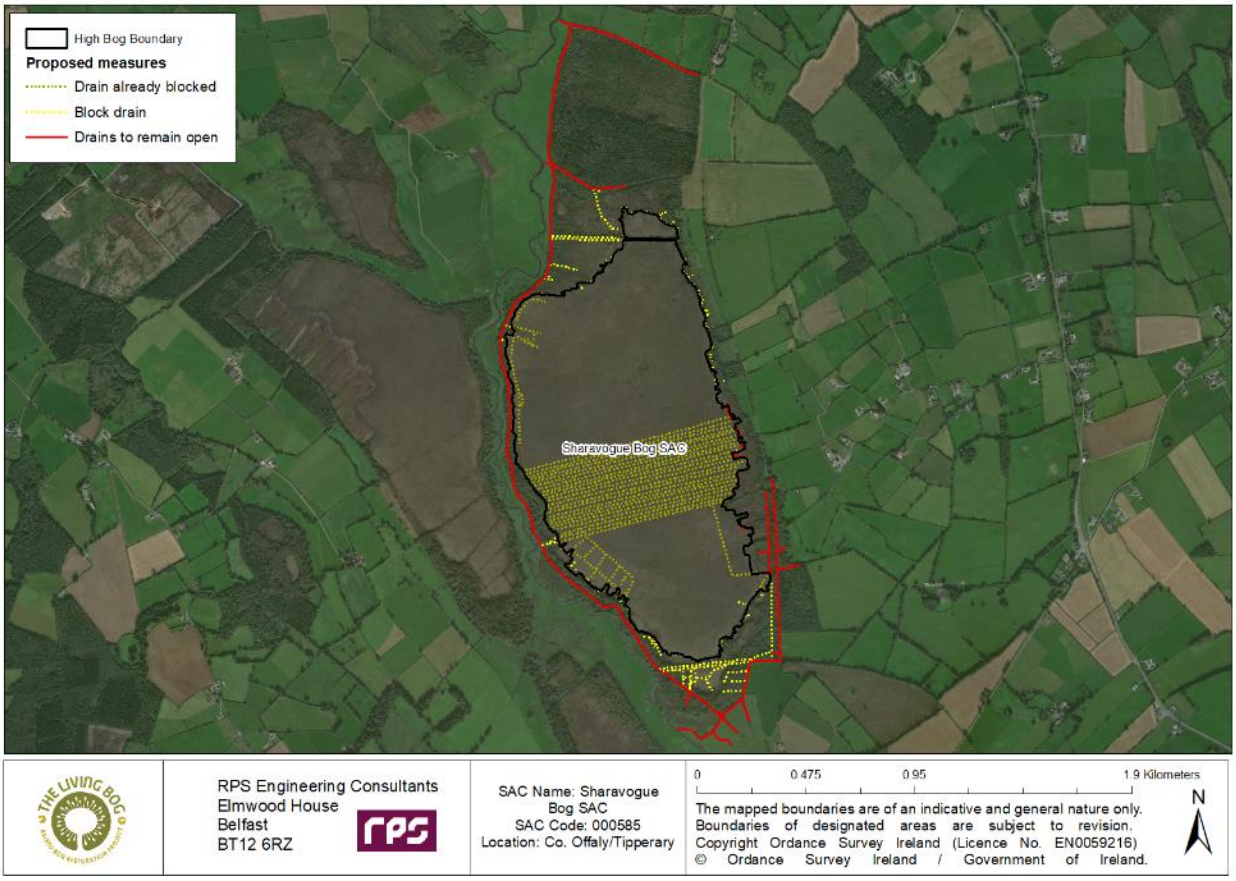


Figure 3-182 Restoration measures specified in support of hydrological goals.

3.11.4 Restoration potential

Eco-hydrological modelling of the restoration potential on Sharavogue Bog SAC, excluding current areas mapped as ARB, suggested as much as 15.1 ha of habitat had the potential to be positively impacted by restoration works, with 14.7 ha of suitable high bog classified as Degraded Raised Bog (DRB) and 0.4 ha of surrounding cutover bog classified as Potential Peat Forming Habitat (PPFH) (Figure 3-183).

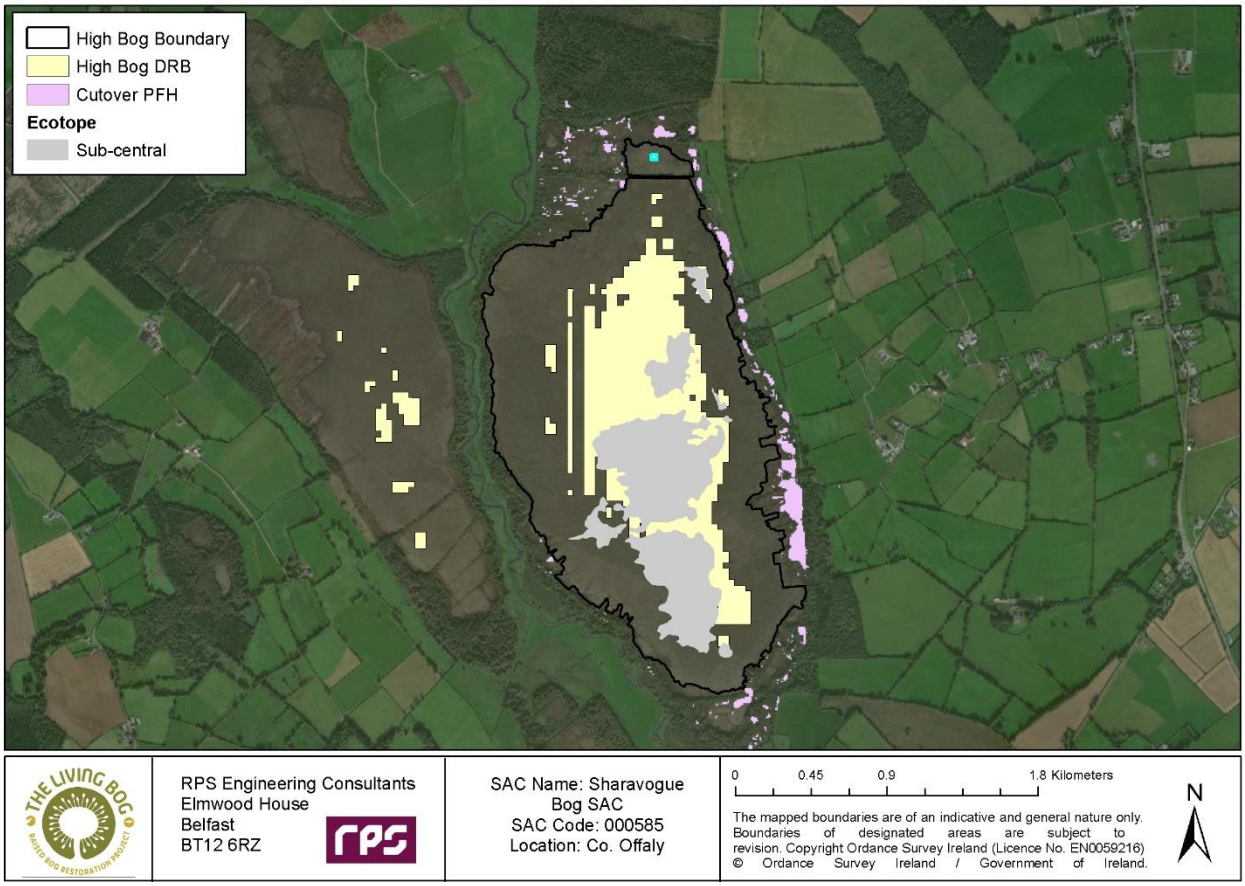


Figure 3-183 Restoration potential of Sharavogue Bog SAC as outlined by eco-hydrological modelling.

3.11.5 Deployed monitoring network

A monitoring network comprising a mixture of 18 shallow phreatic wells (Figure 3-184) was subsequently installed on Sharavogue Bog SAC. On the high bog, 7 phreatic wells were installed, accompanied by 6 deep piezometers to monitor vertical hydraulic gradients. On the cutover, 5 phreatic wells were installed. A total of 2 water level loggers were spread amongst the wells. Water levels across all wells were manually documented monthly, from November 2018 to June 2021, apart from March – June 2020 due to travel restrictions imposed by the Irish Government as a result of the Covid-19 pandemic, whilst those equipped with loggers were set to automatically record levels in 15-minute intervals and downloaded on a quarterly basis. Water level readings were barometrically corrected using the barometric logger installed on the nearby site of Moyclare Bog SAC, located approx. 19 km North of the site.

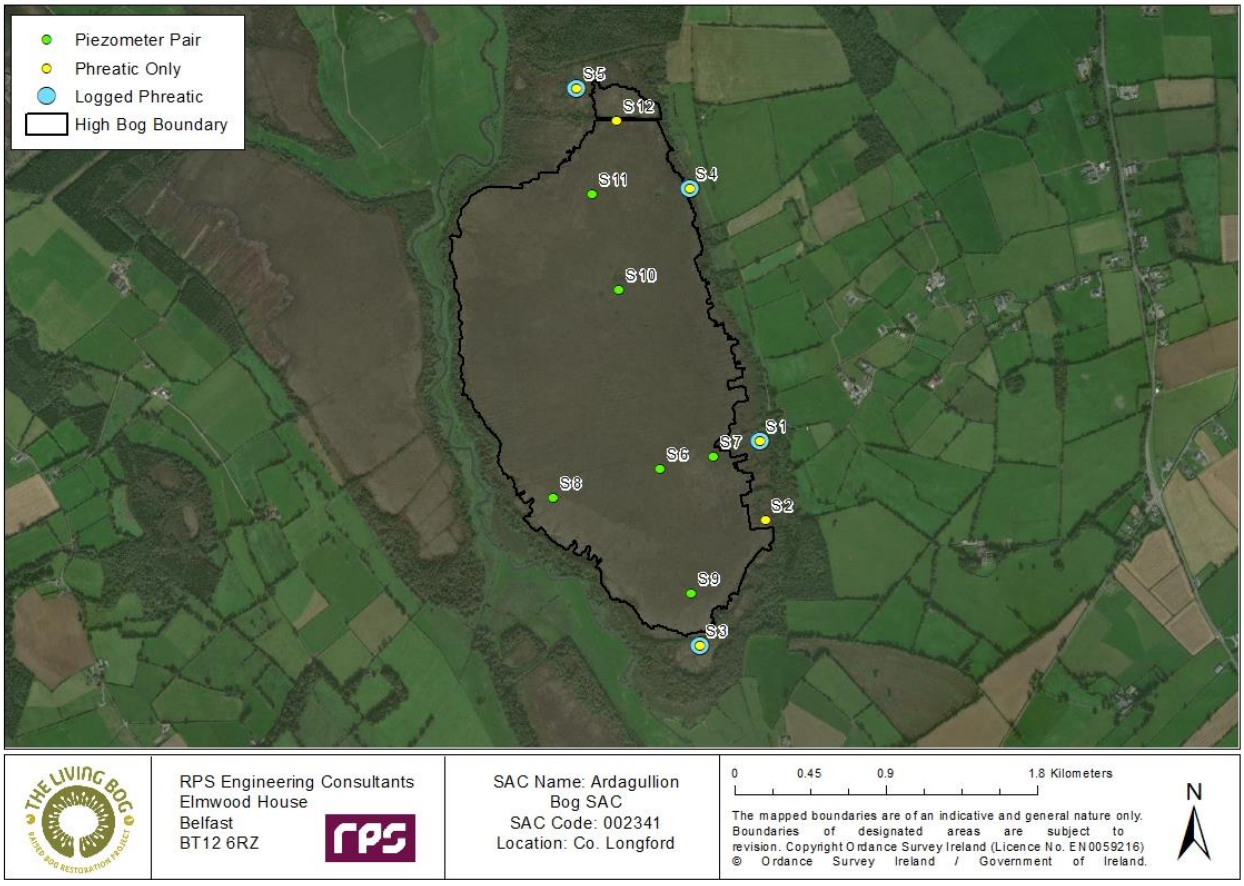


Figure 3-184 Hydrological monitoring network installed and operating on Sharavogue Bog SAC.

3.11.6 General field observations

Limited works were proposed for Sharavogue relative to the other sites, with the majority of high bog drains having been blocked as part of an earlier raised bog restoration programme. The eastern cutover is dominated by a well-developed lagg system and one of the aims of the restoration was to not cause further rewetting of this area as it may have a negative impact on the established ecological communities. Partial blockage was completed in the main drain to the North which was largely successful at raising the water level in the deep marginal drain, without having an impact on the adjacent landFigure 3-185.

Figure 3-185: Rewetting observed on Sharavogue Bog SAC, where the water table came up to the surface throughout the year

A large drain to the South-East could not be blocked due to landowner issues, this drain was particularly large and proposals were put forward by The Living Bog project manager Jack McGaughey to block this drain using a prefabricated concrete dam. Additionally, two high bog tracks intersected the high bog to the north and south, these drains could not be blocked due to landowner issues. The southern track was partially blocked, with plastic sheet piles with limited success. These areas should be prioritised for future restoration works if an agreement can be reached with the landowner.

3.11.7 Results

The following section presents an overview of the results obtained from both the manual dipping and automated logging of water levels. Key findings from Sharavogue Bog SAC are presented with all supplementary results provided in Appendix A.

3.11.7.1 Northern Cutover

In a bid to evaluate and quantify the effects of restoration measures, S5 has been placed in a region of high restoration potential in cutover bog (Figure 3-186), north of the high bog.

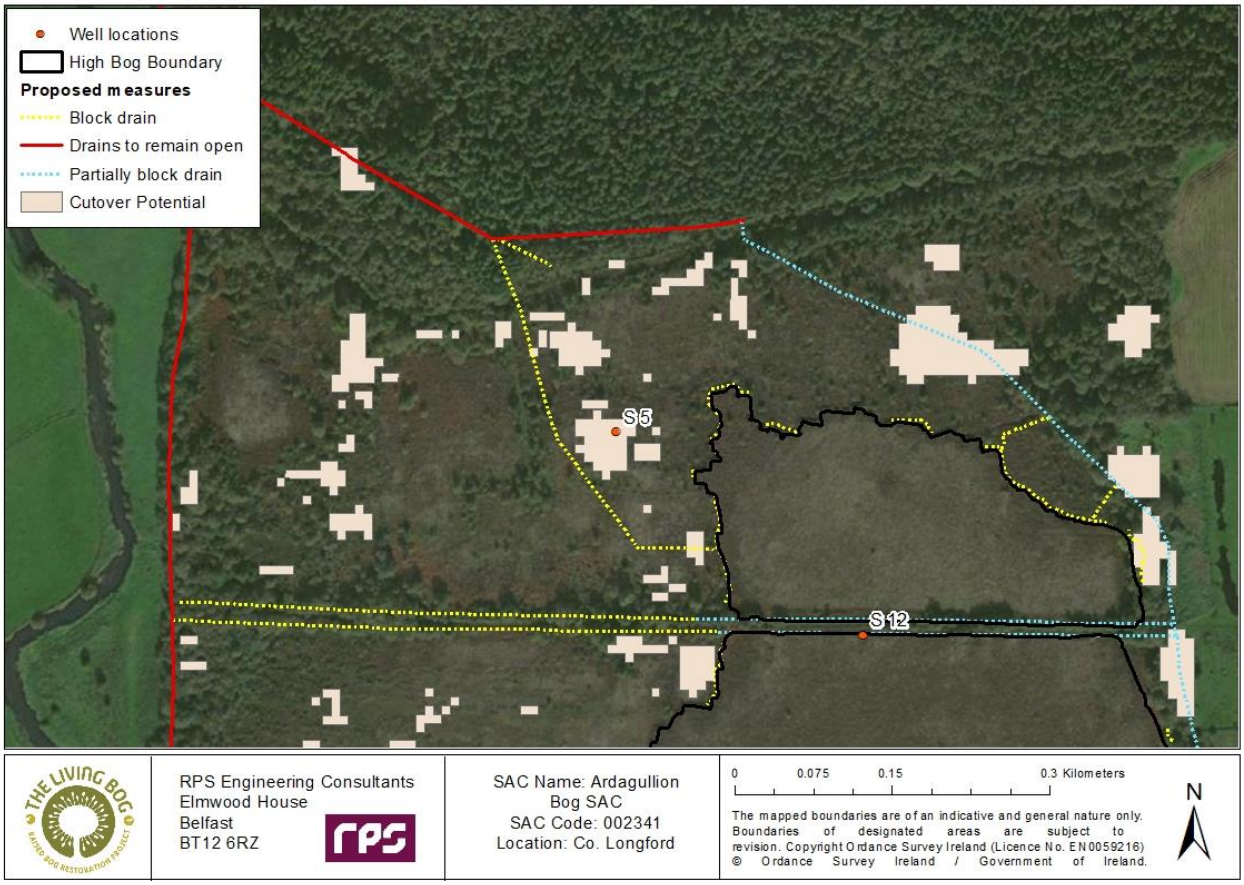


Figure 3-186: Location of wells S5 on the northern cutover at Sharavogue Bog SAC

Figure 3-187–Figure 3-189illustrate results from the hydrological monitoring points located on the northern cutover at Sharavogue Bog SAC. Figure 3-187 presents the hydrograph at S5, as demonstrated the water table fluctuated extensively in the year of data recorded prior to restoration, dropping lower than 40cm below ground surface in the summer dry period (April – October) of 2018. For the most part, water levels remained predominantly beneath ground surface, rising above surface on only a limited number of occasions. Following restoration water levels rose and stayed consistently at or above ground surface for the majority of the remainder of the record length, dipping below but staying close to surface between June 2021. The manual record (Figure 3-188) for the same well during this period reveals water levels remained

consistent with only one significant drawdown post-restoration in July 2021 which was within 20cm of the ground surface.

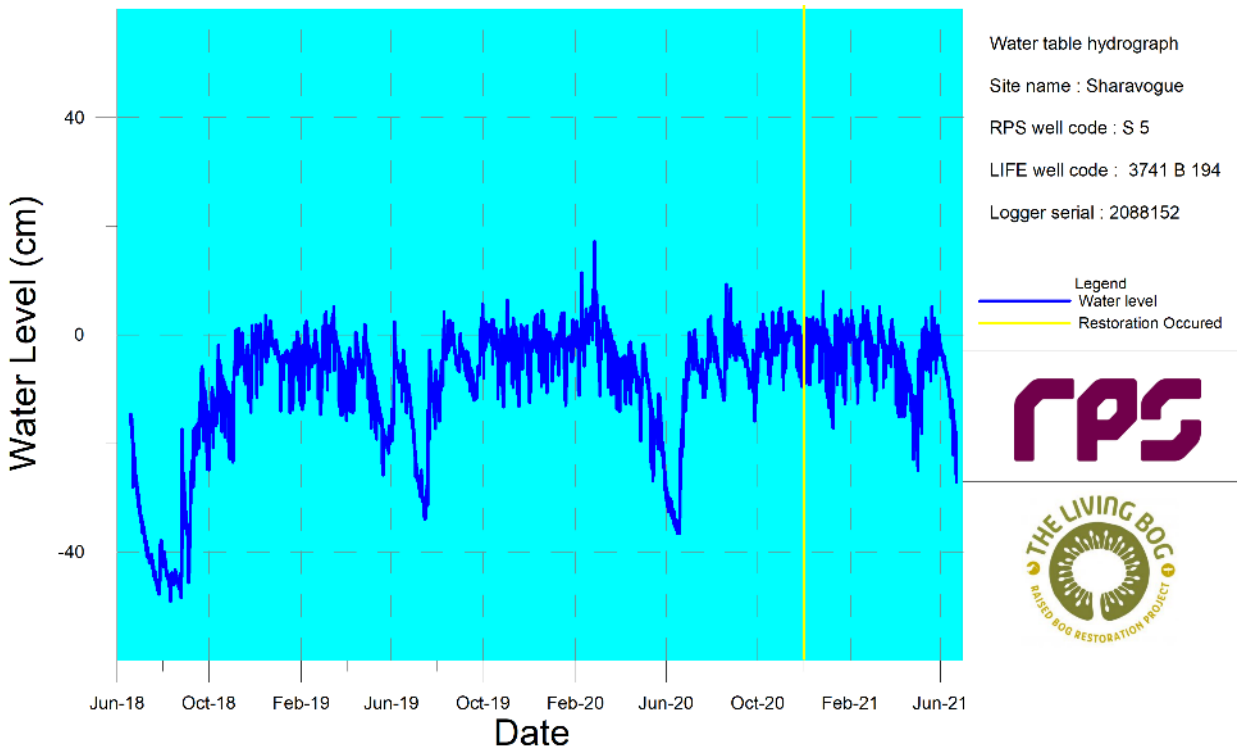


Figure 3-187: Hydrograph of manual monthly water levels S 5, Sharavogue Bog SAC

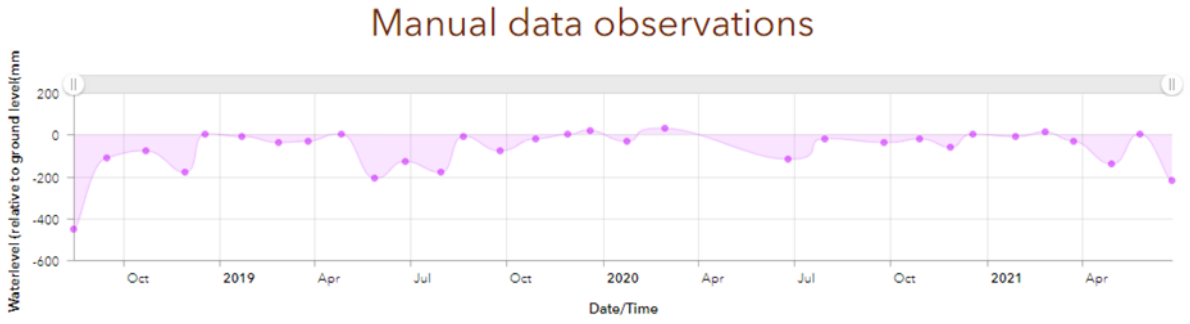


Figure 3-188: Hydrograph of manual monthly water levels S 5, Sharavogue Bog SAC

Figure 3-189 illustrates the duration curves generated from the data obtained from S5. The duration curves indicate a clear difference between water levels pre (2020) and post (2021) restoration. With a difference of 21.2cm between the annual D90 values pre-post restoration. Overall, this highlights the success of the restoration measures attributable to drain blocking in the area.

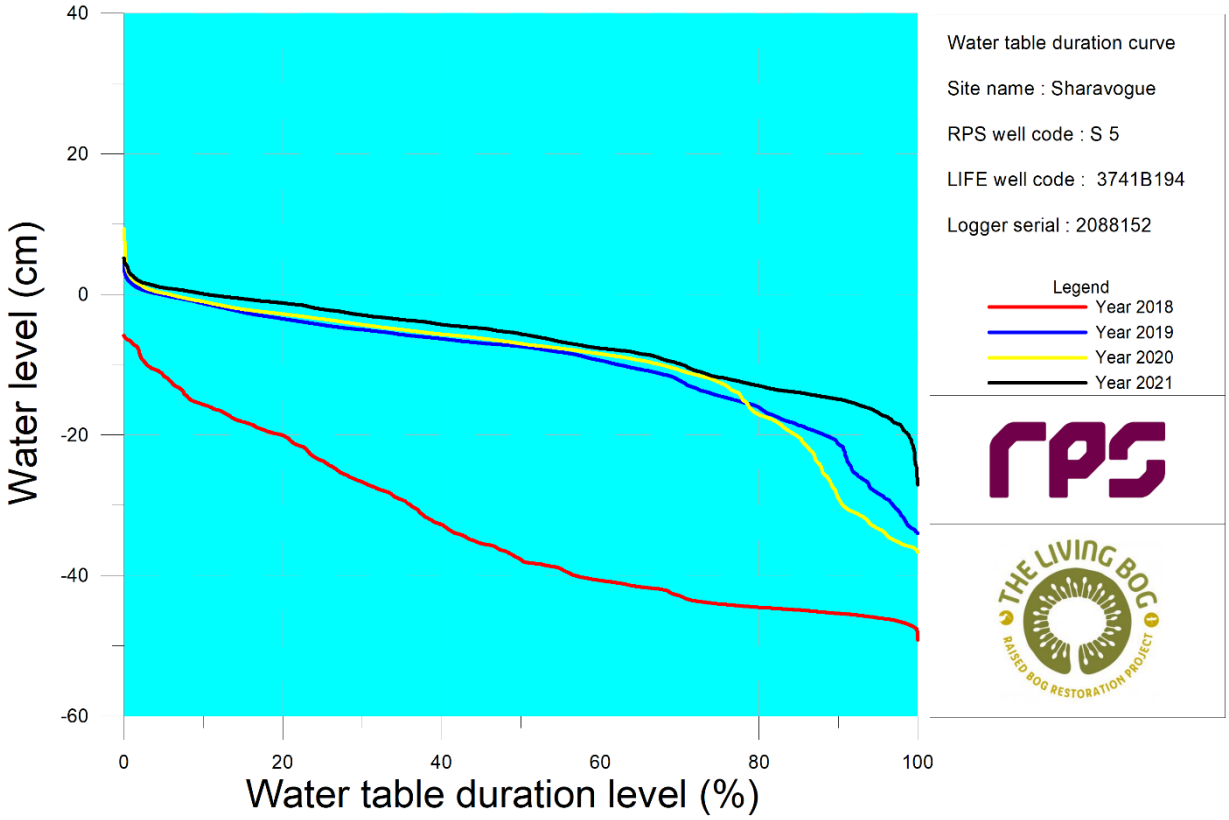


Figure 3-189 Duration curve data recorded between the summer period (April and October) for the individual years collected during the investigation at well S5, Sharavogue Bog SAC.

3.11.7.2 Eastern Cutover

In a bid to evaluate and quantify the effects of restoration measures, S1 has been placed in a region of high restoration potential in cutover bog (Figure 3-190), east of the high bog.

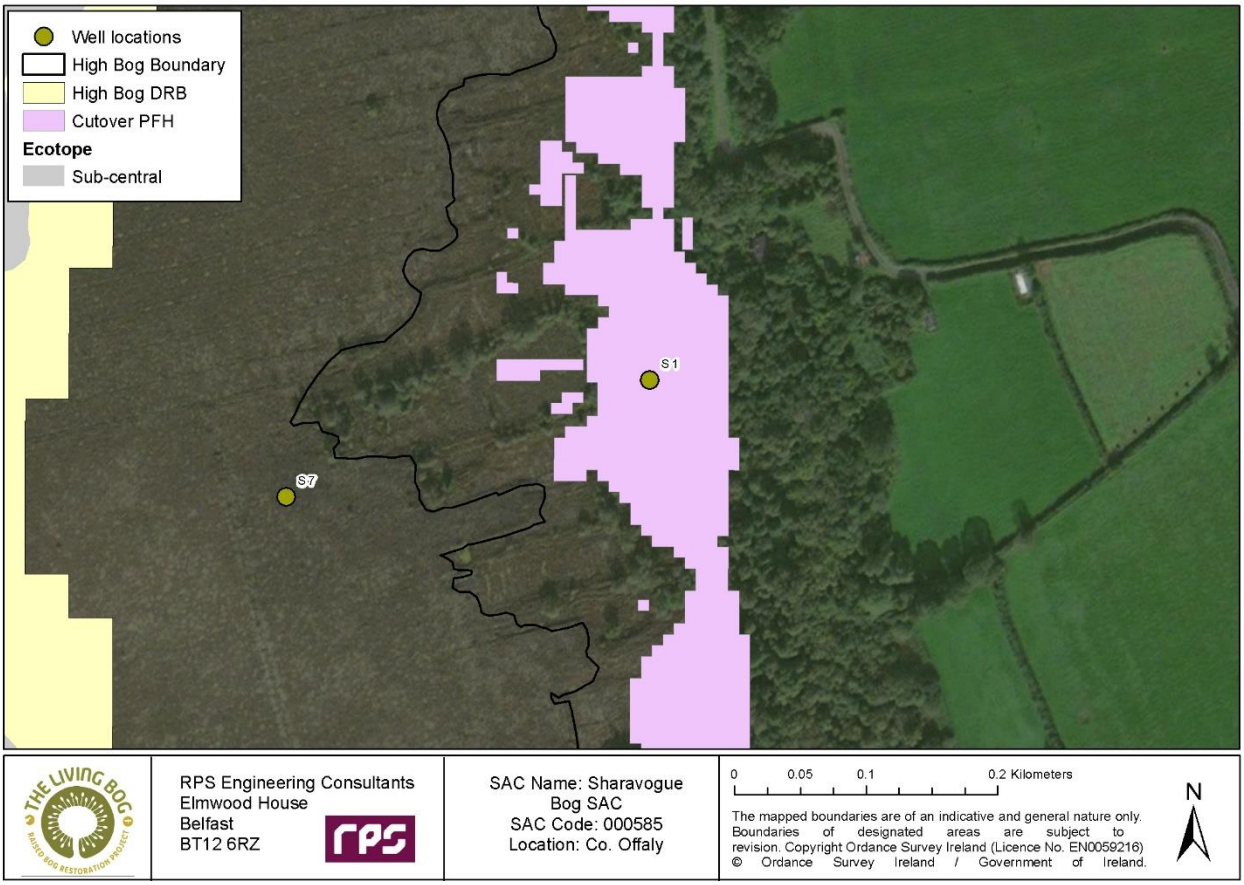


Figure 3-190: Location of wells S1 on the eastern cutover at Sharavogue Bog SAC

Figure 3-191– Figure 3-192 illustrate results from the hydrological monitoring points located on the eastern cutover at Sharavogue Bog SAC. Figure 3-191 presents the hydrograph at S1, as demonstrated the water table in the area was already relatively close to the surface during the winter period, with fluctuations up to 15cm of the ground surface in the summer dry period (April – October) of 2018. Following restoration water levels rose and stayed consistently at or above ground surface for the majority of the remainder of the record length, dipping below but staying close to surface. The manual record (Figure 3-192) for the same well during this period reveals water levels remained consistently above surface post-restoration.

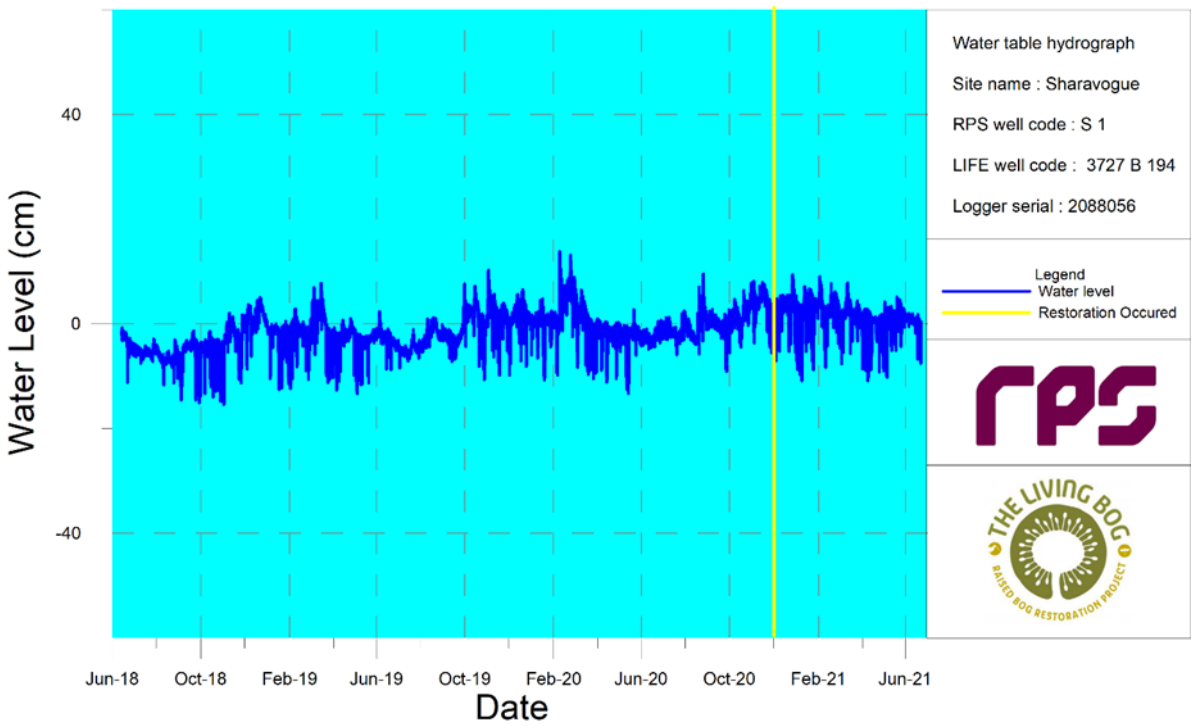


Figure 3-191: Level logger data recorded between June 2018 and July 2021 at well S1, Sharavogue Bog SAC

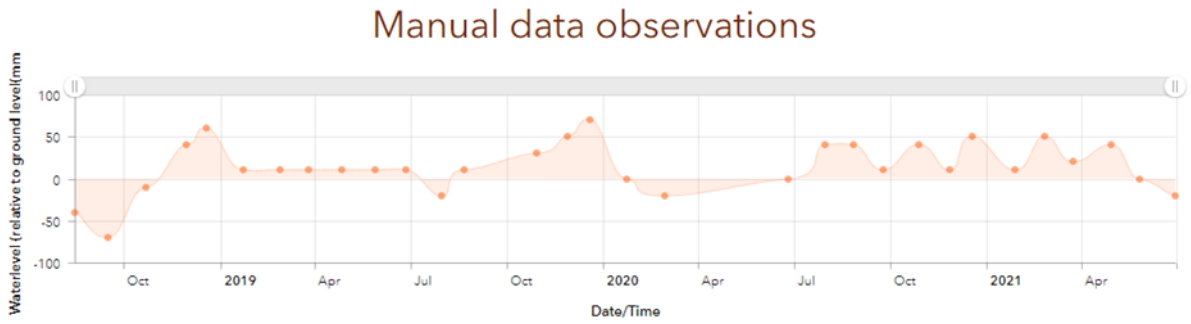


Figure 3-192: Hydrograph of manual monthly water levels S 1, Sharavogue Bog SAC

3.11.7.3 High Bog

To investigate the impact restoration measures would have on the high bog at Sharavogue Bog SAC, piezometers were located in areas currently defined as Active raised bog (ARB), Degraded Raised Bog (DRB) and areas of supporting high bog. Figure 3-193 shows the location of the high bog monitoring network at Sharavogue, SAC.

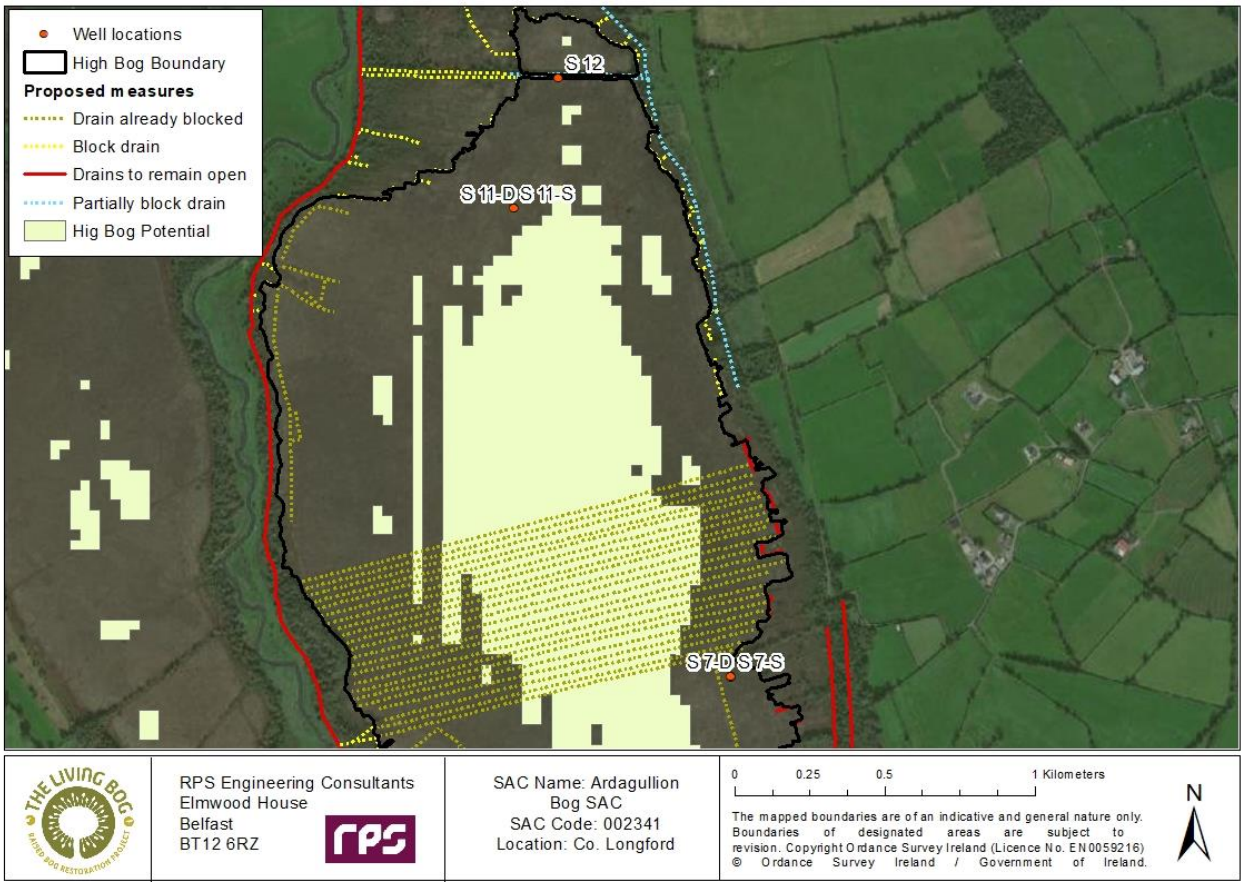


Figure 3-193: Location of well S7, S11 and S12 on the high bog in Sharavogue Bog SAC

Overall, modest responses to drain blocking was observed on the High Bog compared to cutover areas. Water levels in ARB areas were observed close to the bog surface and remained so throughout the study, as expected. Limited fluctuations were also noted in areas of DRB or supporting high bog and it is recommended that longer-term data is collected to investigate the impact of drain blocking over time. Manual data obtained from S7s, S11s and S12 can be used to demonstrate the negligible variation in water levels observed pre/post-restoration on the high bog at Sharavogue bog SAC which was representative of a majority of monitoring points on the high bog. Post-restoration the water table appears to rise to at or near the surface but dips to levels similar to pre-restoration periods during the summer dry period in 2021.

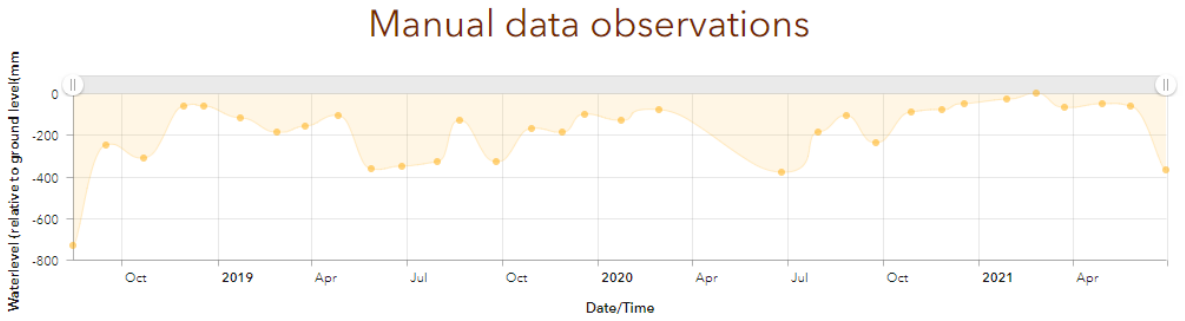


Figure 3-194 Hydrograph of manual monthly water levels S 7S, Sharavogue Bog SAC

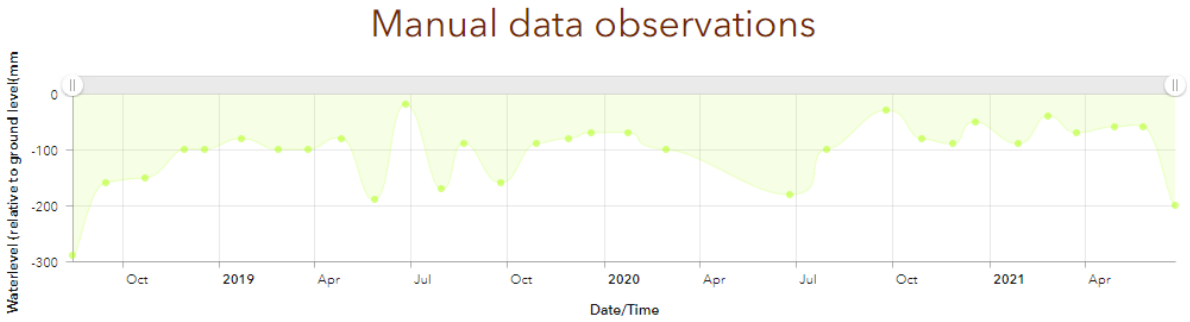


Figure 3-195 Hydrograph of manual monthly water levels S 11S, Sharavogue Bog SAC

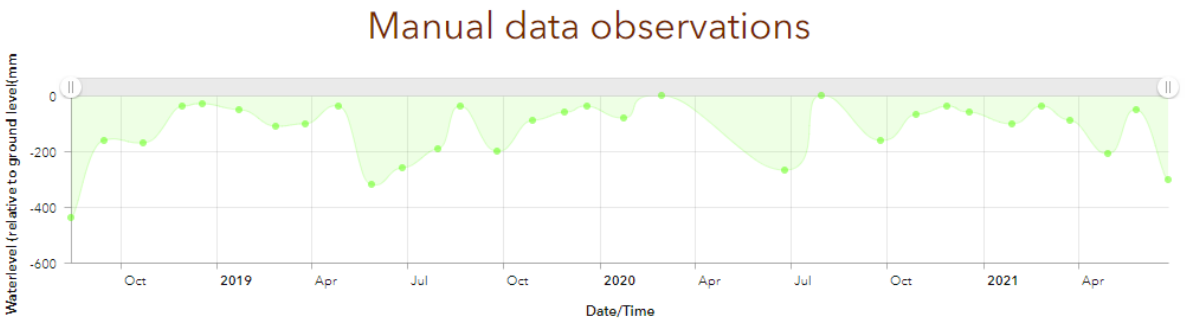


Figure 3-196 Hydrograph of manual monthly water levels S 12, Sharavogue Bog SAC

3.11.8 Statistical analysis (90th percentile)

Statistical analysis of the 90th percentile water levels shows an increase in the 90th Percentile water level in every instance between pre-restoration levels (2018) and post-restoration levels (2020) (Table 3.10Table 3.1). although it is worth noting that Summer 2018 was a notably dry summer with a prolonged dry spell with high rates of evapotranspiration The largest increases were noted in all cutover wells. Significant changes were observed on the high bog with multiple wells in areas designated as DRB or Supporting High Bog now displaying a post-restoration hydrological regime capable of supporting ARB.

Site name	RPS well code	Habitat	Sub-Habitat	Pre restoration D90 (cm)	Post restoration D90 (cm)
Sharavogue	S1	Cutover	PFH	-6.70	-1.60
Sharavogue	S2	Cutover	NPFH	-24.70	-11.40
Sharavogue	S3	Cutover	PFH	-37.90	-20.00
Sharavogue	S4	Cutover	PFH	-23.80	-3.60
Sharavogue	S5	Cutover	PFH	-41.60	-20.40
Sharavogue	S10-S	High Bog	ARB	-30.30	-21.00
Sharavogue	S11-S	High Bog	Supporting High Bog	-27.70	-17.20
Sharavogue	S12	High Bog	Supporting High Bog	-41.20	-28.20
Sharavogue	S6-S	High Bog	DRB	-8.70	-9.80
Sharavogue	S7-S	High Bog	Supporting High Bog	-68.20	-30.80
Sharavogue	S8-S	High Bog	Supporting High Bog	-22.50	-6.80
Sharavogue	S9-S	High Bog	Supporting High Bog	-28.40	-19.40

Table 3.10: 90th percentile water levels Sharavogue Bog SAC, pre and post-restoration.

4 COMPARISON WITH ECOLOGICAL DATASETS

The observed hydrological results presented in this report suggest that the restoration measures were largely successful in restoring the supporting hydrological conditions required to promote the return of ARB/PFH across the project sites. The result presented in the project Vegetation Monitoring Final Report (Crowley & Smith 2022) supports the hydrological findings and suggests that the measures have been successful with an improvement in the percentage cover of *Sphagnum* observed on several project sites, indicating that the supporting hydrological conditions were improved. Table 4.1 highlights the increase in Active Raised Bog (ARB) on five of the project sites as a result of restoration after approximately 1-3 years.

Table 4.1: Total extent (and type) of ARB in ha on the high bog across the five sites surveyed 1-3 years post-restoration.

Site Code/Name	Year of Survey	Sub-central	Central	Active Flush	Total ARB	Increase in ARB since baseline
000575 Ferbane Bog SAC	2021	34.6	2.3	0	36.9	4.3
000581 Moyclare Bog SAC	2021	18.2	4.6	0.6	23.4	1.7
000679 Garriskil Bog SAC	2021	52.7	15.8	0.4	68.9	18.0[1]
001242 Carrownagappul Bog SAC	2021	41.5	3.0	0.8	45.3	17.2[2]
002341 Ardagullion Bog SAC	2020	8.9	0.2	0.1	9.2	2.0
TOTAL						**43.0**

Work is currently ongoing to combine the initial ecological data and hydrology data to derive relationships that help expand the current scientific understanding of ecohydrological processes on Irish Raised bogs. Through collaboration between The Living Bog project, RPS Belfast, NPWS and Queen's University Belfast, statistical analysis and modelling of results are being trialled, with the aim of establishing statistical relationships between the hydrology and ecology data, to influence future restoration programmes and policy decisions. The aim is to publish these findings in a peer-reviewed ecohydrological journal article in a relevant scientific journal in 2022. It has become apparent from initial data analysis that a direct correlation between the increase in water levels and percentage increase in *Sphagnum* cover cannot be made, with numerous factors influencing the observed results, such as catchment size, site topography and the abundance of existing *Sphagnum* species in areas prior to restoration.

As detailed in the project vegetation results, it is anticipated that the ecological response to the hydrological restoration may take several years to respond, as part of the AfterLIFE plan it has been recommended that ongoing ecological monitoring be conducted so that the overall success of the restoration measures can be assessed. To supplement this dataset, it has been 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. A more compressive comparison of the hydrological and ecological datasets should be completed after the data has been obtained from the AfterLIFE project, as it's anticipated that stronger correlations can be obtained once the bog has been given appropriate time to recover post-restoration.

5 LESSONS LEARNED FOR FUTURE PEATLAND MONITORING PROGRAMMES

Several key lessons were learned from a hydrology perspective on The Living Bog project, these lessons should be deployed in future raised bog hydrological programmes to improve the quality of the data and achieve greater confidence in the results to further aid our understanding of the hydrological processes and impacts of restoration on raised bogs:

- **The importance of baseline measurements** - On several sites, it was possible to collect a full year of baseline data, however on most sites, only 6 months of baseline could be collected due to delays in setting up the monitoring programme. Ensuring a sufficient baseline dataset has been collected, allows for a more detailed and statistically significant analysis of the results to be conducted. Comparison with rainfall and evapotranspiration data indicated that the project captured the most extreme climatic periods pre-restoration, however, if this event had occurred earlier in the year, the was the potential risk that this data would have been missed by the project, which would have impacted upon the results and conclusions gathered and would have under-estimated the success of the restoration measures implemented. Future peatland restoration projects should aim at a minimum, to have at least 12 months of baseline data prior to the construction of any restoration measures.

- **Logger data Vs Manual data** – Several observations were made on the advantages and disadvantages of using logger data collected using pressure transducers compared to that obtained through manual dipping of monitoring wells:
  - Data resolution: Greater confidence is achieved using logger data, due to the frequent sampling rate, extreme events such as droughts and recharge events can be more accurately recorded and characterised. Manual data provides less resolution and confidence in the data to capture the extreme fluctuations in climatic conditions, hence the ability to accurately characterise the hydrological impact of restoration is reduced.
  - Cost: Logger data is expensive to set up compared to manual measurements, due to the associated cost when purchasing the equipment. A standard data logger can range from €400-€500. Manual data is relatively cheap to collect as it only requires a water level dipper/probe, however, it has a larger associated operational cost due to the need for more frequent site visits. When conducting a cost-benefit analysis to decide the most appropriate methodology, it must be noted that when using loggers, the sites still need to be visited on a semi-frequent basis to collect calibration measurements and download the data. This cost implication is often overlooked and must be incorporated into the lifetime cost estimate.
  - Processing time: Logger data takes significantly longer to manage due to the large volume of data collected. This process can be automated using python computer coding however it still represents a significant time investment and must be factored into the overall project budget. Manual data in comparison has a significantly reduced processing requirement

- **Monitoring should be prioritised for the summer period**
    - It's widely understood that maximum water-level drawdowns on raised bogs are observed during the summer period when effective rainfall levels are lower than those observed during the winter. This is supported by the findings of this report, however, an important finding from The Living Bog Project is that in all areas, both cutover and on the high bog, water levels are relatively close to the surface both pre/post-restoration during the winter months. Measurements focused within these time periods offer limited value in distinguishing variations between areas of differing ecological conditions.
    - One caveat to this is where cell bunding / barrier dams were constructed, in these situations and winter level may prove useful, as the water level in the area is likely to be at its highest. A measurement during this period can indicate the maximum level of standing water that exists and if measures are required to lower existing outlets to provide the correct hydrological conditions for ARB/PFH to develop.
    - On projects that do not have the resources to install loggers, manual measurements should be focused during the summer period to increase the likelihood of capturing the maximum water table drawdown

- **Frequency of measurements** – The rate at which water level fluctuates, across the large variety of sub-habitats on raised bogs was poorly characterised prior to The Living Bog Project. To ensure that sufficient data was acquired, a sampling rate of 15 minutes was selected to ensure extreme events were recorded and no data gaps would exist. This however led to a large volume of data acquired which increased the time required to process and calibrate the findings. Initial examination of the data from The Living Bog project indicates that this time interval could be dropped to readings at 6-hour intervals. This would optimise the sampling and ensure data is kept to a minimum without the risk of missing key drawdown/recharge events. Reducing the sampling frequency also increases the battery life on the devices and the memory available.

6 RECOMMENDATIONS

The following section presents several recommendations to build upon in future projects based on the hydrological results of this study, with the overall aim of continuing to improve our hydrological understanding of Irish Raised bogs, their processed and the impact of restoration measures:

- Proposals to continue the hydrological monitoring as part of the AfterLIFE commitments of The Living Bog project have been put forward. 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.
- The results presented in this report, highlight the success of the Eco-hydrological model used to predict the areas of the bog that will re-wet and therefore provide the correct supporting hydrological conditions required for ARB. However, the positive results obtained in areas that were not modelled as PPFH, suggest that the model current under-predicts the extent of these areas, in particular in cutover areas. This model was developed using a limited available dataset and provides indicative results. The data collected during this project should be incorporated into a revised version of the model, learning from the results obtained, to improve upon the accuracy of the current version of the model, in doing so, the accuracy of the targets can be adjusted to provide more accurate indications of the PFH that can be obtained through restoration and the additional ecosystem services that accompany rewetting of these sensitive habitats.
- Although overall the project results indicated that re-wetting was successful in a large proportion of modelled areas. There were several areas where restoration measures did not result in the results anticipated. These wells should be isolated and investigated further to understand why positive results were not obtained and if measures could be altered in the future to improve the results observed in future projects.
- Various drain blocking methodologies were implemented or trialled during this project. The project techniques document details these measures and comments on their effectiveness. These measures should be incorporated as an appendix to the current best practice guidance document (Mackin et al., 2017), to ensure future projects are using the most up-to-date methodologies. These methodologies should continually be developed, with improvements continually added with a routine review of the best practice document.

7 REFERENCES

Crowley, W., and Smith, G.F. (2022) Vegetation Monitoring (D2) Final Report for The Living Bog – Restoring Active Raised Bog in Ireland's SAC Network 2016 – 2020 (LIFE14 NAT/IE/000032).

Cushnan, H (2018) Quantifying the baseline conditions and restoration potential of Irish raised bogs through hydrogeological and geophysical methods, PhD thesis, Queens University, Belfast.

Grootjans, A.P., Schipper, P.C. and Van der Windt, H.J. 1985. Influence of drainage on N-mineralization and vegetation response in wet meadows. I. Calthion palustris stands. Acta Oecologica/Oecologica Plantarum, 6: 403–417.

Regan, S., Flynn, R., Gill, L., Naughton, O., & Johnston, P. (2019). Impacts of groundwater drainage on peatland subsidence and its ecological implications on an Atlantic raised bog. Water Resources Research,55,6153–6168. https://doi.org/10.1029/2019WR024937

8 APPENDIX

8.1 Ardagullion

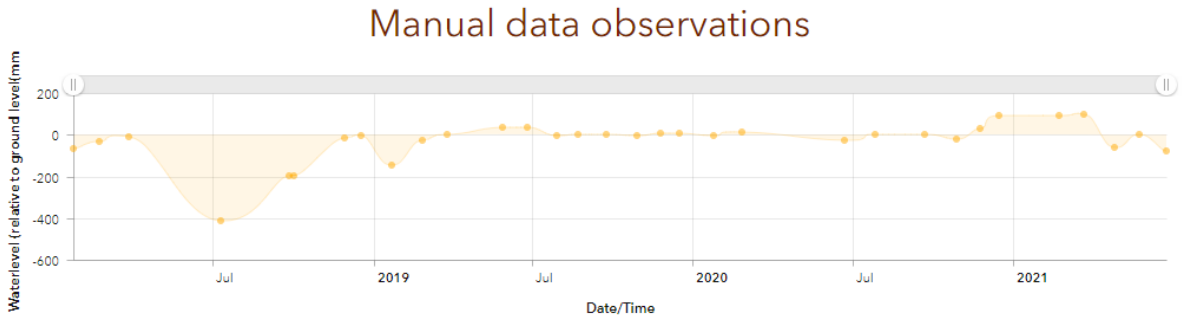


Figure 8-1 Hydrograph of manual monthly water levels AR 1, Ardagullion Bog SAC

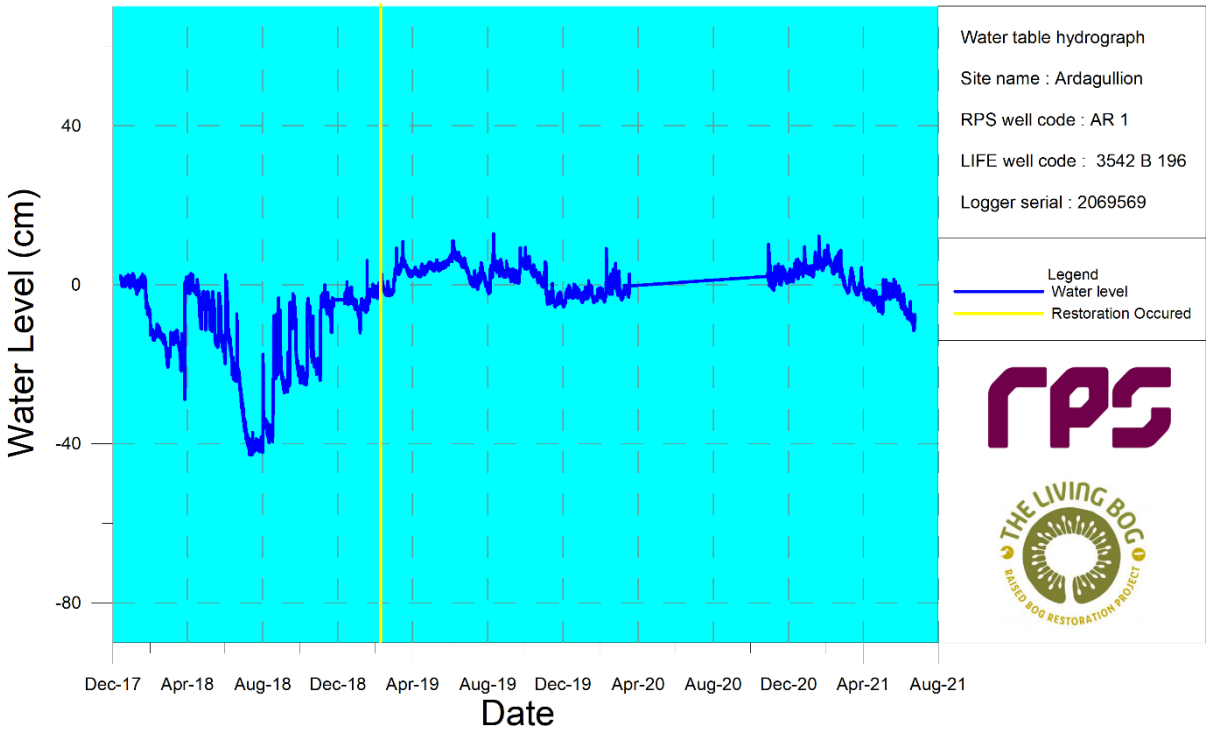


Figure 8-2 Level logger data recorded between December 2017 and August 2021 at well AR 1, Ardagullion Bog SAC

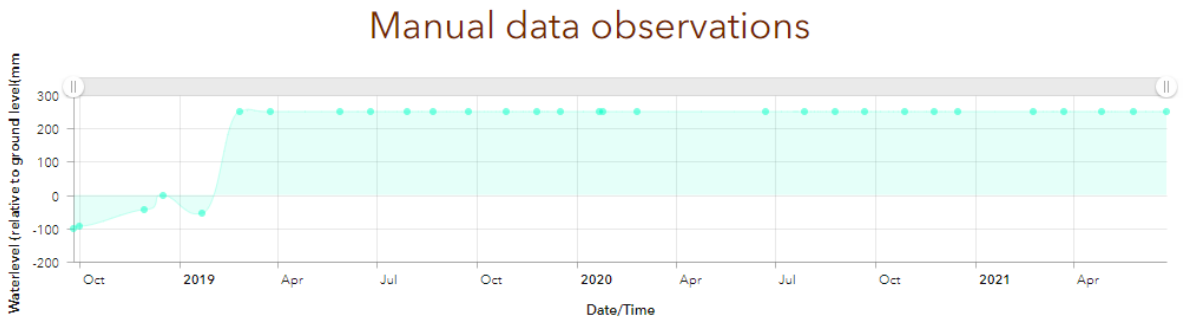


Figure 8-3 Hydrograph of manual monthly water levels AR 2, Ardagullion Bog SAC

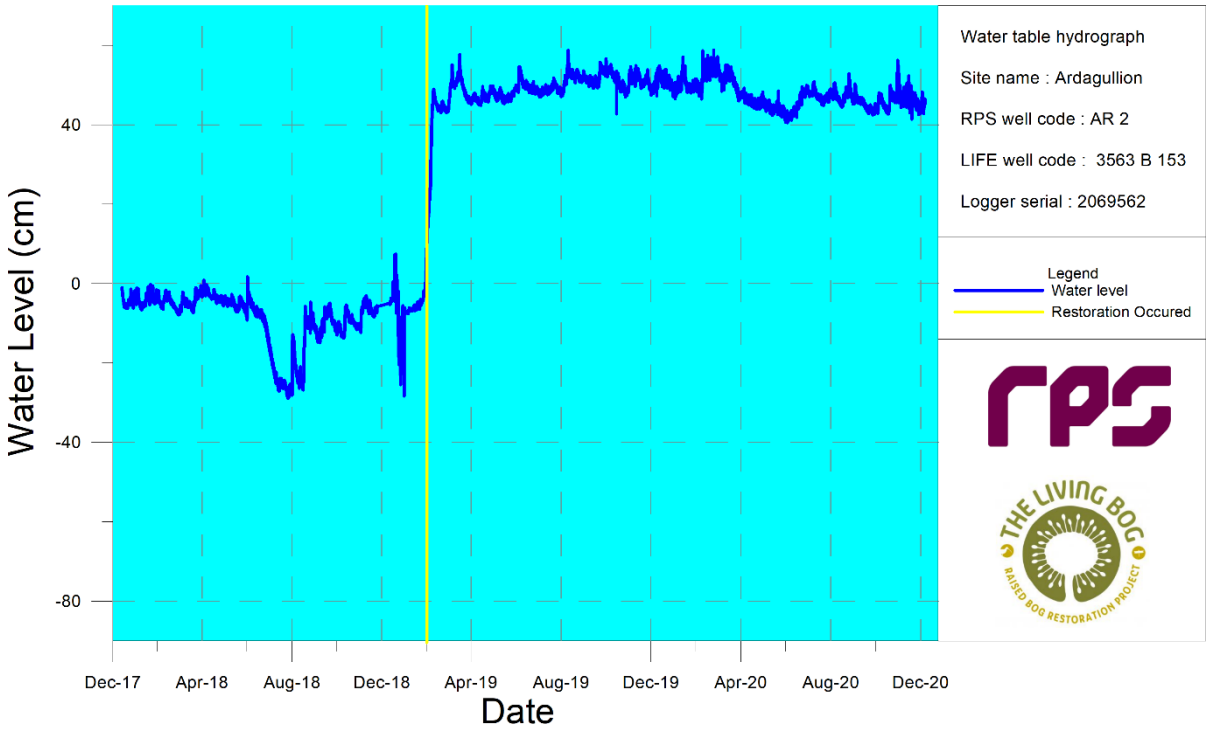


Figure 8-4 Level logger data recorded between December 2017 and December 2020 at well AR 2, Ardagullion Bog SAC

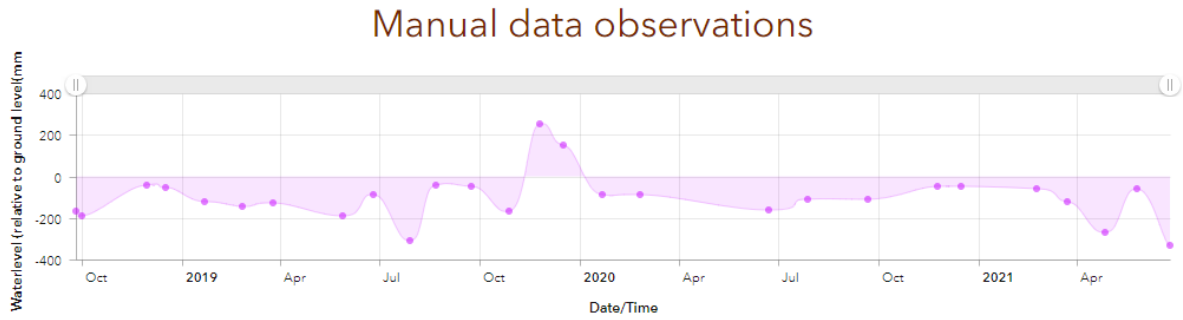


Figure 8-5 Hydrograph of manual monthly water levels AR 3S, Ardagullion Bog SAC

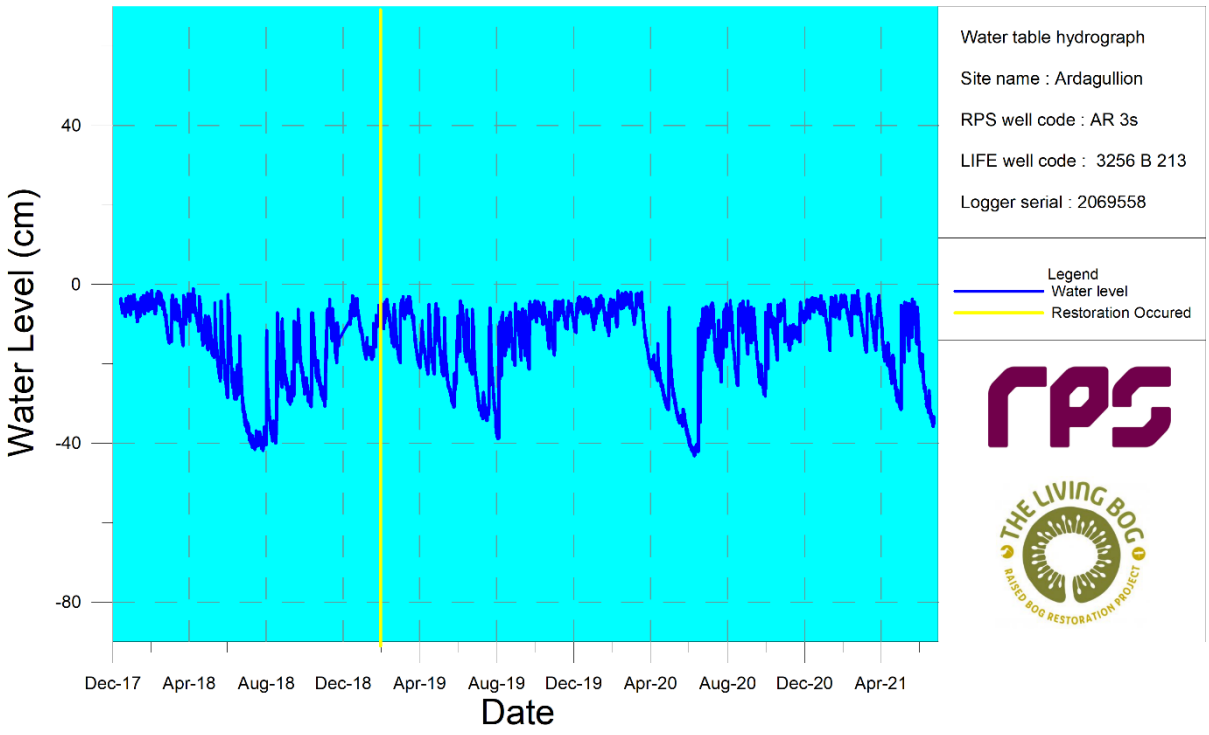


Figure 8-6 Level logger data recorded between December 2017 and April 2021 at well AR 3s, Ardagullion Bog SAC

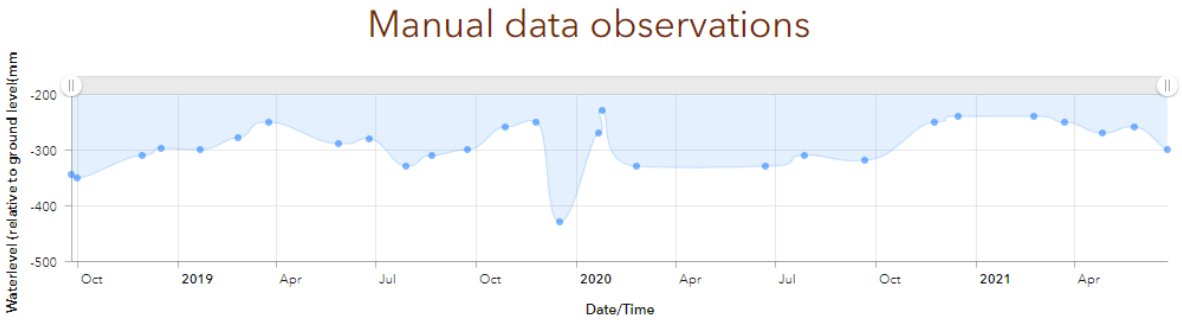


Figure 8-7 Hydrograph of manual monthly water levels AR 3M, Ardagullion Bog SAC

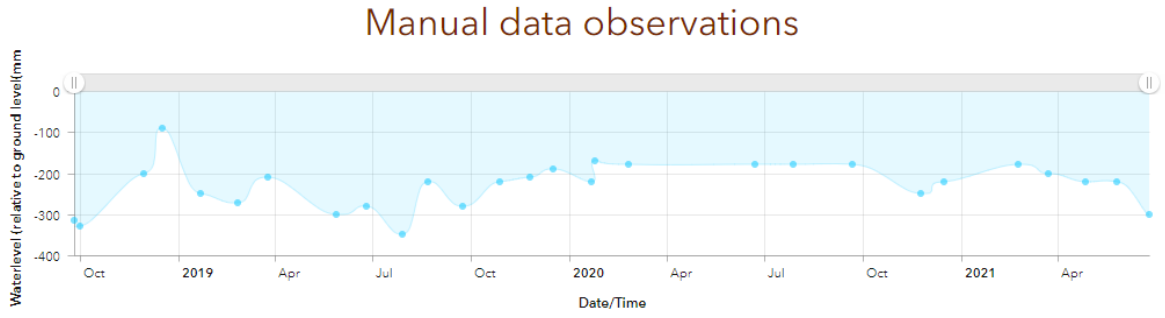


Figure 8-8 Hydrograph of manual monthly water levels AR 3D, Ardagullion Bog SAC

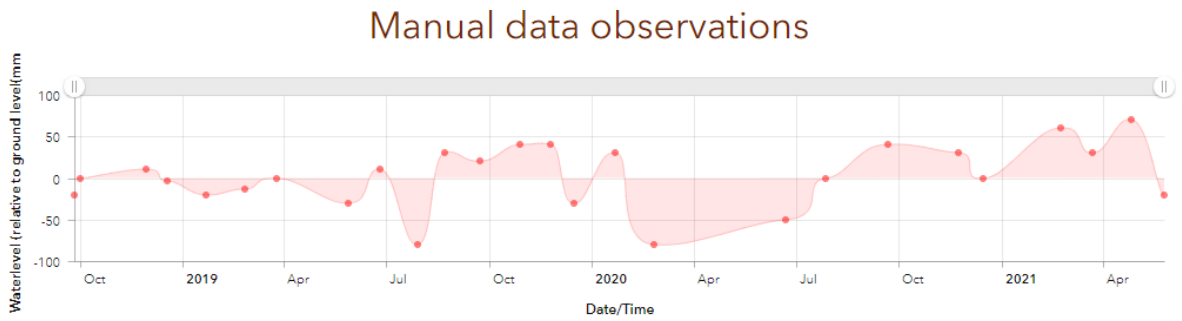


Figure 8-9 Hydrograph of manual monthly water levels AR 4S, Ardagullion Bog SAC

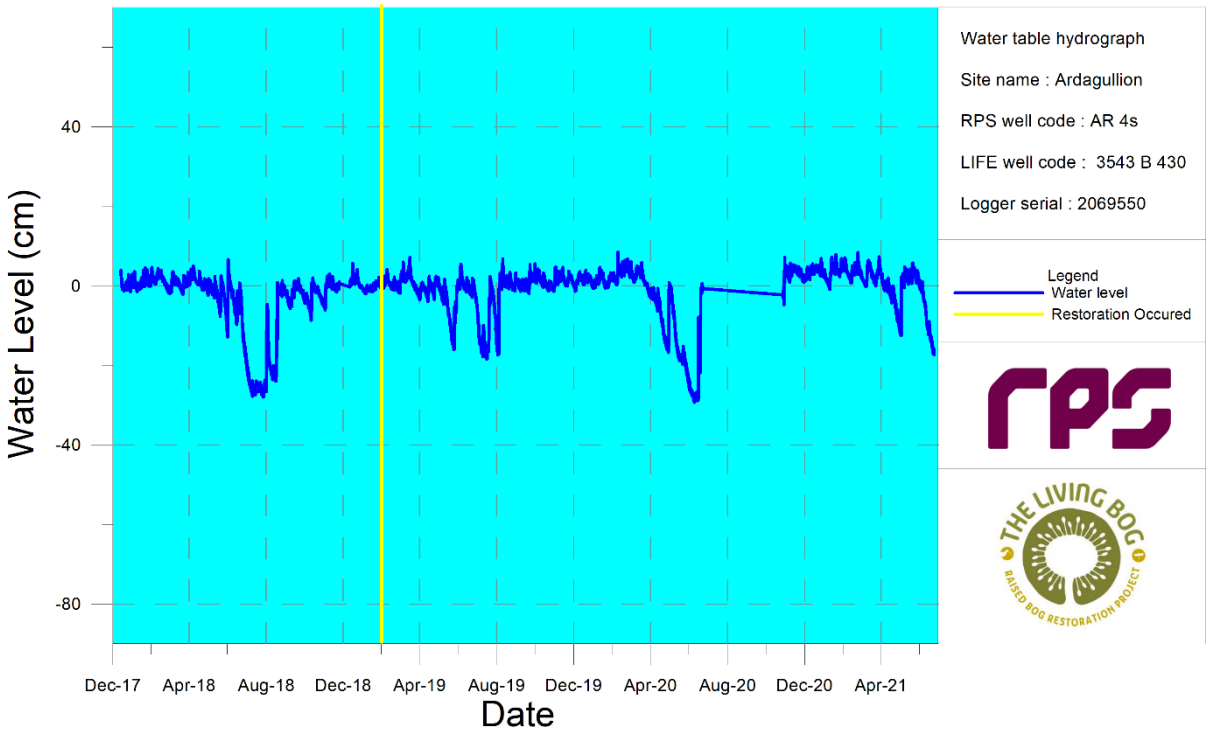


Figure 8-10 Level logger data recorded between December 2017 and April 2021 at well AR 4s, Ardagullion Bog SAC

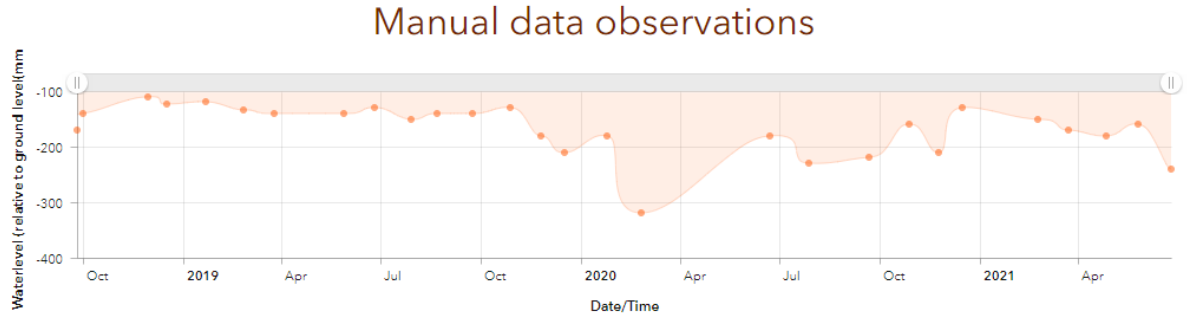


Figure 8-11 Hydrograph of manual monthly water levels AR 4M, Ardagullion Bog SAC

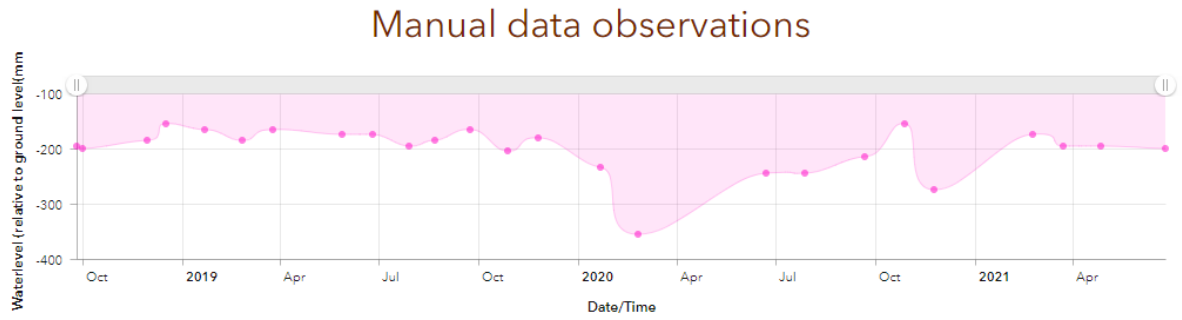


Figure 8-12 Hydrograph of manual monthly water levels AR 4D, Ardagullion Bog SAC

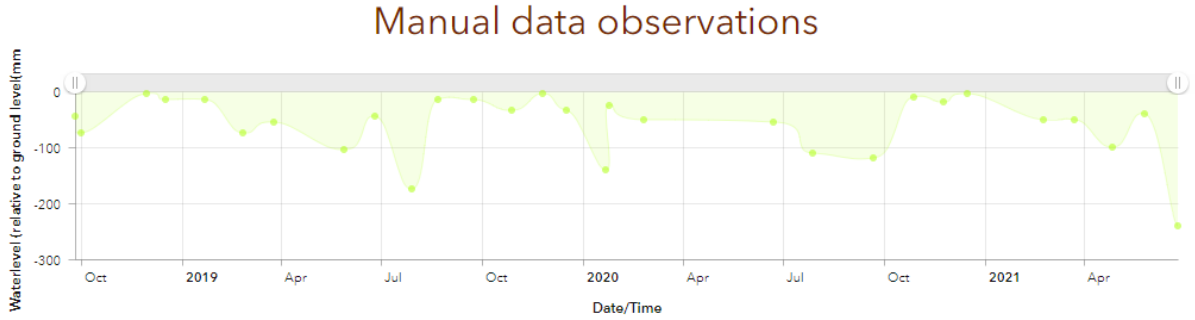


Figure 8-13 Hydrograph of manual monthly water levels AR 5s, Ardagullion Bog SAC

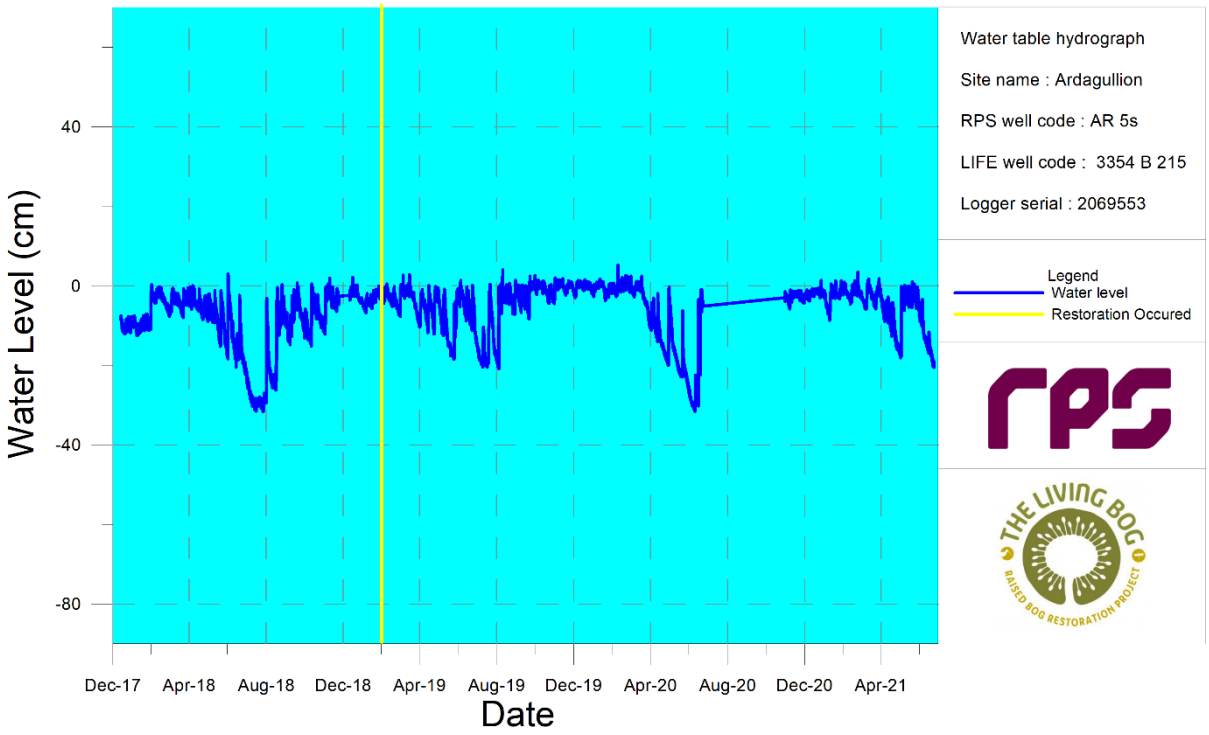


Figure 8-14 Level logger data recorded between December 2017 and April 2021 at well AR 5s, Ardagullion Bog SAC

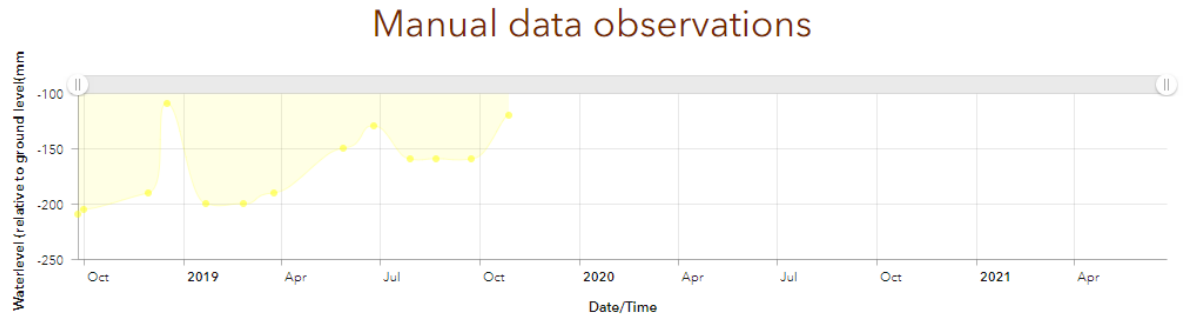


Figure 8-15 Hydrograph of manual monthly water levels AR 5M, Ardagullion Bog SAC

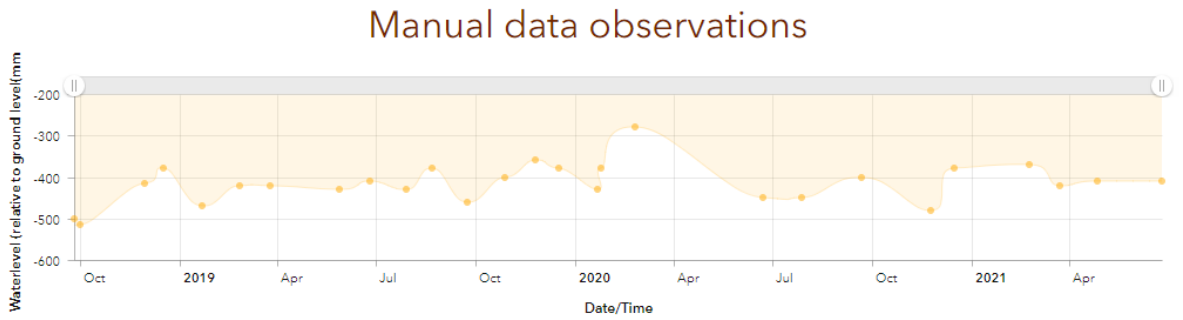


Figure 8-16 Hydrograph of manual monthly water levels AR 5D, Ardagullion Bog SAC

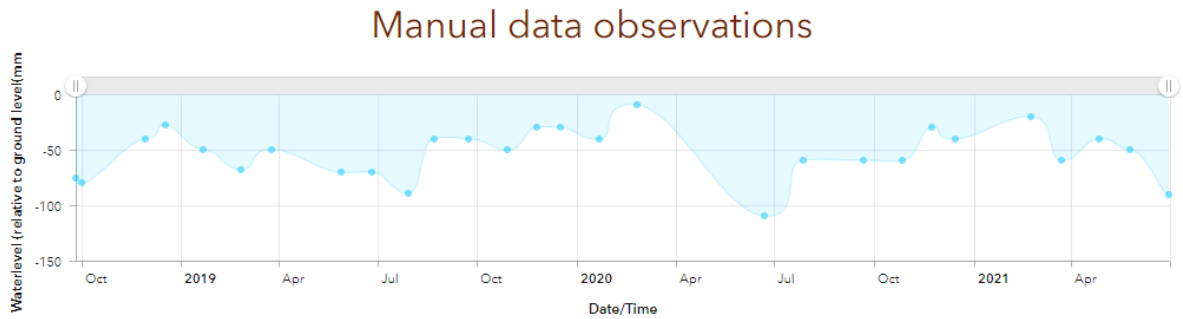


Figure 8-17 Hydrograph of manual monthly water levels AR 6S, Ardagullion Bog SAC

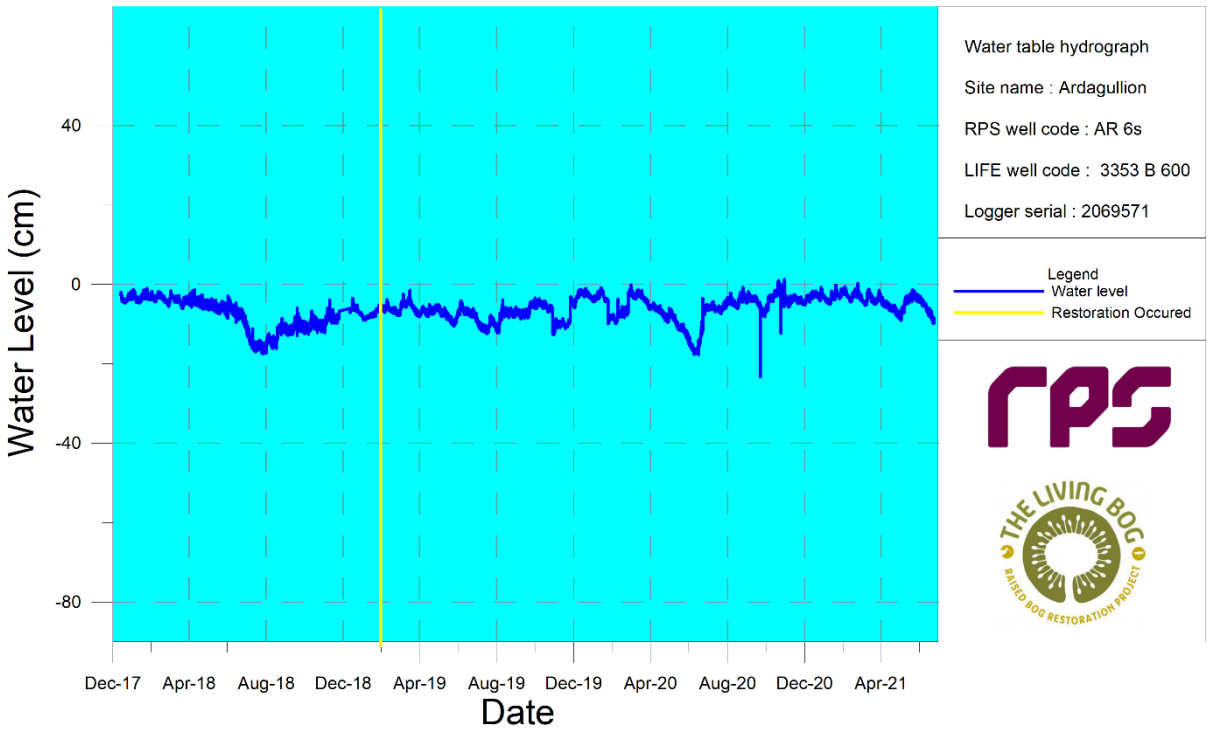


Figure 8-18 Level logger data recorded between December 2017 and August 2021 at well AR 6s, Ardagullion Bog SAC

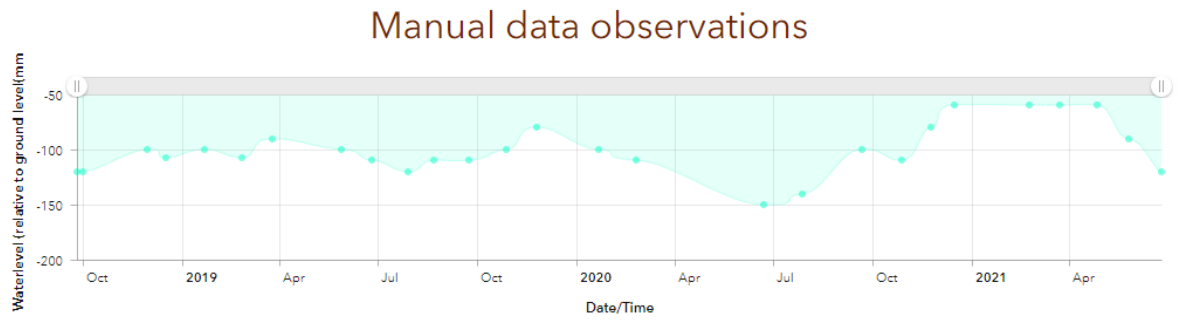


Figure 8-19 Hydrograph of manual monthly water levels AR 6M, Ardagullion Bog SAC

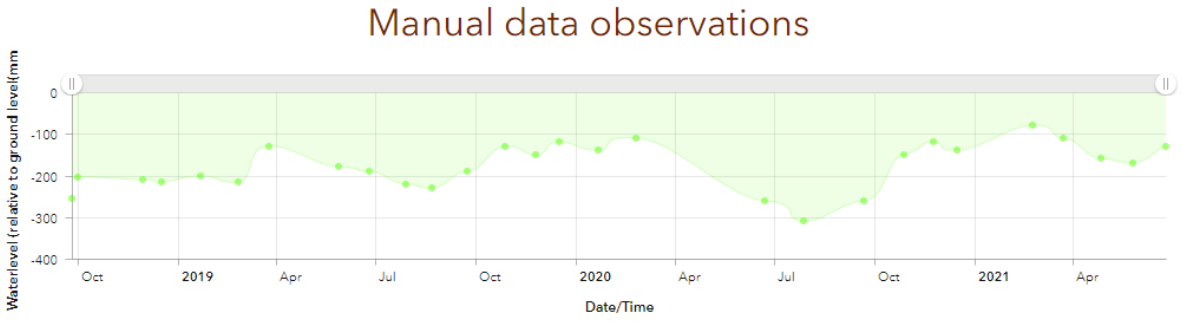


Figure 8-20 Hydrograph of manual monthly water levels AR 6D, Ardagullion Bog SAC

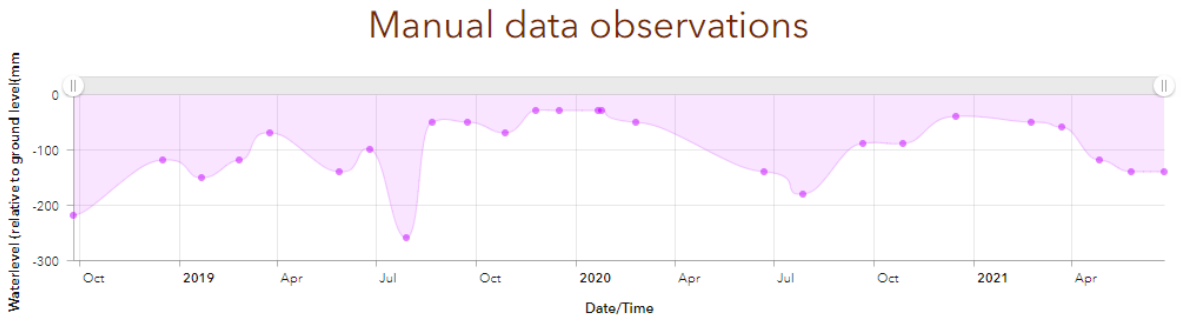


Figure 8-21 Hydrograph of manual monthly water levels AR 7M, Ardagullion Bog SAC

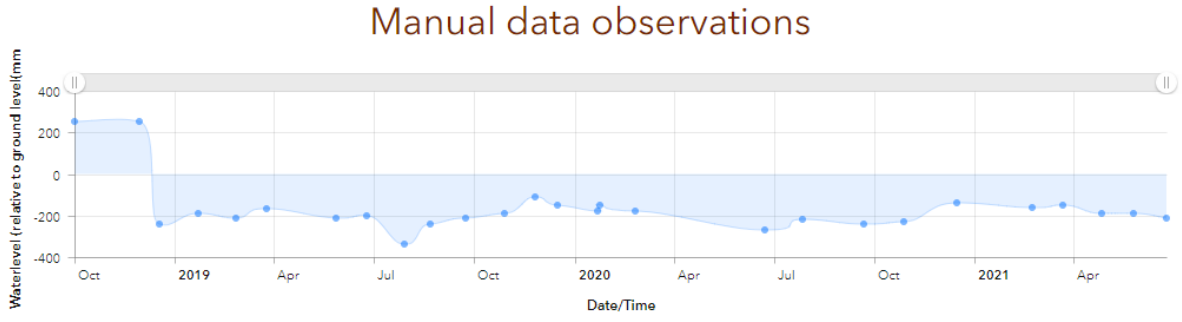


Figure 8-22 Hydrograph of manual monthly water levels AR 7D, Ardagullion Bog SAC

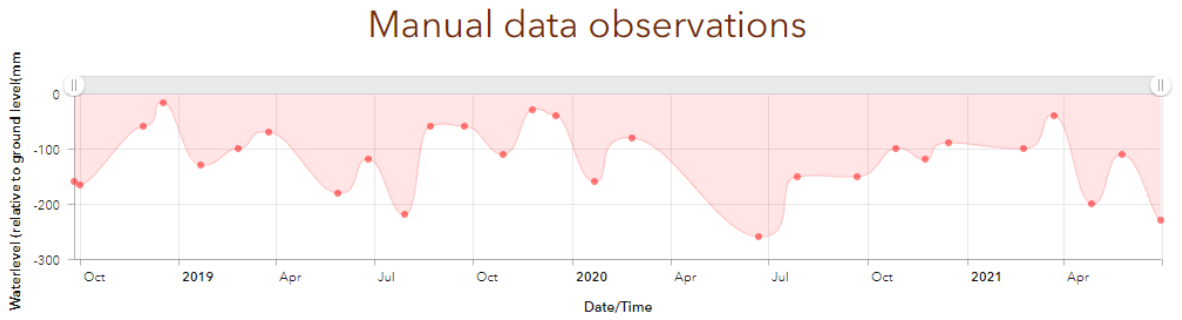


Figure 8-23 Hydrograph of manual monthly water levels AR 8S, Ardagullion Bog SAC

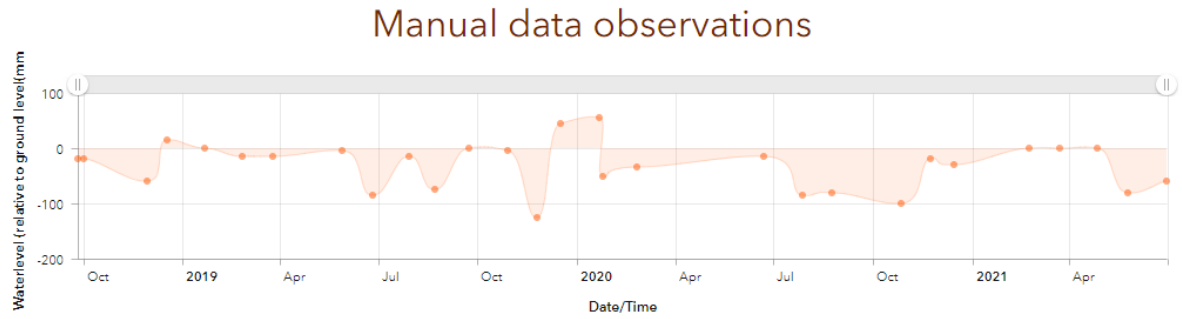


Figure 8-24 Hydrograph of manual monthly water levels AR 8M, Ardagullion Bog SAC

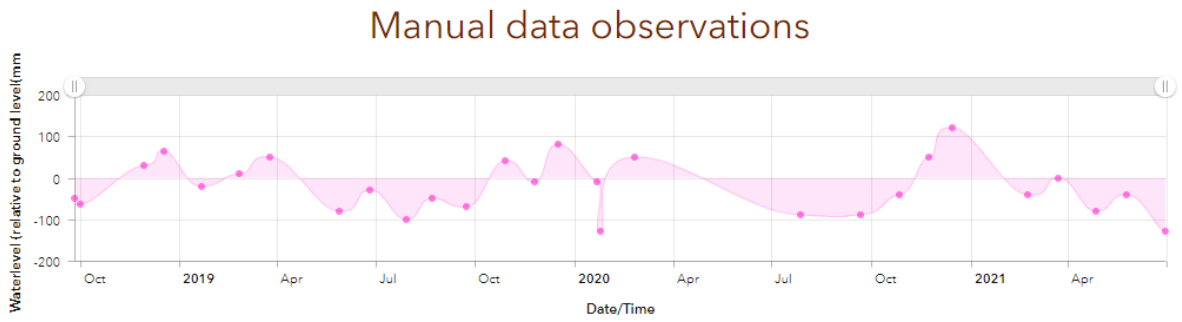


Figure 8-25 Hydrograph of manual monthly water levels AR 8D, Ardagullion Bog SAC

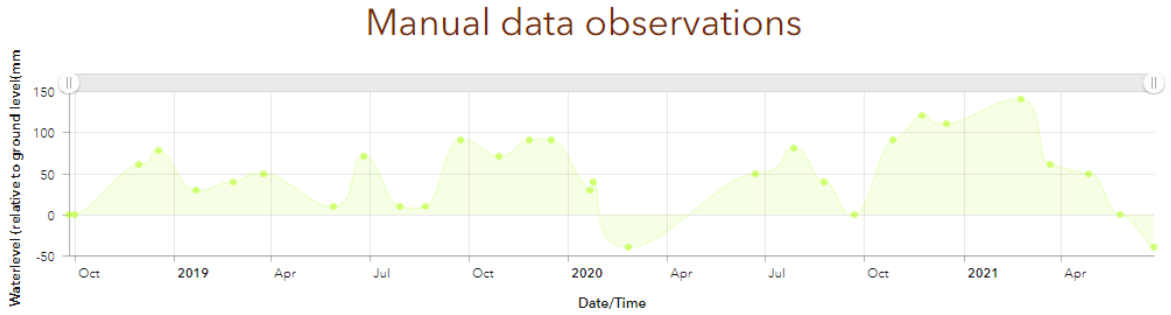


Figure 8-26 Hydrograph of manual monthly water levels AR 9S, Ardagullion Bog SAC

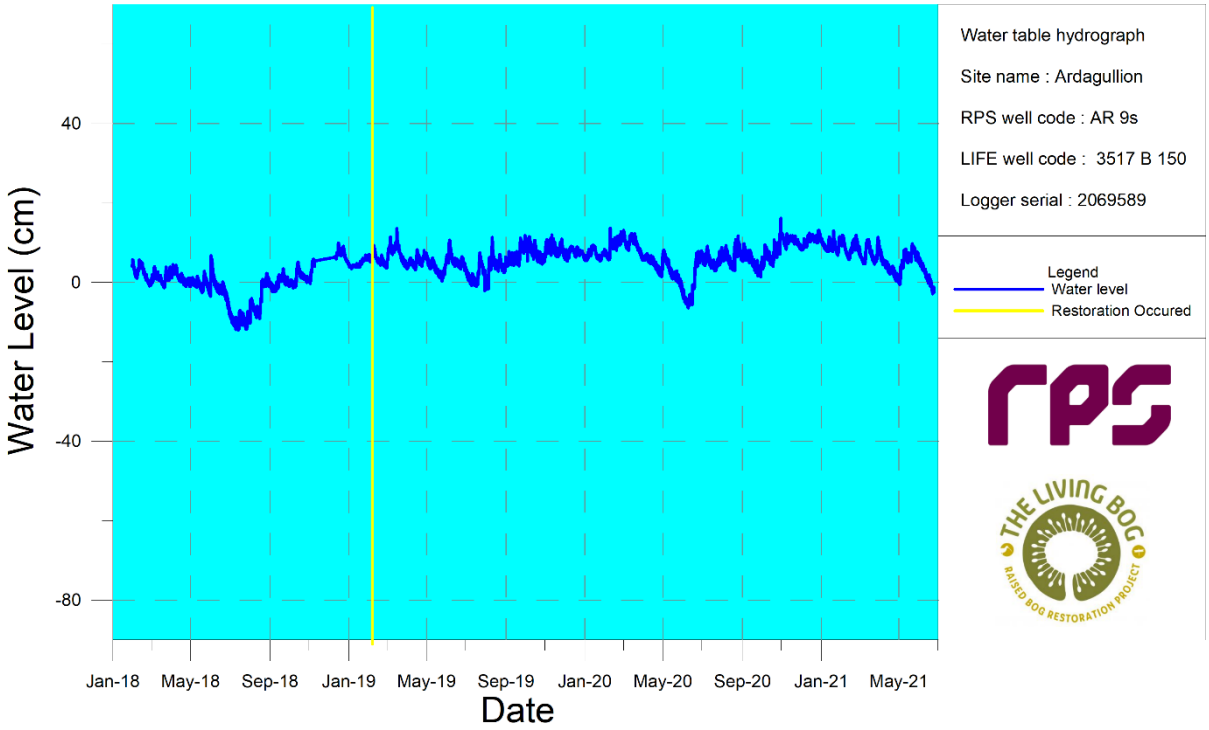


Figure 8-27 Level logger data recorded between January 2018 and August 2021 at well AR 9s, Ardagullion Bog SAC

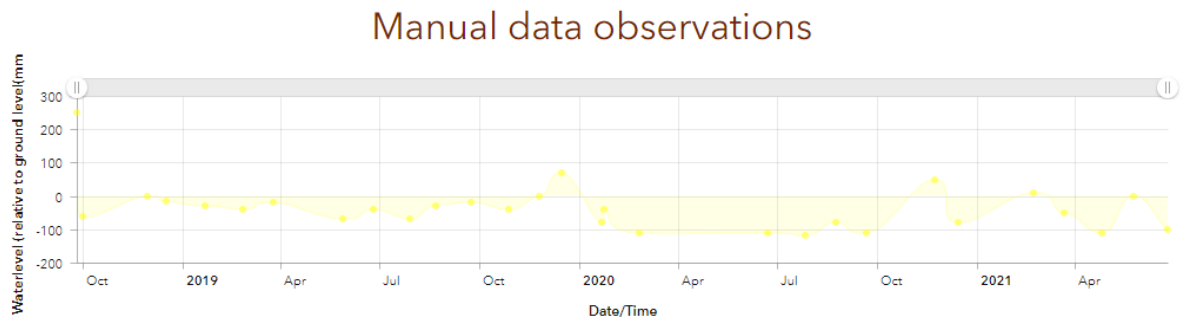


Figure 8-28 Hydrograph of manual monthly water levels AR 9M, Ardagullion Bog SAC

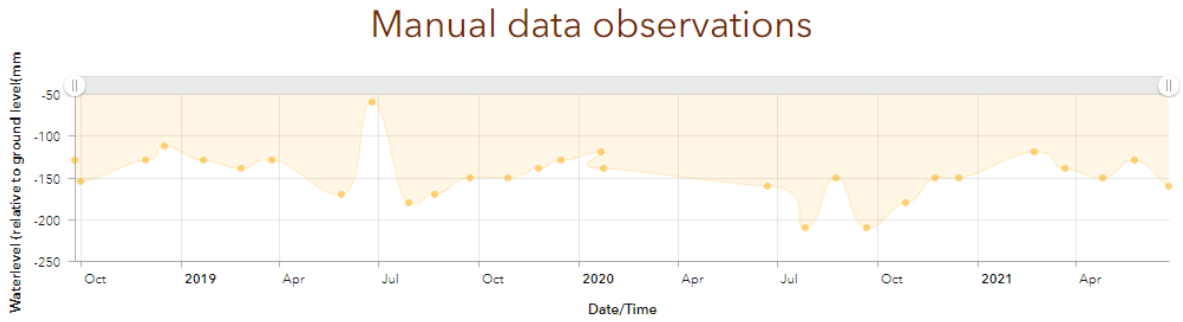


Figure 8-29 Hydrograph of manual monthly water levels AR 9S, Ardagullion Bog SAC

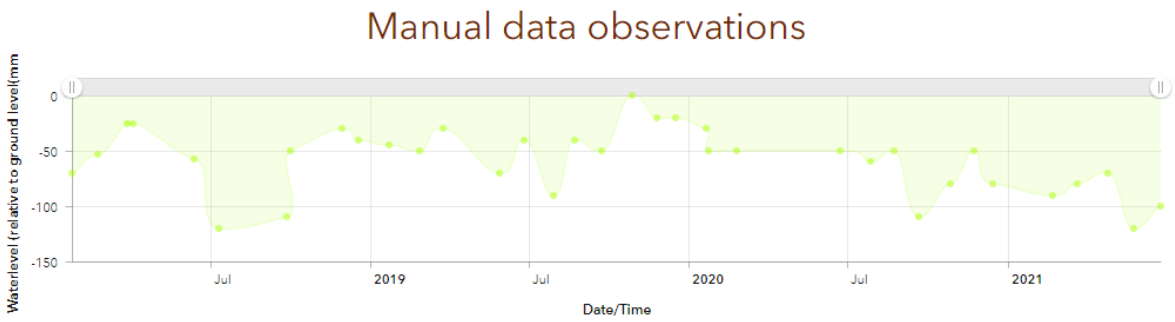


Figure 8-30 Hydrograph of manual monthly water levels AR 10M, Ardagullion Bog SAC

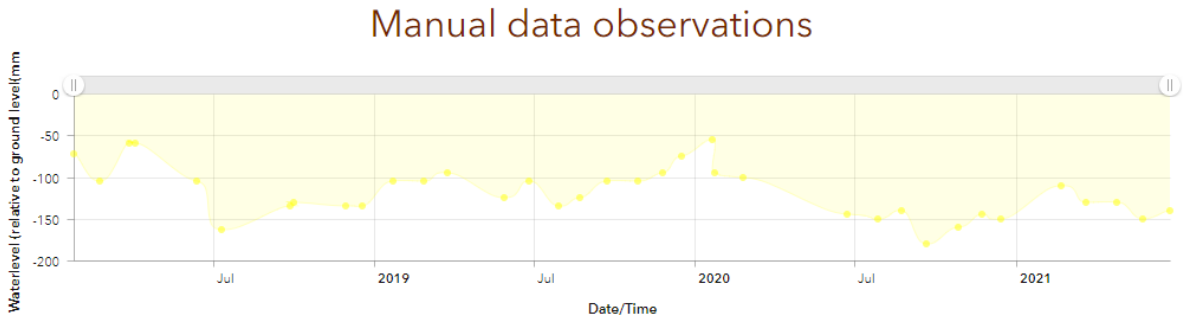


Figure 8-31 Hydrograph of manual monthly water levels AR 10D, Ardagullion Bog SAC

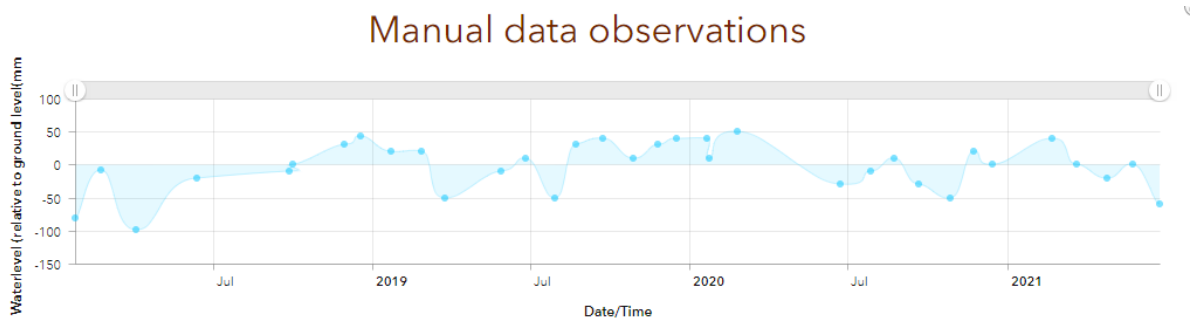


Figure 8-32 Hydrograph of manual monthly water levels AR 11S, Ardagullion Bog SAC

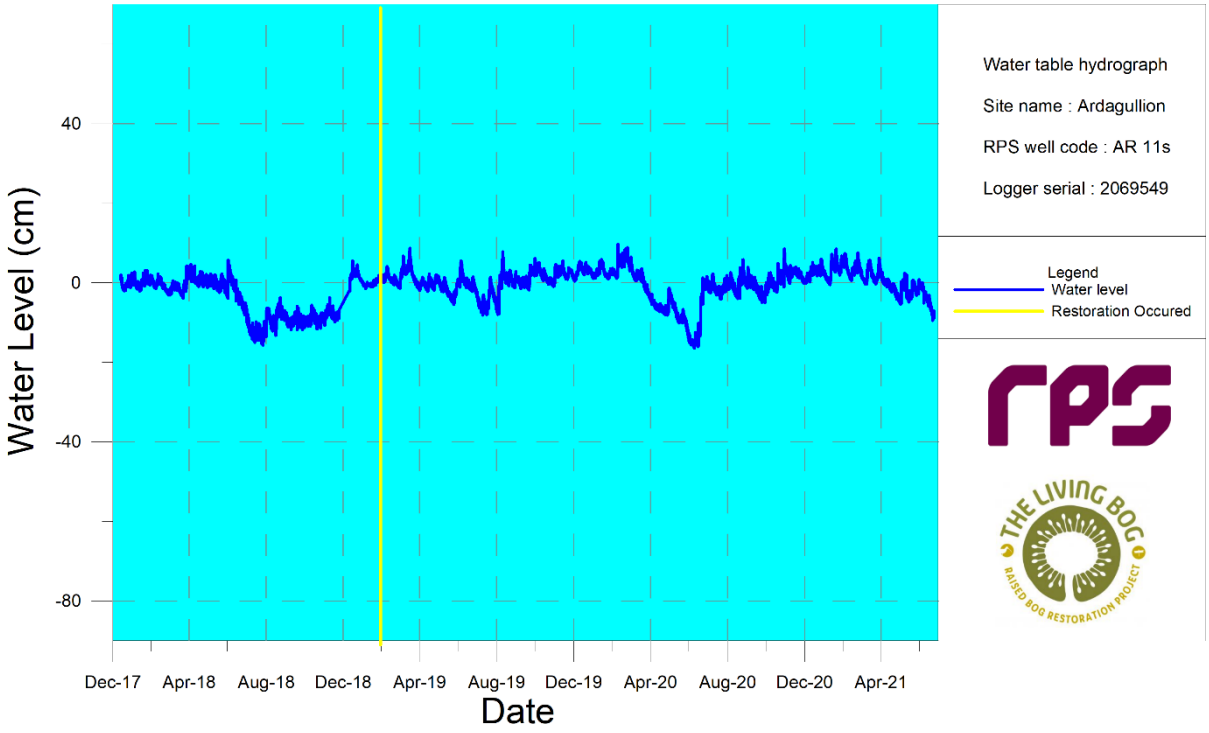


Figure 8-33 Level logger data recorded between December 2017 and August 2021 at well AR 11s, Ardagullion Bog SAC

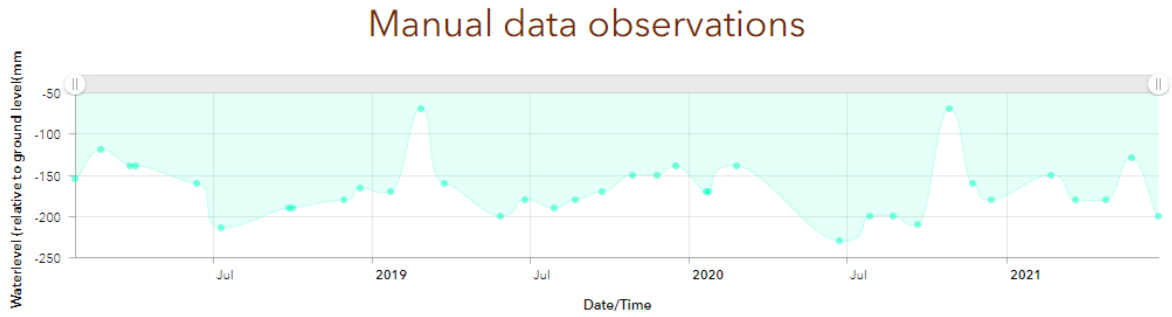


Figure 8-34 Hydrograph of manual monthly water levels AR 11M, Ardagullion Bog SAC

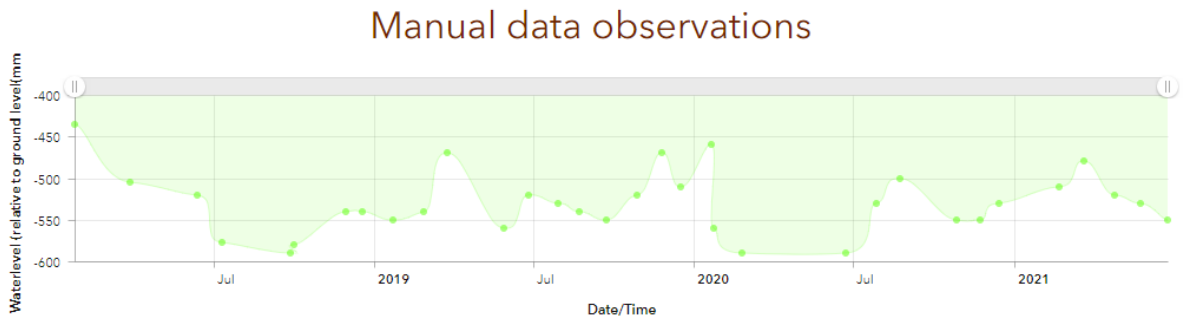


Figure 8-35 Hydrograph of manual monthly water levels AR 11D, Ardagullion Bog SAC

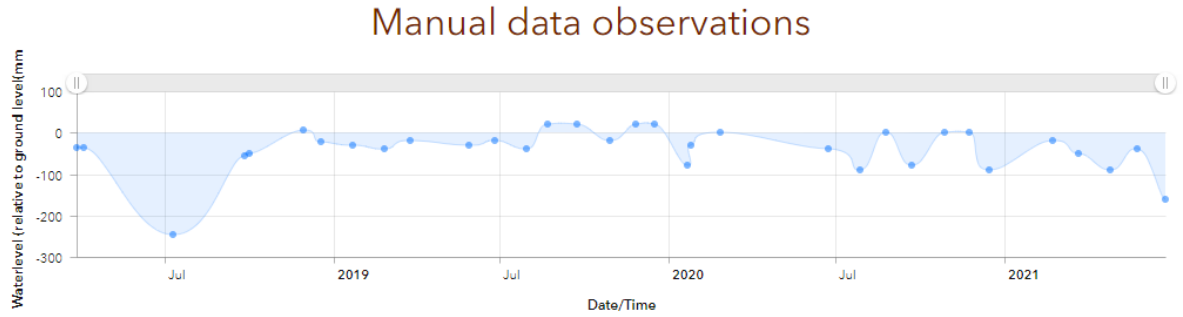


Figure 8-36 Hydrograph of manual monthly water levels AR 12, Ardagullion Bog SAC

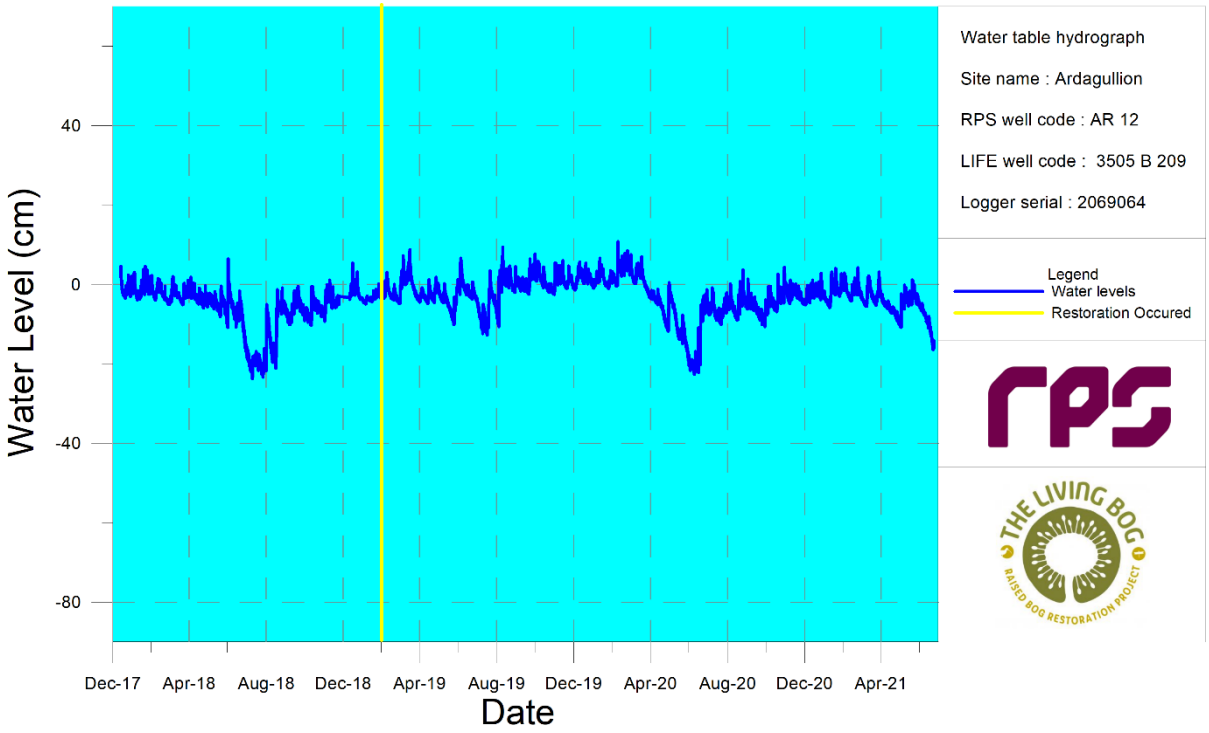


Figure 8-37 Level logger data recorded between December 2017 and August 2021 at well AR 12, Ardagullion Bog SAC

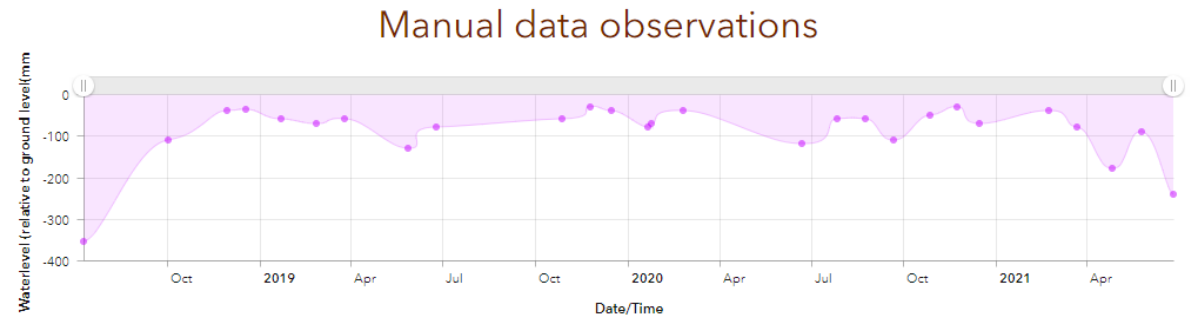


Figure 8-38 Hydrograph of manual monthly water levels AR 13, Ardagullion Bog SAC

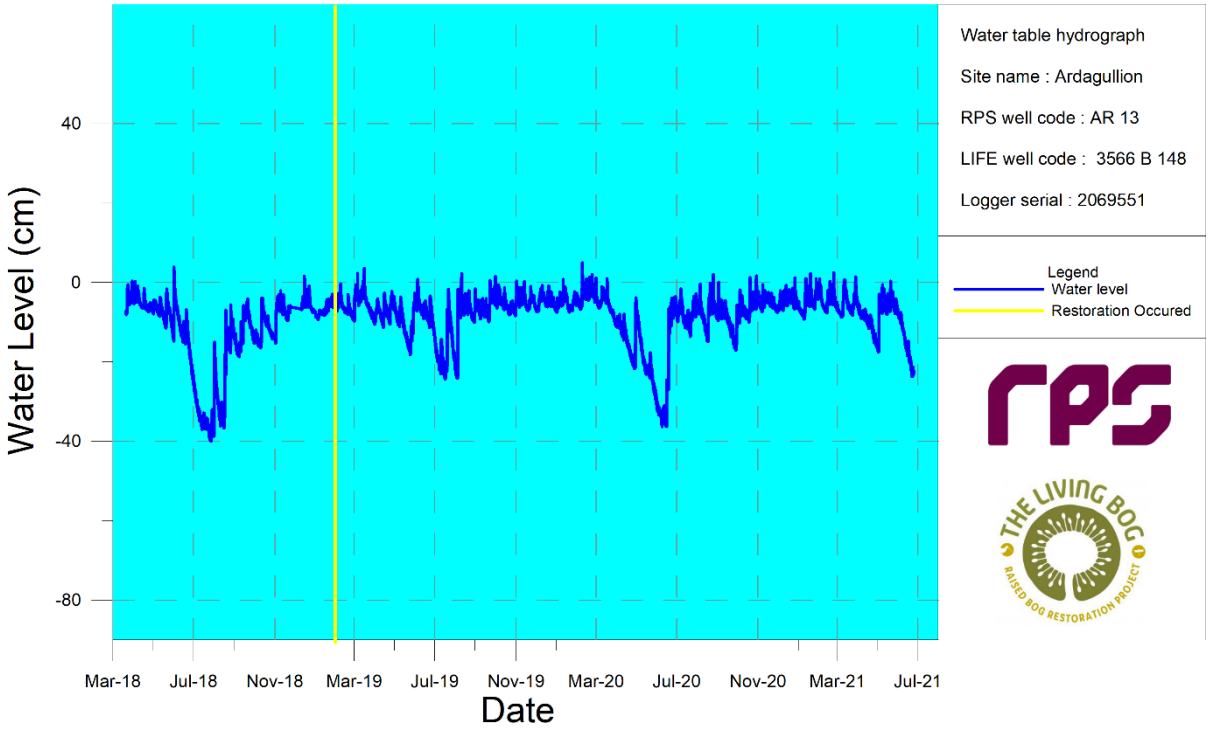


Figure 8-39 Level logger data recorded between March 2018 and July 2021 at well AR 13, Ardagullion Bog SAC

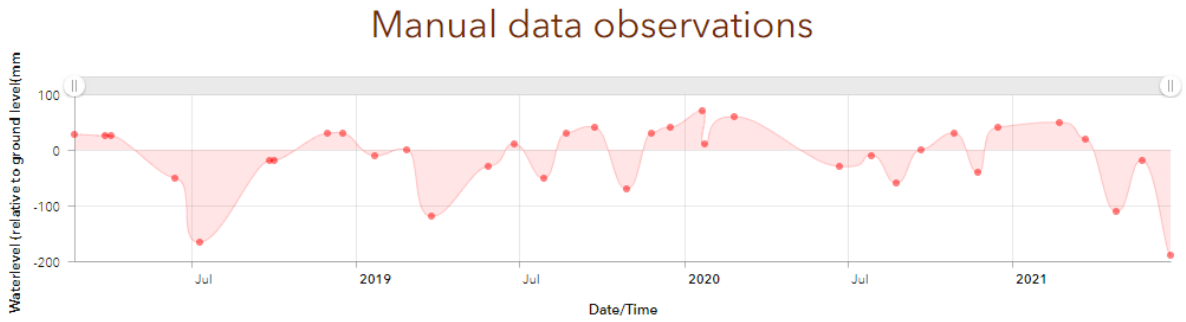


Figure 8-40 Hydrograph of manual monthly water levels AR 14S, Ardagullion Bog SAC

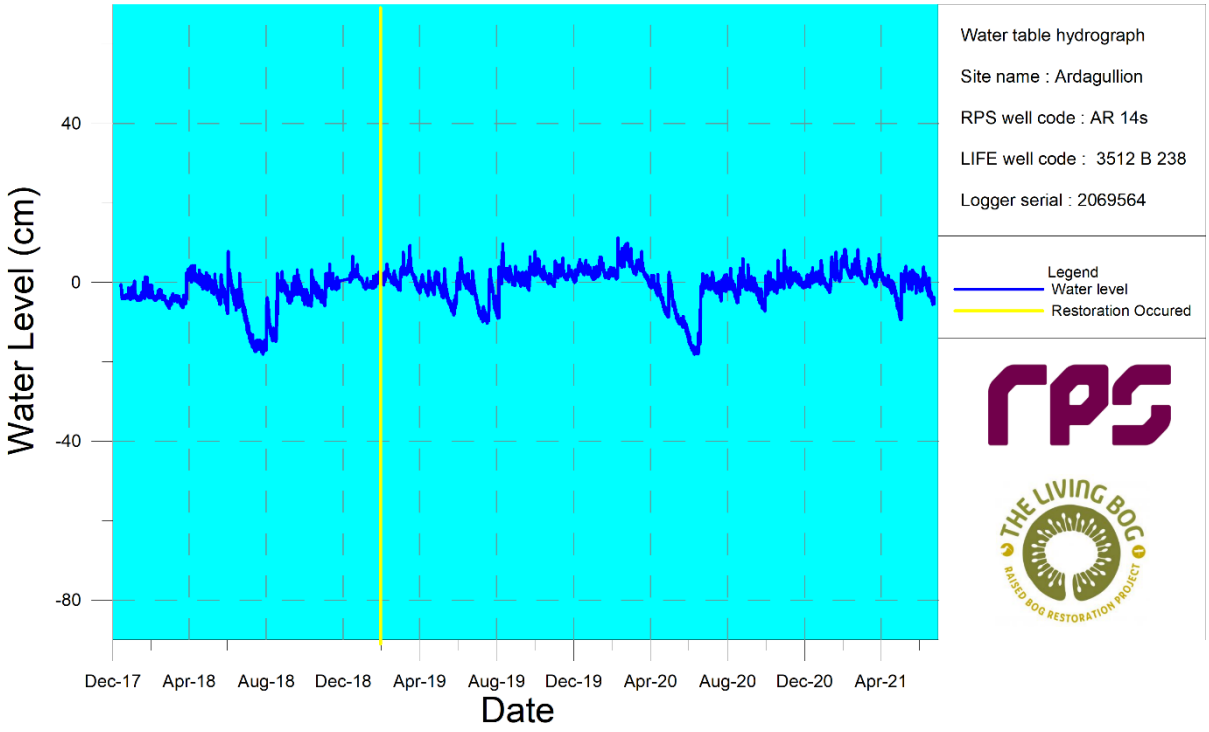


Figure 8-41 Level logger data recorded between December 2017 and August 2021 at well AR 14s, Ardagullion Bog SAC

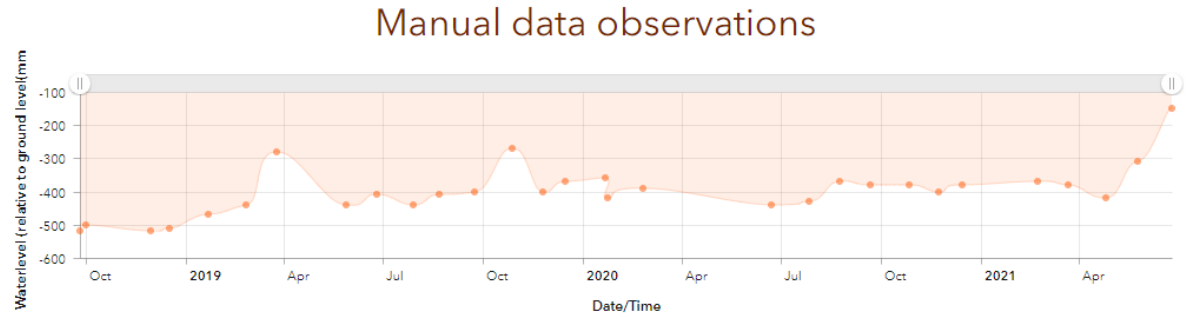


Figure 8-42 Hydrograph of manual monthly water levels AR 14M, Ardagullion Bog SAC

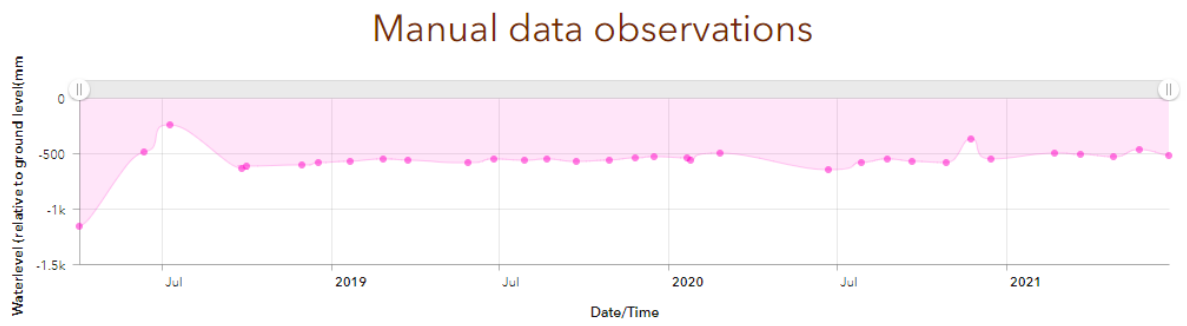


Figure 8-43 Hydrograph of manual monthly water levels AR 14D, Ardagullion Bog SAC

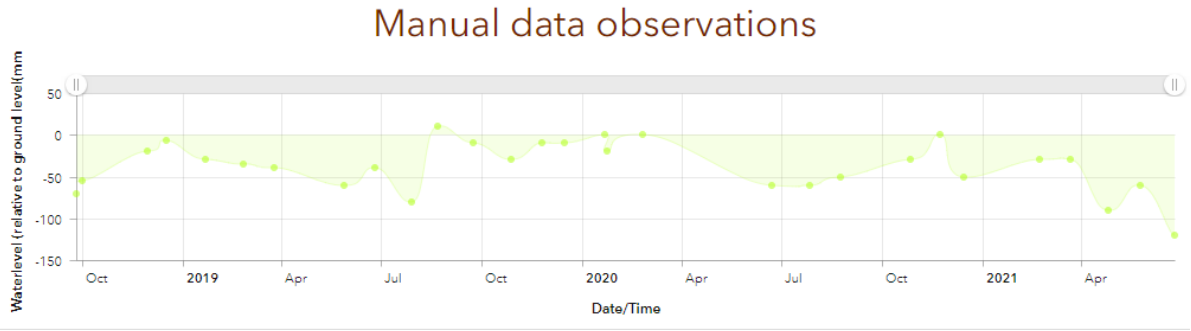


Figure 8-44 Hydrograph of manual monthly water levels AR 15S, Ardagullion Bog SAC

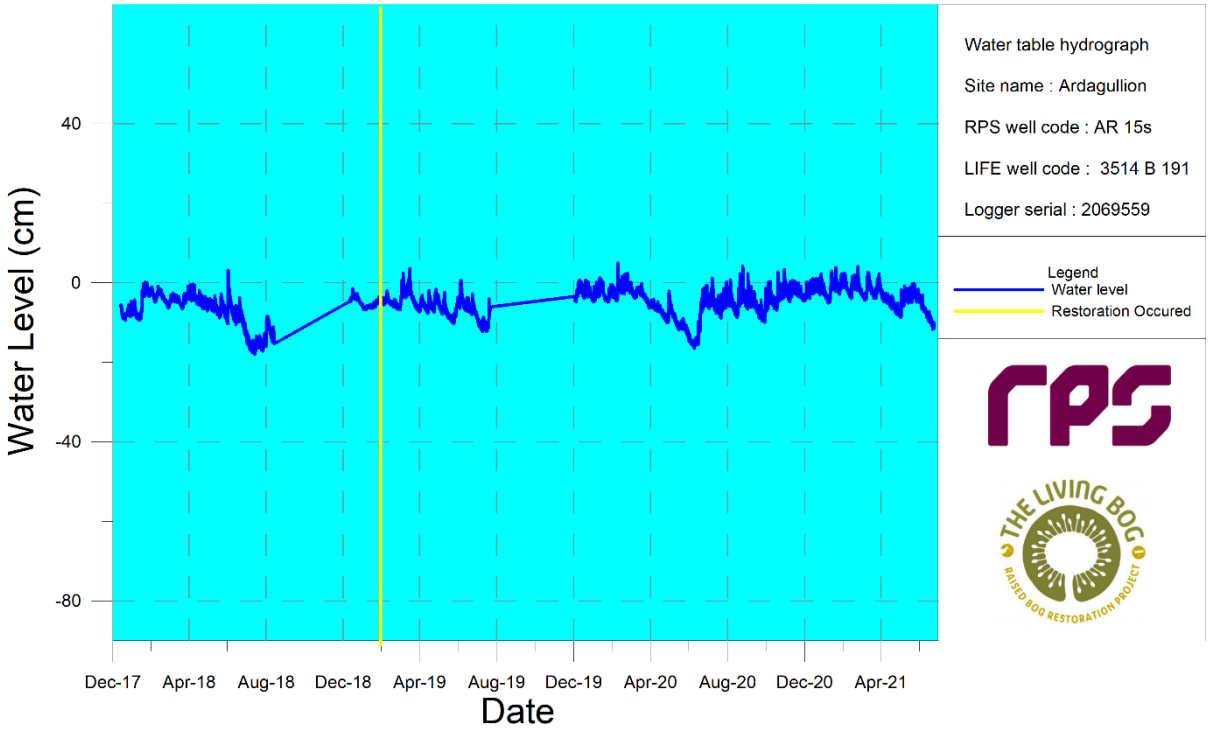


Figure 8-45 Level logger data recorded between December 2017 and August 2021 at well AR 15s, Ardagullion Bog SAC

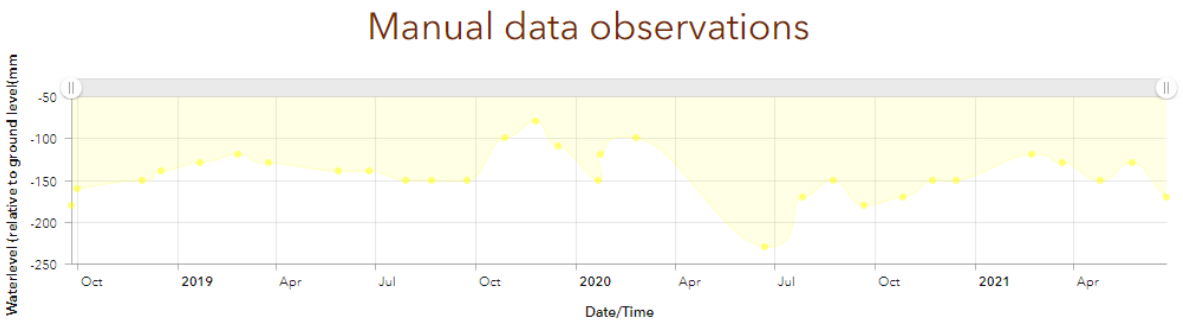


Figure 8-46 Hydrograph of manual monthly water levels AR 15M, Ardagullion Bog SAC

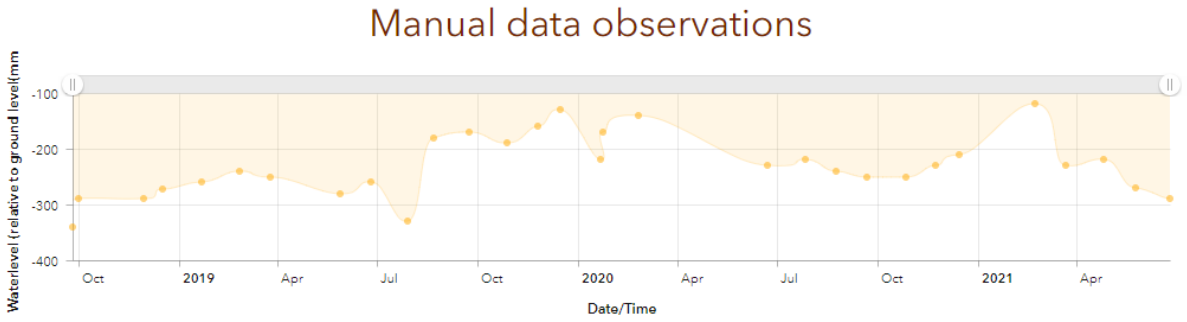


Figure 8-47 Hydrograph of manual monthly water levels AR 15D, Ardagullion Bog SAC

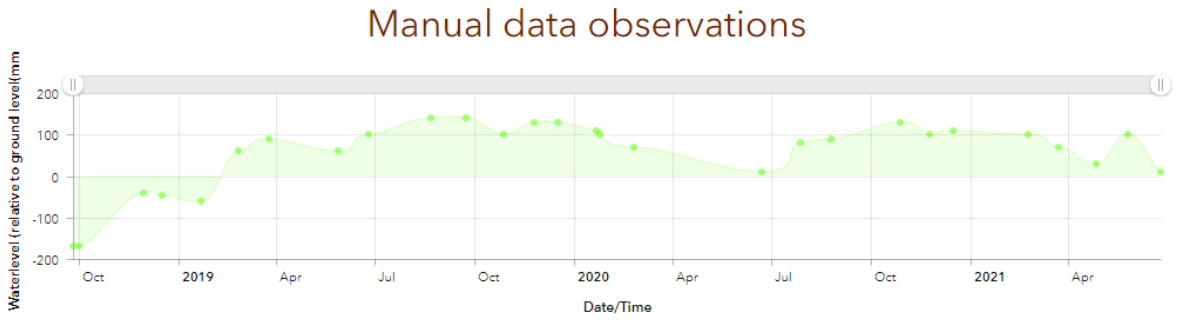


Figure 8-48 Hydrograph of manual monthly water levels AR 16, Ardagullion Bog SAC

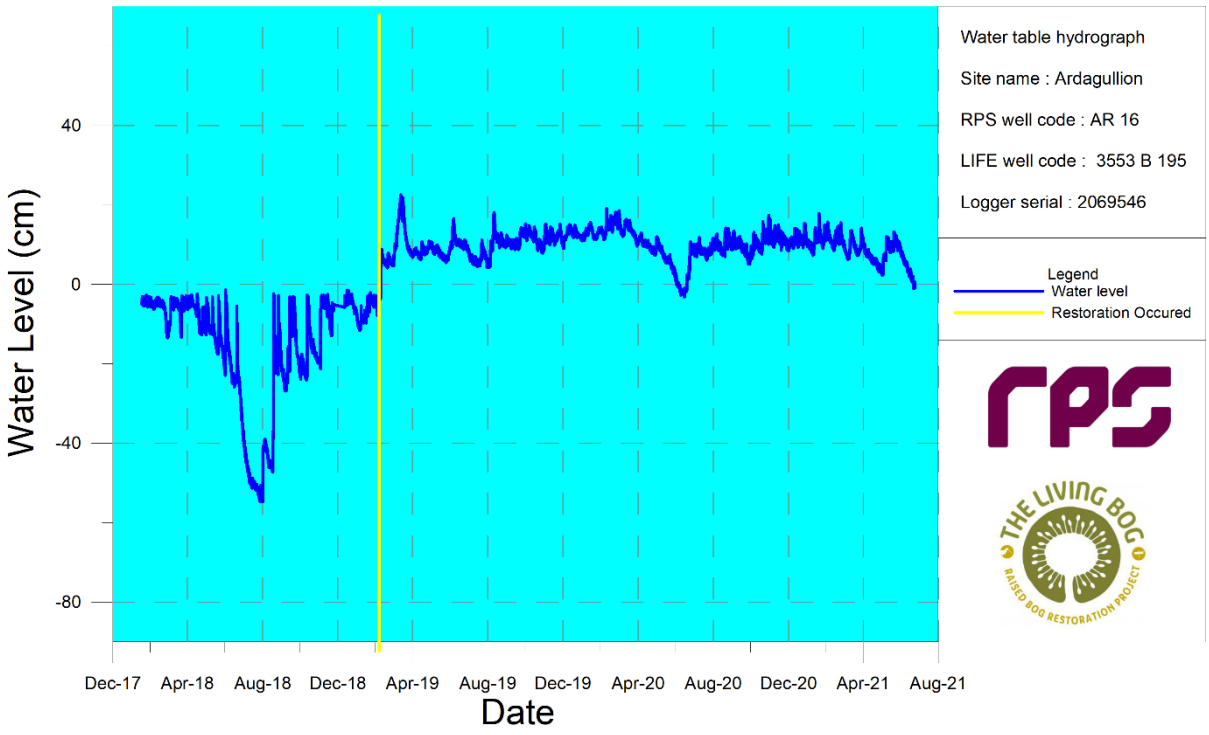


Figure 8-49 Level logger data recorded between December 2017 and August 2021 at well AR 16, Ardagullion Bog SAC

8.2 Carrowbehy

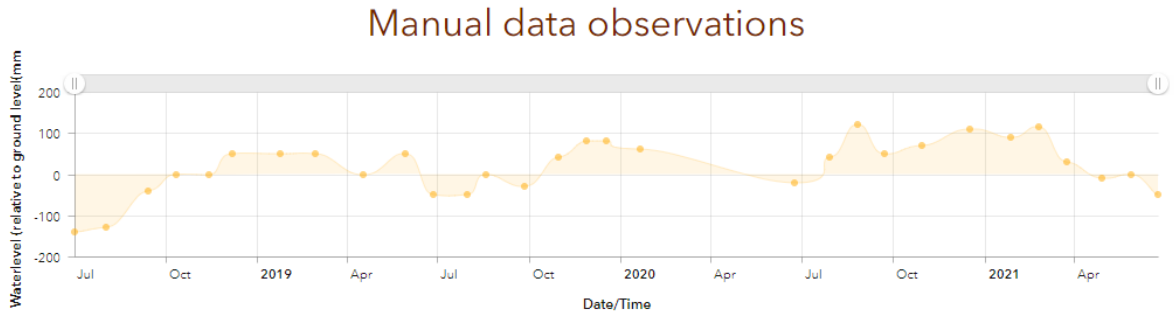


Figure 8-50 Hydrograph of manual monthly water levels CB 1, Carrowbehy Bog SAC

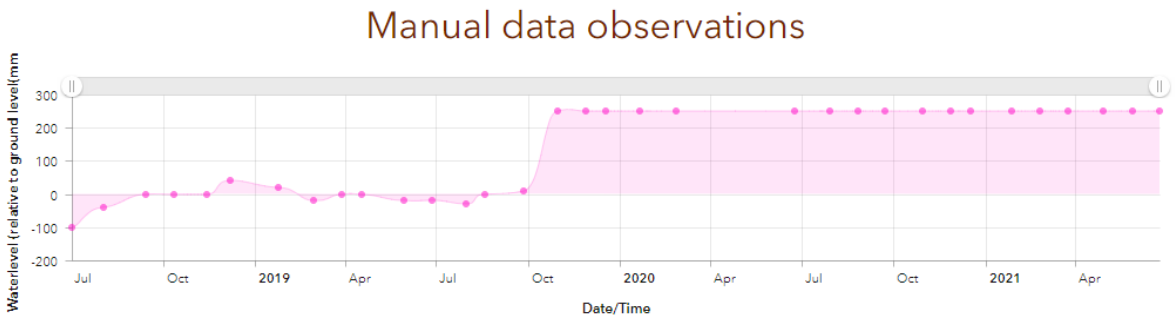


Figure 8-51 Hydrograph of manual monthly water levels CB 2, Carrowbehy Bog SAC

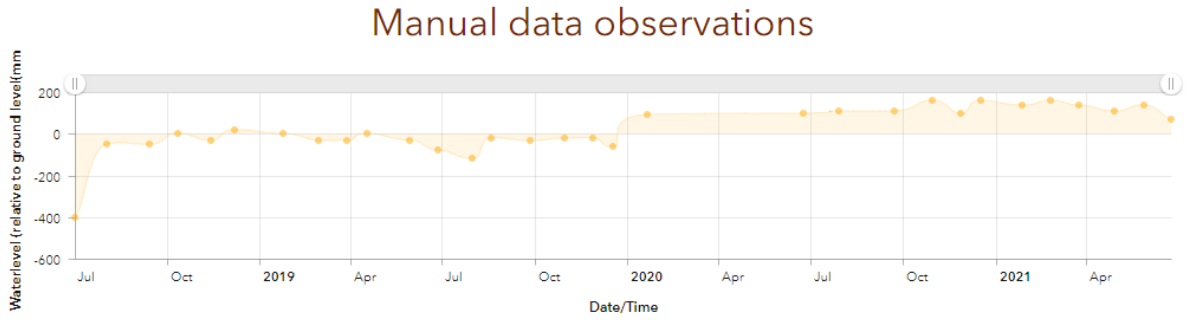


Figure 8-52 Hydrograph of manual monthly water levels CB 3, Carrowbehy Bog SAC

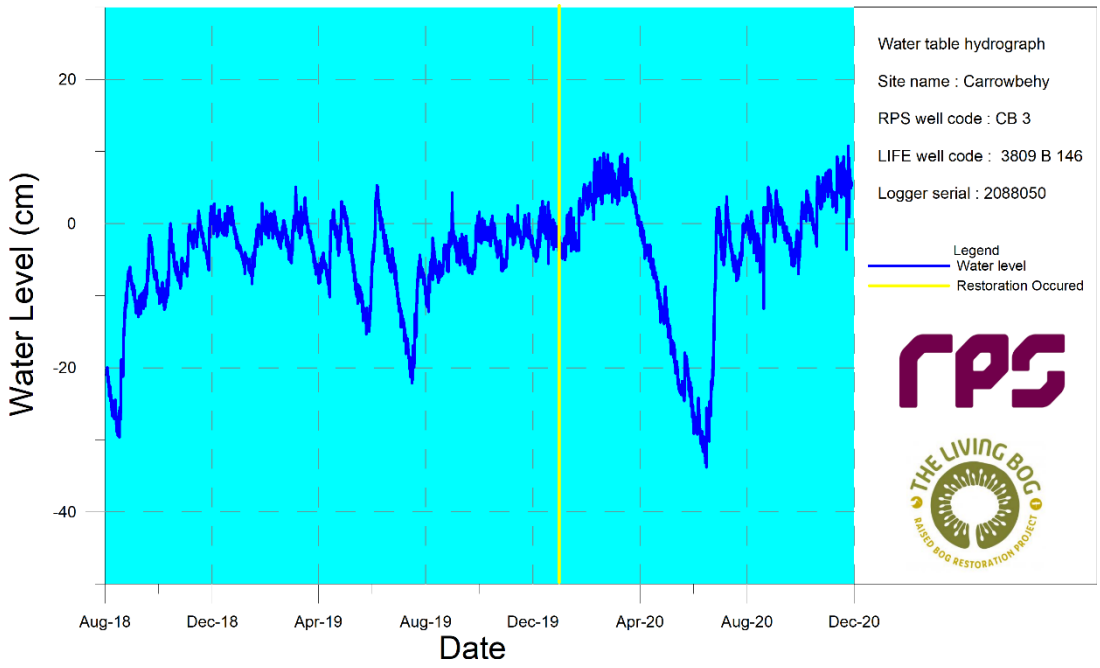


Figure 8-53 Level logger data recorded between December 2018 and December 2020 at well CB3, Carrowbehy Bog SAC

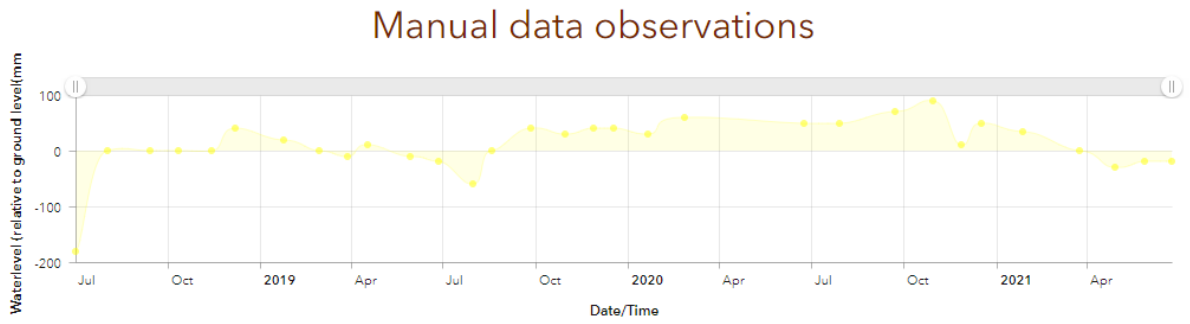


Figure 8-54 Hydrograph of manual monthly water levels CB 4, Carrowbehy Bog SAC

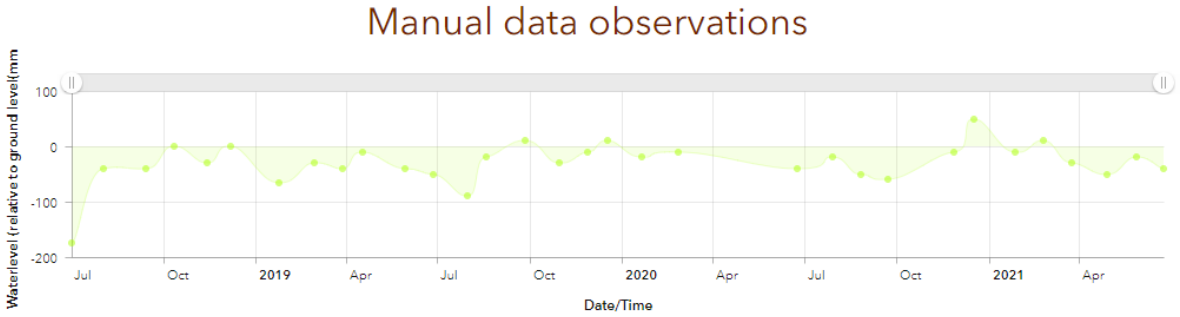


Figure 8-55 Hydrograph of manual monthly water levels CB 5, Carrowbehy Bog SAC

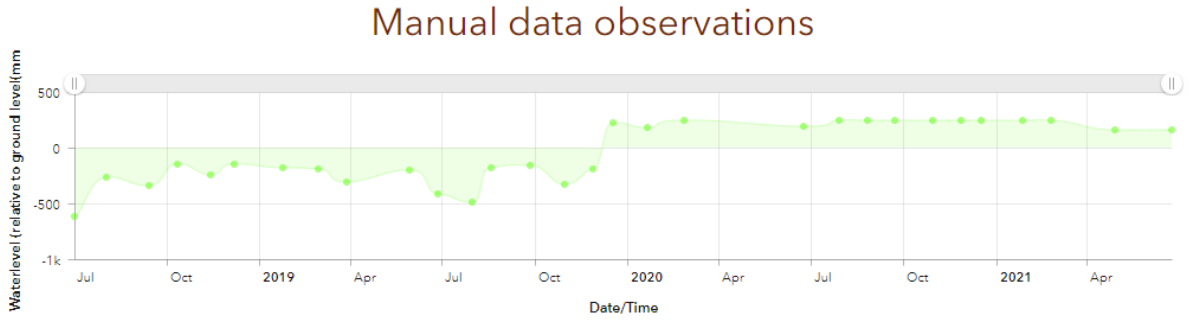


Figure 8-56 Hydrograph of manual monthly water levels CB 6, Carrowbehy Bog SAC

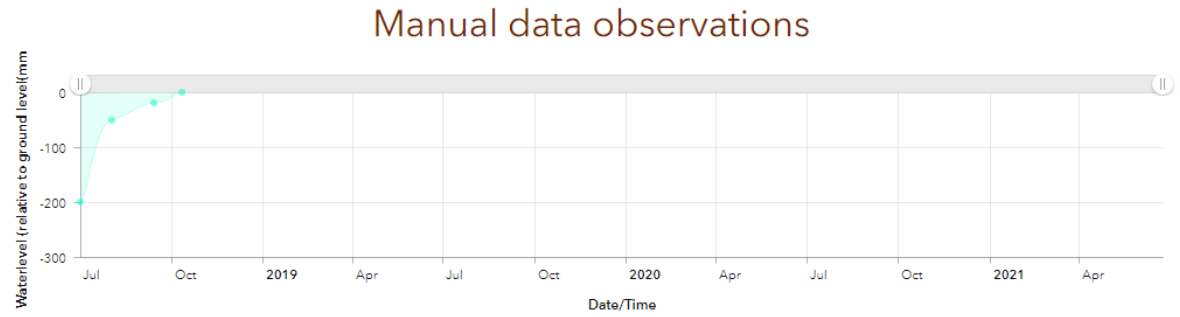


Figure 8-57 Hydrograph of manual monthly water levels CB 7, Carrowbehy Bog SAC

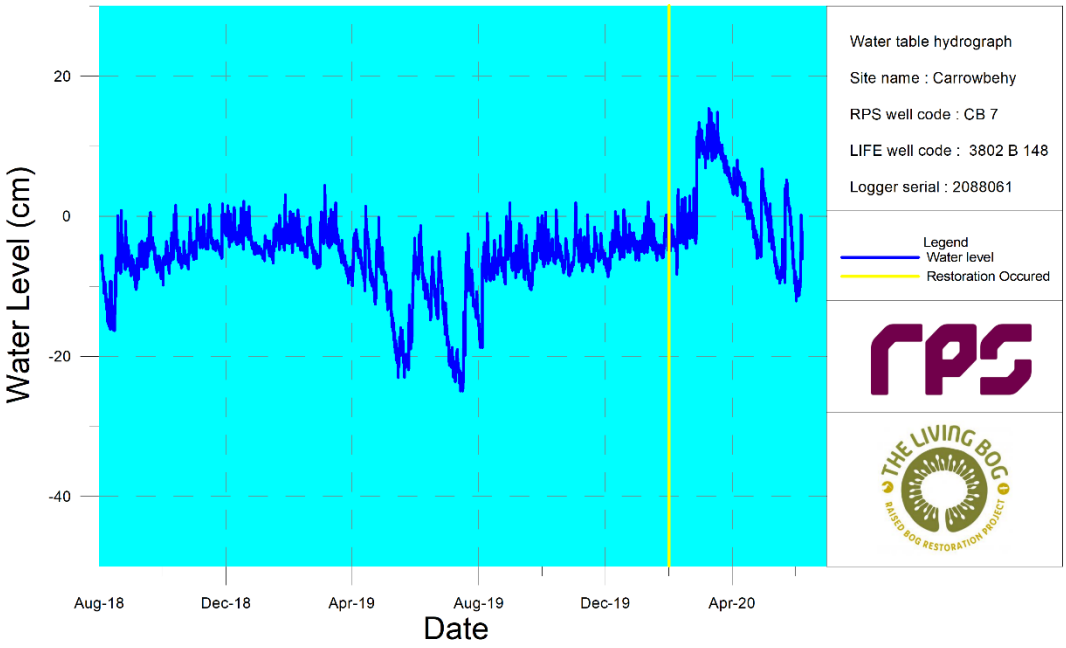


Figure 8-58 Level logger data recorded between August 2018 and August 2020 at well CB7, Carrowbehy Bog SAC

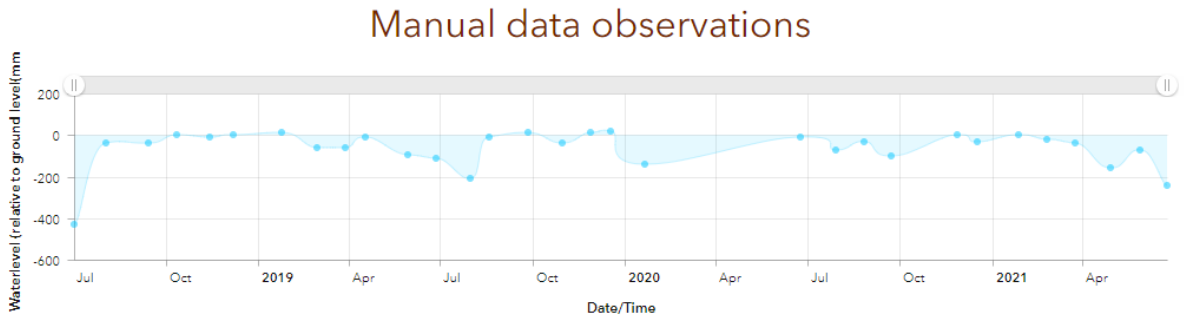


Figure 8-59 Hydrograph of manual monthly water levels CB 8, Carrowbehy Bog SAC

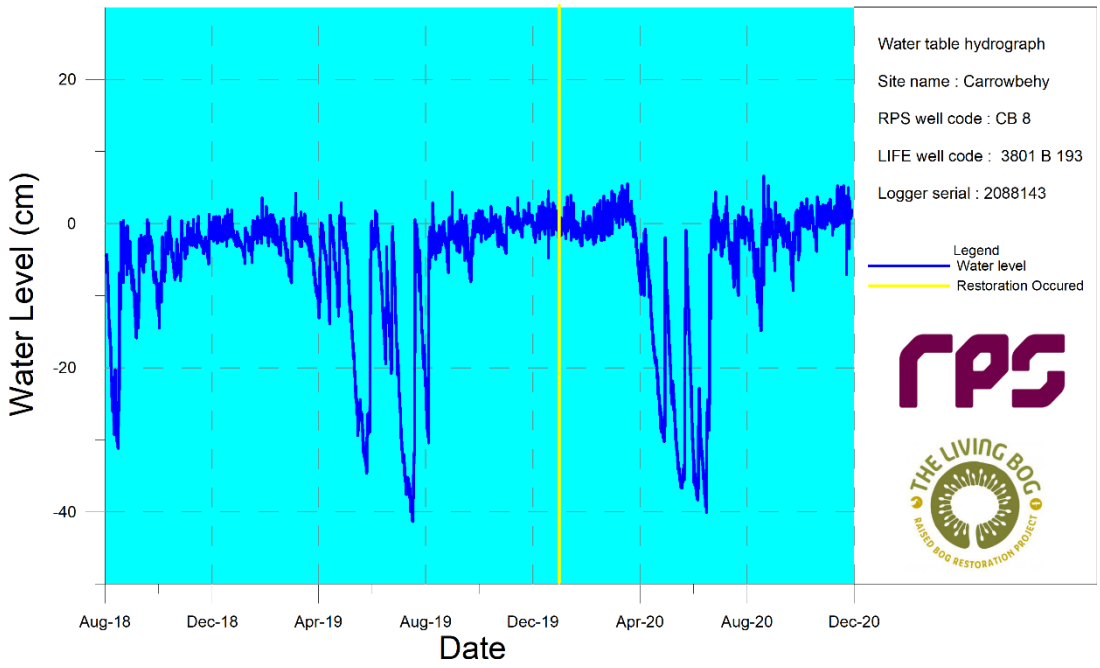


Figure 8-60 Level logger data recorded between August 2018 and December 2020 at well CB8, Carrowbehy Bog SAC

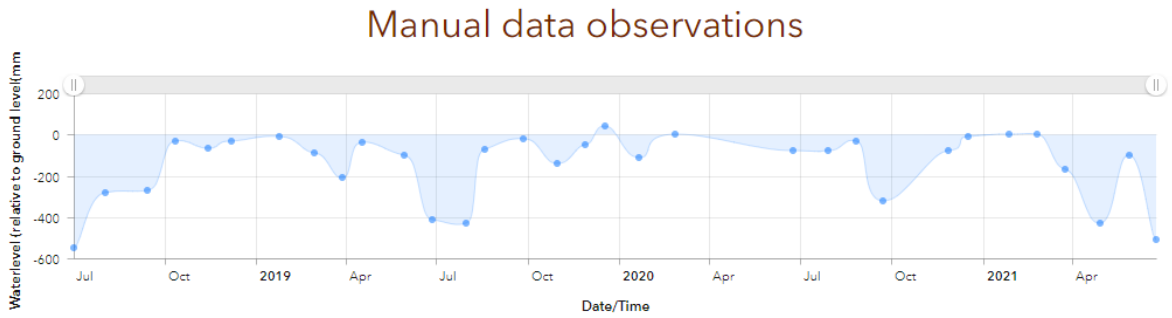


Figure 8-61 Hydrograph of manual monthly water levels CB 9, Carrowbehy Bog SAC

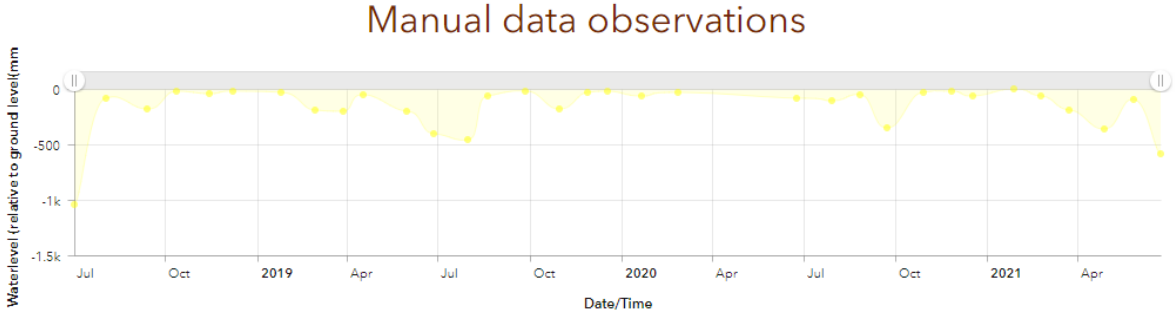


Figure 8-62 Hydrograph of manual monthly water levels CB 10, Carrowbehy Bog SAC

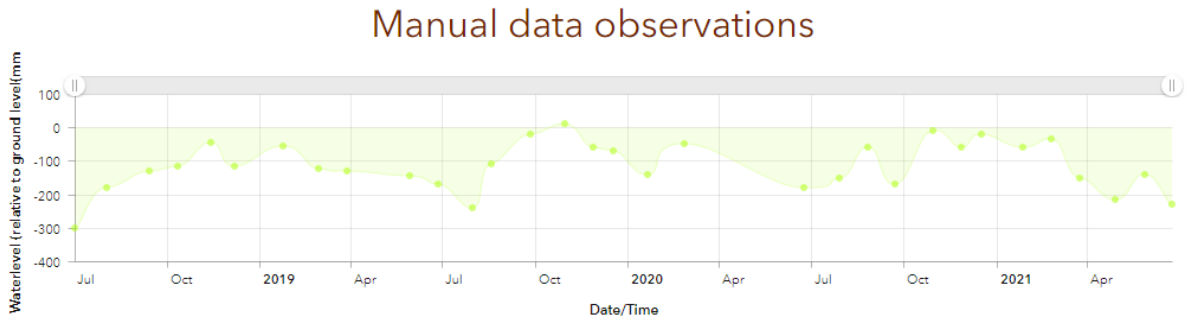


Figure 8-63 Hydrograph of manual monthly water levels CB 11, Carrowbehy Bog SAC

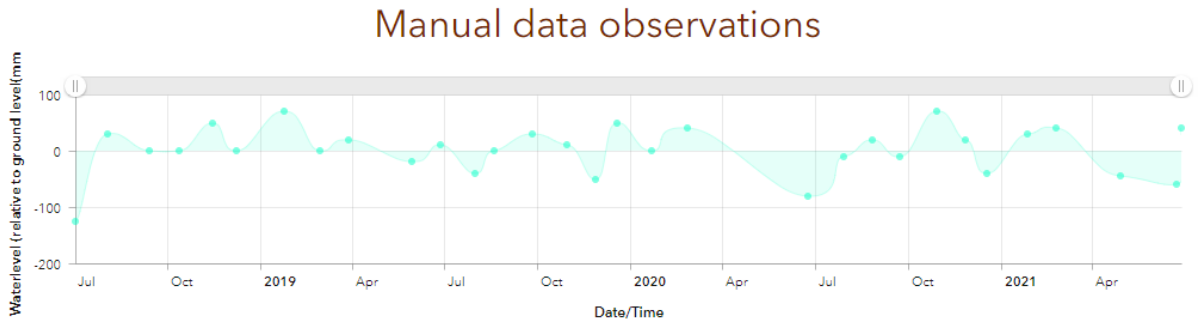


Figure 8-64 Hydrograph of manual monthly water levels CB 12S, Carrowbehy Bog SAC

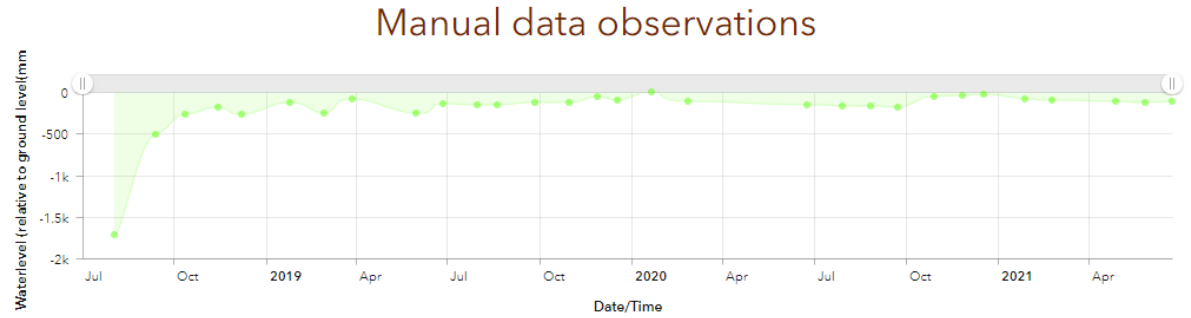


Figure 8-65 Hydrograph of manual monthly water levels CB 12D, Carrowbehy Bog SAC

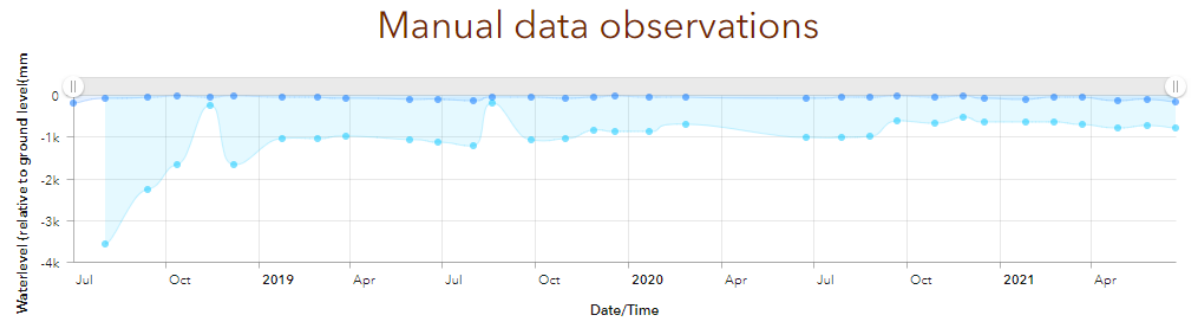


Figure 8-66 Hydrograph of manual monthly water levels CB 13S (dark blue) and 13D (light blue), Carrowbehy Bog SAC

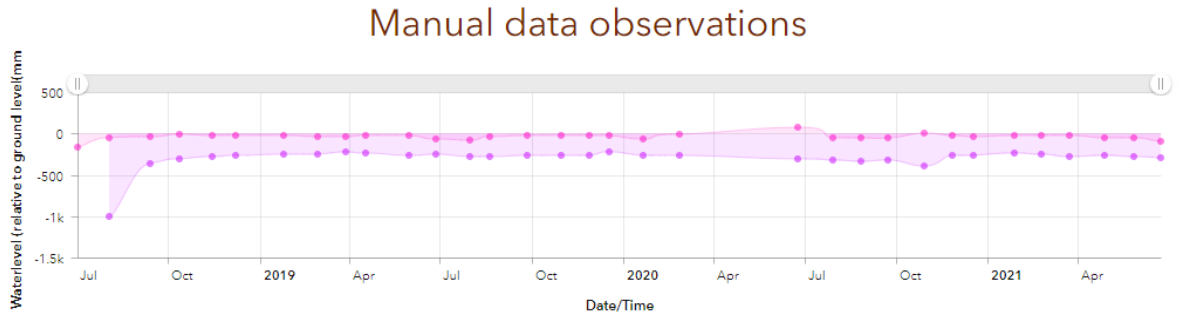


Figure 8-67 Hydrograph of manual monthly water levels CB 14S (pink) and 14D (purple), Carrowbehy Bog SAC

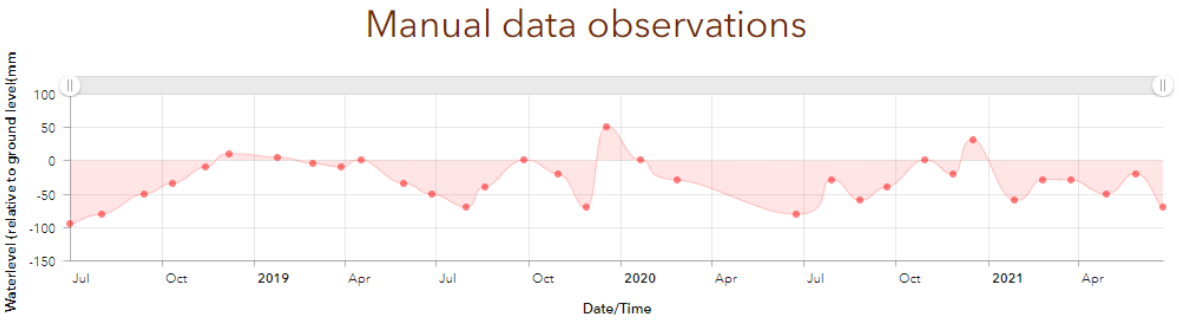


Figure 8-68 Hydrograph of manual monthly water levels CB 15S, Carrowbehy Bog SAC

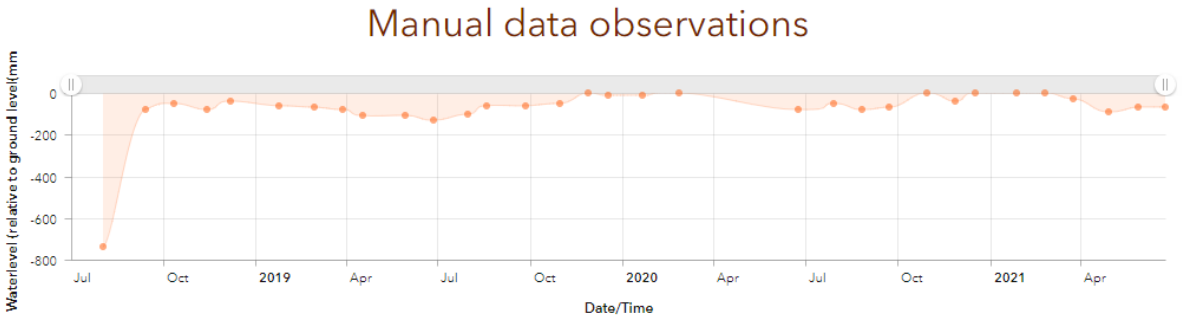


Figure 8-69 Hydrograph of manual monthly water levels CB 15D, Carrowbehy Bog SAC

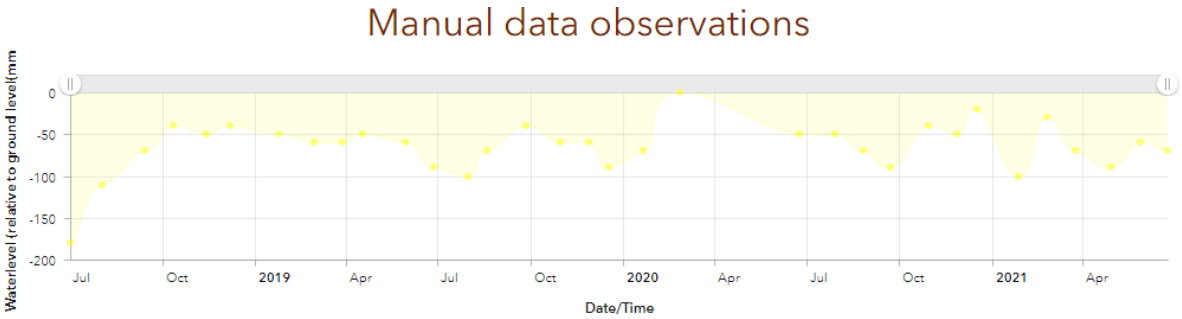


Figure 8-70 Hydrograph of manual monthly water levels CB 16S, Carrowbehy Bog SAC

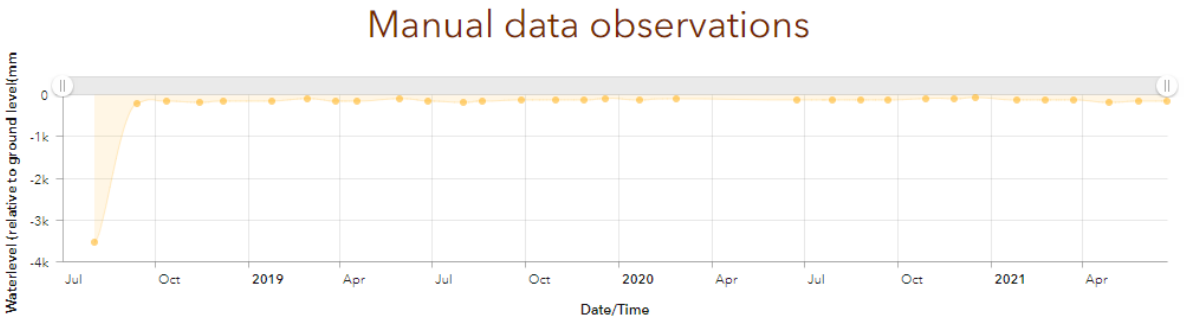


Figure 8-71 Hydrograph of manual monthly water levels CB 16D, Carrowbehy Bog SAC

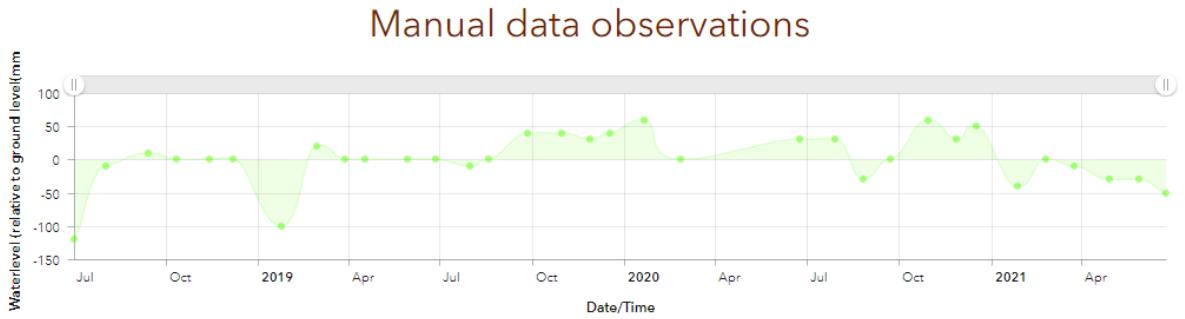


Figure 8-72 Hydrograph of manual monthly water levels CB 17S, Carrowbehy Bog SAC

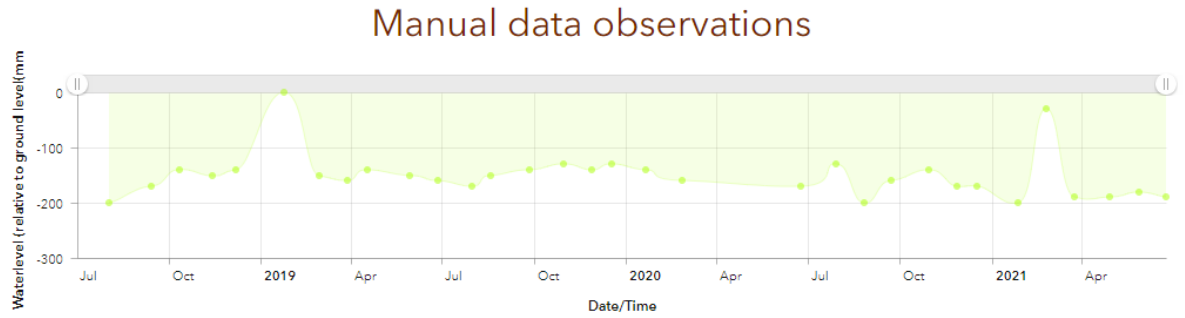


Figure 8-73 Hydrograph of manual monthly water levels CB 17D, Carrowbehy Bog SAC

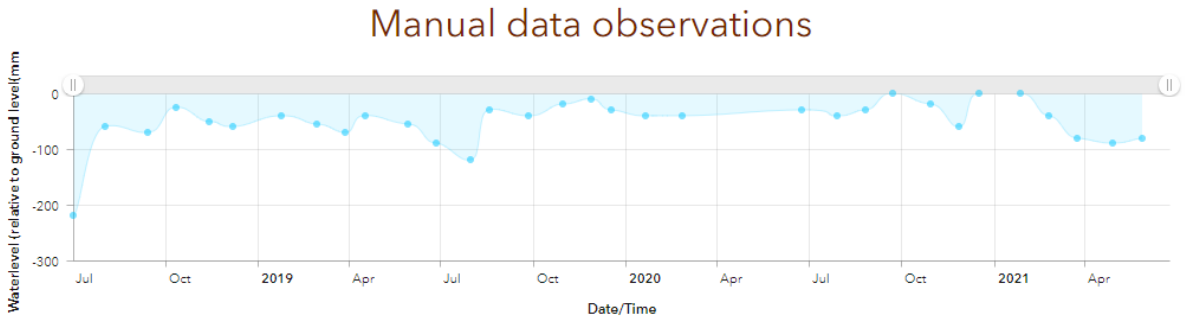


Figure 8-74 Hydrograph of manual monthly water levels CB 18S, Carrowbehy Bog SAC

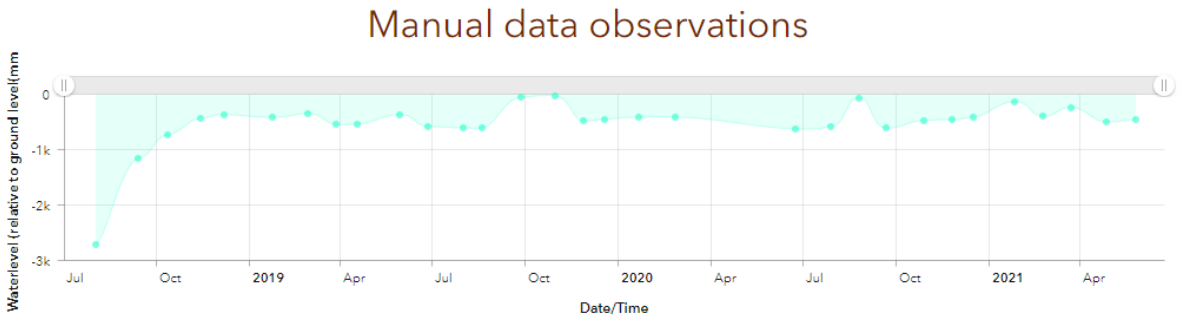


Figure 8-75 Hydrograph of manual monthly water levels CB 18D, Carrowbehy Bog SAC

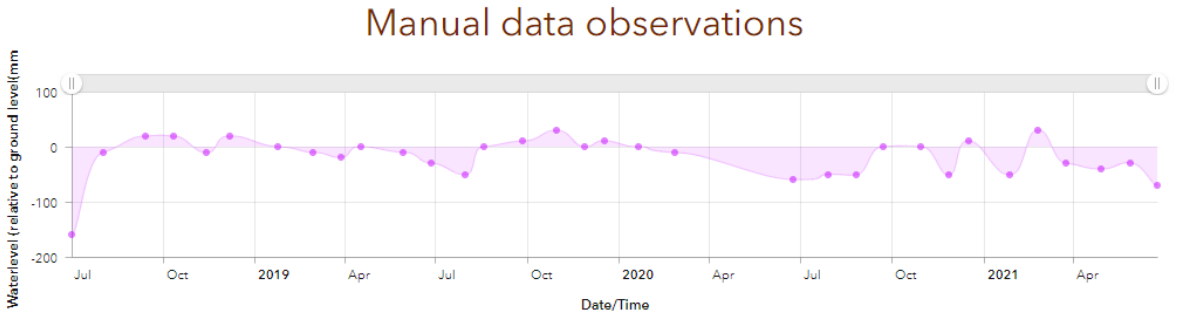


Figure 8-76 Hydrograph of manual monthly water levels CB 19S, Carrowbehy Bog SAC

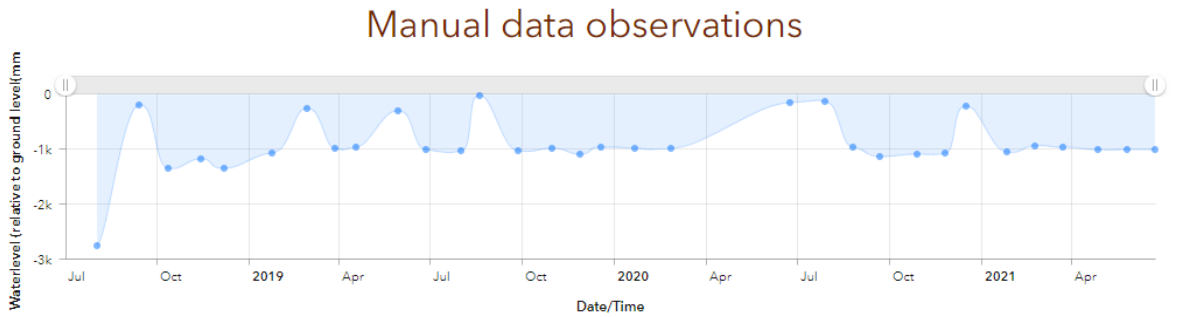


Figure 8-77 Hydrograph of manual monthly water levels CB 19D, Carrowbehy Bog SAC

8.3 Carrownagappul

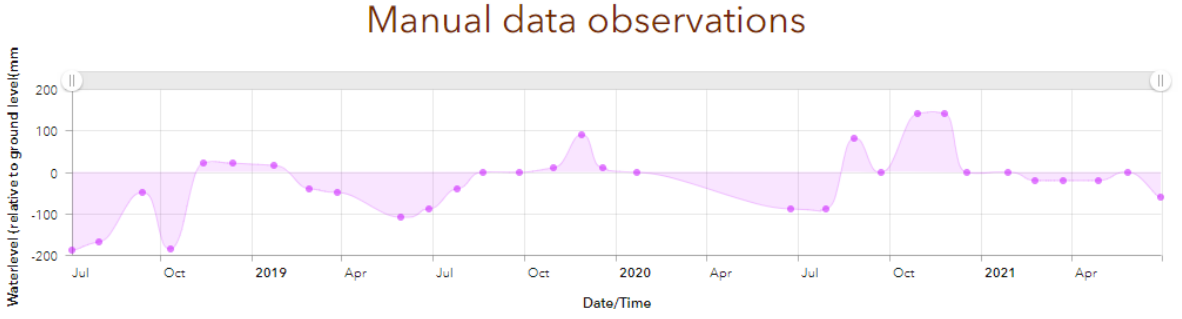


Figure 8-78 Hydrograph of manual monthly water levels CG 1, Carrownagappul Bog SAC

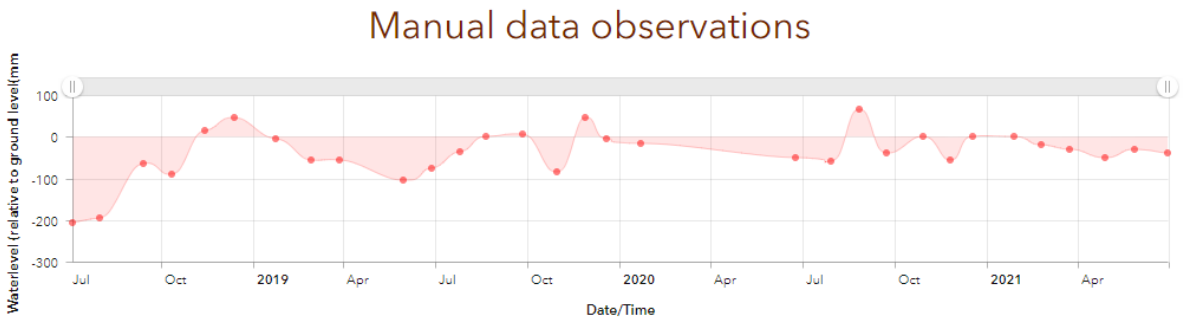


Figure 8-79 Hydrograph of manual monthly water levels CG 2, Carrownagappul Bog SAC

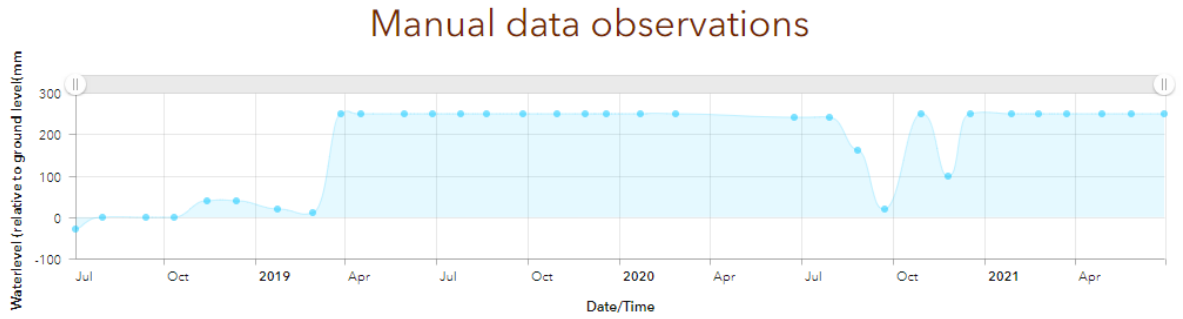


Figure 8-80 Hydrograph of manual monthly water levels CG 3, Carrownagappul Bog SAC

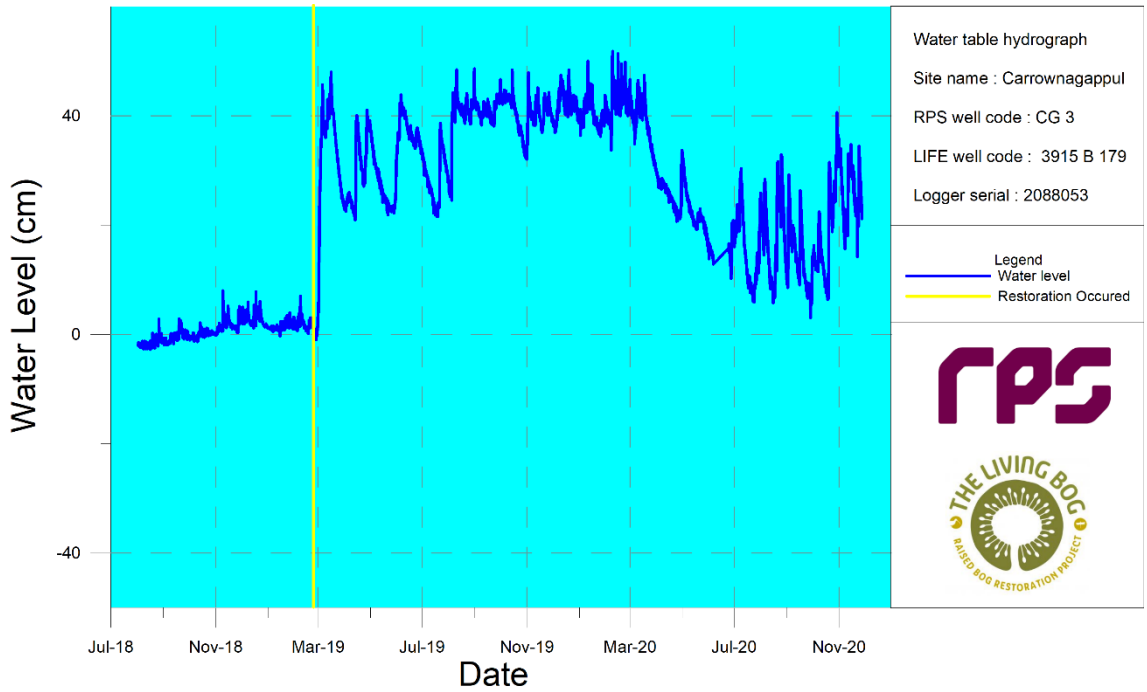


Figure 8-81 Level logger data recorded between July 2018 and December 2020 at well CG3, Carrownagappul Bog SAC

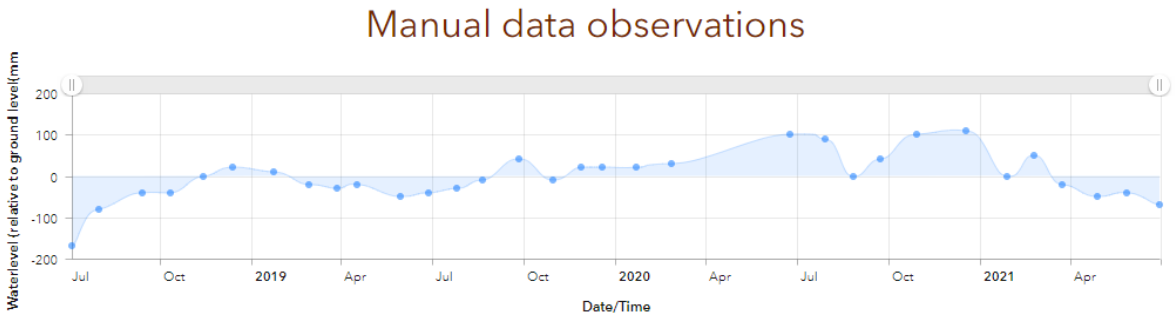


Figure 8-82 Hydrograph of manual monthly water levels CG 4, Carrownagappul Bog SAC

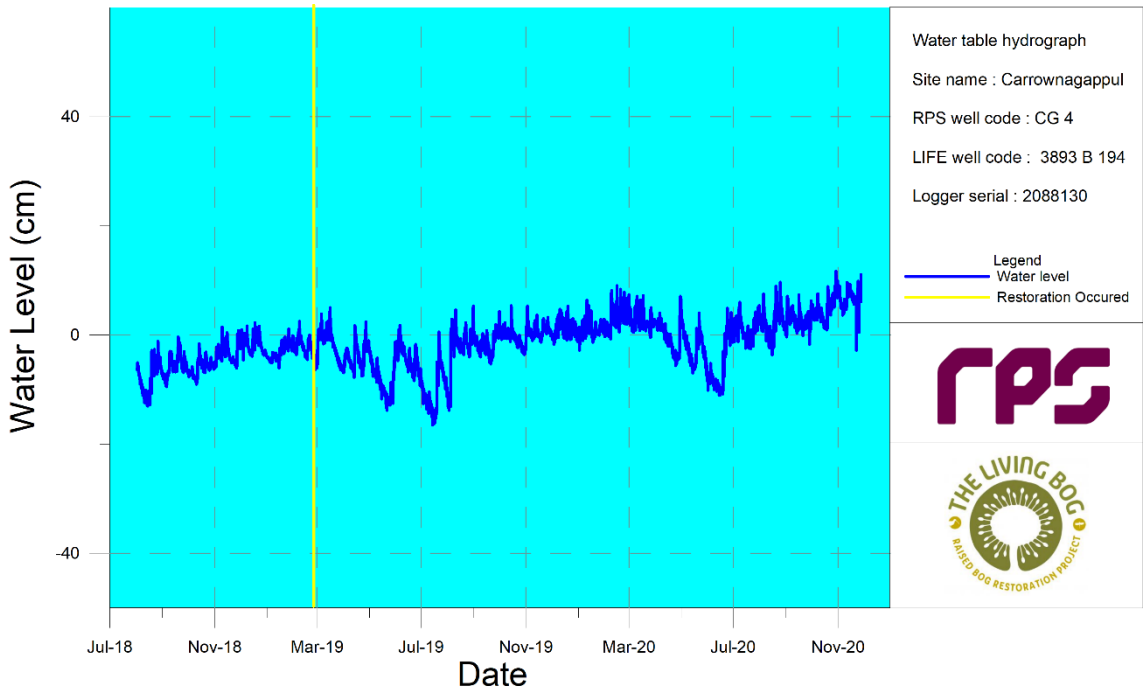


Figure 8-83 Level logger data recorded between July 2018 and December 2020 at well CG4, Carrownagappul Bog SAC

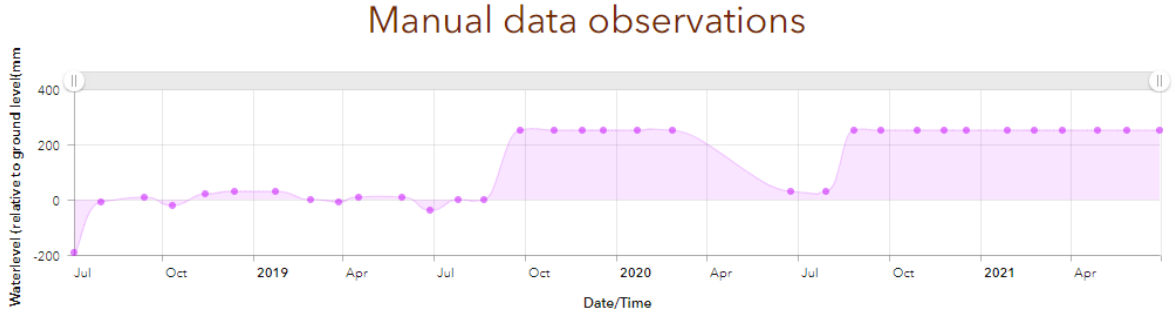


Figure 8-84 Hydrograph of manual monthly water levels CG 5, Carrownagappul Bog SAC

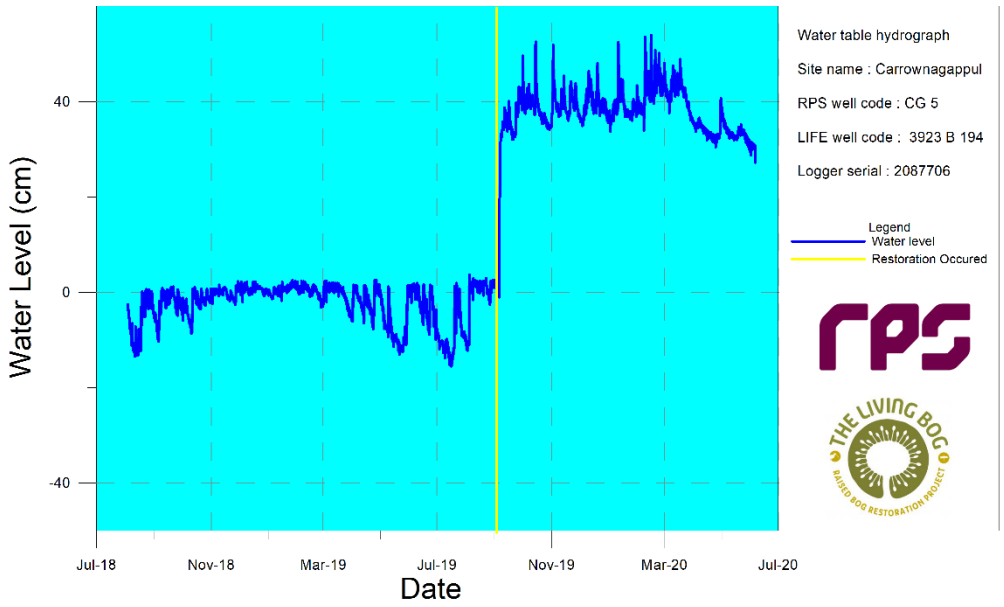


Figure 8-85 Level logger data recorded between August 2018 and June 2020 at well CG5, Carrownagappul Bog SAC

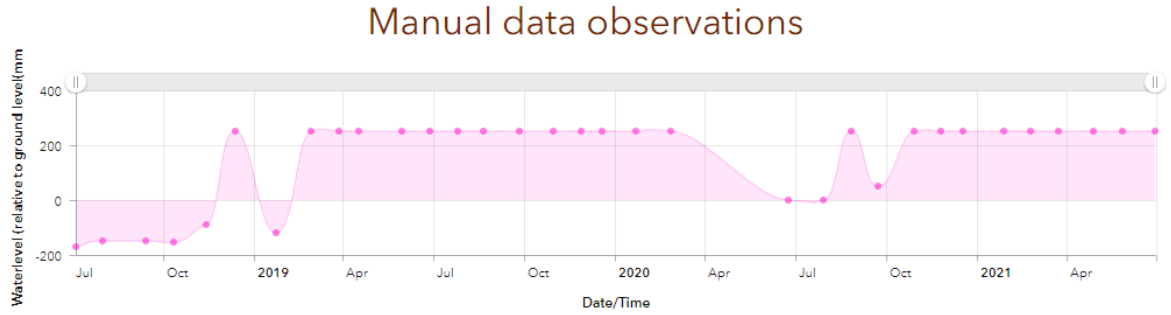


Figure 8-86 Hydrograph of manual monthly water levels CG 6, Carrownagappul Bog SAC

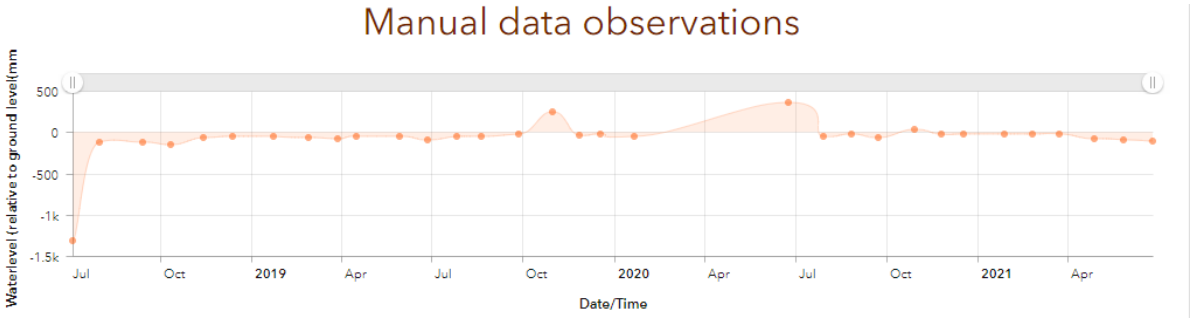


Figure 8-87 Hydrograph of manual monthly water levels CG 7, Carrownagappul Bog SAC

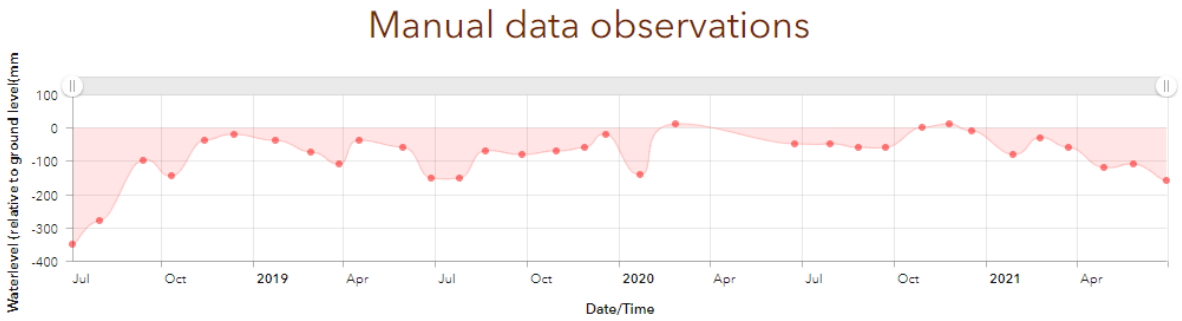


Figure 8-88 Hydrograph of manual monthly water levels CG 9, Carrownagappul Bog SAC

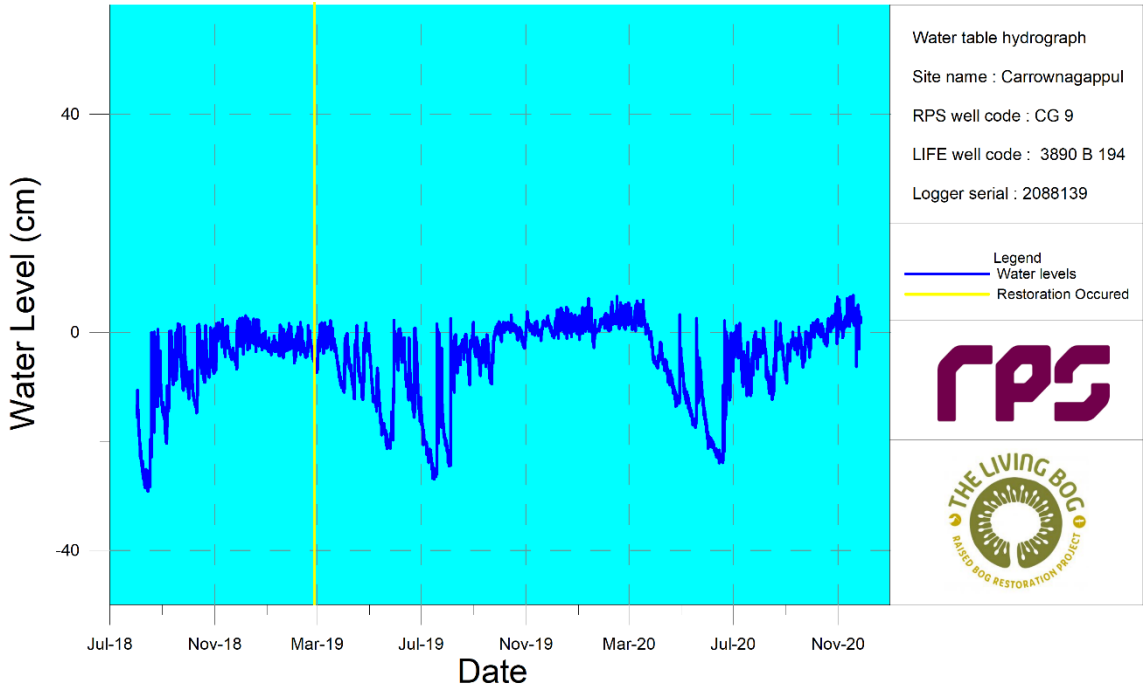


Figure 8-89 Level logger data recorded between July 2018 and December 2020 at well CG9, Carrownagappul Bog SAC

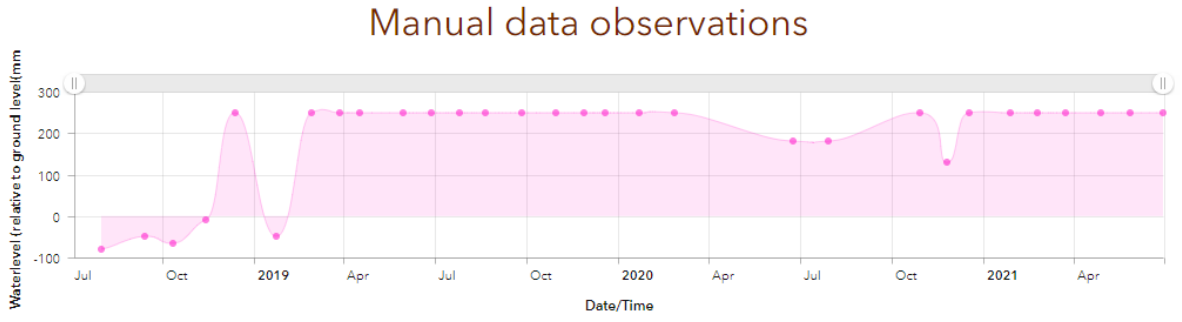


Figure 8-90 Hydrograph of manual monthly water levels CG 10, Carrownagappul Bog SAC

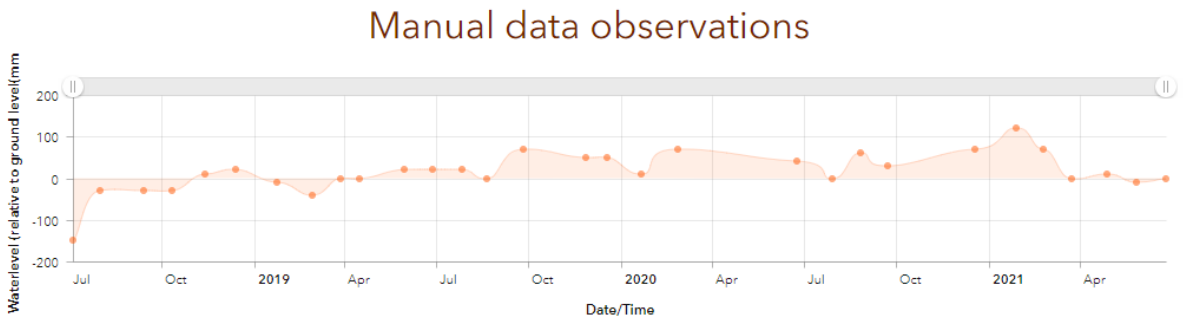


Figure 8-91 Hydrograph of manual monthly water levels CG 11, Carrownagappul Bog SAC

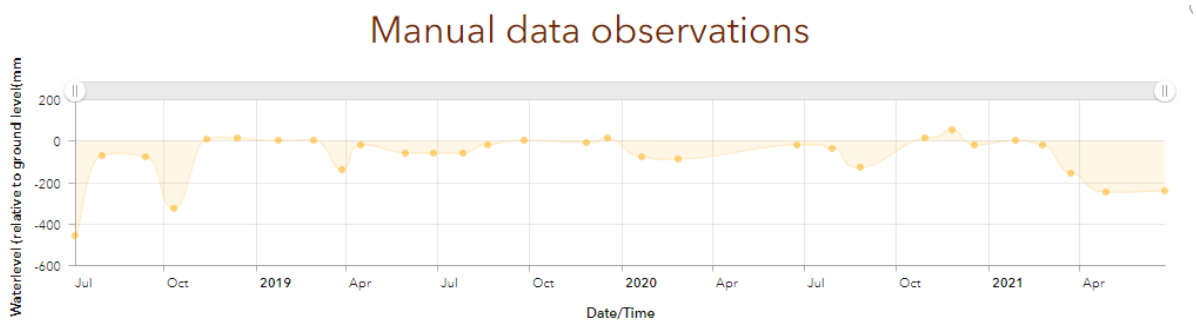


Figure 8-92 Hydrograph of manual monthly water levels CG 12S, Carrownagappul Bog SAC

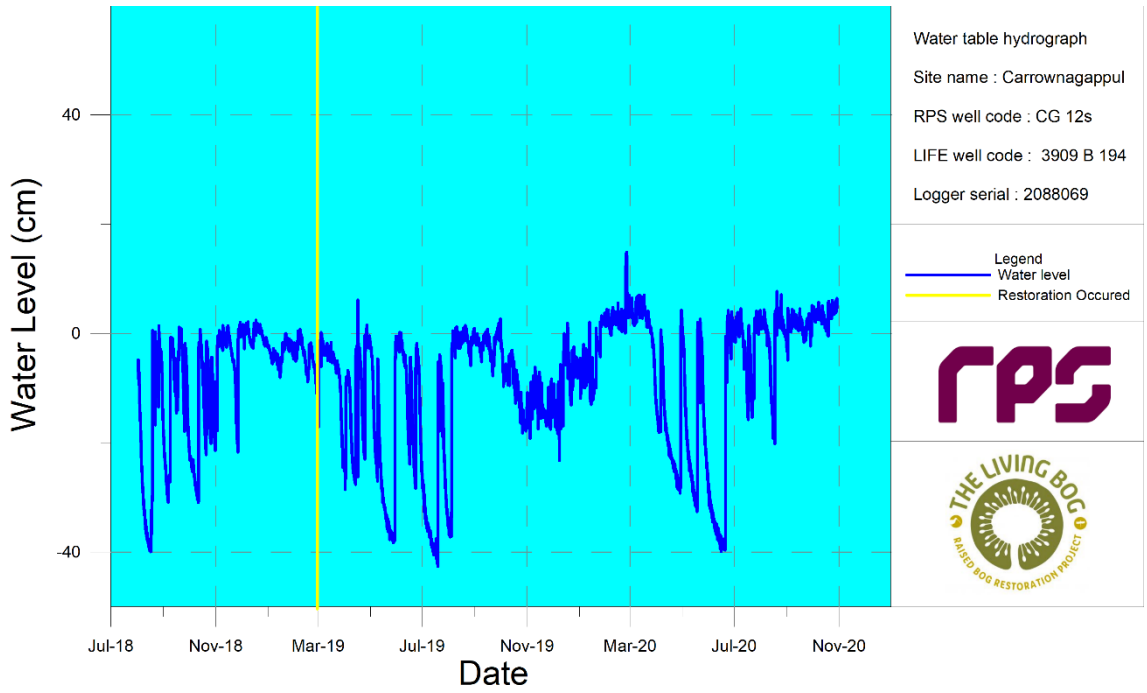


Figure 8-93 Level logger data recorded between July 2018 and November 2020 at well CG12s, Carrownagappul Bog SAC

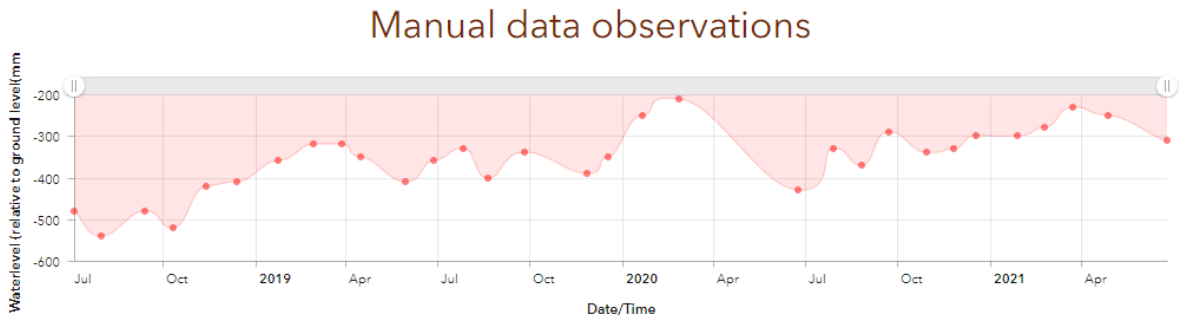


Figure 8-94 Hydrograph of manual monthly water levels CG 12D, Carrownagappul Bog SAC

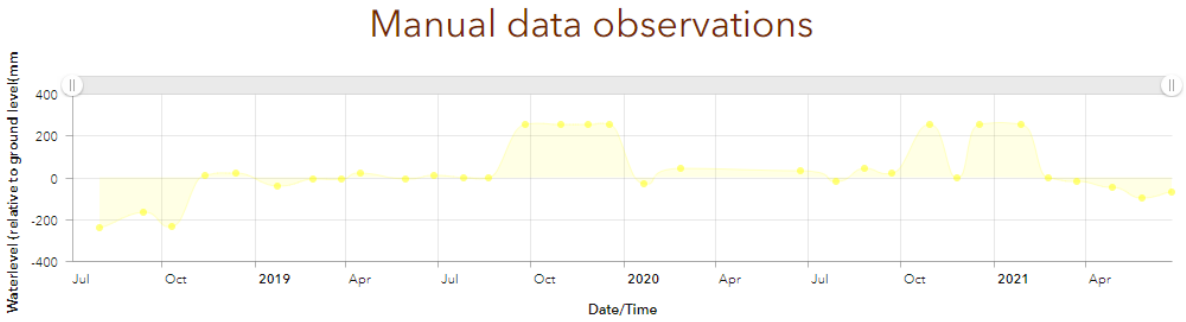


Figure 8-95 Hydrograph of manual monthly water levels CG 13, Carrownagappul Bog SAC

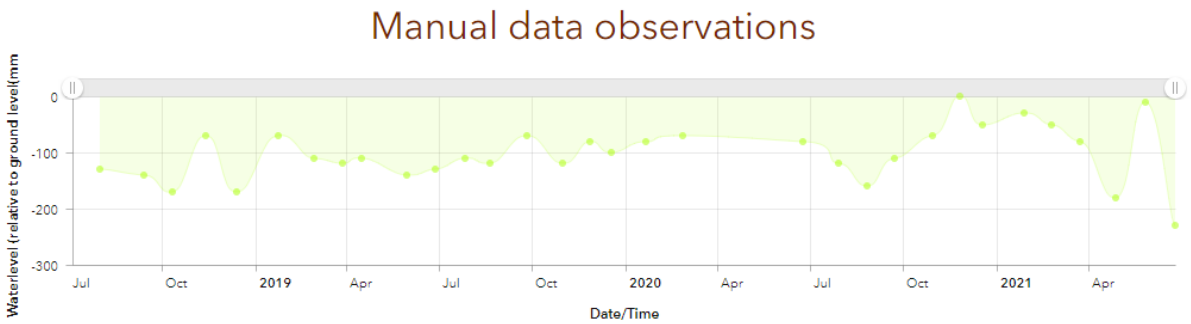


Figure 8-96 Hydrograph of manual monthly water levels CG 14, Carrownagappul Bog SAC

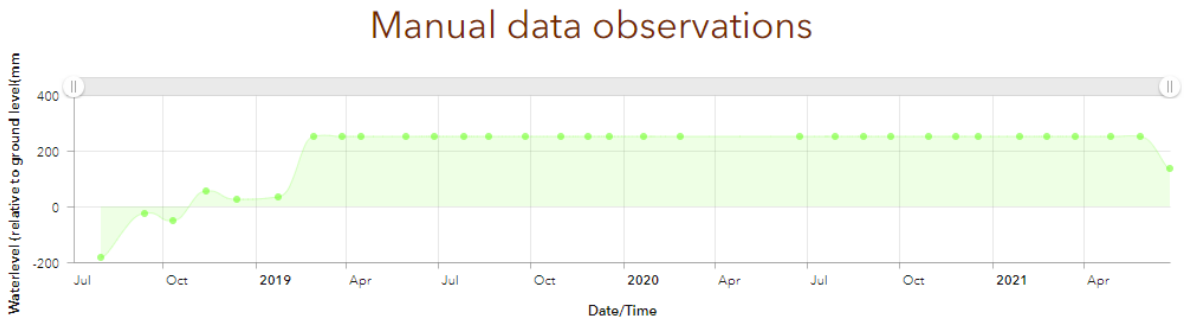


Figure 8-97 Hydrograph of manual monthly water levels CG 16, Carrownagappul Bog SAC

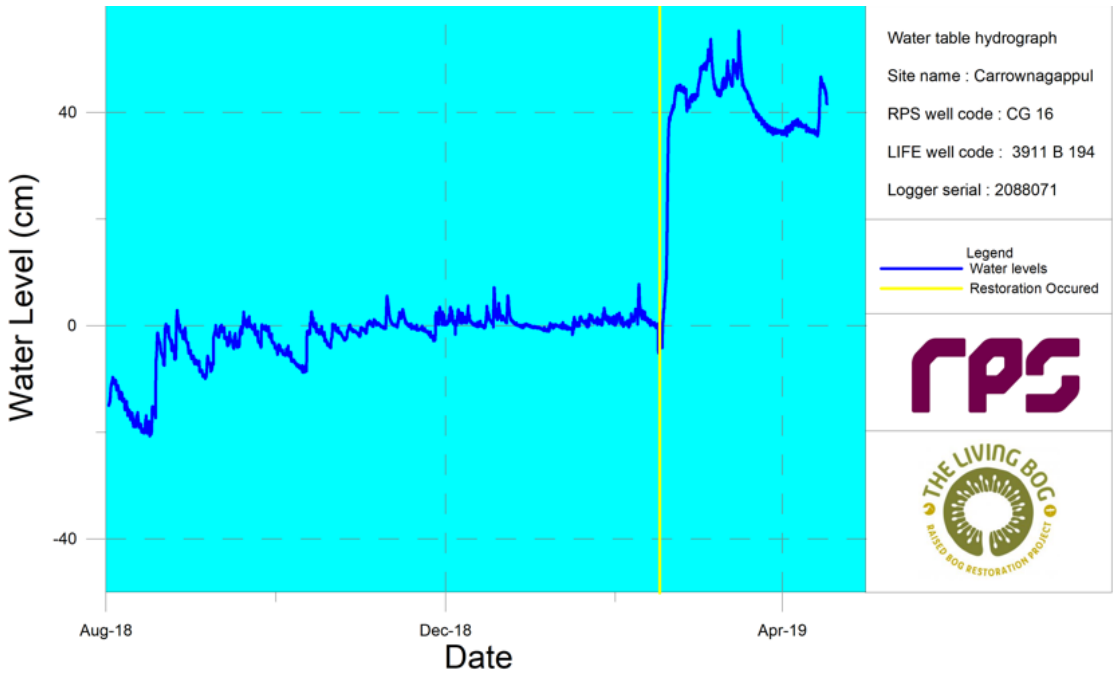


Figure 8-98 Level logger data recorded between August 2018 and May 2019 at well CG16, Carrownagappul Bog SAC

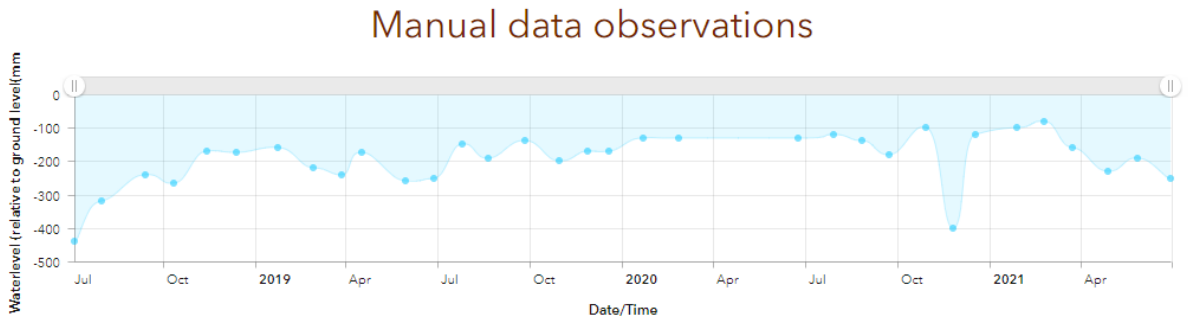


Figure 8-99 Hydrograph of manual monthly water levels CG 17S, Carrownagappul Bog SAC

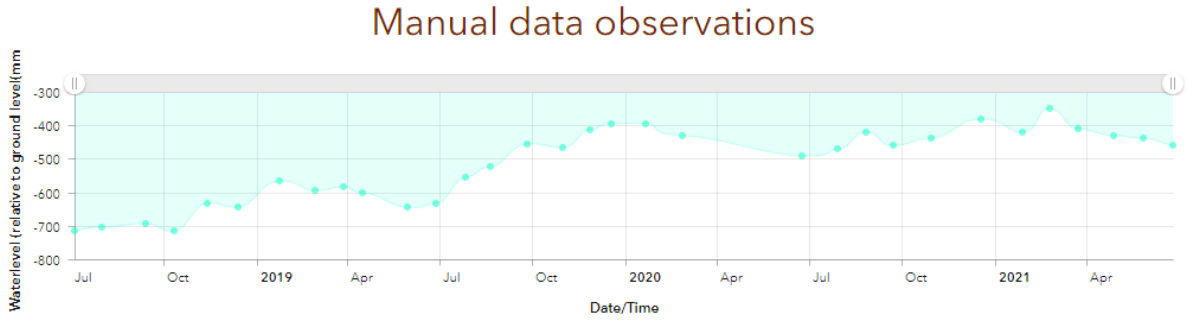


Figure 8-100 Hydrograph of manual monthly water levels CG 17D, Carrownagappul Bog SAC

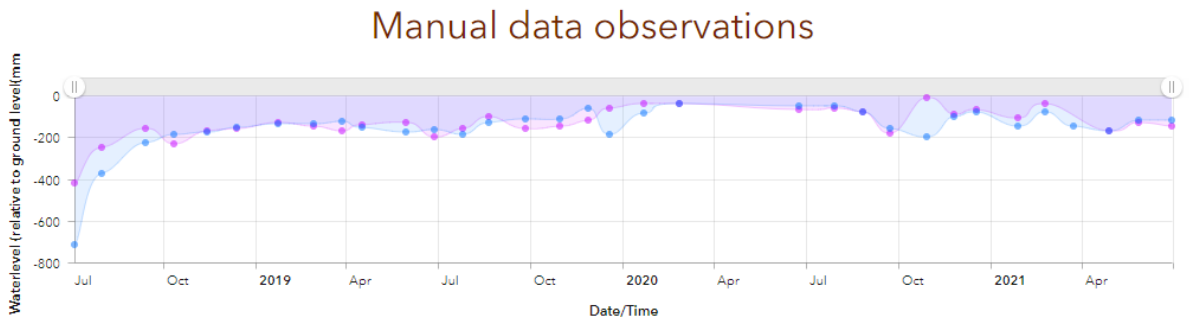


Figure 8-101 Hydrograph of manual monthly water levels CG 18S (purple) and 18D (blue), Carrownagappul Bog SAC

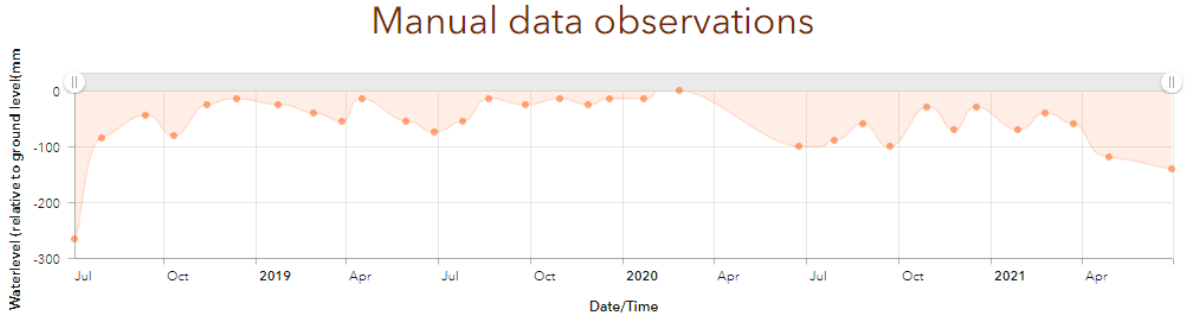


Figure 8-102 Hydrograph of manual monthly water levels CG 19S, Carrownagappul Bog SAC

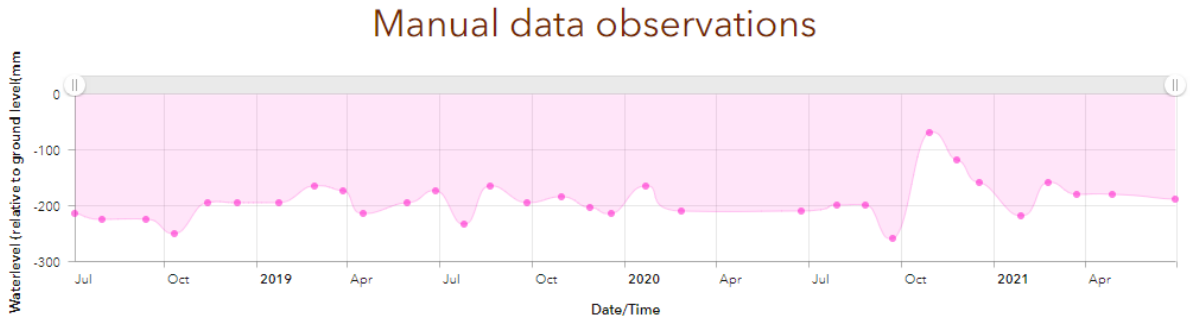


Figure 8-103 Hydrograph of manual monthly water levels CG 19D, Carrownagappul Bog SAC

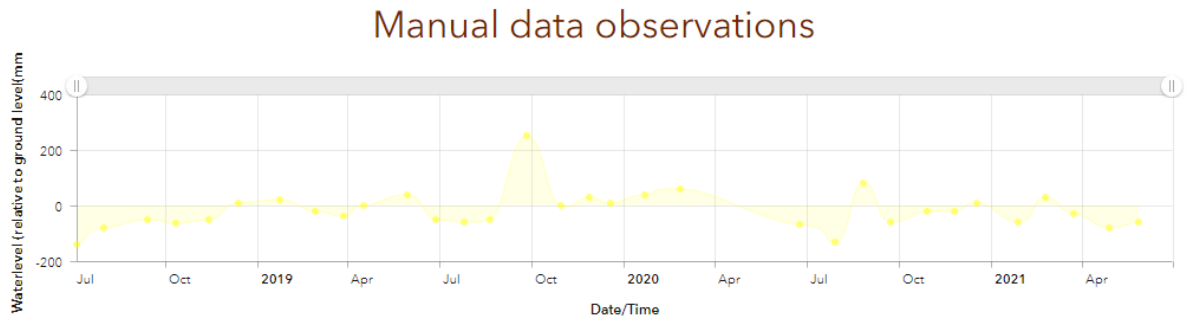


Figure 8-104 Hydrograph of manual monthly water levels CG 20S, Carrownagappul Bog SAC

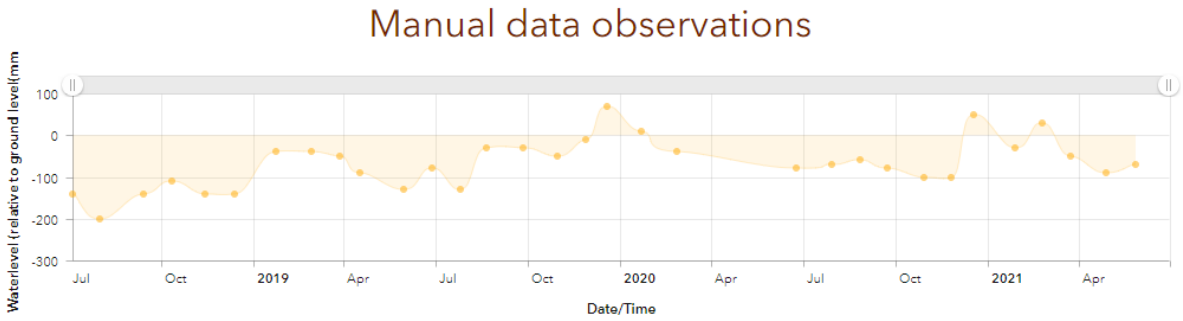


Figure 8-105 Hydrograph of manual monthly water levels CG 20D, Carrownagappul Bog SAC

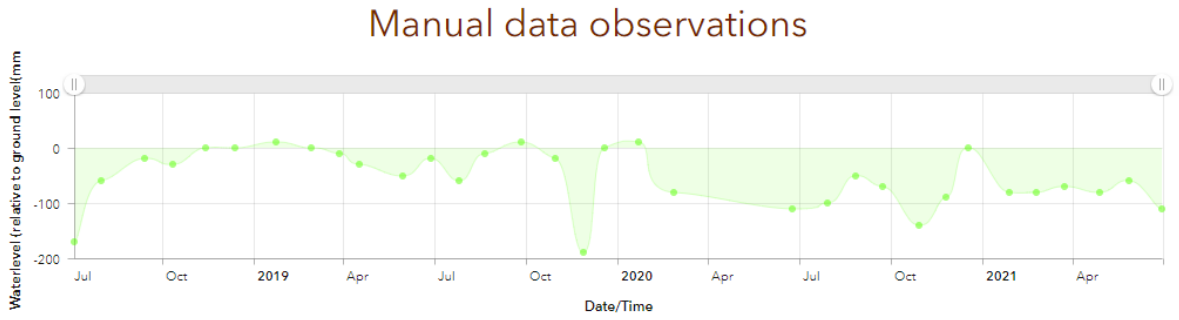


Figure 8-106 Hydrograph of manual monthly water levels CG 21S, Carrownagappul Bog SAC

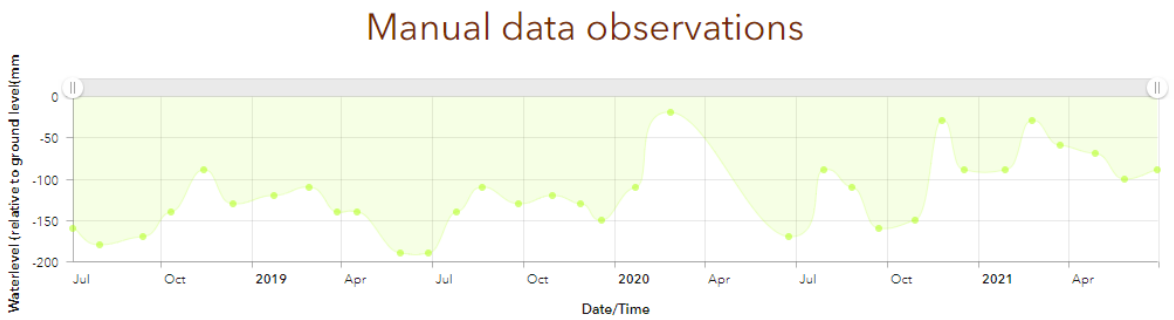


Figure 8-107 Hydrograph of manual monthly water levels CG 21D, Carrownagappul Bog SAC

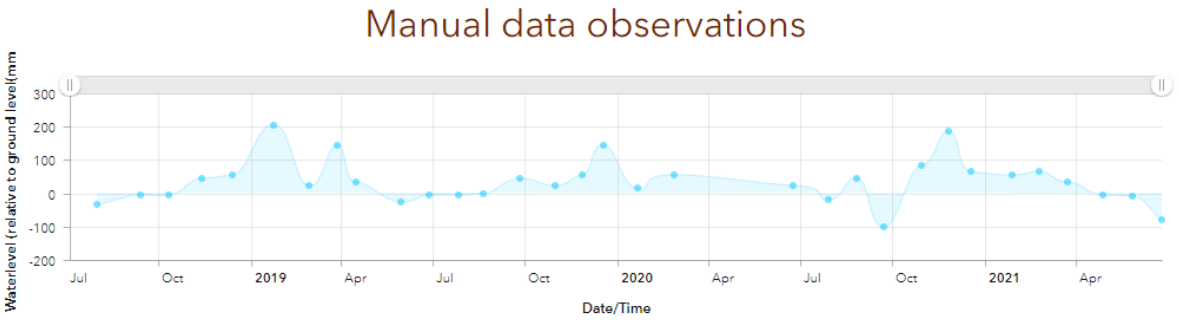


Figure 8-108 Hydrograph of manual monthly water levels CG 22S, Carrownagappul Bog SAC

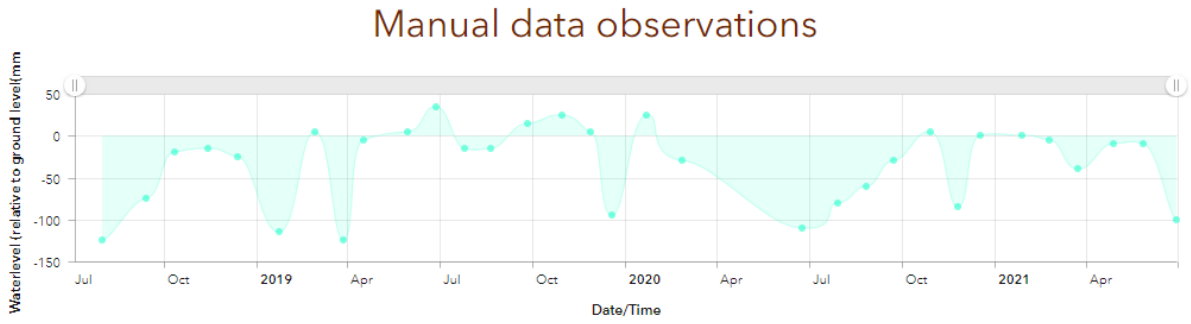


Figure 8-109 Hydrograph of manual monthly water levels CG 22D, Carrownagappul Bog SAC

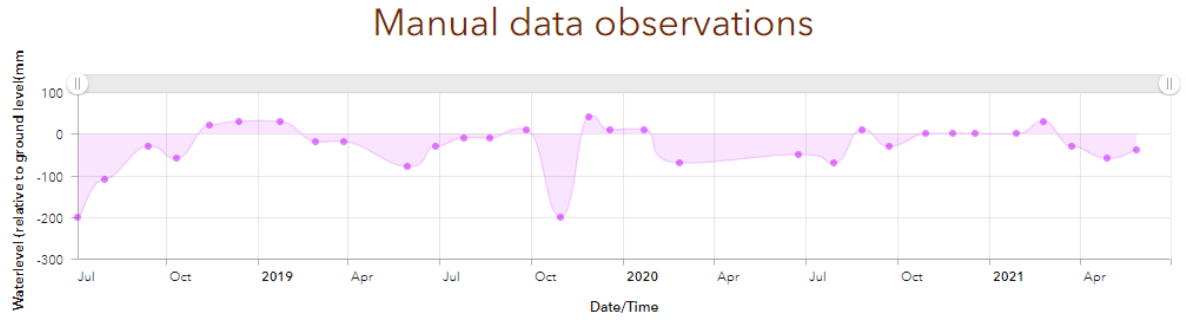


Figure 8-110 Hydrograph of manual monthly water levels CG 23S, Carrownagappul Bog SAC

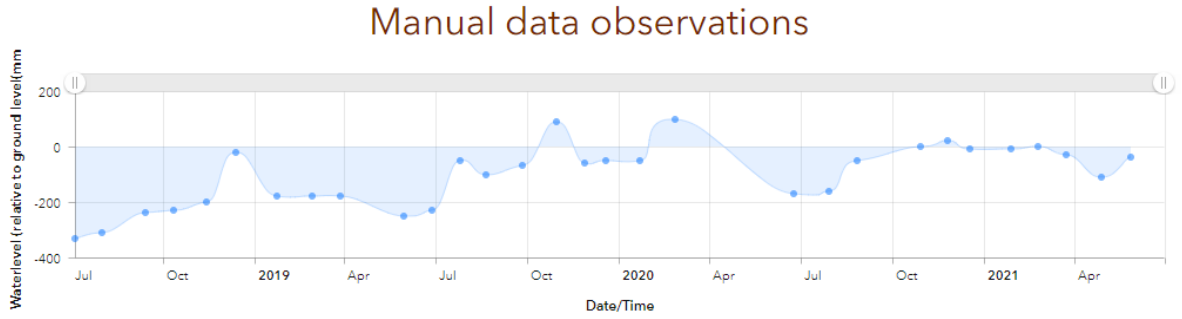


Figure 8-111 Hydrograph of manual monthly water levels CG 23D, Carrownagappul Bog SAC

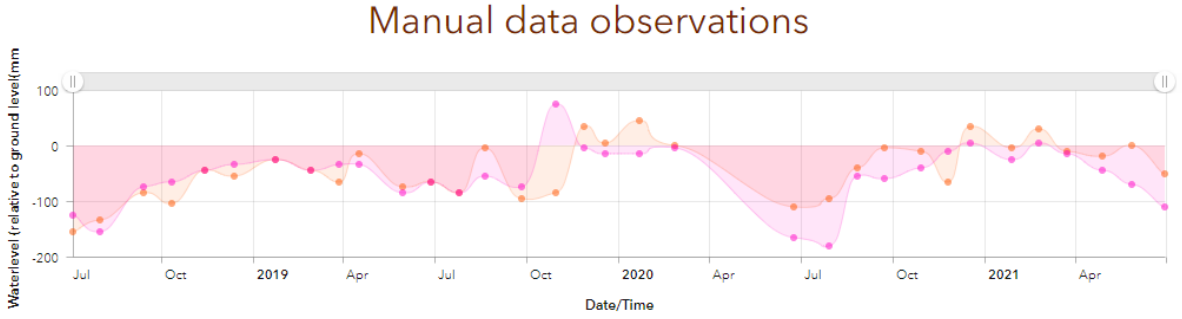


Figure 8-112 Hydrograph of manual monthly water levels CG 24S (orange) and 24D (pink), Carrownagappul Bog SAC

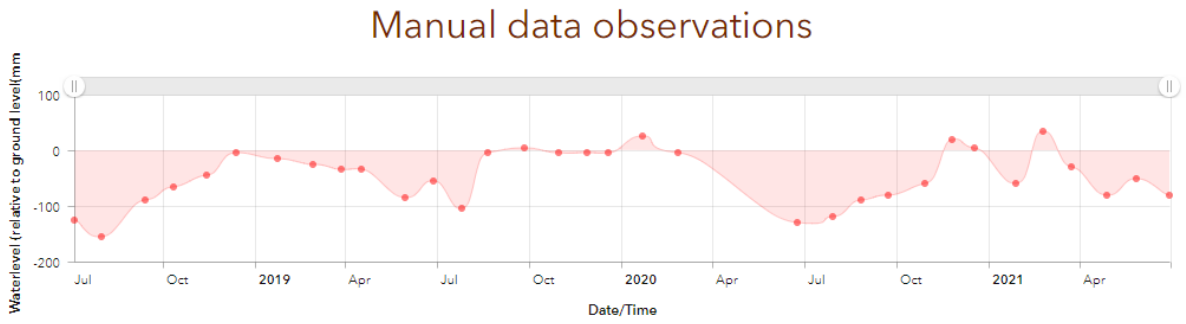


Figure 8-113 Hydrograph of manual monthly water levels CG 25S, Carrownagappul Bog SAC

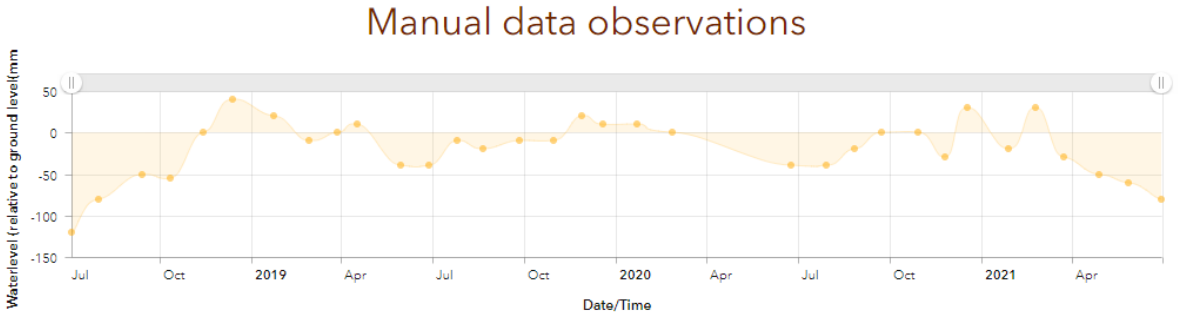


Figure 8-114 Hydrograph of manual monthly water levels CG 25D, Carrownagappul Bog SAC

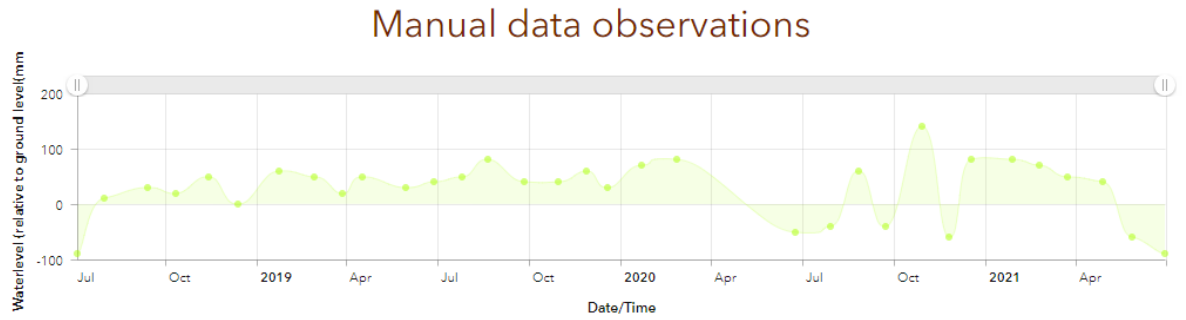


Figure 8-115 Hydrograph of manual monthly water levels CG 26S, Carrownagappul Bog SAC

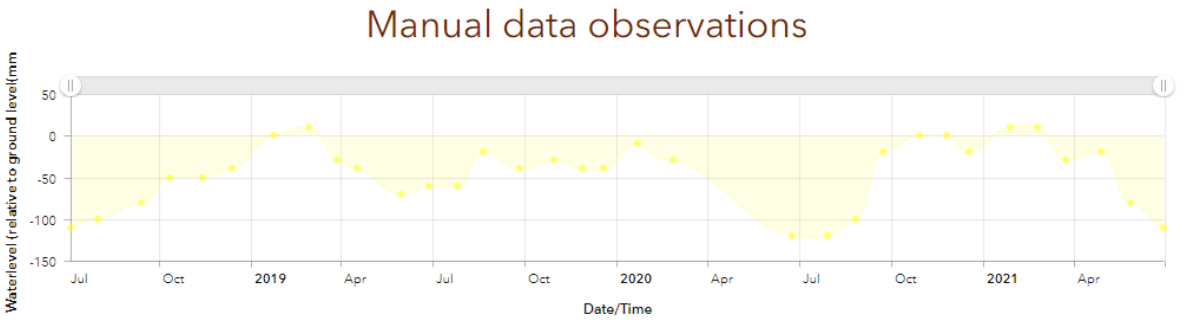


Figure 8-116 Hydrograph of manual monthly water levels CG 26D, Carrownagappul Bog SAC

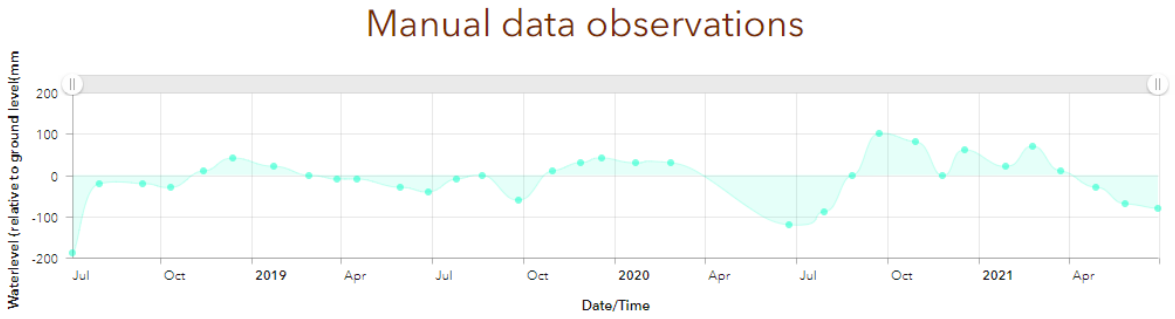


Figure 8-117 Hydrograph of manual monthly water levels CG 27S, Carrownagappul Bog SAC

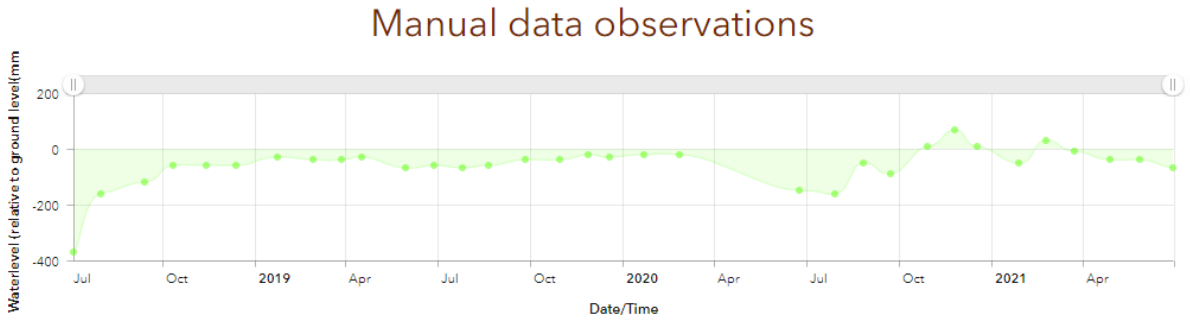


Figure 8-118 Hydrograph of manual monthly water levels CG 27D, Carrownagappul Bog SAC

8.4 Clara

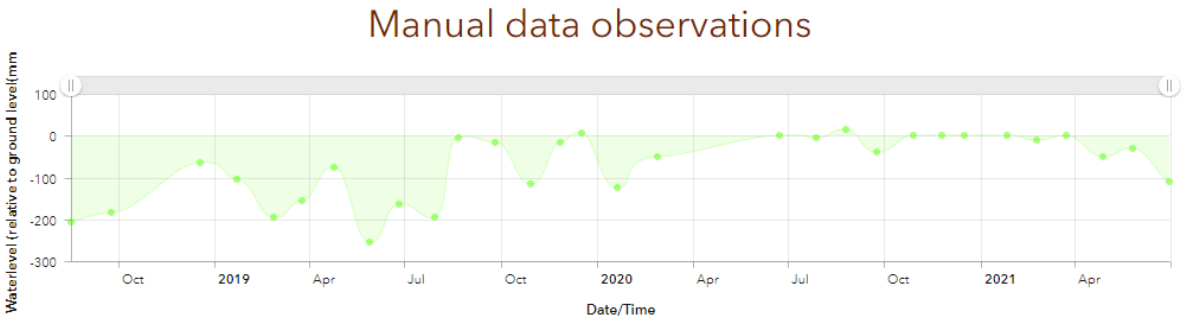


Figure 8-119 Hydrograph of manual monthly water levels C 1, Clara Bog SAC

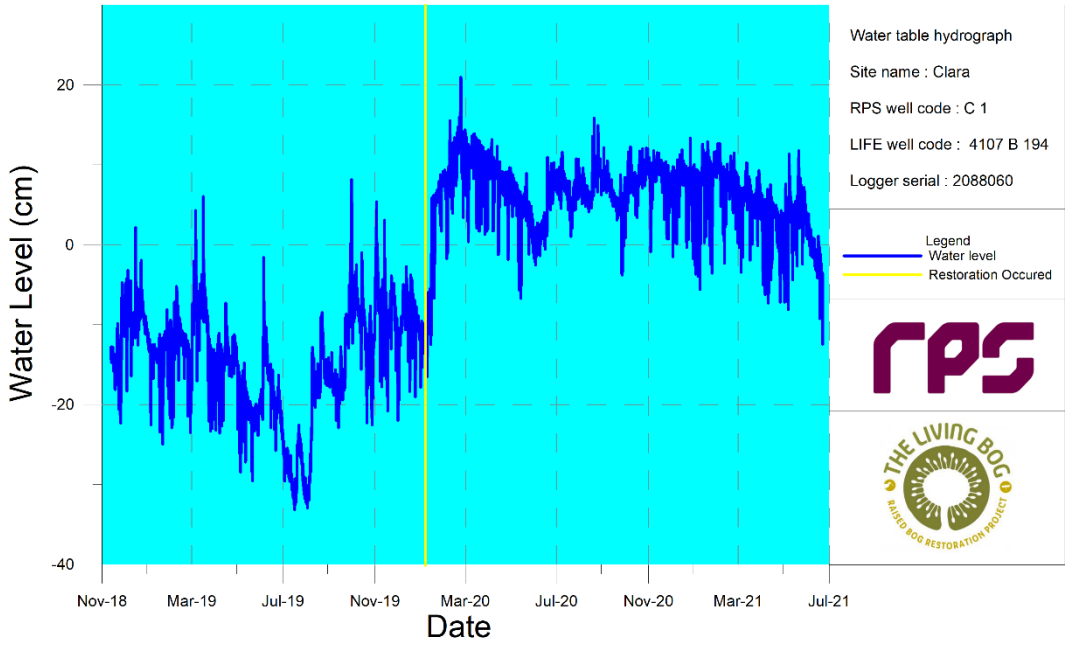


Figure 8-120 Level logger data recorded between April 2018 and August 2021 at well C1, Clara Bog SAC

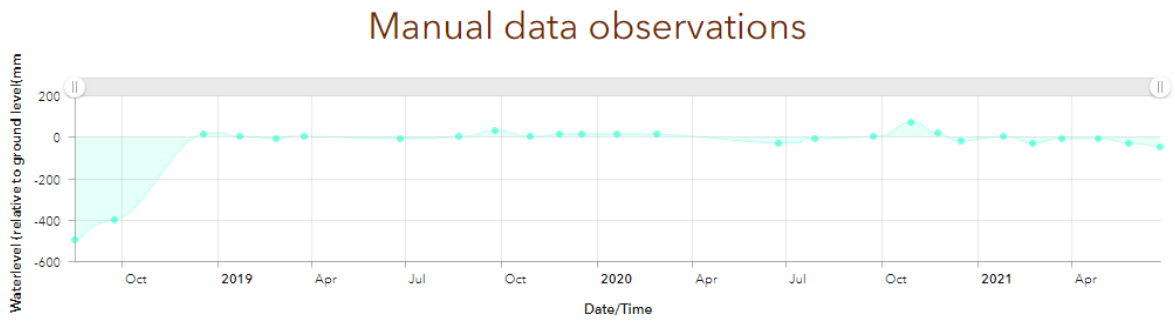


Figure 8-121 Hydrograph of manual monthly water levels C 2, Clara Bog SAC

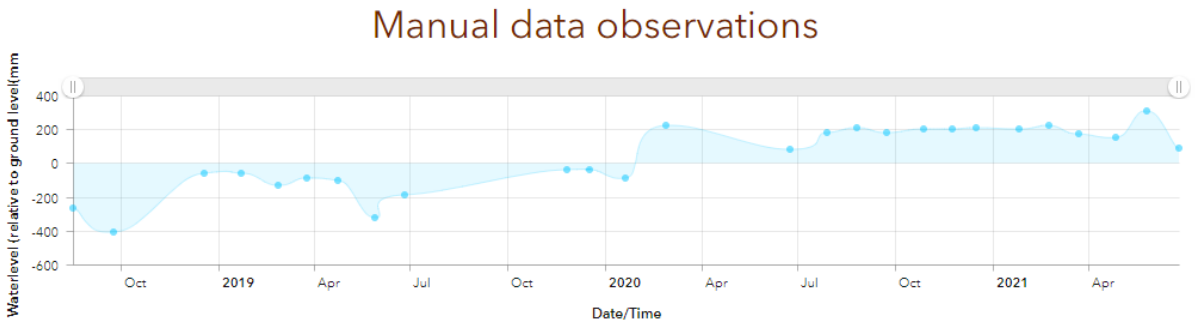


Figure 8-122 Hydrograph of manual monthly water levels C 3, Clara Bog SAC

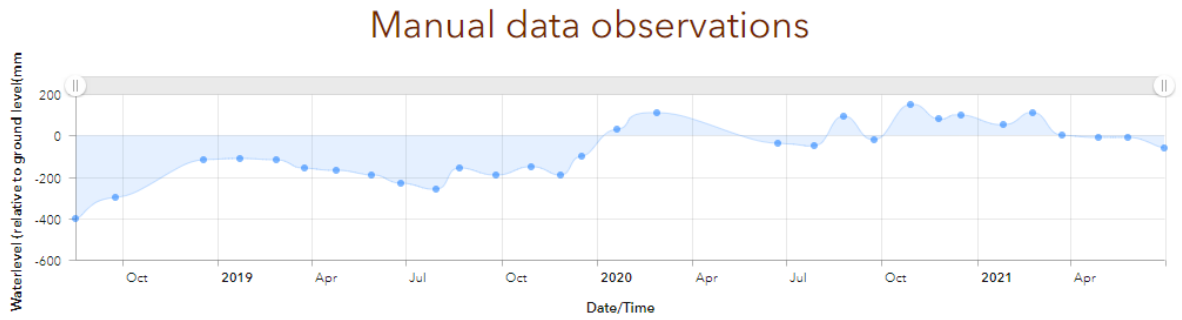


Figure 8-123 Hydrograph of manual monthly water levels C 4, Clara Bog SAC

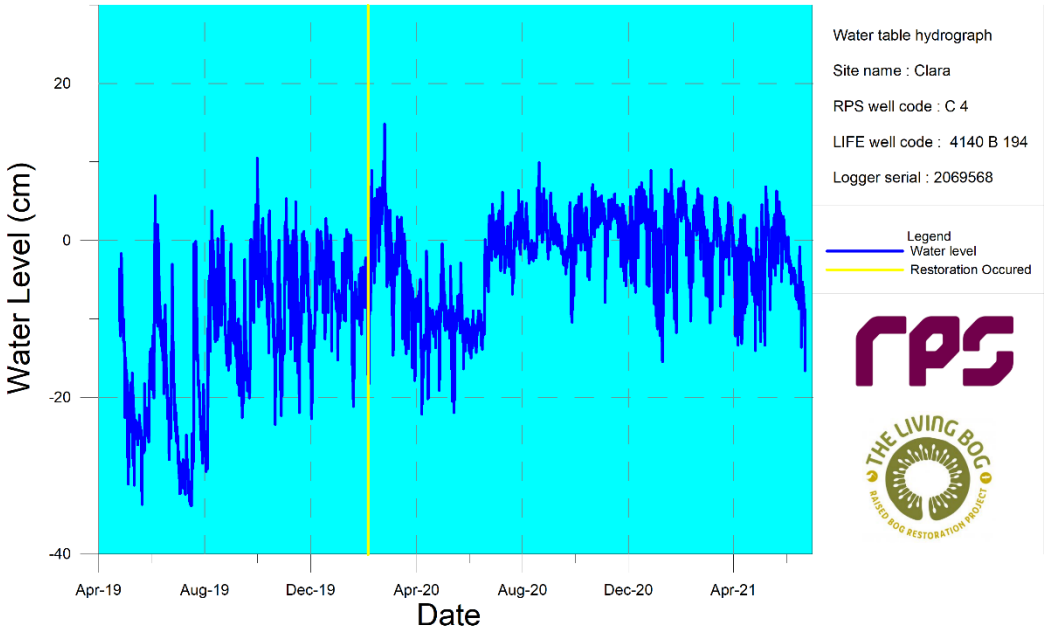


Figure 8-124 Level logger data recorded between April 2019 and August 2021 at well C4, Clara Bog SAC

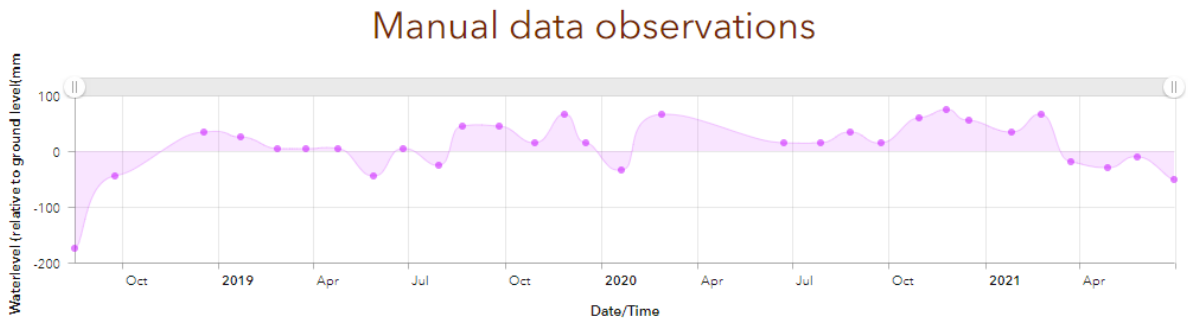


Figure 8-125 Hydrograph of manual monthly water levels C 6, Clara Bog SAC

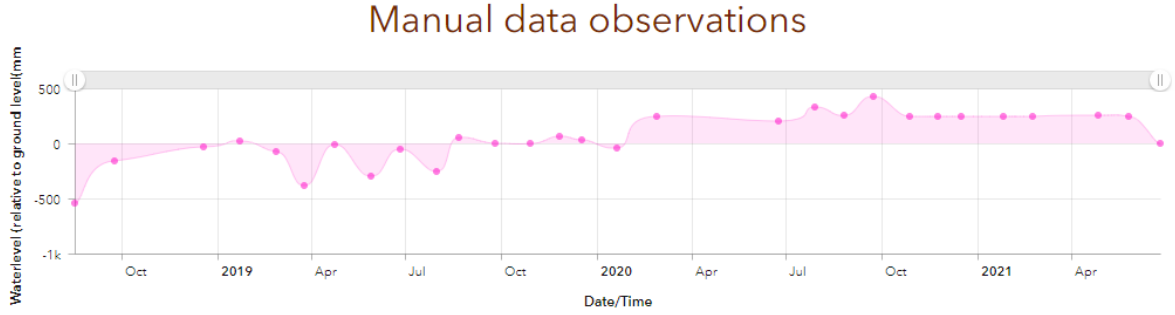


Figure 8-126 Hydrograph of manual monthly water levels C 7, Clara Bog SAC

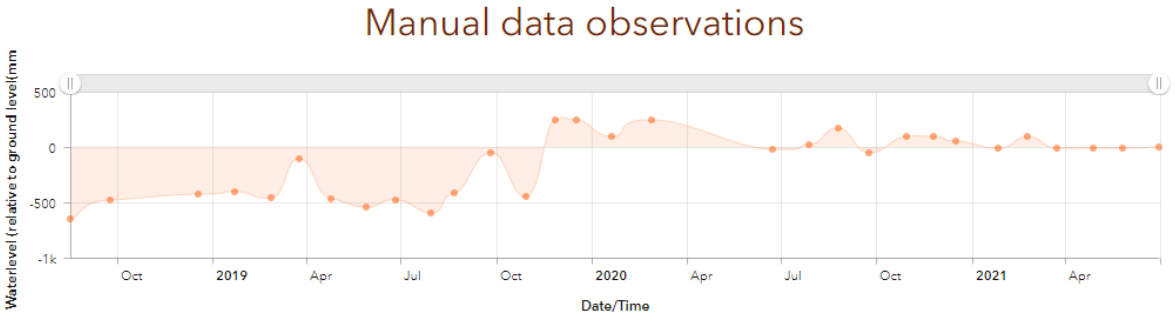


Figure 8-127 Hydrograph of manual monthly water levels C 8, Clara Bog SAC

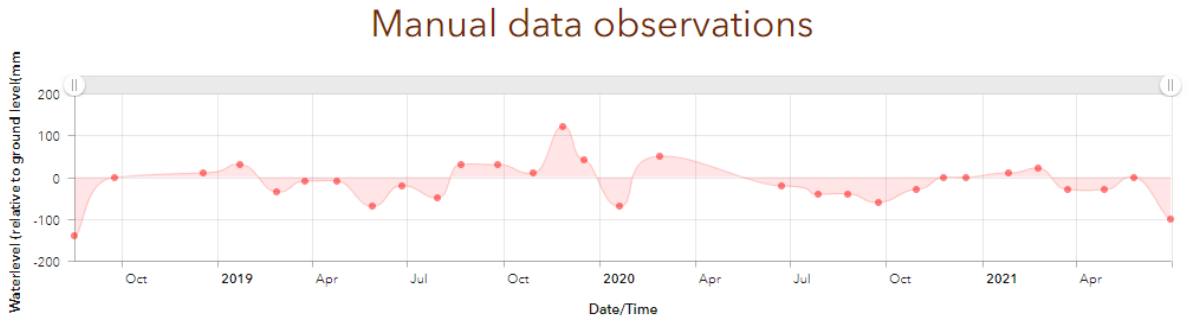


Figure 8-128 Hydrograph of manual monthly water levels C 9, Clara Bog SAC

8.5 Ferbane

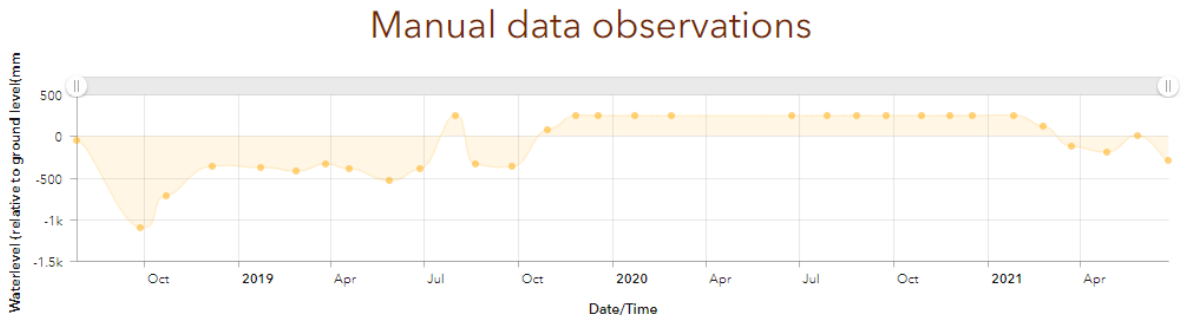


Figure 8-129 Hydrograph of manual monthly water levels F 1, Ferbane Bog SAC

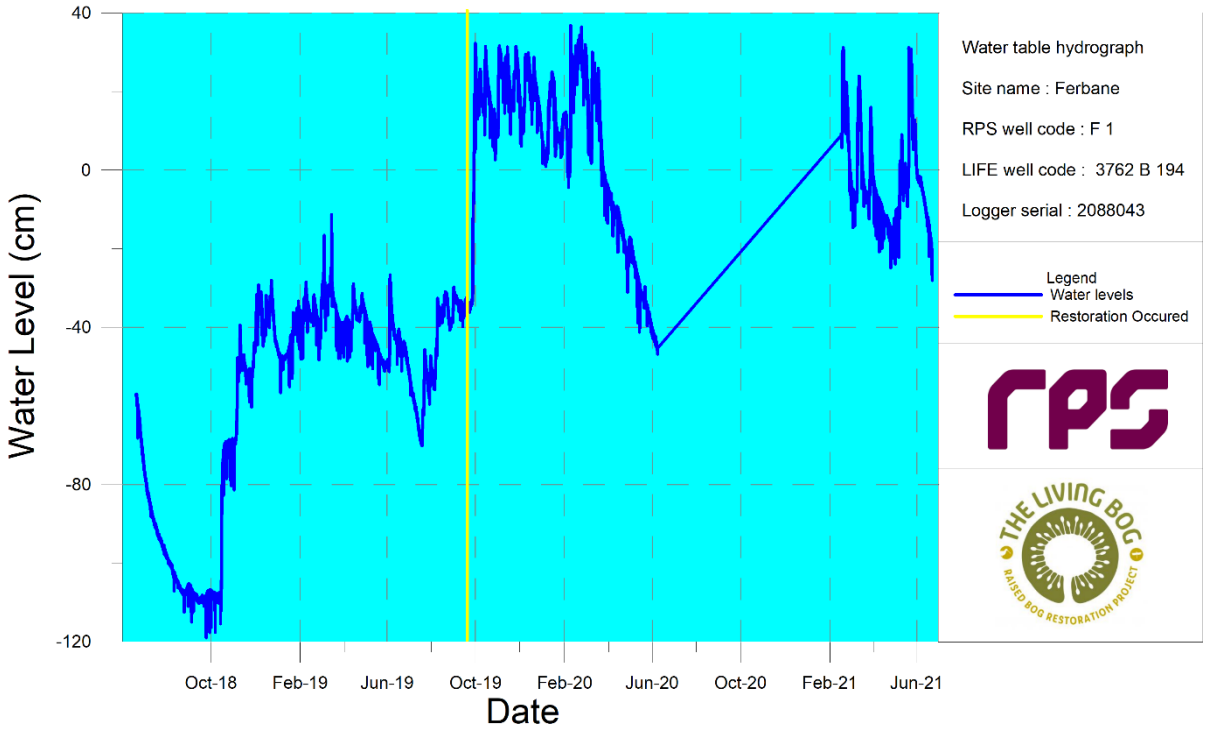


Figure 8-130 Level logger data recorded between June 2018 and June 2021 at well F1, Ferbane Bog SAC

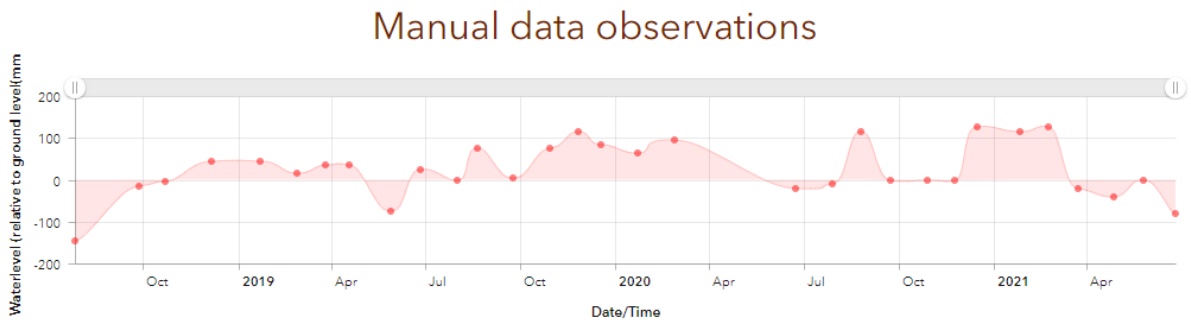


Figure 8-231 Hydrograph of manual monthly water levels F 2, Ferbane Bog SAC

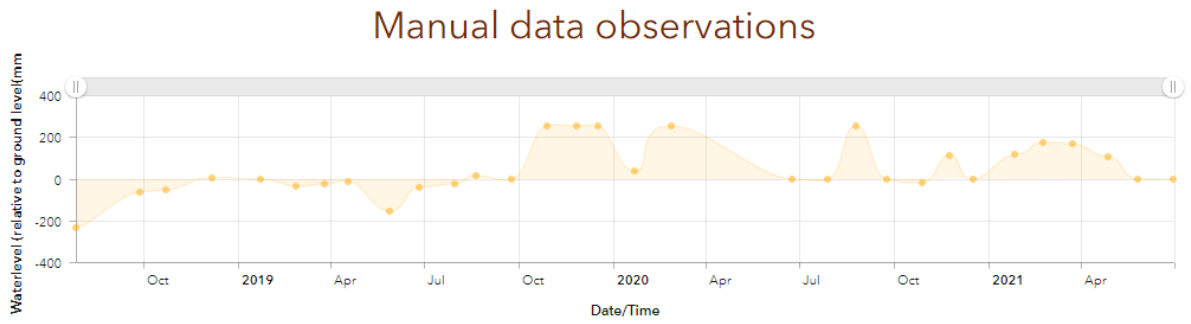


Figure 8-132 Hydrograph of manual monthly water levels F 3, Ferbane Bog SAC

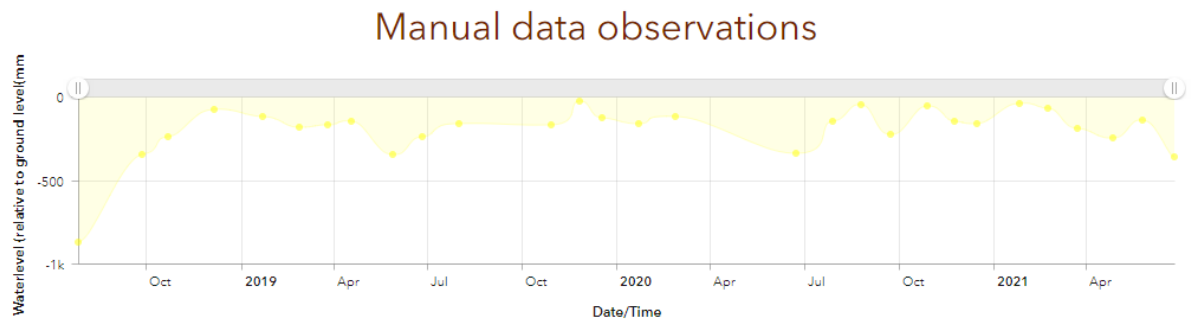


Figure 8-133 Hydrograph of manual monthly water levels F 5, Ferbane Bog SAC

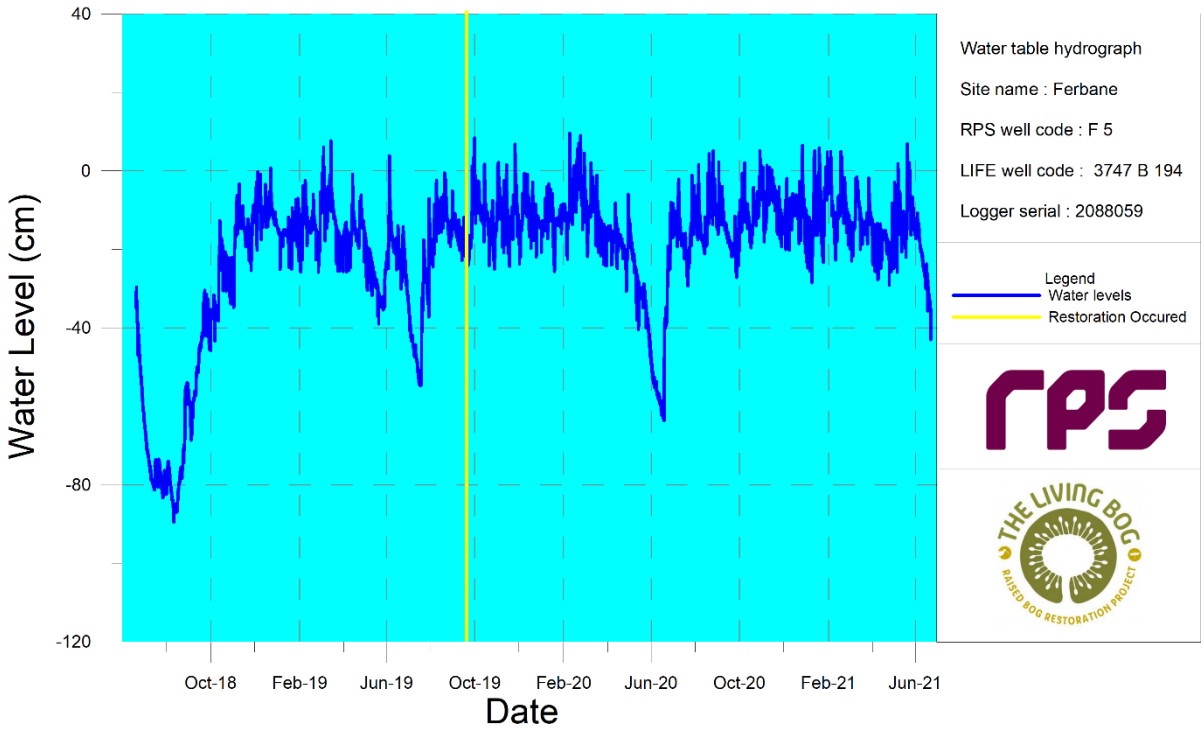


Figure 8-134 Level logger data recorded between July 2018 and June 2021 at well F5, Ferbane Bog SAC

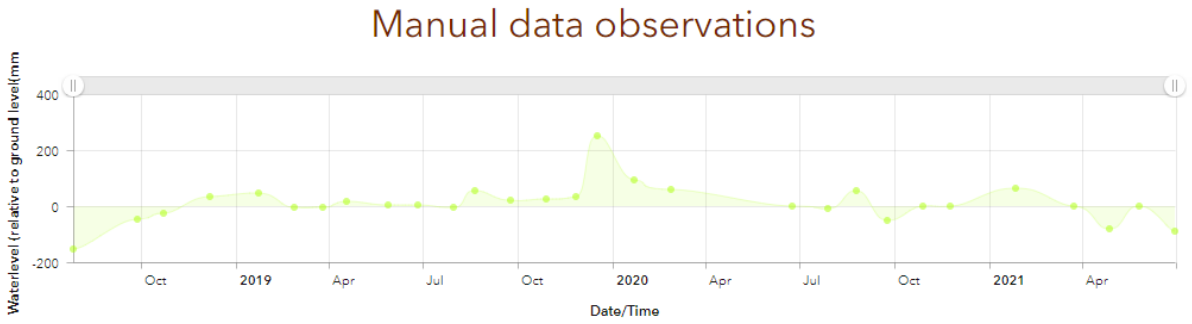


Figure 8-135 Hydrograph of manual monthly water levels F6, Ferbane Bog SAC

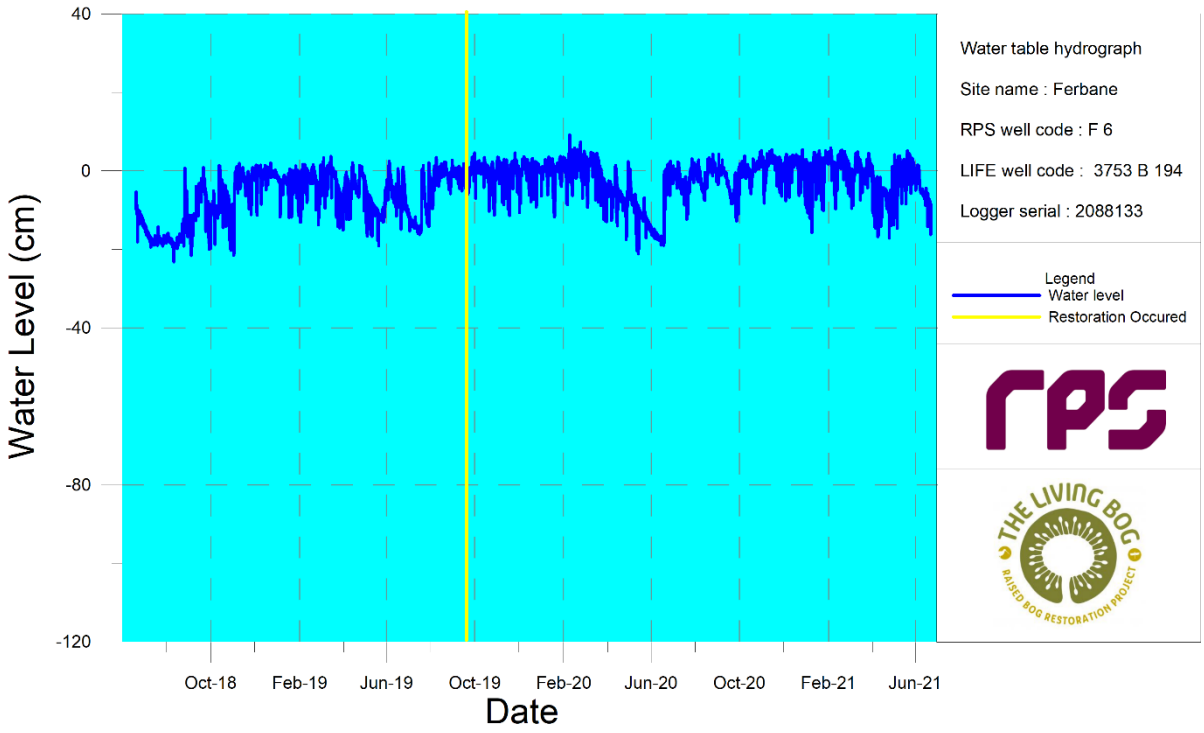


Figure 8-136 Level logger data recorded between June 2018 and June 2021 at well F6, Ferbane Bog SAC

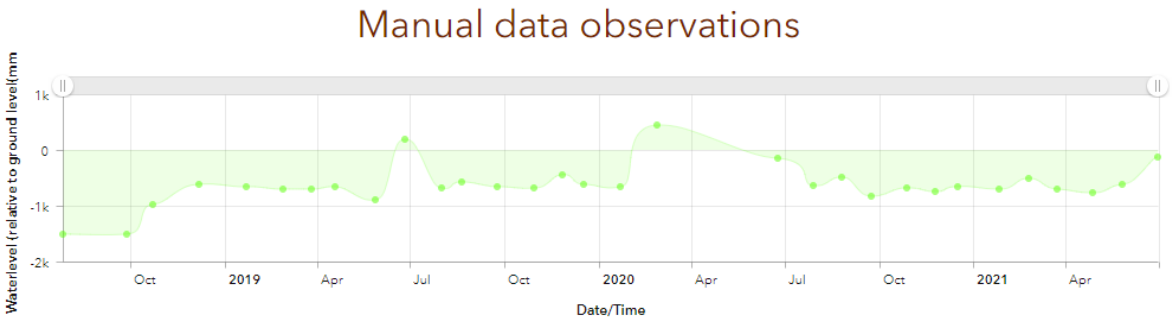


Figure 8-137 Hydrograph of manual monthly water levels F 7, Ferbane Bog SAC

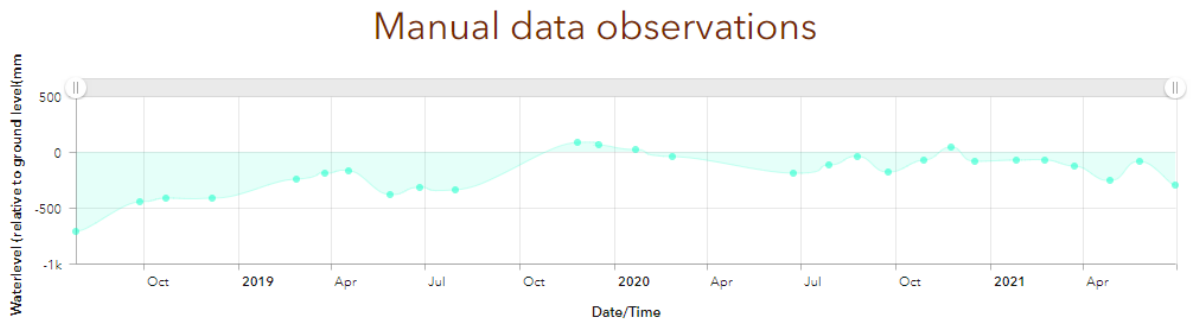


Figure 8-138 Hydrograph of manual monthly water levels F 8, Ferbane Bog SAC

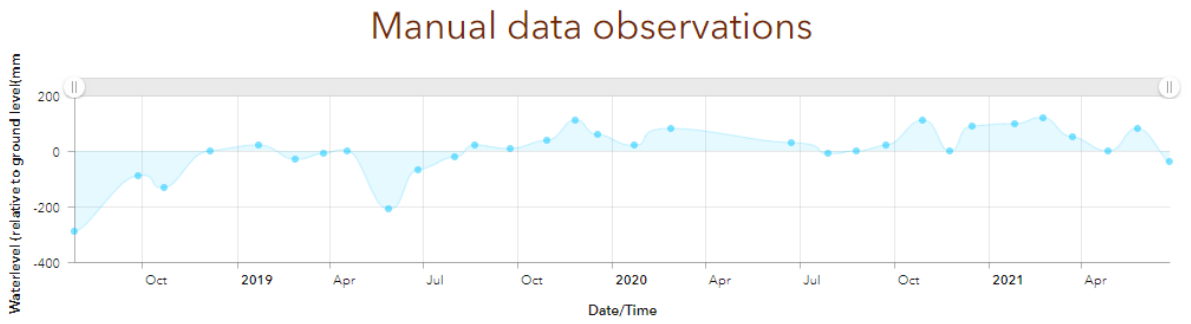


Figure 8-139 Hydrograph of manual monthly water levels F 9, Ferbane Bog SAC

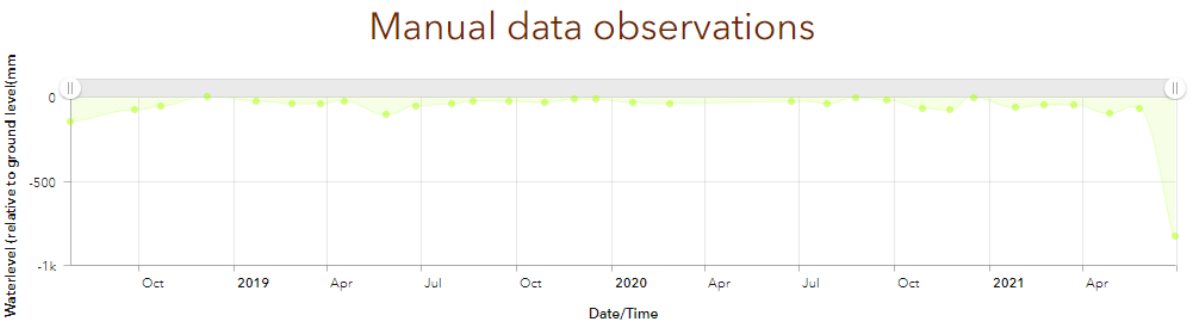


Figure 8-140 Hydrograph of manual monthly water levels F 10S, Ferbane Bog SAC

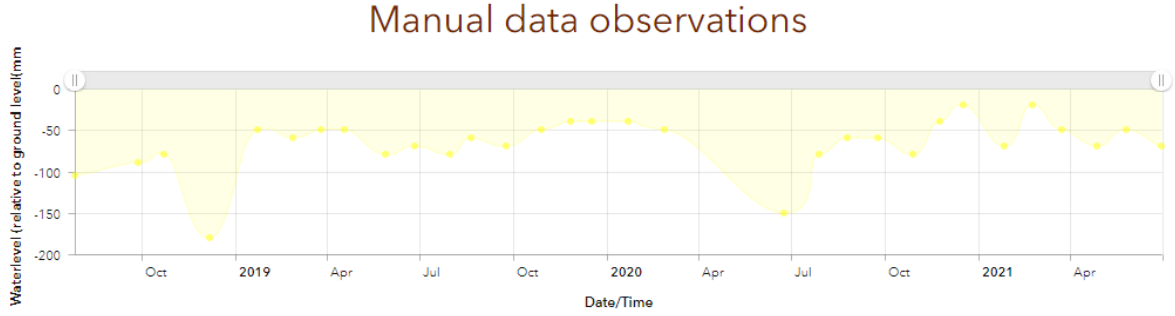


Figure 8-141 Hydrograph of manual monthly water levels F 10D, Ferbane Bog SAC

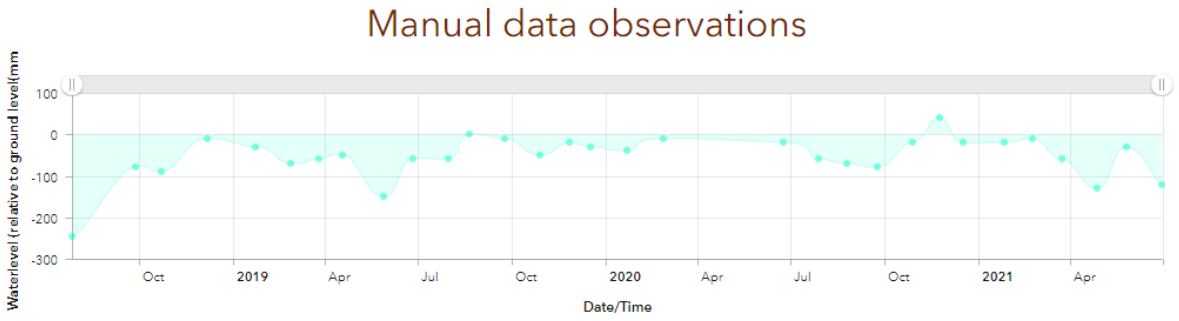


Figure 8-142 Hydrograph of manual monthly water levels F 11S, Ferbane Bog SAC

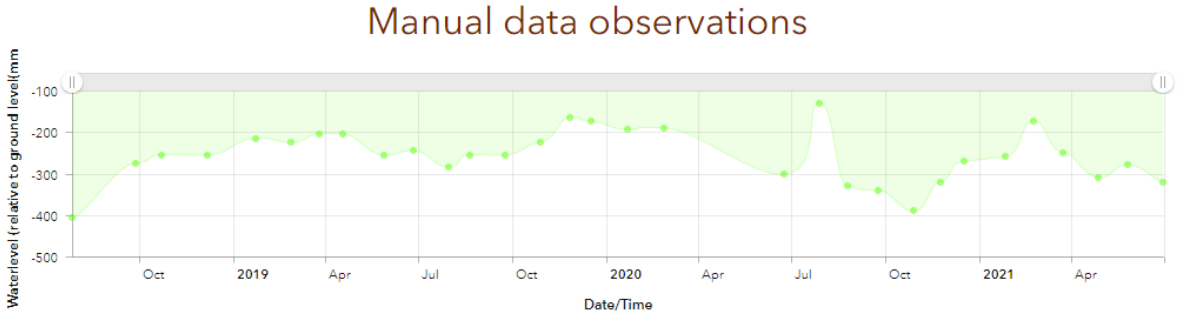


Figure 8-143 Hydrograph of manual monthly water levels F 11D, Ferbane Bog SAC

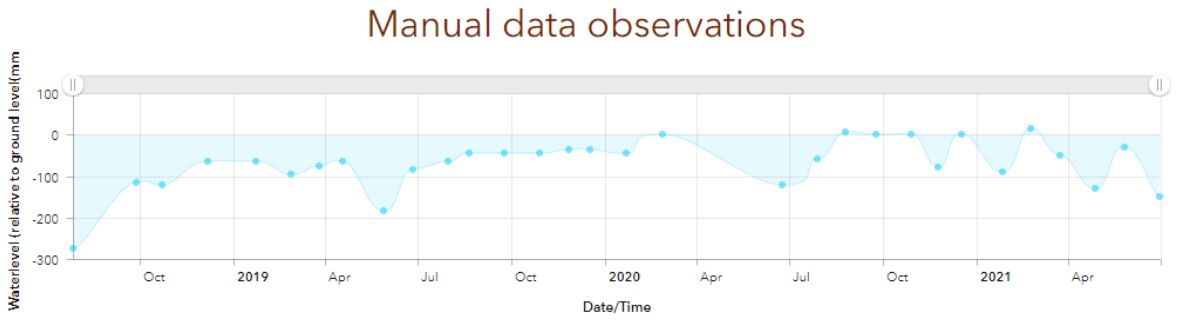


Figure 8-144 Hydrograph of manual monthly water levels F 13, Ferbane Bog SAC

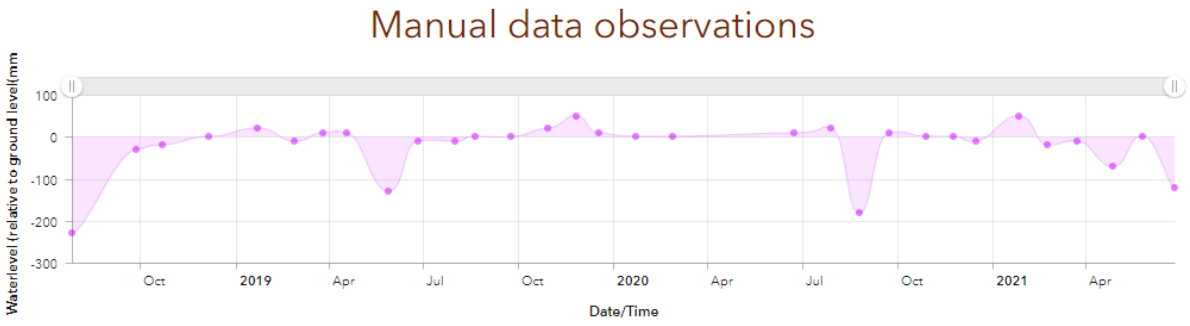


Figure 8-145 Hydrograph of manual monthly water levels F 14S, Ferbane Bog SAC

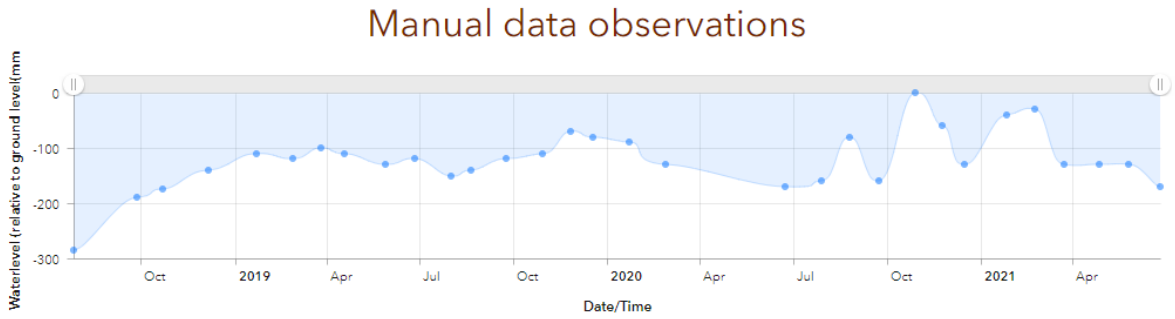


Figure 8-146 Hydrograph of manual monthly water levels F 14D, Ferbane Bog SAC

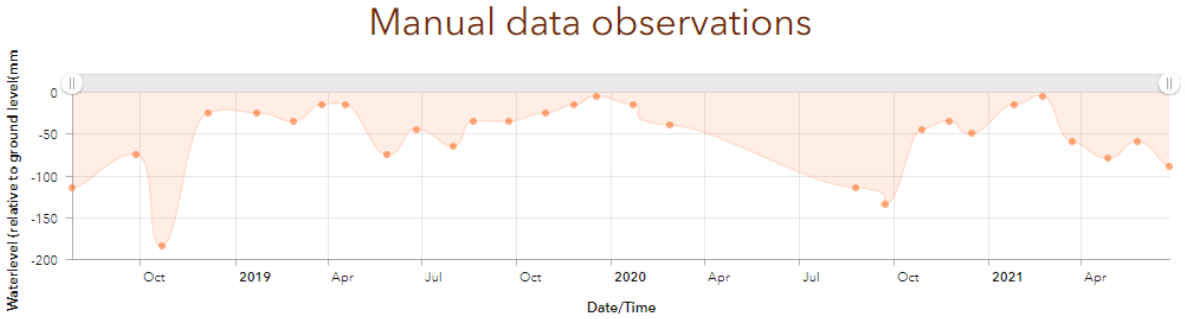


Figure 8-147 Hydrograph of manual monthly water levels F 15S, Ferbane Bog SAC

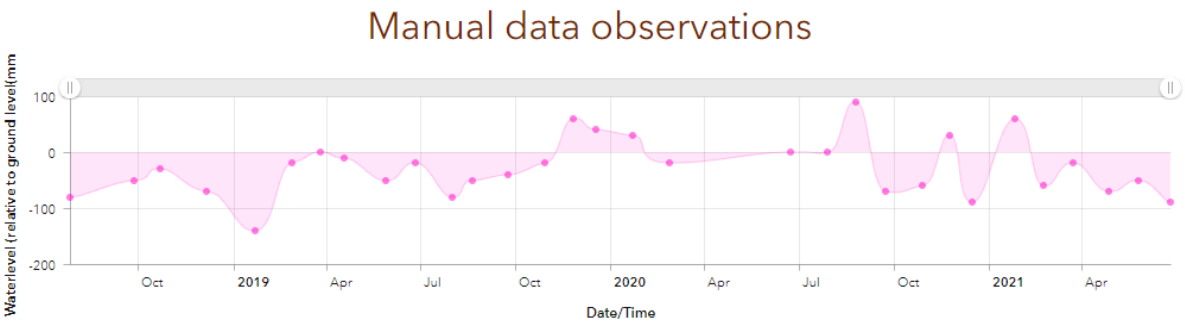


Figure 8-148 Hydrograph of manual monthly water levels F 15D, Ferbane Bog SAC

8.6 Garriskill

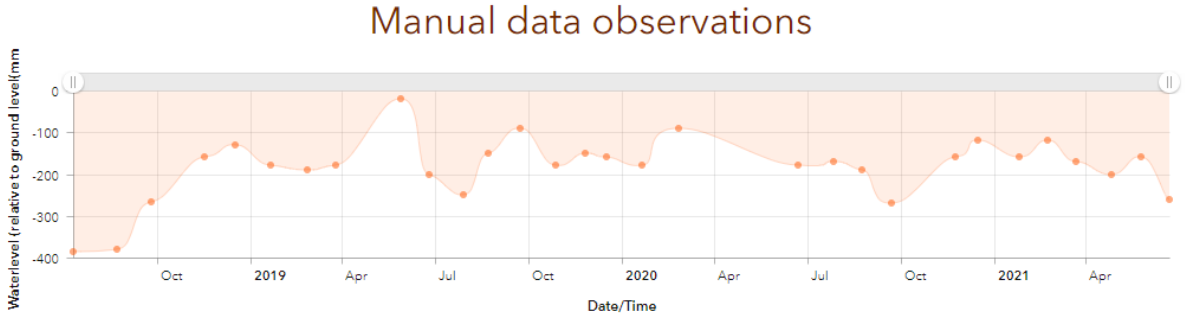


Figure 8-149 Hydrograph of manual monthly water levels G 1S, Garriskill Bog SAC

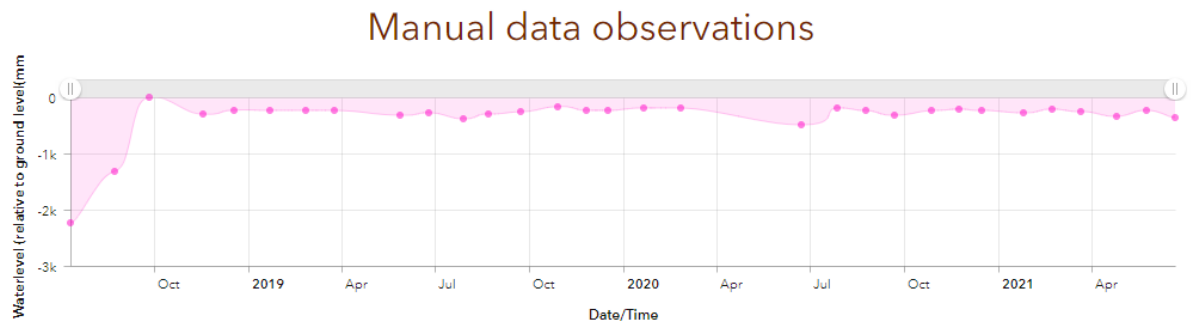


Figure 8-150 Hydrograph of manual monthly water levels G 1D, Garriskill Bog SAC

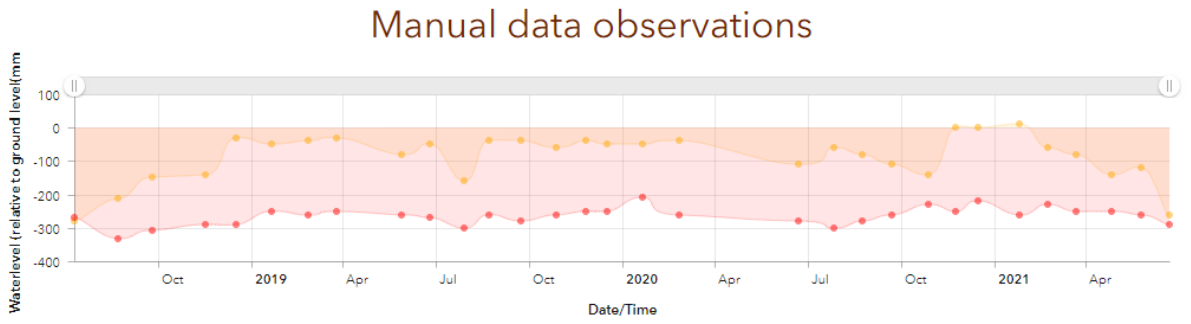


Figure 8-151 Hydrograph of manual monthly water levels G 2S (orange) and 2D (red), Garriskill Bog SAC

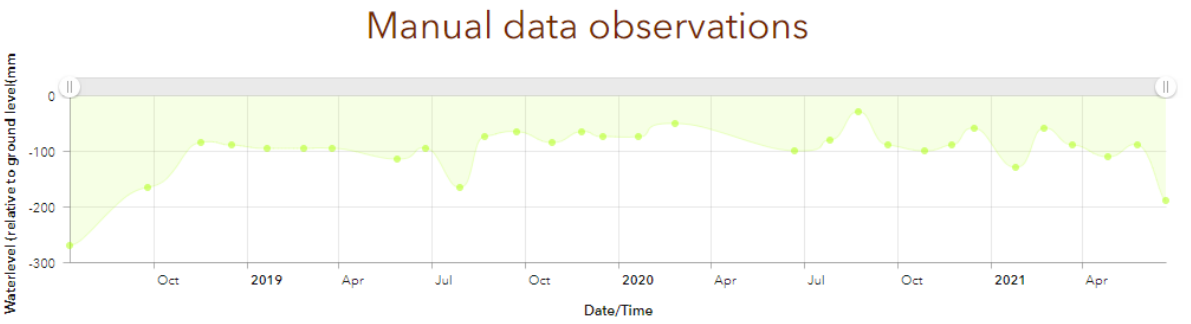


Figure 8-152 Hydrograph of manual monthly water levels G 3S, Garriskill Bog SAC

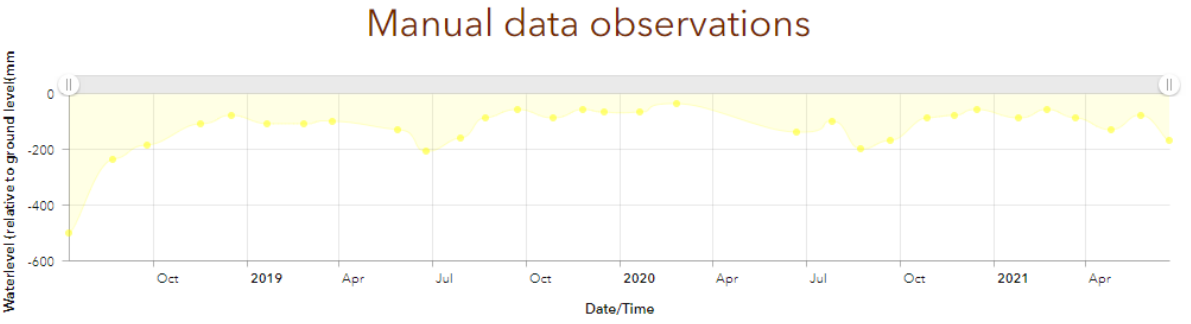


Figure 8-153 Hydrograph of manual monthly water levels G 3D, Garriskill Bog SAC

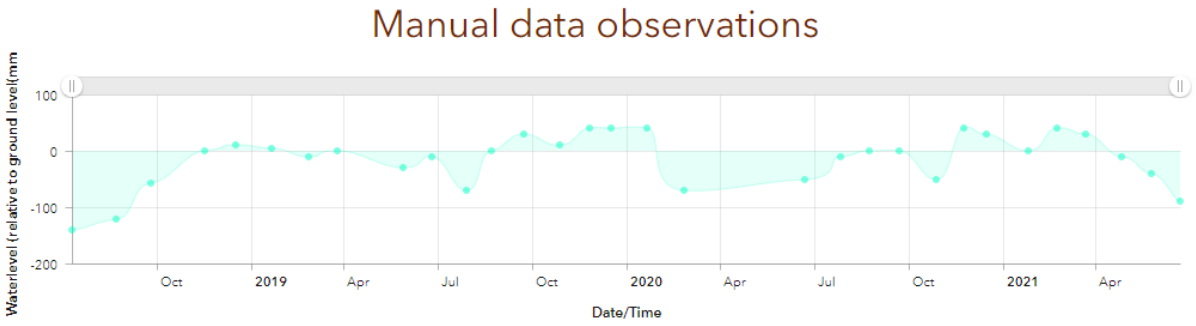


Figure 8-154 Hydrograph of manual monthly water levels G 4S, Garriskill Bog SAC

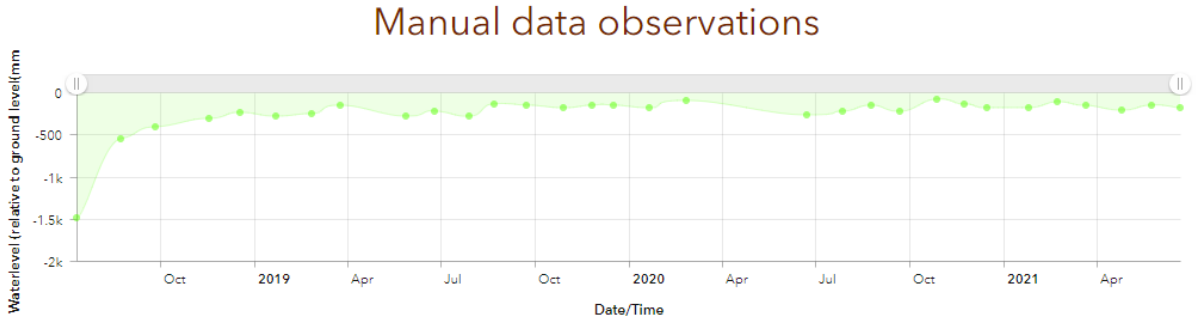


Figure 8-155 Hydrograph of manual monthly water levels G 4D, Garriskill Bog SAC

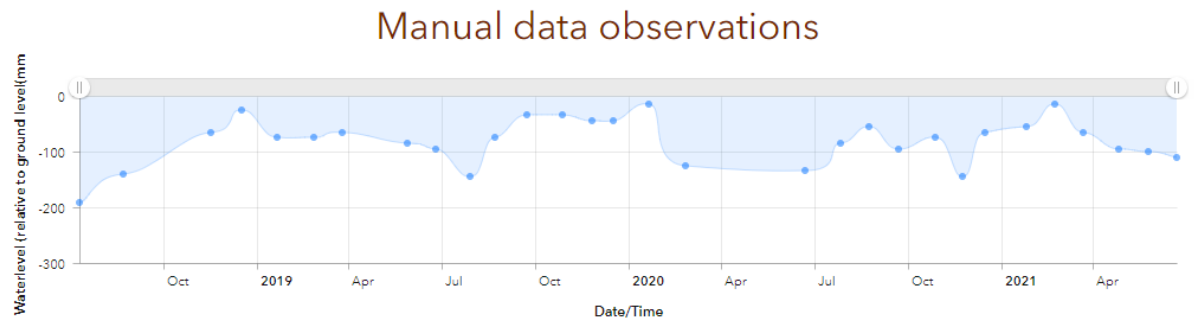


Figure 8-156 Hydrograph of manual monthly water levels G 5S, Garriskill Bog SAC

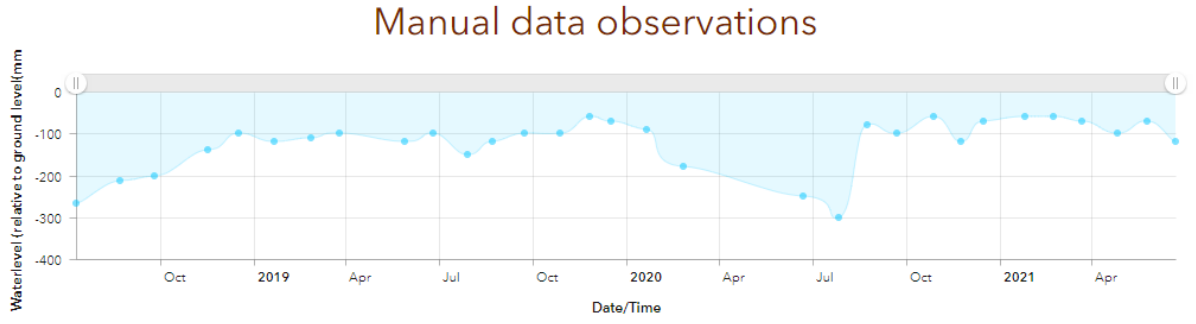


Figure 8-157 Hydrograph of manual monthly water levels G 5D, Garriskill Bog SAC

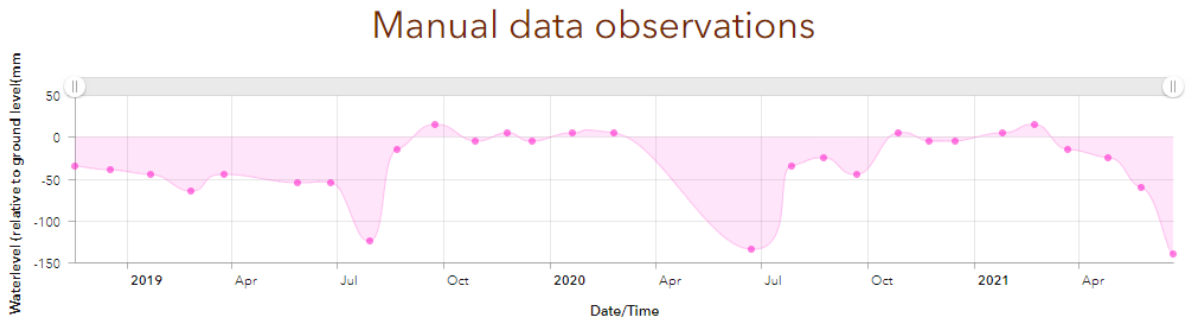


Figure 8-158 Hydrograph of manual monthly water levels G 6S, Garriskill Bog SAC

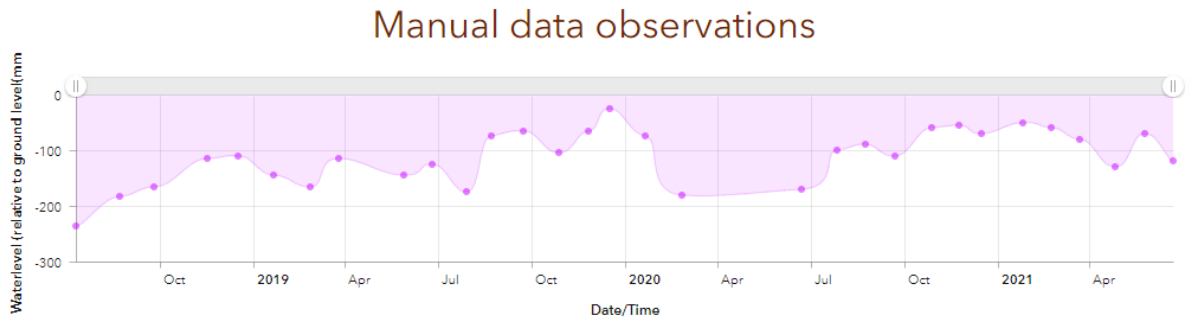


Figure 8-159 Hydrograph of manual monthly water levels G 6D, Garriskill Bog SAC

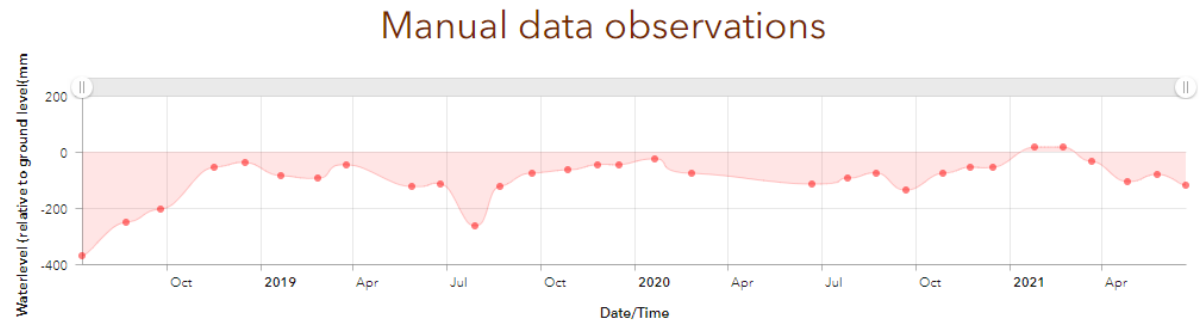


Figure 8-160 Hydrograph of manual monthly water levels G 7S, Garriskill Bog SAC

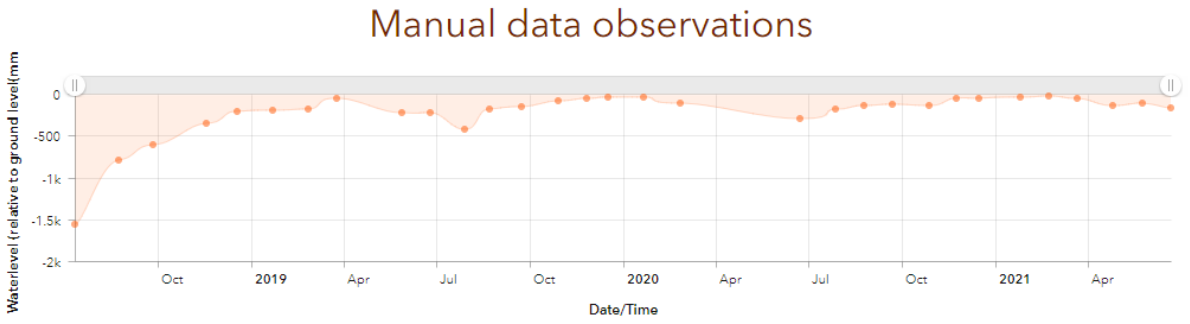


Figure 8-161 Hydrograph of manual monthly water levels G 7D, Garriskill Bog SAC

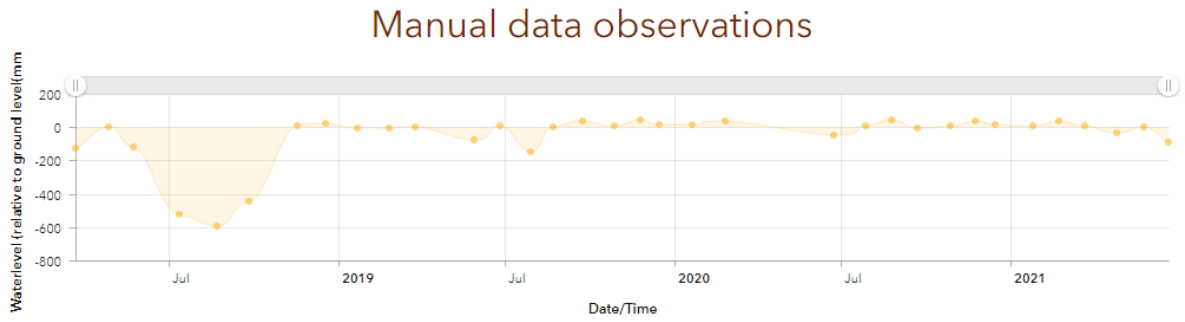


Figure 8-162 Hydrograph of manual monthly water levels G 8, Garriskill Bog SAC

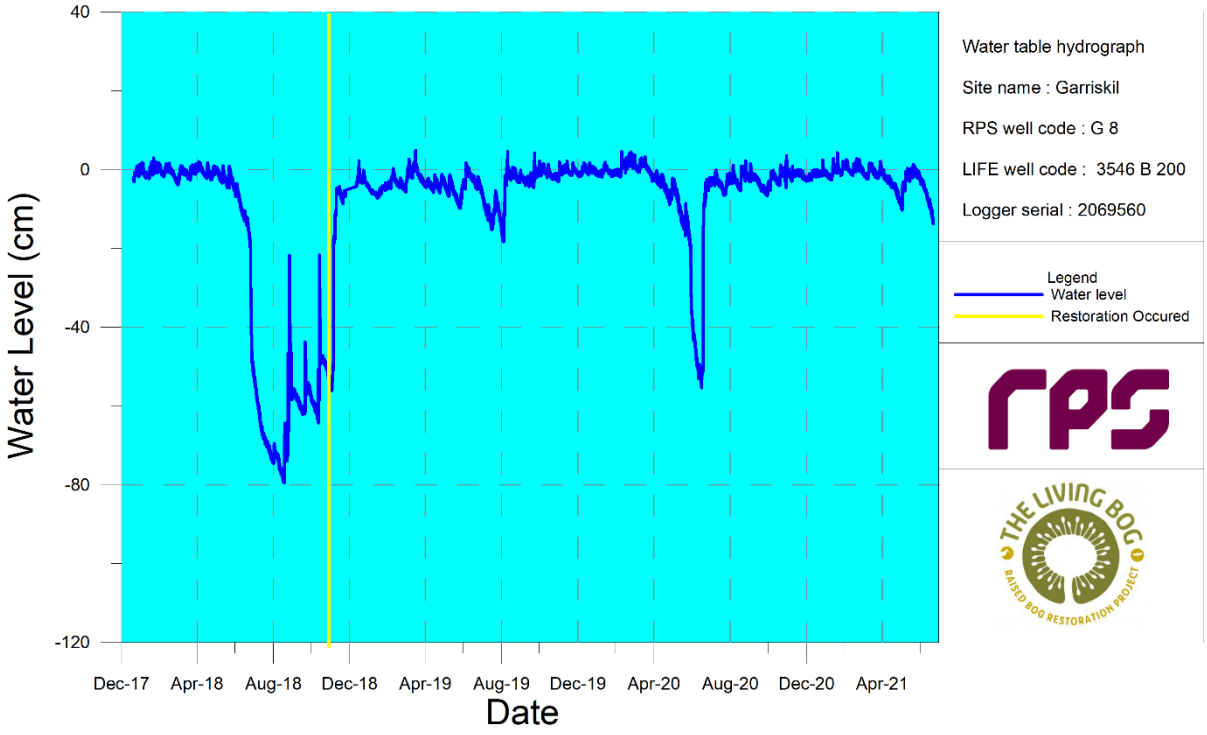


Figure 8-163 Level logger data recorded between December 2017 and August 2021 at well G8, Garriskill Bog SAC

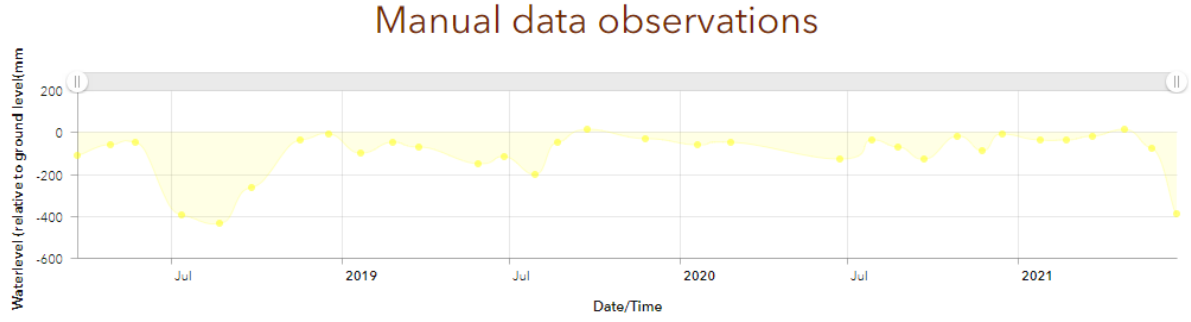


Figure 8-164 Hydrograph of manual monthly water levels G 9, Garriskill Bog SAC

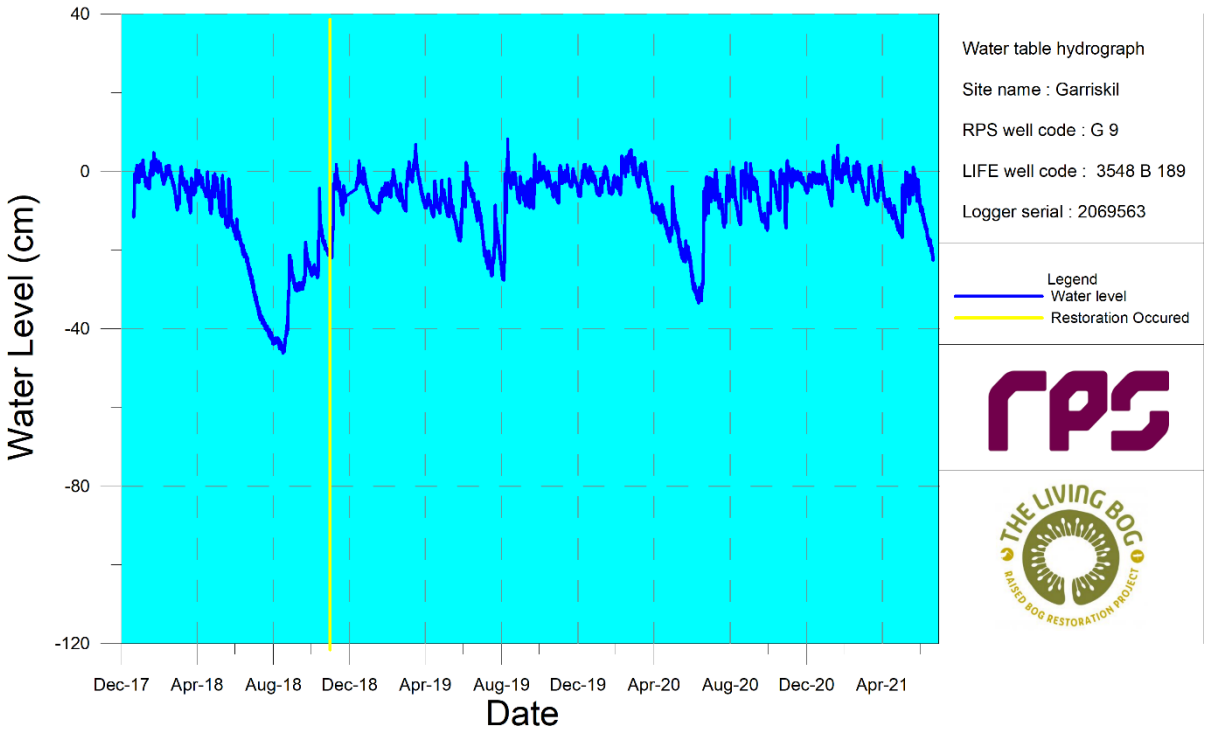


Figure 8-165 Level logger data recorded between December 2017 and August 2021 at well G9, Garriskil Bog SAC

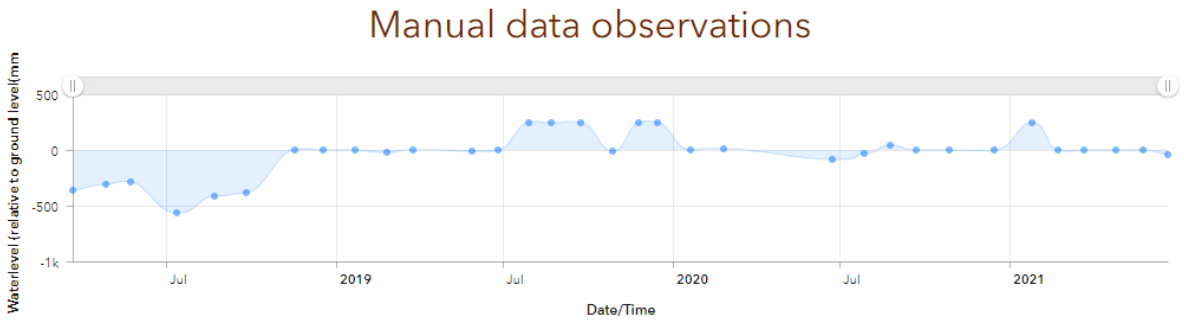


Figure 8-166 Hydrograph of manual monthly water levels G 10, Garriskill Bog SAC

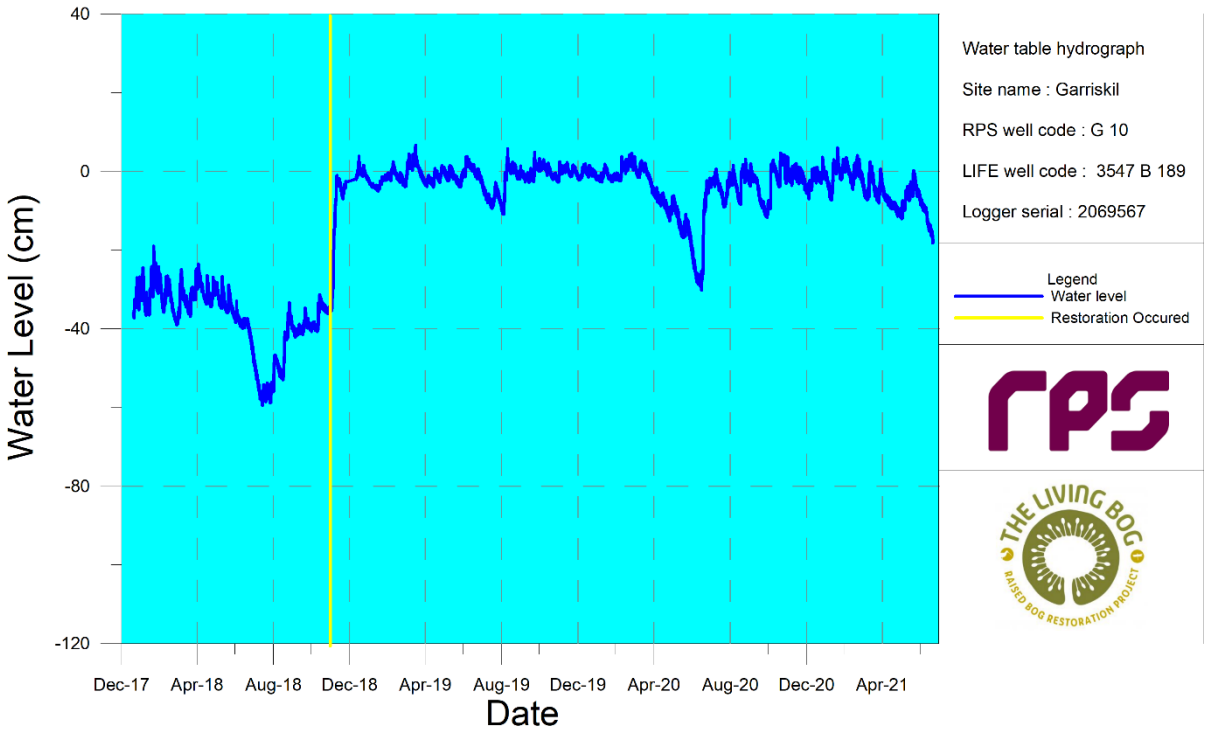


Figure 8-167 Level logger data recorded between December 2017 and August 2021 at well G10, Garriskil Bog SAC

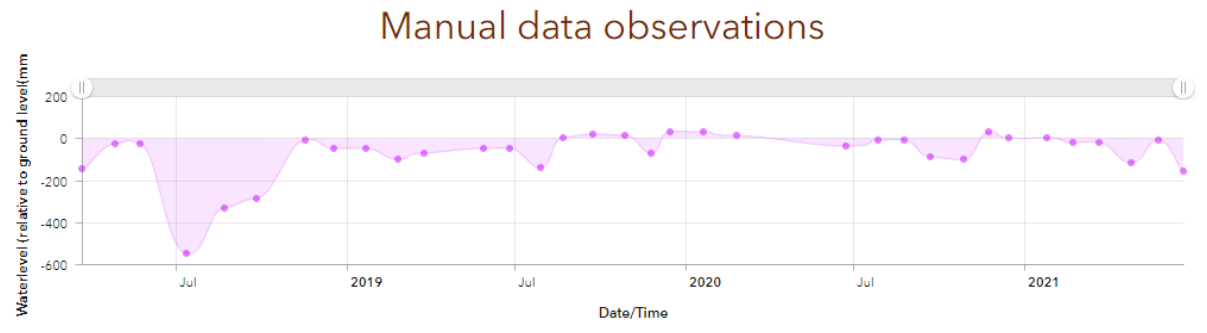


Figure 8-168 Hydrograph of manual monthly water levels G 11, Garriskil Bog SAC

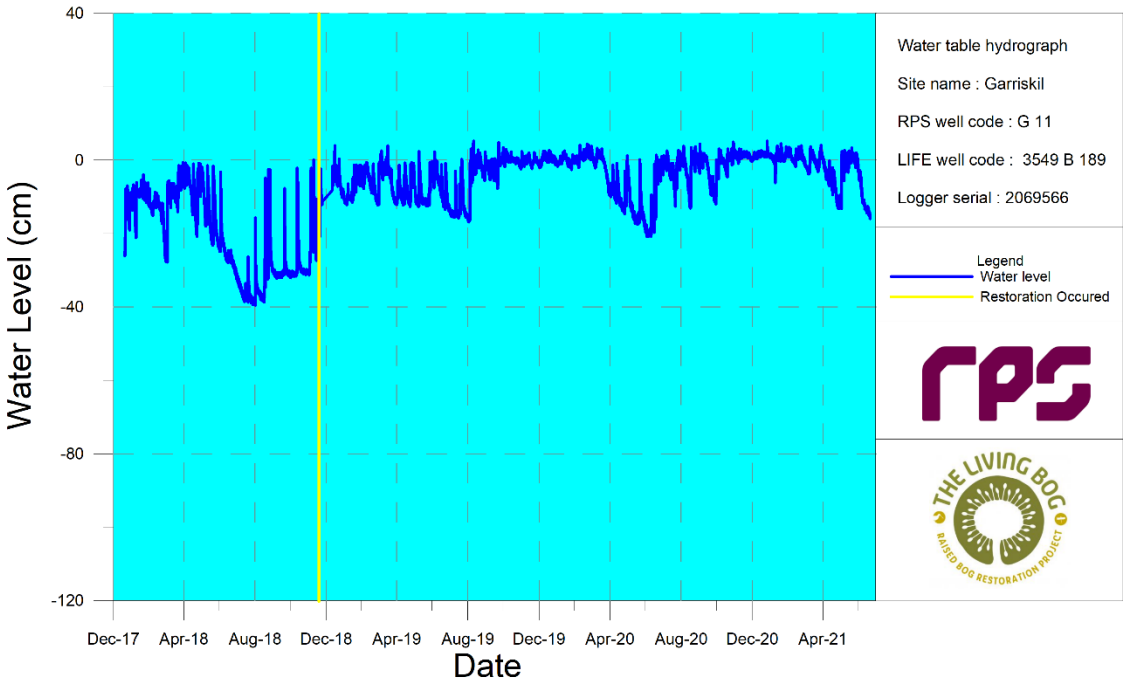


Figure 8-169 Level logger data recorded between December 2017 and August 2021 at well G11, Garriskil Bog SAC

8.7 Killyconny

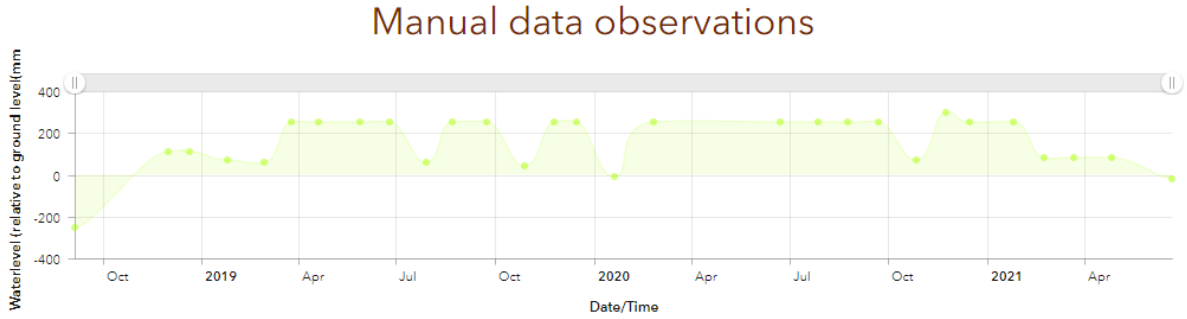


Figure 8-170 Hydrograph of manual monthly water levels K 1, Killyconny Bog SAC

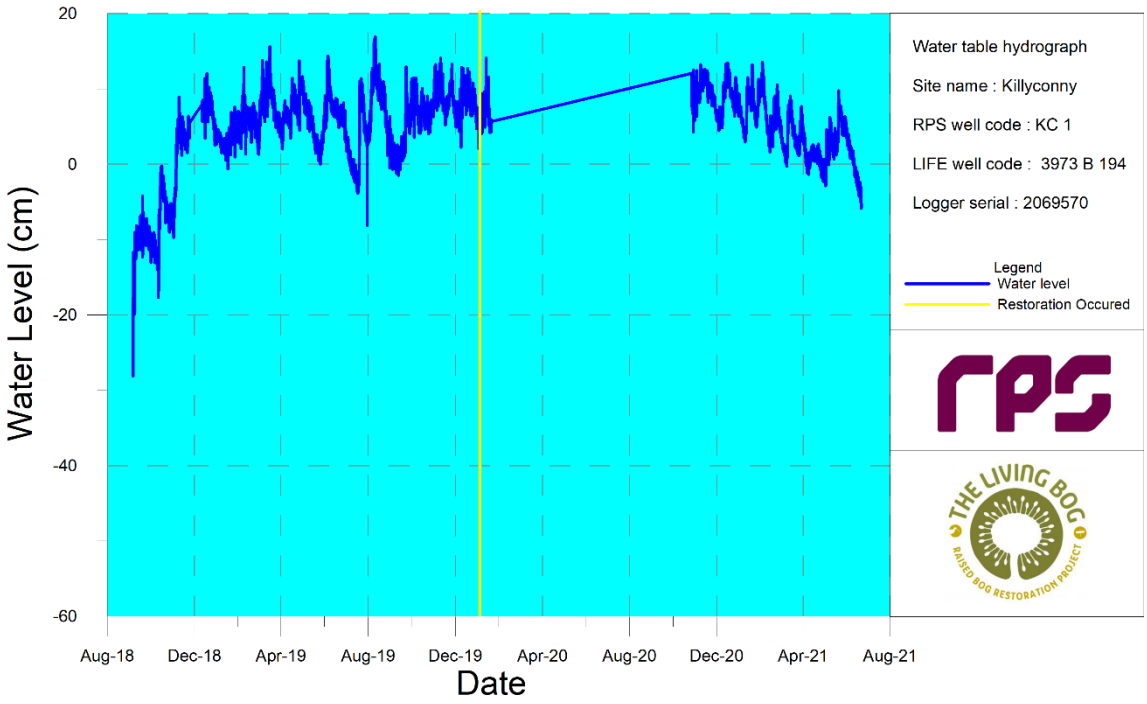


Figure 8-171 Level logger data recorded between August 2018 and August 2021 at well KC1, Killyconny Bog SAC

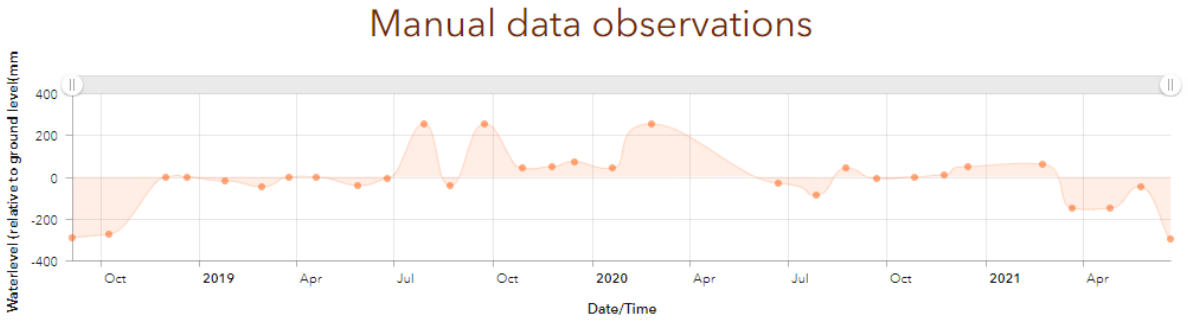


Figure 8-372 Hydrograph of manual monthly water levels K 2, Killyconny Bog SAC

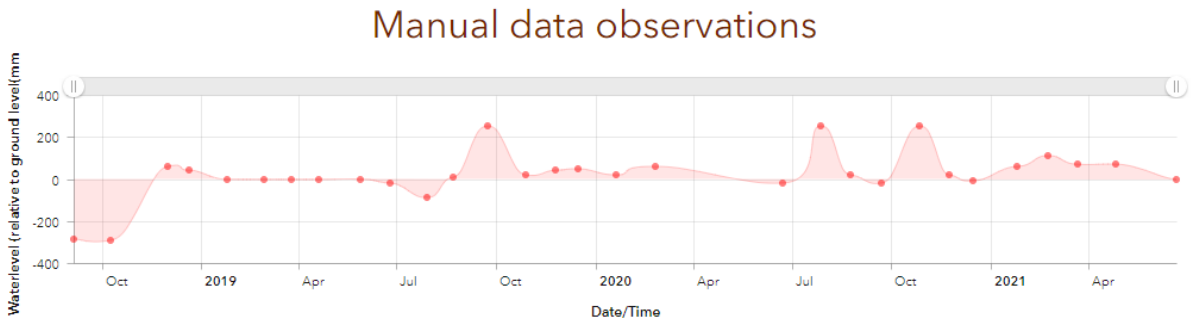


Figure 8-173 Hydrograph of manual monthly water levels K 3, Killyconny Bog SAC

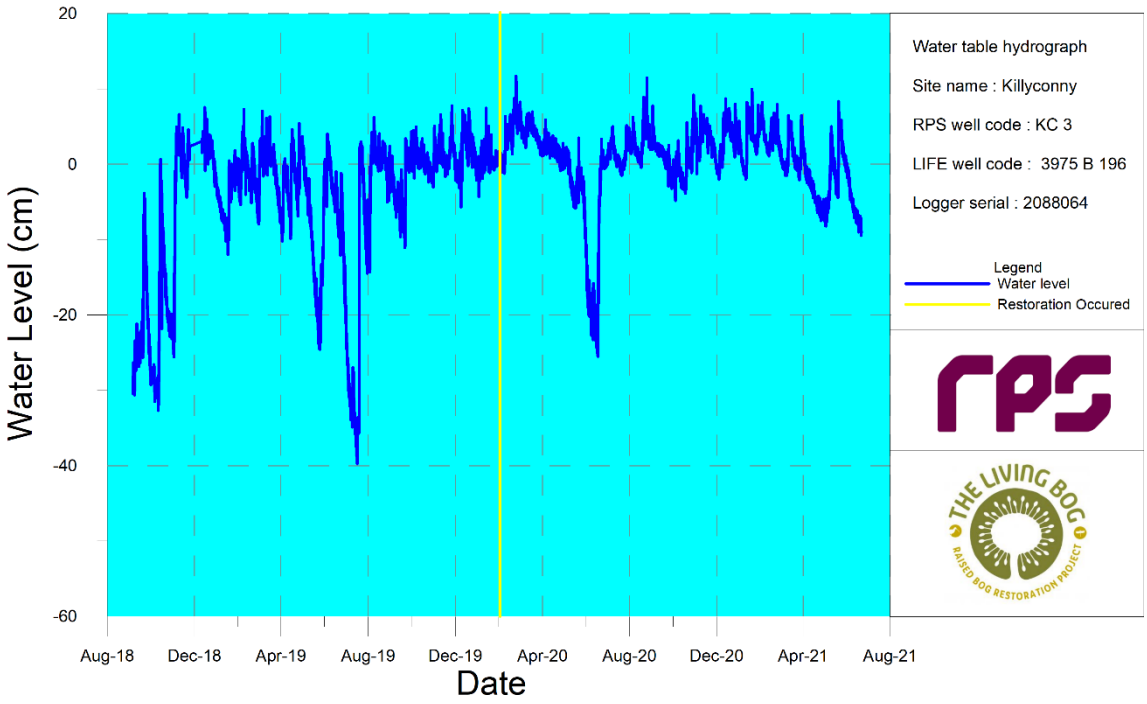


Figure 8-174 Level logger data recorded between August 2018 and August 2021 at well KC3, Killyconny Bog SAC

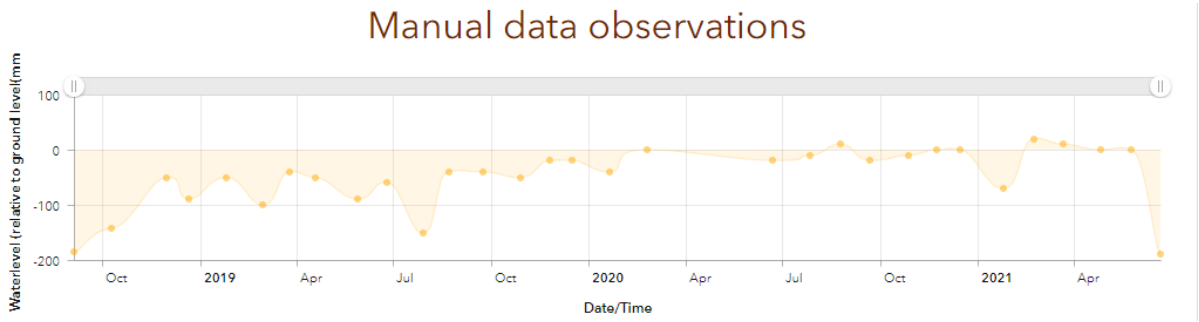


Figure 8-175 Hydrograph of manual monthly water levels K 4, Killyconny Bog SAC

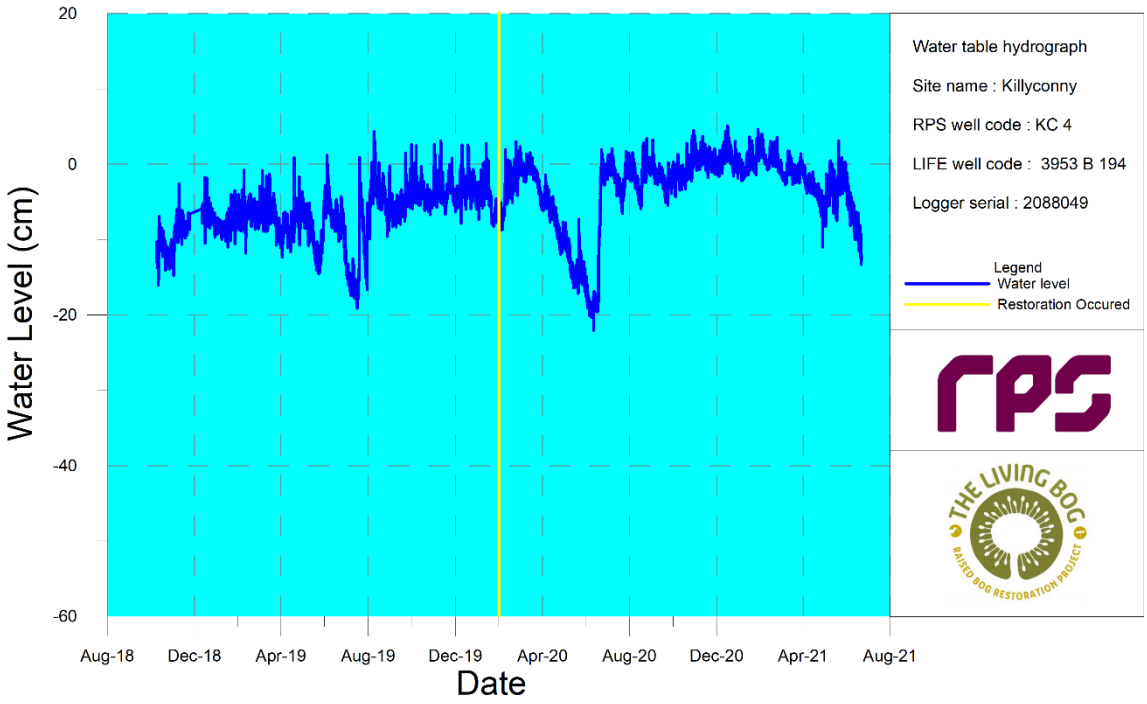


Figure 8-176 Level logger data recorded between August 2018 and August 2021 at well KC4, Killyconny Bog SAC

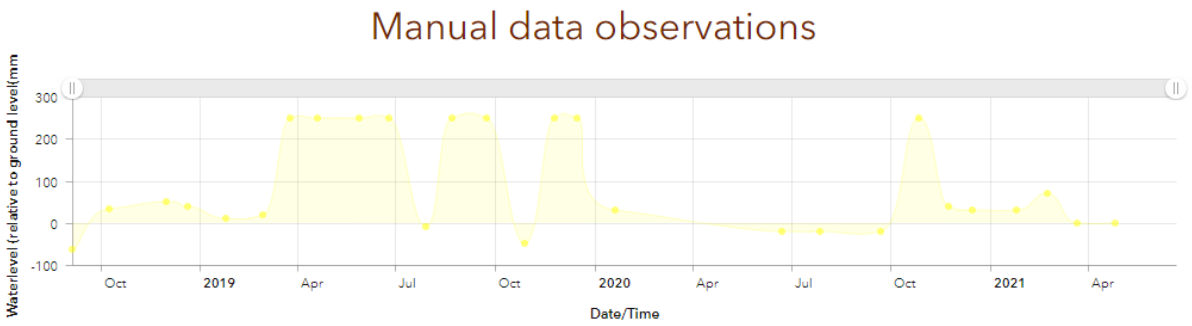


Figure 8-177 Hydrograph of manual monthly water levels K 5, Killyconny Bog SAC

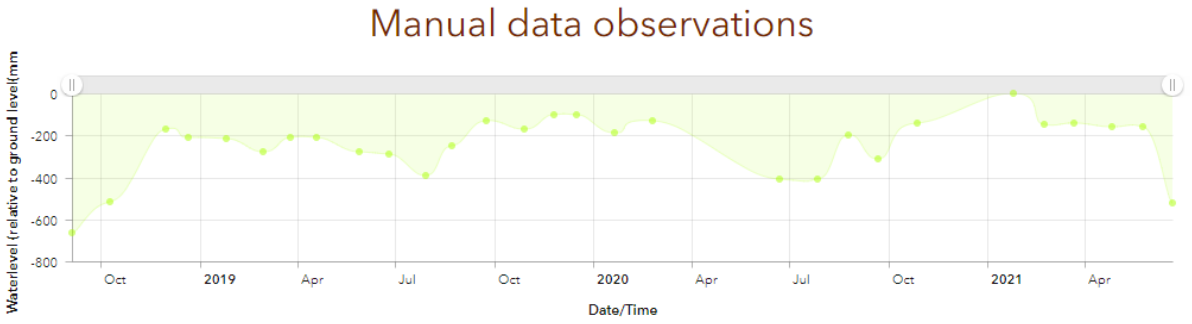


Figure 8-178 Hydrograph of manual monthly water levels K 6, Killyconny Bog SAC

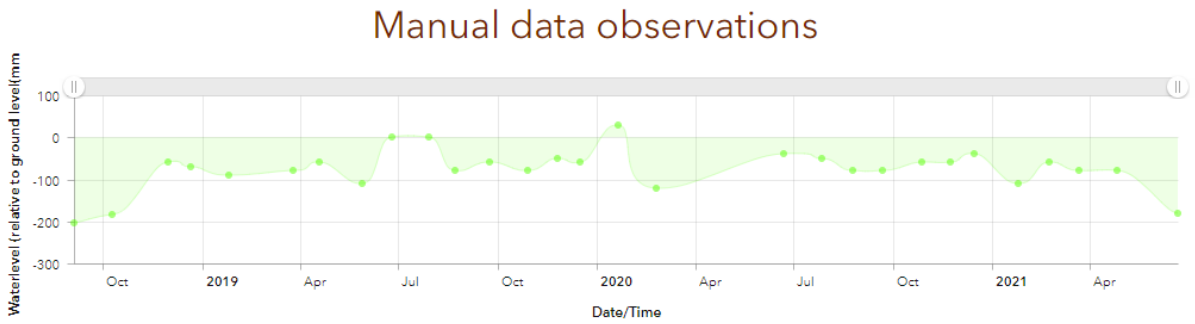


Figure 8-179 Hydrograph of manual monthly water levels K 8, Killyconny Bog SAC

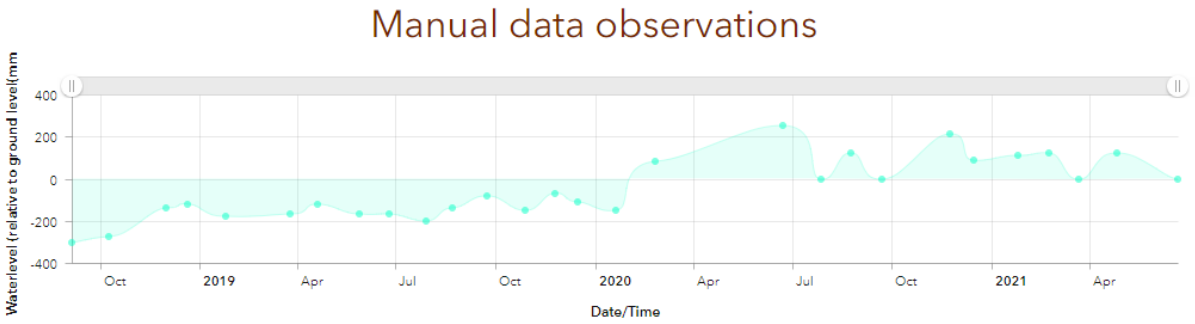


Figure 8-180 Hydrograph of manual monthly water levels K 9, Killyconny Bog SAC

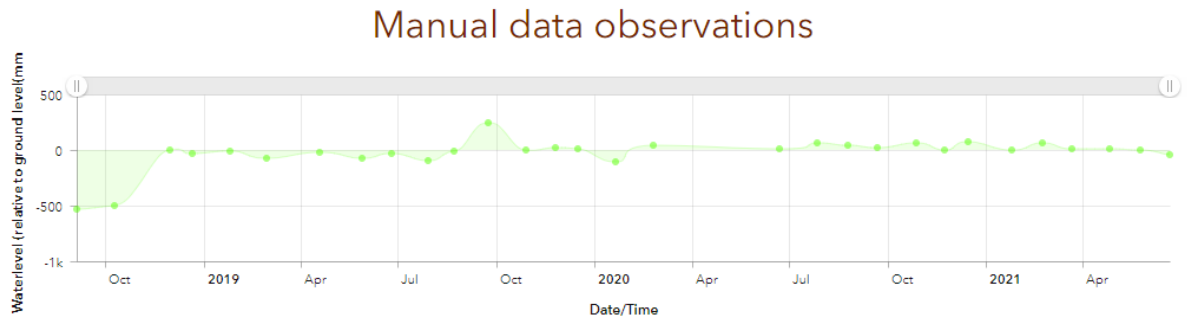


Figure 8-181 Hydrograph of manual monthly water levels K 10, Killyconny Bog SAC

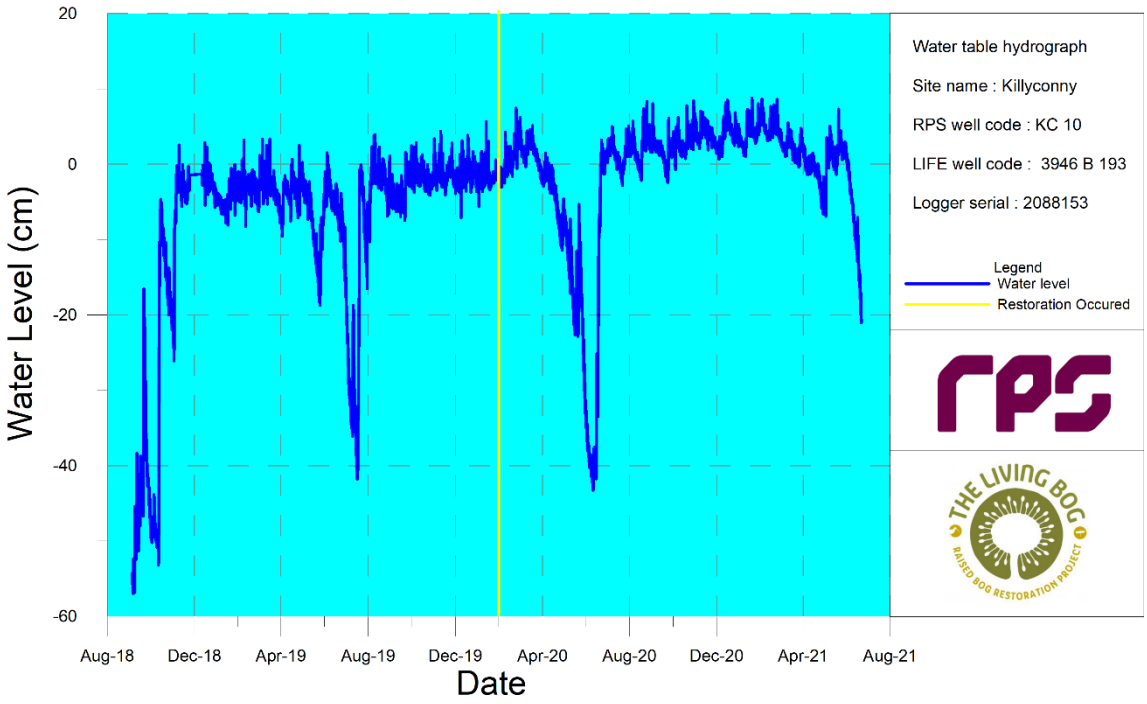


Figure 8-182 Level logger data recorded between August 2018 and August 2021 at well KC10, Killyconny Bog SAC

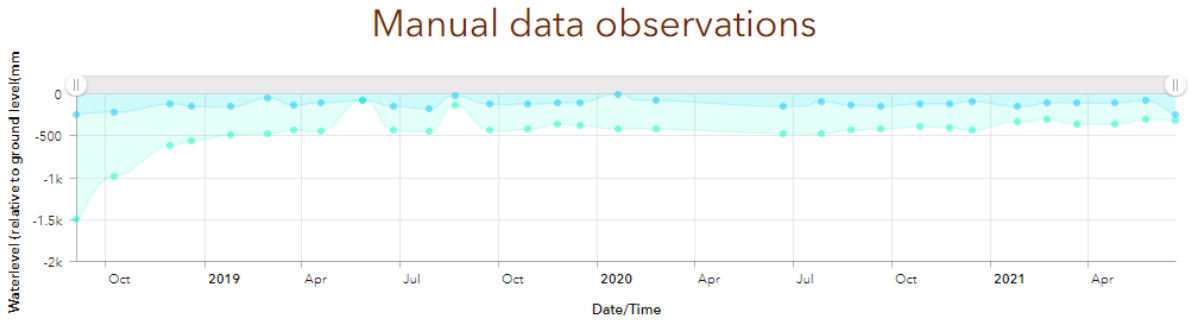


Figure 8-183 Hydrograph of manual monthly water levels K 11S (dark blue) and K 11D (light blue), Killyconny Bog SAC

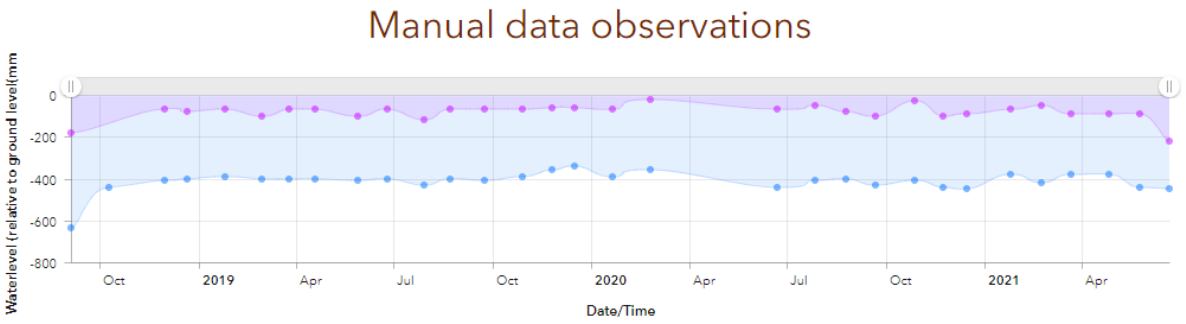


Figure 8-184 Hydrograph of manual monthly water levels K 12S (purple) and K 12D (blue), Killyconny Bog SAC

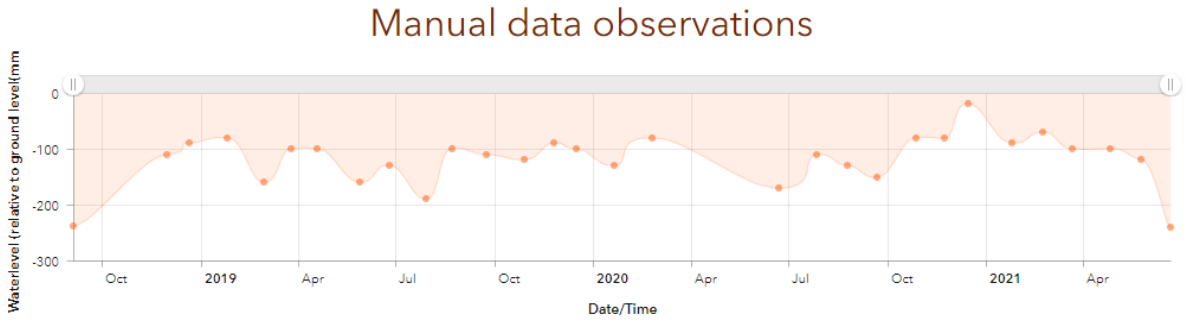


Figure 8-185 Hydrograph of manual monthly water levels K 13S, Killyconny Bog SAC

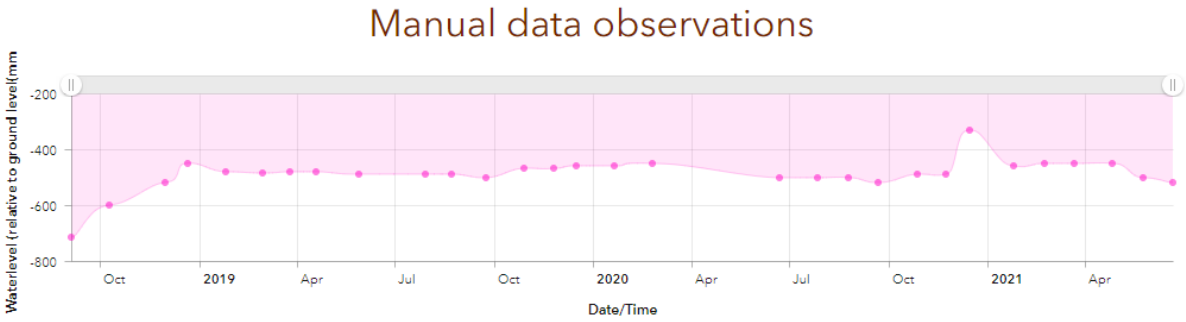


Figure 8-186 Hydrograph of manual monthly water levels K 13D, Killyconny Bog SAC

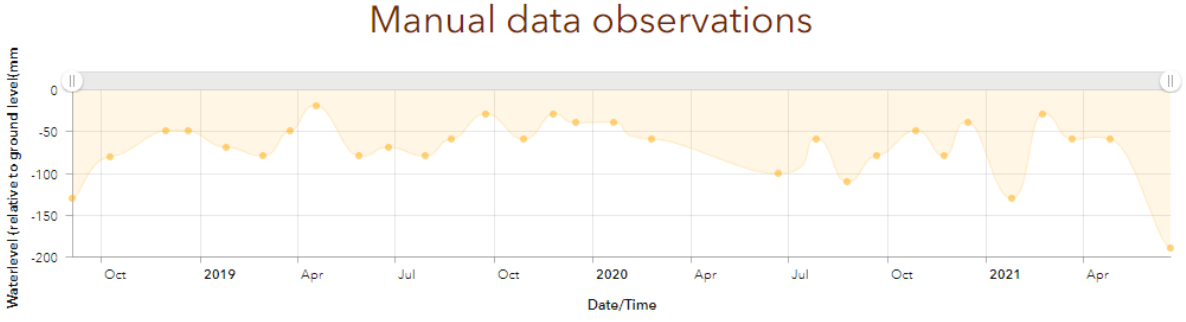


Figure 8-187 Hydrograph of manual monthly water levels K 14S, Killyconny Bog SAC

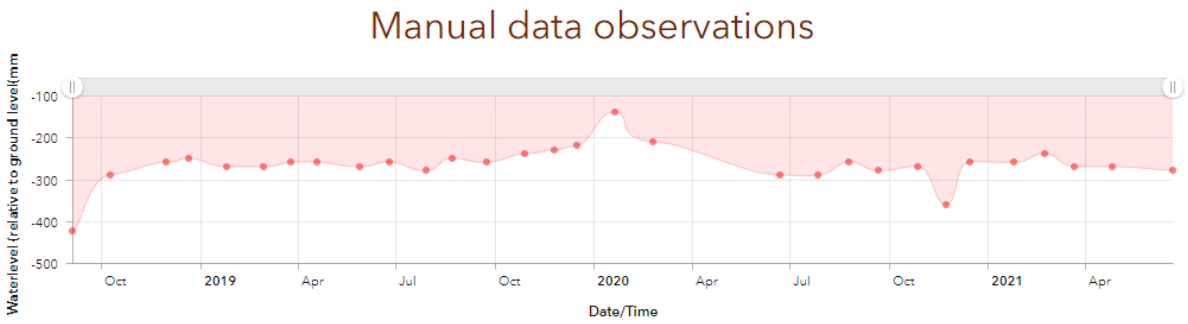


Figure 8-188 Hydrograph of manual monthly water levels K 14D, Killyconny Bog SAC

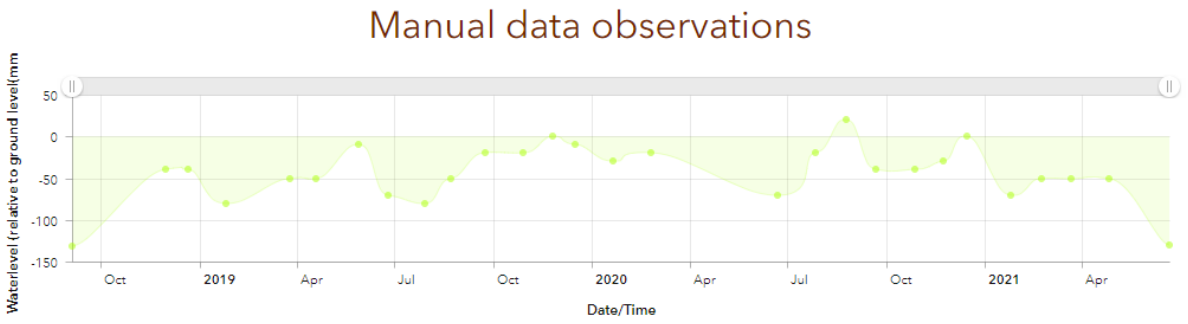


Figure 8-189 Hydrograph of manual monthly water levels K 15S, Killyconny Bog SAC

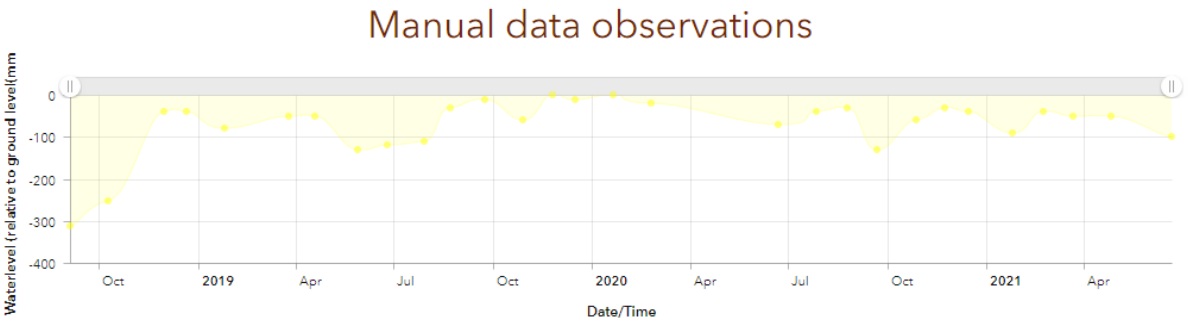


Figure 8-190 Hydrograph of manual monthly water levels K 15D, Killyconny Bog SAC

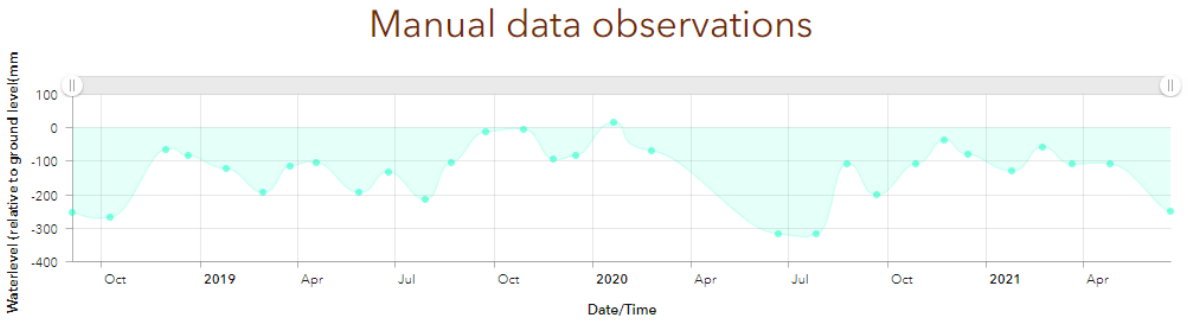


Figure 8-191 Hydrograph of manual monthly water levels K 16S, Killyconny Bog SAC

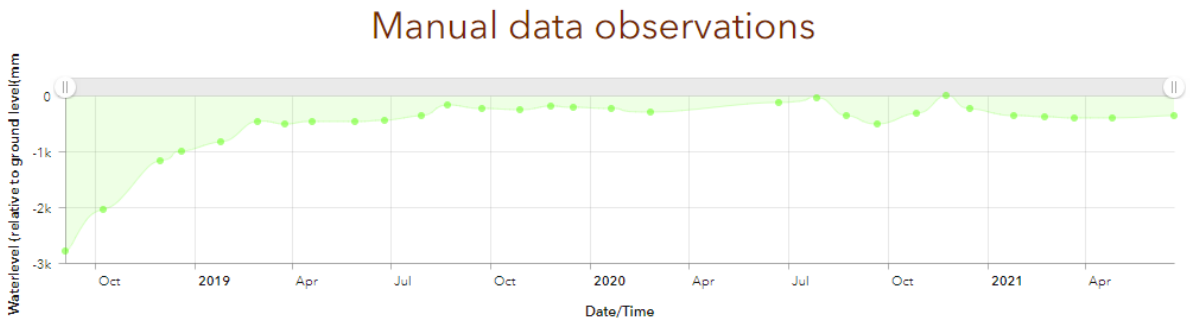


Figure 8-192 Hydrograph of manual monthly water levels K 16D, Killyconny Bog SAC

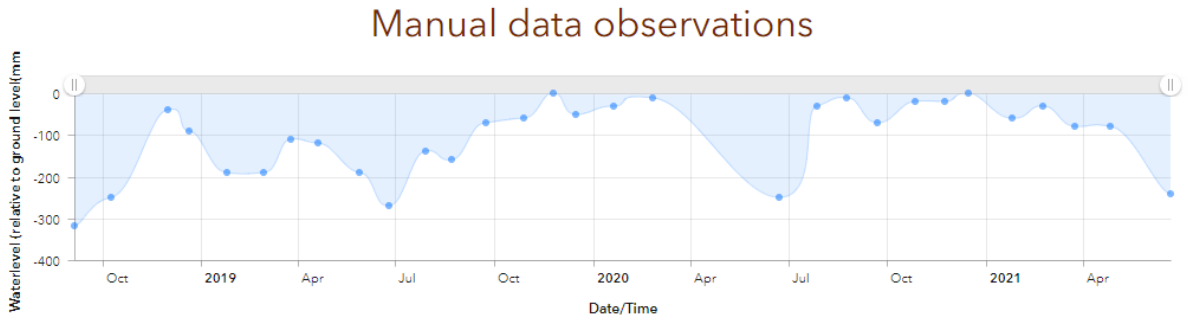


Figure 8-193 Hydrograph of manual monthly water levels K 17S, Killyconny Bog SAC

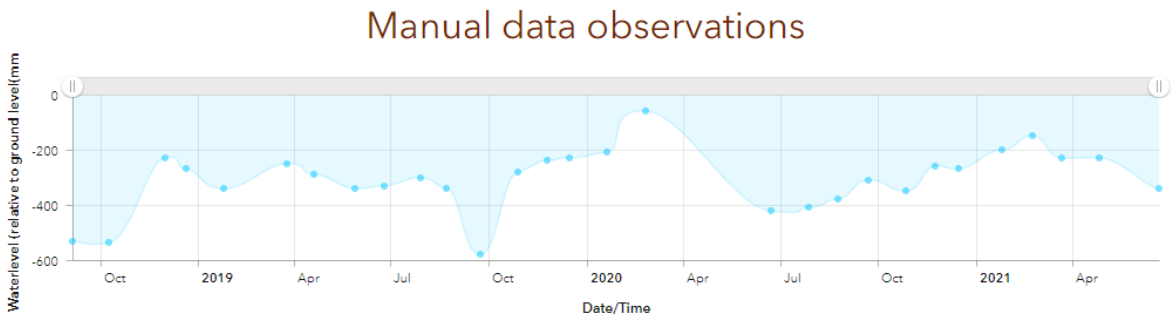


Figure 8-194 Hydrograph of manual monthly water levels K 17D, Killyconny Bog SAC

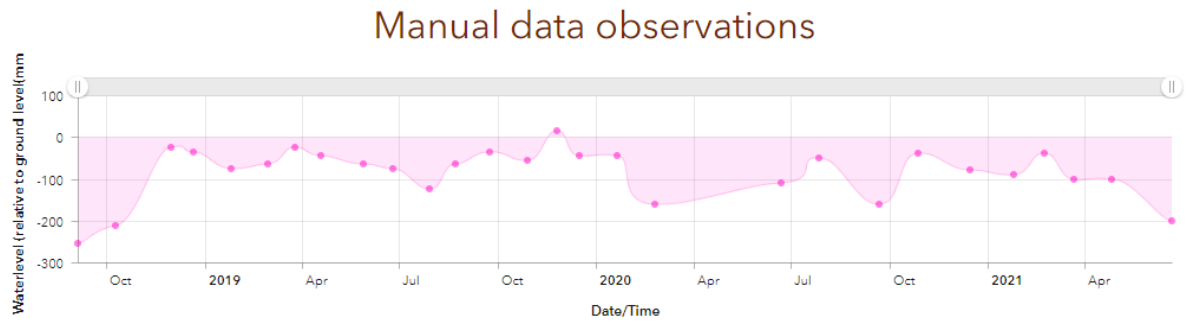


Figure 8-195 Hydrograph of manual monthly water levels K 18S, Killyconny Bog SAC

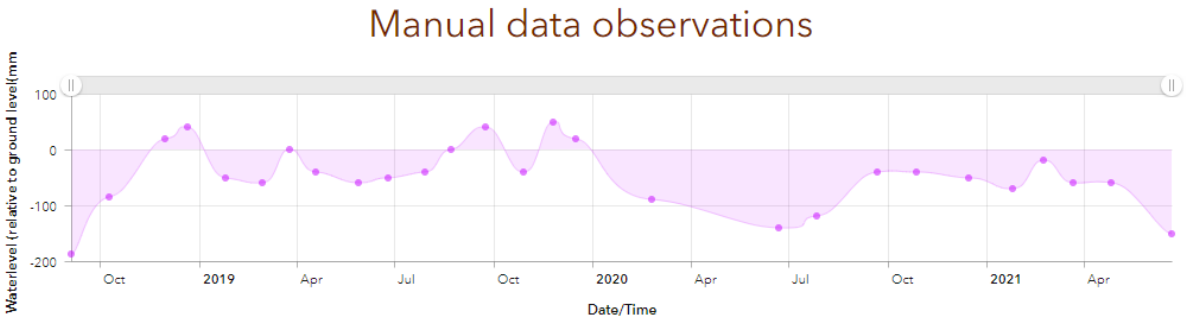


Figure 8-196 Hydrograph of manual monthly water levels K 18D, Killyconny Bog SAC

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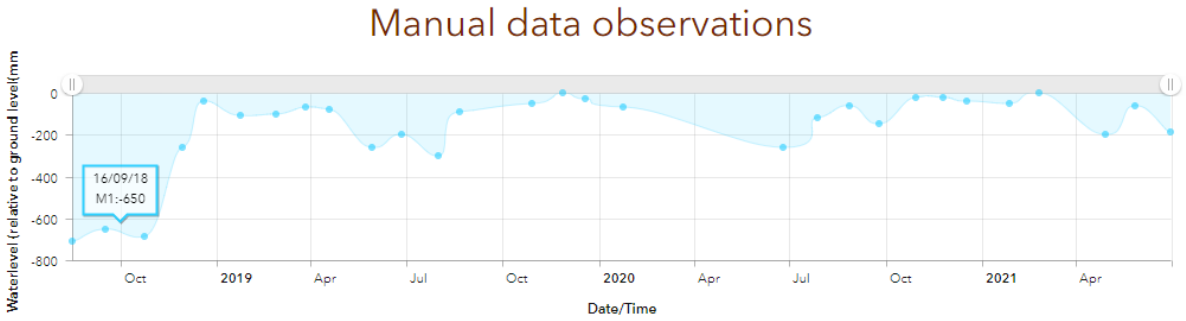

Figure 8-197 Hydrograph of manual monthly water levels M 1, Mongan Bog SAC

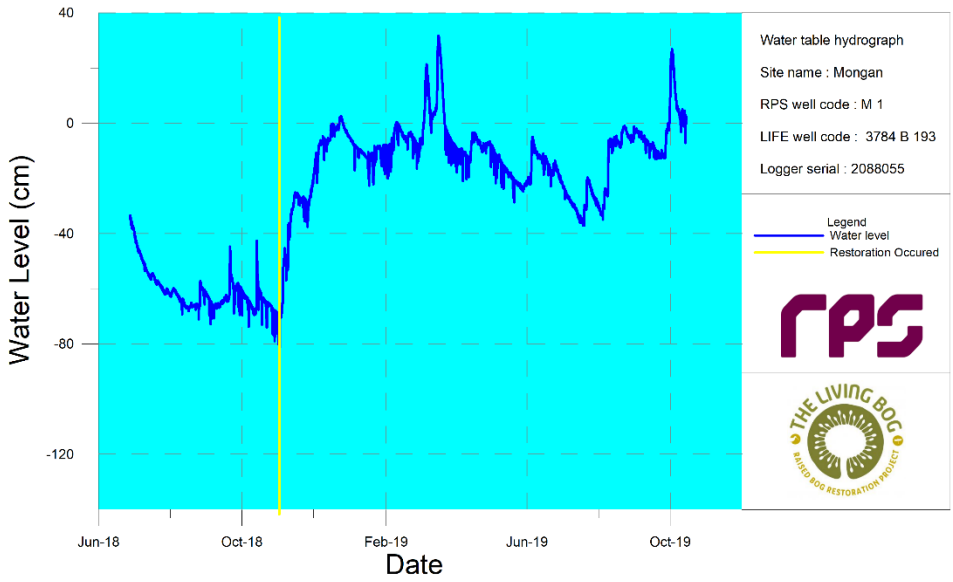

Figure 8-198 Level logger data recorded between June 2018 and November 2019 at well M1, Mongan Bog SAC

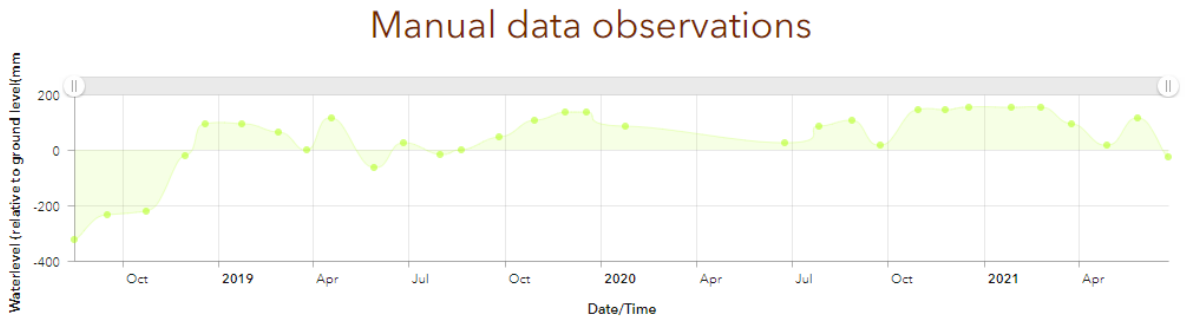

Figure 8-199 Hydrograph of manual monthly water levels M 2, Mongan Bog SAC

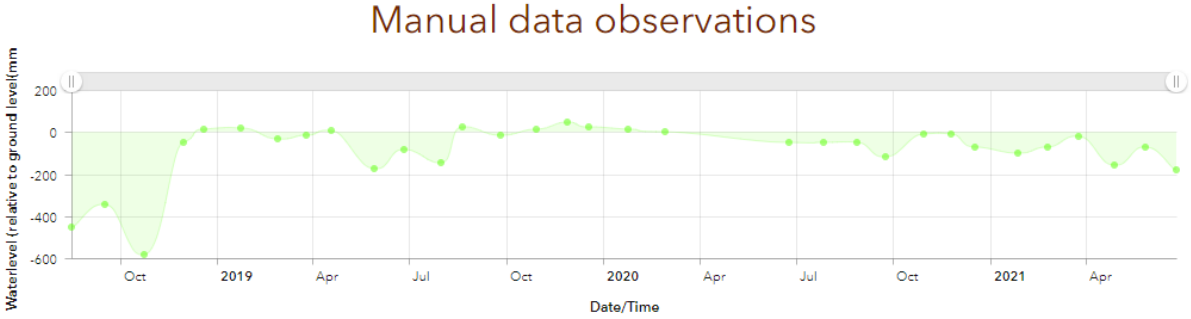

Figure 8-200 Hydrograph of manual monthly water levels M 3, Mongan Bog SAC

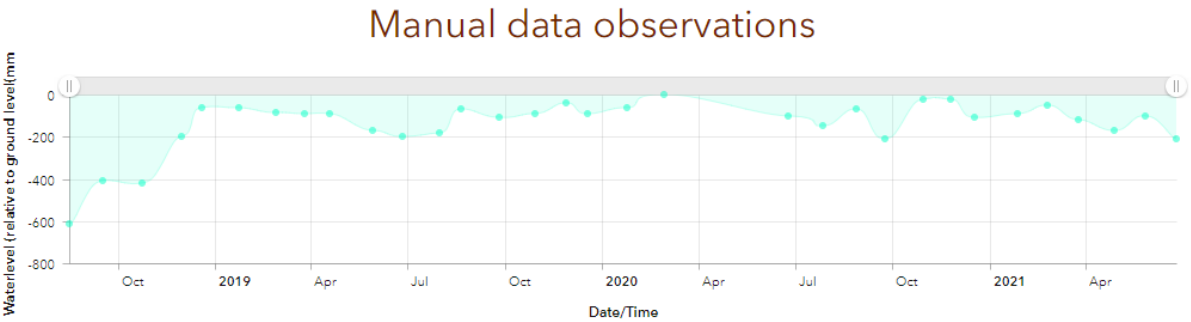

Figure 8-201 Hydrograph of manual monthly water levels M 4, Mongan Bog SAC

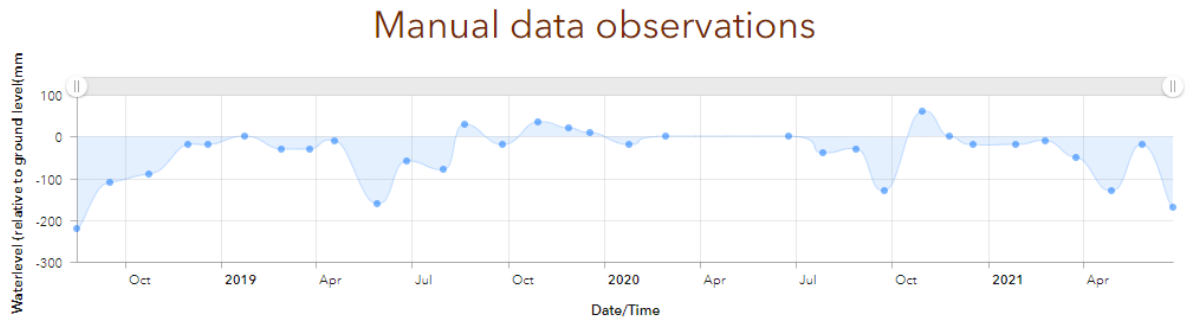

Figure 8-202 Hydrograph of manual monthly water levels M 5S, Mongan Bog SAC

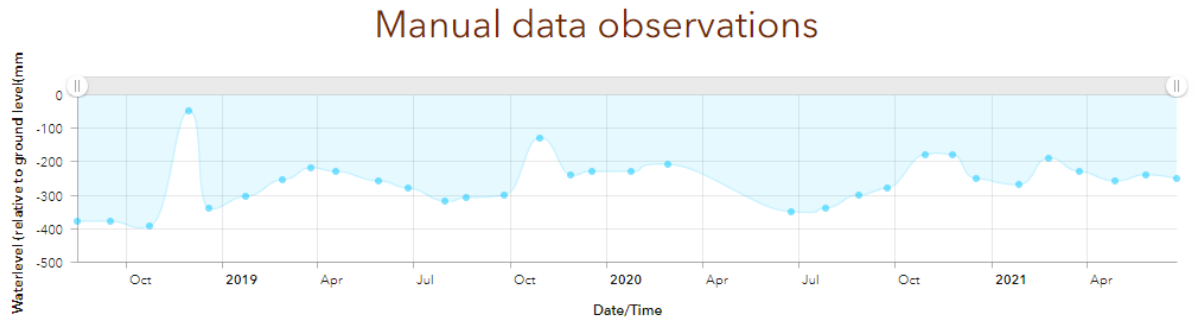

Figure 8-203 Hydrograph of manual monthly water levels M 5D, Mongan Bog SAC

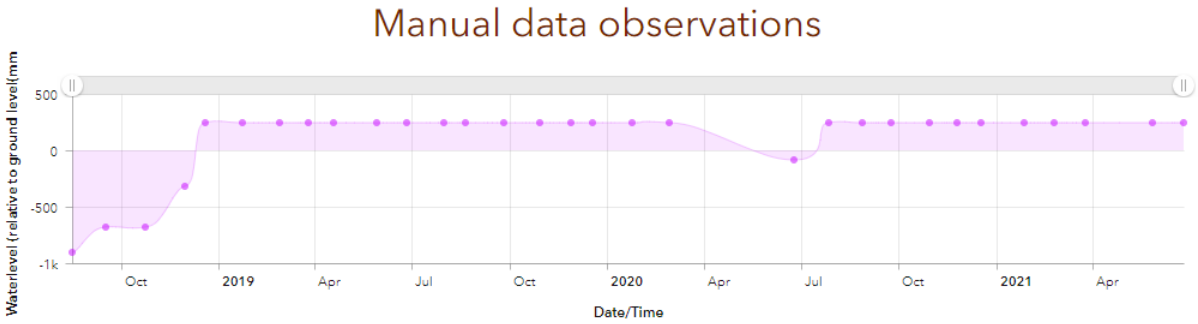

Figure 8-204 Hydrograph of manual monthly water levels M 6, Mongan Bog SAC

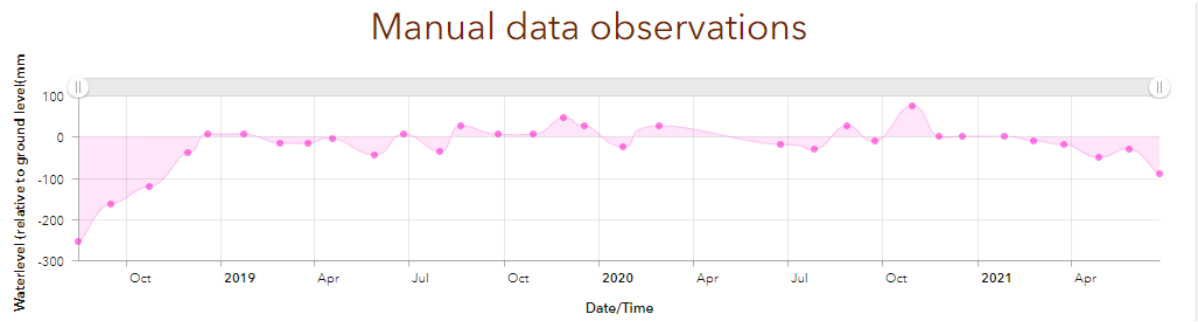

Figure 8-205 Hydrograph of manual monthly water levels M 7, Mongan Bog SAC

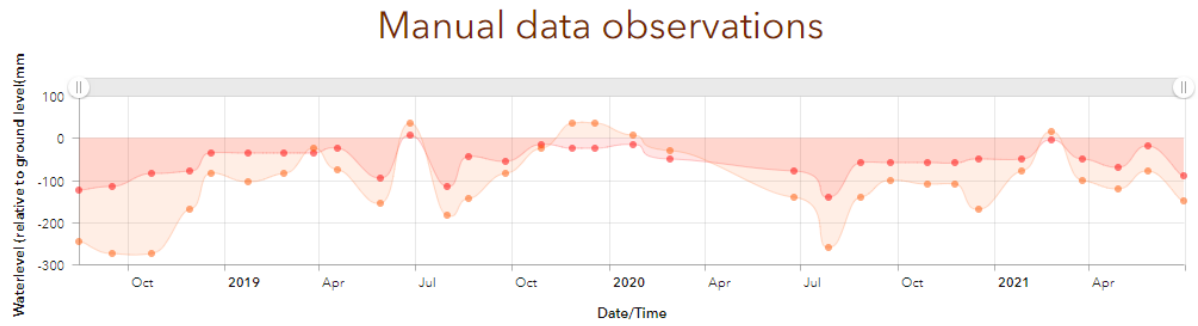

Figure 8-206 Hydrograph of manual monthly water levels M 9S (red) and M 9D (orange), Mongan Bog SAC

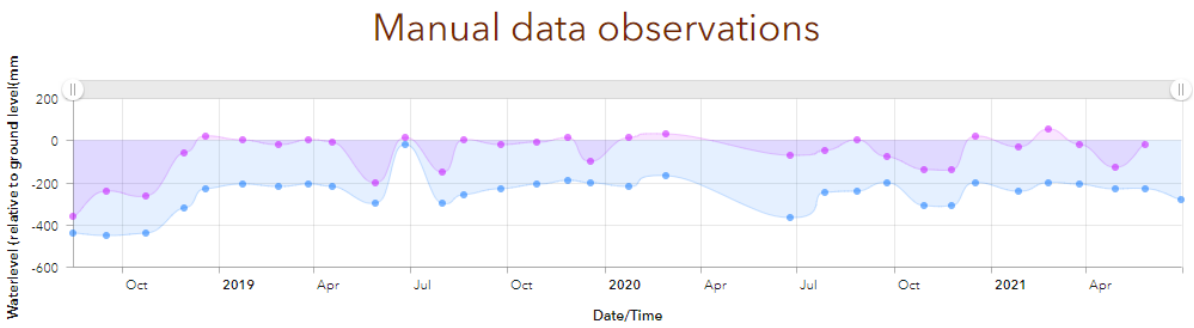

Figure 8-207 Hydrograph of manual monthly water levels M 10S (purple) and M 10D (blue), Mongan Bog SAC

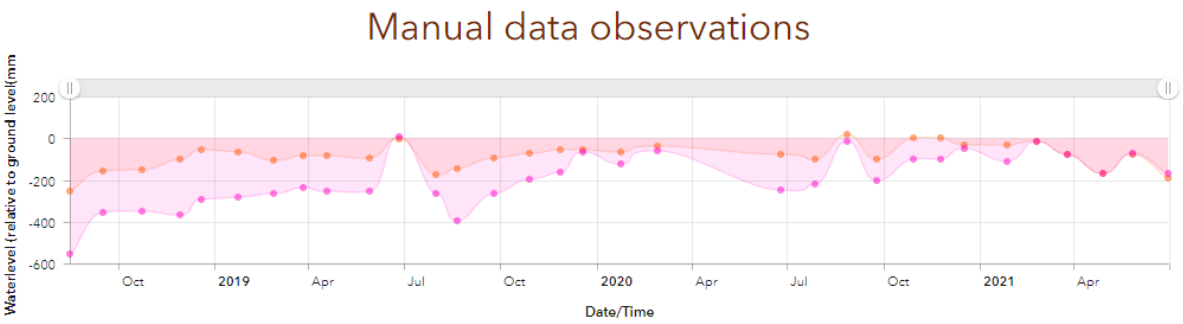

Figure 8-208 Hydrograph of manual monthly water levels M 11S (orange) and M 11D (pink), Mongan Bog SAC

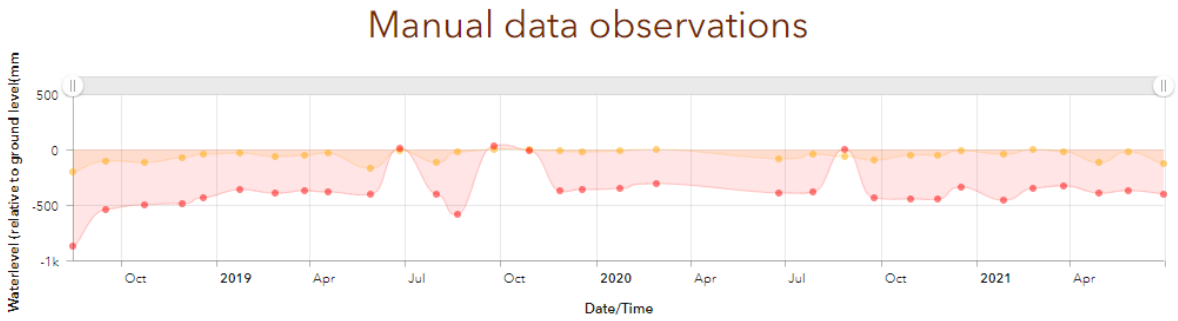

Figure 8-209 Hydrograph of manual monthly water levels M 12S (orange) and M 12D (red), Mongan Bog SAC

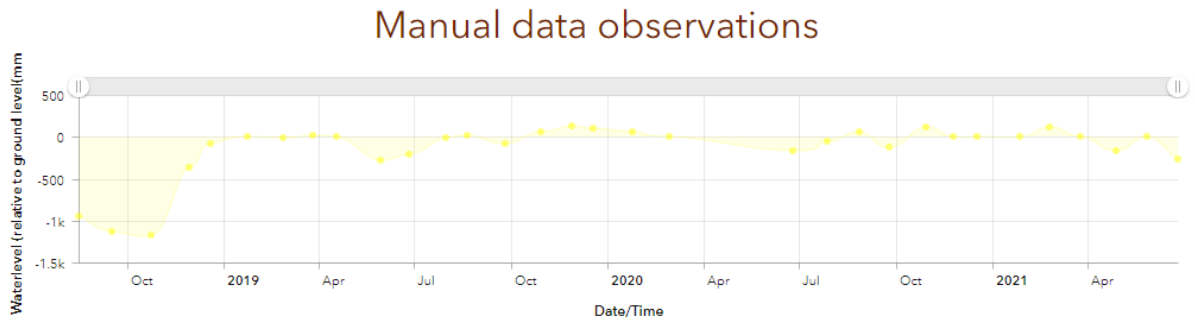

Figure 8-210 Hydrograph of manual monthly water levels M 13, Mongan Bog SAC

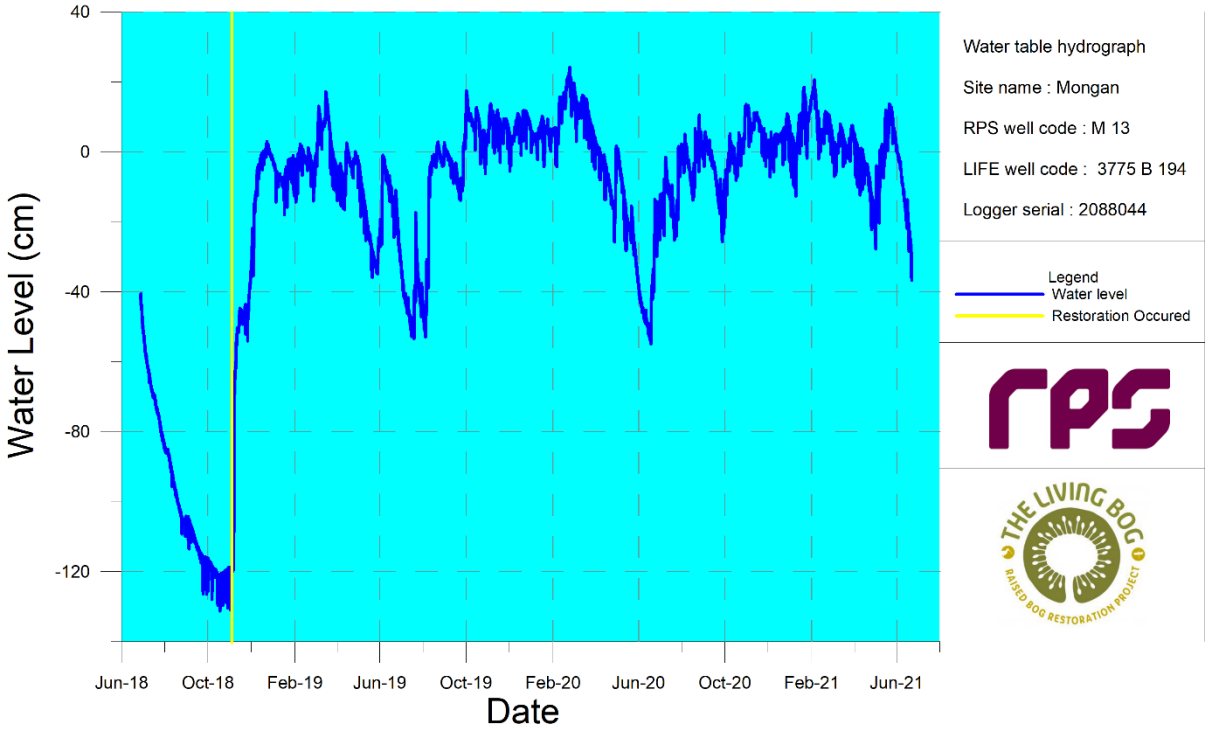

Figure 8-211 Level logger data recorded between June 2018 and July 2021 at well M13, Mongan Bog SAC

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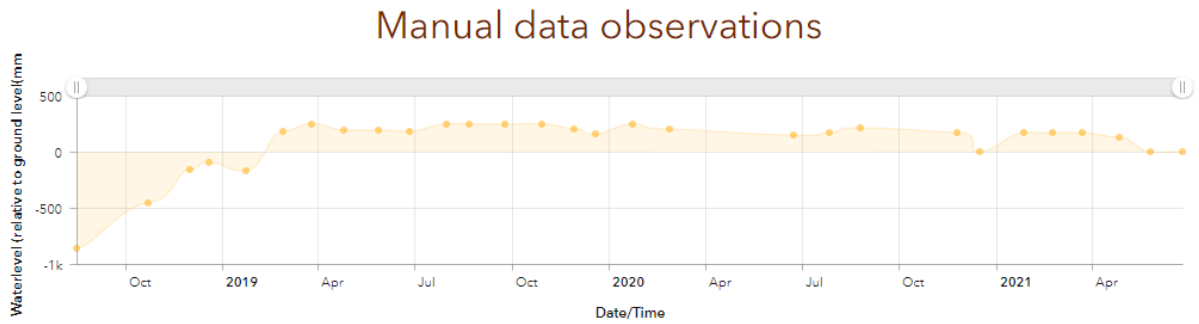

Figure 8-212 Hydrograph of manual monthly water levels MC 1, Moyclare Bog SAC

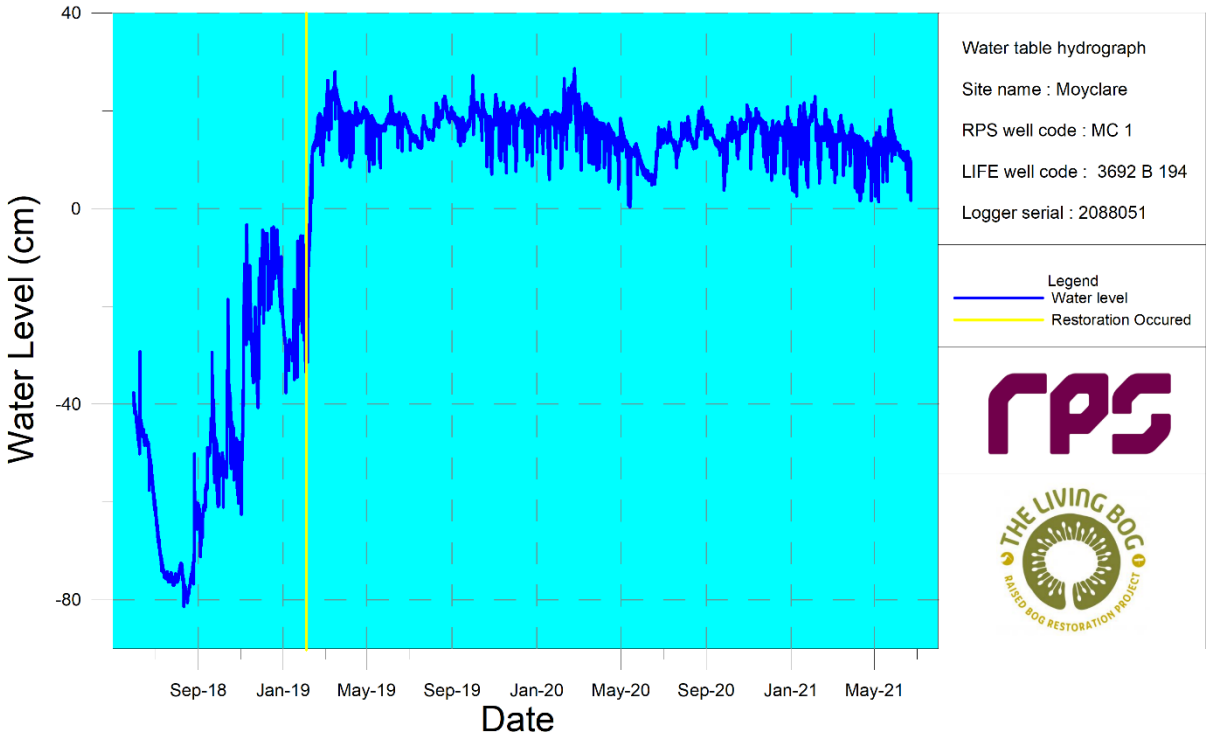

Figure 8-213 Level logger data recorded between June 2018 and July 2021 at well MC1, Moyclare Bog SAC

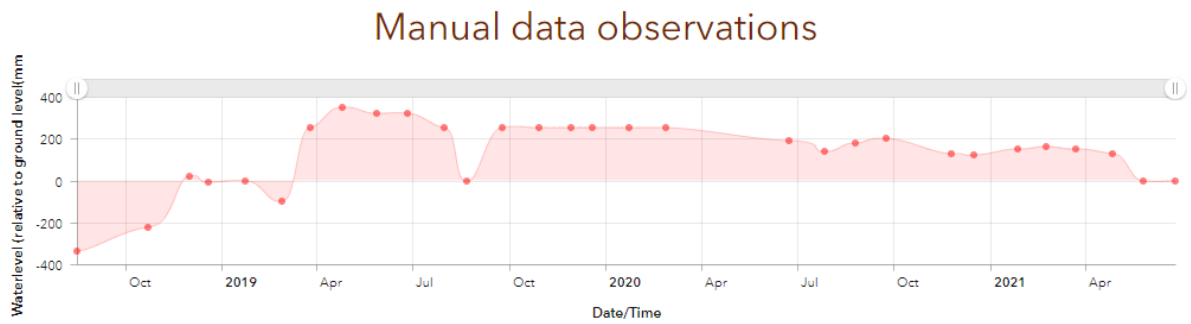

Figure 8-214 Hydrograph of manual monthly water levels MC 2, Moyclare Bog SAC

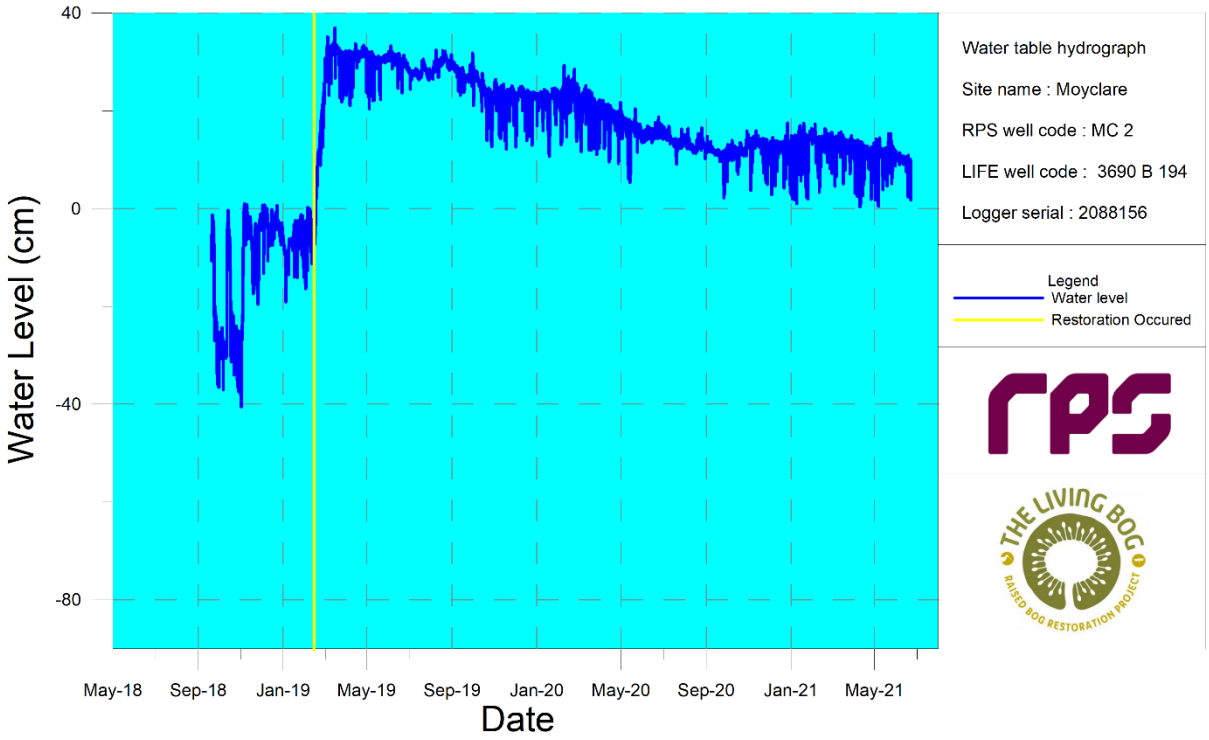

Figure 8-215 Level logger data recorded between September 2018 and July 2021 at well MC2, Moyclare Bog SAC

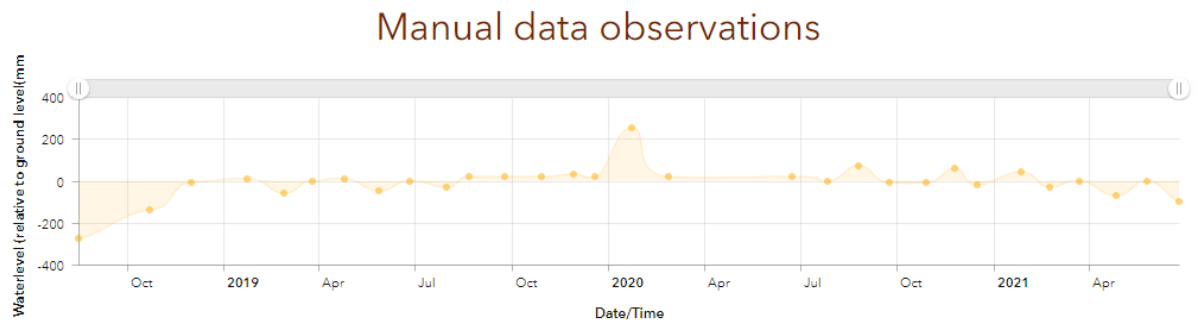

Figure 8-216 Hydrograph of manual monthly water levels MC 3, Moyclare Bog SAC

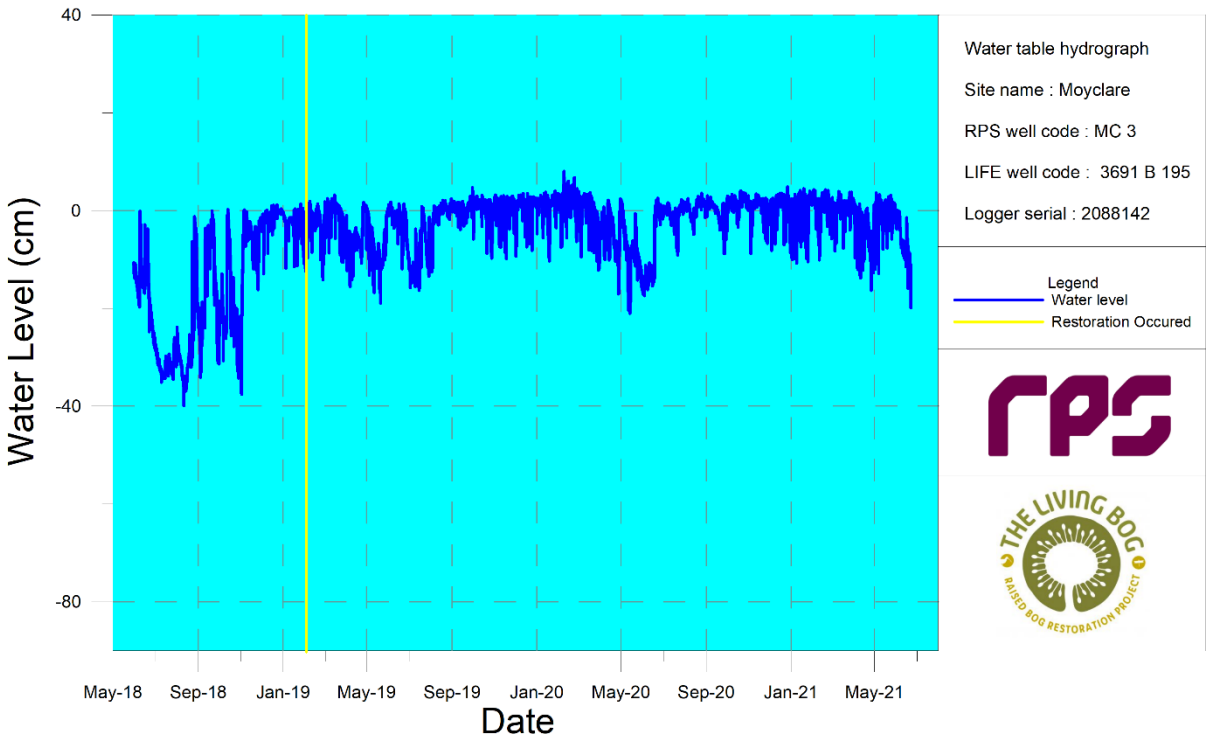

Figure 8-217 Level logger data recorded between June 2018 and July 2021 at well MC3, Moyclare Bog SAC

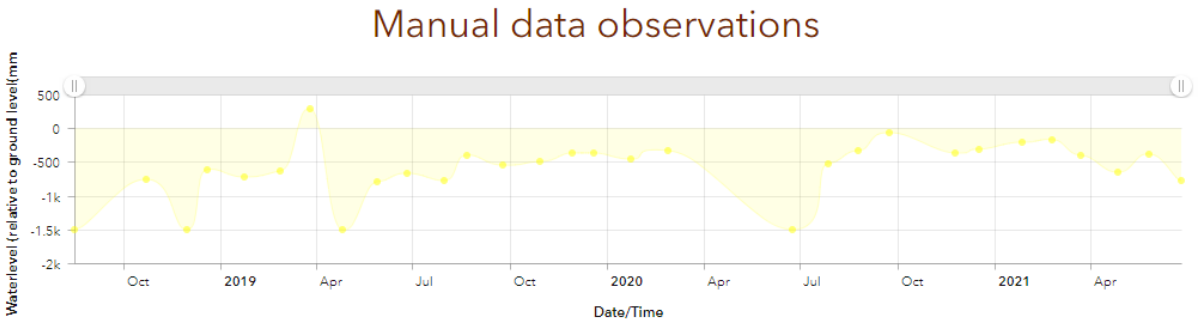

Figure 8-218 Hydrograph of manual monthly water levels MC 4, Moyclare Bog SAC

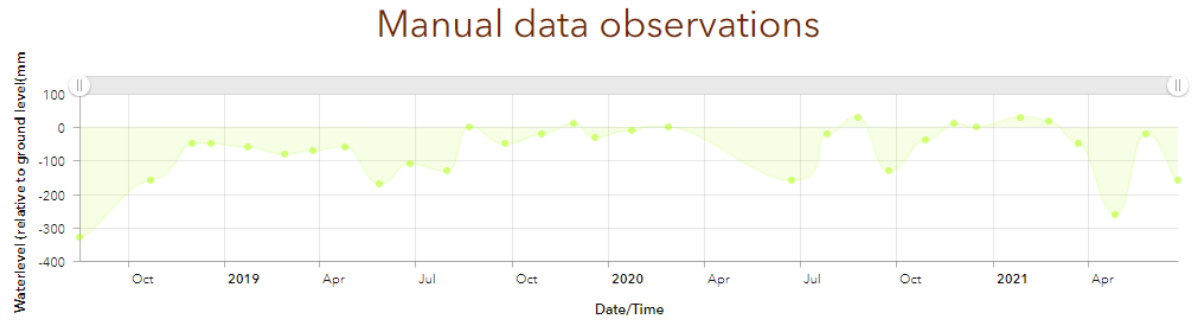

Figure 8-219 Hydrograph of manual monthly water levels MC 5, Moyclare Bog SAC

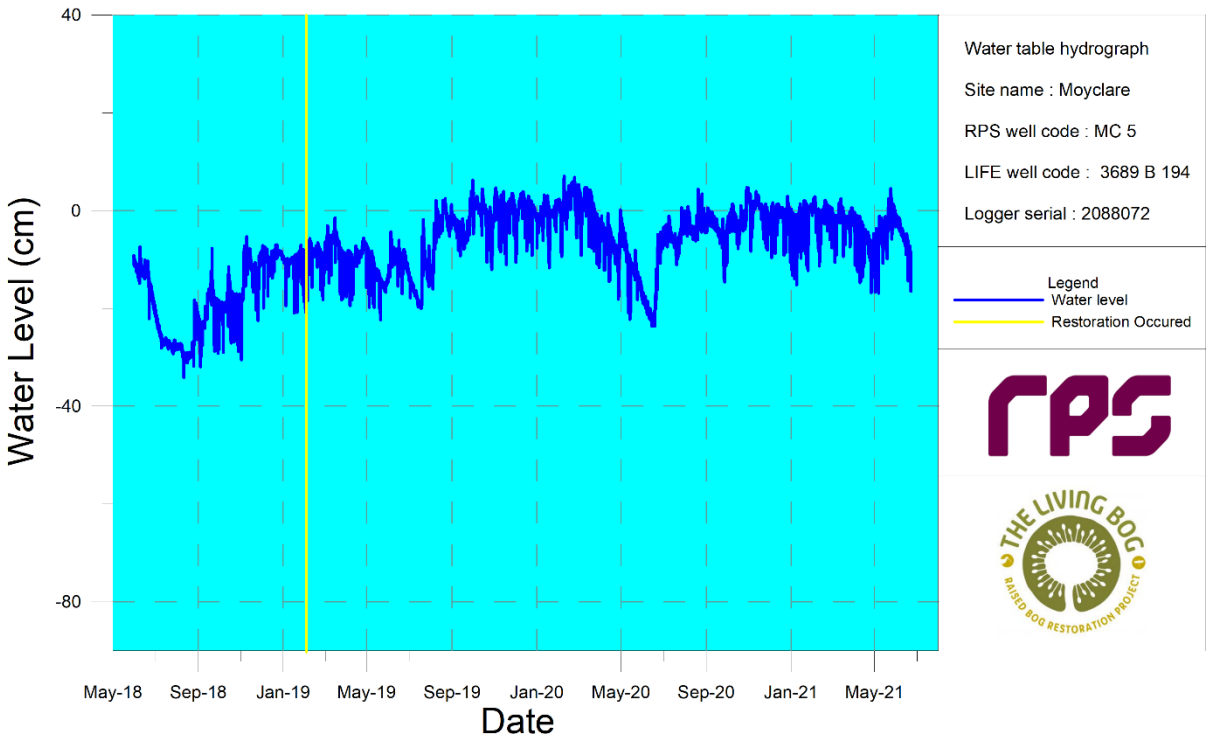

Figure 8-220 Level logger data recorded between June 2018 and July 2021 at well MC5, Moyclare Bog SAC

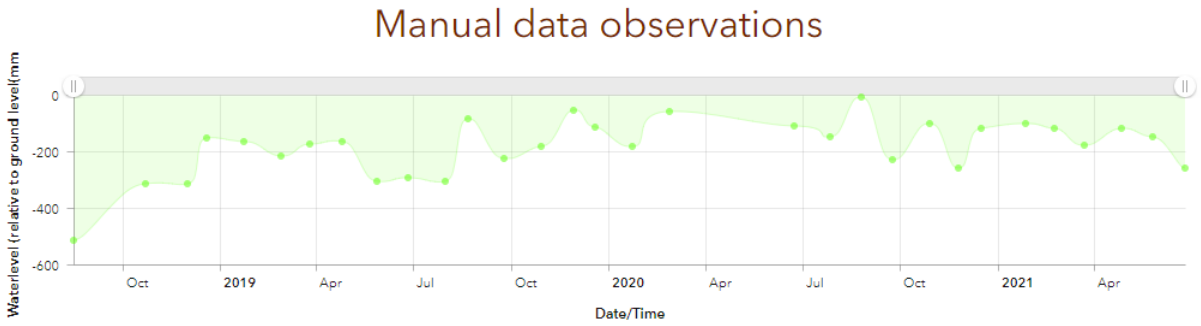

Figure 8-221 Hydrograph of manual monthly water levels MC 6, Moyclare Bog SAC

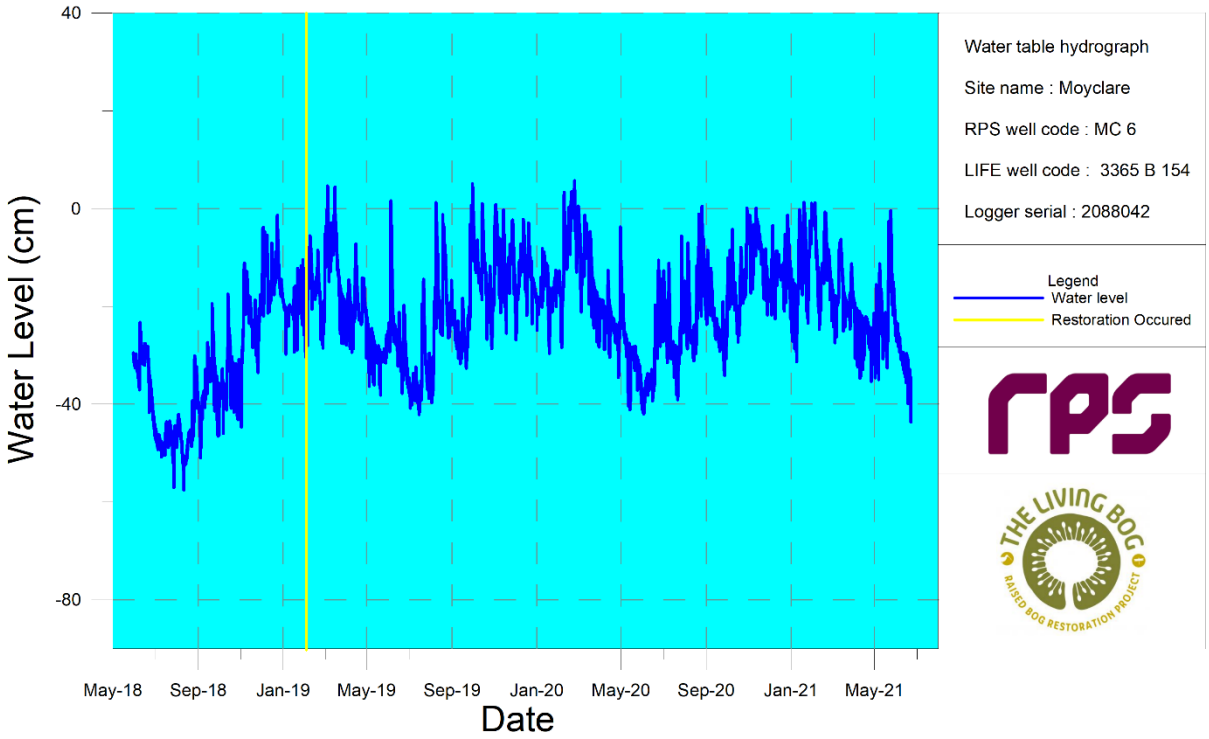

Figure 8-222 Level logger data recorded between June 2018 and July 2021 at well MC6, Moyclare Bog SAC

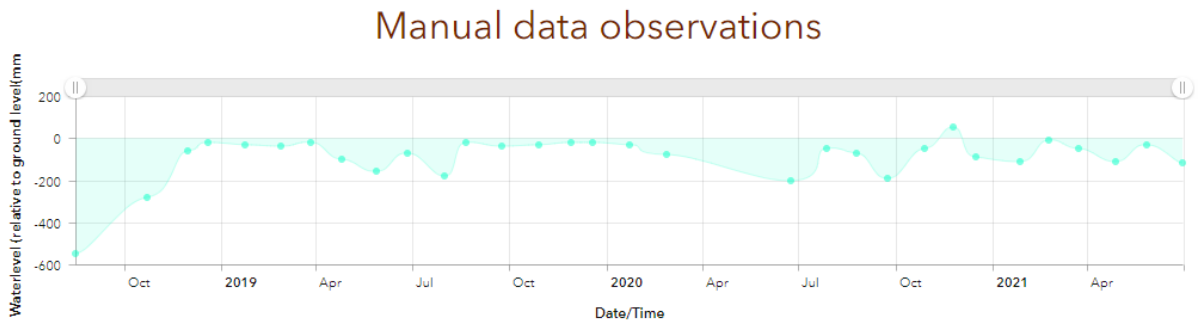

Figure 8-223 Hydrograph of manual monthly water levels MC 7, Moyclare Bog SAC

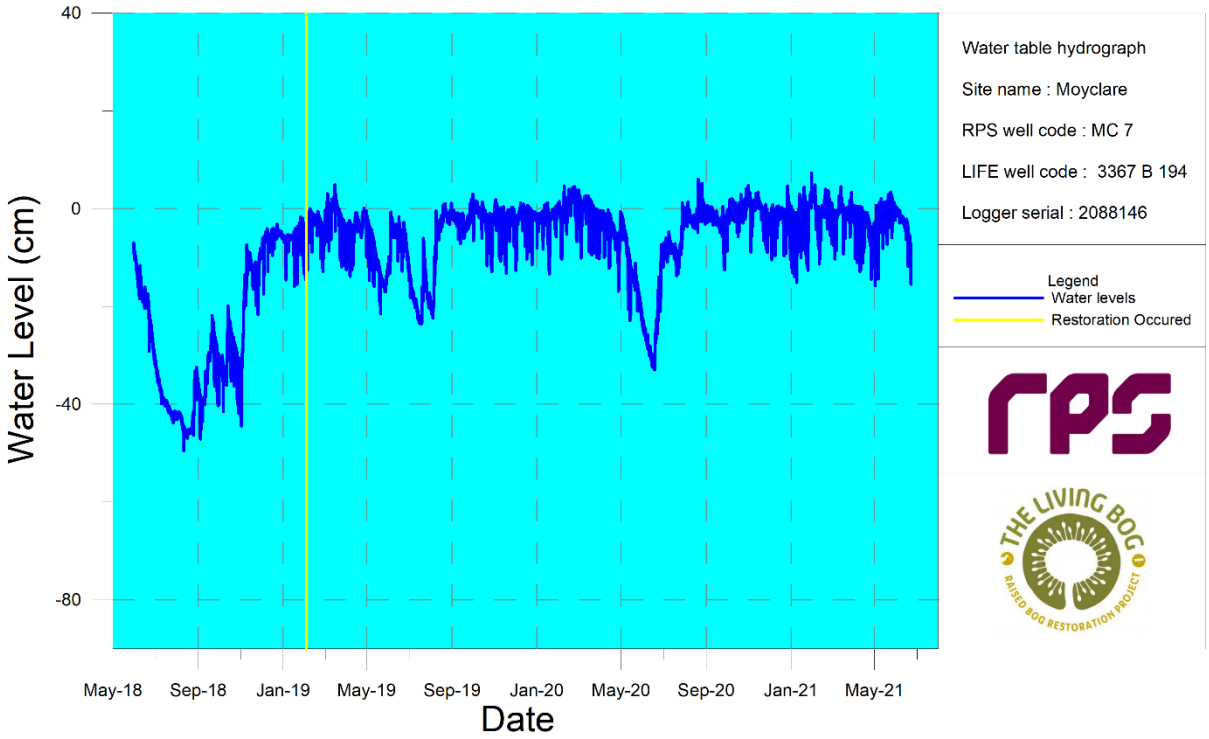

Figure 8-224 Level logger data recorded between June 2018 and July 2021 at well MC7, Moyclare Bog SAC

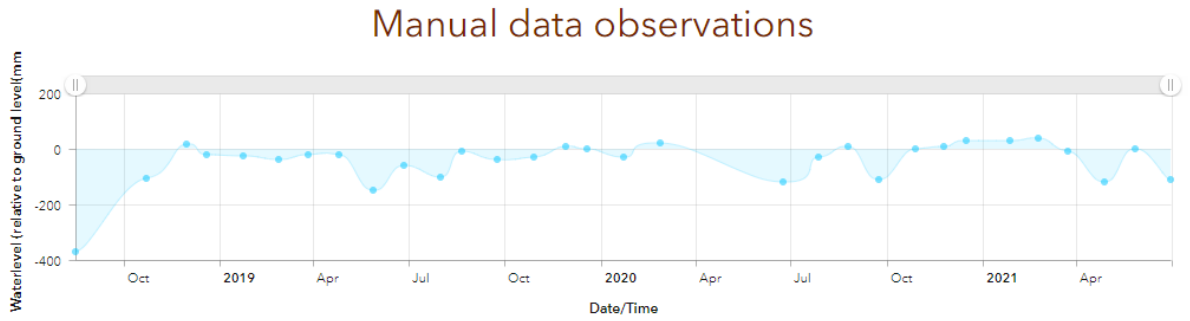

Figure 8-225 Hydrograph of manual monthly water levels MC 8, Moyclare Bog SAC

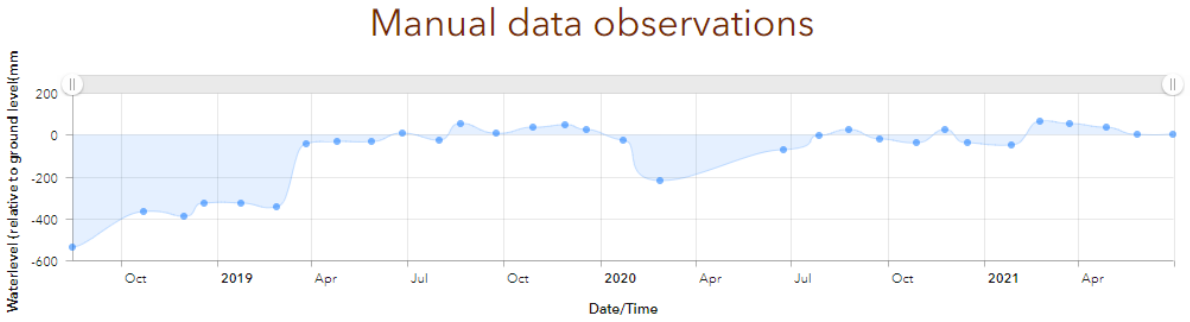

Figure 8-226 Hydrograph of manual monthly water levels MC 9, Moyclare Bog SAC

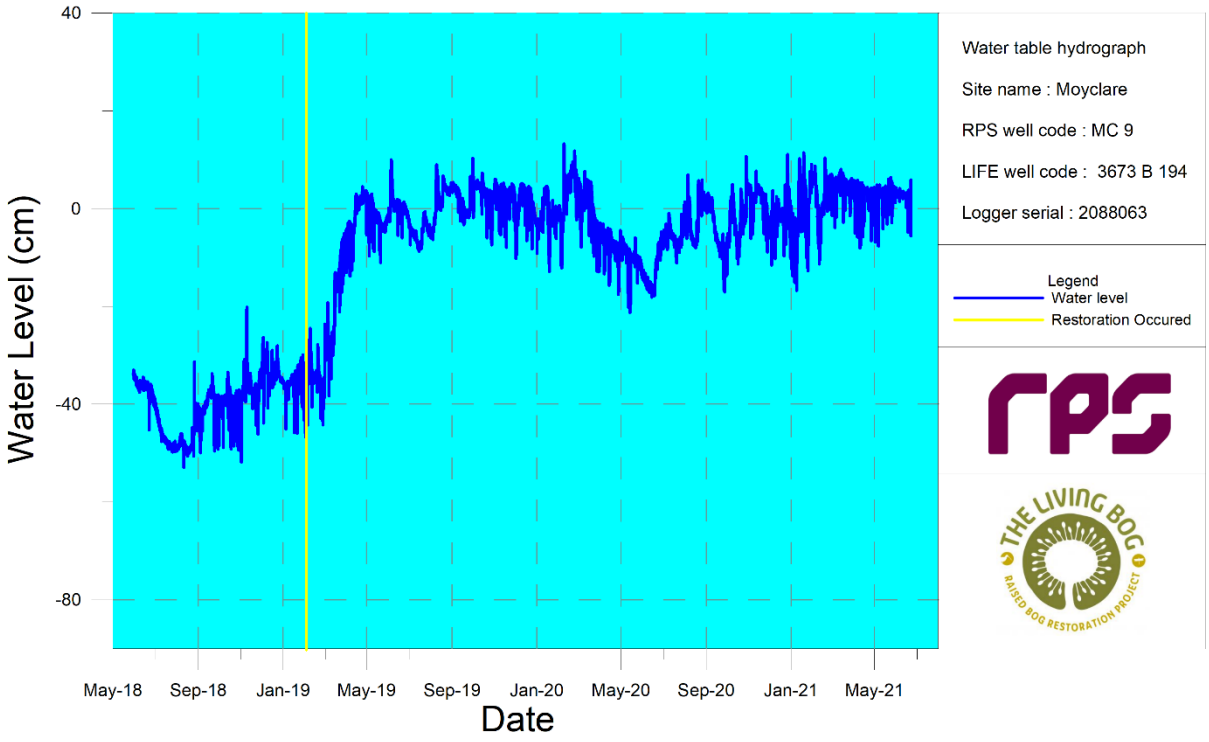

Figure 8-227 Level logger data recorded between June 2018 and July 2021 at well MC9, Moyclare Bog SAC

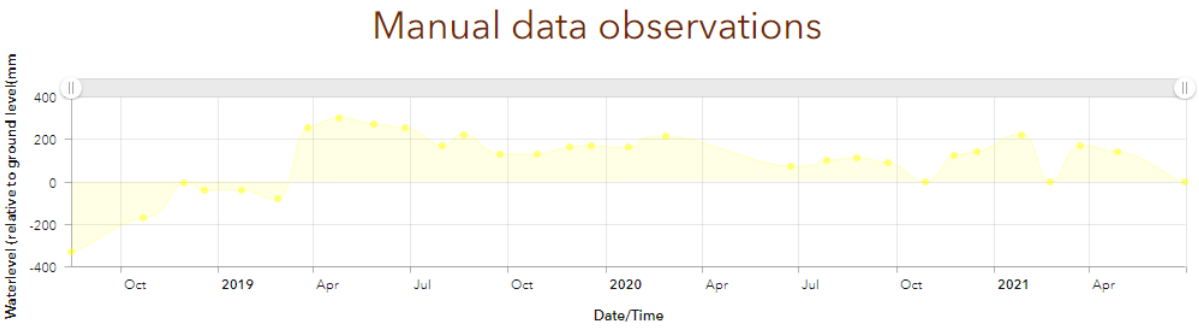

Figure 8-228 Hydrograph of manual monthly water levels MC 10, Moyclare Bog SAC

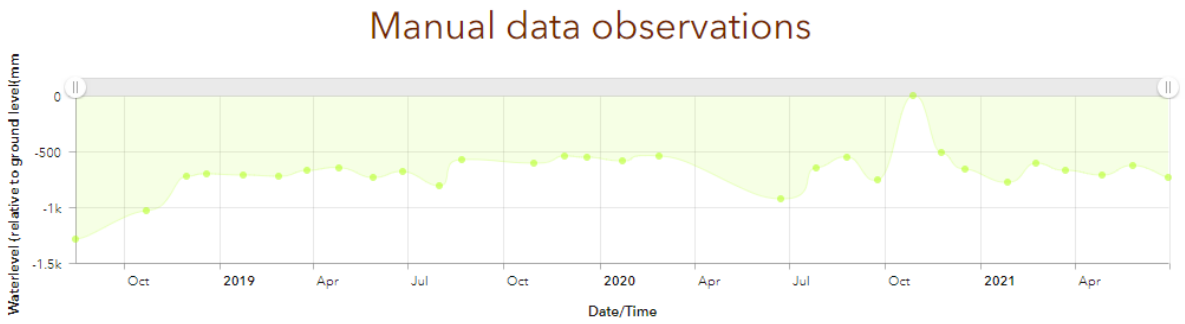

Figure 8-229 Hydrograph of manual monthly water levels MC 11, Moyclare Bog SAC

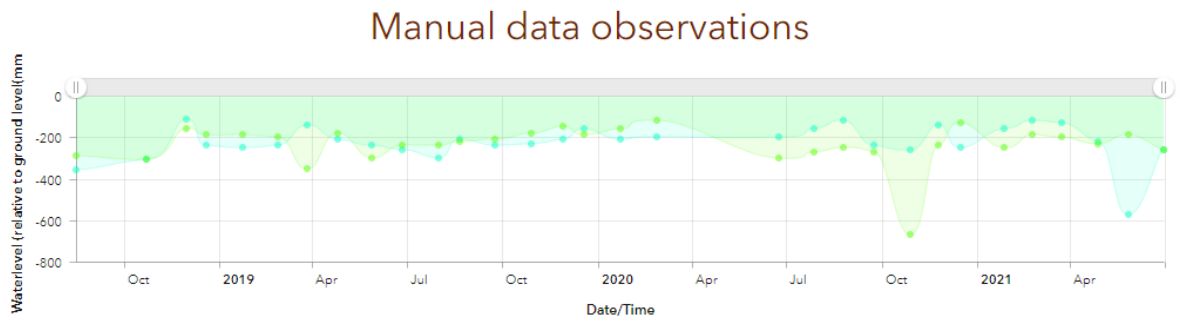

Figure 8-230 Hydrograph of manual monthly water levels MC 12S (blue) and 12D (green), Moyclare Bog SAC

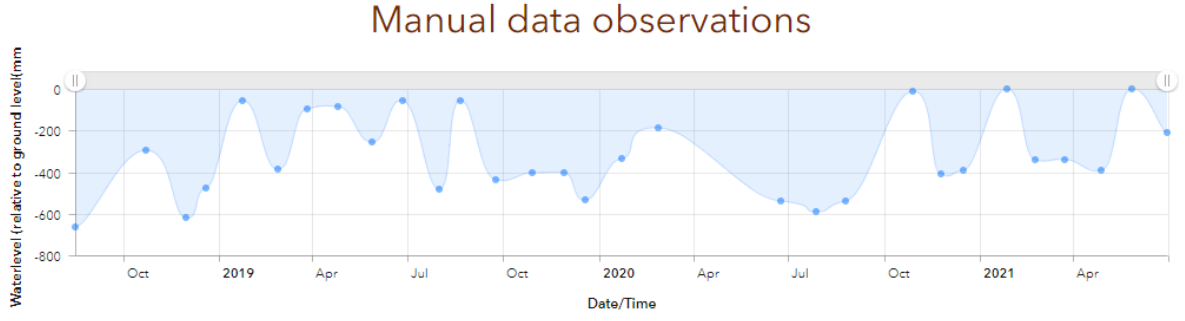

Figure 8-231 Hydrograph of manual monthly water levels MC 13S, Moyclare Bog SAC

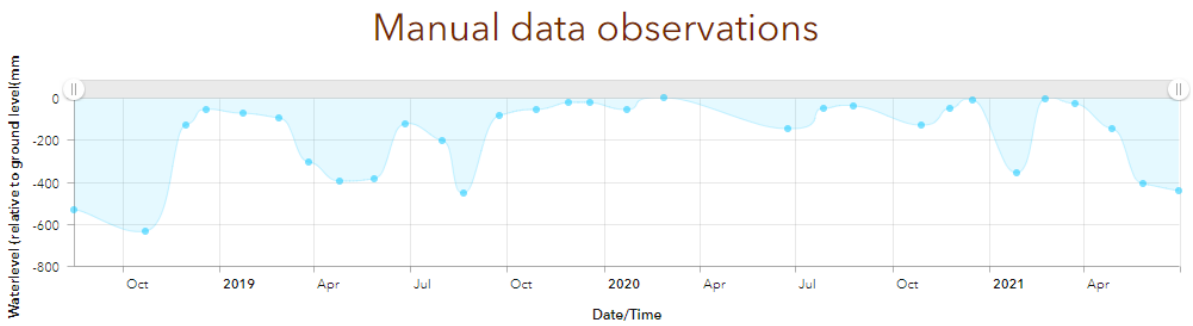

Figure 8-232 Hydrograph of manual monthly water levels MC 13D, Moyclare Bog SAC

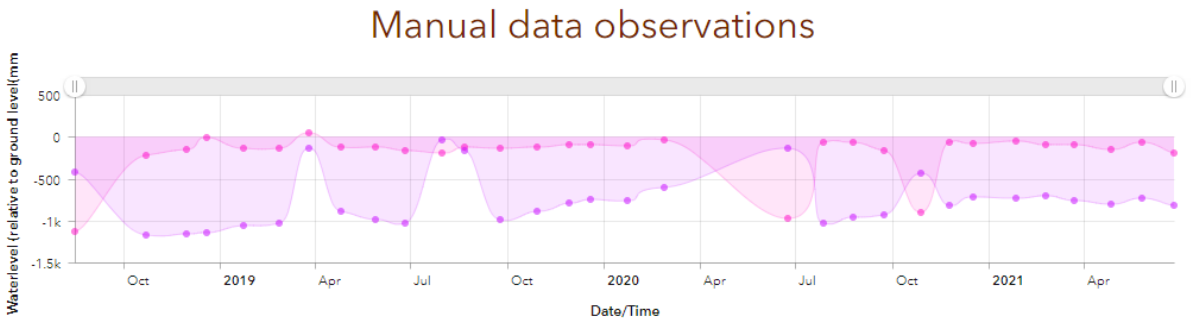

Figure 8-233 Hydrograph of manual monthly water levels MC 14aS (pink) and 14aD (purple), Moyclare Bog SAC

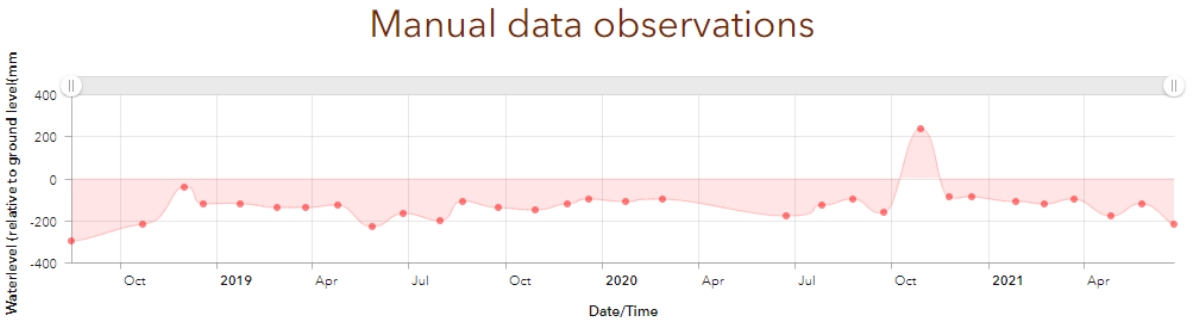

Figure 8-234 Hydrograph of manual monthly water levels MC 14bS, Moyclare Bog SAC

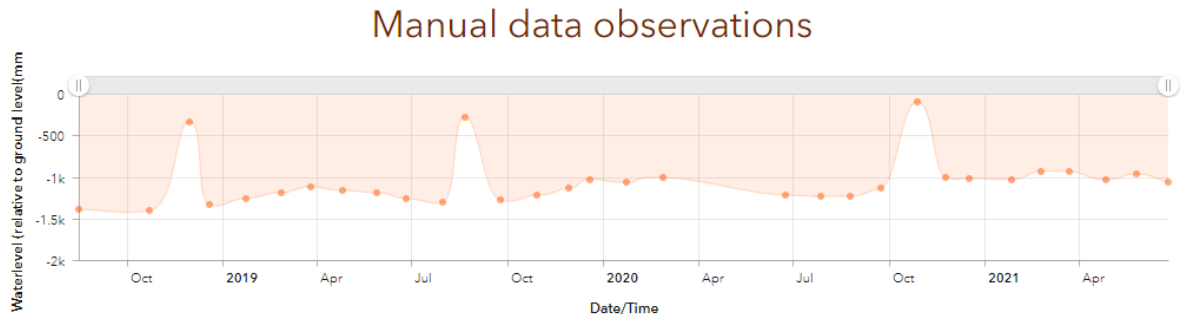

Figure 8-235 Hydrograph of manual monthly water levels MC 14bD, Moyclare Bog SAC

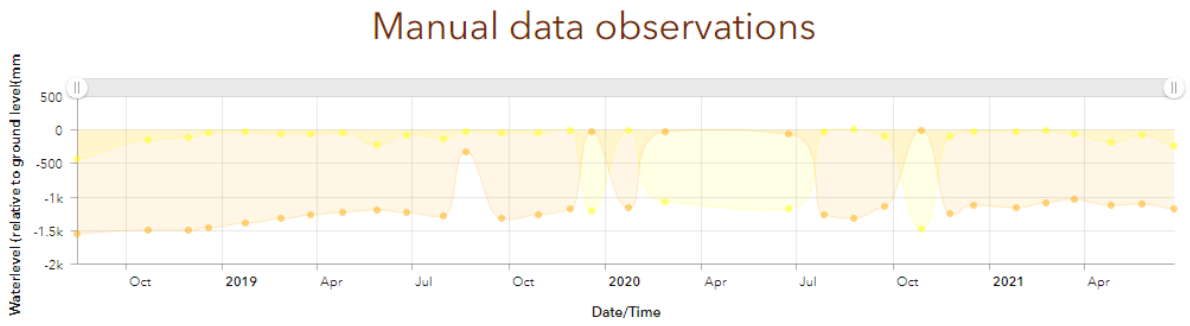

Figure 8-236 Hydrograph of manual monthly water levels MC 15S (yellow) and 15D (orange), Moyclare Bog SAC

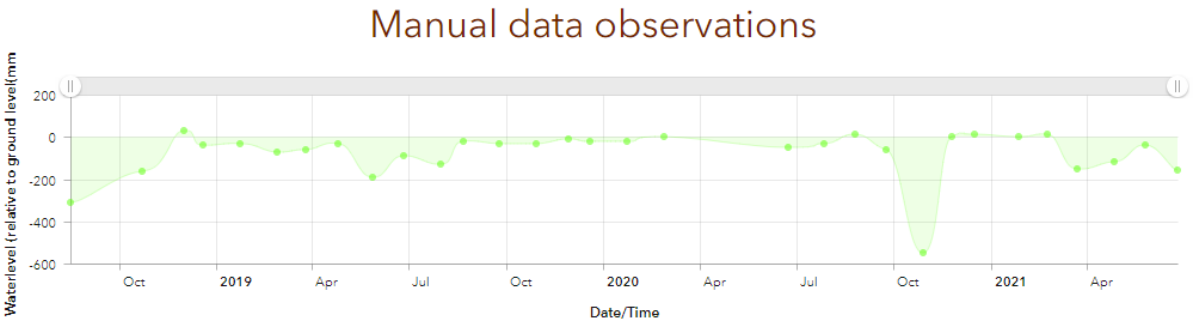

Figure 8-237 Hydrograph of manual monthly water levels MC 16S, Moyclare Bog SAC

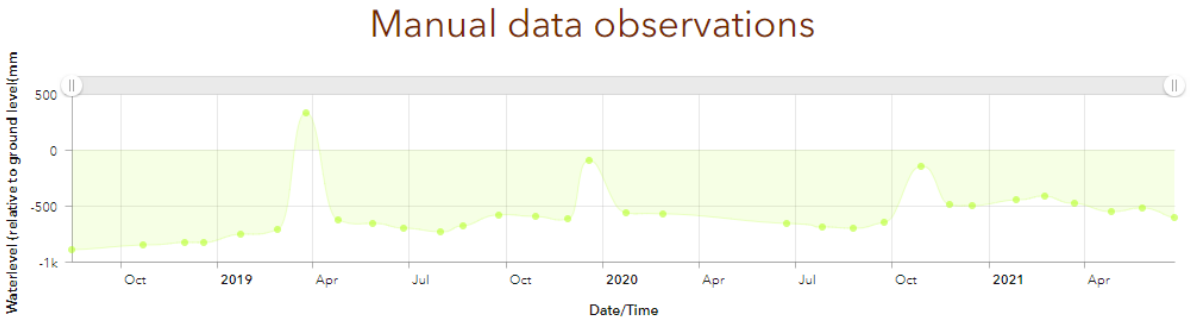

Figure 8-238 Hydrograph of manual monthly water levels MC 16D, Moyclare Bog SAC

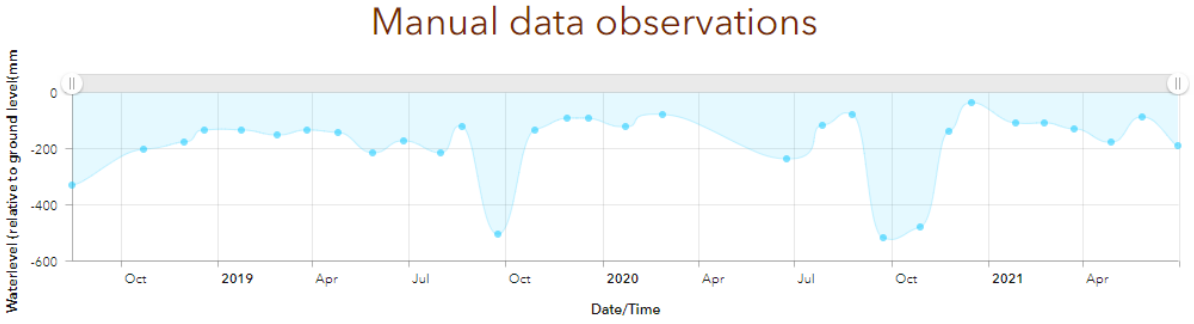

Figure 8-239 Hydrograph of manual monthly water levels MC 17S, Moyclare Bog SAC

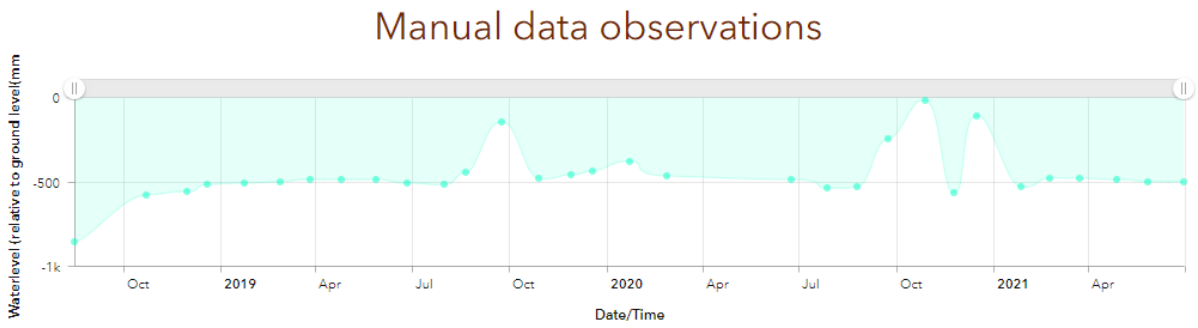

Figure 8-240 Hydrograph of manual monthly water levels MC 17D, Moyclare Bog SAC

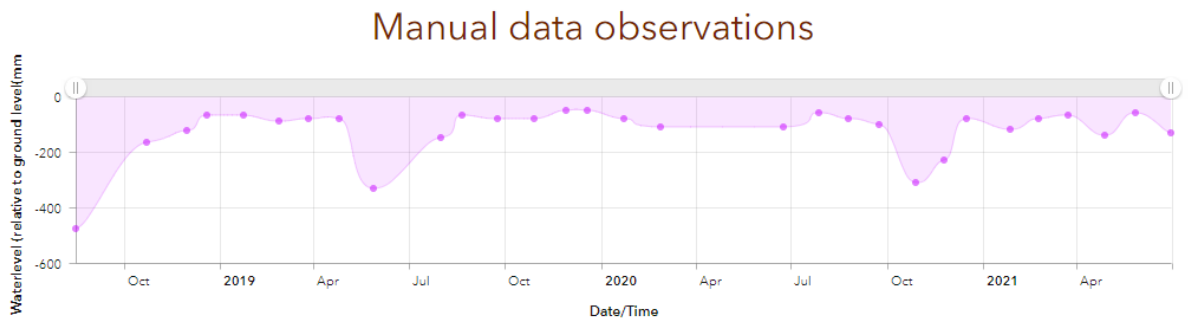

Figure 8-241 Hydrograph of manual monthly water levels MC 18S, Moyclare Bog SAC

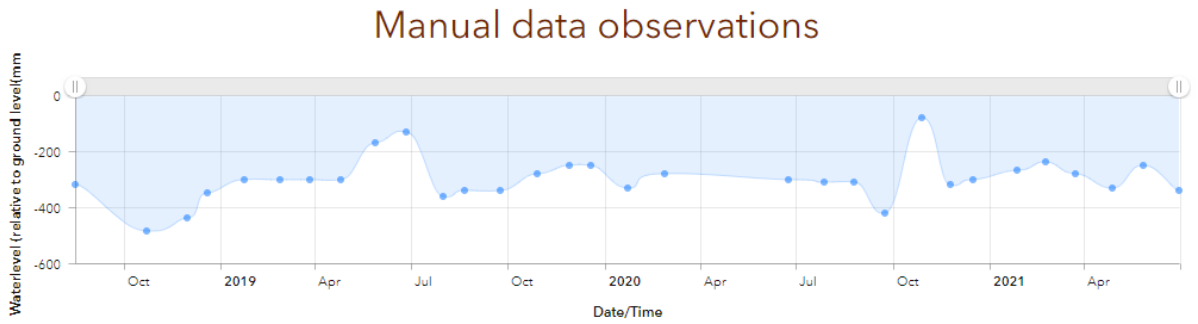

Figure 8-242 Hydrograph of manual monthly water levels MC 18D, Moyclare Bog SAC

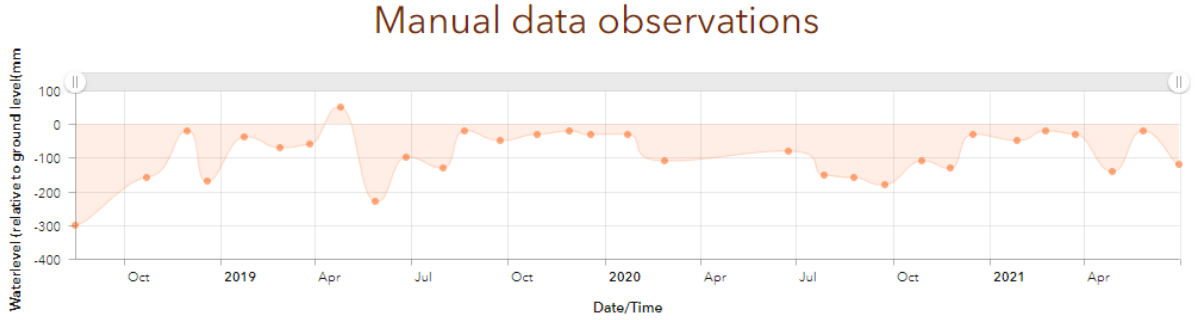

Figure 8-443 Hydrograph of manual monthly water levels MC 19S, Moyclare Bog SAC

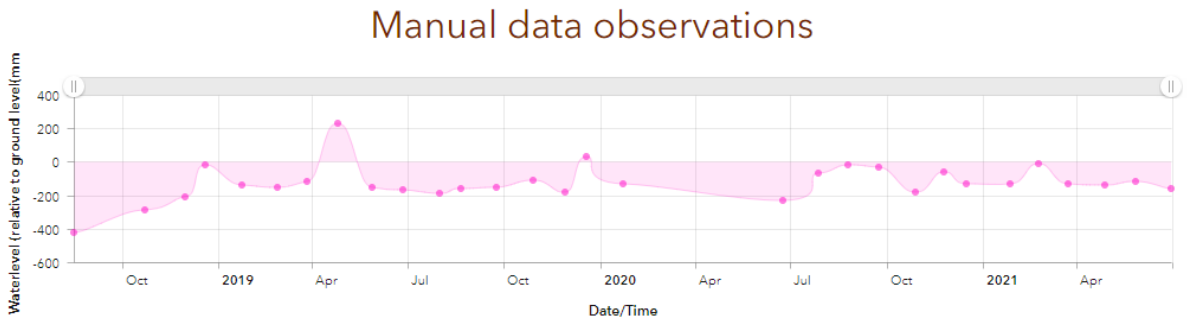

Figure 8-244 Hydrograph of manual monthly water levels MC 19D, Moyclare Bog SAC

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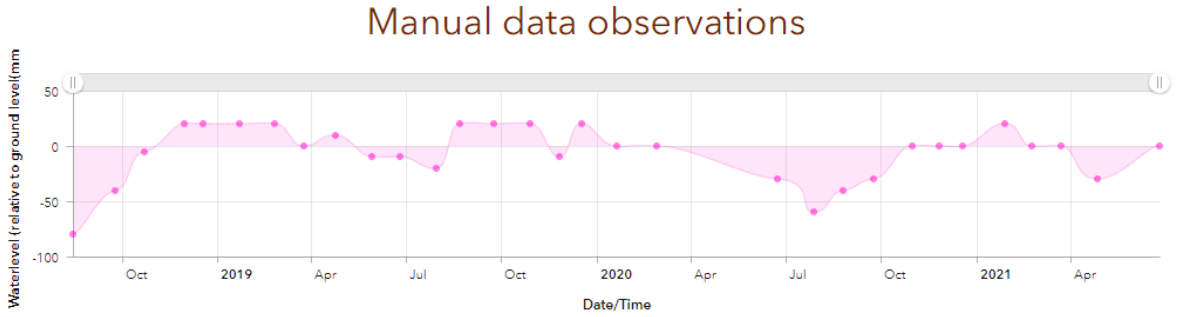

Figure 8-245 Hydrograph of manual monthly water levels R 2, Raheenmore Bog SAC

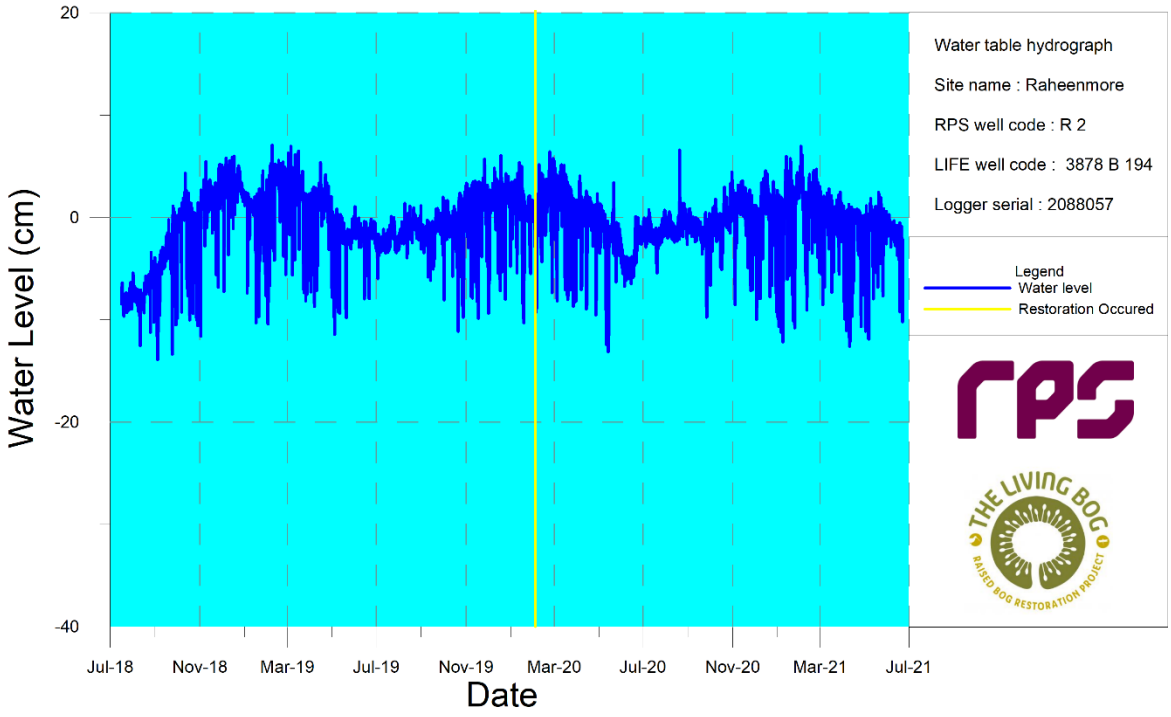

Figure 8-246 Level logger data recorded between July 2018 and July 2021 at well R2, Raheenmore Bog SAC

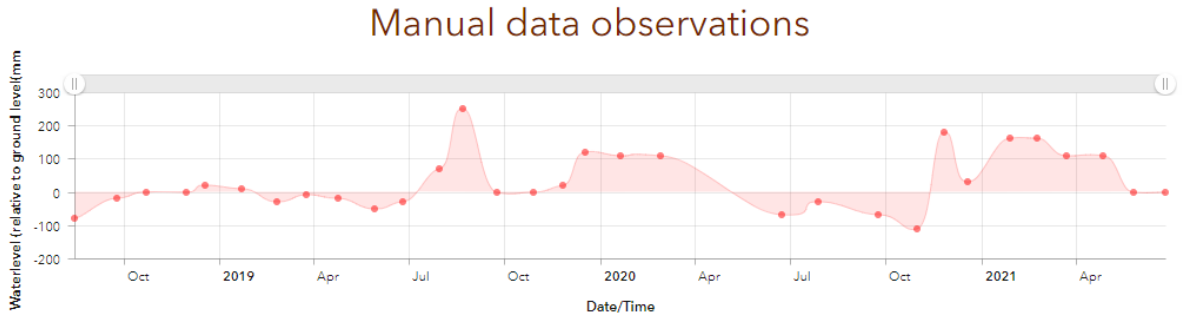

Figure 8-247 Hydrograph of manual monthly water levels R 4S, Raheenmore Bog SAC

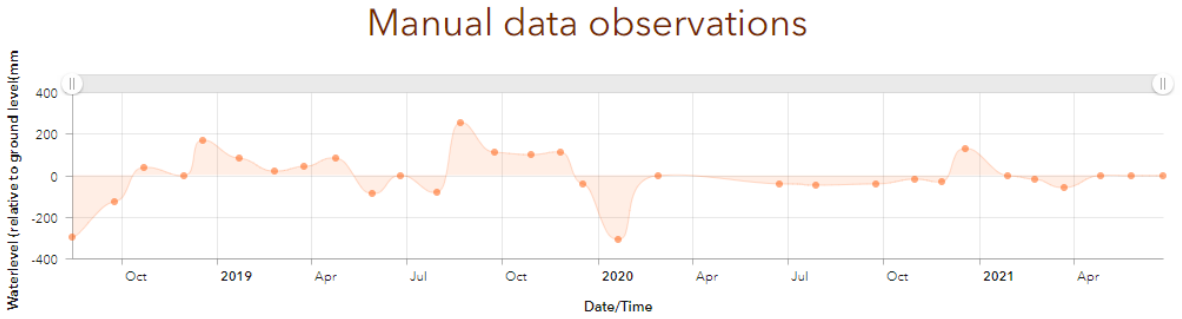

Figure 8-248 Hydrograph of manual monthly water levels R 4D, Raheenmore Bog SAC

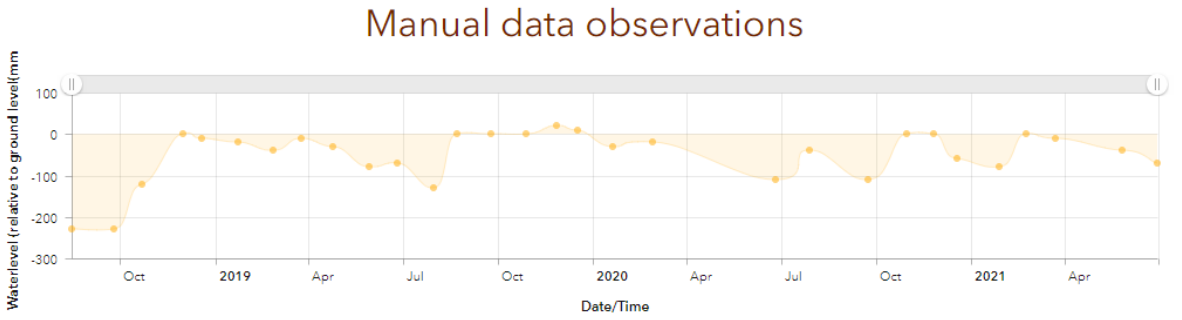

Figure 8-249 Hydrograph of manual monthly water levels R 5, Raheenmore Bog SAC

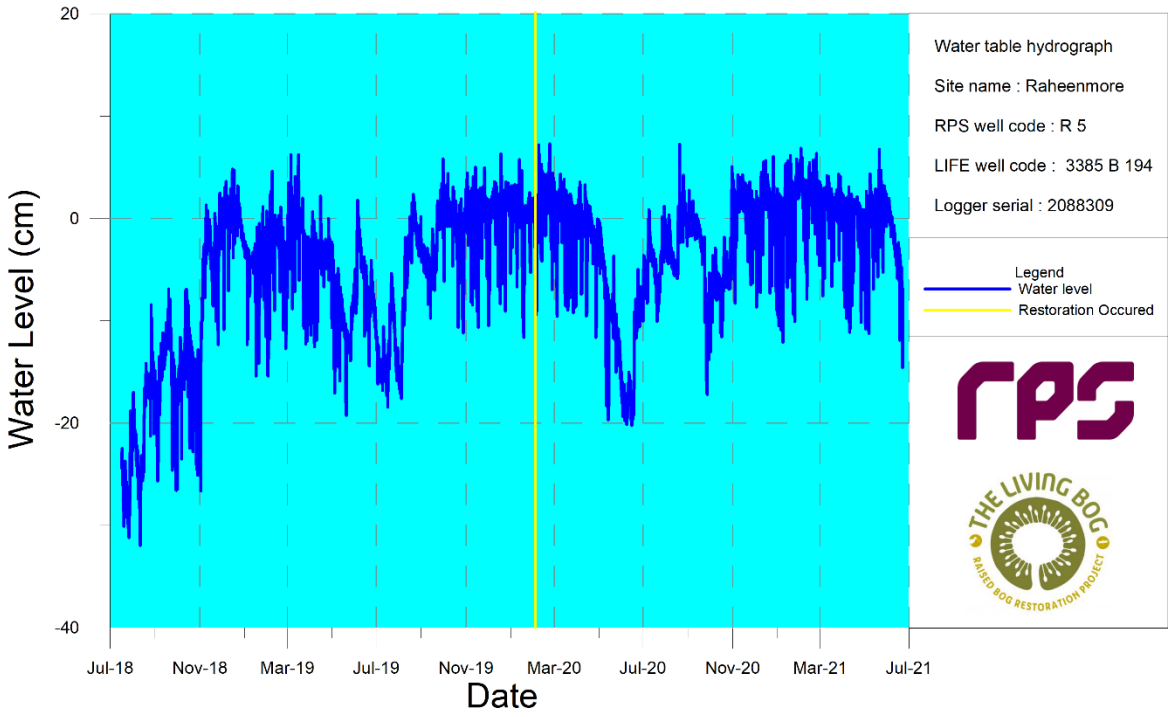

Figure 8-250 Level logger data recorded between July 2018 and July 2021 at well R5, Raheenmore Bog SAC

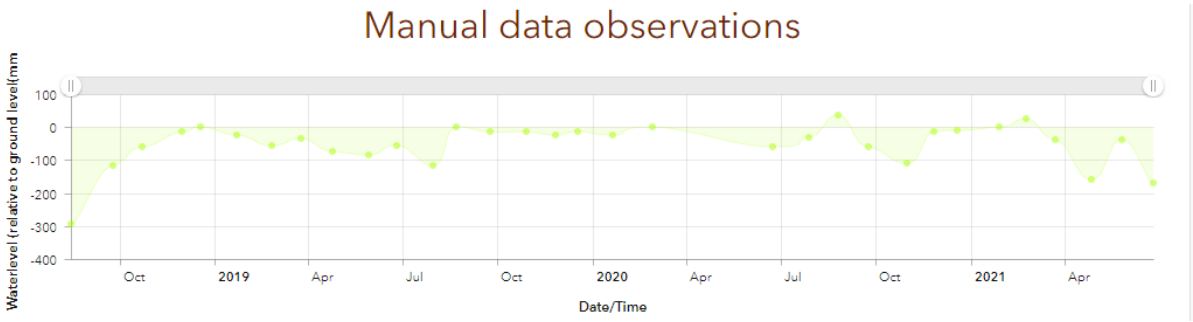

Figure 8-251 Hydrograph of manual monthly water levels R 6S, Raheenmore Bog SAC

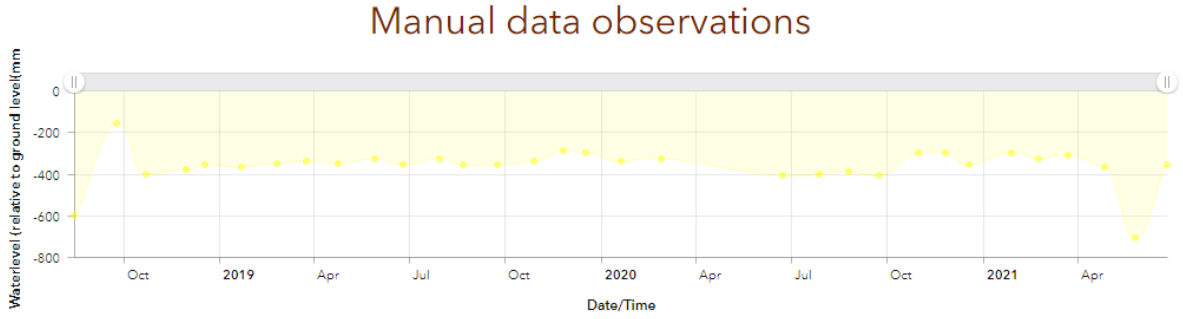

Figure 8-252 Hydrograph of manual monthly water levels R 6D, Raheenmore Bog SAC

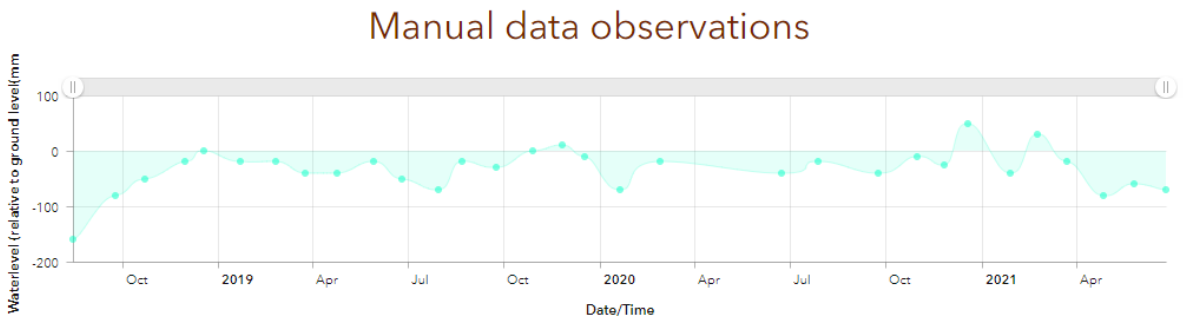

Figure 8-253 Hydrograph of manual monthly water levels R 7S, Raheenmore Bog SAC

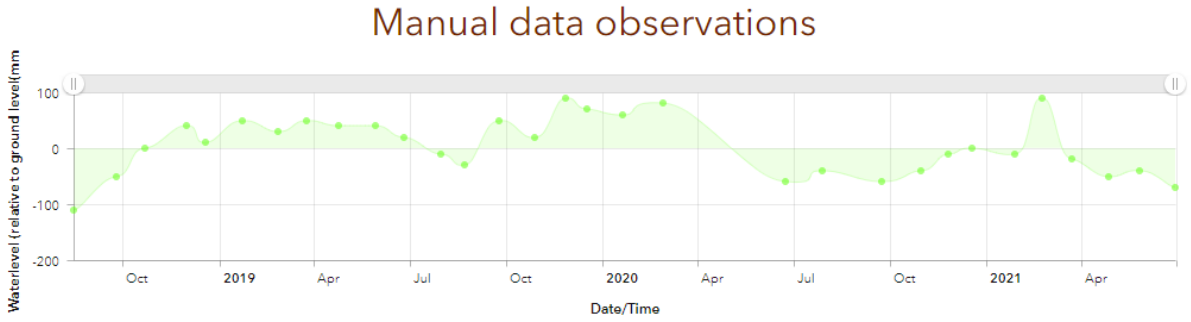

Figure 8-554 Hydrograph of manual monthly water levels R 7D, Raheenmore Bog SAC

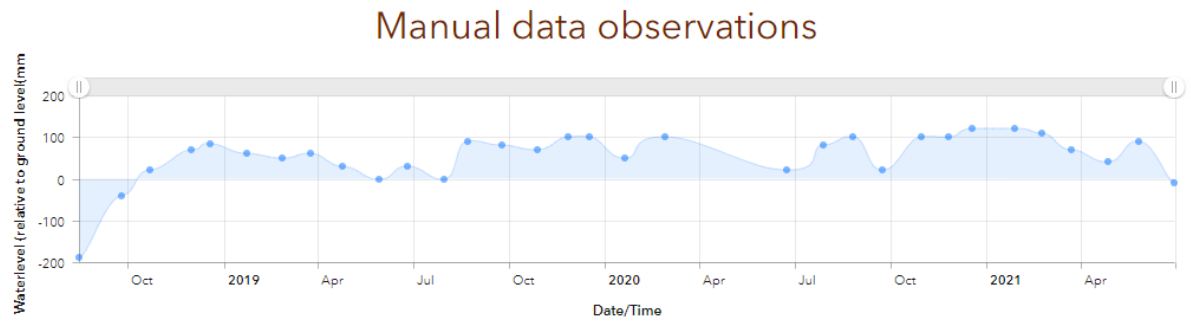

Figure 8-255 Hydrograph of manual monthly water levels R 8S, Raheenmore Bog SAC

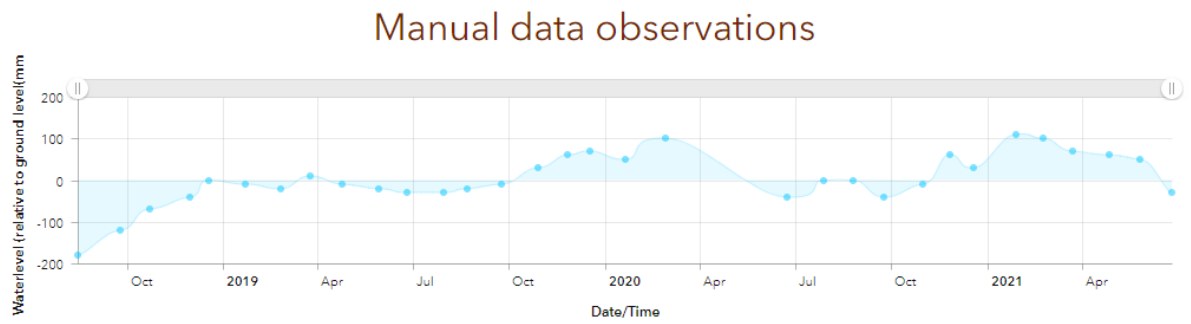

Figure 8-256 Hydrograph of manual monthly water levels R 8D, Raheenmore Bog SAC

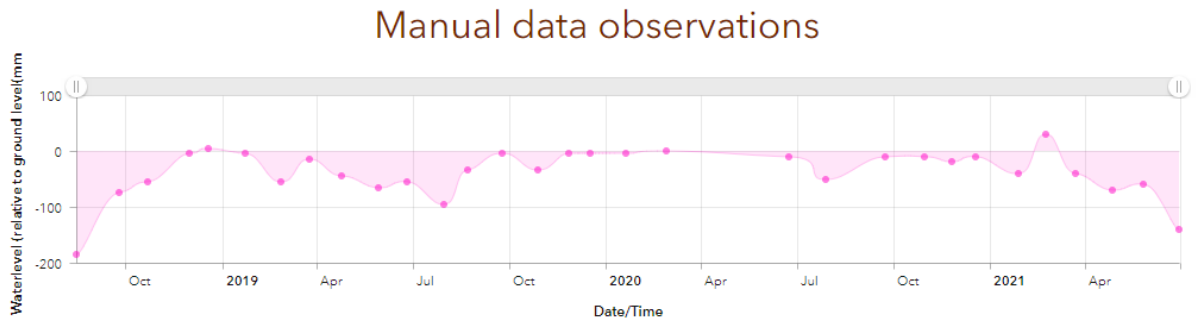

Figure 8-257 Hydrograph of manual monthly water levels R 9S, Raheenmore Bog SAC

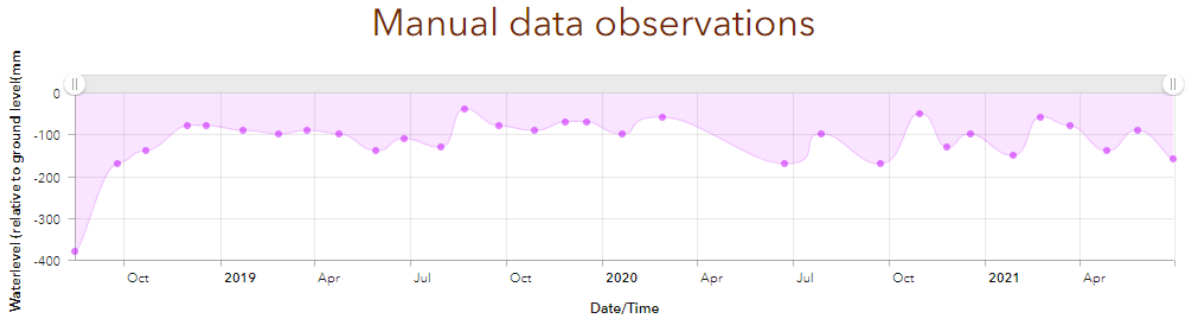

Figure 8-258 Hydrograph of manual monthly water levels R 9D, Raheenmore Bog SAC

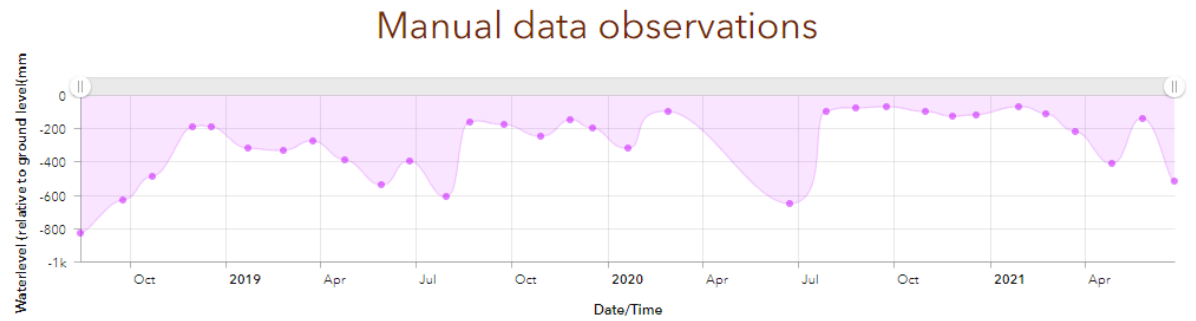

Figure 8-259 Hydrograph of manual monthly water levels R 10, Raheenmore Bog SAC

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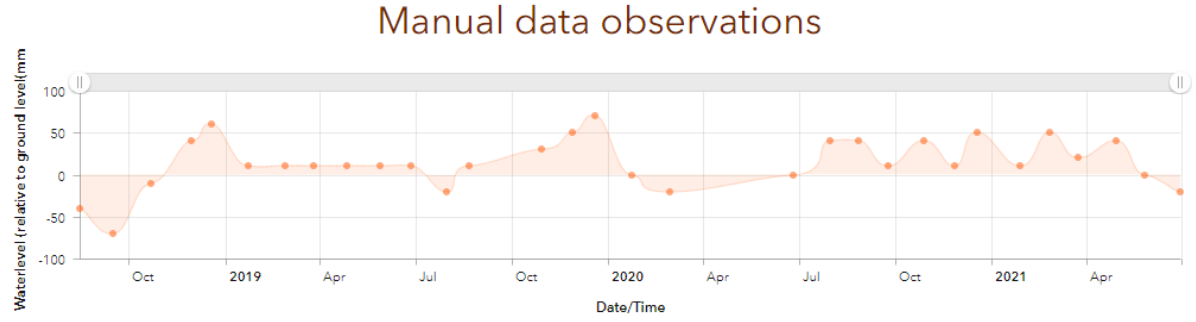

Figure 8-260 Hydrograph of manual monthly water levels S 1, Sharavogue Bog SAC

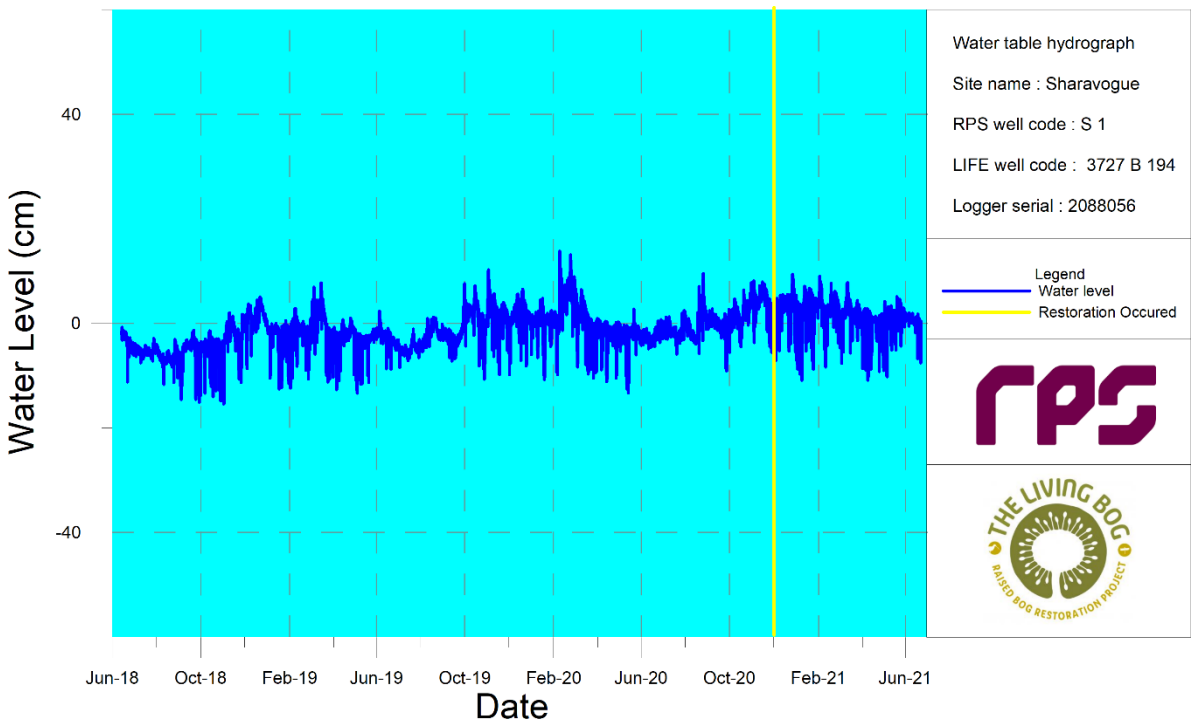

Figure 8-261 Level logger data recorded between June 2018 and July 2021 at well S1, Sharavogue Bog SAC

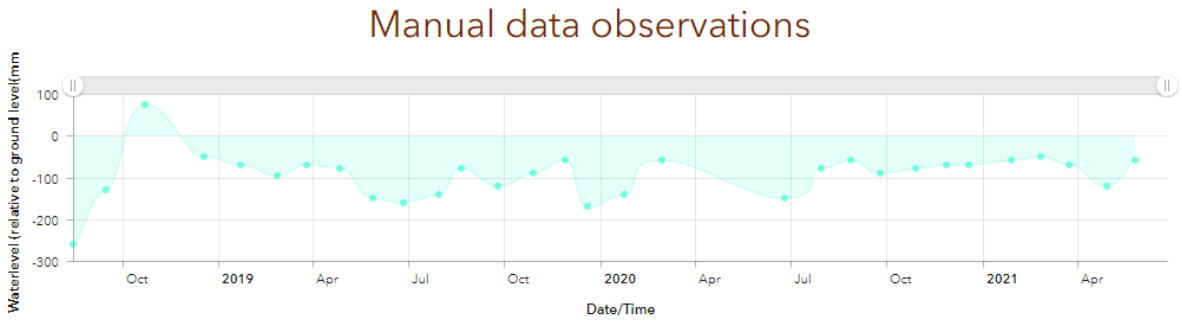

Figure 8-262 Hydrograph of manual monthly water levels S 2, Sharavogue Bog SAC

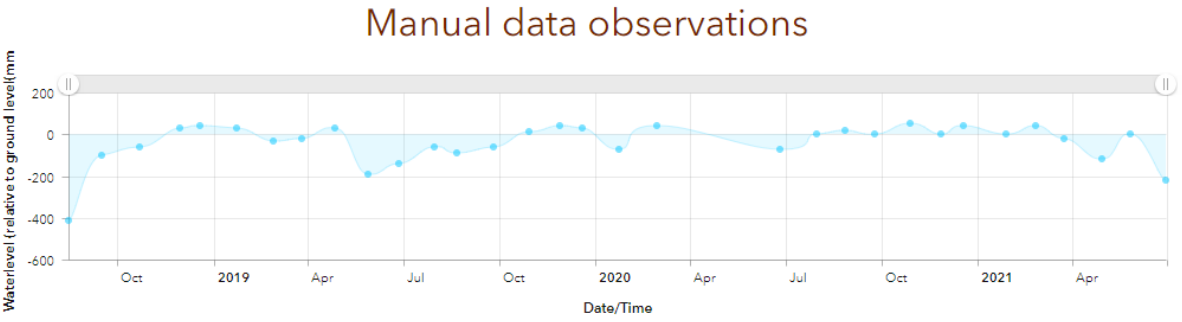

Figure 8-263 Hydrograph of manual monthly water levels S 3, Sharavogue Bog SAC

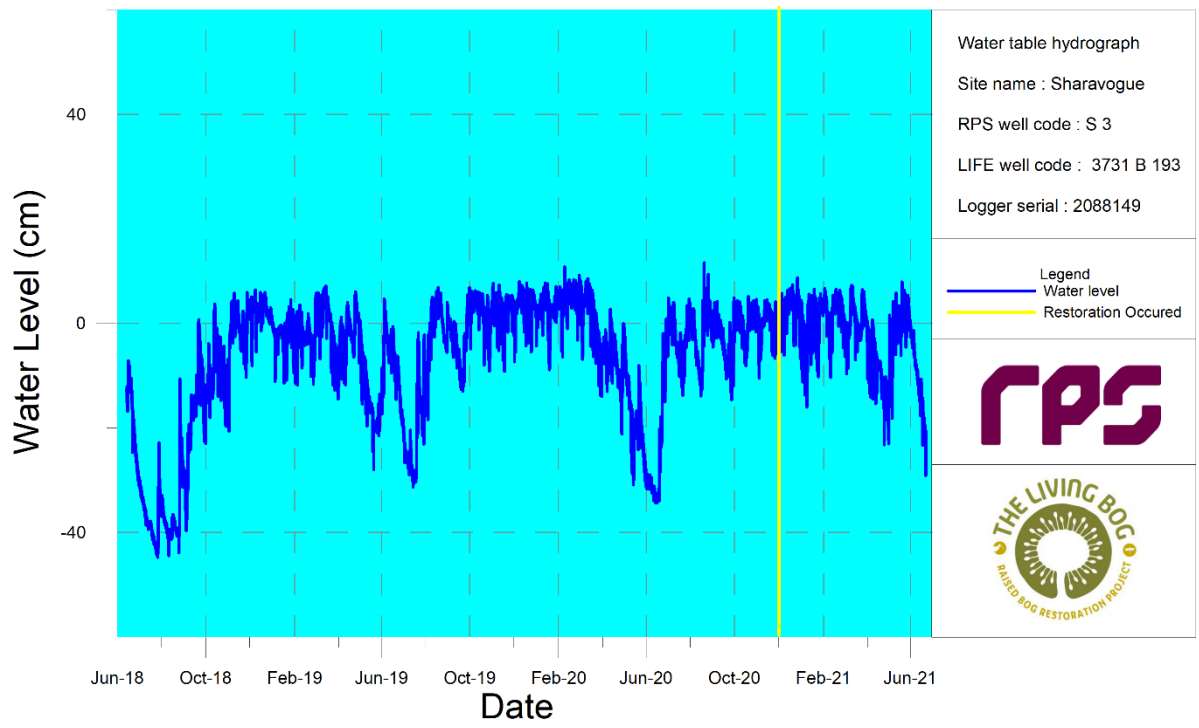

Figure 8-264 Level logger data recorded between June 2018 and July 2021 at well S3, Sharavogue Bog SAC

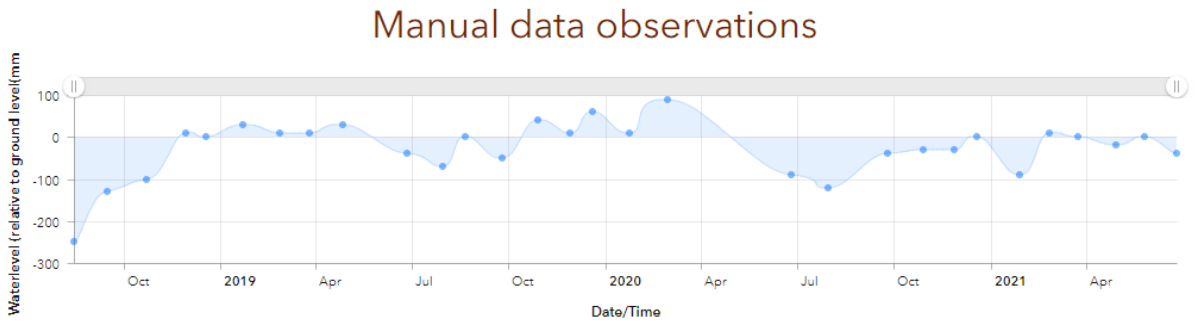

Figure 8-265 Hydrograph of manual monthly water levels S 4, Sharavogue Bog SAC

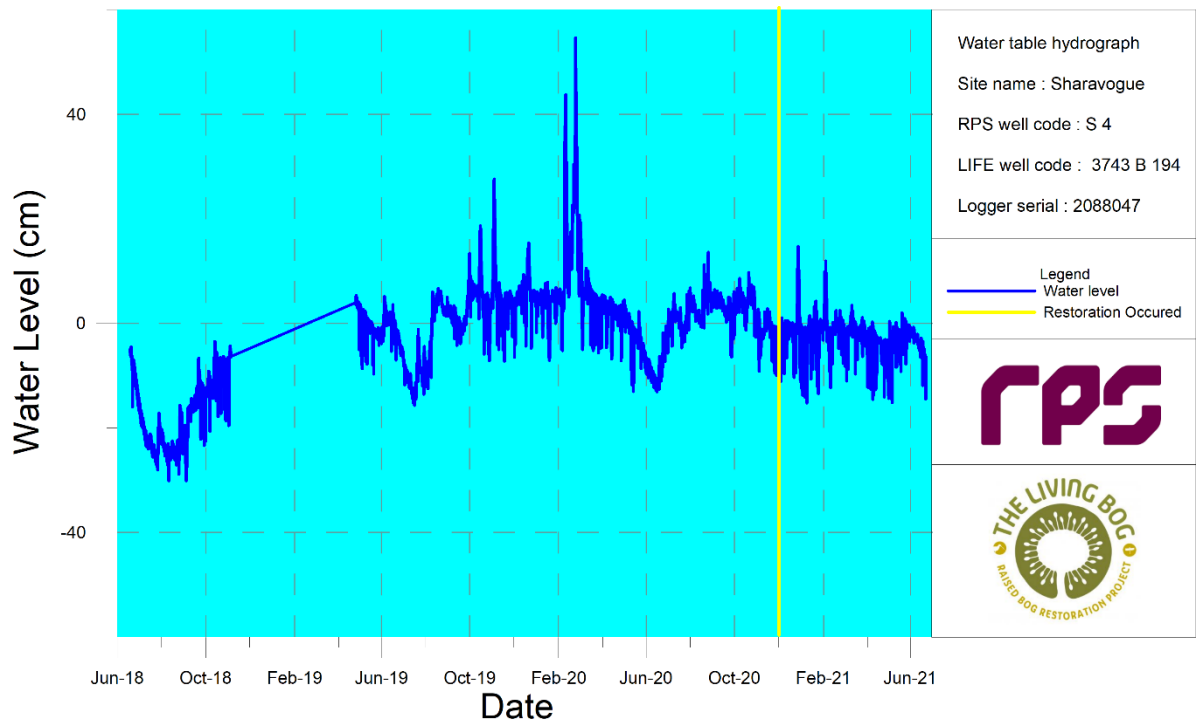

Figure 8-266 Level logger data recorded between June 2018 and July 2021 at well S4, Sharavogue Bog SAC

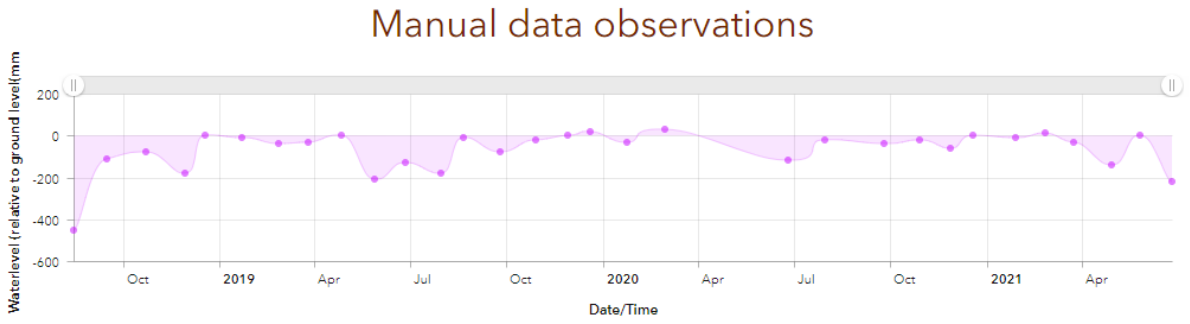

Figure 8-267 Hydrograph of manual monthly water levels S 5, Sharavogue Bog SAC

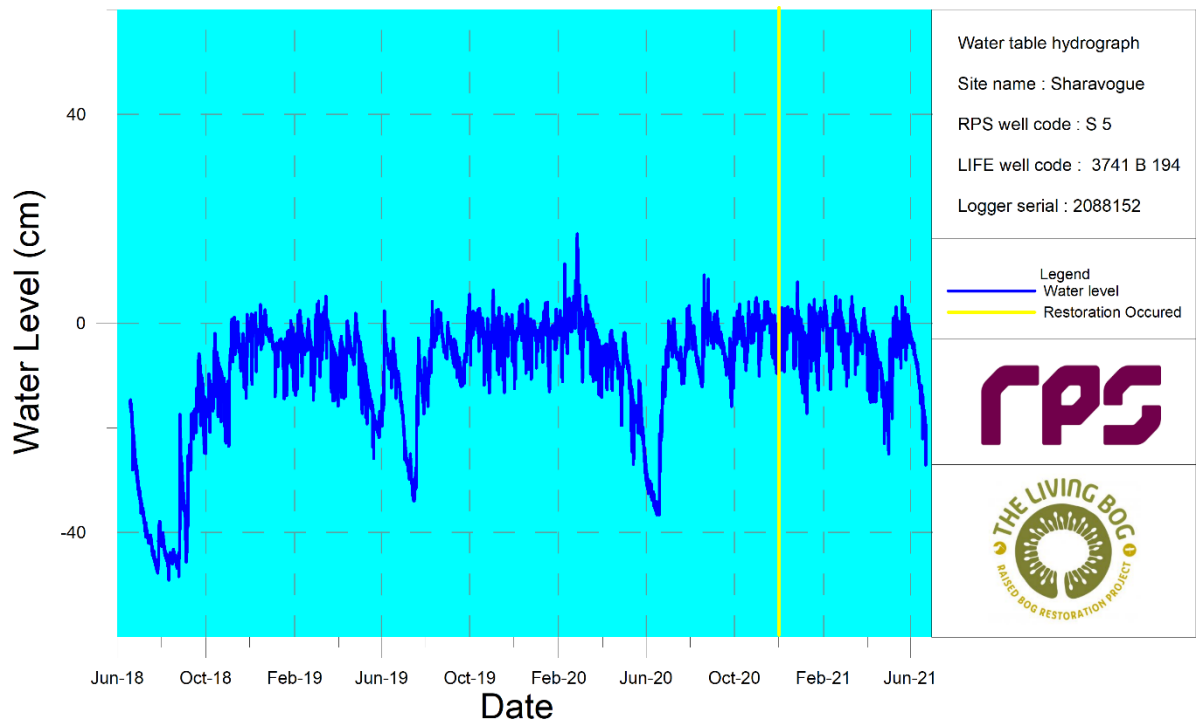

Figure 8-268 Level logger data recorded between June 2018 and July 2021 at well S5, Sharavogue Bog SAC

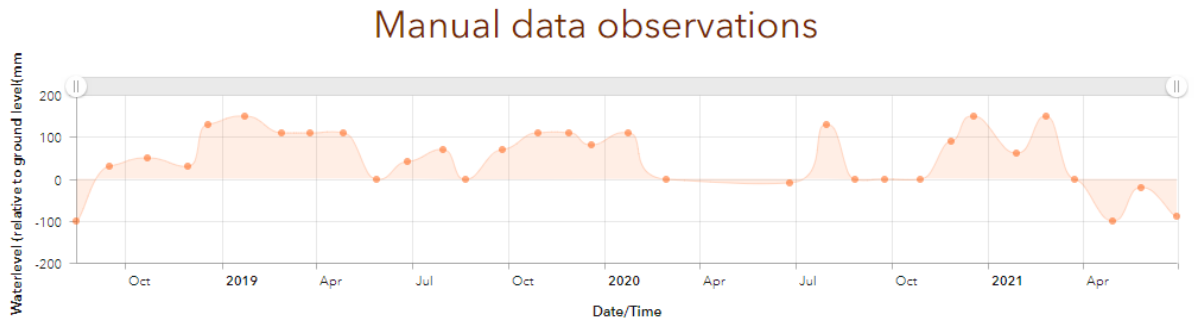

Figure 8-669 Hydrograph of manual monthly water levels S 6S, Sharavogue Bog SAC

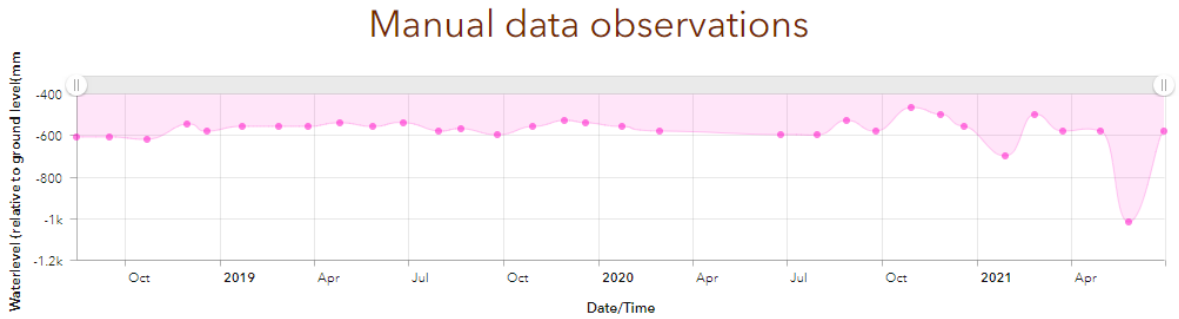

Figure 8-270 Hydrograph of manual monthly water levels S 6D, Sharavogue Bog SAC

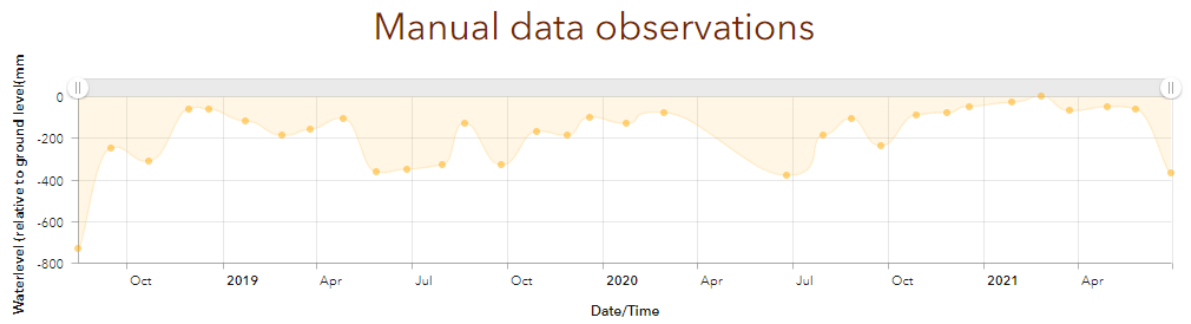

Figure 8-271 Hydrograph of manual monthly water levels S 7S, Sharavogue Bog SAC

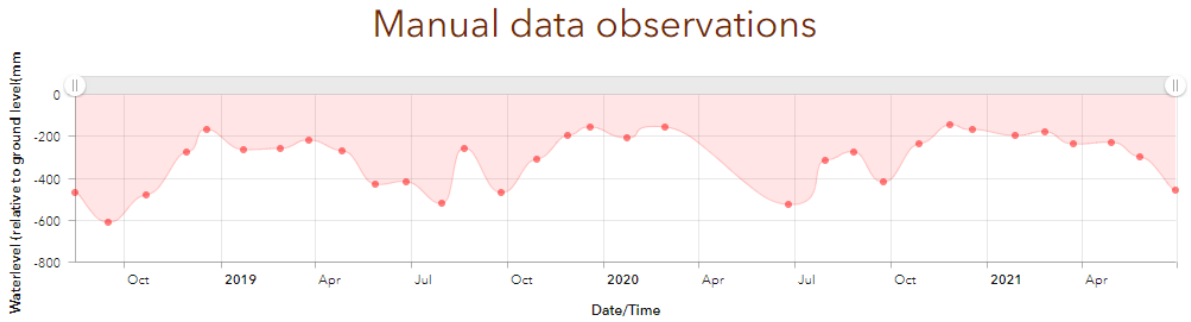

Figure 8-272 Hydrograph of manual monthly water levels S 7D, Sharavogue Bog SAC

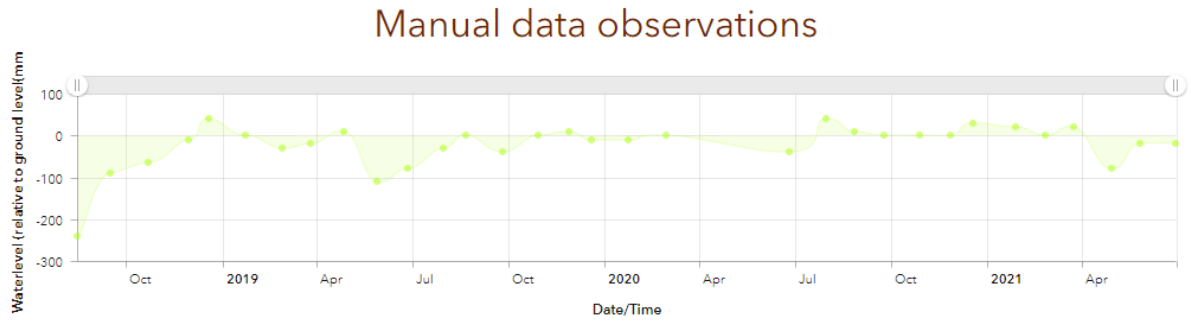

Figure 8-273 Hydrograph of manual monthly water levels S 8S, Sharavogue Bog SAC

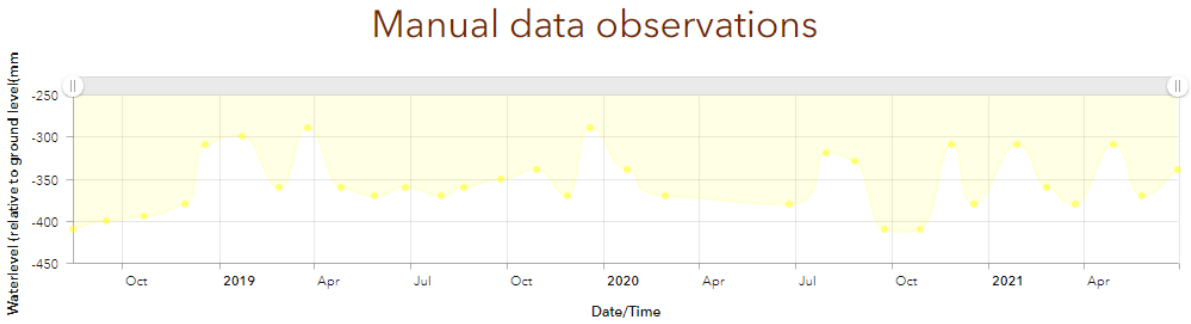

Figure 8-274 Hydrograph of manual monthly water levels S 8D, Sharavogue Bog SAC

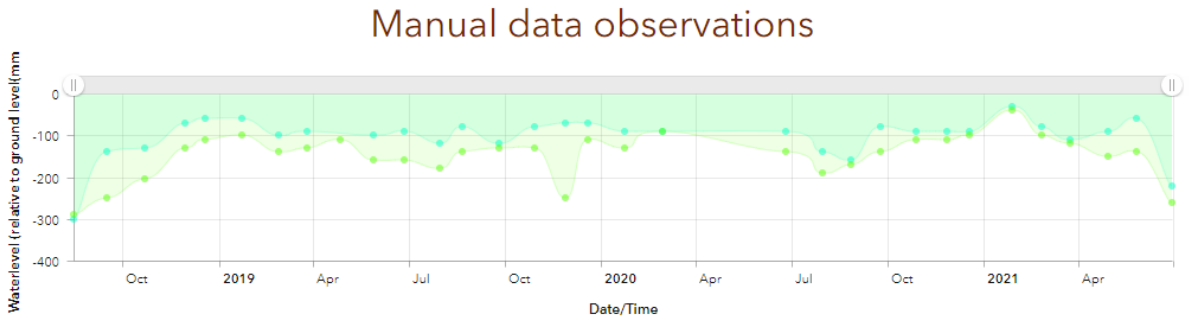

Figure 8-275 Hydrograph of manual monthly water levels S 9S (light green) and 9D (dark green), Sharavogue Bog SAC

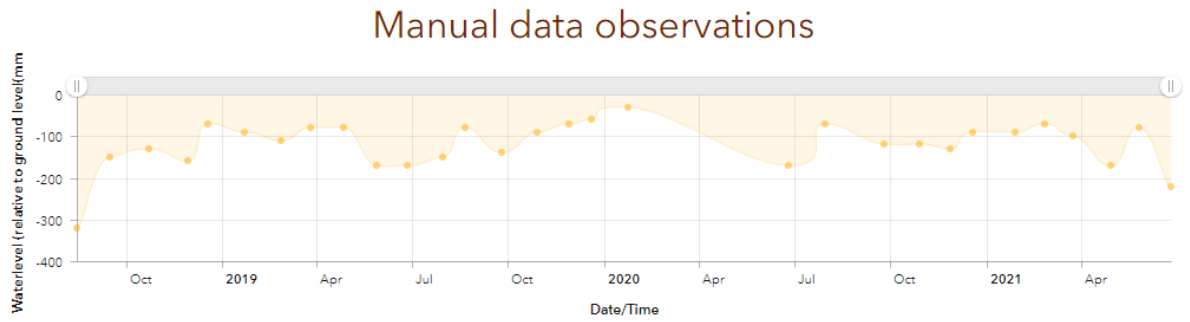

Figure 8-276 Hydrograph of manual monthly water levels S 10S, Sharavogue Bog SAC

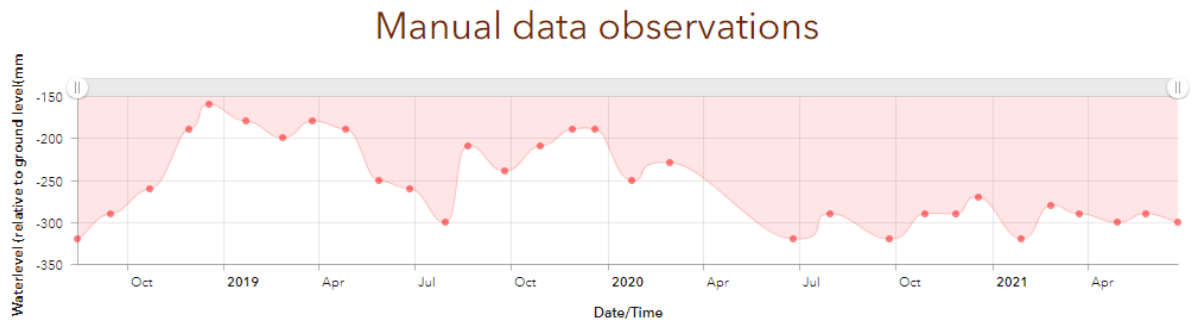

Figure 8-277 Hydrograph of manual monthly water levels S 10D, Sharavogue Bog SAC

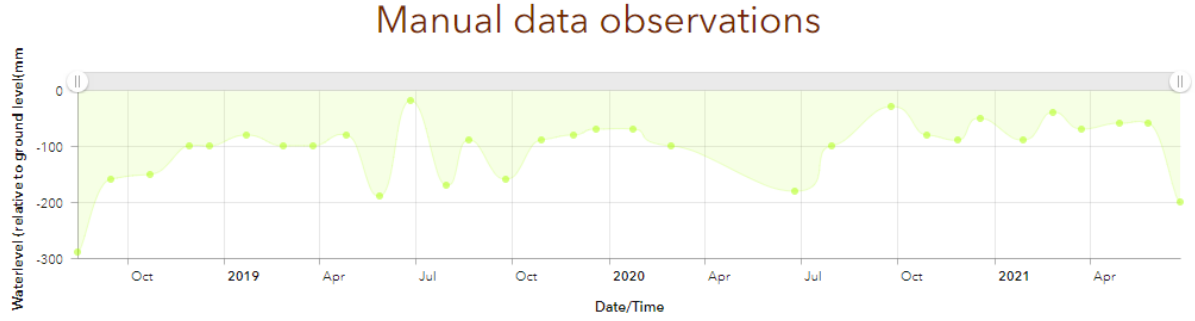

Figure 8-278 Hydrograph of manual monthly water levels S 11S, Sharavogue Bog SAC

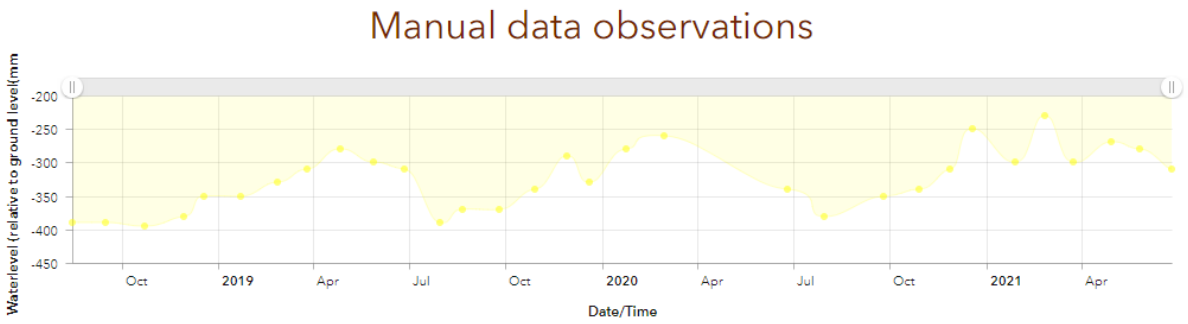

Figure 8-279 Hydrograph of manual monthly water levels S 11D, Sharavogue Bog SAC

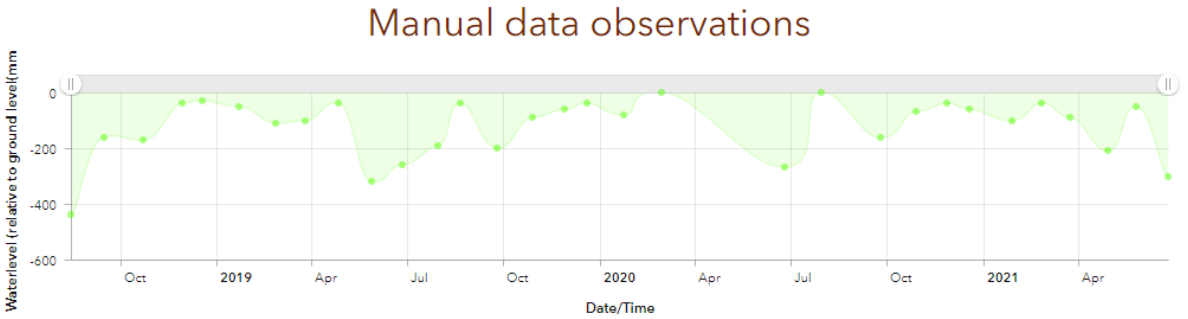

Figure 8-280 Hydrograph of manual monthly water levels S 12, Sharavogue Bog SAC