Galway County Council

Five years annual monitoring of Rahasane Turlough

2022 report (Year 2) on monitoring programme post works on Flood Relief Scheme

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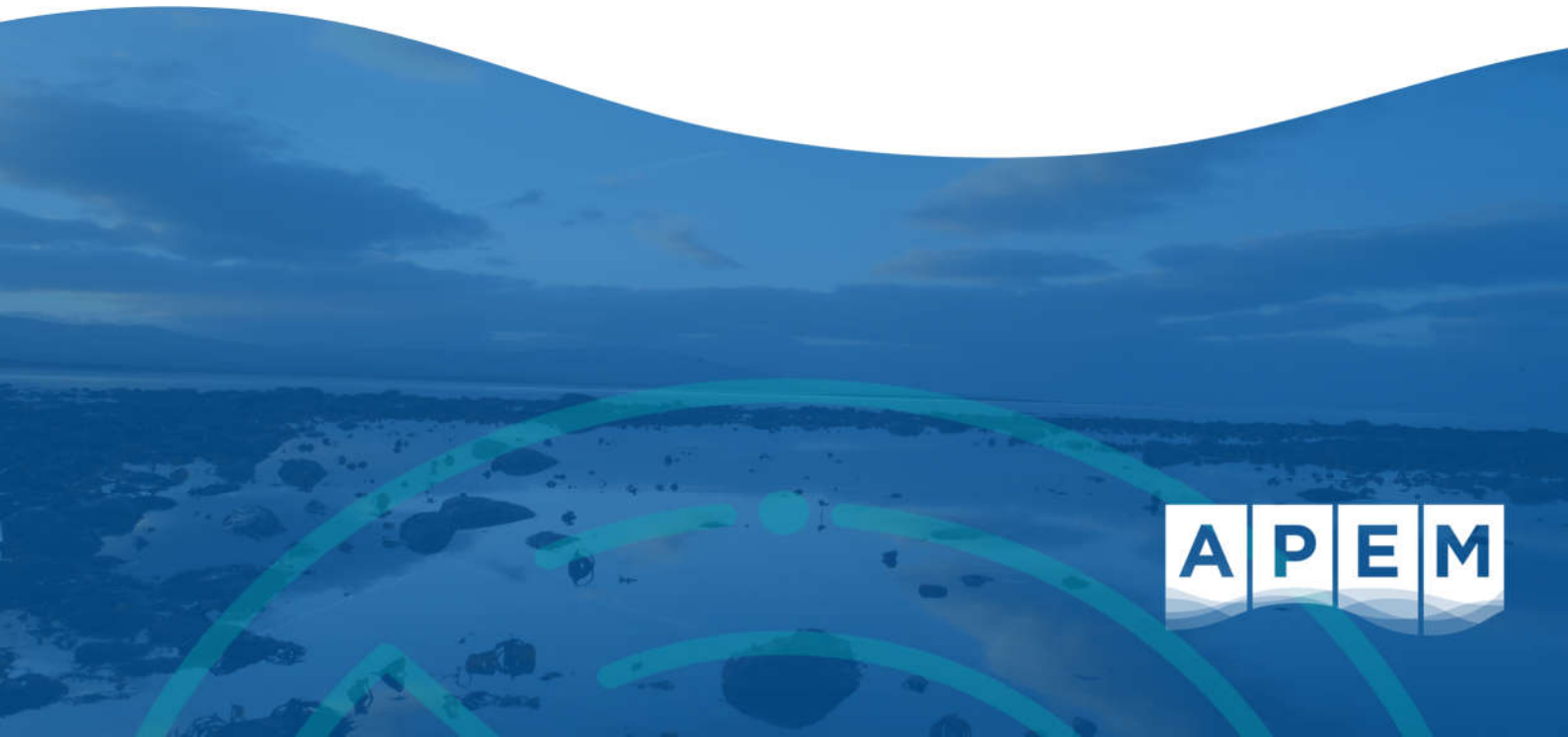
February 2023



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1. Introduction

1.1. Background

In November 2009, the flooding of the Dunkellin River and Aggard Stream caused damage and disruption to life and properties in the Craughwell and Kilcolgan areas in Co. Galway. As a result, the Office of Public Works (OPW) commissioned a study of the flooding, its causes and effects, to identify a preferred flood relief scheme (FRS) to reduce frequency and/or impact of similar future flooding. In 2011, Galway County Council commissioned an assessment of the likely environmental impacts of the proposed scheme. An agreed scheme was developed, including flood relief works (a combination of river widening, deepening, culvert upgrade and replacement, bridge improvement and replacement, and general channel maintenance). The scheme was designed to provide optimum flood relief with minimum environmental impact, whilst also satisfying cost-benefit criteria. The planning application for the scheme (07.JA0035) submitted by Galway County Council, was granted with seven associated conditions. Of these, Condition No. 4 states:

'For a period of five years following completion of all works, the local authority shall undertake annual monitoring at Rahasane Turlough, to include:

(a) field assessment of swallow holes and recording of natural collapse of conduits or infilling of swallow holes
(b) monitoring of water level at existing river gauges up and down gradient of Rahasane Turlough, and
(c) monitoring of vegetation and indicator species at Rahasane Turlough

Reason: In the interest of the protection of the environment and to broaden scientific knowledge.'

Works on the FRS are complete and Galway County Council, wishing to fulfil its commitments under Condition 4 of the issuance of planning permission, have therefore, appointed APEM Ireland Ltd (APEM) to undertake the required field surveys and assessments for a period of five years, starting from July 2021. In each year, APEM will undertake the agreed monitoring and submit an annual findings report, followed by a final report at the end of the 5-year monitoring period.

As no works implemented have directly impacted on Rahasane Turlough itself, the main concerns with regard to the site relate to any possible change in the hydrological regime that pertained/pertains to and within it on an annual basis, and in particular, whether implementation of the FRS might lead to any drying out/reduction in the extent and/or frequency of flooding. The proposed alterations to the Dunkellin River and its bridges have been designed to have virtually no impact on the hydrological regime of Rahasane Turlough, according to the Environmental Impact Assessment. Turlough water levels are predicted to change slightly, but these are not predicted to be significant under flood conditions. Maximum flood levels are predicted to remain unchanged and predicted surface water profiles for various flow scenarios (e.g., 5th percentile, 10th percentile) show no, or, at most, imperceptible changes between the pre- and post-works situations. However, the impact of a possible change in the hydrological regime of the turlough may be detected through the monitoring proposed by An Bord Pleanála (ABP), as follows:

1. Reduction in number, or complete cessation, of changes to the physical structure of the Karst below the turlough, e.g. reduced/zero new incidences of collapse or infilling of swallow holes;
2. Lower water levels and reduced flow volumes and velocity into / out of the turlough as compared to those recorded in the past;
3. Changes in composition of the vegetation, e.g. a shift away from wetland species to more dryland species, and;
4. Changes in the composition of freshwater macroinvertebrate fauna from one characteristic of a regularly flooded habitat to one of a more frequently dry habitat.

This report covers the second year of annual monitoring, conducted between July and September of 2022.

1.2. Report Structure

The report is structured to meet the requirements of Condition No. 4 under which An Bord Pleanála granted the application (07.JA0035). Therefore, the remaining structure of the report is as follows:

- Chapter 2 (Hydrogeology and Hydrology Surveys) will report on Condition 4 part (a) '*field assessment of swallow holes and recording of natural collapse of conduits or infilling of swallow holes*' and on Condition 4 part (b) '*monitoring of water level at existing river gauges up-gradient and down gradient of Rahasane Turlough'*.

- Chapter 3 (Vegetation Survey) will report on the first part of Condition 4 part (c) *monitoring of vegetation… at Rahasane Turlough'.*

- Chapter 4 (Macroinvertebrate Survey) will report on the second part of Condition 4 part (c) *monitoring of … indicator species at Rahasane Turlough'*.

- Chapter 5 (Key Findings from Year 2) will summarise the findings of the surveys for this second year.

2. Hydrogeology and Hydrology Surveys

2.1. Methods

The ecosystem associated with the Rahasane Turlough SAC is highly dependent on the hydrological flow regime at the site. The hydrological flow regime is, in turn, defined by the karst system that underlies the turlough catchment. The surface expression of the karst system is manifested by karst features such as caves, swallow holes, estavelles (ground feature that can act as a sink or supply of water depending on surrounding hydrological and hydrogeological conditions) and springs. The key challenge is differentiating natural changes in hydrological behaviour from those which may be attributed to the flood scheme. To meet this challenge, we have undertaken the following:

- Review of previous datasets and reports;
- The second of five annual drone surveys;
- Visited and conducted a brief assessment of the four OPW hydrometric stations associated with the Rahasane Turlough;
- Collected and assessed relevant hydrometric station data; and
- Conducted a site walkover of the turlough to ground-truth and observe karst features for annual monitoring purposes.

2.1.1. Review of previous datasets and reports

The following sources of site-specific data were reviewed:

- OPW – 2010 Preliminary Flood Risk assessments – Groundwater Flooding;
- OPW – 2018 Flood Risk Management Plan – Galway Bay South East;
- OPW – 2019 Strategic Environmental Assessment Statement - Galway Bay South East;
- RPS - 2014 Environmental Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme);
- RPS – 2014 Natura Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme);
- RPS – 2016 Preconstruction Assessment Geology and Hydrogeology; and
- OPW – Water level and flow data at gauging stations deemed relevant to the FRS, notably on the Dunkellin River near the Rahasane SAC.

The following additional sources of publicly available data and information were checked and used as appropriate:

- Geological Survey Ireland (GSI) web-based groundwater data viewer, specifically the GSI karst database;
- Ordnance Survey Ireland (Geohive) – Historic maps and aerial photography;
- Environmental Protection Agency (EPA web-based data viewer "EPA map viewer"); and
- National Parks and Wildlife Service (NPWS) web-based data viewer (Special Areas of Conservation; Special Protection Areas).

2.1.2. Annual Drone Survey

The second of five annual drone surveys of the Rahasane Turlough was conducted in September 2022 to assist with the ground-truthing and monitoring of karst features. The survey was conducted using a DJI Mavic 2 Pro drone flown at a height of 125 m. The imagery captured was processed using the

software programme DroneDeploy. Access to view and compare the processed and collated imagery for 2021 and 2022 has been provided to Mr Enda Gallagher of Galway County Council.

2.1.3. OPW Hydrometric Stations

OPW Hydrometric Stations (gauging stations) are measurement stations installed on rivers and lakes to record water levels, temperature and/or flow, mainly for flood risk management purposes. In the context of the FRS and the Rahasane Turlough SAC, three existing hydrometric stations on the Dunkellin River were visited in August 2021 for preliminary assessment:

- Craughwell 29007
- Aggard Bridge 29010
- Rahasane Turlough 29002

These stations measure water levels upstream (29007, 29010) and downstream (29002) of Rahasane Turlough. Their locations are shown on Drawing 1 in Appendix 1.

Craughwell 29007 (Plate 1) is a relatively new hydrometric station on the Dunkellin River. It is approximately 230 m downstream of former monitoring station 29007. The latter was replaced with the new station following the construction of the FRS through Craughwell village. The new station 29007 is located upstream of a bridge and is positioned to measure the river levels where the natural river course and the FRS are combined. It records the water level and temperature at 15-minute intervals using an OTT PLS sensor. The data are stored in a data logger and automatically loaded to a server via solar-powered telemetry.

The riverbed at the hydrometric station appears relatively clean (i.e. free of vegetation or other obstacles). The riverbanks are built up with rocks for stability purposes, to a level of approx. 2.7 m above the stream bed. There is a concrete structure which slopes 45° towards the stream at the base of the nearby bridge.

Aggard Bridge 29010 (Plate 2) records the water level and temperature on a tributary of the Dunkellin River at 15-minute intervals. Data are recorded using an OTT sensor and stored in an in-situ data logger (Plate 3). The data are automatically transmitted to a server via solar-powered telemetry. The stream banks are heavily vegetated and the profile of the tributary changes over short distances. Downstream, the flow is channeled under a bridge.

Rahasane Turlough 29002 (Plate 4) records the water level and temperature of the Dunkellin River downstream of the Rahasane Turlough SAC. Data are recorded at 15-minute intervals using an OTT sensor and stored in a data logger. The data are automatically loaded to a server via solar-powered telemetry. The riverbanks at and upstream of the monitoring station are heavily vegetated.

2.1.4. Walkover survey – Rahasane Turlough

The second walkover survey to took place on 8 September 2022. The purpose of the walkover survey was two-fold:

a) to monitor the features recorded during the 2021 walkover; and
b) to record features exposed by the low turlough water level, where present.

During the 2022 walkover, the turlough was not inundated on the day of the visit. This was a result of the prolonged dry period that preceded the walkover. The low water levels can be seen from the drone survey which indicates that approximately 90% of an estimated total turlough area of 3.27 km^2 (NPWS) was above water.

2.1. Results and Discussion

2.1.1. Hydrometric Station Data

Water level data for each of the hydrometric stations are shown in Figures 1 - 3 for the period from the inception of this project (third quarter (Q3) of 2021, i.e. July, August, September) through the third quarter (Q3) of 2022. The data were obtained by the OPW Hydro-Data website (www.waterlevel.ie). Daily rainfall data from the Craughwell weather station (www.met.ie) were added to the graphs for illustration purposes (note, this data runs through end of July 2022 only).

Water level data for Q3 2021 through Q3 2022 for Craughwell 29007 are presented in Figure 1. During this period, water levels ranged between 17.1 mOD and 18.7 mOD (mean = 17.4 mOD). In 2022, water levels were at their lowest from June through September, generally between 17.1 and 17.3 m, corresponding to summer low flow. A large rainfall event towards the end of June resulted in a sharp water level rise to 17.6 mOD. Water levels fell through July to <17.2 m by the start of August. Notably, high rainfall events in July and August 2022 (up to 22.5 mm) were not mirrored by increased stream water levels. Highest water levels were recorded in February 2022 at 18.87 mOD followed by decreasing water levels with the lowest values recorded in the summer months of 2022.

Water level data for Q3 2021 through Q3 2022 from Aggard Bridge 29010 are presented in Figure 2. Water levels over this period ranged from 21.5 mOD to 21.9 mOD (mean = 21.3 mOD). The data incorporate some 'noise' but the water levels response is generally very similar to that described for Station 29007.

Water level data for Q3 2021 through Q3 2022 from Rahasane Turlough 29002 are presented in Figure 3. Water levels over this period ranged from 13.6 mOD to 16.4 mOD (mean = 14.3 mOD). As with the other streams, a large rainfall event towards the end of June resulted in a sharp water level rise to 14.2 mOD. Water level fell through July to <13.8 m by the start of August. As with Craughwell 29007, the high rainfall events in July and August 2022 (up to 22.5 mm) were not mirrored by increased stream water levels.

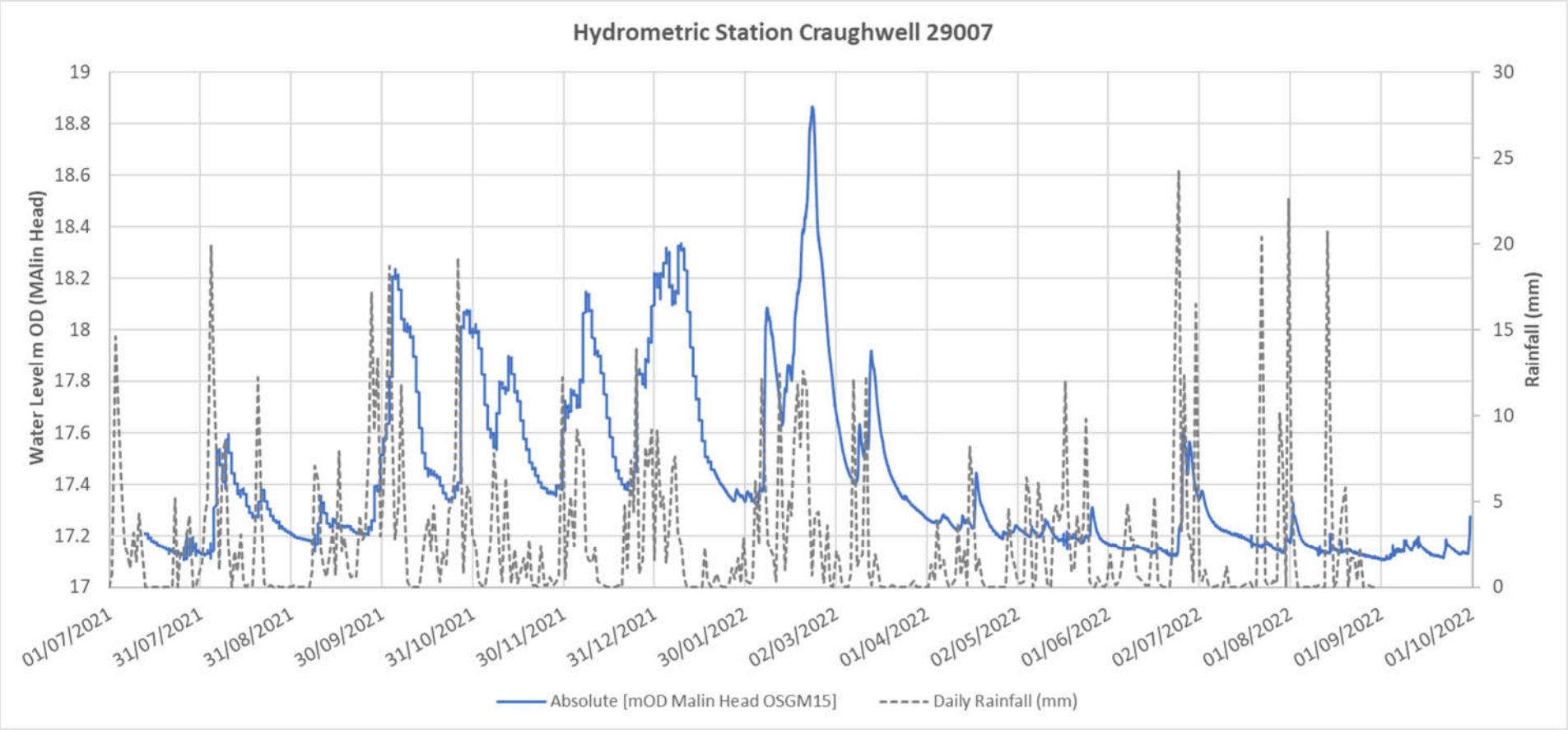

Figure 1:**Craughwell 29007, Q3 2021 through Q3 2022 Water Level and Craughwell Rainfall Data**

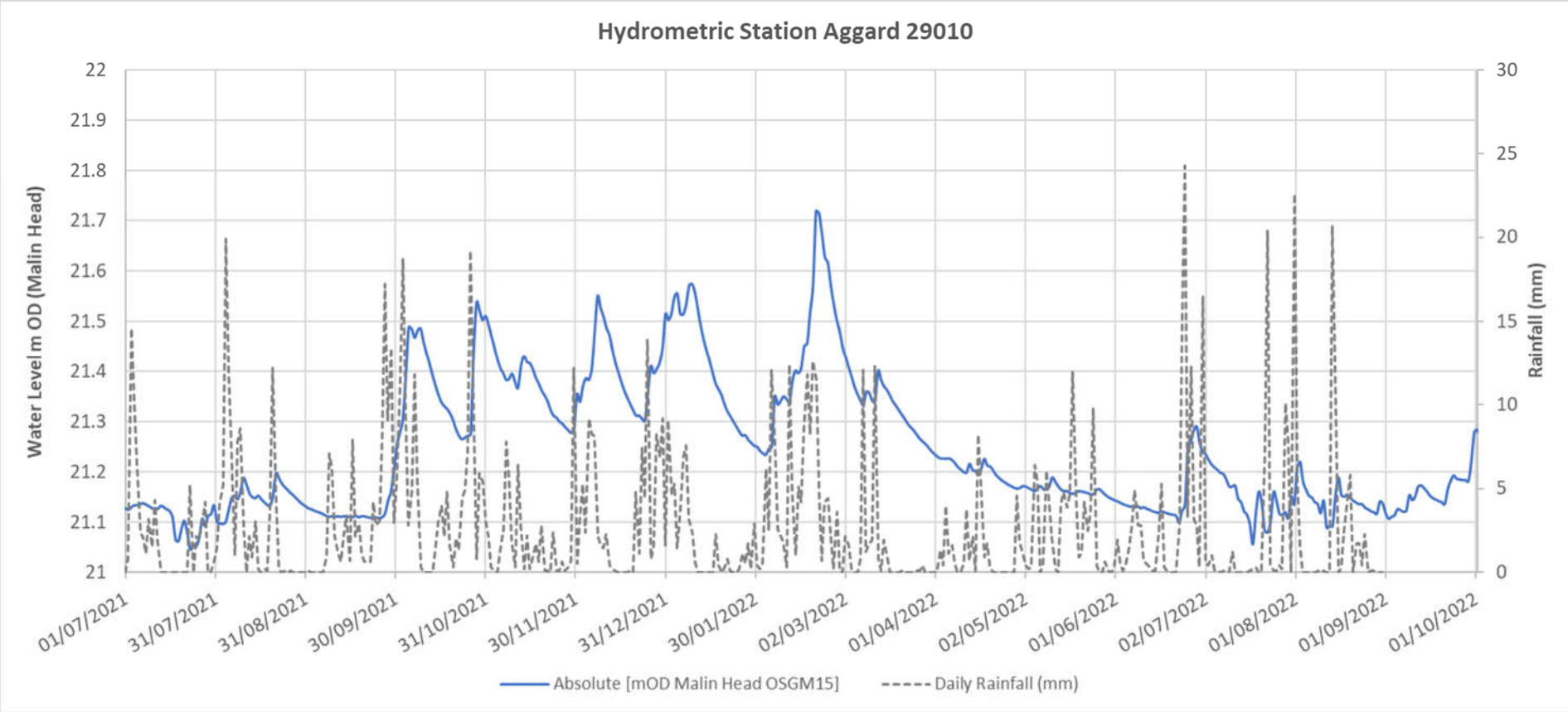

Figure 2: Aggard 29010, Q3 2021 through Q3 2022 Water Level and Rainfall (Craughwell) Data

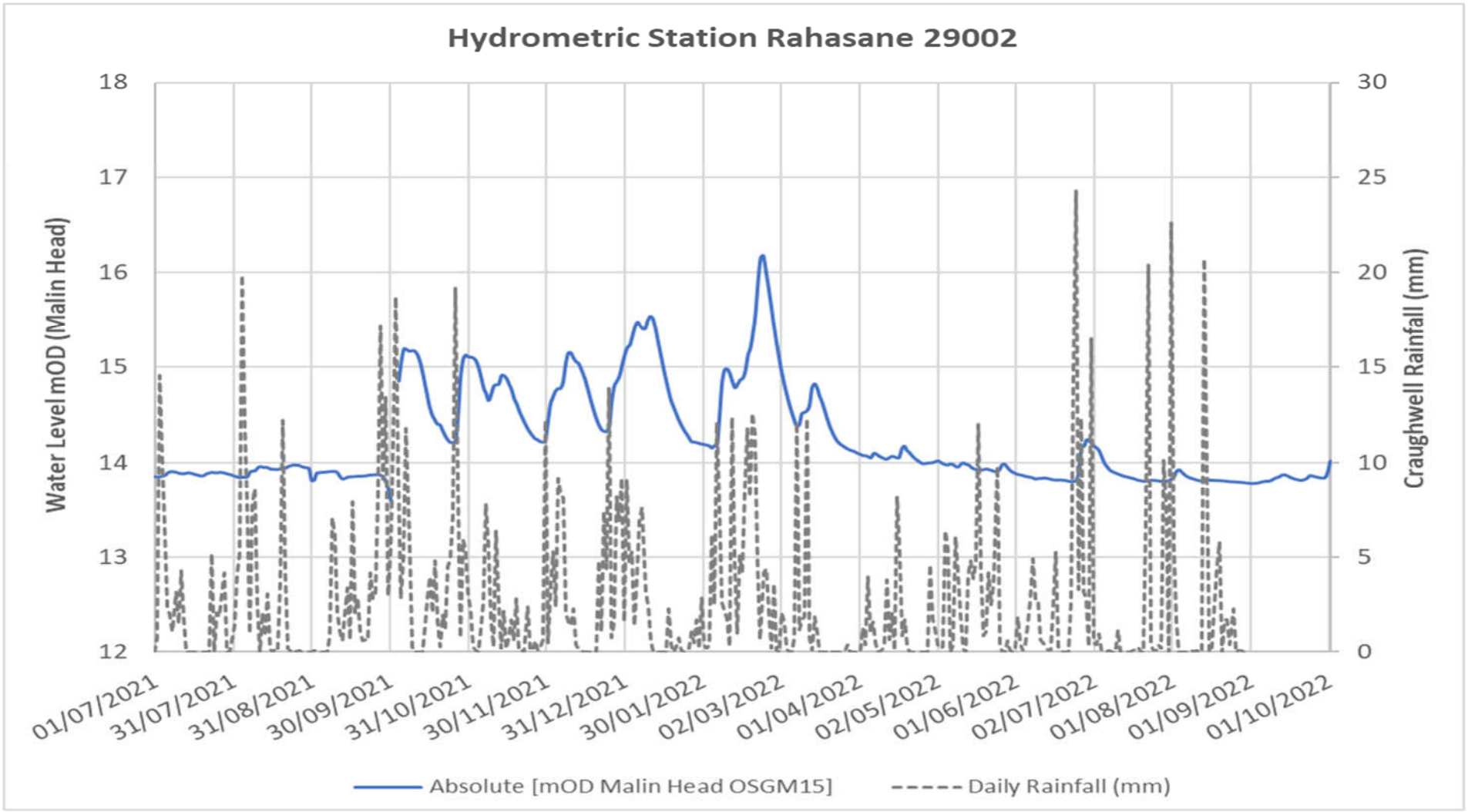

Figure 3: Rahasane Turlough 29002, Q3 2021 through Q3 2022 Water Level and Rainfall (Craughwell) Data

2.1.2. Walkover survey – Rahasane Turlough

Known karst features in the Rahasane Turlough SAC are shown on Drawing 1 (Appendix 1) and listed in Table 1. These incorporate those features in the GSI database, those mapped by RPS from Lidar data during the FRS project and those that were ground-truthed or identified during the site walkover survey.

Specific other features of interest noted on the site walkover survey are summarised in Table 1 and include monitoring wells. The team checked with GSI and other researchers of turlough hydrology, but the purpose or circumstances around the presence of monitoring wells are not known.

A selection of images of features during both 2021 and 2022 is provided in Plates 5 through 7, for comparison. A selection of features identified by this survey in 2022 are provided in Plates 8 through 10.

Karst features identified during the 2021 survey were monitored and no changes were identified. However, several newly identified features were recorded due to the lower water levels in the turlough during the 2022 survey, which were much lower compared to 2021 as a result of a prolonged dry period. Numerous small-scale depressions, possible estavelles with gentle slopes and wetland vegetation were recorded during the walkover survey.

The main difference between 2021 and 2022 is the notably reduced amount of water in the turlough in 2022 compared to 2021, due to the preceding extended dry period in 2022.

Table 1: Summary of hydrogeological and hydrological features at the Rahasane Turlough

ID*	X (ITM)	Y (ITM)	Feature	Comment	Change between 2021 & 2022
A1	546108	718854	Enclosed depression	Monitor for changes.	No change
A2	546310	718914	Dunkellin River	Hydrological reference feature – observation point within turlough.	
A3	546327	718940	10+ small scale depressions	Possible near surface expression of epikarst. Monitor for changes.	No change
A4	546325	718991	Enclosed depression	Monitor for changes.	No change
A5	546570	719115	Area receiving inflow from river	Possible nearby swallow hole.	No change
A6	546653	719086	Wetland vegetation	Monitor for changes – ecologist	
A7	546681	719110	50+ small depressions of Approx. 200 mm diameter	Possible near surface expression of epikarst. Monitor for changes.	No change
A8	546689	719158	Enclosed depression	Possible location for groundwater recharge/discharge (estavelle). Monitor for changes	No change
A9	546912	719483	Monitoring well	Condition unknown. Consider condition survey for possible monitoring.	
A10	547683	718724	Existing well	Condition unknown. Consider condition survey for possible monitoring.	
A11	547408	718725	Enclosed depression	Possible location for groundwater recharge/discharge (estavelle). Monitor for changes.	No change
A12	547411	718730	Enclosed depression	Possible location for groundwater recharge/discharge (estavelle). Monitor for changes.	No change
B1	546551	718960	Small scale depression	Monitor for changes.	NA (newly identified)
B2	546629	719112	Estavelle (?) Low water levels (<200mm)	Possible location for groundwater recharge/discharge. Monitor for changes.	NA (newly identified)
B3	546839	719313	Estavelle/spring	Feeds steam that flows SW to main channel. Monitor for changes.	NA (newly identified)
B4	547006	719548	Turlough water	-	NA (newly identified)
B5	547308	719874	Estavelle	Location of groundwater recharge/discharge. Monitor for changes.	NA (newly identified)
B6	547310	719876	Estavelle	Location of groundwater recharge/discharge. Monitor for changes.	NA (newly identified)
B7	547320	719912	Localised depression	Small scale depression. Monitor for changes.	NA (newly identified)
B8	547857	720058	Pond	Appears to drain to main channel. Source unknown. Monitor for changes.	NA (newly identified)
B9	547998	720015	Old Dunkellin channel	Monitor for changes.	NA (newly identified)

ID*	X (ITM)	Y (ITM)	Feature	Comment	Change between 2021 & 2022
B10	548042	720136	Estavelle	Location of groundwater recharge/discharge. Monitor for changes	NA (newly identified)
B11	548090	720139	GW in depression	Small scale depression. Monitor for changes.	NA (newly identified)
GSI 1	547409	718761	Spring	Monitor for estimated flow	No change
GSI 2	547732	718806	Enclosed depression	Monitor for changes	No change
GSI 3	546483	718930	Swallow hole	Monitor for changes	No change
GSI 4	548512	719832	Enclosed depression	Monitor for changes	No change
GSI 5	548647	719790	Enclosed depression	Monitor for changes	No change
GSI 6	549994	719655	Swallow hole	Monitor for changes	No change
GSI 7	550433	719748	Swallow hole	Monitor for changes	No change
RPS 1	550577	719824	Enclosed depression	Monitor for changes	No change
RPS 2	547982	719853	Enclosed depression	Monitor for changes	No change
RPS 3	548582	719523	Enclosed depression	Monitor for changes	No change
RPS 4	548744	719523	Enclosed depression	Monitor for changes	No change
RPS 5	547832	719589	Enclosed depression	Monitor for changes	No change
RPS 6	547473	719282	10+ small scale depressions	Possible near surface expression of epikarst. Monitor for changes.	No change
RPS 7	547372	718848	Enclosed depression	Monitor for changes	No change
RPS 8	547041	718867	Enclosed depression	Monitor for changes	No change
RPS 9	546943	718755	Enclosed depression	Monitor for changes	No change
RPS 10	546994	718861	Enclosed depression	Monitor for changes	No change
RPS 11	546920	719065	Enclosed depression	Monitor for changes	No change
RPS 12	546509	718456	Enclosed depression	Monitor for changes	No change
RPS 13	546205	718203	Enclosed depression	Monitor for changes	No change
RPS 14	545843	717986	Enclosed depression	Monitor for changes	No change
RPS 15	546277	718983	Enclosed depression	Monitor for changes	No change
RPS 16	546459	719099	Enclosed depression	Monitor for changes	No change

*ID with prefix A: features identified by CDM Smith in 2021; ID with prefix B: features identified by CDM Smith in 2022 ; ID GSI 1-7: GSI features; ID RPS 1-16: RPS features

3. Vegetation Surveys

3.1. Review of previous datasets and reports

Turlough vegetation is of high ecological interest and importance for two main reasons:

1. Turloughs are extremely rare in a European and global context, with almost all examples found in Ireland;
2. The unusual and dynamic seasonal water regime facilitates an unusual range of plant species

This ecological rarity and importance is emphasised by the fact that turloughs have been listed as priority habitats in the EU Habitats Directive (EU habitat code 3180). The vegetation of turloughs reflects the fact that these habitats are transitional in nature, with a very dynamic water regime. The composition of the vegetation tends to change in accordance with the flooding gradient.

A comprehensive study of turlough vegetation in Ireland was undertaken on behalf of NPWS (Waldren, 2015). In addition, NPWS commissioned a Conservation Objectives supporting document (O'Connor, 2017) to cover forty-five SACs selected for the Annex I Priority habitat Turloughs (3180), for which individual Conservation Objectives Supporting documents had not been prepared. These documents were reviewed to inform the methodological approach to surveying.

The vegetation of Rahasane Turlough was surveyed in detail by Roger Goodwillie in 1992, as part of a study of 61 Irish Turloughs commissioned by NPWS. This survey focussed on distinctive plant communities and specific indicator species, to ascertain the flora present and to examine any habitat variation, including variation between Rahasane and other turloughs, in order to evaluate the site's ecological interest.

A further study undertaken in 2012 (Sharkey, 2012) documented the vegetation communities of 22 turloughs within Counties Galway, Clare, Roscommon and Mayo. The categorisation of turlough vegetation communities was updated by Sharkey, and this updated classification was used for the 2021 and 2022 surveys at Rahasane.

The vegetation communities identified in Rahasane Turlough by Goodwillie (1992) and Sharkey (2012) were re-surveyed by RPS environmental consultants during 2014-2015 in order to inform the planning submission for the Dunkellin River & Aggard Stream Flood Relief Scheme (RPS, 2016). This study revisited Goodwillie's transects and examined twelve transects and 249 relevés in detail. The results of the surveys by RPS were reviewed and used to inform the site selection process.

The present report also includes comparison tables which give the results of the previous surveys (RPS, 2016) survey alongside the results from 2021 and 2022, allowing direct comparisons of vegetation groups and plant species' abundance to be made.

3.2. Methods

For the current vegetation monitoring of Rahasane Turlough, the fieldwork methodology was adapted from Waldren (2015), in accordance with the scheduled time available, including mapping of broad vegetation zones during the dry season (mid-summer to early autumn) by the use of transects, and focused on vegetation monitoring by recording vegetation in relevés in the locations selected.

The focus on vegetation units takes cognisance of the units specified by Goodwillie (1992) and Sharkey (2012), with the latter classification being used to produce the vegetation community maps (Appendix 3).

The vegetation records from the transects and relevés identified in the RPS survey were reviewed in order to inform the selection of a subset of these for re-assessment, with the intention of focusing on those areas previously identified as being of particular botanical importance. This subset of fifteen relevés were the focus of the 2021 study, and were again visited and surveyed in 2022. These relevés are located along three transect lines, and are shown in Appendix 2.

Details of the surveys undertaken on site

The surveys were carried out on 12 and 13 July 2022, this being within both the optimum survey season for wetland habitats and the usual dry season for the turlough.

The site field survey included the following:

- Mapping of broad vegetation zones, by means of examination and recording of vegetation along the selected transects, identifying the points of transition to different identified vegetation zones along each transect.
- Detailed examination of each of the 1x1 m relevés selected for re-survey, along the three selected transect lines (Transects 2, 4, and 6). For each relevé this included an assessment of its physical characteristics, vegetation cover, vegetation type, all plant species present and percentage cover of each species, management and observed pressures/threats.

Water levels were lower during the 2022 surveys than levels encountered the previous year, allowing access to some relevés which had been inaccessible during the 2022 survey.

All results from the vegetation zone mapping were processed on QGIS, and maps produced showing the relevant vegetation zones.

3.3. Results and Discussion

This section presents the results of surveys conducted at Rahasane Turlough in the summer of 2022. The following summary tables give a synopsis of the species lists and vegetation cover in each relevé. Full results for each relevé are given in Appendix 4. Vegetation maps produced from these surveys are given in Appendix 2. In addition, comparisons between the results from the 2022 surveys and those conducted in 2021 and 2014-2015 are given in Appendix 5.

The classification system of Sharkey (2012) corresponded only approximately with the vegetation communities as recorded at Rahasane. However, this is not remarkable given that the set of turloughs studied by Sharkey did not include Rahasane, and such habitats, as with all natural systems, are naturally variable in character. Nonetheless, the information gathered for each quadrat in the present study includes all species records and percentage cover for each, and could therefore be used in conjunction with improved or more closely-tailored classification systems in the future for the sake of comparison, if required.

3.3.1. Transect 2

Along Transect 2, vegetation remained generally similar to that which was recorded during the 2021 survey season, with creeping bent grass (*Agrostis stolonifera*) and silverweed (*Potentilla anserina*), both again being widespread along the transect. Some plant species were recorded in 2021 and 2022 which were not noted in 2014-2015, such as yarrow (*Achillea millefolium*) and ribwort plantain (*Plantago lanceolata*). Creeping cinquefoil (*Potentilla reptans*), typical of lakeshores and turlough habitats, was recorded much more frequently in both 2021 and 2022 than in 2014-2015. In a few relevés, the cover by creeping bent grass (*Agrostis stolonifera*) had decreased, although this was still one of the more dominant species recorded. Autumn hawkbit (*Scorzoneroides autumnalis*), a typical species of habitats with fluctuating wet and dry periods, remained frequently recorded.

As in 2021, species richness in 2022 was again found to be generally higher than that recorded in 2014-2015, with a greater percentage of bryophytes. Smaller lattice moss *(Cinclidotus fontinaloides),* one of the most characteristic and indicative of turlough species, was recorded more frequently along this transect than it had been in 2014-2015, generally growing on small patches of stone. A small amount of pointed spear moss (*Calliergonella cuspidata*), not recorded along this transect in 2014-2015 or 2021, was recorded in 2022. However, this is a common species and not especially significant.

As in 2021, grazing (by sheep, cattle or horses) was recorded in the majority of relevés along Transect 2. As mentioned in the 2021 report, close grazing is a longstanding situation at Rahasane, with the shortness of the vegetation due to grazing being a chief feature of the turlough as recorded by Goodwillie in 1992. However, recorded levels of poaching and bare ground were lower during the 2022 survey season in comparison to the 2021 survey season. This may suggest that the previous higher than optimal seasonal stocking rate highlighted in the 2021 report are being addressed by the landowners, although the degree of poaching could also be related to the wet spells of weather in the summer of 2021, which caused the turlough's water levels to be particularly high.

3.3.1. Transect 4

Due to lower water levels this year than in 2021, more relevés along Transect 4 were accessible. Relevé 10 and 22, inaccessible during the 2021 surveys, were surveyed this year, allowing a comparison with the 2014-2015 data. In Relevé 10, the plant diversity was much higher than in 2014-2015, rising from three species to ten. There appears to have been a fairly substantial change in the vegetation at this point since 2014-2015; red fescue (*Festuca rubra*), which at that time made up 40% of the vegetation, was no longer present in 2022. Creeping bent grass (*Agrostis stolonifera*), not recorded in 2014-2015, accounted for 50% of the overall cover in 2022. Other species absent in 2014-2015 but recorded in 2022 were lesser water parsnip (*Berula erecta*), cuckooflower (*Cardamine pratensis*), spike rush (*Eleocharis palustris*), marsh bedstraw (*Galium palustre*), floating sweetgrass (*Glyceria fluitans*), and water mint (*Mentha aquatica*). At Relevé 22, there were fewer changes between 2014-2015 and 2022, with several of the same species being recorded in both surveys. Creeping bent grass (*Agrostis stolonifera*) had declined from 90% cover to 30%, and silverweed (*Potentilla anserina*) had increased from 7% cover to 23%. Hairy sedge (*Carex hirta*), not recorded in 2014-2015, made up 10% of the vegetative cover in 2022. In Relevé 5, there was little change in vegetation between 2021 and 2022.

Table 2: Summary vegetation results for relevés surveyed along Transect 2, Rahasane Turlough, July 2022

Transect 2										
Relevé	**T2R2**		**T2R4**		**T2R6**		**T2R12**		**T2R16**	
Location (ITM)	X: 546294 Y: 719189		X: 546346 Y: 719102		X: 546424 Y: 718976		X: 546484 Y: 718877		X: 546547 Y: 718775	
Water height (cm)	0		0		0		0		0	
Vegetation zone (Sharkey, 2012)	7 (15) *Lolium-Trifolium-Agrostis*		3 (19) *Potentilla anserina – Potentilla reptans*		3 (19) *Potentilla anserina – Potentilla reptans*		3 (19) *Potentilla anserina – Potentilla reptans*		3 (19) *Potentilla anserina – Potentilla reptans*	
Vegetation height max (cm)	Generally 5, *Rumex* stems to 25		10		5		10		14	
% graminoids	25		55		32		52		80	
% forbs	90		45		70		46		20	
% shrubs	0		0		0		0		0	
% bryophytes	1-2		0		0		4		0	
% bare ground	0		1		0		1		0	
% poaching	0		0		0		0		0	
Species	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**
Achillea millefolium	12	5								
Agrostis stolonifera	5	3	40	7	25	5	52	8	20	5
Bellis perennis	5	4			2	3				
Calliergonella cuspidata	1	3								
Cardamine pratensis			1	3			<1	1		
Carex nigra	<1	2	5	4	3	3				
Carex panicea					2	3				
Cerastium fontanum					<1	1				
Cinclidotus fontinaloides	<1	2								
Fontinalis antipyretica							4	3		
Festuca rubra					<1	1				
Galium palustre			5	4			<1	1	1	3
Gnaphalium uliginosum							<1	1		
Lolium perenne	5	4								
Mentha aquatica			2	3			4	3		
Myosotis scorpioides			10	4			8	4	<1	1

Transect 2										
Relevé	**T2R2**		**T2R4**		**T2R6**		**T2R12**		**T2R16**	
Species	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**
Plantago major	1	3	4	3					<1	1
Plantago lanceolata	2	3			6	4				
Poa annua	15	5								
Poa pratensis			10	4						
Potentilla anserina	28	6	30	6	28	6	34	7	70	8
Potentilla reptans			2	3	2	3			<1	2
Ranunculus repens	1	3	3	3	<1	1			1	3
Rumex crispus	2	3	1	3	2	3				
Scorzoneroides autumnalis	<1	2			<1	1			<1	1
Stellaria media									<1	1
Taraxacum officinale	1	3								
Trifolium repens	70	8	5	4	28	6			20	5

Table 3: Summary vegetation results for relevés surveyed along Transect 4, Rahasane Turlough, July 2022. Some locations were inaccessible due to water levels.

Transect 4										
Relevé	**T4R5**		**T4R10**		**T4R16**		**T4R18**		**T4R22**	
Location (ITM)	X: 547393 Y: 720048		X: 547437 Y: 719932		X: 547499 Y: 719770		X: 547597 Y: 719511		X: 547629 Y: 719427	
Water height (cm)	0		1		Inaccessible		Inaccessible		0	
Vegetation zone (Sharkey, 2012)	3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*		3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*						3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*	
Vegetation height max (cm)	23		22						10	
% graminoids	28		60						60	
% forbs	73		46						40	
% shrubs	0		0						0	
% bryophytes	1		0						0	
% bare ground	3 (stone)		0						1	
% poaching	0		0						0	
Species	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**
Agrostis stolonifera	28	6	50	7					30	6
Berula erecta			2	3						
Cardamine pratensis			<1	1						
Carex hirta									10	4
Cerastium fontanum	1	3							1	2
Cinclidotus fontinaloides	1	3								
Eleocharis palustris			6	4						
Filamentous green algae			<1	1						
Galium palustre			<1	1					1	2
Glyceria fluitans			4	3						
Juncus sp.									<1	1
Mentha aquatica			3	3					2	3
Myosotis scorpioides	1	3	23	5					5	4
Persicaria amphibia			15	5						

Transect 4										
Relevé	**T4R5**		**T4R10**		**T4R16**		**T4R18**		**T4R22**	
Potentilla anserina	55	8							23	5
Potentilla reptans	2	3							7	4
Species	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**
Ranunculus repens	6	4							1	3
Rumex crispus	3	3								
Scorzoneroides autumnalis	<1	1								
Trifolium repens	4	4								

Table 4: Summary vegetation results for relevés surveyed along Transect 6, Rahasane Turlough, July 2022. Some locations were inaccessible due to water levels.

Transect 6										
Relevé	**T6R2**		**T6R6**		**T6R12**		**T6R16**		**T6R18**	
Location (ITM)	X: 548428 Y: 719865		X: 548378 Y: 719763		X: 548323 Y: 719656		X: 548285 Y: 719580		X: 548258 Y: 719526	
Water height (cm)	Inaccessible		Inaccessible		0		0		0	
Vegetation zone (Sharkey, 2012)					3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*		3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*		3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*	
Vegetation height max (cm)					10		10		8	
% graminoids					40		50		37	
% forbs					60		60		76	
% shrubs					0		0		0	
% bryophytes					0		0		0	
% bare ground					1		0		0	
% poaching					0		0		0	
Species	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**
Agrostis stolonifera					20	5	43	7	22	5
Bellis perennis									1	3
Carex hirta					<1	1				
Carex nigra					20	5	4	3	3	3
Cerastium fontanum									1	3
Festuca rubra							2	3	6	4
Species	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**
Filipendula ulmaria							<1	1		
Galium palustre					3	3	<1	1	1	3
Juncus sp.					<1	2	1	3	2	3
Lolium perenne									2	3
Myosotis scorpioides					3	3	<1	1		
Phleum pratense									2	3
Plantago major							<1	1	1	3

Transect 6								
Relevé	**T6R2**	**T6R6**	**T6R12**		**T6R16**		**T6R18**	
Potentilla anserina			35	7	25	5	36	7
Potentilla reptans			<1	1	<1	1	2	3
Prunella vulgaris							2	3
Ranunculus repens			15	5	3	3	3	3
Scorzoneroides autumnalis							<1	2
Taraxacum officinale			<1	1	<1	1		
Trifolium repens			3	3	20	5	25	5
Veronica serpyllifolia							<1	1

However, looking at the 2014-2015 data for this relevé suggests a substantial change since that time. In 2014-2015, red fescue (*Festuca rubra*) made up 60% of the vegetative cover, but this species was not present in 2021 or 2022. Conversely, creeping bent grass (*Agrostis stolonifera*), not recorded in 2014-2015, was one of the dominant species in both 2021 and 2022. Silverweed (*Potentilla anserina*) was the species that remained most unchanged among all three surveys.

Grazing pressure varied along this transect, as noted in the tables in Appendix 4. Some areas did not appear to have been grazed recently at the time of the 2022 survey, although one relevé was grazed fairly tightly by sheep. No poaching was noted.

3.3.2. Transect 6

As in the 2021 survey season, Relevés 2 and 6 along Transect 6 were inaccessible due to the water levels in the turlough at the time of the 2022 survey season. Particularly prevalent species along this transect included silverweed (*Potentilla anserina*), creeping bent (*Agrostis stolonifera*), white clover (*Trifolium repens*) and creeping buttercup (*Ranunculus repens*). At Relevé 12, the vegetation remained similar to that recorded in 2021, except that black sedge (*Carex nigra*) had shown an increase in cover. Comparing these results to those recorded in 2014-2015, it is clear that the vegetation was more diverse in 2022 (11 species, up from 6), although creeping bent grass (*Agrostis stolonifera*), silverweed (*Potentilla anserina*) and creeping buttercup (*Ranunculus repens*) remain among the most dominant species. In Relevé 16, species richness was also higher in 2022 (13 species) than in 2014-2015 (7 species). The new additions since 2014-2015 are red fescue (*Festuca rubra*), marsh bedstraw (*Galium palustre*), bulbous rush *(Juncus bulbosus*), water forget-me-not (*Myosotis scorpioides*), creeping cinquefoil (*Potentilla reptans*), broadleaf plantain (*Plantago major*), and dandelion (*Taraxacum officinale*). At Relevé 18, again there has been a large increase in species richness since 2014-2015, with 17 species recorded in 2022, compared to 7 species previously. One species which has remained almost constant in this relevé is creeping bent grass (*Agrostis stolonifera*), whereas species present in 2022 but not in 2014-2015 include daisy (*Bellis perennis*), mouse-ear chickweed (*Cerastium fontanum*), red fescue (*Festuca rubra*), jointed rush (*Juncus articulatus*), perennial ryegrass (*Lolium perenne*), Timothy grass (*Phleum pratense*), broadleaf plantain (*Plantago major*), creeping cinquefoil (*Potentilla reptans*), selfheal (*Prunella vulgaris*), creeping buttercup (*Ranunculus repens*), and thyme-leaved speedwell (*Veronica serpyllifolia*).

At all the accessible relevés along this transect, it was noted that grazing pressure appeared high, and the vegetation had been eaten very close to the ground.

4. Macroinvertebrate and Pond PSYM Surveys

4.1. Background

The purpose of undertaking annual monitoring of the freshwater macroinvertebrate communities and indicator species is to establish whether any changes in their composition has occurred that would indicate a transition from a habitat characteristic of being regularly flooded to one that is more frequently dry. However, given the ephemeral nature of a turlough, natural changes in the hydroperiod of the system occur year on year, and therefore it is important to look for changes in the community composition over a longer period to establish whether a transition in the habitat, and thus the community composition, is occurring.

With this in mind, the Predictive System for Multi-metrics (PSYM; Howard, 2002), designed for habitat survey and the assessment of standing waters, was used as a standard survey method for the turlough, allowing year on year comparison of results. This metric was developed by the Freshwater Habitats Trust and the Environment Agency in England and provides a standardised method for surveying and assessing the biological quality of standing waters, using macroinvertebrates and macrophytes.

In this second year of the survey, macroinvertebrate samples were identified to family level, with water beetles identified to species level where possible, allowing comparison with the survey of water beetles conducted in the first year, as well as the previous surveys prior to commencement of the works at the site, conducted by D.T. Bilton in 1989, G.N. Foster in 1992, A. O'Connor in 2002, F. Waldron in 2003 and 2004 and RPS in 2016 (reported in Foster, 1992 and RPS, 2016).

The presence and abundance of ephemeral taxa such as Trichoptera and Heteroptera, correlated with turloughs with longer hydroperiods, and of Gastropoda, which occur in higher abundances in turloughs with longer hydroperiods, probably owing to their limited mobility, was also examined (Porst, 2009). Standard metrics were calculated in addition to the calculation of the PSYM, which were compared to the first year's results, and to examine if any changes in the macroinvertebrate communities present have occurred. This report describes the second year of post-works monitoring, and the results are compared to those of the first year, and of previous surveys.

4.2. Review of previous datasets and reports

The following sources of site-specific data were reviewed:

- RPS, 2014. Environmental Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme);
- RPS, 2014. Natura Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme);
- RPS, 2016. Dunkellin River and Aggard Stream Flood Relief Scheme: Pre-construction Aquatic Beetle Survey

The following additional sources of relevant publicly available data and information were also reviewed:

- Environmental Protection Agency (EPA web-based data viewer (EPA map viewer; Water)

- National Parks and Wildlife Service (NPWS) web-based data viewer (Special Areas of Conservation; Special Protection Areas).
- National Biodiversity Data Centre Database
- Porst, 2009. The Effects of Season, Habitat, Hydroperiod and Water Chemistry on the Distribution of Turlough Aquatic Invertebrate Communities. PhD Thesis, Trinity College Dublin.
- Relevant published peer reviewed papers associated with turlough macroinvertebrate community composition (Foster *et al.*, 1992; Lahr, 1997; Lahr *et al.*, 1999; Follner and Henle, 2006 and Williams, 2006)

4.3. Method

4.3.1. Physico-chemical Measurements

Temperature, pH, conductivity and dissolved oxygen concentration and saturation were measured on-site at each sample location using a multiparameter probe. Additional information on the local environment, substrate, shading, level of grazing and emergent plan cover was also recorded.

4.3.2. Macroinvertebrate Survey and Analysis

Macroinvertebrate sampling was carried out at four locations at the Rahasane Turlough on 23 August 2022 (Figure 20). Site was further south than in 2021. The substrate at each site was comprised of semi-permanent wetted areas with grazed grassland, with submerged, emerging and floating leaved aquatic plants present.

The survey was conducted by sweep netting through the submerged vegetation at all mesohabitats present at each location, using a standard pond net with 1mm mesh size for a period of 45 seconds at each site (bringing the total to a 3-minute sample), as outlined in the PSYM method by Howard (2002). The samples were preserved in > 90% Isopropyl alcohol on-site and returned to the laboratory for further analysis, where they were combined into a single composite sample.

An additional targeted aquatic beetle combined sample was selectively collected from a number of isolated pools around the turlough by sweep netting through submerged vegetation at all mesohabitats present using a small handheld pond net with 1mm mesh size for a period of 30 seconds at each site, in order to maximise the number of species encountered; this is a slight adjustment to the 2021 method, following an external review of the first year's sampling programme. This sample was preserved in > 90% Isopropyl alcohol on-site and returned to the laboratory for further analysis. This sample was kept separately from the kick sample, but the results were combined to provide a full species list of aquatic beetles encountered in this year's survey.

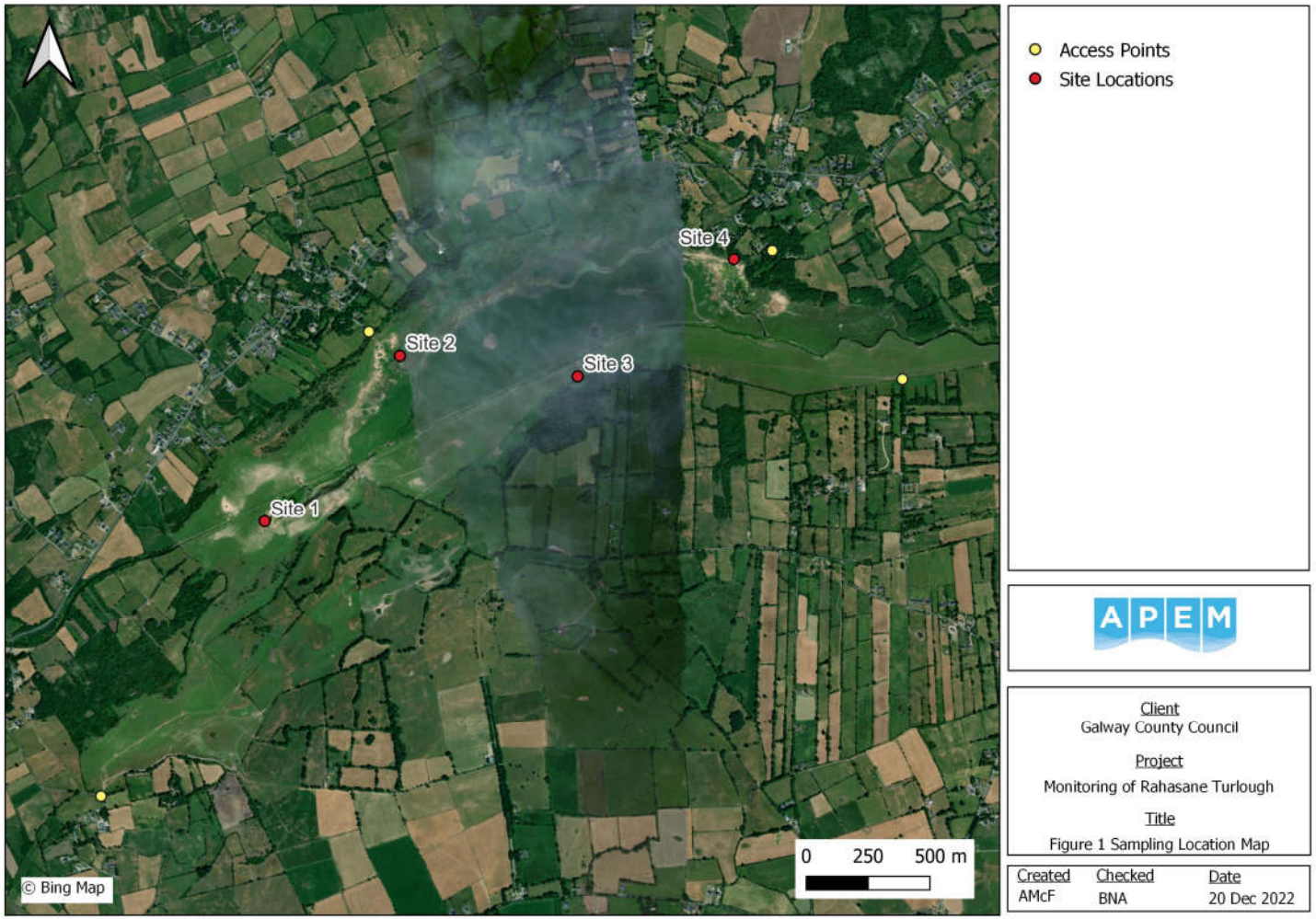

Figure 4: The four sites surveyed for macroinvertebrates and PSYM analysis in 2022

Specimens were identified under a binocular microscope to family level in the laboratory using the standard range of identification keys published by the Freshwater Biological Association, AIDGAP and others, with the exception of water beetles, which were identified to the finest resolution possible (species level where possible). A list of the macroinvertebrate taxa recorded can be found in Appendix 5 of this report. This list informed the calculation of all macroinvertebrate indices.

4.3.3. Plant Survey and Analysis

Pond macrophytes were surveyed by wading the perimeter of the dry and shallow water areas at each of the four locations, with deeper areas sampled using the pond net. Species were recorded on the PSYM plant recording sheet as outlined in Howard (2002).

4.3.4. Metrics Calculation

PSYM was calculated for Rahasane Turlough based on the assessment of aquatic plant and macroinvertebrate assemblages present as well as environmental data. PSYM is a predictive tool, comparing observed species assemblages with expected composition based on the type and location of the water body, and metric scores are then combined to provide a single value which summarises the overall ecological quality of the water body. However, the reference data used to enable the prediction is currently only available for England and Wales. Instead, the survey metrics will be compared to one another over five consecutive years, to identify any changes over this time.

For the macroinvertebrate samples the metrics calculated for invertebrates in PSYM are Biological Monitoring Working Party (BMWP) score, Average Score Per Taxon (ASPT), the number of dragonfly and alderfly (Odonata and Megaloptera) families (OM) and the number of beetle families (Coleoptera); and for the macrophytes the number of submerged and emergent plant species and the Trophic ranking score (TRS) for aquatic and emergent plants. PSYM also includes a metric for uncommon species, assigning a rarity value, but as this is derived from species' status in small ponds in England, it was not considered valid and therefore not applied here.

The BMWP and ASPT scores exploit the natural sensitivity of each taxon to organic pollution. Macroinvertebrate families which are sensitive to pollution are assigned high BMWP scores, while pollution-tolerant taxa score low. BMWP index may be altered significantly depending on whether the sampling process captures species found in some habitats but not in others. Standardisation of the BMWP score is therefore provided by the ASPT, allowing robust comparisons among sites. BMWP was developed in the UK and has since been adapted for a range of locations globally, including Iberia (BMWP-I) and Costa Rica (BMWP-CR); the original version works well in Ireland.

TRS is a measure of the average trophic rank for the pond, calculated by assigning each plant species with a trophic score based on its affinity to waters of a particular nutrient status. Plant scores in this system vary between 2.5 (dystrophic i.e., very nutrient poor conditions) and 10 (eutrophic, i.e., nutrient rich conditions).

An EPA Q value classification was assigned to each site. The Q-values were assigned based on the presence and relative abundance of sensitive groups and the consideration of additional qualifying criteria, as described by Toner *et al.* (2005), and in Feeley *et al.* (2020), outlined in more detail in Appendix 6. The Whalley Hawkes Paisley Trigg (WHPT) NTAXA (number of taxa) and WHPT-ASPT were

also calculated. The WHPT is an enhancement of BMWP, now used in the UK for monitoring, assessing and classifying rivers in accordance with the requirements of WFD.
The Q value and WHPT metrics are designed for use on samples collected from rivers, and so have limitations when applied to samples from standing waters, particularly as these are often naturally subject to low oxygen concentrations and have a different assemblages of taxa to rivers. Many of the metrics incorporating macroinvertebrates as bioindicators use a species or overall community's response to levels of dissolved oxygen to assess impact. This makes their use in standing waters less robust, so other measures of ecological health or value are needed, such as the presence/absence of particular species. In addition, given that much of Rahasane Turlough is ephemeral, the samples collected are likely have quite distinct assemblages. However, the metrics can still be useful as a means of comparison of samples taken from the same water body over time and were calculated here on that basis. In the case of the Q value assigned, a corresponding WFD Ecological Status was not assigned, given that this metric is being used as a means of comparison among years, and is not designed for use in still waters.

4.3.5. Assessment using water beetles

Foster et al (1992) identified that aquatic Coleoptera as a group possess a range of attributes required to evaluate the conservation status of wetlands. They identified ten distinct assemblage types of Irish water beetles and developed a classification system for habitats typical of these assemblages. The Rahasane Turlough was identified as Community Type F, described as 'turloughs and more permanent, large, shallow, water bodies on base-rich substrata' (Foster et al., 1992).

This research also devised a classification system to assess water beetle assemblages, ranking sites by community significance using a simple metric that can demonstrate the quality of different wetland habitat types and identify sites of highest ecological value (Foster et al., 1992). This involves calculating Individual Species Quality Scores (SQS), assigned based on how commonly or rarely the species occurs in certain habitat types, and is based on an initial study that looked at their frequency within 10km squares across Ireland. The scores of elusive species are downgraded, as are those associated with tidal water or confined to habitats of man-made origin. The scores of species restricted to undisturbed natural habitats are upgraded within the system. Then a Mean Quality Score (MQS) for a site is calculated by dividing the total of individual SQS by total number of scoring species. This method was followed here.

The water beetle community of the Rahasane Turlough has been surveyed several times in the past by Bilton (1989), O'Connor (2001), Waldron (2003/ 2004) and RPS (2016), prior to the most recent APEM survey in 2021. A summary of the results from the previous surveys was presented in the report by RPS (2016). Using the MQS from each of these studies enables a comparison to be made over time.

4.4. Results and discussion

4.4.1. Water quality

Key water chemical parameters were recorded on-site and are summarised in Table 5. Water temperature was relatively high, but similar to that recorded in 2021, reflecting the warm summer weather and the standing waters. Of interest was the high oxygen concentrations; the water was supersaturated with oxygen, a symptom of high levels of photosynthesis. The probable cause of this

is high densities of algae, which were responding to the warm water and presumably to high concentrations of nutrients. Slimy floating algae was visually observed at all sites, as were cattle, sheep and horses and evidence of grazing and poaching, providing further evidence of nutrient impact. Photosynthesis raises pH, and the high values recorded are therefore probably at least partially due to this. The concentrations contrast with 2021, when oxygen was low (29-51%) and pH much more acidic (6.3-6.7). Conductivity readings were general similar in 2022 to 2021, except at site 2, where it had approximately doubled, suggesting a possible localised runoff input.

Table 5. Summary of in situ physicochemical data at Rahasane Turlough, August 2022

Parameter	Unit	Site 1	Site 2	Site 3	Site 4
Temperature	°C	24.3	22.9	24.4	21.9
pH		9.38	8.38	8.39	8.3
Dissolved Oxygen	% Saturation	180.9	162.1	192.3	171.6
Dissolved Oxygen	Mg/L	15.19	13.96	16.2	16.14
Conductivity	µS/cm	254	996	424	522

4.4.2. Taxonomic richness

All sampling sites were inundated grazed pastures, with grassy substrates and light to moderate siltation. Among the 4 sites surveyed, 18 families of macroinvertebrates from ten orders were identified (Appendix 5, Table 29). In 2021, greater diversity was observed, with 24 families of macroinvertebrates from 14 orders identified. Similar to 2021, the 2022 sample was dominated by various taxa of aquatic gastropod snails including Lymnaeidae, Bithyniidae and Planorbiidae, as well as high numbers of Physidae and Valvatidae and the bivalve Sphaeriidae. There were also high numbers of damselflies (Coenagrioniidae) and backswimmers (Corixidae).

Forty seven taxa of aquatic plants were also recorded among sites, 45 of which were identified to species (Appendix 5, Table 30). This was a significant increase in recorded diversity compared with 2021, when 24 taxa were recorded, of which 19 were identified to species, and reflects availability of a specialist botanist in 2022, rather than a real increase in diversity. It is proposed that a specialist botanist be used for future surveys, when available.

4.4.3. PSYM Results

The Pond PSYM metrics are described in Tables 6 and 7. There were 16 PSYM macroinvertebrate taxa present, which represents a moderately diverse sample, although slightly lower than the 19 taxa recorded in 2021 (Table 6). The ASPT score, which can range from 0 to 10, was relatively low in both years, reflecting few taxa pollution sensitive taxa recorded. A low ASPT score is typical of standing water bodies, particularly those with high aggregations of organic matter. There were two Coleoptera families (Haliplidae and Helophoriidae), as in 2021, although Dytiscidae and not Helophoridae were recorded in 2021. One Odonata and Megaloptera (OM) taxon (Coenagrioniidae) was present, as also observed in 2021. The OM number is a good indicator of water quality in British ponds (Biggs *et al.*, 2000). Therefore, these results provide further evidence for a nutrient impact at the turlough.

Table 6. Pond PSYM macroinvertebrate metrics calculated at Rahasane Turlough, August 2022

Metric	2021	2022
BMWP	78	62
No of PSYM Taxa (NTAXA)	19	16
ASPT	4.11	3.88
No. of Odonata & Megaloptera Taxa (OM)	1	1
No. of Coleoptera Taxa	2	2

The aquatic plant metrics associated with PSYM are recorded in Table 7 and the PSYM aquatic plants recorded at the turlough are documented in Table 30 of Appendix 5. The Trophic Ranking Score (TRS) for the site was high at 7.97, which was only slightly lower than that recorded in 2021. Scores vary between 2.5 (very nutrient poor) to 10 (very nutrient rich). Twenty seven species had TRS scores, and 7.97 represents the average score of these species, indicating moderately high nutrient levels at the site.

Table 7. Pond PSYM aquatic plant metrics calculated at Rahasane Turlough, August 2022

Metric	2021	2022
No. of Emergent & Submerged species	21	44
Trophic Ranking Score	8.35	7.97

4.4.4. Standard Macroinvertebrate Metric Results

The standard metrics used for freshwater macroinvertebrate surveys recorded below in Table 8 are designed for use on samples collected from rivers, and so have limitations when applied to standing waters. Nevertheless, these metrics were calculated for the Rahasane Turlough as an additional comparative tool, useful for comparison among years (Table 11). The Q value classification, the ASPT score, the % EPT and the WHPT-ASPT are all low, indicating the absence of sensitive taxa and possible pollution stress. The Q value was unchanged from 2021 , but the ASPT was lower than that recorded in 2021, suggesting a decline in ecological quality. However, the WHPT ASPT was slightly higher than in 2021, suggesting the opposite. The % EPT was also slightly lower than in 2021. Overall, the results indicate little change at the site in terms of the ecological quality, with more tolerant species present, indicating an impact at the site.

Table 8. Standard macroinvertebrate metrics calculated at Rahasane Turlough, August 2022

Metric	2021	2022
Total number of Families	24	18
Q Value	Q3	Q3
BMWP	93	62
ASPT	4.23	3.88
% EPT	0.2	0.06
WHPT ASPT	3.4	3.6
WHPT NTAXA	24	18

Porst (2009) conducted a study of Irish turloughs, which showed that Trichoptera (caddisflies) and Heteroptera (true bugs) abundances have a significant positive correlation with the hydroperiod of the turlough. These macroinvertebrate groups are ephemeral residents of temporary waters and need more permanent habitats to complete their life cycles (Lahr, 1997; Lahr *et al.*, 1999). Porst (2009) hypothesized that higher abundances of ephemeral taxa occur in more permanent turloughs, because in turloughs with longer habitat permanence there is a greater possibility of colonisation. Among Heteroptera, the 2022 survey recorded moderate numbers of Corixidae (approximately 2.3% of the sample) and small numbers of Notonectidae and Veliidae (all Hemipterans), but no Trichopterans were recorded (Appendix 5, Table 29). This was slightly different from the results from 2021, where high numbers of Corixidae were recorded (approximately 6% of the sample), and single Gerridae (Hemiptera) and a small number of Trichopterans were recorded. It is too early to say whether this represents a change in community composition with respect to the Trichoptera, given the low number of Trichopterans found in the first year. The composition and abundance of these two orders will continue to be examined and compared in the coming years to assist in understanding if a transition in the habitat is occurring.

The association of higher abundances of Gastropoda in turloughs with longer hydroperiods concurs with their limited mobility (Follner and Henle, 2006). Despite possessing adaptations to drought (Williams, 2006), the limited mobility of molluscs seems to permit greater survival in sites inundated for longer periods. There was a high diversity and abundance and proportional abundance of gastropods (85%) in the 2022 samples at the turlough (5 families), similar to that recorded in 2021, (82% proportional abundance from 6 families) suggesting that they are not subject to drought pressure. However, this community will also continue to be monitored over the coming years to assess whether any compositional change is occurring post works.

4.4.5. Beetle Survey Comparison

Six species of aquatic beetle were identified, as well as a number of specimens that could only be identified to two groupings of species (Table 9). This represented a large increase in the number and diversity of adult specimens recorded in 2022 compared with 2021. *Haliplus lineolatus* and *Haliplus ruficollis* group was recorded in both years. Although *Ilybius fuliginosa* was not recorded in 2022, at least four taxa were newly recorded.

Table 9. Aquatic Beetle species recorded in the 2022 Survey of the Rahasane Turlough

Species / Species group	Combined water beetle sample	Combined Pond SYM sample
Haliplus ruficollis **group**	5	1
Haliplus lineolatus	1	
Haliplus ruficollis	2	
Hygrotus inaequalis	3	
Hydroporus palustris	5	
Helophorus longitarsis/griseus/minutus	2	1
Helophorus minutus	2	1
Laccobius colon	1	

Previous surveys recorded four of the six species identified in 2022 (Table 10). Two species had moderately high Species Quality Scores (SQS) of 16, *Laccobius colon* and *H. lineolatus*. *Helophorus minutus* had a moderate SQS of 8. A species with a high SQS represents aquatic species that are rare, without being elusive, with a higher score for rarer species or those restricted to undisturbed, natural habitats. None of the aforementioned species were restricted to undisturbed habitats, their scores being based on their rarity in Ireland. *Laccobius colon* (also known as *L. biguttatus*) is a characteristic species of a turlough, known to occur on exposed muddy edges (Foster, 1992)

Beetle diversity in the 2022 samples was higher than 2021, but low when compared to the previous studies (Table 10). The sample taken in 2021 was based only on the Pond SYM sampling method and did not specifically target beetles. In contrast, additional effort was put into beetle collection in 2022, with targeted beetle samples taken at a number of locations around the turlough in addition to those collected through the Pond SYM sampling. This decision was taken both as a result of a recommendation from an external reviewer of the report and based on the poor beetle diversity results observed in 2021. It is likely that the increase in beetle species observed is as a result of the additional collection effort.

The MQS score of 7.7 in 2022 reflects the presence of the aforementioned rarer species (Tables 9 and 10). It is a higher score than has been recorded in all previous surveys, with the exception of the survey conducted in 2004 (Table 10), reflecting overall that the ecological quality of the site has not shown evidence of decline.

Table 10. Mean Quality Score (MQS) calculated for the water beetle community and number of aquatic beetle species surveyed at the Rahasane Turlough, in this survey (bold) compared with previous years

Year	MQS Score	No. of species	Surveyor
2022	**7.7**	**6**	**APEM**
2021	6.7	3	APEM
2016	6.5	17	RPS
2004	10.4	13	Waldron
2003	7.5	12	Waldron
2002	5.7	10	O'Connor
1992	3	11	Foster
1989	3.3	11	Bilton

The Environmental Impact Statement (EIS) noted that several beetle species which are sensitive to hydrological alterations had been identified in the turlough previously. These were the turlough species *Agabus nebulosus, Hygrotus quinquelineatus* and *Hygrotus impressopunctatus*; and the moss dwelling species *Graptodytes bilineatus. G. bilineatus* is listed as Near Threatened on the Irish Waterbeetle Red List (Foster *et al.*, 2009) and is considered likely to be vulnerable to disturbance and sensitive to alterations in flooding (Sheehy Skeffington *et al.*, 2006). None of these species were recorded in the 2021 or 2022 surveys. Therefore, continued monitoring in the coming years should maintain a focus on the beetle communities, and assess whether the absence of these species is an

anomaly or whether a longer-term pattern of change in the aquatic beetle community is occurring at the turlough, and whether a hydrological change has prompted this.

5. Key Findings from Year 2

Hyrdrogeology and Hydrology Survey:

- As part of the second year of monitoring the Rahasane Turlough, a drone survey and walkover survey of Rahasane Turlough were conducted and hydrometric data (OPW hydrometric station data and local rainfall data) was collected and reviewed. Approximately 10% of the turlough SAC was submerged when the aerial imagery was obtained.
- The water levels in the turlough during the 2022 survey were much lower compared to 2021 as a result of a prolonged dry period. Karst features identified during the 2021 survey were monitored and several newly identified features were recorded due to the lower water levels in the turlough. Numerous small-scale depressions, possible estavelles with gentle slopes and wetland vegetation were recorded during the walkover survey.
- The main difference recorded between the 2021 and 2022 surveys was the amount of water in the turlough (notably less in 2022 compared to 2021). This was due to the preceding extended dry period in 2022.

Vegetation Surveys:

- The turlough's water level was lower in summer 2022 than in summer 2021, allowing access to more relevés.
- Grazing levels were noted to be high in several areas, similar to that recorded in 2021; however, the amount of poaching of the soil by livestock was less than in 2021.
- The classification system of Sharkey (2012) was found to correspond only approximately with the vegetation communities as recorded at Rahasane.
- Relevé species lists showed much similarity between results recorded in 2021 and 2022.
- Comparisons between data from 2014-2015 (RPS, 2016) and 2021-2022 showed that there appeared to be substantial changes in the vegetation communities at some relevé locations – these are summarised in Section 2.3 and full details are given in Appendix 5.

Macroinvertebrate and PSYM Survey:

- Water quality readings demonstrated very high levels of photosynthesis, a consequence of extensive algal growths. This suggests significant nutrient inputs, which may be related to the presence of livestock and horses grazing, including heavily grazed margins and poaching apparent next to the turlough. The pH at all sites was basic, in contrast with the slightly acid pH of the water at all sites observed in 2021, and more consistent with the Karst nature of the catchment.
- A total of 18 macroinvertebrate families were recorded, principally gastropods, with some corixids, bivalves and damselflies in relatively high abundance. Pond PSYM metrics supported a conclusion of nutrient impact at the site, corroborated by the Q3 classification, and low ASPT and WHPT-ASPT scores, plus the visual observation of slimy green algae in rafts on the water surface.
- The high abundance (>1400 specimens, and proportional abundance of 85%) and diversity of gastropods at the site (6 families) suggests that this group are not subject to drought pressure.
- Beetle diversity in the samples collected was higher than that recorded in 2021, likely owing to additional sampling targeting beetles that was conducted. However, the diversity was still lower when compared with earlier studies, although the Mean Quality Score was consistent with that recorded in previous years.
- Future surveys will continue to compare results such as the PSYM scores, community structure, abundance of ephemeral taxa (positively correlated with more permanent

turloughs), gastropod community and beetle MQS scores, recorded here, among years, to establish whether a transition has occurred from a habitat characteristic of being regularly flooded to one that is more frequently dry.

6. References

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Plates

Plate 1 OPW Hydrometric Station Craughwell 29007 (facing west)

Plate 2 Aggard Bridge 29010 Hydrometric Station (facing downstream)

Plate 3 Aggard Bridge 29010 Data Logger

Plate 4 Rahasane Turlough 29002 Hydrometric Station

Plate 5 Shallow depressions (left: 2021, right: 2022)

Plate 6 Shallow depressions (left: 2021, right: 2022)

Plate 7 Monitoring well (condition unknown) (left: 2021, right: 2022)

Plate 8 Old Dunkellin channel

Plate 9 Pond appears to drain to main channel

Plate 10 Estavelle

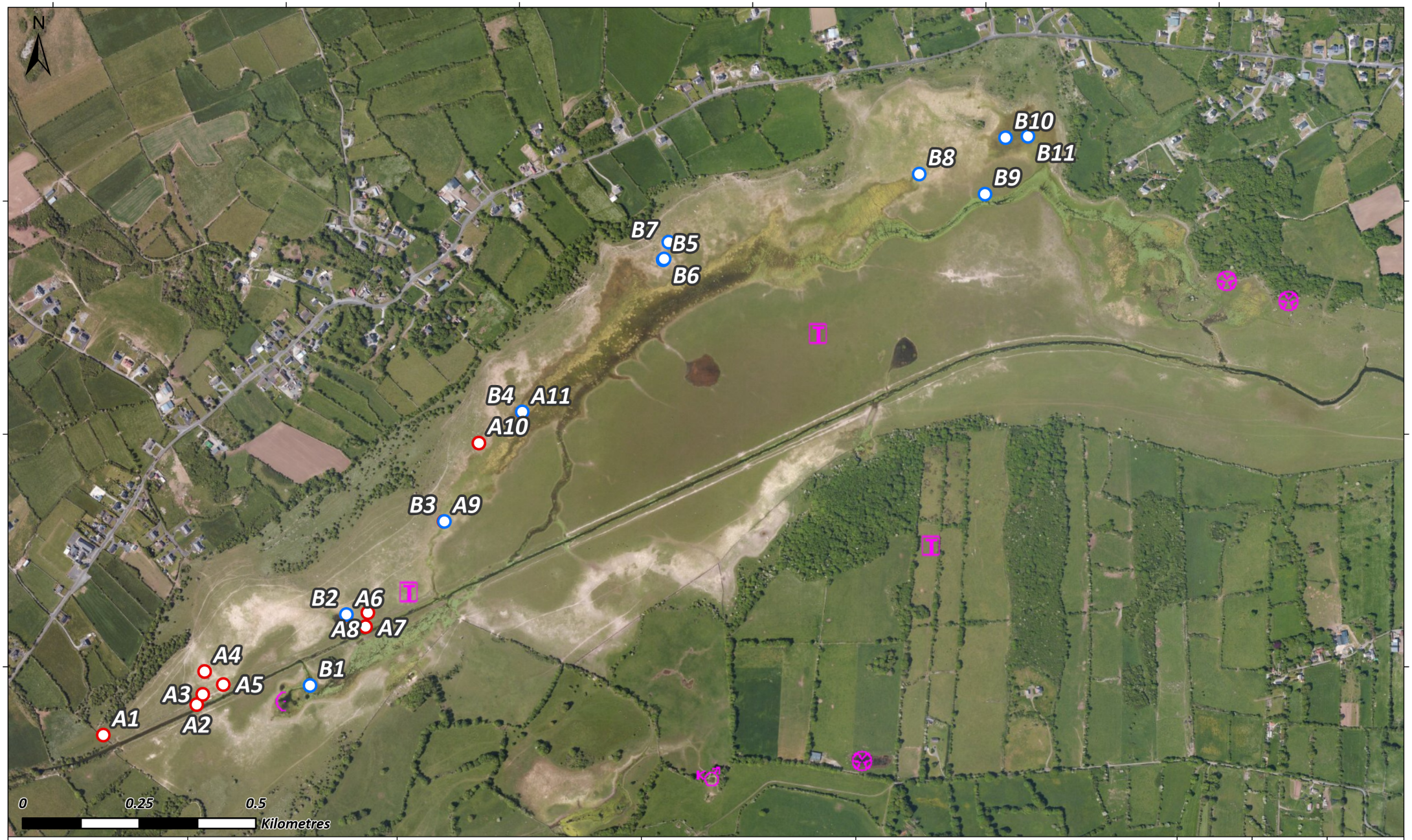
Plate 11 Photo of Site 1 (macroinvertebrate and PSYM survey; 23.08.22)

Plate 12 Photo of Site 2 (macroinvertebrate and PSYM survey; 23.08.22)

Plate 13 Photo of Site 3 (macroinvertebrate and PSYM survey; 23.08.22)

Plate 14 Photo of Site 4 (macroinvertebrate and PSYM survey; 23.08.22)

Appendix 1: Known karst features in the Rahasane Turlough SAC



Client: APEM Ireland Ltd	*Consultant:* 15 Wentworth, Eblana Villas, Dublin 2, D02 A611, Dublin (Ireland). Tel: +353 1 232 1044. Web: www.cdmsmith.com	*Drawing Title:* Hydrogeological Features	*Project Name:* RAHASANE TURLOUGH MONITORING. *Project Code:* 264298	***Karst Landforms (GSI)*** Enclosed Depression; Spring; Swallow Hole; Turlough. ***Site Walkover Location - see report for details*** 2021; 2022	*Drawn:* BP	*Checked:* LF	*Approved:* JH
					Date: 18/11/2022	*Scale:* 1:10,500 @ A4	
					Drawing Number: 1	*Revision:* D	
					Spatial Reference Name: IRENET95 Irish Transverse Mercator		

Document Path: C:\Users\pittsb\OneDrive - CDM Smith\Teams - GIS Team Europe - Ireland\Drone Operations\Rahasane\Rahasane.aprx

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Appendix 2: Vegetation Survey Maps

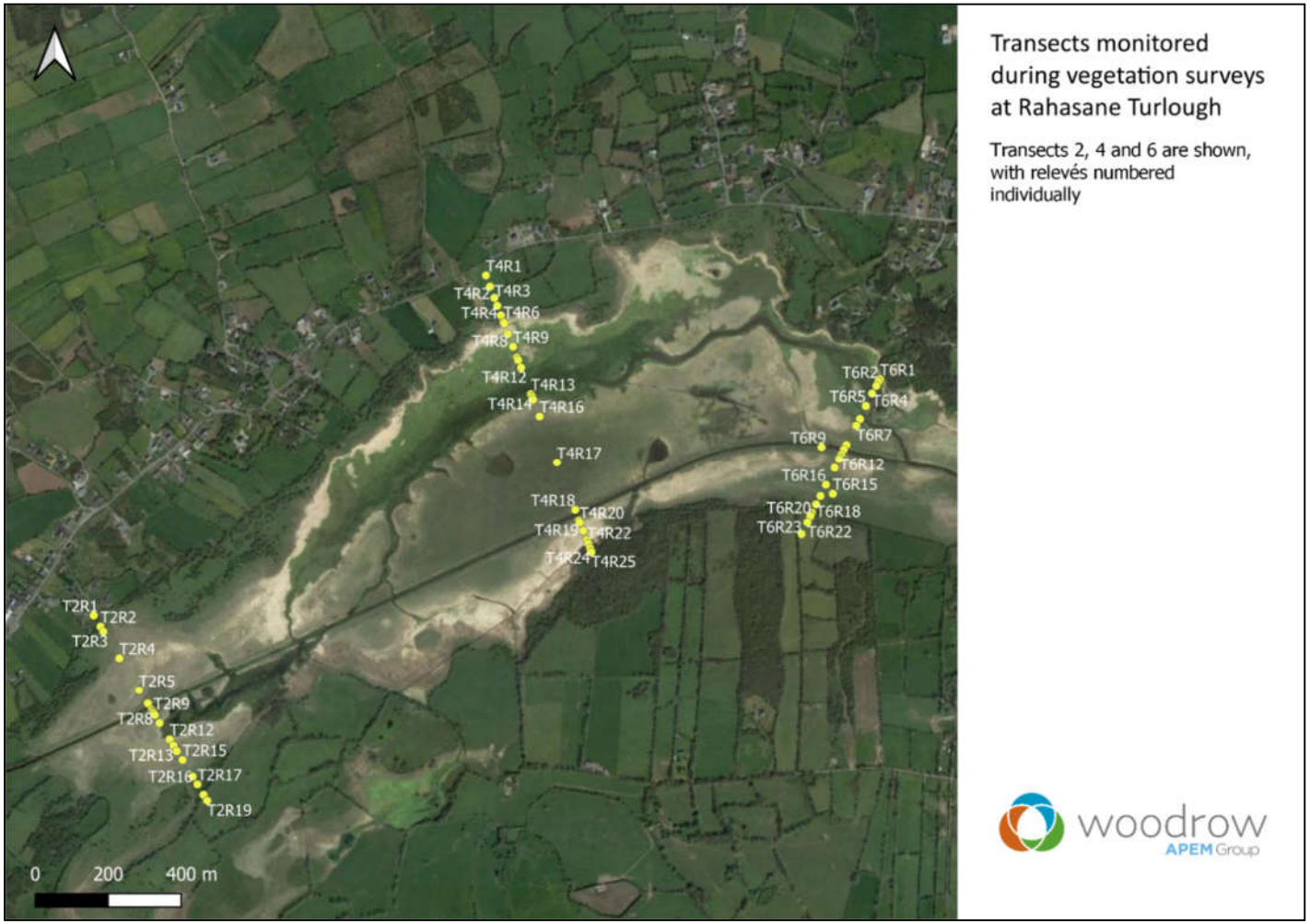


Figure 5 :Three transects selected for surveys at Rahasane Turlough

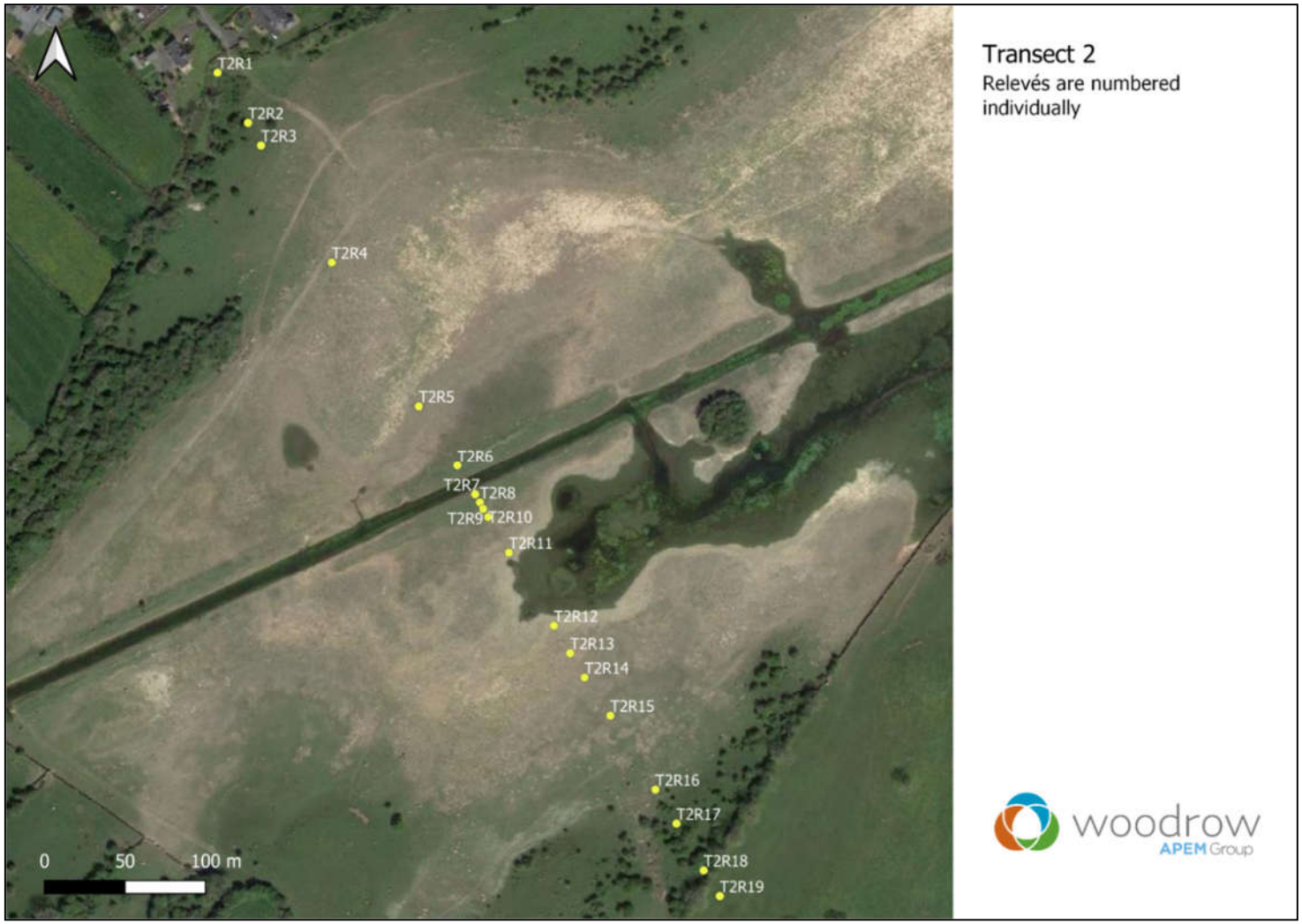


Figure 6: Transect 2 and the surrounding area, Rahasane Turlough, Co. Galway

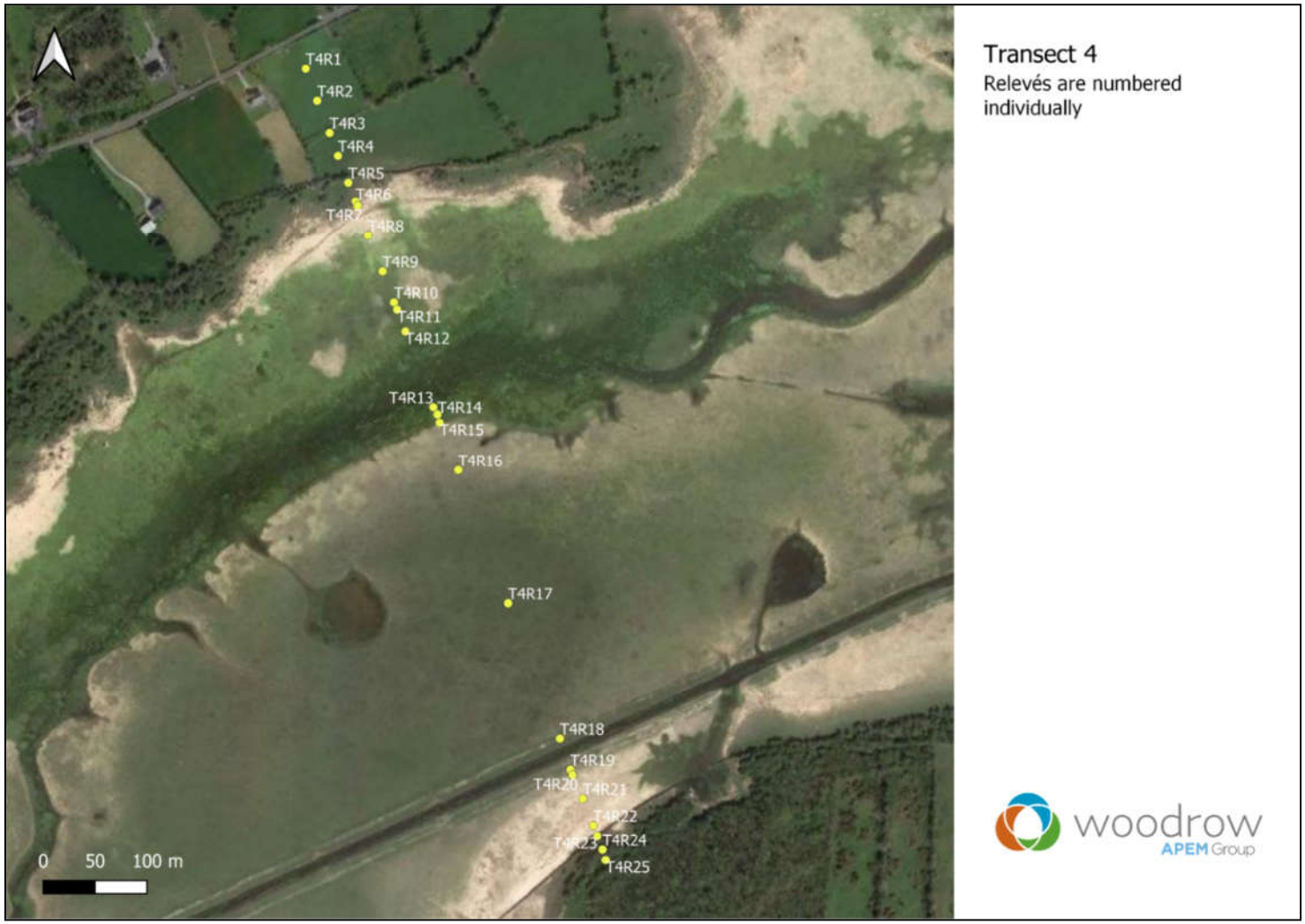


Figure 7: Transect 4 and the surrounding area, Rahasane Turlough, Co. Galway

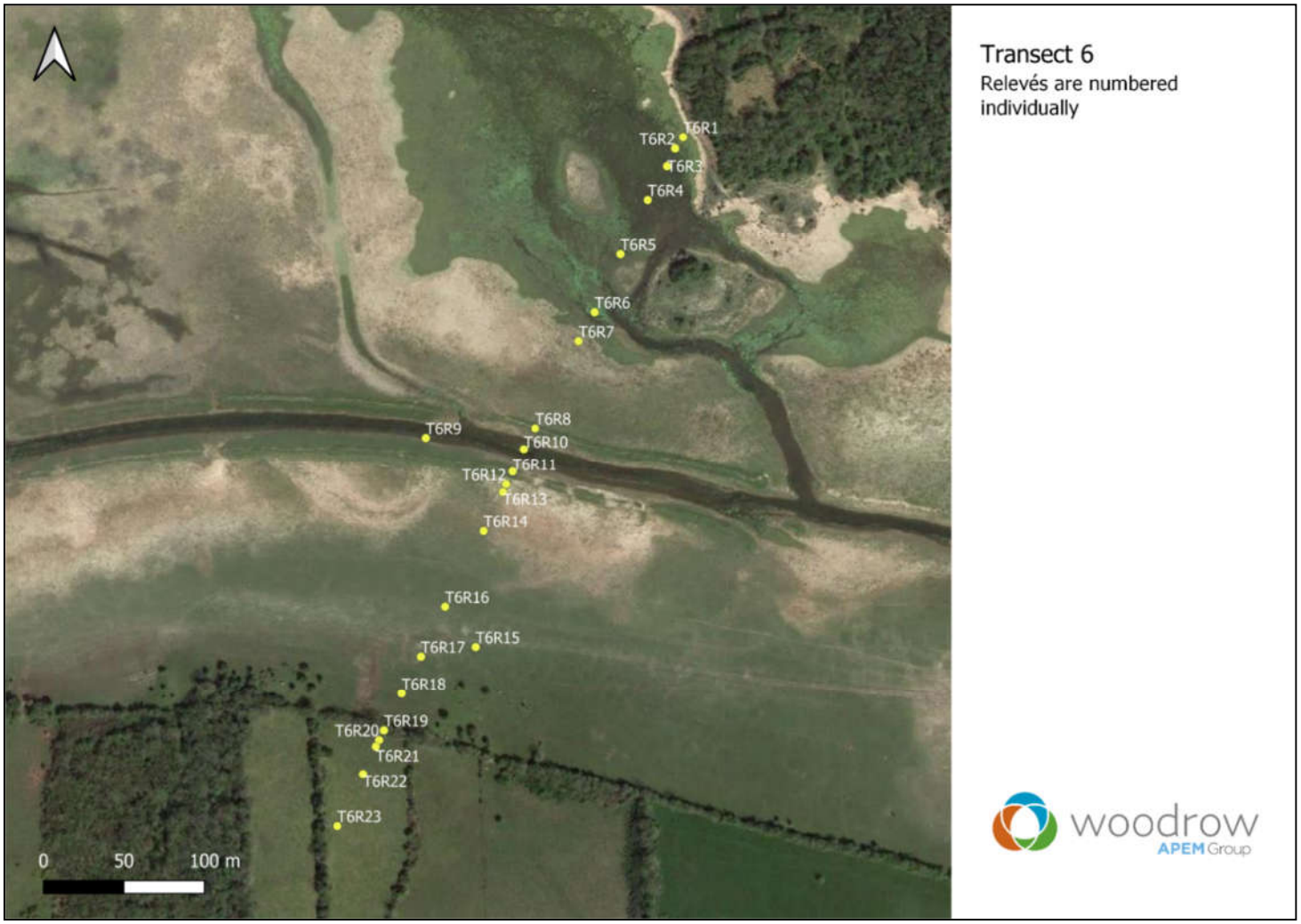


Figure 8: Transect 6 and the surrounding area, Rahasane Turlough, Co. Galway

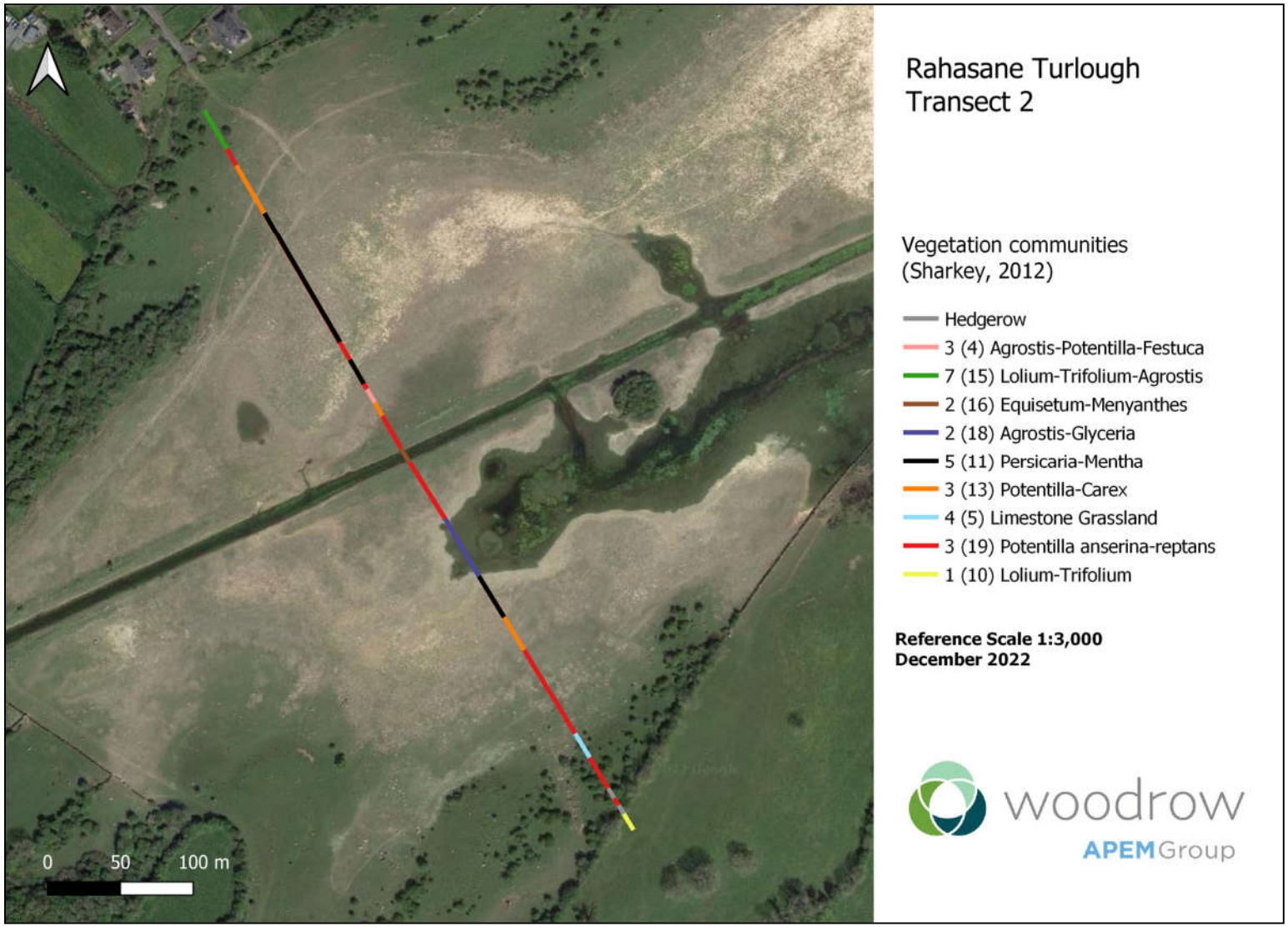


Figure 9 Vegetation communities recorded at Transect 2

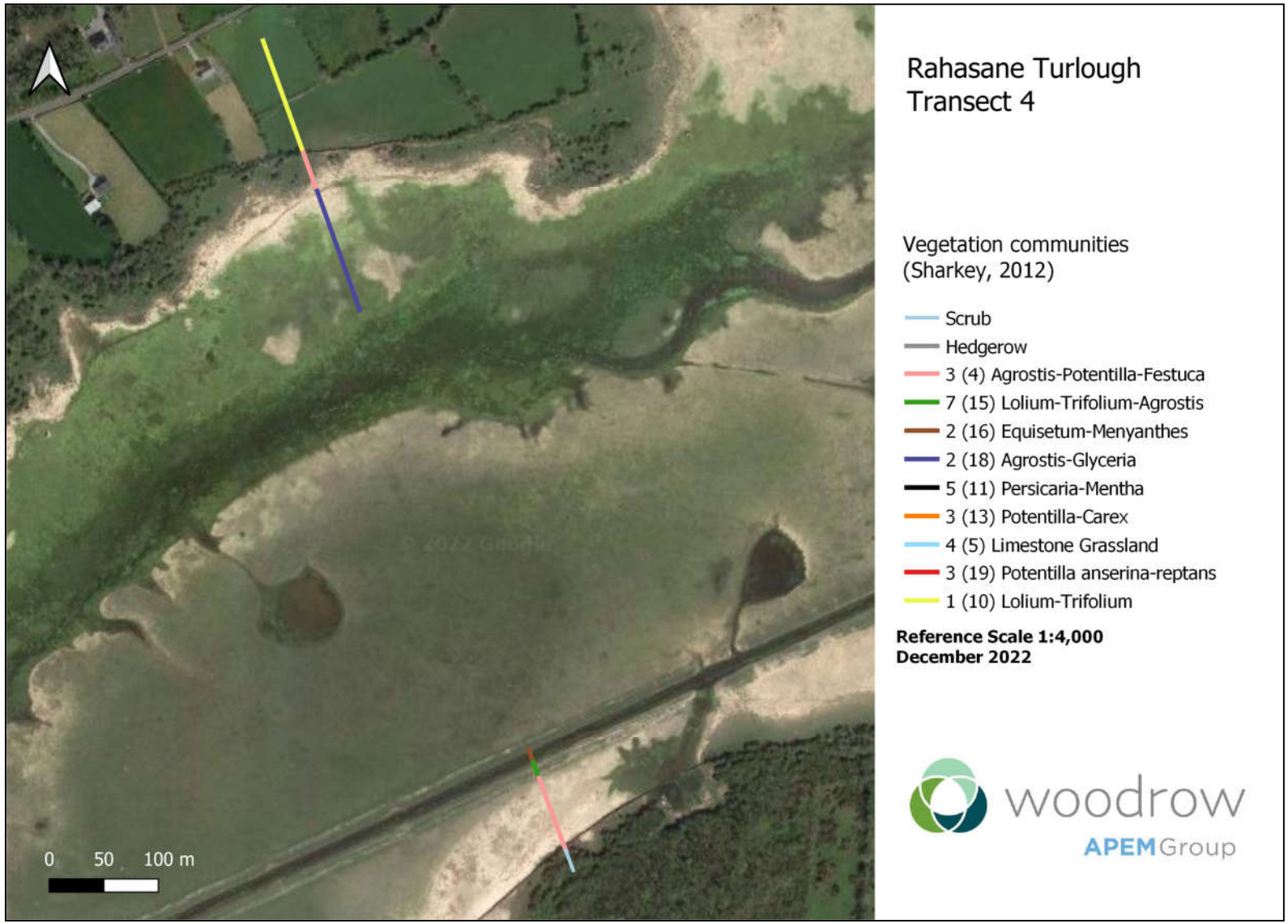


Figure 10 Vegetation communities recorded at Transect 4

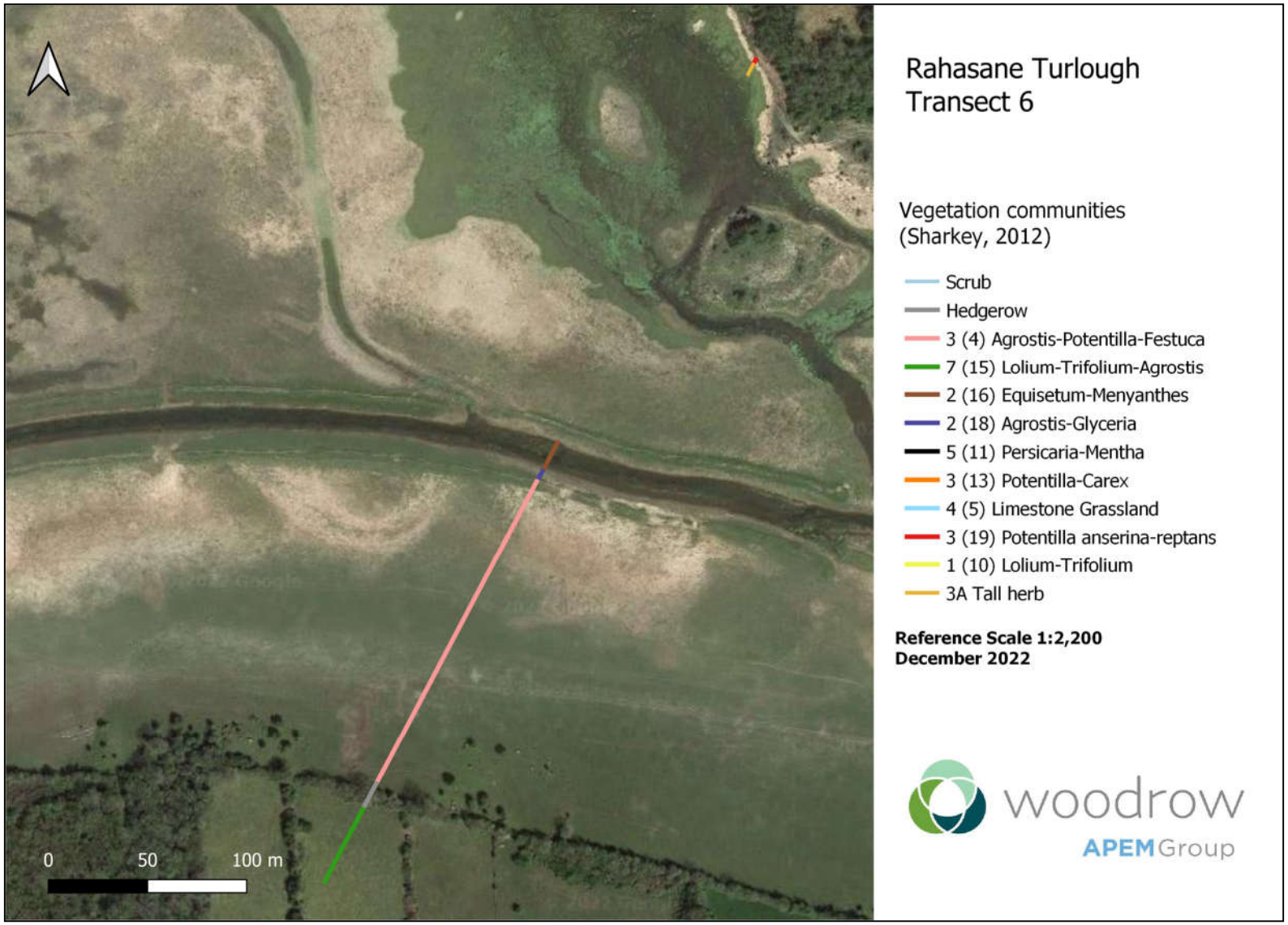


Figure 11 Vegetation communities recorded at Transect 6

Appendix 3: Additional Vegetation Survey Results

Table 11: Photo and additional notes from Relevé 2 (Transect 2), Rahasane Turlough, Co. Galway.

Relevé	T2R2
Date	12-07-2022
Comments, notes or threats: This area was grazed closely by sheep, and sheep droppings were present at the time of the survey. No bare ground or signs of poaching were noted. The general area around the relevé had several rocks on the surface. The ground was dry and firm underfoot, locally undulating slightly but overall quite level.	
	

Table 12: Photo and additional notes from Relevé 4 (Transect 2), Rahasane Turlough, Co. Galway.

Relevé	T2R4
Date	12-07-2022
Comments, notes or threats: The area in which this relevé is located was grazed by sheep and horses. The vegetation had been grazed quite tightly by the time of the survey. The relevé was almost fully vegetated, with no poaching recorded.	
	

Table 13: Photo and additional notes from Relevé 6 (Transect 2), Rahasane Turlough, Co. Galway.

Relevé	T2R6
Date	12-07-2022
Comments, notes or threats: This relevé is located on a raised bank along the central channel. The ground was dry and firm underfoot at the time the survey was conducted. The vegetation was grazed very short by sheep. A lot of sheep droppings were present in this area. The ground did not show signs of poaching.	
	

Table 14: Photo and additional notes from Relevé 12 (Transect 2), Rahasane Turlough, Co. Galway.

Relevé	T2R12
Date	12-07-2022
Comments, notes or threats: The vegetation in the area of this relevé was grazed short by sheep and horses. The area was almost fully vegetated and no poaching of the ground was recorded.	
	

Table 15: Photo and additional notes from Relevé 16 (Transect 2), Rahasane Turlough, Co. Galway.

Relevé	T2R16
Date	12-07-2022
Comments, notes or threats: The area in which this relevé was located was grazed by sheep, horses and donkeys, which were present in the surrounding area during the survey. Sheep's wool and droppings were noted within the relevé. The vegetation was dominated by *Potentilla anserina* (silverweed), which was growing quite luxuriantly. The ground in this area was generally level, with minor localised undulations, and was dry and firm underfoot during the survey. Some outcrops of rock were present in the surrounding area.	
	

Table 16: Photo and additional notes from Relevé 5 (Transect 4), Rahasane Turlough, Co. Galway.

Relevé	T4R5
Date	13-07-2022
Comments, notes or threats: This relevé was located near a hedgerow. The ground was very firm and dry underfoot at the time of the survey. Several rocks were present on the ground in the general area surrounding the relevé. The area did not appear to have been recently grazed. The relevé was fully vegetated, except for some small stones.	
	

Table 17: Photo and additional notes from Relevé 10 (Transect 4), Rahasane Turlough, Co. Galway.

Relevé	T4R10
Date	13-07-2022
Comments, notes or threats: This was a wet area with a little surface water, but the ground was quite firm underfoot. The vegetation did not appear to have recently been grazed at the time of the survey.	
	

Table 18: Vegetation survey results from Relevé 16 (Transect 4), Rahasane Turlough, Co. Galway.

Relevé	T4R16
Location (ITM)	X: 547499 Y: 719770
Inaccessible due to high water level	

Table 19: Vegetation survey results from Relevé 18 (Transect 4), Rahasane Turlough, Co. Galway.

Relevé	T4R18
Location (ITM)	X: 547597 Y: 719511
Inaccessible due to high water level	

Table 20: Photo and additional notes from Relevé 22 (Transect 4), Rahasane Turlough, Co. Galway

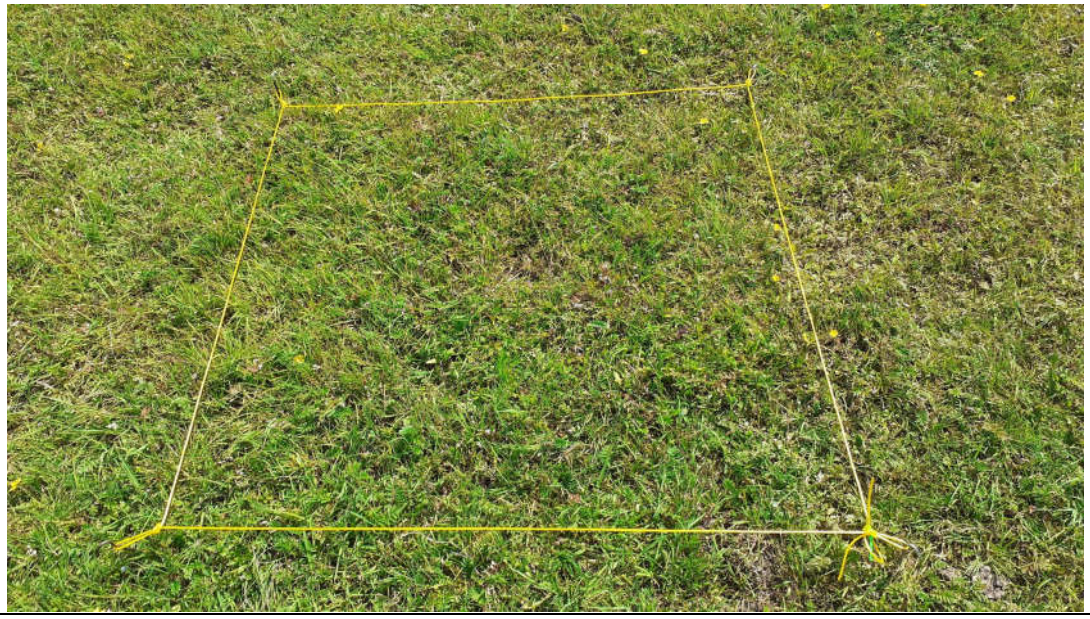
Relevé	T4R22
Date	13-07-2022
Comments, notes or threats: The vegetation at this location was grazed quite tightly by sheep at the time of the survey. The relevé and surrounding area was almost fully vegetated, and poaching was not recorded at his location. The ground was dry and firm underfoot**.**	
	

Table 21: Vegetation survey results from Relevé 2 (Transect 6), Rahasane Turlough, Co. Galway.

Relevé	T6R2
Location (ITM)	X: 548428 Y: 719865
Inaccessible due to high water level	

Table 22:Vegetation survey results from Relevé 6 (Transect 6), Rahasane Turlough, Co. Galway.

Relevé	T6R6
Location (ITM)	X: 548378 Y: 719763
Inaccessible due to high water level	

Table 23: Photo and additional notes from Relevé 12 (Transect 6), Rahasane Turlough, Co. Galway.

Relevé	T6R12
Date	13-07-2022
Comments, notes or threats: The ground at this location was dry and firm underfoot at the time of the survey visit. The area is level, and the vegetation had been grazed tightly by sheep.	
	

Table 24: Photo and additional notes from Relevé 16 (Transect 6), Rahasane Turlough, Co. Galway

Relevé	T6R16
Date	13-07-2022
Comments, notes or threats: This relevé was located on an area of level ground, very firm underfoot at the time of the survey. The relevé was fully vegetated but had been grazed very short by sheep, which were present at the time of the survey. No poaching was noted.	
	

Table 25: Photo and additional notes from Relevé 18 (Transect 6), Rahasane Turlough, Co. Galway

Relevé	T6R18
Date	13-07-2022
Comments, notes or threats: This relevé is located in a flat area, which was firm underfoot and dry at the time of the survey. The area was grazed by sheep and cattle, with lots of animal droppings present in the area. While the vegetation had been grazed very short, no poaching was recorded.	
	

Appendix 4: Vegetation Comparison Tables

Table 26: Comparison between plant species recorded in 2014-2015 and 2021-2022 at Rahasane Turlough. Figures show percentage cover for each plant species.

Transect 2	Relevé T2R2			Relevé T2R4			Relevé T2R6			Relevé T2R12			Relevé T2R16		
Species	2014-2015	2021	2022	2014-2015	2021	2022	2014-2015	2021	2022	2014-2015	2021	2022	2014-2015	2021	2022
Achillea millefolium		6	12												
Agrostis stolonifera	60	23	5	40	40	40	50	33	25	55	65	52	35	38	20
Alopecurus geniculatus										2					
Bellis perennis	+	<4	5				1	<1	2						
Brachythecium rutabulum					<4			<1			2			<4	
Bryum sp.					<1										
Calliergonella cuspidata			1												
Cardamine pratensis	+				<1	1		<1		3		<1	0.5	<4	
Carex hirta	+						20								
Carex nigra	6	5	<1			5			3						
Carex panicea									2						
Cerastium fontanum							1	<1	<1						
Cinclidotus fontinaloides		<4	<1				5								
Cirsium arvense	4			+											
Festuca rubra		<4							<1						
Fontinalis antipyretica												4			
Galium palustre				+	10	5		5		3		<1	1	<4	1
Gnaphalium uliginosum					<1							<1			
Hydrocotyle vulgaris		<4												<4	
Juncus articulatus				2											
Juncus sp.								<1							
Lolium perenne			5												
Mentha aquatica				3	5	2				6	<4	4			

Transect 2	Relevé T2R2			Relevé T2R4			Relevé T2R6			Relevé T2R12			Relevé T2R16		
Species	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**
Myosotis scorpioides				10	10	10	+	2		10	12	8	5	<4	<1
Nasturtium officinale											<4				
Persicaria amphibia					<4										
Persicaria minus													0.5		
Plagiochila sp.	+														
Plantago lanceolata		<4	2					4	6						
Plantago major	+		1		2	4	+			1			2		<1
Poa annua			15												
Poa pratensis						10									
Potentilla anserina	35	32	28	65	15	30	70	25	28		16	34	40	30	70
Potentilla reptans		4				2		<4	2					<4	<1
Prunella vulgaris					<1										
Ranunculus repens	10		1	5	<4	3	10	<1	<1				15	<4	1
Ranunculus trichophyllus										1					
Rorippa sp.					<1						<4				
Rumex crispus	10	7	2		<4	1	5	1	2	0.5				<4	
Taraxacum officinale			1												
Scorzoneroides autumnalis	1	<4	<1				4	<4	<1				15	<4	<1
Stellaria media															<1
Trifolium repens	30	18	70			5	15	30	28				30	26	20
Viola ?persicifolia					<4										
Species richness	**12**	**13**	**16**	**9**	**16**	**13**	**12**	**15**	**13**	**9**	**7**	**8**	**10**	**12**	**10**

Table 27: Comparison between plant species recorded in 2014-2015 and 2021-2022 at Rahasane Turlough. Figures show percentage cover for each plant species.

Transect 4	Relevé T4R5			Relevé T4R10			Relevé T4R16			Relevé T4R18			Relevé T4R22		
Species	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**
Agrostis stolonifera		25	28		Inaccessible	50	75			50	Inaccessible	Inaccessible	90	Inaccessible	30
Alopecurus geniculatus													1		
Berula erecta						2									
Cardamine pratensis						<1							3		
Carex hirta															10
Carex nigra										3					
Cerastium fontanum		<1	1												1
Cinclidotus fontinaloides		<1	1												
Eleocharis palustris					Inaccessible	6					Inaccessible	Inaccessible		Inaccessible	
Festuca rubra	60			40											
Filamentous green algae						<1									
Fontinalis antipyretica													0.5		
Galium palustre						<1	5						3		1
Glyceria fluitans						4									
Juncus bulbosus															<1
Mentha aquatica					Inaccessible	3	10				Inaccessible	Inaccessible		Inaccessible	2
Myosotis scorpioides	+	5	1	5		23	5						5		5
Persicaria amphibia		<4				15									
Persicaria minus													1		
Plantago lanceolata															
Plantago major		2								15					
Potentilla anserina	50	50	55		Inaccessible		5			15	Inaccessible	Inaccessible	7	Inaccessible	23
Potentilla reptans	10	2	2												7
Ranunculus repens	20	10	6				5			5					1
Rorippa sp.													2		
Rumex acetosa										5					

Transect 4	Relevé T4R5			Relevé T4R10			Relevé T4R16			Relevé T4R18			Relevé T4R22		
Species	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**
Rumex crispus	+	5	3												
Scorzoneroides autumnalis	+		<1							5					
Stellaria media		<1								2					
Trifolium repens			4							5					
Viola persicifolia	+														
Species richness	**8**	**11**	**10**	**2**	**-**	**10**	**6**	**-**	**-**	**9**	**-**	**-**	**9**	**-**	**10**

Table 28: Comparison between plant species recorded in 2014-2015 and 2021-2022 at Rahasane Turlough. Figures show percentage cover for each plant species.

Transect 6	Relevé T6R2			Relevé T6R6			Relevé T6R12			Relevé T6R16			Relevé T6R18		
Species	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**
Agrostis stolonifera		Inaccessible	Inaccessible		Inaccessible	Inaccessible	15	50	20	10	48	43	20	20	22
Alopecurus geniculatus								<4							
Bellis perennis														<1	1
Cardamine pratensis				1				<1			<4			<1	
Carex hirta									<1						
Carex nigra								3	20	20	4	4	10		3
Cerastium fontanum															1
Festuca rubra							15	<4			4	2			6
Filipendula ulmaria										20		<1			
Galium palustre								<1	3		<4	<1	5	2	1
Glyceria fluitans				50											
Juncus articulatus															2
Juncus bulbosus												1			
Juncus sp.									<1						
Lolium perenne															2
Myosotis scorpioides				3			1	3	3		<4	<1			
Phleum pratense															2
Plantago major												<1			1
Potentilla anserina							50	30	35	30	32	25	15		36
Potentilla reptans									<1		<4	<1		<1	2
Prunella vulgaris														<4	2
Ranunculus repens							20	10	15	5		3		<4	3
Rumex acetosa														<1	
Rumex crispus				2				<4							
Scorzoneroides autumnalis							+			5			5	2	<1
Sparganium erectum				1											
Stellaria media													5		

Transect 6	Relevé T6R2			Relevé T6R6			Relevé T6R12			Relevé T6R16			Relevé T6R18		
Species	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**	**2014-2015**	**2021**	**2022**
Taraxacum officinale									<1			<1			
Trifolium repens				1					3	10		20	45		25
Veronica catenata				1											
Veronica chamaedrys											<4				
Veronica serpyllifolia															<1
Species richness	**-**	**-**	**-**	**7**	**-**	**-**	**6**	**10**	**11**	**7**	**9**	**13**	**7**	**9**	**17**

Appendix 5: Macroinvertebrate and Aquatic Plant Taxa Lists

Table 29: List of macroinvertebrate taxa recorded at Rahasane Turlough and their abundance, August 2022

Order/Group	Family	Abundance
Odonata	Coenagrioniidae	60
Crustacea	Gammaridae	10
Hemiptera	Corixidae	38
	Notonectidae	2
	Veliidae	5
Coleoptera	Haliplidae	1
	Helophoridae	2
Ephemeroptera	Baetidae (*Baetis rhodani*)	4
Gastropoda	Bithyniidae	355
	Lymnaeidae	499
	Physidae	69
	Planorbidae	410
	Valvatidea	85
Bivalvia	Sphaeriidae	111
Isopoda	Asellidae	13
Hirudinea	Glossiphonidae	3
Diptera	Chironomidae	5
	Tabaniidae	1
	Total	**1673**

Table 30. Aquatic plant species recorded at the Rahasane Turlough, August 2022

Type of Macrophyte	Species Recorded	Rarity Score	Trophic Ranking Score
Emergent Plants	*Agrostis stolonifera*	1	LP
	Alisma plantago-aquatica	1	LP
	Berula erecta	2	10
	Cardamine pretensis	1	
	Carex nigra	1	5
	Equisetum palustre	1	
	Filipendula ulmaria	1	
	Galium palustre	1	
	Geum rivale	1	
	Glyceria fluitans	1	LP
	Juncus acutiflorus	1	

Type of Macrophyte	Species Recorded	Rarity Score	Trophic Ranking Score
	Juncus bulbosus	1	5.3
	Lythrum salicaria	1	
	Mentha aquatica	1	7.3
	Myosotis scorpiodes	1	9
	Myosotis sp. (undetermined)	1	
	Oenanthe fluviatilis	2	
	Phalaris arundinacea	1	8.5
	Potentilla erecta	1	
	Potentilla palustris	1	5.3
	Ranunculus flammula	1	LP
	Ranunculus reptans	32	
	Ranunculus sceleratus	1	10
	Rorippa islandica	8	
	Sparganium erectum	1	8.5
	Stellaria palustris	2	
	Stellaria uliginosa	1	
	Typha latifolia	1	8.5
	Veronica catenata	2	
	Veronica beccabunga	1	10
	Veronica sp. (undetermined)	1	
Floating Leaved Plants	*Lemna trisulca*	1	10
	Nuphar lutea	2	8.5
	Persicaria amphibia	1	9
	Potamogeton natans	1	LP
Submerged Plants	*Apium inundatum*	2	6.3
	Callitriche sp	1	
	Chara sp	2	7.3
	Elodea canadensis	1	7.3
	Fontinalis antipyretica	1	6.3
	Hippuris vulgaris	2	7.7
	Myriophyllum verticillatum	4	
	Potamogeton pusillus	2	9
	Ranunculus aquatilis	2	10
	Ranunculus circinatus	2	10
	Ranunculus trichophyllus	2	8.5
	Sparganium angustifolium	2	4
	Sparganium emersum	1	10
	Utricularia vulgaris	2	5

Appendix 6: Macroinvertebrate metrics

Q-Value Assessment

The EPA Q-value classification is assigned based on the assessment of the macroinvertebrate sample, which involves recording the taxa present at a suitable and attainable (under field conditions) taxonomic resolution and their categorical relative abundance determined using approximate counts (as described in Feeley *et al.*, 2020). From this, the number of taxa present and categorical relative abundance of sensitive (Group A), less sensitive (Group B), tolerant (Group C), very tolerant (Group D) and most tolerant (Group E) taxa to organic pollution is examined. Additional Qualifying Criteria are also considered, consisting of recording the abundance of *Cladophora* spp, Macrophytes, and slime growths / sewage fungus, as well as the Dissolved Oxygen Saturation % and the level of substratum siltation. Then, based on the combination of number of taxa and relative abundance of the sensitive or tolerant groups present a Q-value is assigned. Details on the assignment of the scores can be found in Toner *et al.*, (2005).

In Ireland, macroinvertebrates are the main Biological Quality Element (BQE) determining the ecological status in rivers (required by the Water Framework Directive; WFD) and are based on the Q-value. The WFD requires BQE scores to be expressed as an Ecological Quality Ratio (EQR) to standardize and provide a common scale of ecological quality across participatory Member States using differing national methods. Intercalibration of the Q-value with the EQR and the corresponding ecological status are described in Table 31.

Table 31 EPA water quality status summary
Comparing the Q-value, ecological quality ratio (EQR), corresponding Water Framework Directive (WFD) status and pollution gradient resulting from anthropogenic pressures (Feeley *et al.*, 2020).

Q value Score	EQR	Pollution Gradient	WFD Ecological Status
Q5	1.0	Unpolluted	High
Q4-5	0.9	Unpolluted	High
Q4	0.8	Unpolluted	Good
Q3-4	0.7	Slightly Polluted	Moderate
Q3	0.6	Moderately Polluted	Poor
Q2-3	0.5	Moderately Polluted	Poor
Q2	0.4	Seriously Polluted	Bad
Q1-2	0.3	Seriously Polluted	Bad
Q1	0.2	Seriously Polluted	Bad

BMWP and ASPT

The Biological Monitoring Working Party (BMWP) index was designed to identify the degree of organic pollution based on the natural sensitivity of taxon to the pollution. Aquatic organisms respond to chemical changes in water, in particular to the changes in dissolved oxygen concentrations. As pollution levels increase, the microbial oxygen demand rises, resulting in a decline in available oxygen

concentrations. Many stream organisms require high dissolved oxygen concentration and are therefore not found in water bodies with lower oxygen concentrations. Macroinvertebrate families which are sensitive to pollution are assigned high BMWP scores, while pollution-tolerant taxa score low. In the BMWP system, benthic invertebrate taxa are assigned a score between 1 (tolerant to organic pollution) and 10 (intolerant to organic pollution). The BMWP score is the sum of the values for all families present in the sample. The number of BMWP-scoring families is typically recorded alongside the BMWP score, as is the Average Score Per Taxon (ASPT), which can be determined by dividing the BMWP score by the number of scoring taxa present. The BMWP score may vary significantly depending on whether the sampling process captures species found in some habitats but not in others. Standardisation of the BMWP score is therefore provided by the ASPT, with the average BMWP score per taxon allowing robust comparisons among sites.

WHPT and WHPT-ASPT

The Whalley Hawkes Paisley Trigg (WHPT) metric is used in the UK for monitoring, assessing and classifying rivers in accordance with the requirements of WFD based on assessing the ecological quality of the macroinvertebrates present when sampled. It is a revised version of the original BMWP index. Empirical data was used in the development of the WHPT index to assign abundance related sensitivity weights to taxa. The taxa included in the index are modified from those used for the BMWP index and a number of taxa were removed due to insufficient data; some additional families were included where sufficient data were available, and some existing BMWP composite taxa were split into their constituent families. The WHPT-ASPT values typically range from 1 (indicative of sites with high organic pollution and degradation) to 13 (indicative of sites with very low organic pollution and degradation). The WHPT-ASPT score standardises the WHPT score to an average per taxa to allow a robust comparison among sites.

In the UK, a WFD macroinvertebrate classification for a river site is generated by calculating the number of abundance weighted WHPT scoring families found during sampling (WHPT NTAXA), and the WHPT-ASPT, and comparing these values to the values that might be expected under undisturbed or reference conditions for that site. These undisturbed or reference scores are predicted by statistical models produced by the River Invertebrate Classification Tool (RICT) – as RICT predicts invertebrate communities at reference conditions. The observed values of WHPT ASPT and WHPT NTAXA are compared to the predicted values to generate an Environmental Quality Ratio (EQR). EQRs close to 1.0 indicate that invertebrate communities are close to their natural state. However, the RICT is only appropriate for use in the UK and is not used in Ireland.