Hawk's Tor Pit

Environmental Assessment Report

Stantec

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3	10/01/2023	all	all	Final report	CB / ASJ
4	12/01/2023	all	all	Final report after additional comments	CB

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Glossary

Term	Definition
AOD	Above Ordnance Diatom
AONB	Area of Natural Beauty
ASPT	Average Score per Taxon
BGS	British Geological Society
BMWP	Biological Monitoring Working Party
BOD	Biological Oxygen Demand
CIEEM	Chartered Institute of Ecology and Environmental Management
CWS	County Wildlife Site
DO	Drought Order
DP	Drought Permit
EA	Environment Agency
EAR	Environmental Assessment Report
EMP	Environmental Management Plan
EQR	Ecological Quality Ratio
EQS	Environmental Quality Standards
HRA	Habitat Regulations Assessment
INNS	Invasive non-native species
LCA	Landscape Character Area
LIFE	Lotic invertebrate Index for Flow Evaluation
MCZ	Marine Conservation zone
Ml/d	Megalitres per day
NE	Natural England
NERC	Natural Environment Research Council
NNR	National Nature Reserve
NRFA	National River Flow Archive
NRW	Natural Resources Wales
NTAXA	Number of Taxa
PET	Potential Evapotranspiration
PTV	Pollution Tolerant Valves
RICT	River Invertebrate Classification Tool

RMHI	River Macrophyte Hydraulic Index
RNAG	Reason for Not Achieving Good Status
RWTs	Raw Water Transfers
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
SWW	South West Water
TDI	Trophic Diatom Index
TWL	Top Water Level
UKTAG	UK Technical Advisory Group
WFD	Water Framework Directive
WINEP	Water Industry National Environment Programme
WHPT	Walley Hawkes Paisley Trigg metric
WTW	Water Treatment Works

Executive Summary

Background & The Drought Permit

Hawk's Tor Pit is a former China clay pit that has filled with water since quarrying ceased. It is located on Bodmin Moor at SX 151 745. South West Water (SWW) operated an abstraction license here between 1977 and 1986, and a drought order abstraction in 1995 and 1996 and have more recently bought the pit with a view to future licensed water abstraction.

The proposed drought permit will involve the abstraction of approximately 4.78Ml/d from the granting of the drought permit until the end of April 2023. This will be used to pump abstracted water directly to Colliford Reservoir. A compensation flow will be provided, either under gravity and/or pumped, to the Warleggan River at the outlet channel from Hawk's Tor Pit.

The implementation of the drought permit is critical to the ongoing recovery of water storage in the Colliford Reservoir supply zone following a period of exceptional prolonged dry weather in 2022. Reservoir levels in Cornwall are currently considered to be extremely low for the time of year, with Colliford storage at 26% (04/12/2022).

Scope of Environmental Assessment

An Environmental Assessment Report (EAR), which includes a monitoring plan and mitigation measures, is required to support the drought permit application. This EAR provides details of baseline conditions and assesses impacts of potential changes focusing on the hydrological and ecological regime due to implementation of the drought permit. The EAR also assesses the potential effects of the works on the recreational, archaeological, geological and landscape value of the Hawk's Tor Pit area.

The EAR follows a 'source-pathway-receptor' approach, focusing on how the proposed works at Hawk's Tor Pit (the source) will affect the hydrological environment (the pathways), and then how this will affect the ecological (and other) features (the receptors).

The significance of impact on the receptor is calculated by determining the magnitude of the impact on the impact pathway, combined with the sensitivity of the receptor. In addition to this, confidence categories are included to state the quality of the information available.

Hydrological Impacts

Hawk's Tor Pit has been represented as a 'reservoir' unit in the HEC-HMS model. A detailed bathymetry survey has been used to define the volume-elevation relationship of the 'reservoir' unit, and the outfall structure from the lake has been defined using the results of a topographical survey of the outlet channel.

The main hydrological input to the lake is flow from the upper catchment of the Warleggan River. Daily mean flow time series for this catchment have been estimated using both QUBE software and by pro-rating from the Warleggan at Trengoffe gauging station; these time series formed the main inputs to the HEC-HMS model.

The HEC-HMS model has been used to assess a total of 15 scenarios, each run over a simulation period of c. 50 years. The 15 scenarios represent differing permutations of daily mean flow time series and the seasonal timing and magnitude of both abstraction and compensation flow releases (the latter being required to protect fish habitats on the Warleggan River). The primary metric used for assessing the viability of these scenarios was recovery to Top Water Level (TWL) by the 1st of November each year, following the cessation of abstraction in the preceding April, and the number of years throughout the simulation period where this was not achieved. 'High-Risk' scenarios are defined as those which resulted in a relatively large number of years over the simulation period during which TWL recovery did not occur by the 1st of November; 'Low-Risk' scenarios are those for which this was a relatively infrequent occurrence.

The daily mean flow time series generated by pro-rating from the Warleggan at Trengoffe gauging station was found to be more conservative than that generated using the QUBE software and, as such, all but the first three of the 15 scenarios retained the use of this input data. For all 15 scenarios, abstraction from Hawks Tor Pit generally occurred between the months of November through to April within each simulation year, at rates typically between 4 and 8Ml/d. The 'highest-risk' scenarios were those for which abstraction from the lake persisted at a constant rate of 8Ml/d over each November to April period; the risk was proportionally lower for those scenarios that used variable abstraction rates; and the 'lowest-risk' scenarios were those for which the abstraction rate was closer to 4Ml/d.

Ecological Impacts

There is a risk of impacts to receptors which are sensitive to a reduction in water level within Hawk's Tor Pit itself and reduced flows within the receiving Warleggan River waterbody. The majority of headwater river flows in the Warleggan catchment flow directly through Hawk's Tor Pit prior to gravity fed releases back into the river channel. The following receptors are predicted to encounter moderate impacts as a result of implementation of the Drought Permit:

- GB108048007630 WFD ecological status
- Macrophytes
- Macroinvertebrates
- Atlantic salmon
- Sea/Brown trout
- NERC habitats (Lowland Fen/peatland/wet woodland)

Other Environmental Impacts

Due to the very limited public access to Hawk's Tor Pit, the impact on tourism and recreation is predicted to be negligible. Similarly, the low numbers of people using the accessible common land to the east of the site, and the lack of significant above ground structures, means that the impact to landscape and visual amenity is considered to be minor.

Due to the lack of intrusive works to the area surrounding Hawk's Tor Pit, the risk to archaeological receptors is considered to be minor. The reduction in water level has the potential to disturb submerged heritage assets, however the water level is not expected to drop below the level the lake was reduced to in the 1995/96 abstractions.

The drawdown of the lake is not predicted to result in any increased risk to slope stability, therefore the overall significance of impact from the works on this receptor is predicted to be minor.

Mitigation & Monitoring Plans

A series of mitigation measures are proposed and have already been agreed with the Environment Agency with an aim to reduce the overall impact of the Temporary Drought Permit on the environment these include:

- Provision of a compensation flow of 32 l/s (November to April) through temporary pumps and/or natural gravity flow from Hawk's Tor Pit into the Warleggan River.
- Provision (in response to written request from the EA) of two artificial spates for twelve hours duration during December 2022 at 96 l/s to aid migration of salmonid fish.
- Provision of a post drought permit compensation flow of 18 l/s (April to October 2023) or until recovery of Hawk's Tor Pit to TWL, whichever is sooner).
- Provision of three artificial spates for twelve hours during May 2023 at 32 l/s to aid migration of salmonid smolts.
- Provision for a fish rescue team to support migration of fish around the site as TWL is drawn down.
- Additionally, fish rescue provision if the draw down encounters fish in distress in Hawk's Tor Pit and/or Warleggan River.
- A commitment to provide further compensation and artificial spates in the autumn of 2023 in the event that of Hawk's Tor Pit does not return to TWL as expected.
- A commitment to maintaining a 'Hands-Off' Water Level of TWL-12m (i.e. 208.50m AOD) as part of its Drought Permit operation in order to protect the Hawk's Tor Pit SSSI.

Additional Mitigation Measures are identified in Section 6

An Environmental Monitoring Plan (EMP) has been prepared for this EAR (Table 7.1) which includes pre-drought permit implementation, during-drought permit implementation and post-drought permit implementation environmental monitoring. This includes checking for signs of ecological stress, including:

- potential effects on inhibition of movement of fish downstream of Hawk’s Tor Pit,
- fish in distress monitoring,
- vegetation surveys
- other biological sampling to increase the confidence level of the significance of impact assessment.
- Continuous water quality monitoring in the reach between Hawk’s Tor Pit and the A30 during and post the abstraction period

Where monitoring is designed to identify negative influences of the Temporary Drought Permit mitigation actions are also presented in the EMP, these may include fish rescue, aeration deployment or changes to the embedded mitigation measures.

1. Introduction

1.1 Background

Hawk's Tor Pit is a disused china clay pit on Bodmin Moor (SX 151 745), just north-west of Colliford Reservoir. It has an estimated volume of 1,500,000m³ and a maximum depth of 31.28m.

Quarry workings at the pit ended in the early 1970s, after which operational groundwater pumping ceased, and the waterbody was allowed to naturally fill with water. South West Water (SWW) operated an abstraction licence at the lake between 1977 to 1986, a licence which has subsequently been surrendered following the construction of the Colliford Reservoir in 1983. Drought Order abstractions were permitted in 1995 and 1996.

Hawk's Tor Pit is ideally geographically placed, either to enable pumped storage to Colliford Reservoir (most likely during the winter months) or to provide raw water directly to St Cleer, De Lank and/or Lowermoor Water Treatment Works (WTWs) (most likely during the summer months). It thus offers great flexibility as a raw water resource.

The former South West Water Authority held a temporary Licence to Abstract Water relating to Hawk's Tor Pit from 16 June 1977 to 28 February 1986 (pre Colliford Reservoir construction). The licence authorised an abstraction from the pit of up to 10,000 cubic metres per day (2.2 Mg/d) or one million cubic metres per year (220 Mg/year). The water taken was used to support De Lank and/or Lowermoor Water Treatment Works (WTW) at times of low river flows and/or major depletion of storage in Crowdy Reservoir.

This former operation was brought back into use on 20 September 1995, using existing mains, when a Drought Order (DO) was made (Statutory Instrument 1995 Number 2477) authorising a temporary abstraction of up to 10,000 cubic metres per day (2.2 Mg/d) from the pit. Thereby providing additional raw water to support De Lank and/or Lowermoor WTWs and helping to conserve raw water storage in Colliford Lake. In 1996, a second DO granted a new temporary abstraction link to Colliford Reservoir.

During the above abstraction periods, Hawk's Tor Pit was considered to be hydrologically isolated from the Warleggan River, which was diverted around the pit during its operational phase as a clay pit extraction site. Following a natural diversion in the winter of 2009/10 the Warleggan River now flows through Hawk's Tor pit. Objectives and Scope

This EAR has been prepared to support the Hawk's Tor Temporary Drought Permit application. The report assesses the potential environmental impact that may occur as a result of implementing the planned works at Hawk's Tor Pit, and, where required, provides a summary of the monitoring and mitigation measures to avoid and reduce the effect of any potential impacts.

The report presents baseline data relevant to the potentially affected area, the Zone of Influence, and assesses the potential impacts to the environment due to the operation of the temporary drought permit.

The report follows a 'source-pathway-receptor' approach, assessing how the proposed abstraction (the source) may impact the hydrological, geomorphological and hydrogeological environment (the pathways), and considers how this may impact the local ecology, archaeology, landscape and other relevant features (the receptors).

1.2 Structure Of This Report

This report has been structured in line with drought planning guidance, consistent with the latest EA guidance on Environmental Assessment for Water Company Drought Planning[1], which is considered to be a robust and thorough framework which demonstrates good practice for undertaking ecological impact assessments (CIEEM, 2018) and on NRW technical guidance for Water Company Drought Plans (NRW, 2017).

The report is structured as follows:

Section 2 – Temporary Drought Permit details, including requirement and location of application

Section 3 – Details on the environmental assessment methodology applied to assess the potential impacts on the environment

Section 4 – Details on the Pathways of effect from the temporary drought permit

Section 5 – Impact assessment of receptors. Details on Water Framework Directive status and designated sites within geographical extent of study. Details on receptors, their sensitivity, and possible impacts from the temporary drought permit, in the absence of any mitigation. Summary of impact assessment

Section 6 – Details of mitigation measures to be applied to reduce impacts

Section 7 – Proposed monitoring, pre, during and post temporary drought permit requirement

[1] Environment Agency - Environmental assessment for water company drought planning supplementary guidance. July 2020.

2. Description of Proposal

2.1 Site Setting and Background

The site comprises Hawk's Tor Lake/Pit. This is a historic quarry that was originally used to extract china clay. The quarry has since been allowed to naturally fill with water to form a man-made lake.

The site is located within the civil parish of Blisland, approximately 10km to the northeast of Bodmin, near to the centre of Bodmin Moor, Cornwall, setting shown in Figure 2.1. The total area of the lake is approximately 11.4 hectares. The lake connects to the local river network via the Warleggan River, which flows south entering the northern side of the lake. It leaves via an outlet channel at the south end of the lake, continuing under the A30.

Figure 2.1 – Setting of Hawk's Tor Pit within Bodmin Moor.

Hawk's Tor Pit is visible from the A30 to the south, which serves as the main spine route through Cornwall. The nearest settlement is Temple, which lies approximately 1km to the south of site. Hawk's Tor pit is not visible from this settlement.

Two residential properties are located to the southwest of the site and are accessed from the same access track. Lower Hawk's Tor Farm is adjacent to the Site on the western side. A conifer plantation is located 250m to the west of the lake. Hawk's Tor Hill is located approximately 600m to the northwest of the site. Brockabarrow Common is located immediately to the east of the site.

2km southeast of the site is Colliford Reservoir. This is the largest inland body of water in Cornwall, which offers a range of recreational activities such as watersports, fishing and picnic areas in addition to being a key component of the potable water supply system. Colliford Reservoir are supported by car parking, toilets and visitor information facilities.

The surrounding land is predominantly agricultural grazing to the north and south, with amenity woodland along the southwestern boundary (established as part of the quarrying environmental restoration measures on site). A former silica heap is located adjacent to the western boundary of site- this is covered in scrub vegetation.

2.2 Current Operation and Abstraction Regime

Hawk's Tor Pit is currently not an operational site and is not subject to any ongoing abstraction regime. The site is currently occupied by Kier Construction Group, who are working on installing the pontoons and pumps needed to temporarily abstract water from the lake.

2.3 Proposed Drought Permit

The proposed drought permit will involve the following provision of a new temporary abstraction licence:

Abstract a volume of 4.78 Ml/d starting from date the licence is granted until 30 April 2023 to give SWW flexibility to either:

a) pump the water abstracted from Hawk's Tor Pit directly to Colliford Lake via existing raw water mains; and/or
b) pump the water abstracted from Hawk's Tor Pit to the De Lank Water Treatment Works, via existing raw water mains.

The following safeguards are also proposed:

- Provision of compensation flow to the Warleggan River at the outlet channel from Hawk's Tor Pit.
- Provision of a hand-off flow level at 12.0m from TWL to preserve bank stability.
- Provision to visually inspect Hawk's Tor Pit bankside stability during draw-down.
- Provision to publish an Environmental Assessment Report and revised Monitoring Plan by 31st December 2022 (this report).

For the purposes of this assessment these safeguards are detailed in the mitigation part of the report (section 6) and the potential impact on receptors (section 5) are assessed in the absence of mitigation, to demonstrate their requirement and likely success on reducing impacts. These safeguard measures are however included in the pathways assessment (section 4) to enable the modelling of different flow scenarios.

2.4 Geographical Extent of the Study (Zone of Influence)

The geographical extent of the study consists of Hawk's Tor Pit, including surrounding water dependant riparian habitats and the downstream reaches of the Warleggan River to the point where the river is joined by other flow inputs. Beyond this location, flow contributions from other inputs are considered to be the main sources of river flow. This is considered further in Section 4.1.7 below, based on flow accretion data received.

3. Environmental Assessment Methodology

Our environmental assessment methodology follows an approach that is consistent with:

- the latest EA guidance on environmental assessment for water company drought planning (EA, 2020a&b);
- draws on industry good practice for undertaking ecological impact assessments (CIEEM, 2018); and
- NRW technical guidance for water company Drought Plans (NRW, 2017).

Figure 3.1 summarises the process used to describe and categorise the impact of the temporary drought permit/order on each receptor.

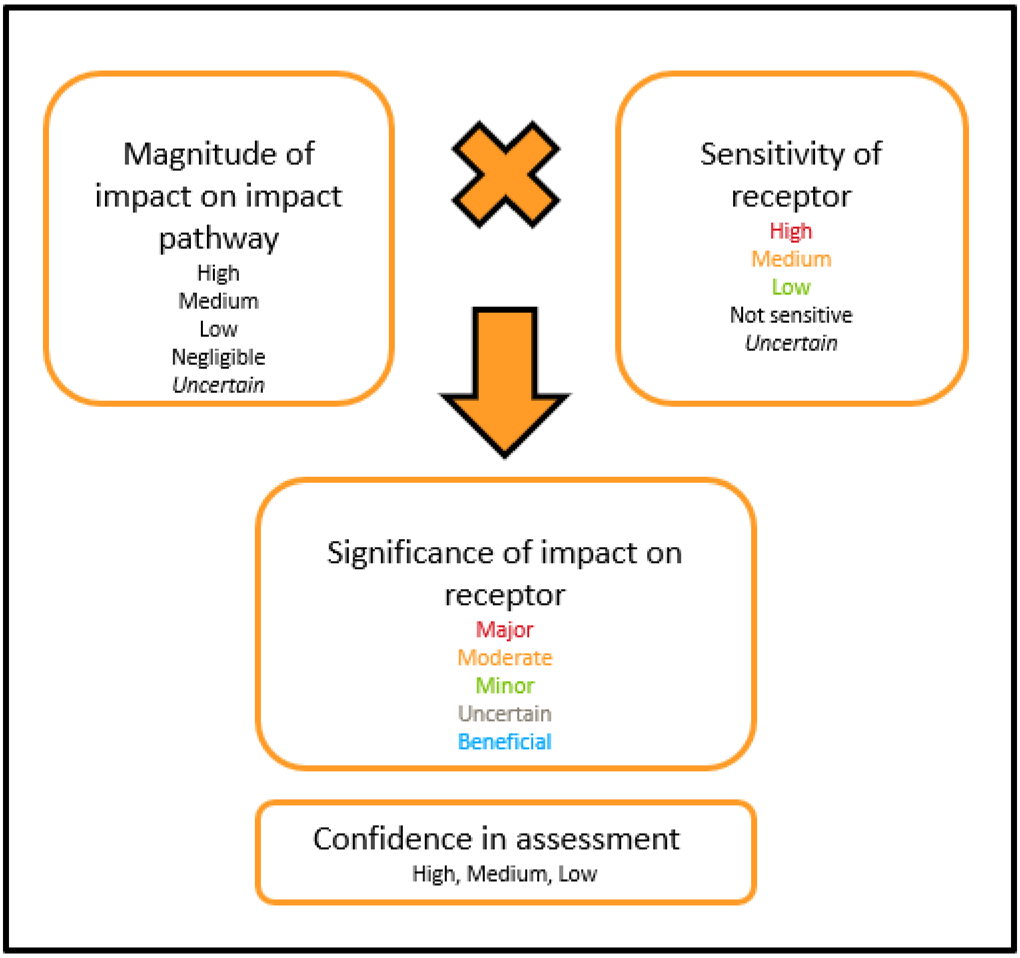

Figure 3.1 Flow chart outlining the environmental assessment process

The first step is to assess magnitude of impact on each pathway. We have categorised these impacts on a five-point scale, advocated by the EA for assessing the sensitivity of receptors

(EA, 2020b): High, Medium, Low, Negligible, or Uncertain. These categories and associated definitions are provided in Table 3.1.

Table 3.1: Magnitude categories

Category	Definition
High	A large, extensive, long-term and/or very frequent change.
Medium	A medium-sized, substantial, medium-term and/or frequent change.
Low	A small, localised, short-term and/or infrequent change.
Negligible	A change unlikely to be noticeable / measurable.
Uncertain	Insufficient information is available to judge the magnitude of impact.

Following NRW (2017) and CIEEM (2018) guidance, the assessment of magnitude takes into account some or all of the following factors (as necessary) to understand the resulting impact on receptors:

- severity – the degree of change, relative to the baseline (large, medium, small);
- extent – the area over which the impact occurs (extensive, substantial, localised);
- duration – the time for which the impact occurs (short, medium, long-term); and
- frequency – how often the impact may occur (very frequent, frequent, infrequent).

Where relevant, the specific location and timing of any impacts is also described. Impacts on pathways may then be translate into positive or negative impacts on receptors. So, whilst the direction of change is important (e.g. increase or decrease) the impacts on pathways are not described as being positive or negative.

Next, the sensitivity of each receptor is categorised as High, Medium, Low, Not Sensitive, or Uncertain, in accordance with EA Water Company Drought Plan guidance (EA, 2020b). Definitions are provided in Table 3.2.

Table 3.2: Sensitivity categories

Category	Definition
High	Receptor is highly sensitive to changing environments due to inability to tolerate and recover from changes.
Medium	Receptor is sensitive to changing environments due to limited ability to tolerate and/or recover slowly from the environmental change.
Low	Receptor is relatively insensitive to changing environments due to ability to tolerate and/or recover quickly from the environmental change.
Not sensitive	Receptor is not sensitive due to high tolerance to environmental change and/or ability to recover rapidly.
Uncertain	Insufficient information is available to judge the sensitivity of the receptor.

Sensitivity is a function of the receptor's capacity to accommodate change and its ability to recover if it is affected. A receptor may be more sensitive to changes in certain pathways than others. The assessment of sensitivity takes into account some or all of the following factors (adapted from NRW, 2017):

- adaptability – the degree to which a receptor can avoid or adapt to an impact;
- tolerance – the ability of a receptor to accommodate change without a significant adverse impact; and
- recoverability – the temporal scale over and extent to which a receptor will recover following an impact.

The magnitude of impact is combined with the sensitivity of receptor to assess the significance of impact on each receptor, as shown in Table 3.3 (adapted from NRW (2017)). In accordance with EA guidance (EA, 2020b), impacts on receptors are categorised as: Major, Moderate, Minor, or Uncertain. Impacts on receptors can be positive as well as negative, however, so (in line with a previous APEM submission in the region that was agreed with the EA) we have included a fifth category – Beneficial – to identify any positive impacts. Definitions, adapted from NRW (2017), are provided in Table 3.3.

Table 3.3: Determining the significance of impacts on receptors

Magnitude of impact on pathway	Sensitivity of receptor				
	High	Medium	Low	Not sensitive	Uncertain
High	Major	Major	Moderate	Minor	Uncertain
Medium	Major	Moderate	Minor	Minor	Uncertain
Low	Moderate	Minor	Minor	Minor	Uncertain
Negligible	Minor	Minor	Minor	Minor	Uncertain
Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain

Table 3.4: Significance categories

Category	Definition
Major	Very large or large change in environmental or socio-economic conditions, which, if lost, cannot be replaced or relocated. The impacts are generally, but not exclusively associated with features and sites of international, national and regional importance because they contribute to achieving national / regional objectives. The impacts are likely to result in exceedance of statutory objectives and/or breaches of legislation (e.g. Likely Significant Effects or deterioration of WFD status).
Moderate	Intermediate change in environmental or socio-economic conditions. The impacts are likely to affect important considerations at a regional and local level. The impacts are unlikely to affect key decision-making processes (e.g. statutory objectives). Nevertheless, the cumulative effect of such impacts

Category	Definition
	may lead to an increase of overall effect on a particular area or on a particular feature.
Minor	Small or negligible change in environmental or socio-economic conditions. These effects may be raised as local issues but are unlikely to be of importance in the decision-making process.
Uncertain	Insufficient information is available to judge the impact significance.
Beneficial	Any significant, moderate or minor change predicted to have a net positive effect on environmental or socio-economic conditions.

Impact significance provides a consistent means of expressing impacts which, in turn, informs the need for mitigation measures to offset the impacts. The determination of impact significance, both pre and post mitigation, also provides a transparent means for regulators to understand the impacts of a drought permit/order.

In practice, determining the significance of impact carries a degree of subjectivity and requires expert judgement. This may be because of limited evidence / data on the sensitivity of the receptors and / or the complexity of interactions that require assessment to determine the magnitude of change. For example, receptors may experience direct impacts as a result of changes in pathways, but also indirect impacts as a secondary response to changes in other receptors. If a receptor is subject to different impacts via different pathways, then the combined effect of the different pathways is integrated to assess the overall significance of impact.

Finally, in accordance with EA guidance (EA, 2020b), the degree of confidence in the assessment of impact significance is categorised as High, Medium or Low. Definitions are provided in Table 3.5. Key sources of uncertainty are identified and used to inform the design of the EMP.

Table 3.5: Confidence categories

Category	Definition
High	Judgments based on high-quality, robust information, and/or the nature of the impact makes it possible to render a solid judgement.
Medium	Credibly sourced and plausible information, but not of sufficient quality or corroboration to warrant a higher level of confidence.
Low	The information available is too fragmented or poorly corroborated to make solid analytic inferences, or significant concerns or problems with information sources exist.

The assessment has also considered the legislative requirements of the following:

- Conservation of Habitats and Species Regulations (2017);

- Fisheries legislation: Salmon and Freshwater Fisheries Act 1975 and the Eel (England and Wales) Regulations (2009);
- Water Environment (Water Framework Directive) Regulations (2017) including the objectives set out in river basin management plans;
- Section 40 of the Natural Environment and Rural Communities Act 2006 (NERC);
- Legislation covering Invasive Non-Native Species (INNS): The Wildlife and Countryside Act (1981);
- Other non-statutory requirements (local wildlife sites e.g. County Wildlife Sites etc.);
- Protected areas designated under international agreements (including Ramsar & Natura 2000 sites); and
- Protected areas designated under national legislation (SSSIs), nationally protected species and habitats covered under the Wildlife and Countryside Act 1981 and Countryside and Rights of Way Act 2000 and other locally important sites.

4. Impact Assessment: Pathways

A long list of pathways and receptors was initially screened to identify the environmental features of interest for inclusion in the full environmental assessment. Features were excluded only if:

- the pathway or receptor is absent from the area of potential impact;
- there is no pathway by which the receptor could be impacted; or
- the receptor is not sensitive to changes in these pathways.

The key pathways of impact are detailed in this section. These relate to the water level drawdown impacts within Hawk's Tor Pit and the reduction of flow within the receiving Warleggan River waterbody.

4.1 Hydrology

4.1.1 Baseline Conditions

4.1.1.1 Hydrological Context

Hawk's Tor Pit is located within the topographical catchment area of the Warleggan River, which drains a small, rural, relatively natural catchment on Bodmin Moor. The planform alignment of the Warleggan River was artificially modified at least in part - in order to allow mineral extraction to commence. Routine flows were conveyed to the east of the pit in a 'perched' channel (leat) throughout the duration of minerals extraction, although it is unclear to what extent higher flows were able to interact directly with the lake throughout this period.

Equally, following the cessation of the mineral extraction operations, the extent to which direct interaction between the Warleggan River and the pit was able to naturally re-establish is unclear, although some degree of direct interaction was probable, given that the pit was permitted to fill and a high-level outfall channel was created to allow lake outflows to connect back into the Warleggan River further downstream (Figure 4.1 below; this concept is also explored further below, in the section on Hydrological Model Calibration).

During the winter of 2009/10, the Warleggan River breached its western bank and began to flow directly into the lake, forming a new connection channel, which is braided in places. This breach occurred just to the north of the lake and its location and 'newly' formed channels are shown in Figure 4.2 below. Lake outflows continued to discharge back to the Warleggan River further downstream via the channel shown in Figure 4.1.

Since this event, site observations and spot flow gauging (discussed further below) confirm that 100% of the flow from the upper catchment of the Warleggan River now enters the lake via the features shown in Figure .2; the former 'perched' leat channel to the east of the lake subsequently only carries small surface water flow components from the Brockabarrow Common catchment, which enter this channel just above its confluence with the lake outflow channel, prior to the A30. This is discussed further in the sections below.

Figure 4.1: The high-level lake overflow channel (red circle), located on the southern bank of the pit. This overflow channel connects directly into the Warleggan River further downstream. Image adapted from Google Earth.

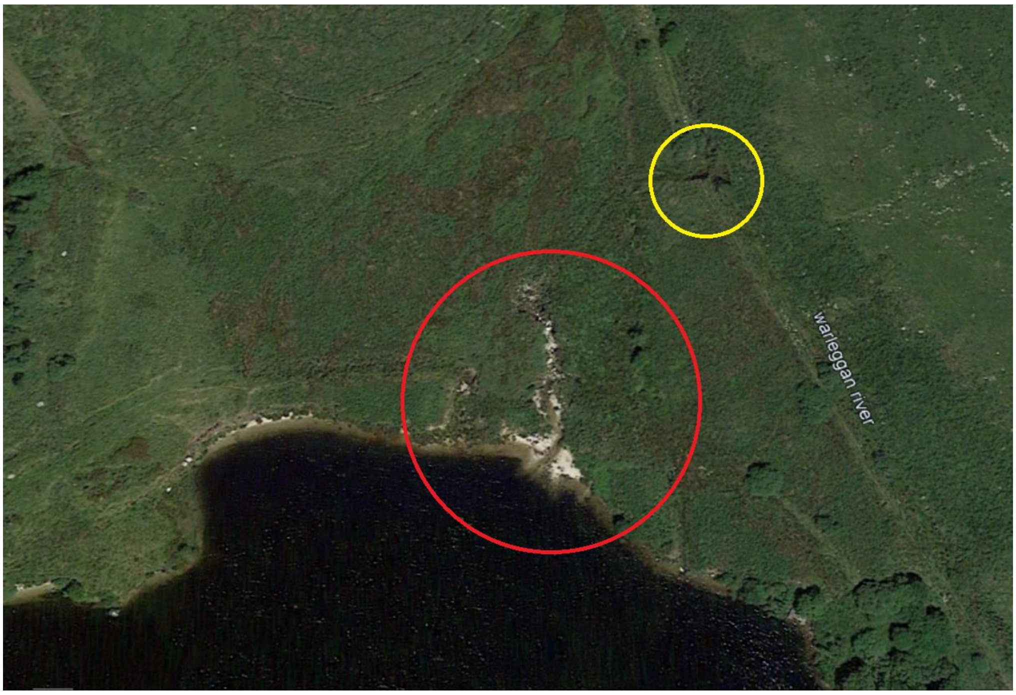

Figure 4.2: Estimated location of the breach in the western embankment of the Warleggan River (yellow circle) and subsequent 'newly' formed channels that connects directly to Hawk's Tor Pit (red circle). Image adapted from Google Earth

4.1.1.2 Catchment Areas

The topographical area of the Upper Warleggan River catchment that drains to Hawk's Tor Pit has, therefore, been delineated based on Ordnance Survey contours and is shown in Figure 4.3 below. This figure also shows the small Brockabarrow Common catchment that drains to the 'perched' leat channel directly to the east of the lake (these inflows are not, however, thought to significantly interact with the lake). The area of the Upper Warleggan River catchment that discharges to the lake is c. 2.52km^2; the Brockabarrow Common catchment is c. 0.56km^2 i.e. a ratio of 0.22 (Figure 4.3). The Brockabarrow Common catchment has been included in Figure 4.3 below because it provides a small contribution to the Warleggan River downstream of its confluence with the pit outfall channel and, as such, has been included in the hydrological modelling. This catchment does not, however, contribute flows to the pit itself.

Figure 4.3: Hawk's Tor Pit Hydrometric Areas

4.1.1.3 Lake Bathymetry

SWW commissioned Randall Surveys LLP to undertake a bathymetric survey of the lake pit in October-November 2022; their results are shown in Figure 4.4 below (full survey details are provided in Appendix A), which also indicate the position of the HoL of TWL-12m. The water level recorded at the time of the bathymetry survey (i.e. October 2022) was 220.56m AOD, which is broadly in line with the typical TWL value for the lake contained within previous SWW documents of 220.50m AOD.

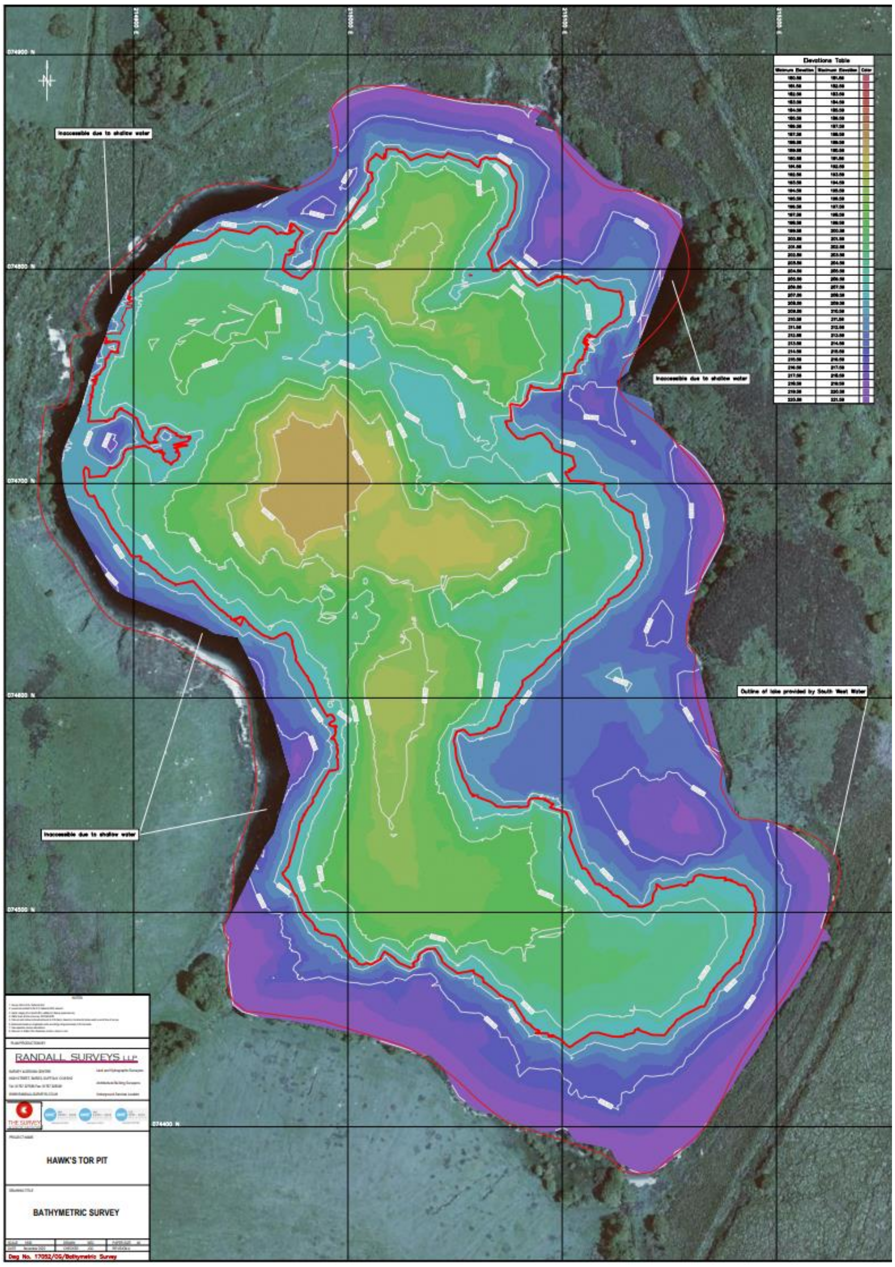

Figure 4.4: Hawk's Tor Pit Bathymetry, including the 'HoL' TWL-12m contour line in red (full survey details are provided in Appendix A).

(NB: This figure updates the bathymetric figure include in the interim Environmental Assessment Report)

4.1.1.4 Lake Volume-Elevation relationship

The volume-elevation relationship for the lake derived from the bathymetric survey is shown in Table 4.1. The estimated volume limit of the pit is 1,526,587 m³.

Table 4.1 - Volume-elevation relationship for Hawk Tor Pit derived from the bathymetric survey.

Volume in lake (m^3)	Water Level (m AOD)
1,526,587.36	220.26
1,526,585.05	219.76
1,472,405.38	219.26
1,419,033.16	218.76
1,366,455.22	218.26
1,314,725.39	217.76
1,263,908.22	217.26
1,213,881.89	216.76
1,164,670.13	216.26
1,116,306.55	215.76
1,068,828.14	215.26
1,022,303.95	214.76
976,904.43	214.26
932,856.08	213.76
890,342.58	213.26
849,418.37	212.76
810,025.79	212.26
771,832.86	211.76
734,620.77	211.26
698,312.15	210.76
662,846.88	210.26
628,144.42	209.76
594,189.96	209.26
560,952.72	208.76
528,431.27	208.26
496,638.80	207.76
465,566.87	207.26
435,252.22	206.76
405,830.53	206.26
377,375.07	205.76
349,913.10	205.26
323,488.04	204.76
298,135.71	204.26
273,881.54	203.76
250,752.83	203.26
228,827.43	202.76
208,103.34	202.26
188,596.71	201.76
170,324.24	201.26

153,216.33	200.76
137,230.38	200.26
122,308.07	199.76
108,689.57	199.26
96,023.60	198.76
84,184.93	198.26
73,238.92	197.76
63,280.37	197.26
54,273.09	196.76
46,211.18	196.26
39,103.13	195.76
33,007.14	195.26
27,799.39	194.76
23,260.58	194.26
19,285.60	193.76
15,841.36	193.26
12,848.86	192.76
10,258.82	192.26
7,993.42	191.76
5,999.70	191.26
4,347.41	190.76
3,063.13	190.26
1,943.13	189.76
977.85	189.26
194.69	188.76
0	188.26

4.1.1.5 Lake Outfall Channel Topography

The bathymetric survey did not contain surveyed details of the lake outfall channel. This information was subsequently captured by AP Land Surveys during November 2022; an extract of which is shown in Figure 4.5 below (full survey details are provided in Appendix B). A natural 'weir crest' is shown to be present within the outfall channel at an elevation of c. 220.41m AOD; channel levels both up and downstream of this crest are lower than this elevation. As such, this natural 'weir crest' is likely to form the main water level control for the lake.

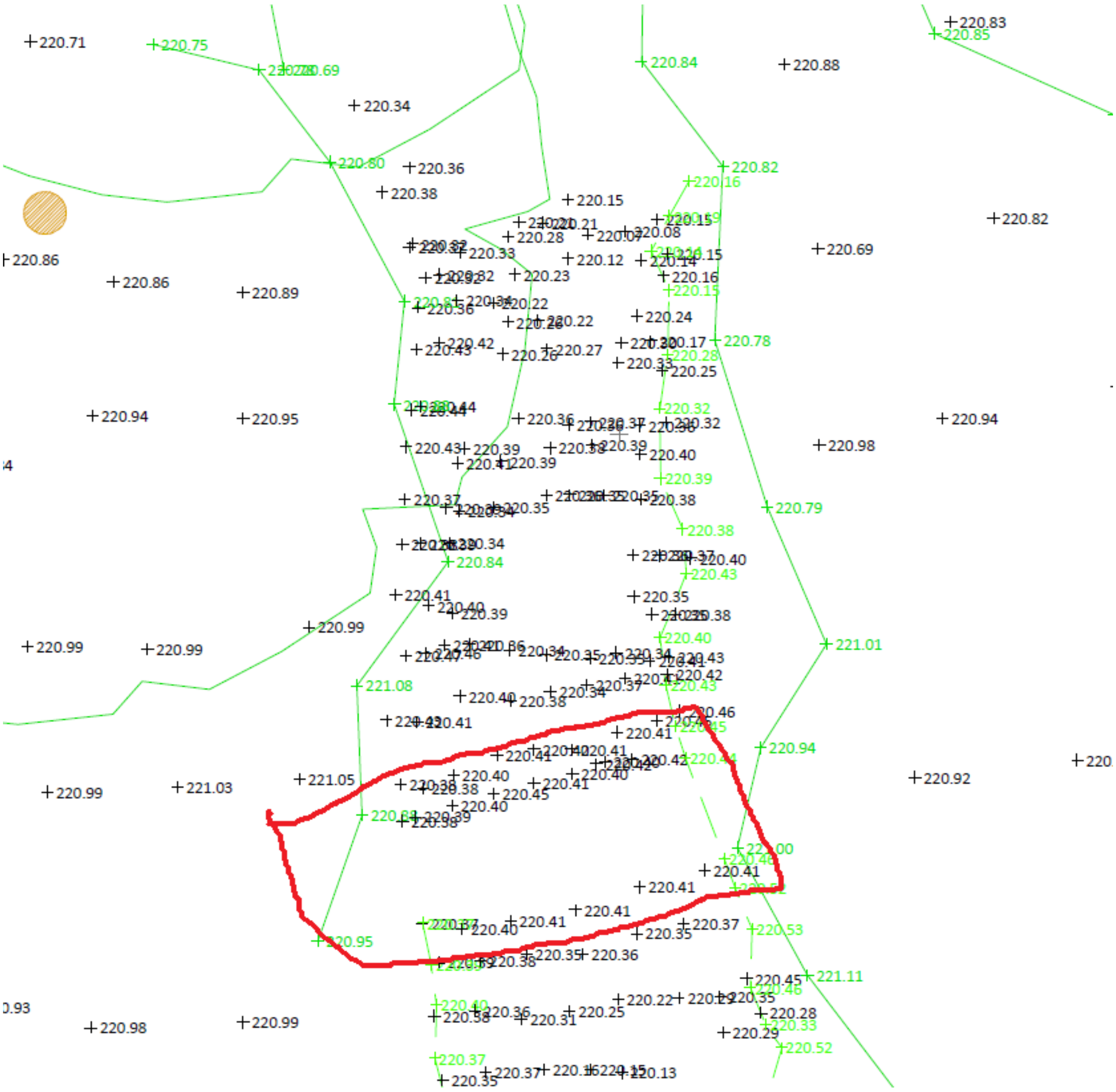

Figure 4.5: Extract from the lake outfall topographical survey undertaken by AP Land Surveys in November 2022 (full survey details are shown in Appendix B). The red highlight shows the location of a natural ‘weir crest’, with an elevation of c. 220.41m AOD.

4.1.1.6 Catchment Hydrology and Flow Gauging

Daily mean flow time series for the catchments shown in Figure 4.3 above have been estimated in two ways. Firstly, the QUBE[2] software was used to generate a ‘naturalised’ daily mean flow time series for the c. 2.5km^2 catchment of the upper Warleggan River (Figure 4.3) over the period 1961 to 2015. These data were then pro-rated to generate an equivalent time series for the Brockabarrow Common catchment (Figure 4.3), using a reduction multiplier of 0.22.

[2] Software developed by Wallingford HydroSolutions (WHS) for the estimation of river flows within ungauged catchments.

Secondly, data from National River Flow Archive (NRFA) station 48004 'Warleggan at Trengoffe' were used to estimate a time series of daily mean flows for the c. 2.5km^2 catchment of the Upper Warleggan River (Figure 4.3) over the period 1969 to 2021. The NRFA describes this station as *"The only gauged natural catchment on Bodmin moor"* and, as such, this station is ideally suited for data transposition for the study catchment. The catchment area of the Warleggan River to station 48004 is 25.3km^2. The time series was estimated by pro-rating the data from station 48004 according to the factorial difference in these catchment areas (i.e. a reduction multiplier of c. 0.1). The equivalent time series for the Brockabarrow Common catchment (Figure 4.3) was then re-calculated as described above. Table 4.2 below summaries the flow statistics for the main inflow to Hawk's Tor Pit derived from QUBE (1961 to 2015) and from pro-rating based on the NRFA series at station 48004 (1969 to 2021).

Table 4.2: Summary comparison of annual flow statistics for Hawk's Tor Pit

Flow Statistic	Trengoffe GS (pro-rate) (m^3/s) (1969 to 2021)	QUBE estimated flow (m^3/s) (1961 to 2015)
Mean flow	0.0871	0.0952
Q95	0.0200	0.0111
Q70	0.0389	0.0286
Q50	0.0624	0.0494
Q10	0.1853	0.2230
Q5	0.2361	0.3370

The above data indicate that the QUBE estimates are lower for low flow statistics (Q95-Q50) but higher for high flow statistics (Q10 – Q5). Spot flow gauging undertaken by both SWW and Hydro-Logic between October and November 2022, however, indicates that both estimates (i.e. derived from QUBE and Trengoffe GS pro-rated) are broadly reasonable. This is discussed further below.

During October 2022, SWW undertook spot flow gauging of the inflows to the lake, the lake outflow, and the combined flow on the Warleggan River downstream. These spot flow gauging locations are shown in Figure 4.6 below and the results are presented in Table 4.3. These data indicate that lake inflow was broadly the same as lake outflow and indicative of the estimated mean flow for the upper Warleggan catchment (see Table 4.2 and Table); flows from the Brockabarrow Common catchment (i.e. 'South East inflow) were insignificant by comparison (Table 4.3Table).

The gauging locations are shown in Figure 4.6 and the results in Table 4.3 below for the spot flow gauging undertaken throughout October and November 2022. The spot flow gauging undertaken by both Hydro-Logic and SWW indicate that the estimated flow statistics for the upper Warleggan River catchment shown in Table 4.2 above are broadly reasonable, and that the 'perched' leat channel directly to the east of the lake only receives nominal flows from the Brockabarrow Common catchment.

Figure 4.6 – Location of spot flow gauging undertaken by SWW in October 2022.

Table 4.3 – Spot flow gauging undertaken by SWW during October 2022.

	Date / Time	Location	NGR	Flow (cumecs)	Flow (l/sec)	
INFLOW	26/10/2022 10:27	South east inflow	SX 15222 74485	0.00155	1.55	**81.14**
	26/10/2022 10:54	North east inflow	SX 15106 74864	0.02264	22.64	
	26/10/2022 11:00	North main inflow	SX 15086 74889	0.05695	56.95	
OUTFLOW	26/10/2022 10:00	Lake outlet flow	SX 15127 74363	0.08251	82.51	**82.51**
COMBINED	26/10/2022 12:30	Combined flow (on Warleggan River)	SX 15088 73767	0.06583	65.83	**73.66**
	26/10/2022 12:50	Combined flow (small flow west	SX 15068 73777	0.00783	7.83	

J4634 - Hawks Tor Flow Monitoring

Site No.	Site Name	NGR	W3W	Datum	Comments
1	Lake Outflow	SX 15128 74369	dine.glossed.royal	0.520	Gauging / WL sensor
2	Warleggan River U/S of confluence	SX 15155 74212	scrapped.servants.alarm	-	Gauging
3	Warleggan River D/S of confluence	SX 15133 74188	relations.quick.deposits	-	Gauging / WL sensor
4	Lake inflow 1, East Bank	SX 15225 74485	mirroring.cobble.bags	-	Gauging
5	Lake inflow 2, North bank	SX 15094 74865	shirtless.grief.candles	-	Gauging
6	Lake inflow 3, North bank	SX 15085 74871	landed.socialite.novels	-	Gauging

Figure 4.7 – Hydro-Logic spot flow gauging locations October to November, 2022.

Table 4.4 – Hydro-Logic spot flow gauging data October to November, 2022.

Hydro-Logic Services — J4634 - Hawks Tor Flow Monitoring — Hydro International

Date	Site 1 - Lake Outflow					Site 2 - Warleggan River U/S of confluence					Site 3 - Warleggan River D/S of confluence				
	Start Time	End Time	Mean Stage (m)	Flow (m^3/s)	Meter	Start Time	End Time	Mean Stage (m)	Flow (m^3/s)	Meter	Start Time	End Time	Mean Stage (m)	Flow (m^3/s)	Meter
14/10/2022	09:30	10:15	-	0.0289	BFM002 3404	10:20	10:40	-	0.0030	EM10	10:45	11:00	-	0.0245	EM10
18/10/2022	09:04	09:15	0.035	0.0265	BFM002 3404	09:20	09:28	-	0.0015	EM10	09:32	09:42	-	0.0233	EM10
27/10/2022	13:54	14:09	0.052	0.0675	BFM002 3404	14:17	14:29	-	0.0089	BFM002 3404	14:29	14:40	-	0.0974	BFM002 3404
03/11/2022	14:39	14:54	0.320	0.2637	BFM002 3404	14:56	15:08	-	0.0127	BFM002 3404	15:08	15:26	-	0.2644	BFM002 3404
11/11/2022	11:31	11:44	0.170	0.1386	BFM002 3404	11:50	11:58	-	0.0134	BFM002 3404	12:09	12:19	-	0.1697	BFM002 3404
14/11/2022	08:53	09:05	0.165	0.1216	BFM002 3404	09:08	09:17	-	0.0294	BFM002 3404	09:20	09:36	-	0.1568	BFM002 3404

Flow is in cumecs

Stage is in meters as a GB has been used to obtain level

4.1.1.7 Identification of representative dry years

Using the time series of flows pro-rated from NRFA station 48004 (Warleggan at Trengoffe), annual total flow accumulations and November to April flow accumulations have been calculated to identify representative dry years for the Upper Warleggan River catchment that feeds Hawk's Tor Pit (Table 4.5 below). Calendar year flow accumulations were lowest during 2003, 1989 and 1976; November to April accumulations were lowest during 1991-92, 2016-17, and 1975-76.

Table 4.5 – Representative dry years based on flow accumulations (using the pro-rated daily mean flow time series from Trengoffe).

Year	Accumulated Calendar Year Flow (m^3)	Year Nov-April	Accumulated Nov-April Flow (m^3)
2003	1907552	1991-1992	1125373
1989	2034049	2016-2017	1246302
1976	2034058	1975-1976	1287335
2011	2038094	2007-2008	1309211
2006	2047853	1996-1997	1325278
1983	2079962	2004-2005	1358299
1971	2082862	2003-2004	1415675
1997	2092931	1988-1989	1437508
1975	2095779	2010-2011	1442249
2010	2178809	1983-1984	1524892
1973	2224360	1985-1986	1599100
2005	2245539	2005-2006	1613808
1977	2277424	2008-2009	1634427
1984	2339592	2011-2012	1691338
1995	2353620	1995-1996	1717233
2004	2413336	1978-1979	1732422
1978	2426348	1970-1971	1754273
1992	2444532	2001-2002	1789428
2001	2500428	2014-2015	1811312
2016	2524885	1972-1973	1818008

1987	2561736	1971-1972	1842801
1990	2571546	1980-1981	1847638
1985	2630282	2002-2003	1866467
1996	2635402	1976-1977	1904961
1991	2646314	2009-2010	1936209
2007	2762528	1981-1982	1965710
2017	2769266	1974-1975	1993206
2015	2810058	1992-1993	1994110
2013	2889189	1990-1991	2018748
1980	2916237	1977-1978	2038060
1979	2961126	1984-1985	2043060
1982	2978208	2006-2007	2066588
1970	2985859	2018-2019	2092957
2019	2986195	1979-1980	2097044
1972	2987683	1989-1990	2103533
1999	3015764	1982-1983	2108533
2002	3041470	1986-1987	2124041
2008	3043949	1997-1998	2126580
2009	3082718	1969-1970	2137526
1988	3088183	1999-2000	2156588
2018	3116160	1987-1988	2188972
1981	3159310	2017-2018	2256279
1998	3335886	2012-2013	2327837
1986	3370825	1998-1999	2388861
2014	3382030	1973-1974	2395771
1993	3393708	2015-2016	2443302
2020	3401101	2020-2021	2518414
2012	3594096	1994-1995	2554748
1994	3692014	2019-2020	2607734
1974	3878899	1993-1994	2784576
2000	4272686	2013-2014	2865971
		2000-2001	2950429

4.1.1.8 1995-6 Drought Order Data

As described in Section 1.2 above, SWW operated Drought Order (DO) abstractions from Hawk's Tor Pit during one period in 1995, and two periods in 1996. SWW captured the water level drawdown within the lake during the 1995 DO period (Figure 4.8 below), and the maximum drawdown and timing of TWL recovery during the two 1996 DO periods (4.6Table 4.6 below).

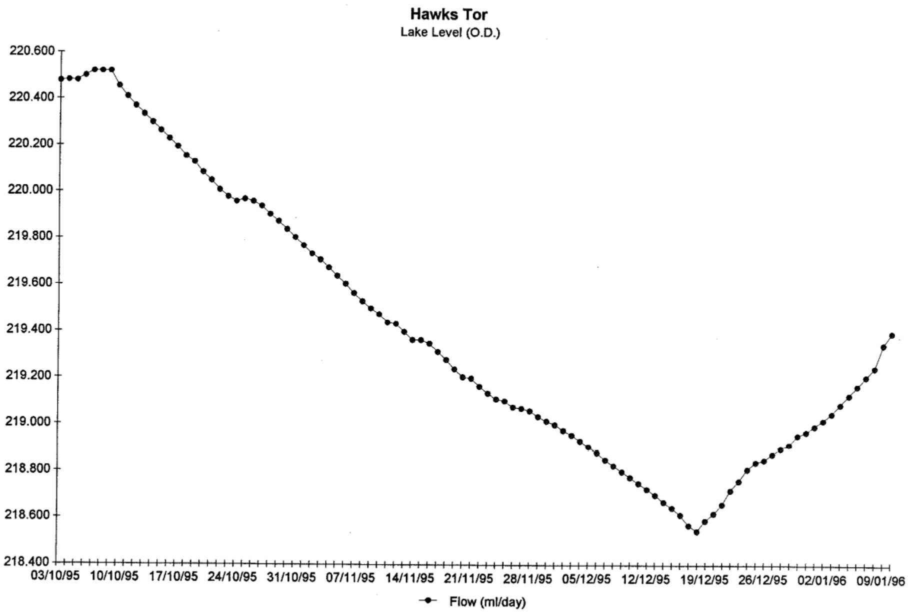

Figure 4.8 - Water levels within Hawk's Tor Pit during the 1995/96 Drought Order abstraction period.

Table 4.6 – Performance of the pit in response to DO/DP implementation.

	DO I	DO II (phase 1)	DO II (phase 2)
Abstraction Period	03/10/95 – 19/12/95	23/02/96 – 10/06/96	23/07/96 – 16/08/96
No of Pumping Days	78	109	25
Average Abstraction	4.31 Ml/d	11.92 Ml/d	6.59 Ml/d
Maximum Abstraction	7.98 Ml/d	16.83 Ml/d	14.96 Ml/d
Maximum Draw-down	1.91m	11.55m (12m cut-off)	11.78m (12m cut-off)
Cessation & Recovery date	06/02/96	23/07/96	24/07/97
Cessation & Recovery depth	+ 1.91m (to TWL)	+ 1.31m	+ 11.78m (to TWL)

4.1.1.9 Potential Groundwater Influence

When the mining ended in the early 1970s and operational pumping ceased, it is known that the pit void began to fill with groundwater, it is therefore expected that there is some groundwater present still, at least up to a certain depth.

Apart from this probable groundwater contribution, which is likely to have a greater influence at lower depths within the lake, the inflows to Hawk's Tor Pit are likely to be from surface water runoff from its (limited) topographical catchment, and (principally) from direct interaction with the Warleggan River, which used to run north-south to the east of the lake prior to the breach in 2009/10, and directly into the lake after this date.

SWW has initiated a field monitoring programme of groundwater levels within both the peat deposits and at depth within the granite strata starting in December 2022, the results from this ongoing monitoring will help determine the extent to which groundwater feeds the lake; the depth at which this occurs within its c.30m water column depth; and its relative significance within the context of the overall hydrological balance of the lake.

4.1.1.10 Fish Migration

SWW's Fisheries Officer (D. Griffiths) has undertaken a fish habitat survey of the Warleggan River and the Hawk's Tor Pit. The results of this survey have been shared and agreed with the EA. This survey concludes that the Warleggan River has a low fish habitat value below the pit to the A30, and that fish are very unlikely to be able to migrate further upstream through Hawk's Tor Pit, due to the morphology of its inlet flow channels. Further details are provided below in Section 5.5.

4.1.1.11 Peat Strata and Riparian Lake Communities

SWW (D.M. Smith) attended a site walkover on the 17th November 2022 with the EA (J. Burke) to investigate the potential risk to the peat deposits and lake shore wetland communities that surround Hawk's Tor Pit from water level draw down associated with the Drought Permit.

The pit location and surrounds would have once been occupied by extensive valley mire; the remains of which are present all around the lake, but at an elevated level, due to the pit having been excavated through these strata. All around the edges at various points are peat masses, up to 1m thick, with dry exposed edges, well above the lake level and sitting on mineral and clay materials. The site visit confirmed that for the most part there is no hydraulic link between lake level and the old, stranded peat layers and, therefore, there is limited risk of lake level draw down damaging any mire communities on these already dry peats.

Only one location, on the southeast side of the pit, was identified with some connectivity between the lake body and the peat masses on the shore surrounding the lake. The draw down will partially affect this area, but SWW and the EA agreed a simple intervention measure to quickly mitigate this potential impact.

In addition, the site visit assessed the potential for lake draw down to affect other lakeshore wetland communities. It was concluded that for the most part this was not possible, as the shore is steeply sided and dominated by sandy material, although a wet fenland area was identified, on the southwest side of the pit outlet, for which simple intervention measures were again agreed.

The site visit concluded that the impact of future lake level draw-down on the peatlands or mire/wetland communities adjacent to the lake would be limited to two restricted areas, where simple intervention measures were agreed with the EA to mitigate any potential minor impacts. Draw down within the lake would not affect the wider Bodmin moor peatlands, given that the lake is not in hydraulic continuity with these rainfed systems. Further details can be found in Section 5.4.

Geology, Geotechnical and Palaeoenvironments

The British Geological Survey (BGS) on-line viewer shows the bedrock geology underlying the Late Quaternary deposits and extending across the whole district comprises the Bodmin Granite Intrusion, and superficial deposits of peat are shown on the geological map surrounding the eastern side of the reservoir, and extending upslope onto the moors, forming the bed of the Warleggan River.

The site partially falls within the Hawk's Tor Pit Site of Special Scientific Interest (SSSI), which was designated due to the presence of superficial waterlogged Late Quaternary and Early Holocene deposits, containing well preserved pollen sequences important in demonstrating and interpreting landscape responses to rapid climate change for the period in upland south-west England (see receptors below).

Lake level draw down due to the operation of the Drought Permit may be a critical factor in the stability of slopes that are currently partially or totally submerged. The lake side sand/gravel beaches would be expected to be secure against rapid drawdown as the water level inside the slope will quickly equalize with that outside the slope (i.e. the lake water level); draw down is not expected to result in slope instability in this material. The underlying granite is intact and is standing near vertical, where it is exposed in the quarry. This suggests it would also not be affected by draw down even where it is currently submerged. Anecdotally, the Drought Order abstractions during 1996 resulted in a maximum water level draw down within Hawk's Tor Pit of 11.78m (Table 4.6 above) without any reported accounts of associated bank instability.

The peat extends for a significant distance upslope of the pit perimeter, and therefore is expected also to be well above lake water levels. Therefore, a reduction of the water level in the pit is not expected to have any detrimental effect on the peat. Further details can be found in the Geotechnical section of this EAR (Section 5.7).

4.1.2 Hydrological Modelling (HEC-HMS)

4.1.2.1 HEC-HMS model development

SWW has commissioned Stantec to develop a Hydrologic Engineering Centre - Hydrologic Modelling System (HEC-HMS) model to serve as a tool for the new Drought Permit optioneering abstraction modelling and to investigate the viability of several abstraction scenarios.

The Hawk's Tor Pit has been represented as a 'reservoir' unit in HEC-HMS. The results of the bathymetry survey have been used to define the volume-elevation relationship of the 'reservoir' unit on the basis of Table 4.1 above. The outfall structure from the reservoir has been defined using the results of the topographical survey of the outlet channel as shown in Figure 4.1 above. The outfall structure was represented as a weir, with a width of 2m and a crest elevation of 220.41m AOD.

The daily mean flow time series for the Warleggan River (and for the Brockabarrow Common catchment) generated using the QUBE software and by pro-rating from the Trengoffe gauge (Section 4.1.1.6 above) were used as the inflows to the HEC-HMS model. The flow series for the Warleggan River were used as direct inflows to the lake; the Brockabarrow Common flow series was included as an additional input to the representation of the Warleggan River to the east of the lake although these flow inputs did not enter the lake itself within the HEC-HMS model.

Evaporative losses were represented using PET data from the Centre for Ecology and Hydrology, Wallingford (CEHW CHESS).

The HEC-HMS model was run over c. 50-year simulation periods (depending on scenario) to provide estimates of lake level and outflow variability. The model was then used to test the impacts of the proposed new abstraction on lake water level and outflow, especially during notable drought years.

4.1.2.2 HEC-HMS model input data

The HEC-HMS model, therefore, was created using the following input data:

- The lake volume-elevation data taken from the bathymetric survey (Table 4.1 above);
- Daily mean flow time series estimates derived from either QUBE or via pro-rating from the Trengoffe gauge (Section 4.1.1.6 above). Flows from the Upper Warleggan Catchment (Figure 4.3Figure above) entered the lake directly; flows from the Brockabarrow Common catchment entered the representation of the Warleggan River to the east of the lake, and did not enter the lake directly (i.e. as per Figure 4.3Figure above);
- Topographical survey of the lake outflow channel (Figure 4.5Figure above); and
- PET data from the CEHW CHESS dataset.

4.1.2.3 HEC-HMS model assumptions

The HEC-HMS model was created on the basis of the following assumptions:

- Routine TWL is taken to be 220.50m AOD;
- Reservoir outflow channel weir crest elevation is 220.41m AOD, with width 2m;
- Water level within the lake at the start of all simulation runs was taken to be 220.50m AOD;
- Infiltration losses via the sides/base of the lake were assumed to be zero;
- The contribution of groundwater to lake level variability is assumed to be insignificant (i.e. it is assumed for the purposes of the model that the reservoir is entirely surface water fed from the Upper Warleggan catchment); and
- There is no significant interaction between the Brockabarrow Common catchment and the reservoir (as described above, these inflows enter the HEC-HMS representation of the Warleggan River to the east of the reservoir, and do not enter the reservoir itself).

Based on discussions with the EA regarding the protection of downstream fisheries and fish migration, during the key spawning period of November to January inclusive, recovery to TWL by the 1st November the following year (assuming abstraction commences in November/December of the preceding year, depending on scenario) has also been set as a modelling boundary. This will facilitate natural gravity discharges from the pit via its outlet channel within this key period, following recovery to TWL.

4.1.2.4 HEC-HMS model schematic

The HEC-HMS model schematic is shown in Figure 4.9Figure below.

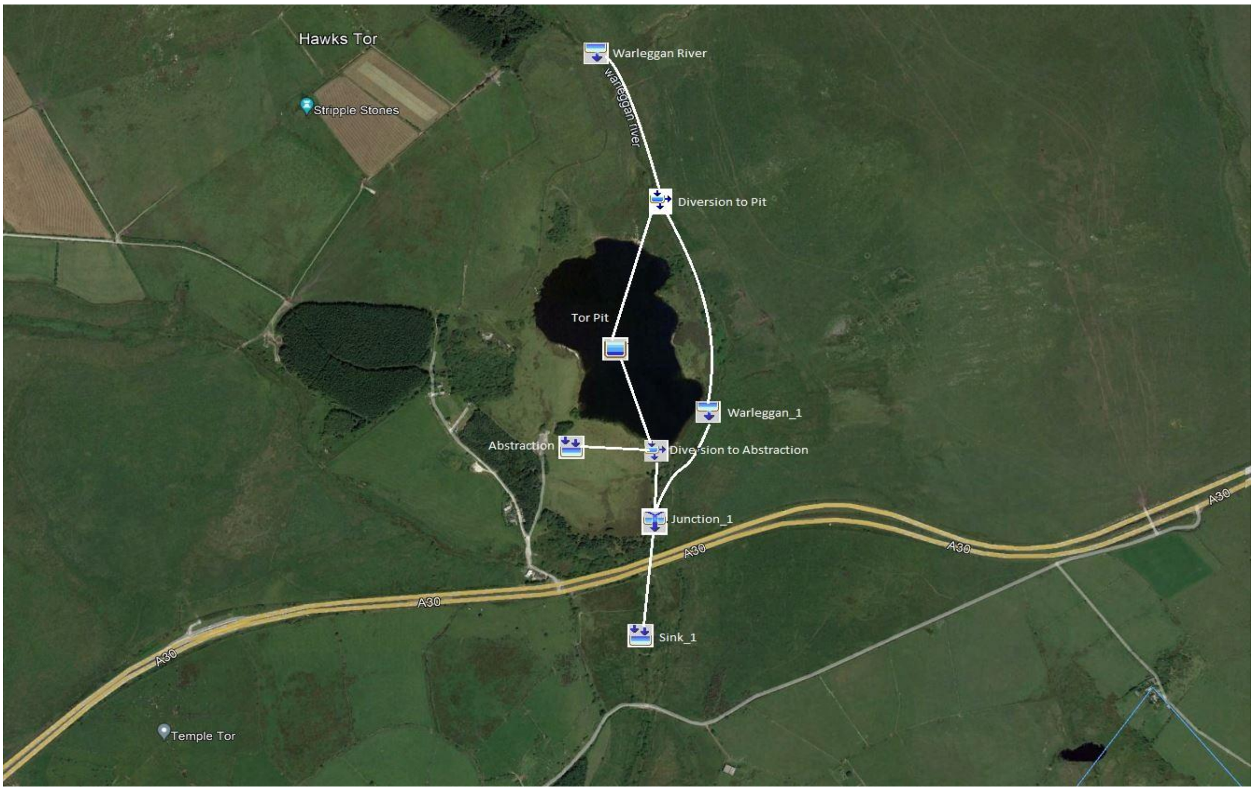

Figure 4.9 - HEC-HMS model schematic.

The main Warleggan River inflow series enters the model at 'Warleggan River'. This represents inflows from the Upper Warleggan catchment to the north of the lake. The lake is represented by 'Tor Pit'. Lake outflow via the outflow channel returns to the Warleggan River at 'Junction 1'. 'Warleggan_1' represents inflows to the Warleggan River from the Brockabarrow Common catchment, just upstream of the confluence of the lake outflow channel and the Warleggan River. Abstraction from the lake exits the model entirely (via the 'Abstraction' unit shown on the left). Pumped compensation flows from the lake return to the Warleggan River at 'Junction 1'. Flows on the Warleggan downstream are calculated in the reach just upstream of 'Sink-1'. Flow here is a combination of a) natural gravity lake outflow; b) flow contributions from the Brockabarrow Common catchment; and c) pumped compensation flows.

4.1.2.5 HEC-HMS model 'calibration'

'Calibration' of the HEC-HMS model was attempted using the following data:

- daily abstraction data for the 1995 Drought Order period;
- timeseries data for lake level draw down during the 1995 Drought Order period (i.e. Figure 4.8 above);
- data on the maximum draw down and lake level recovery during the x2 1996 Drought Order abstraction periods (i.e. Table 4.6Table above).

Prior to 2009/10, after which the change in the alignment of the Warleggan River was identified and 100% of upstream flows enter the pit, the relationship between the Warleggan River and the pit is not clearly qualified/understood, although it is anticipated that there would have been a degree of interaction. For the purposes of the initial calibration, it was assumed that 100% of the Warleggan River flows entered the pit during the 1995-6 Drought Order periods.

A relatively poor calibration to the 1995 lake level data was achieved by assuming that 100% of the Warleggan River flows entered the pit during this period (Figure 4.10Figure below). A more successful calibration was achieved by assuming that 50% of the Warleggan River flows entered the pit during this period (Figure 4.11Figure below). Table 4.7Table below confirms that the HEC-HMS model performed well on the basis of this assumption and was able to broadly simulate the observed maximum draw down levels and TWL recovery times.

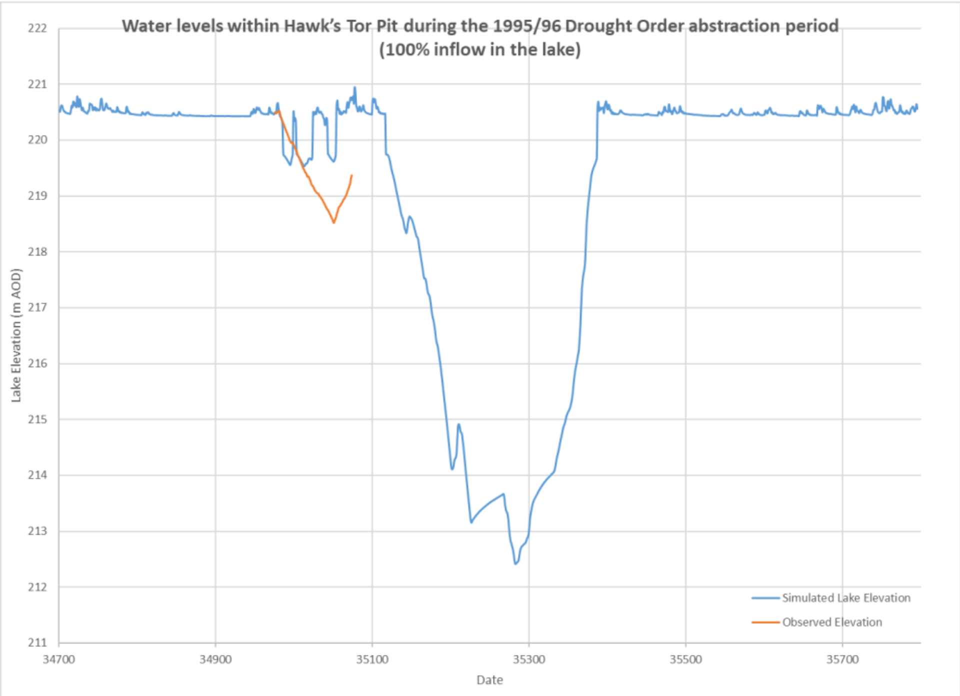

Figure 4.10 - Calibration to 1995/6 assuming 100% of Warleggan flows entered the lake.

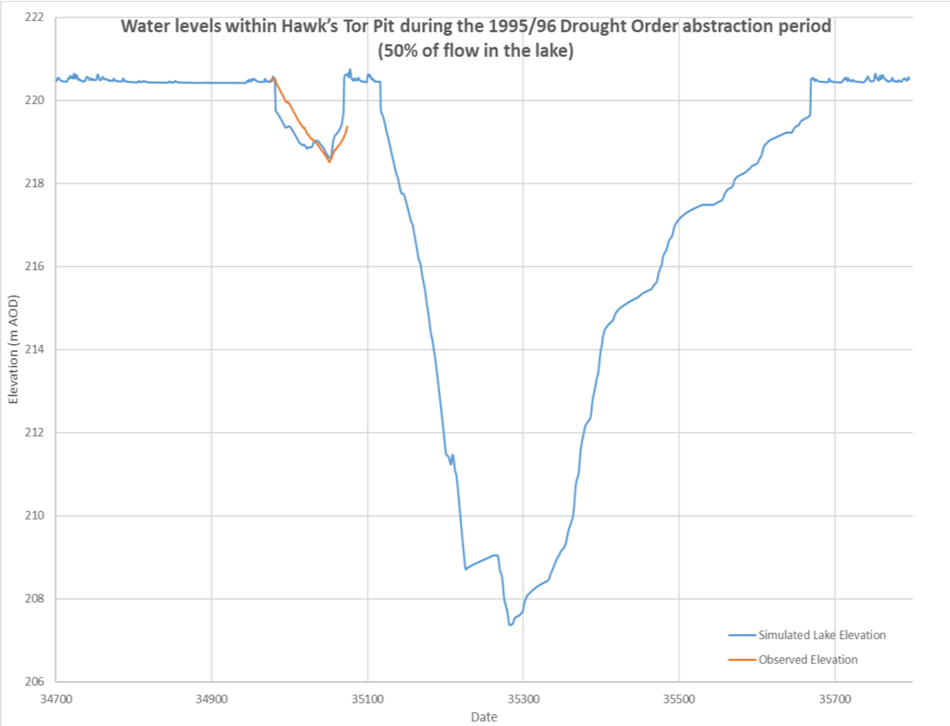

Figure 4.11 - Calibration to 1995/6 assuming 50% of Warleggan flows entered the lake.

Table 4.7 - Calibrated HEC-HMS model performance to the observed draw down and TWL recovery data for the 1995/6 DO periods, assuming that 50% of the Warleggan River flows entered the pit during this period.

Performance of the pit in response to DO/DP implementation						
	DO I		DO II (phase 1)		DO II (phase 2)	
Abstraction Period	03/10/95 – 19/12/95		23/02/96 – 10/06/96		23/07/96 – 16/08/96	
No of Pumping Days	78		109		25	
Average Abstraction	4.31 Ml/d		11.92 Ml/d		6.59 Ml/d	
Maximum Abstraction	7.98 Ml/d		16.83 Ml/d		14.96 Ml/d	
	Simulated	Observed	Simulated	Observed	Simulated	Observed
Draw-down	1.88 m	1.91m	11.81 m (12m cut-off)	11.55m (12m cut-off)	13.17 m (12m cut-off) on 05/08/96	11.78 m (12m cut-off)
Cessation & Recovery date	01/05/1996	02/06/1996	21/07/96	23/07/96	26/08/97	24/07/97
Cessation & Recovery depth	1.88 m (to TWL)	+ 1.91m (to TWL)	0.32 m	+ 1.31m	13.17m (to TWL)	+ 14.53 m (to TWL)

This 'calibration' exercise, however, only serves to demonstrate that the HEC-HMS model is capable of producing plausible simulations of the pit response to draw down and TWL recovery, given that the interaction between the Warleggan River and the lake is known to have changed significantly after the 2009/10 breach event. For the purposes of the scenario testing, therefore, the 'baseline' condition assumes that 100% of the inflow series from the Upper Warleggan catchment enters the lake.

4.1.3 Hydrological Modelling Scenarios

4.1.3.1 Baseline Scenario

The baseline model scenario has been generated based on the input data, assumptions and HEC-HMS model schematic outlined above and assumes that 100% of the inflow series from the Upper Warleggan catchment enters the lake, but abstraction and compensation flow releases are set at zero. The baseline model simulation period varied depending on whether the QUBE series or the pro-rated Trengoffe series were used. Additional flows from the Brockabarrow Common catchment continue to enter the baseline model at the location of 'Warleggan_1' shown in Figure 4.8 above.

4.1.3.2 Compensation flow releases

Following discussions with the EA, SWW has proposed two compensation flow release rates as follows, which have been applied to the abstraction scenarios:

- November to April inclusive: 32 l/s (equivalent to a winter, Nov-Jan Q90); and
- April to October inclusive: 18 l/s (equivalent to a summer, May-Oct Q80).

These flows are considered appropriate by the EA to ensure the protection of salmonid fish life and the wider aquatic ecology of the Warleggan River downstream of Hawk's Tor Pit. In addition to these flows, SWW has also proposed 3 no. simulated spate events in the November to January window, to aid salmonid fish migration, by increasing compensation flows to 64 l/s for 12 hours overnight (NB: given the small scale of these releases they are not included in the HEC-HMS model and given the date of permitting this has been reduced to 2 spate events in December on written request from the EA). In addition, 3 no. spate events are proposed for May, by increasing flows to 32 l/s, to aid salmonid smolt migration (NB: given the small scale of these releases they are also not included in the HEC-HMS model).

4.1.3.3 Scenario 1

This scenario assumes fish CAN migrate through Hawk's Tor Pit into the upper Warleggan River during the months of November to January each year, and that TWL needs to be maintained throughout this period to sustain a gravity overflow in the lake outlet channel of 32 l/s.

This scenario uses the inflow time series for the Upper Warleggan River and the Brockabarrow Common catchments generated using the QUBE software (the model simulation period is therefore 1961 to 2015).

The abstraction rate between the months of November to January for this scenario is variable, whereby inflows over and above 32l/s are abstracted each day. Abstraction between the months of February to April is 8Ml/d, and 0Ml/d between the months of May to October, for all simulation years.

The compensation release rate for this scenario is 32l/s between November and January, achieved using gravity discharges via the lake outflow channel. Between February to April the compensation flow is set at 32l/s and 18l/s between May to October; these compensation flow releases would need to be delivered by direct pumping from the lake into the outflow channel, depending on lake water level. The HoL would be TWL between the months of November to January (i.e. to allow a 32l.s gravity discharge) and TWL-12m (i.e. 208.50m AOD) during February to April. Recovery to TWL by the 1st November for each year was also a requirement for this scenario.

Scenario 1 assumes that TWL (i.e. 220.50m AOD) needs to be maintained to enable migratory salmonid fish to move through the pit (November to January incl.) and into the upper reaches of the Warleggan River. This scenario was modelled prior to SWW survey work (23/11/2022) which confirmed fish were very unlikely to be able to migrate through Hawk's Tor Pit, due to the morphology of its inlet flow channels.

4.1.3.4 Scenario 2

This scenario assumes fish CANNOT migrate through Hawk's Tor Pit into the upper Warleggan River during the months of November to January each year, and that TWL DOES NOT need to be maintained throughout this period.

This scenario uses the inflow time series for the Upper Warleggan River and the Brockabarrow Common catchments generated using the QUBE software (the model simulation period is therefore 1961 to 2015).

Abstraction between the months of November to April is 8Ml/d for this scenario, and 0Ml/d between the months of May to October, for all simulation years. Between November to April the compensation flow is set at 32l/s and 18l/s between May to October; these compensation flow releases would need to be delivered by direct pumping from the lake into the outflow channel, depending on lake water level. The HoL would be TWL-12m (i.e. 208.50m AOD) between November to April. Recovery to TWL by the 1st November for each year was also a requirement for this scenario.

4.1.3.5 Scenario 3

This scenario assumes fish CANNOT migrate through Hawk's Tor Pit into the upper Warleggan River during the months of November to January each year, and that TWL DOES NOT to be maintained throughout this period.

This scenario uses the inflow time series for the Upper Warleggan and the Brockabarrow Common catchments generated using the QUBE software (the model simulation period is therefore 1961 to 2015).

The abstraction and compensation flow arrangement for this scenario is as per Scenario 1, with the exception that abstraction during April is set at 4Ml/d.

4.1.3.6 Scenario 4

This scenario assumes fish CANNOT migrate through Hawk's Tor Pit into the upper Warleggan River during the months of November to January each year, and that TWL DOES NOT need to be maintained throughout this period.

This scenario uses the inflow time series for the Upper Warleggan and the Brockabarrow Common catchments generated using pro-rating from the Trengoffe gauge (the model simulation period is therefore 1969 to 2021).

The abstraction and compensation flow arrangement for this scenario is as per Scenario 3.

4.1.3.7 Scenarios 5a, 5b, and 5c

These scenarios assume fish CANNOT migrate through Hawk's Tor Pit into the upper Warleggan River during the months of November to January each year, and that TWL DOES NOT need to be maintained throughout this period.

These scenarios use the inflow time series for the Upper Warleggan, and the Brockabarrow Common catchments generated using pro-rating from the Trengoffe gauge (the model simulation period is therefore 1969 to 2021).

Scenario 5a

Abstraction for this scenario is 8Ml/d between November to February, 4Ml/d between March and April, and 0Ml/d between the months of May to October, for all simulation years. Between November to April the compensation flow is set at 32l/s and 18l/s between May to October; these compensation flow releases would need to be delivered by direct pumping from the lake into the outflow channel, depending on lake water level. The HoL would be TWL-12m (i.e. 208.50m AOD) between November to April. Recovery to TWL by the 1st November for each year was also a requirement for this scenario.

Scenario 5b

Abstraction for this scenario is 4Ml/d between November to April and 0Ml/d between the months of May to October, for all simulation years. Between November to April the compensation flow is set at 32l/s and 18l/s between May to October; these compensation flow releases would need to be delivered by direct pumping from the lake into the outflow channel, depending on lake water level. The HoL would be TWL-12m (i.e. 208.50m AOD) between November to April. Recovery to TWL by the 1st November for each year was also a requirement for this scenario.

Scenario 5c

Abstraction for this scenario is 4Ml/d between November to February, 2Ml/d between March and April, and 0Ml/d between the months of May to October, for all simulation years. Between November to April the compensation flow is set at 32l/s and 18l/s between May to October; these compensation flow releases would need to be delivered by direct pumping from the lake into the outflow channel, depending on lake water level. The HoL would be TWL-12m (i.e. 208.50m AOD) between November to April. Recovery to TWL by the 1st November for each year was also a requirement for this scenario.

4.1.3.8 Scenario 6

This scenario assumes fish CANNOT migrate through Hawk's Tor Pit into the upper Warleggan River during the months of November to January each year, and that TWL DOES NOT need to be maintained throughout this period.

This scenario uses the inflow time series for the Upper Warleggan and the Brockabarrow Common catchments generated using pro-rating from the Trengoffe gauge (the model simulation period is therefore 1969 to 2021).

Abstraction between the months of November to April is 8Ml/d for this scenario, and 0Ml/d between the months of May to October, for all simulation years. Between November to April the compensation flow is set at 32l/s and 18l/s between May to October; these compensation flow releases would need to be delivered by direct pumping from the lake into the outflow channel, depending on lake water level. The HoL would be TWL-12m (i.e. 208.50m AOD) between November to April. Recovery to TWL by the 1st November for each year was also a requirement for this scenario.

4.1.3.9 Revised Scenarios 5b and 5c (12th December abstraction start date)

These scenarios have been requested by and agreed with the EA in support of the Drought Permit application. These scenarios are as per the original Scenarios 5b and 5c, but the starting date for abstraction has been set to the 12th December in all simulation years.

4.1.3.10 'New' Scenarios 7 to 11

Throughout the process of liaising with the EA regarding the Drought Permit application, SWW has explored additional scenarios and, upon reviewing the initial hydrological modelling results, the EA has also asked for additional scenarios to be considered. These 'new' scenarios are Scenarios 7 to 11 and represent the latest scenarios to be tested in the HEC-HMS model (up to 8th December 2022).

Scenarios 7 and 8 are similar to revised Scenario 5b (i.e. abstraction starts on 12th December in each simulation year), but the rate of abstraction is 4.78 Ml/d and 6 Ml/d, respectively.

Scenarios 9, 10 and 11 are the same as revised Scenario 5b, Scenario 7 and 8 in terms of abstraction timings and rates, although the compensation releases have been set at 32l/s between 1st October and 30th April, and 18l/s between May and the end of September, in each simulation year.

All of the above scenarios have been performed using the Trengoffe GS derived timeseries inflow data starting from 21st September 1969 to 30th September 2021. The simulation period comprises a total of 53 years, of which 51 (1970-2020) are complete simulation years, and two (1969 and 2021) partial simulation years. The results for these revised and 'new' scenarios are broadly the same as those for the originals, although subtle differences are readily identifiable. This is discussed further below.

4.1.3.11 Abstraction scenarios - discussion

Scenarios 2 and 6 provide a direct comparison of the sensitivity of using QUBE vs. the pro-rated Trengoffe flows for a single abstraction regime (i.e. November-April incl. at 8Ml/d).

Scenarios 3 and 4 provide a direct comparison of the sensitivity of using QUBE vs. the pro-rated Trengoffe flows for the 'three-stage' abstraction scenario (i.e. November to January = 'hunting' surplus flows above the compensation rate; February to March = 8Ml/d; and April = 4Ml/d). Whilst surplus flow in the November to January period is not strictly required (explained above) these scenarios assist in understanding the sensitivity of the different abstraction regimes.

Scenarios 5a to 5c, which all use the pro-rated Trengoffe flow data, assessed the sensitivity of different abstraction regimes to limit the number of years during which TWL is not achieved by 1st November. These scenarios are, however, more relevant to a long-term sustainable abstraction regime than the Drought Permit application.

Scenario 6, which also uses the pro-rated Trengoffe flow data, assesses the effect of an 8Ml/d abstraction between November and April inclusive, on recovery to TWL (see Scenario 2 for a direct comparison with the QUBE timeseries data).

'New' Scenarios 7 to 11 also use the pro-rated Trengoffe flow data. Scenario 7 is similar to Revised Scenario 5b, although considers a 'pro-rated' abstraction rate of 4.78 Ml/d, to account for the fact that abstraction starts later in the year (i.e. on 12th December); Scenario 8 is similar to this, although represents a slightly higher abstraction rate that has been explored by SWW (i.e. 6 Ml/d). Scenarios 9, 10 and 11 are the same as revised Scenario 5b, Scenario 7 and 8 in terms of abstraction timings and rates, although have been included in response to a request from the EA to consider the impact of starting the higher compensation flow release of 32l/s earlier in each simulation year (i.e. on the 1st of October).

Given that the Warleggan River now runs through the pit (unlike during the 1995-6 Drought Order period), the model includes the maintenance of the compensation flows post-cessation of the abstraction period and beyond the 1st November (where recovery to TWL is not achieved by this date).

4.1.4 *Hydrological Modelling Results*

4.1.4.1 Scenario 1

Scenario 1 (using the QUBE data) presented a moderated in-year risk (12.7%) of TWL not being achieved by the 1st November. This scenario has been included for completeness but given fish passage through the pit is very unlikely it does not need to be considered further. Results for Scenario 1 are presented in Table 4.8 and Figure 4.12 Figure below.

4.1.4.2 Scenario 2

Scenario 2 (using the QUBE data) presented the second highest in-year risk (12 of 55 years, c. 21.8% risk) of TWL not being achieved by the 1st November with 11 years where recovery to TWL did not occur in-year. Results for Scenario 1 are presented in Table 4.9Table and Figure 4.13Figure below.

4.1.4.3 Scenario 3

Scenario 3 (using the QUBE data) presented the lowest modelled in-year risk with only 3 years (c. 5.5% risk) of TWL not being achieved by the 1st November in the following year. Given this, the year 1969 is unusual in that TWL is achieved before the 1st November (i.e. on 11/09/1969) but decreases temporarily after this date and then hunts TWL (220.48m AOD) from 07/11/1969. Given model dependencies, it is likely that recovery to TWL before the 1st November would have occurred in 1969. Results for Scenario 3 are presented in Table 4.10 and Figure 4.14 below.

4.1.4.4 Scenario 4

Scenario 4 (using the pro-rated Trengoffe flows) was more conservative (c.f. Scenario 3) with 8 years (15% risk) where TWL was not achieved by the 1st November. Interestingly, Scenario 3 and Scenario 4 shared only 1 year (2011) during which TWL did not recover by the required date. The differences in the years during which TWL did not recover between Scenarios 3 and 4 are due to the use of different inflow time series. In Scenario 4, for 6 of the 8 years, recovery to TWL did still occur during the month of November and for 7 of the 8, recovery was within-year. Furthermore, for those years where TWL was not achieved by the 1st November, lake levels were more than 99% relative to the outlet channel weir level on the 1st November in-year. Consequently, whilst the use of the pro-rated Trengoffe flow series does indicate an increased risk to TWL recovery, there is a relatively low risk (1 year, c. 1.9% risk) of TWL not being achieved in-year. Results for Scenario 4 are presented in Table 4.11 and Figure 4.15 below.

4.1.4.5 Scenarios 5a, 5b and 5c

Scenario 5a (using the pro-rated Trengoffe flows) indicated 7 years where TWL was not achieved by the 1st November in-year (c. 13.2% risk), of which 3 recovered by the 31st December in-year and the remaining 4 early in the following year. This level of risk is not dissimilar to Scenario 4. Results for Scenario 5a are presented in Table 4.12Table and Figure 4.16 below.

Scenario 5b (using the pro-rated Trengoffe flows) resulted in only one year (1984, 1.9% risk) were recovery to TWL was not achieved by the 1st November and recovery was still achieved within year. Results for Scenario 5b are presented in Table 4.13 and Figure 4.17 below.

Scenario 5c (using the pro-rated Trengoffe flows) resulted in the lowest risk overall with all years in the timeseries recovering in year to TWL by the 1st November. Results for Scenario 5c are presented in Table 4.14 and Figure 4.18 below.

4.1.4.6 Scenario 6

Scenario 6 (using the pro-rated Trengoffe flows) presented the greatest risk to TWL recovery overall, with 25 years (of 53 years, 47.2% risk) where TWL was not achieved by the 1st November in the same year. In 3 of the 25 years (1992, 1999 and 2010), TWL was achieved by the 31st December in-year and a further 3 (1969, 1973 and 2001) early in the subsequent year. Furthermore, there were 18 years where TWL did not recover in the subsequent year and in certain instances over multiple subsequent years (e.g. 1975-1978 incl.). This multiple year-on-year effect is a consequence of the need to maintain compensation flows under this scenario post the 1st November (something which was not a requirement in the 1995-1996 Drought Order periods) where TWL is not achieved by this date. Results for Scenario 6 are presented in Table 4.15 and Figure 4.19 below.

4.1.4.7 Revised Scenarios 5b and 5c (12th December abstraction start date)

For revised Scenario 5b (using the pro-rated Trengoffe flows), TWL is not achieved by the 1st November in only one year in the simulation period (1984), although TWL recovery occurs earlier in the month of November when compared with the original scenario (i.e. compare Table 4.13 and Table 4.16 below). Also, in revised Scenario 5b, low water levels are experienced slightly less frequently over the simulation period (for example, compare the frequency of water levels falling below 218.50m AOD in Figure 4.18 and Figure 4.20 below).

For revised Scenario 5c (using the pro-rated Trengoffe flows), TWL is still achieved by the 1st November in all years in the simulation period (i.e. compare Table and Table 4.17 below), although low water levels are also, again, experienced slightly less frequently over the simulation period (for example, compare the frequency of water levels falling below 218.65m AOD in Figure 4.19 and Figure 4.21 below).

4.1.4.8 Scenario 7 (12th December abstraction start date)

For Scenario 7, TWL is not achieved by the 1st of November for three years in the simulation period (1984, 1995 and 2011), and for 1990, TWL is achieved on the 1st November. However, TWL recovery still occurs in the month of November for all the years (Table 4.18 and Figure 4.23).

4.1.4.9 Scenario 8 (12th December abstraction start date)

For Scenario 8, TWL is not achieved by the 1st of November for seven years in the simulation period (1984, 1990, 1992, 1995, 1997, 2006 and 2011), and for 1976, TWL is achieved on the 1st November. However, TWL recovery still occurs in the month of November for all the years (Table 4.19 and Figure 4.24).

4.1.4.10 Scenario 9 (12th December abstraction start date; 1st October start date for 32l/s compensation flow)

For Scenario 9, TWL is not achieved by the 1st of November for two years in the simulation period (1984 and 1990), though TWL recovered in the month of November in -year for both years (Table 4.20 and Figure 4.25). Due to the increased compensation release of 32 l/s (starting from the 1st October), there are ten years (1969, 1971, 1972, 1977, 1978, 1983, 1995 ,2003, 2007 and 2016) during which water level dropped below TWL in the month of October and did not recover by the 1st November, although recovery to TWL still occurred in the same year for all these ten years. Of these ten years, six years (1969, 1971, 1972, 1977, 2003 and 2016) experienced TWL recovery in the month of November, and for the remaining four years (1978, 1983, 1995 and 2007), TWL recovered in the month of December.

4.1.4.11 Scenario 10 (12th December abstraction start date; 1st October start date for 32l/s compensation flow)

For Scenario 10, TWL is not achieved by the 1st November for five years in the simulation period (1984, 1990, 1995, 1997 and 2011), although TWL recovered in the month of November for four of these five years, and for one year (1995), TWL recovered in early December (Table 4.21 and Figure 4.26). Due to the increased compensation release of 32 l/s (starting from the 1st October), there are nine years (1969, 1971, 1972, 1977, 1978, 1983, 2003, 2007 and 2016) during which water level dropped below TWL in the month of October and did not recover by the 1st November, although TWL recovered in-year for all of these nine years. Of these nine years, six years (1969, 1971, 1972, 1977, 2003 and 2016) experienced TWL recovery in the month of November, and for the remaining three years (1978, 1983, and 2007), TWL recovered in the month of December.

4.1.4.12 Scenario 11 (12th December abstraction start date; 1st October start date for 32l/s compensation flow)

For Scenario 11, TWL is not achieved by the 1st November for eleven years in the simulation period (1975, 1976, 1984, 1989, 1990, 1992, 1995, 1997, 2005, 2006 and 2011), although for nine years out of these eleven, TWL recovered in the month of November, and for one year (2011), TWL recovered in early December. For 1995, TWL did not recover in the same year, but in early January the following year (Table 4.22 and Figure 4.27). Due to the increased compensation release of 32 l/s (starting from the 1st October), there are nine years (1969, 1971, 1972, 1977, 1978, 1983, 2003, 2007 and 2016) during which water level dropped below TWL in the month of October and did not recover by the 1st November, although TWL recovered in the same year for all these nine years. Of these nine years, six years (1969, 1971, 1972, 1977, 2003 and 2016) experienced TWL recovery in the month of November, and for the remaining three years (1978, 1983 and 2007), TWL recovered in the month of December.

4.1.4.13 Scenario Results - Discussion

As a consequence of 100% of the Warleggan River flows entering the pit the HoL of TWL-12m (i.e. 208.50m AOD) was not exceeded in any year in any Scenario.

Whilst HoL compliance is met as a result of all Warleggan River flows entering the pit, the need to maintain compensation flows to the river impacts recovery to TWL in all but Scenario 5c, although the level of risk with Scenarios 4 and 5b is also very low. In general, the level of risk to TWL recovery is reduced slightly in revised Scenario 5b, given that the abstraction is timed to start later in the year. Revised Scenario 5c is broadly the same as the original, although low water levels occur slightly less frequently.

4.1.4.14 Scenario Results – Tables and Graphs

Table 4.8 - Scenario 1 Model Output Summary (QUBE derived timeseries inflow data).

<table>
<tr><td rowspan="3">Scenario 1</td><td colspan="3">Assumes fish CAN migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL needs to be maintained to sustain a gravity overflow at the pit outlet of 32 l/s Nov-Jan incl.</td></tr>
<tr><td colspan="3">Period</td></tr>
<tr><td>Nov - Jan incl.</td><td>Feb - Apr incl.</td><td>May – Oct incl.</td></tr>
<tr><td>Abstraction Rate (Ml/d)</td><td>Variable

(surplus available water above compensation rate)</td><td>8</td><td>0</td></tr>
<tr><td>Compensation Rate (l/s)</td><td>32</td><td>32</td><td>18</td></tr>
<tr><td>Compensation mechanism</td><td>Gravity</td><td colspan="2">Pumped depending on pit water level</td></tr>
<tr><td>Hands off Level</td><td>TWL (to achieve gravity comp. flow rate at pit outlet)</td><td>TWL-12m (208.5mAOD)</td><td>Recovering to TWL (220.50 mAOD)</td></tr>
<tr><td colspan="2">Years TWL NOT achieved by end October</td><td>Level (mAOD) achieved by 1st November</td><td>Date TWL achieved</td></tr>
<tr><td colspan="2">1962</td><td>219.48</td><td>13/11/1962</td></tr>
<tr><td colspan="2">1971</td><td>219.02</td><td>02/12/1971</td></tr>
<tr><td colspan="2">1978</td><td>219.23</td><td>03/12/1978</td></tr>
<tr><td colspan="2">1984</td><td>218.87</td><td>07/12/1984</td></tr>
<tr><td colspan="2">2003</td><td>219.48</td><td>13/11/2003</td></tr>
<tr><td colspan="2">2005</td><td>219.45</td><td>14/11/2005</td></tr>
<tr><td colspan="2">2011</td><td>218.45</td><td>22/12/2011</td></tr>
</table>

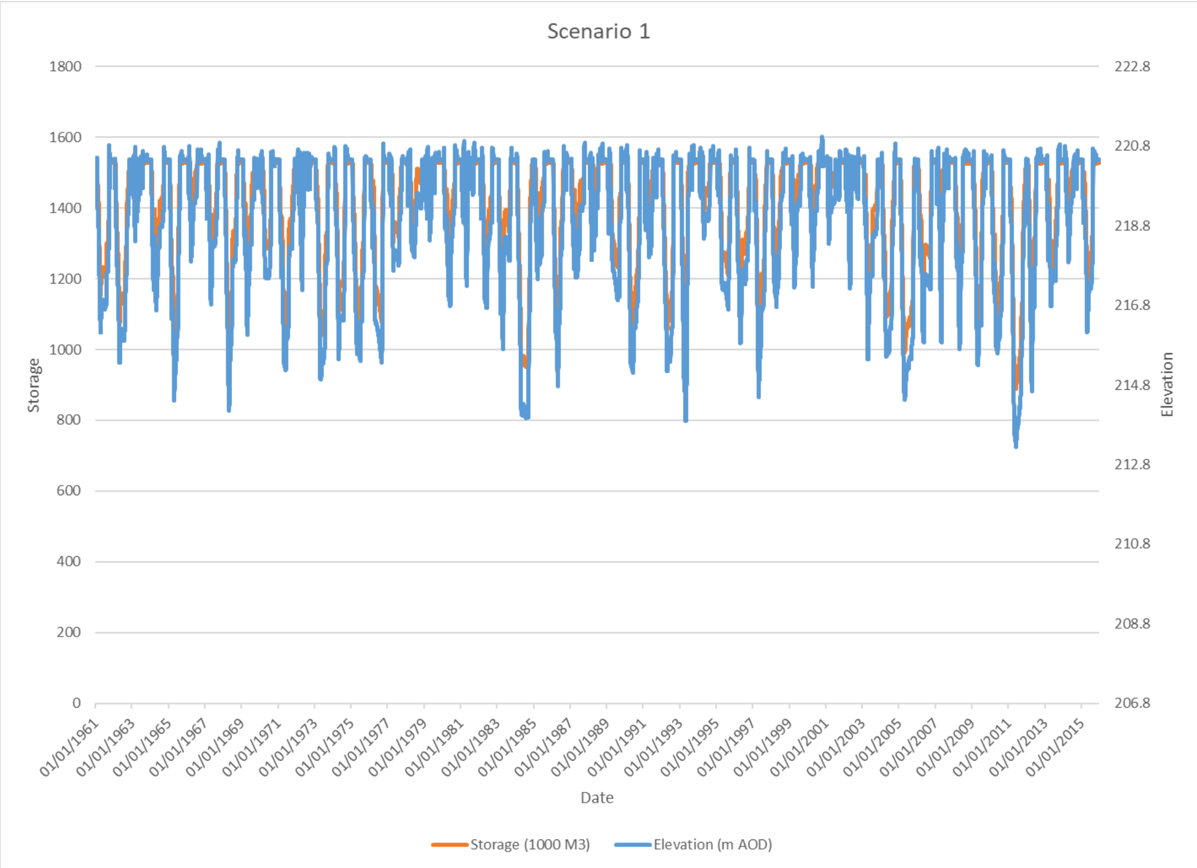

Figure 4.12 - Scenario 1 model output.

Table 4.9 - Scenario 2 Model Output Summary (QUBE derived timeseries inflow data).

Scenario 2	Assumes fish CAN'T migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January	
	Period	
	Nov - Apr incl.	**May – Oct incl.**
Abstraction Rate (Ml/d)	8	0
Compensation Rate (l/s)	32	18
Compensation mechanism	Gravity or pumped depending on pit water level	
Hands off Level	TWL-12m (208.5mAOD)	Recovering to TWL (220.50 mAOD)
Years TWL NOT achieved by end October	**Level (mAOD) achieved by 1st November**	**Date TWL achieved** (recovery date in following year)

1962	219.29	Did Not Recover in Year (22/08/1963)
1964	217.51	Did Not Recover in Year (11/09/1965)
1971	218.96	Did Not Recover in Year (08/09/1972)
1978	219.18	Did Not Recover in Year (09/08/1979)
1984	218.87	Did Not Recover in Year (06/08/1985)
1989	219.46	05/11/1989
1992	218.83	Did Not Recover in Year (07/09/1993)
1997	216.98	Did Not Recover in Year (11/09/1998)
2003	219.10	Did Not Recover in Year (12/10/2004)
2005	217.51	Did Not Recover in Year
2006	217.83	Did Not Recover in Year (25/06/2007)
2011	215.76	Did Not Recover in Year (03/09/2012)

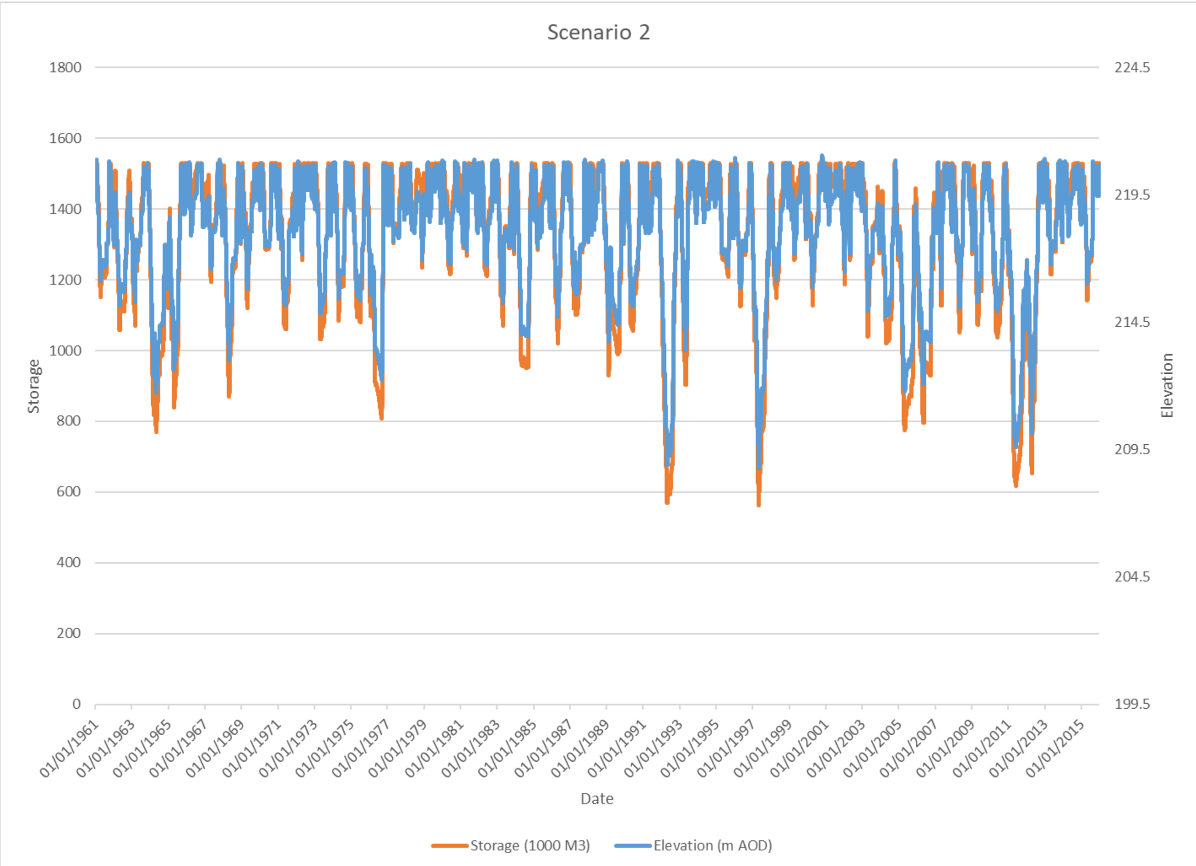

Figure 4.13 - Scenario 2 model output.

Table 4.10 - Scenario 3 Model Output Summary (QUBE derived timeseries inflow data).

Scenario 3	**Assumes fish CAN'T migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT**

	need to be maintained between November & January. Reducing the no. of years that TWL is NOT achieved by 1st November (c.f. Scenario 2).			
	Period			
	Nov - Jan incl.	Feb - Mar incl.	April	May – Oct incl.
Abstract Rate (Ml/d)	Variable (surplus available water above compensation rate)	8	4	0
Compensation Rate (l/s)	32			18
Compensation mechanism	Gravity	Pumped depending on pit water level		
Hands off Level	TWL-12m (208.5mAOD)	TWL-12m (208.5mAOD)		Recovering to TWL (220.50 mAOD)
Years TWL NOT achieved by end October		Level (mAOD) achieved by 1st November		Date TWL achieved
1969 [1]		219.76		11/09/1969 (07/11/1969)
1978		219.39		24/11/1978
2011		219.58		09/11/2011

NB1: Timeseries data starts in Sept 1969.

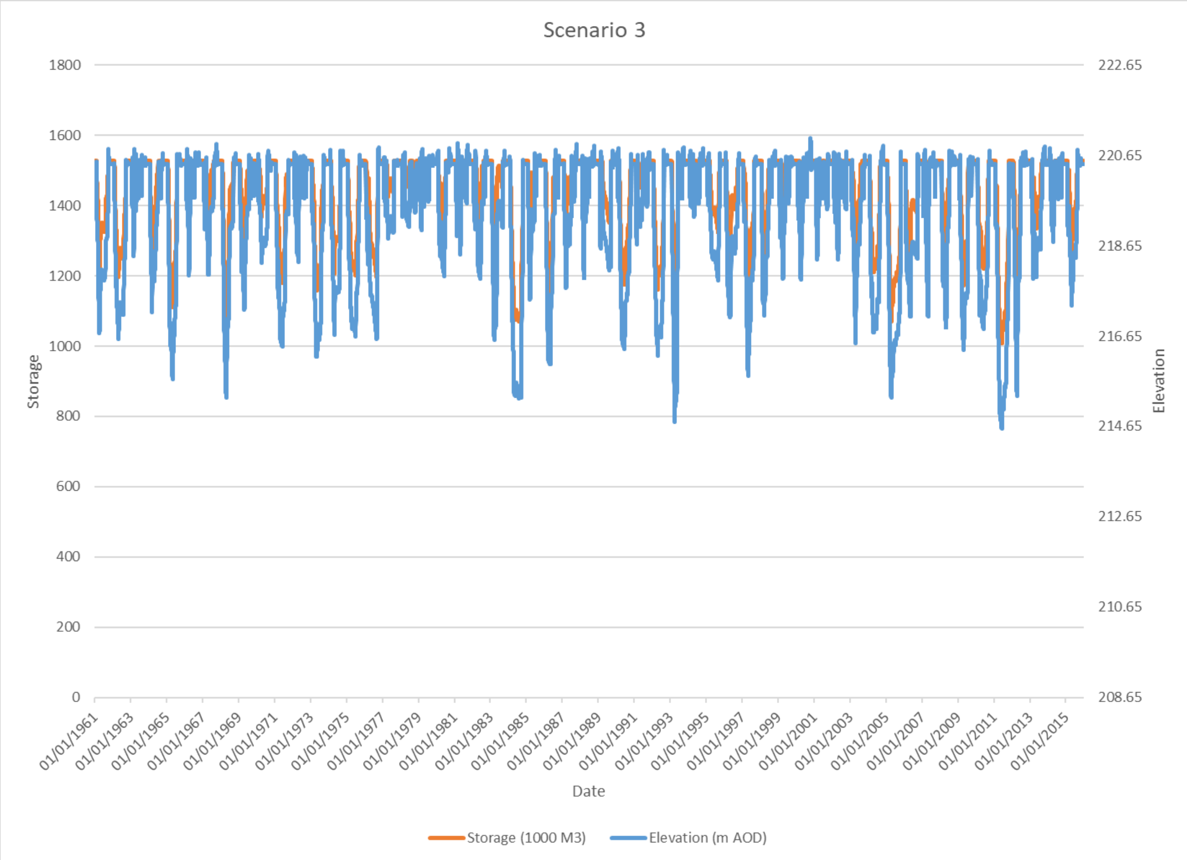

Figure 4.14 - Scenario 3 model output.

Table 4.11 - Scenario 4 Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 4 (Scenario 3, with Trengoffe GS derived timeseries inflow data (1969 – 2021))	Assumes fish CAN'T migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January. As per Scenario 3 but using Trengoffe GS			
	Period			
	Nov - Jan incl.	Feb - Mar incl.	April	May – Oct incl.
Abstract Rate (Ml/d)	Variable (surplus available water above compensation rate)	8	4	0
Compensation Rate (l/s)	32			18

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Compensation mechanism	Gravity	Pumped depending on pit water level	
Hands off Level	TWL-12m (208.5mAOD)	TWL-12m (208.5mAOD)	Recovering to TWL (220.50 mAOD)
Years TWL NOT achieved by end October		**Level (mAOD) achieved by 1st November**	**Date to TWL achieved**
1975		219.72	03/11/1975
1984		217.33	21/06/1985
1990		219.32	19/11/1990
1995		219.62	16/11/1995
1997		219.33	19/11/1997
2005		219.42	16/11/2005
2006		219.74	03/11/2006
2011		218.26	31/12/2011

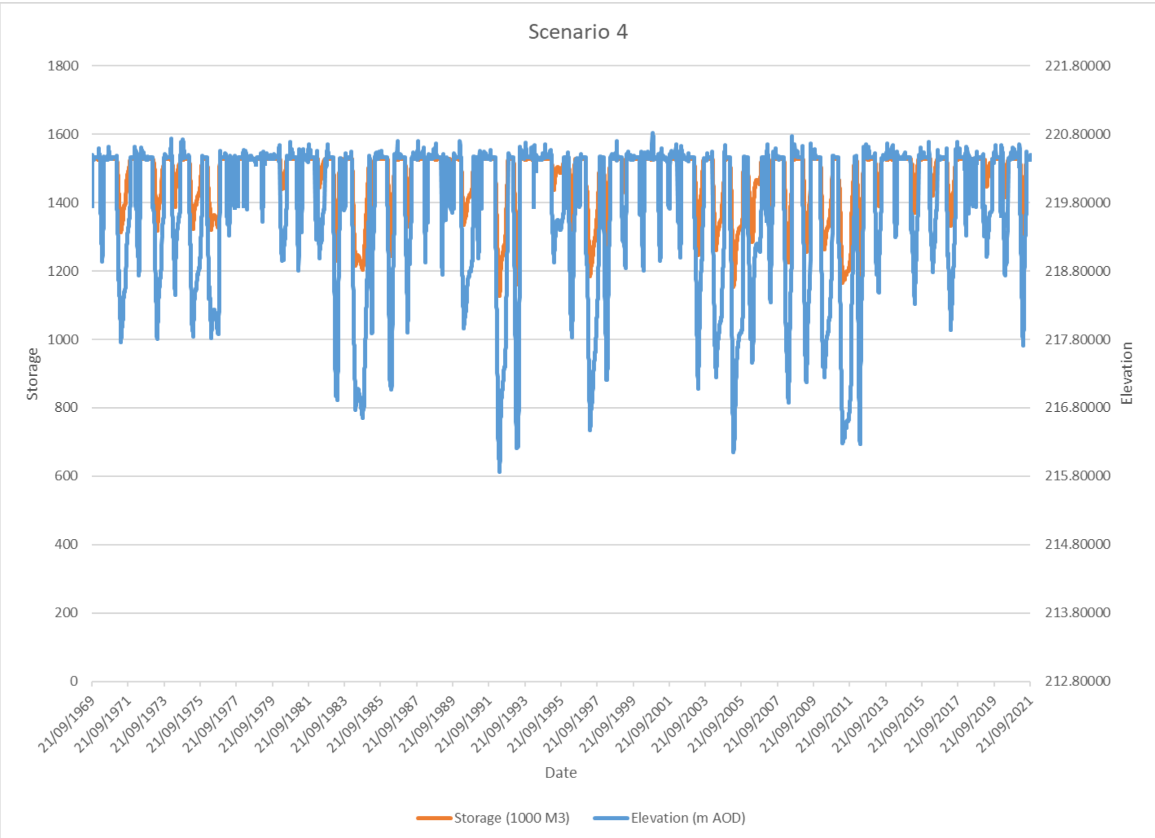

Figure 4.15 - Scenario 4 model output.

Table 4.12 - Scenario 5a Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 5a	**Assumes fish CAN'T migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.**		
	Period		
	Nov – Feb incl.	**Mar-Apr incl.**	**May – Oct incl.**
Abstract Rate (Ml/d)	**8**	**4**	**0**
Compensation Rate (l/s)	**32**	**32**	**18**
Compensation mechanism	**Gravity or pumped depending on pit water level**		
Hands off Level	**TWL-12m (208.5mAOD)**	**TWL-12m (208.5mAOD)**	**Recovering to TWL (220.50 mAOD)**

Years TWL NOT achieved by end October	**Level (mAOD) achieved by 1st November (in year)**	**Date to TWL achieved (Date**
1976	**218.36**	**15/03/1977**
1984	**218.40**	**06/12/1984**
1989	**218.30**	**08/02/1990**
1992	**218.43**	**02/12/1992**
1997	**217.90**	**30/12/1997**
2006	**218.63**	**15/02/2007**
2011	**218.14**	**02/07/2012**

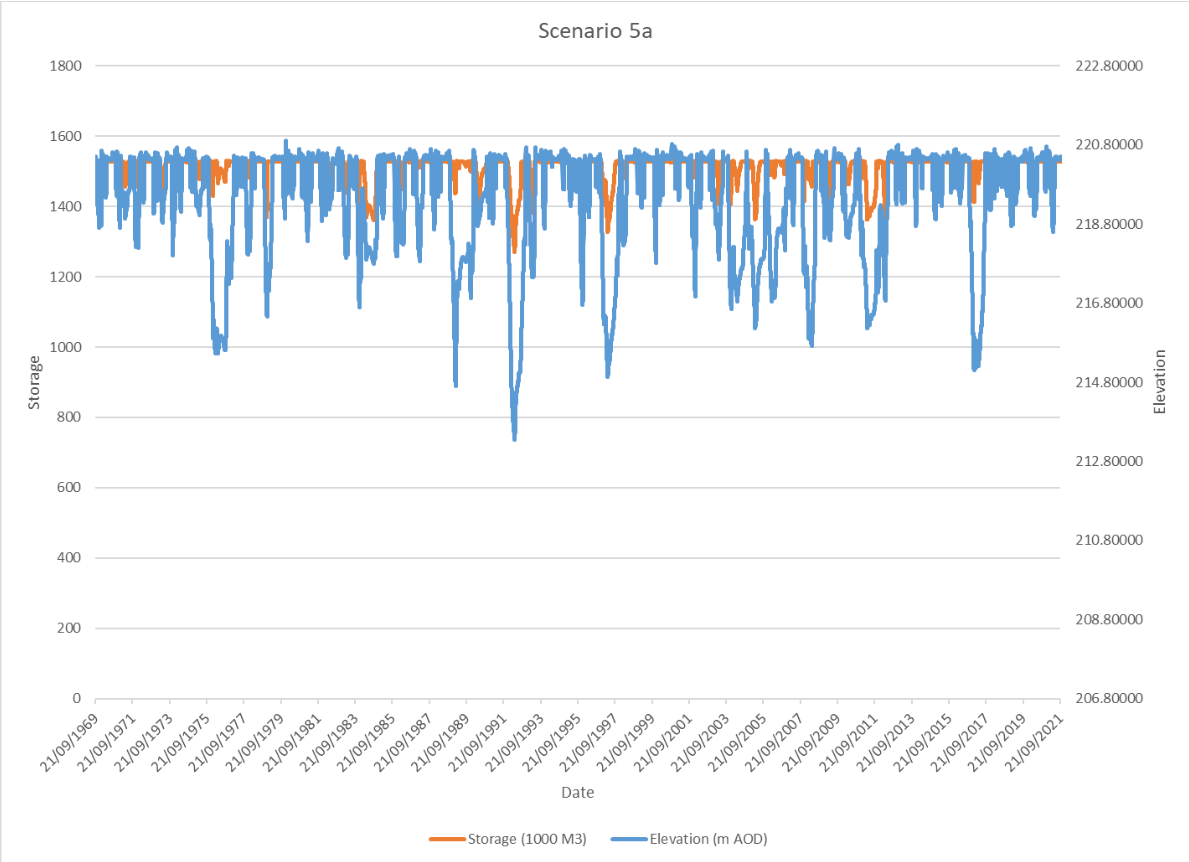

Figure 4.16 - Scenario 5a model output.

Table 4.13 - Scenario 5b Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 5b	**Assumes fish CAN'T migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.**	
	Period	
	Nov – Apr incl.	**May – Oct incl.**
Abstract Rate (Ml/d)	**4**	**0**
Compensation Rate (l/s)	**32**	**18**
Compensation mechanism	**Gravity or pumped depending on pit water level**	
Hands off Level	**TWL-12m** **(208.5mAOD)**	**Recovering to TWL** **(220.50 mAOD)**
Years TWL NOT achieved by end October	**Level (mAOD) achieved by 1st November (in year)**	**Date to TWL achieved**
1984	**218.822**	**22/11/1984**

Stantec

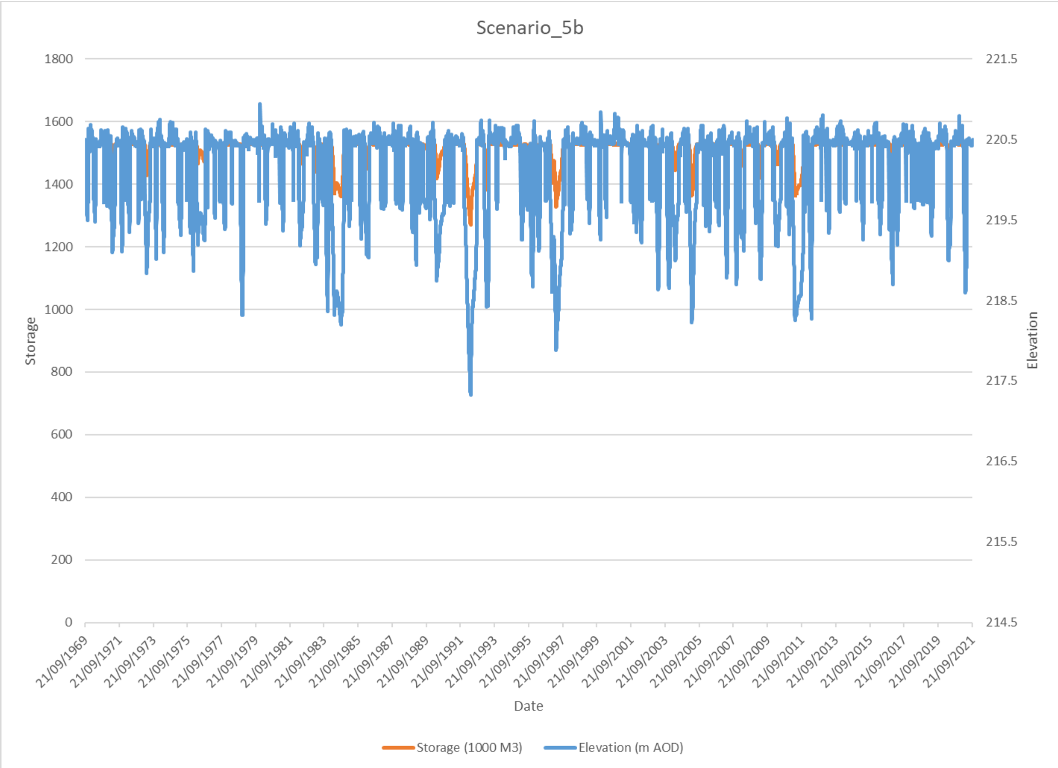

Figure 4.17 - Scenario 5b model output.

Table 4.14 - Scenario 5c Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 5c	**Assumes fish CAN'T migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.**		
	Period		
	Nov – Feb ncl.	**Mar-Apr incl.**	**May – Oct incl.**
Abstract Rate (Ml/d)	**4**	**2**	**0**
Compensation Rate (l/s)	**32**		**18**
Compensation mechanism	**Gravity or pumped depending on pit water level**		
Hands off Level	**TWL-12m (208.5mAOD)**		**Recovering to TWL (220.50 mAOD)**
Years TWL NOT achieved by end October		**Level (mAOD) achieved by 1st November**	**Date to TWL achieved**
Pit recovered in year for all years to TWL by 1st November			

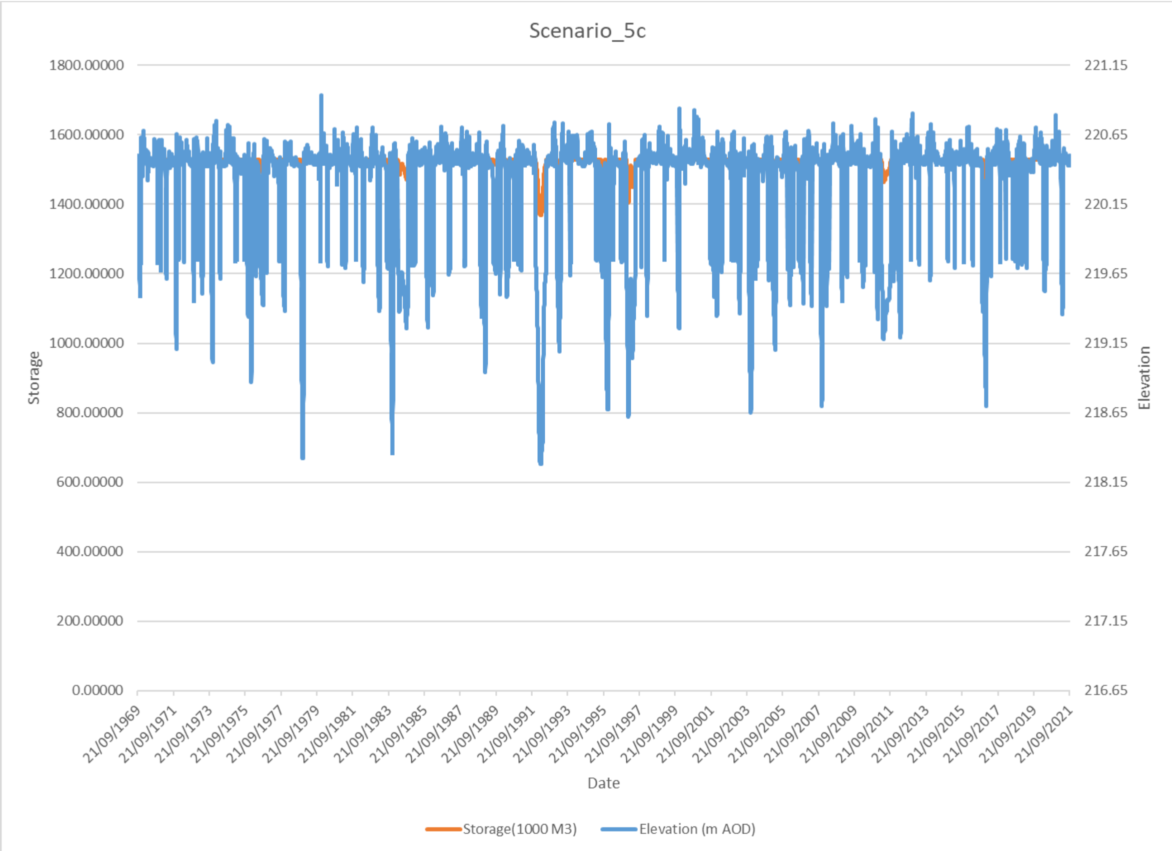

Figure 4.18 - Scenario 5c model output.

Table 4.15 - Scenario 6 Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 6 **(as per Scenario 2, with Trengoffe GS derived timeseries inflow data)**	Assumes fish CAN'T migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January. As per Scenario 3 but using Trengoffe GS		
	Period		
	Nov-April incl.		**May – Oct incl.**
Abstract Rate (Ml/d)	8		0
Compensation Rate (l/s)	32		18
Compensation mechanism	Gravity or pumped depending on pit water level		
Hands off Level	TWL-12m (208.5mAOD)		Recovering to TWL (220.50 mAOD)
Years TWL NOT achieved by end October	**Level (mAOD) achieved by 1st November (in year)**	**Date of Recovery to TWL** (recovery date in following year)	**No. of Days to Recovery** [1]

Stantec

1969 [2]	219.73	19/01/1970	263
1971	218.55	19/06/1972	415
1973	219.59	09/01/1974	253
1975	218.57	Did not recover in Year	N/A
1976	214.63	Did not recover in Year	N/A
1977	215.74	Did not recover in Year	N/A
1978	218.63	Did not recover in Year (24/10/1979)	N/A
1983	218.99	Did not recover in Year	N/A
1984	215.17	Did not recover in Year (08/09/1985)	N/A
1988	219.75	Did not recover in Year	N/A
1989	215.89	Did not recover in Year (21/02/1990)	N/A
1992	216.04	21/12/1992	234
1995	218.46	Did not recover in Year	N/A
1996	218.69	Did not recover in Year	N/A
1997	219.09	Did not recover in Year (07/09/1998)	N/A
1999	219.75	22/12/1999	235
2001	219.75	26/02/2002	301
2003	218.72	Did not recover in Year	N/A
2004	218.23	Did not recover in Year	N/A
2005	215.62	Did not recover in Year	N/A
2006	214.45	Did not recover in Year (18/08/2007)	N/A
2010	219.13	20/11/2010	203
2011	215.72	Did not recover in Year (26/08/2012)	N/A
2016	219.69	Did not recover in Year (10/10/2017)	N/A
2021	(no 2022 data to forecast on)	Did not recover in Year (no 2022 data to forecast on)	N/A

NB1: Total no. of days between 01/05 and 31/10 = 184.

NB2: Timeseries flow data starts in September.

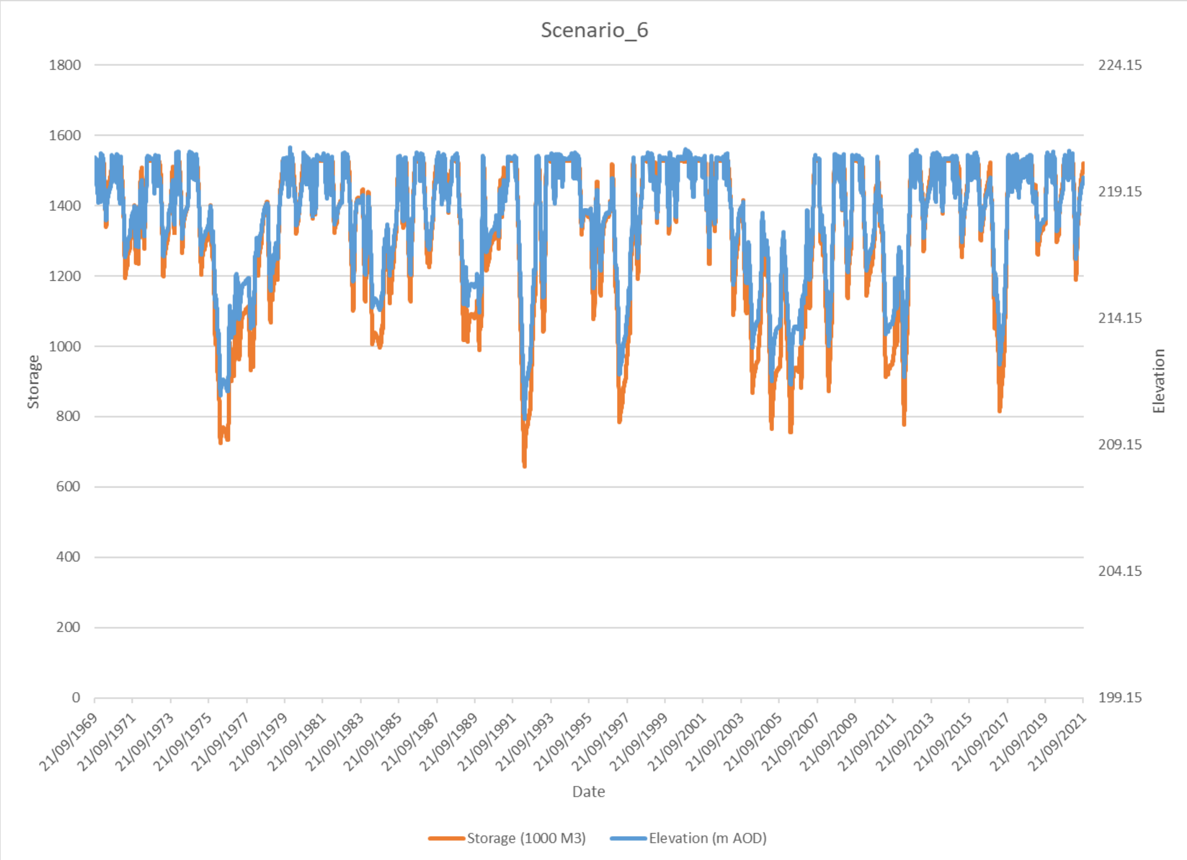

Figure 4.19 - Scenario 6 model output.

Table 4.16 - : Revised Scenario 5b Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 5b	Assumes fish CAN'T migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.	
	Period	
	12 Dec – Apr incl.	May – 11 Dec incl.
Abstract Rate (Ml/d)	4	0
Compensation Rate (l/s)	32	18
Compensation mechanism	Gravity or pumped depending on pit water level	
Hands off Level	TWL-12m (208.5m AOD)	Recovering to TWL (220.50m AOD)
Years TWL NOT achieved by end October	Level (m AOD) achieved by 1st November (in year)	Date to TWL achieved
1984	218.8464	14/11/1984

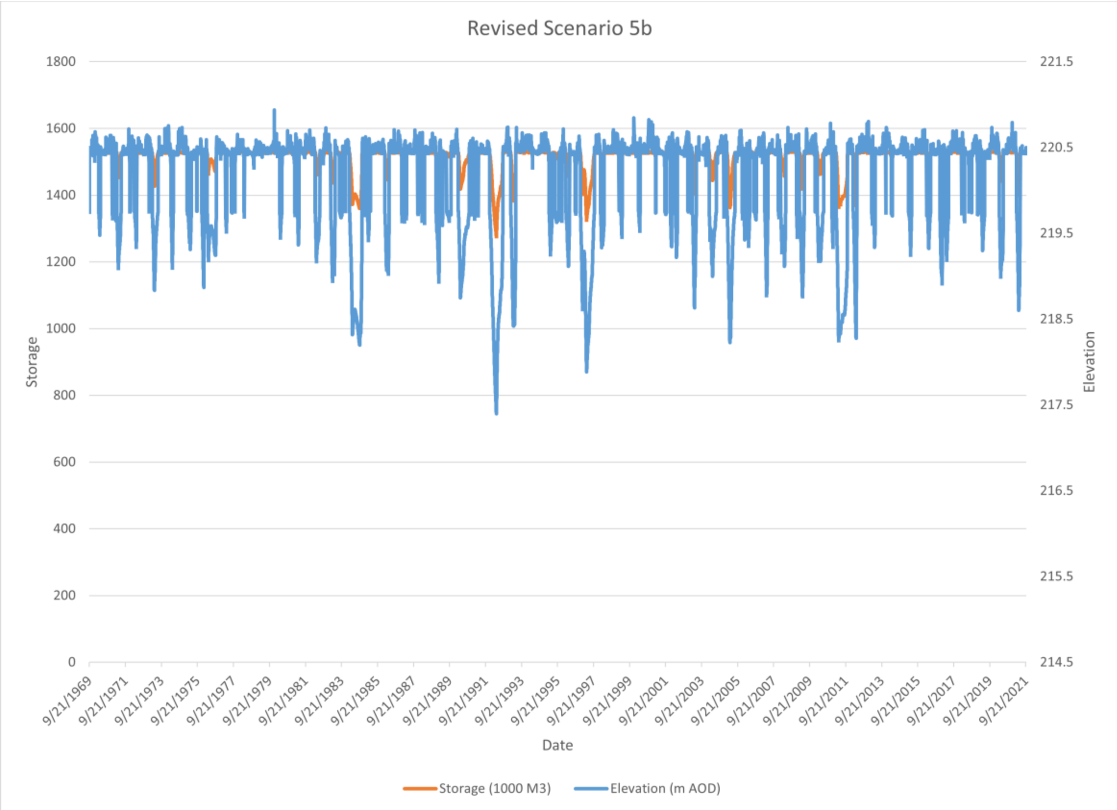

Figure 4.20 - Revised Scenario 5b model output.

Table 4.17 - Revised Scenario 5c Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 5c	Assumes fish CAN'T migrate through Hawk's Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.		
	Period		
	12 Dec – Feb incl.	Mar-Apr incl.	May – 11 Dec incl.
Abstract Rate (Ml/d)	4	2	0
Compensation Rate (l/s)	32		18
Compensation mechanism	Gravity or pumped depending on pit water level		
Hands off Level	TWL-12m (208.5m AOD)		Recovering to TWL (220.50m AOD)
Years TWL NOT achieved by end October		Level (m AOD) achieved by 1st November	Date to TWL achieved
Pit recovered in year for all years to TWL by 1st November			

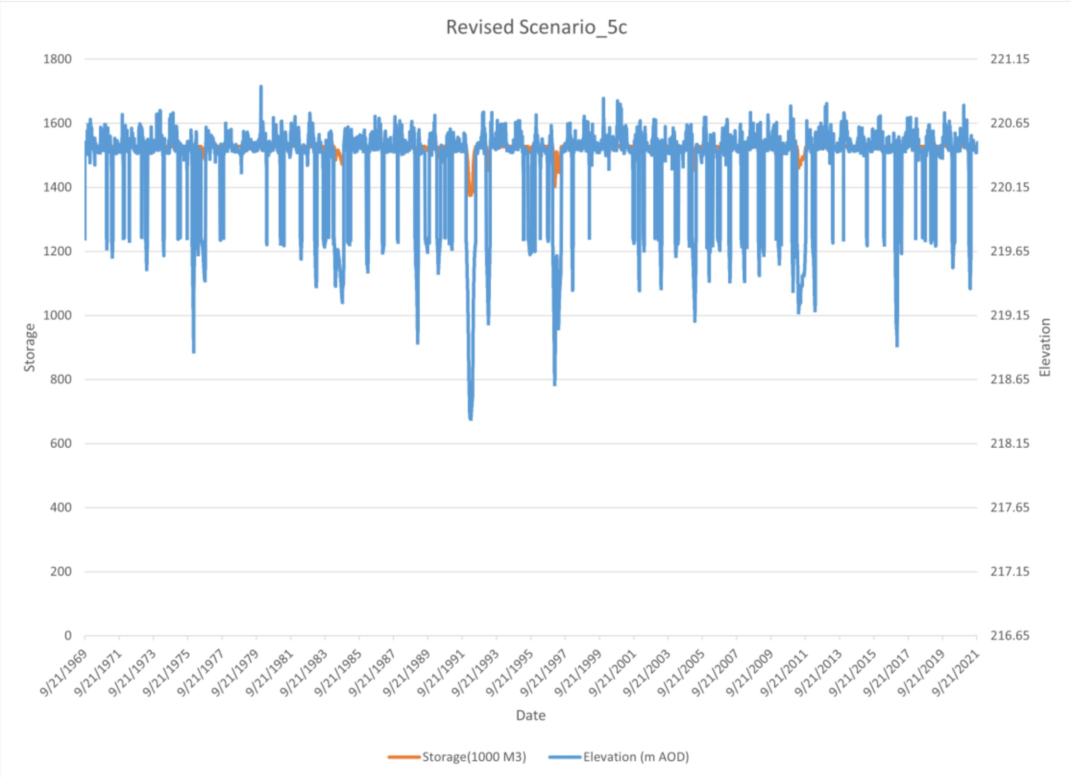

Figure 4.21 - Revised Scenario 5c model output.

Table 4.18: Scenario 7 Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 7	**Assumes fish CAN'T migrate through Hawks Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.**	
	Period	
	12 Dec – Apr incl.	**May – 11 Dec incl.**
Abstract Rate (Ml/d)	**4.78**	**0**
Compensation Rate (l/s)	**32**	**18**
Compensation mechanism	**Gravity or pumped depending on pit water level**	
Hands off Level	**TWL-12m (208.5m AOD)**	**Recovering to TWL (220.50m AOD)**
Years TWL NOT achieved by end October	**Level (m AOD) achieved by 1st November (in year)**	**Date to TWL achieved**
1984	**218.36752**	**18/11/1984**
1995	**219.68945**	**18/11/1995**
2011	**219.73813**	**02/11/2011**

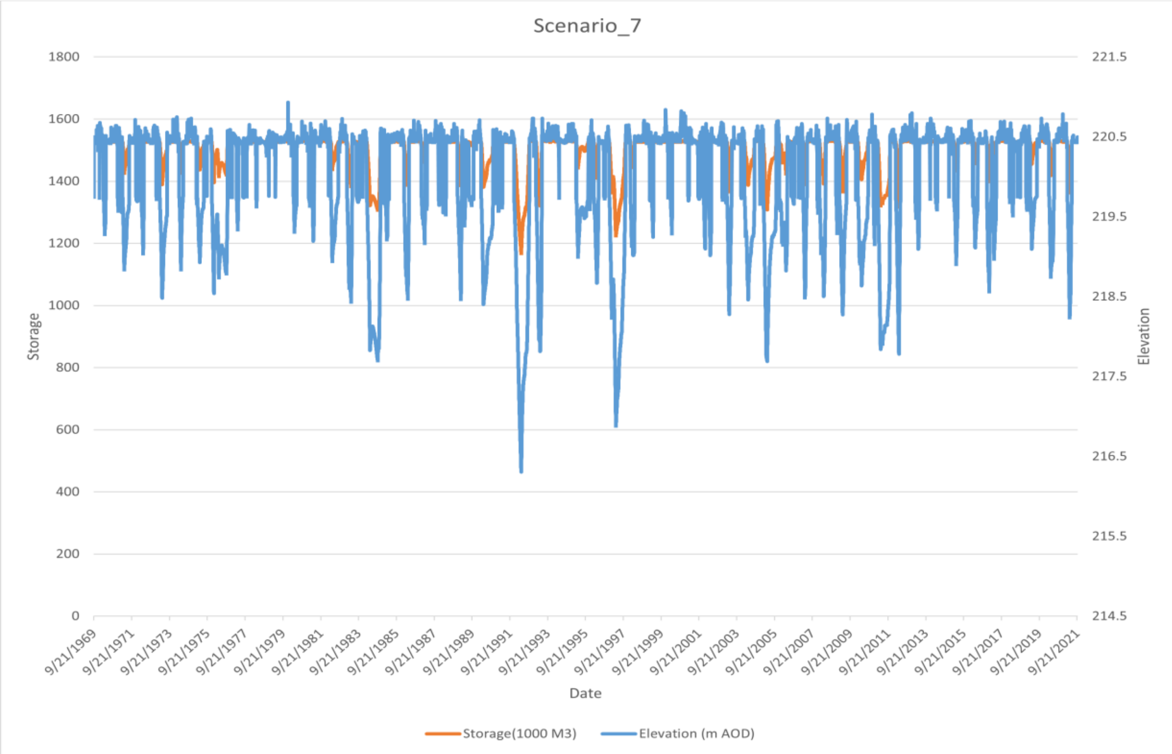

Figure 4.23: Scenario 7 model output.

Table 4.19: Scenario 8 Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 8	**Assumes fish CAN'T migrate through Hawks Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.**	
	Period	
	12 Dec – Apr incl.	**May – 11 Dec incl.**
Abstract Rate (Ml/d)	**6**	**0**
Compensation Rate (l/s)	**32**	**18**
Compensation mechanism	**Gravity or pumped depending on pit water level**	
Hands off Level	**TWL-12m** **(208.5m AOD)**	**Recovering to TWL** **(220.50m AOD)**
Years TWL NOT achieved by end October	**Level (m AOD) achieved by 1st November (in year)**	**Date to TWL achieved**
1984	**217.57361**	**23/11/1984**
1990	**219.22736**	**09/11/1990**

1992	**219.39878**	**07/11/1992**
1995	**219.31414**	**30/11/1995**
1997	**218.21196**	**20/11/1997**
2006	**219.53199**	**12/11/2006**
2011	**218.70076**	**19/11/2011**

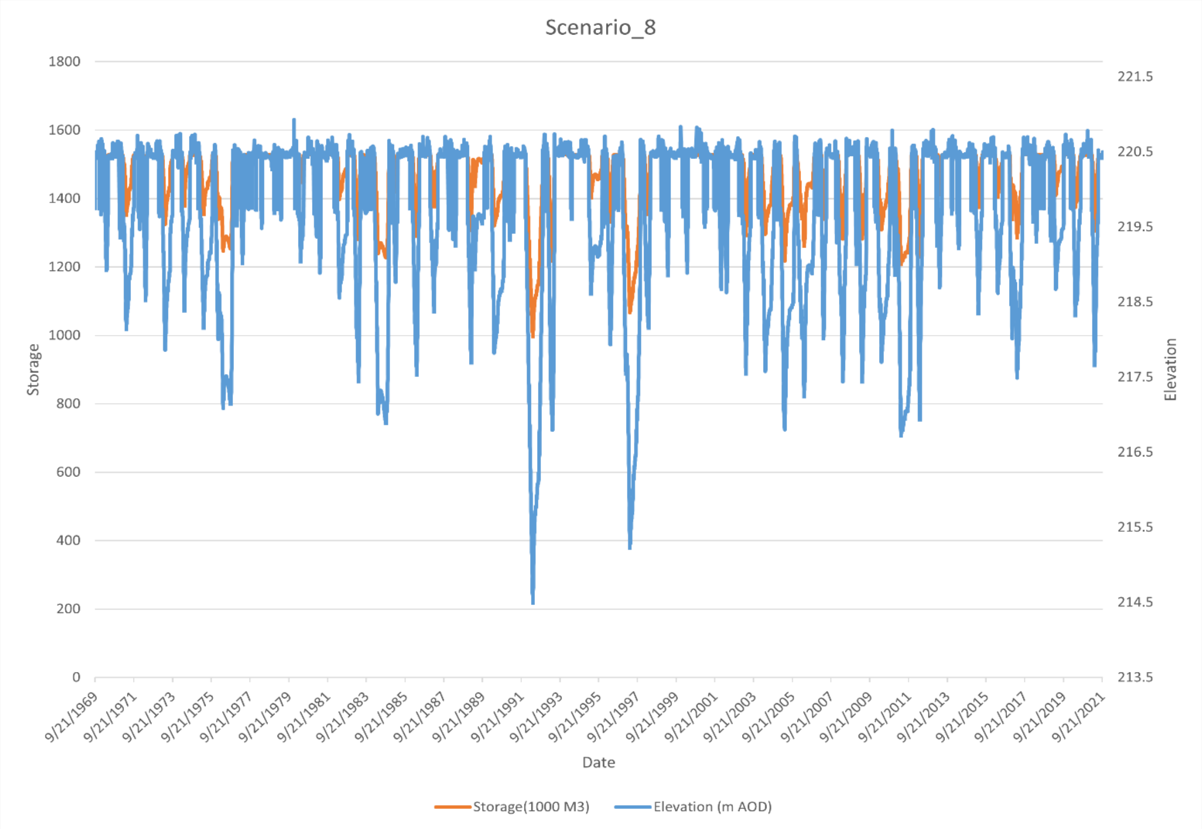

Figure 4.24: Scenario 8 model output.

Table 4.20: Scenario 9 Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 9	**Assumes fish CAN'T migrate through Hawks Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.**		
	Period		
	01 Oct-11 Dec incl.	**12 Dec-Apr incl.**	**May – Sep incl.**
Abstract Rate (Ml/d)	**0**	**4**	**0**
Compensation Rate (l/s)	**32**	**32**	**18**

Compensation mechanism	Gravity or pumped depending on pit water level	
Hands off Level	TWL-12m (208.5m AOD)	Recovering to TWL (220.50m AOD)
Years TWL NOT achieved by end October	**Level (m AOD) achieved by 1st November**	**Date to TWL achieved**
1984	218.48548	19/11/1984
1990	220.35101	2/11/1990

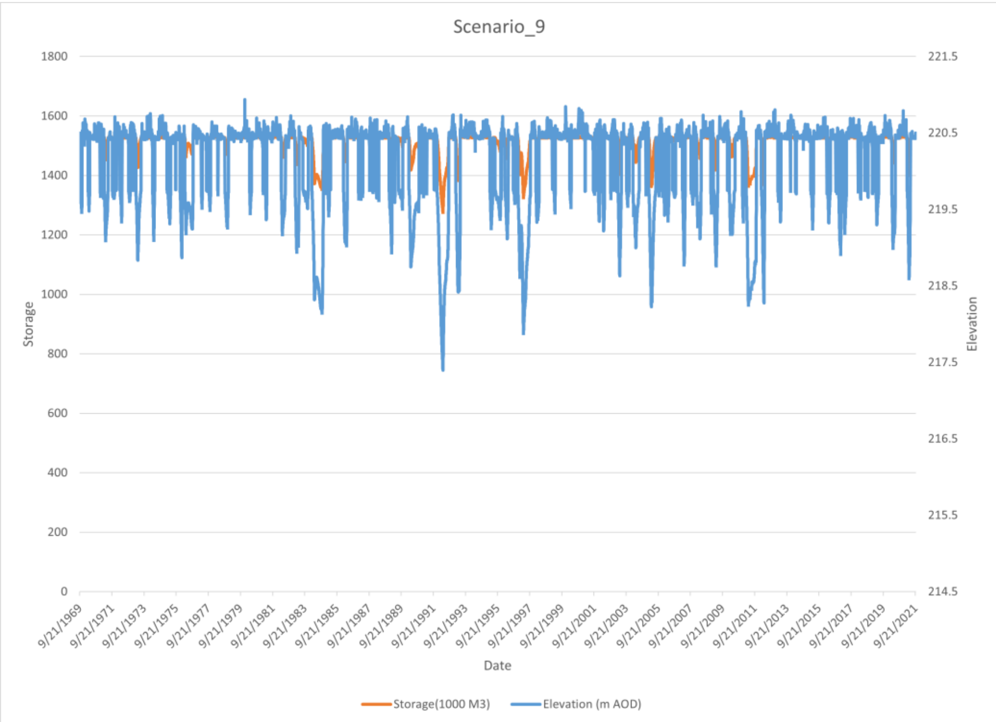

Figure 4.25: Scenario 9 model output.

Table 4.21: Scenario 10 Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 10	**Assumes fish CAN'T migrate through Hawks Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.**		
	Period		
	01 Oct-11 Dec incl.	**12 Dec-Apr incl.**	**May – Sept incl.**

Abstract Rate (Ml/d)	0	4.78	0
Compensation Rate (l/s)	32	32	18
Compensation mechanism	Gravity or pumped depending on pit water level		
Hands off Level	TWL-12m (208.5m AOD)		Recovering to TWL (220.50m AOD)

Years TWL NOT achieved by end October	Level (m AOD) achieved by 1st November	Date to TWL achieved
1984	218.00112	22/11/1984
1990	219.42945	06/11/1990
1995	219.33784	08/12/1995
1997	219.35573	10/11/1997
2011	219.38659	09/11/2011

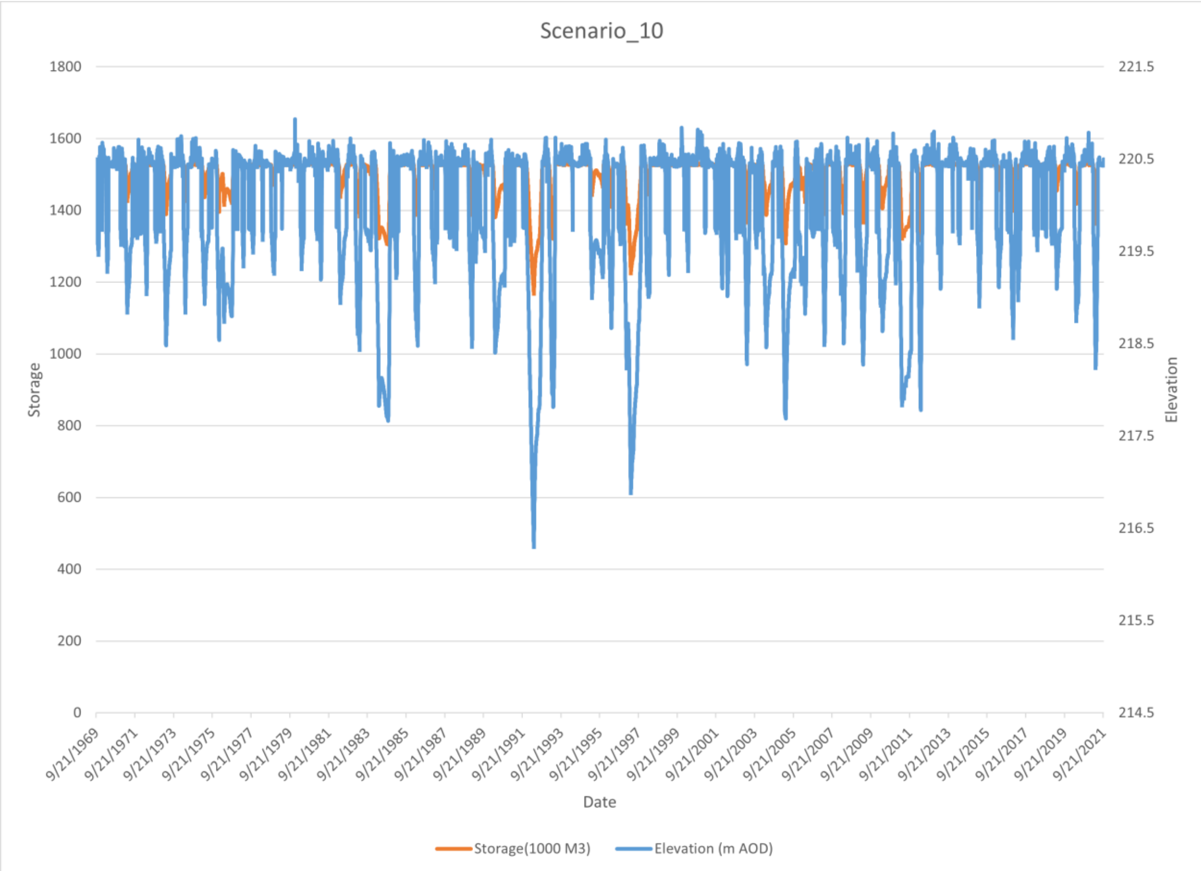

Figure 4.26: Scenario 10 model output.

Table 4.22: Scenario 11 Model Output Summary (Trengoffe GS derived timeseries inflow data).

Scenario 11	Assumes fish CAN'T migrate through Hawks Tor Pit into the upper Warleggan River during Nov-Jan incl. so TWL does NOT need to be maintained between November & January.		
	Period		
	01 Oct-11 Dec incl.	12 Dec-Apr incl.	May – Sept incl.
Abstract Rate (Ml/d)	0	6	0
Compensation Rate (l/s)	32	32	18
Compensation mechanism	Gravity or pumped depending on pit water level		
Hands off Level	TWL-12m (208.5m AOD)		Recovering to TWL (220.50m AOD)
Years TWL NOT achieved by end October	Level (m AOD) achieved by 1st November		Date to TWL achieved
1975	219.67769		07/11/1975
1976	219.46859		08/11/1976
1984	217.19786		27/11/1984
1989	219.68898		04/11/1989
1990	218.87052		17/11/1990
1992	219.04305		13/11/1992
1995	218.95811		08/01/1996
1997	217.84379		23/11/1997
2005	219.68293		02/11/2005
2006	219.17922		23/11/2006
2011	218.3386		04/12/2011

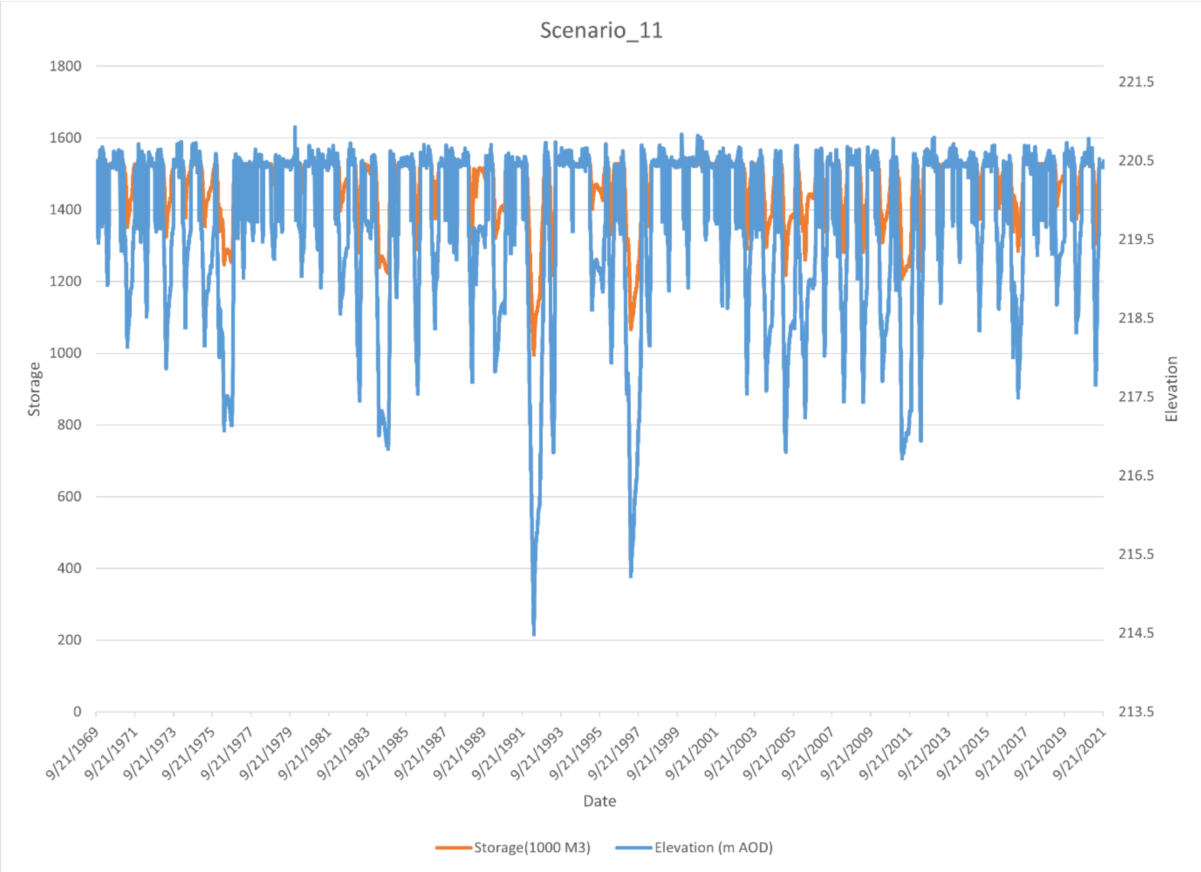

Figure 4.27: Scenario 11 model output.

4.1.5 Impacts on Lake Water Level

All scenarios considered in the HEC-HMS modelling involve abstracting water from the Hawk's Tor Pit, for use as potable supply/reservoir recharge. SWW last abstracted water from the pit during the Drought Order episodes of 1995-6; the 'baseline' water level regime of the lake after this period (and especially after 2009/10, when 100% of the Warleggan River inflows naturally diverted into the pit) has, therefore, not been affected by abstraction. As such, all of the abstraction scenarios considered here will have a **High** magnitude of impact on the water level regime of the lake, when compared with its 'baseline' water level regime; the impacts of Scenarios 2 and 6 would be particularly notable.

4.1.6 Impacts on Flows on the Warleggan River

All of the abstraction scenarios considered here would have a **High** magnitude of impact on the flow regime of the Warleggan River downstream of its confluence with the lake outflow channel.

4.1.7 Downstream Flow Accretion on the Warleggan River

In order to better understand the potential impacts of the proposed abstraction (without mitigation measures) on the Warleggan River, a flow accretion assessment has been undertaken, using the QUBE software. Table 4.1.7 below shows the results of this assessment and quantifies how the proportion of the Hawk's Tor catchment to overall flow on the Warleggan River changes with distance downstream from the pit.

Table 4.1.7. Flow Accretion Profile on the Warleggan River downstream of Hawk's Tor Pit (QUBE Estimates).

Flow Percentile	**Hawks Tor Catchment** *Area* 2.52km^2 *Eastings* 214994 *Northings* 74439	**D/S Blacktor Downs trib** *Area* 5.83km^2 *Eastings* 215000 *Northings* 73550	**D/S Greenbarrow Downs trib** *Area* 9.98km^2 *Eastings* 214450 *Northings* 72350	**D/S Warleggan Downs trib** *Area* 13.3km^2 *Eastings* 214900 *Northings* 70100	**D/S Lantewey trib** *Area* 22.3km^2 *Eastings* 215800 *Northings* 68150	**U/S Fowey conf** *Area* 28.9km^2 *Eastings* 215400 *Northings* 65450
Flow in m^3/s (annual)						
Q5	0.337	0.754	1.218	1.370	2.097	2.752
Q25	0.109	0.245	0.399	0.552	0.907	1.226
Q50	0.049	0.112	0.182	0.285	0.480	0.684

Q75	0.025	0.057	0.093	0.156	0.260	0.397
Q95	0.011	0.026	0.042	0.078	0.131	0.221
Hawks Tor Catchment Flow as a % (annual)						
Q5	100%	45%	28%	25%	16%	12%
Q25	100%	44%	27%	20%	12%	9%
Q50	100%	44%	27%	17%	10%	7%
Q75	100%	44%	27%	16%	10%	6%
Q95	100%	44%	26%	14%	8%	5%

The Hawks Tor catchment contributes 44-45% of low to normal flows on the Warleggan River at the confluence with the Blacktor Downs tributary just downstream of the A30. Its contribution to low to normal flows on the Warleggan River reduces further downstream beyond this point to the extent that at the confluence with the River Fowey, its contribution is relatively minor (5% at Q95 flows). As such, any changes in flow associated with the drought abstraction are most likely to only have a noticeable impact (without mitigation measures) on the reach between the Hawks Tor Pit outfall channel and on a short reach of the Warleggan River downstream of the A30, prior to receiving flows from the Blacktor Downs tributary.

4.1.8 Impacts on Lake Hydromorphology

The impact of lake level draw down due to the Drought Permit on the sand/gravel/granite strata that comprise the surrounding morphology of the pit is deemed **Low** and discussed in section 5.7.

4.1.9 Impacts on Peat and Riparian Lake Communities

The magnitude of impact of lake level draw down due to the Drought Permit on the peat deposits and riparian lake ecological communities is expected to be ***Negligible,*** with the exception of in two isolated locations, these are discussed in Section 5.

4.1.10 Summary

Table 4.23 Summary of predicted impacts on hydrology

Pathway	Magnitude of impact	Confidence level
Lake Water Level	High	Medium
Flows on the Warleggan River	High	Medium
Lake Hydromorphology	Low	Medium

4.2 Water Quality

This section assesses the potential effects of the proposed Drought Permit on water quality within the zone of influence of the Drought Permit. Assessment of the water quality of Hawk's Tor Pit was undertaken and reported separately by SWW (a breakdown is presented in Appendix B).

4.2.1 Potential routes of impact

The Drought Permit has the potential to reduce the quantity of water in the Warleggan River downstream of the proposed abstraction, which could in turn affect water quality in the river downstream via reduced dilution of point source and diffuse inputs as well as increasing water temperature and reducing dissolved oxygen.

4.2.2 Sources of information and methods

The Warleggan River (GB108048007630) discharges into the Lower River Fowey water body (GB108048001420). Environment Agency water quality data is available for the Warleggan River and were downloaded via the Defra Data Services Platform. Data was downloaded for the period 2015 to present and includes a wide range of determinants. A total of four sample locations are present on the Warleggan River though two sites only contain data for 2022 (Table 4.24Table 4.24).

Table 4.24 EA water quality monitoring locations

Site name	NGR	Data Period
Panters Bridge	SX 15900 68020	2015 - 2022
Temple	SX 14588 73133	2015 - 2022
Trengoffe	SX SX 15940 67380	2022
Crift	SX 14786 68936	2022

4.2.3 Hawk's Tor Pit Baseline

The results of South West Water's analysis are presented in Appendix B: Breakdown of Hawk's Tor Pit Water Quality Analysis. The key finding of this analysis is that the quality of water is typical of that generally found in surface waters in the South West, as well as being very similar to that currently found in the various supplies presented for treatment at the proposed works location.

4.2.4 Warleggan River Baseline

Characterisation of the recent baseline condition for the Warleggan River: WFD physico-chemical elements: dissolved oxygen, total ammonia, soluble reactive phosphorus (SRP), water temperature, and pH. Though not included in WFD classification EQS's exist for nitrate, biochemical oxygen demand (BOD), un-ionised ammonia, and suspended solids these are also presented as an indication of general water quality.

Observations in time series are compared against the relevant WFD Environmental Quality Standards (EQS) for each location (Figure 4.22Figure). To apply EQS under the WFD it is necessary to assign a river type and water hardness (as alkalinity measured by $CaCO_3$ mg/l) to the watercourses (this is known as typology).

Table 4.25 Alkalinity to pH 4.5 as CaCO3 (annual average, mg/l) at monitoring stations on the Warleggan. The number of observations in each year is denoted (n).

Year	Panters Bridge (n)	Temple (n)
2015	10 (4)	5.5 (2)
2016	9.75 (4)	-
2017	9.5 (2)	-
2018	10.1 (10)	-
2019	8.33 (12)	-
2020	7.66 (3)	-
2021	11.16 (12)	-
2022	7.9 (10)	-

Alkalinity at Panters bridge is most often below 10 mg/l CaCO3, which makes the Warleggan River Type 1 for the purposes of BOD, DO, and total ammonia EQS's. Altitude at Panters Bridge is ~80m which is the demarcation between river types should alkalinity be higher. However, as salmon are present in the reach, thresholds are as follows:

Table 4.26 - WFD thresholds for water quality element status calculation

Status	Dissolved Oxygen (% saturation)	Total Ammonia (mg/l)	Phosphorus (ug/l)	Temperature (°C as an annual 98-percen-tile standard)	pH
Percentile	10	90	-	98	()

High	80	0.2	10.64	20	6 – 9 (5 and 95)
Good	75	0.3	23.92	23	6 – 9 (5 and 95)
Moderate	64	0.75	71.88	28	4.7 (10)
Poor	50	1.1	171.68	30	4.2 (10)

WFD water quality classifications for physico-chemical elements are consistently recorded as "high" in this reach. A poor status for dissolved oxygen in 2015 and good status for phosphate in 2015-16 are the only exception. These physico-chemical elements are shown in Figure 4.28. However, the chemical status of the Warleggan River is failing due to the role of priority hazardous substances in the reach such as cadmium and its compounds, an issue since 2015, mercury and its compounds, and polybrominated diphenyl ethers (PBDE). These are not necessarily flow related pressures.

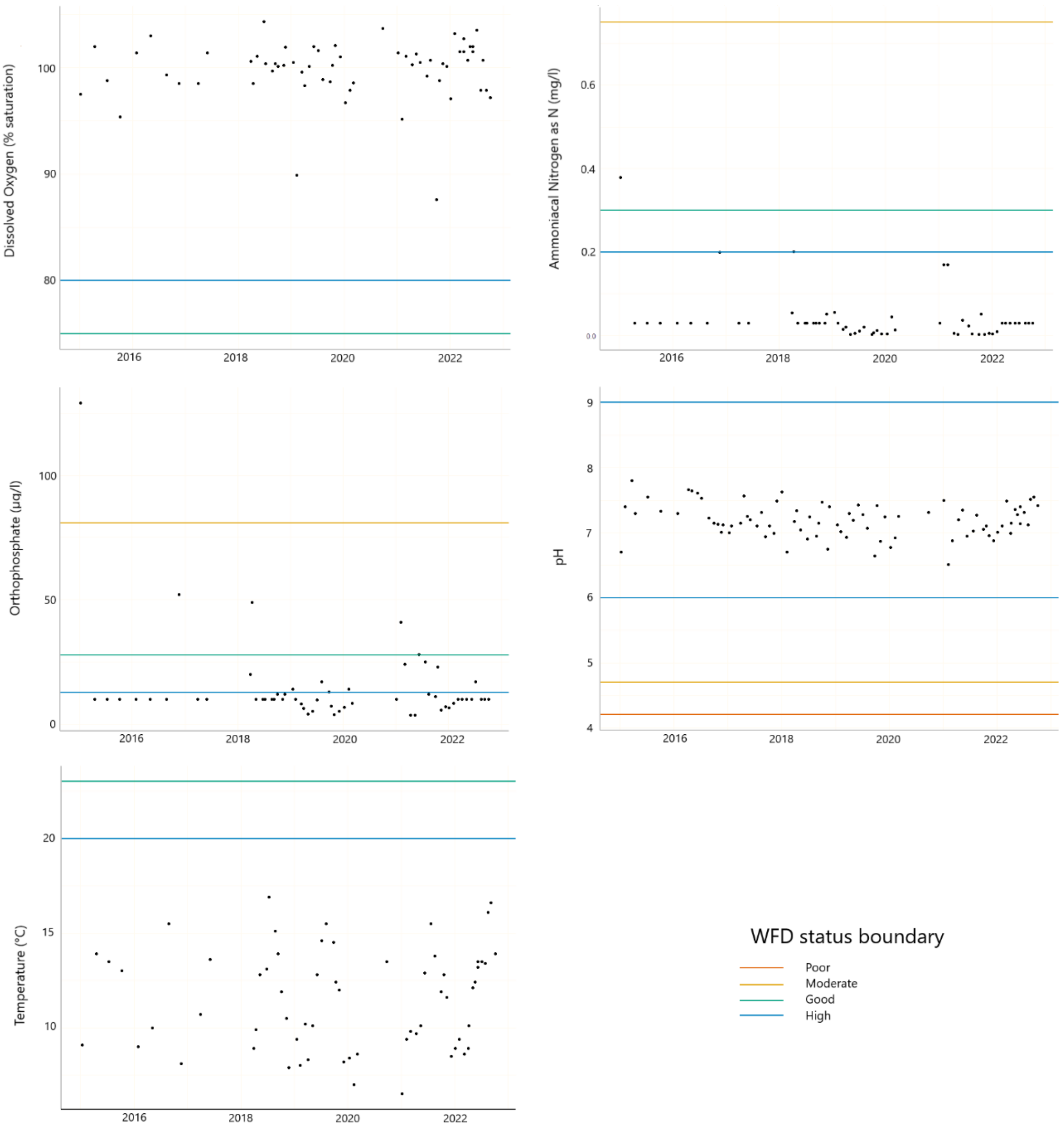

Figure 4.28 Water Quality and Water Framework Directive status boundaries for the EA monitoring station at Panters Bridge.

Dissolved oxygen has been recorded as below 90% saturation only twice in the last six years, a further 10% reduction would be required to result in a lower WFD status of “good”.

Temperature, pH, and total ammonia are consistently above the threshold for a classification of “high”. Phosphorus has been recorded at levels that equate to moderate status on occasion; there is no clear seasonal signal due to the level of detection for much of the record. It is therefore possible that a reduction in dilution could impact the WFD status for phosphorus, depending on the nature, location and periodicity of potential sources .

4.2.5 Impact assessment

A pathway for negatively impacting water quality in the Warleggan is via a reduction in dilution of nutrients resulting from reduced flow volumes. Several hydrological scenarios were considered in section 4.1, all with a **High** magnitude of impact on the flow regime of the Warleggan River downstream of Hawk's Tor Pit.

Another potential risk is that water level draw-down and reduced circulation could cause eutrophication/algal blooms within the lake during summer months.

The monitoring results demonstrate that water quality is consistently of high quality in the Warleggan River, resulting in this water body having good and high WFD status.

Based on the duration of the Drought Permit, resulting in artificial changes in flow for a period less than 12 months, and given that Hawk's Tor Pit water quality is typical of that found in other waterbodies used by SWW for supply, the magnitude of impact of this pathway is predicted to be **Medium.** The water body has a reasonable temporal but not spatial coverage of data, which is presumed to be accurate and reliable. On this basis a **Medium** confidence level is assigned, summarised in Table 4.27 Table 4.27.

Table 4.27 Summary of predicted impacts on water quality

Pathway	Magnitude of impact	Confidence level
Water quality	Medium	Medium

5. Impact Assessment: Receptors

5.1 Water Framework Directive Status

5.1.1 Water Framework Directive Status

The Warleggan River (GB108048007630) is a tributary within the catchment of the Upper River Fowey. Stream flow will include any outflow from the overflow of Hawk's Tor Pit and any surface run-off draining into the leat system which circumvents Hawk's Tor Pit.

Historically, the Warleggan River also included discharges from Hawk's Tor Pit when it was previously a China Clay Works site whilst the river was diverted around Hawk's Tor Pit in the perched leat. SWW surveys in 2022 revealed the leat has been naturally diverted (during the winter 2009/10) into the pit itself, which means the river now flows from its source through Hawk's Tor Pit, which needs to be considered in future monitoring.

The most recent Water Framework Directive (WFD) classification data for the Warleggan River waterbody is the 2019 cycle 3 data. The waterbody is classed at Moderate ecological status. A comparison of cycle 2 and cycle 3 data is provided in Table 5.1 that shows a decline in fish quality elements since 2015. The ecological discontinuity posed by barriers is the reason for the moderate classification attributed to the fish element.

Table 5.1 Biological quality elements 2013-2019

Classification item	2013	2014	2015	2016	2019
Fish	Good	Good	Good	Moderate	Moderate
Invertebrates		High	High	High	High
Macrophytes and Phytobenthos combined		Good	Good	Good	Good

The combined ecological and chemical classifications of the waterbody from Cycle 2 are shown in Table 5.2. There are three specific chemicals listed for failures since 2015 including Cadmium and Its Compounds, Mercury and Its Compounds, and Polybrominated diphenyl ethers (PBDE).

Table 5.2 Combined ecological and chemical classifications 2013-2019

Classification item	2013	2014	2015	2016	2019
Biological quality elements	Good	Good	Good	Moderate	Moderate
Physico-chemical quality elements			Moderate	Good	High

Hydromorphological Supporting Elements	Supports good	Supports good	Supports good	Supports good	Supports good
Specific pollutants	Moderate	Moderate	High	High	High
Chemical	Good	Good	Fail	Fail	Fail

5.1.1.1 Impact assessment

The WFD ecological status of the Warleggan River is currently Moderate, based on 2019 data. The drought permit scenario, without compensation flows, could ultimately impact the fish quality element, which is already not achieving good status due to the impact of barriers (ecological discontinuity) and has the potential for deterioration of other ecological quality elements (macrophytes and macroinvertebrates) presenting a **Medium** sensitivity to the WFD ecological status. Impacts on flow downstream of Hawk's Tor Pit are predicted to be High (Section 4.1.6) for the immediate downstream reach of the river from Hawk's Tor Pit, however this impact will reduce with the contribution of other flow sources further downstream. Additionally, the duration of the drought permit is short term (December to April), resulting in artificial changes in flow for a period less than 12 months. As a result, the impacts on flows for the WFD waterbody are predicted to be **Medium.**

Impacts on water quality pathways are predicted to be **Medium** (Section 0).

On this basis that the sensitivity of the WFD ecological status is predicted to be **Medium** the overall significance of impact is predicted to be **Moderate** with a confidence on this assessment as **Medium**.

The WFD chemical status of the waterbody is Fail (2019), due to two priority hazardous substances. The drought permit will not affect this situation as effects on dilution are predicted to be **Low** (Section 4.1). On this basis the sensitivity of the WFD chemical status to the drought permit is considered **Low**, with significance of impact **Minor.** Confidence in this assessment is **Medium**. Summarised in Table 5.3.

Table 5.3 Summary of predicted impacts on WFD status

Receptor	Sensitivity	Significance of impact	Confidence level
GB108048007630 WFD ecological status	Medium	Moderate	Medium
GB108048007630 WFD chemical status	Not Sensitive	Minor*	High

* Impact predicted to be negligible but categorised as Minor in the absence of a negligible category.

5.2 Designated sites

There are three statutory and four non-statutory designated sites located within the geographical extent of the Drought Permit.

Statutory designated sites

The Hawk's Tor Pit falls partially within the **Hawk's Tor Pit Site of Special Scientific Interest (SSSI)**. This was designated as a geological SSSI in 1993 due to the presence of superficial Late Quaternary and Early Holocene waterlogged deposits, containing well preserved pollen sequences, important in demonstrating and interpreting landscape responses to rapid climate change for the period in upland south-west England[3].

The SSSI is not dependent on water level within the pit as described in section 4.1, as such there is a **Negligible** magnitude of impact, and the receptor is **Not sensitive,** the overall significance of impact is Negligible, but categorised as **Minor** in the absence of a negligible category. Confidence of assessment is **High.** In addition, no equivalent/additional sequences have been recorded within the Hawk's Tor quarry pit that could be directly impacted by dewatering or carving during draw down.

Bodmin Moor North SSSI, located on the northern perimeter of Hawk's Tor Pit. This is designated for its importance as the only upland massif in Cornwall, as well as for the extensive area of semi-natural vegetation, which includes examples of a range of upland plant communities: wet heath, dry grassland, valley bogs, blanket bogs and crags. The area incorporates several catchments; including the Warleggan River and St. Neot River (Colliford Reservoir source) each with a range of wetland communities, supporting rare and local plant species, otters, invertebrates and rare species of bird. The SSSI features are deemed to be outside of the geographical extent of the drought permit, as described in Section 4.2.

However, cited species such as otter may be present in and around Hawk's Tor Pit during the operation of the drought permit. There were no otter holts or resting areas identified during ecological walkovers of Hawk's Tor Pit in November 2022, however spraint was recorded within the riparian areas of the pit which confirmed otter activity within the pit. Whilst otter may be displaced from foraging during the operation of the permit the overall magnitude of impact of Bodmin Moor North SSSI is predicted to be **Low,** the receptor of **Low** sensitivity and the significance of impact on receptor as **Minor**. Confidence of assessment is **Medium.** See also impact on mammals in the vicinity of the Hawk's Tor Pit below.

Cabilla Manor Wood SSSI, located 5km downstream of Hawk's Tor Pit. The Warleggan River bisects the SSSI, which is designated for deciduous woodland and heathland habitat

[3] Hawkstor SSSI. Online. Available at: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1002616 HawkstorHawk's Tor SSSI. Online. Available at: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1002616

communities as well as supporting wet woodland and river habitat. The river and riparian habitat lie within the zone of influence of the drought permit however at its location the flows within the Warleggan River are supported by additional flow contributions which are likely to negate any temporary reduction in flow from Hawk's Tor Pit. The magnitude of impact on the SSSI supported by the flows within the Warleggan River is considered to be **Medium**, the sensitivity of the sites is considered to be **Low** based on the areas of the sites that may be impacted overall, the short term nature of the drought permit and the recovery of the site beyond the permit. The significance of impact on the SSSI receptor is considered to be **Minor**, with **Low** confidence of assessment based on the lack of data on water dependance on the SSSI or listed features and the likely contribution of flow from Hawk Tor Pit at its location.

5.2.1 Non-statutory designated sites

North Bodmin Moor County Wildlife Site (CWS) (NC/CN7/N) is located on the northern perimeter of Hawk's Tor Pit, the site covers several areas on the periphery of Bodmin Moor, North SSSI, forming part of the larger moorland and wetland complex. Bodmin Moor as a whole is the only distinctive upland area within Cornwall and is of particular importance for its extensive areas and range of semi-natural

South West Moor CWS (NC/CN7/S1) forms a large part of South Bodmin Moor and comprises Treslea Downs, Bury Castle, Fore Downs, Cardinham Moor and Temple Tor. Cardinham Moor consists of a gently undulating granite outcrop rising to 268 metres and extends from the valley lying to the south west of Colvannick and St Bellarmin's Tors, across to the Warleggan River valley in the east, which lies circa 2km downstream of Hawk Tor Pit.

On the western side of Blacktor Downs CWS (NC/CN7/S3) an area of wet, acid grassland is dissected by wet flushes which drain westwards into the valley mire near the Warleggan River. The banks of the river are disturbed, with a hummock/hollow system of acid grassland, gorse and bracken scrub. The valley along the eastern edge has waterlogged soils supporting a well-developed wet heath which borders Colquite Lake, a deep man-made pool with abundant floating and emergent vegetation and surrounded by willow. The site is located downstream of the A30 from Hawk's Tor Pit, circa 300m from the pit outflow. Temple bridge, one of Cornwall's Key Odonata (Damselfly and Dragonfly) sites, falls within the boundary of this CWS.

Hardhead Down and Warleggan Down CWS (NC/CN7/S2) is located circa 1.5km downstream of Hawk's Tor Pit. The site is formed around the Warleggan River valley and is important for its fen and swamp habitat as well as areas of acid grassland and lowland heath.

The impact to Bodmin Moor North CWS is comparable to the SSSI assessment above.

The magnitude of impact on County Wildlife Sites supported by the flows within the Warleggan River is considered to be **Medium**, the sensitivity of the sites is considered to be **Low** based on the areas of the sites that may be impacted overall, the short term nature of the drought permit and the recovery of the site beyond the permit. The significance of impact on these receptors is considered to be **Minor**, with **Low** confidence of assessment based on the current lack of data on water dependance of these CWS habitats.

Designated site assessments are summarised in Table 5.4 Table 5.4.

Table 5.4 Summary of predicted impacts on designated sites

Receptor	Sensitivity	Significance of impact	Confidence level
Hawk's Tor Pit SSSI	Low	Minor*	Medium
Bodmin Moor North SSSI	Low	Minor	Medium
Cabilla Manor Wood SSSI	Low	Minor	Low
Bodmin Moor North CWS (NC/CN7/N)	Low	Minor	Medium
South West Moor (NC/CN7/S1)	Low	Minor	Low
Blacktor Downs (NC/CN7/S3)	Low	Minor	Low
Hardhead Down and Warleggan Down (NC/CN7/S2)	Low	Minor	Low

* Impact predicted to be negligible but categorised as Minor in the absence of a negligible category.

5.3 Macrophytes and Diatoms

The Warleggan River has an overall WFD ecological status of moderate, driven by the moderate status achieved for fish, while good ecological status is achieved for macrophytes and phytobenthos element. No macrophyte survey data was available for this reach, so this refers to phytobenthos only.

Table 5.5 Table 5.5 shows the available data for WFD monitoring of diatoms in the Warleggan between 2010-2022.

Table 5.5 Diatom monitoring sampling locations

River	BIOSYS ID	Monitoring location name	NGR	Data period	Data included in assessment
Warleggan	1707		SX 15830 68100	2013-2021	Y
Warleggan	79079		SX 14550 73080	2013-2014	Y

Site 1707 is ca. 8km downstream of Hawk's Tor Pit. Site 79079 is c. 1.5km downstream and was not included in this assessment as data are limited to four samples over two years.

5.3.1 Background

This assessment focusses on potential effects of the proposed licence on phytobenthos communities associated with the Warleggan River (GB108048007630), including consideration of potential effects on WFD status. The standard WFD methodology for the recording and classification of the combined element macrophytes and phytobenthos is targeted specifically at detecting impacts of eutrophication, and not at the detection of possible low flow stress.

5.3.2 Potential pathways of impact

Communities could theoretically be affected by reduced flows leading to:

- Changes to available habitat: increased sedimentation will drive changes in phytobenthos community (motile diatoms)
- Increased concentration of nutrients and residence times
- Transition from epilithic to planktonic communities as flows reduce. [though assemblages will be resilient to single season low flow periods]
- Reduction in wetted width can expose marginal emergent and submerged plants leading to desiccation.
- Reduced depth increasing light penetration potentially increasing the growth rate of filamentous algae, as well as epilithic and epiphytic algae which is an issue for normally deep-water systems.
- Reductions in water velocity can also favour the growth rate of attached algae. The RMHI is indicative of a plant community adapted to high flows and therefore a sustained reduction in discharge could cause a shift in community composition.

5.3.3 Baseline Macrophyte and Phytobenthos

Table 5.6 WFD Water Body Classifications

Target area	Classification year	WB ID	WB Name	Overall	Macrophytes and phytobenthos
Colliford	2019	GB108048007640	St Neot River	Moderate	High
Colliford	2019	GB108048001410	Fowey (Warleggan to St Neot)	Good	-
Hawk's Tor	2019	GB108048007630	Warleggan River	Moderate	Good
Hawk's Tor & Colliford	2019	GB108048001420	Lower River Fowey	Good	Good

The assessment of diatoms (phytobenthos) in rivers according to the requirements of the WFD is completed using a tool called DARLEQ2 (Diatoms for Assessing River and Lake Ecological Quality), based on a metric called the Trophic Diatom Index (TDI). The TDI describes the nutrient preferences of a diatom community. It ranges from 1 (preference for extremely low nutrient levels) to 100 (preference for extremely high nutrient levels). The TDI4 scores were used by the Environment Agency in the assessment of WFD status of the Cycle 2 assessments.

Percentage Motile Taxa data are also provided which gives the relative proportions of phytobenthos taxa within the community that are motile. A high proportion of motile taxa (>50%) can indicate that light availability is influencing the community, which can be brought about by pressures such as siltation and high covers of filamentous algae. The available baseline TDI scores for the sites associated with the Warleggan (Table 5.7) are indicative of low nutrient conditions, while the low percentage motile taxa is indicative of clear, low turbidity waters.

Table 5.7 EA derived Phytobenthos indices (Trophic Diatom; TDI 4). Monitoring locations within the catchment. . Dates highlighted in grey denote TDI5 DNA methodology derived scores

Location	NGR	Date	% Motile	% PTV	Observed	Expected	EQR	WFD Class
Warleggan (79079)	SX 14550 73080	28/03/2013	4.46	0.96	17.15	18.66	0.82	High
		15/10/2013	12.97	1.9	22.55	18.66	0.78	Good
		21/03/2014	4.13	16.81	22.99	18.66	0.76	Good
		15/09/2014	13.5	20.26	26.47	18.66	0.73	Good
Warleggan (10707)	SX 15830 68100	28/03/2013	5.08	13.79	27.56	23.31	0.76	Good
		15/11/2013	3.63	3.93	22.56	23.31	0.81	High
		22/04/2015	6.98	20.95	21.48	23.31	0.82	High
		17/09/2018	9.07	4.78	11.41	23.31	0.92	High
		03/04/2019	3.08	24.02	15.15	23.31	0.89	High
		22/09/2020	30.96	33.7	22.77	23.31	0.81	High
		20/04/2021	2.74	11.22	15.73	23.31	0.88	High
		17/10/2021	11.56	12.67	17.34	23.31	0.86	High

- %PTV give an indication of the reliability of the TDI as an estimate of eutrophication.
- %motile – growth forms can provide insights into factors influencing community composition and assemblage structure. Motile diatoms suggest could indicate a sedimentation pressure, which in turn indicates that light may influence diatom presence absence rather than WQ.
- Ecological Quality Ratio (EQR): A measure of observed vs. predicted reference values which are used to determine ecological status (Table 5.8Table 5.8).

Table 5.8 Trophic Diatom Index (TDI) Ecological Quality Ratio (EQR) boundaries

Ecological status	EQR status boundaries
High/Good status	0.80
Good/Moderate status	0.60

Moderate/Poor status	0.40
Poor/bad status	0.20

Sampling of diatom assemblages has been carried out semi-regularly on the Warleggan River, all records indicate that the phytobenthos communities present are indicative of good to high ecological status. Figure 5.1 shows Trophic Diatom Index (TDI) scores calculated using the updated DARLEQ3 software, compared with expected scores to give an Ecological Quality Ratio (EQR). DARLEQ3 contains an update to taxon scores which may explain the deviation from the ecological status reported on the EAs Catchment Data Explorer (Table 5.9Table 5.9). Samples collected after 2018 were analysed using DNA techniques and score consistently higher than samples analysed traditionally. The difference could be an improvement in water quality reflected in diatom assemblages, though sampling method cannot be discounted as the reason for the apparent improvement. However, the phytobenthos ecological element in the Warleggan has been indicative of good/high status for the best part of a decade.

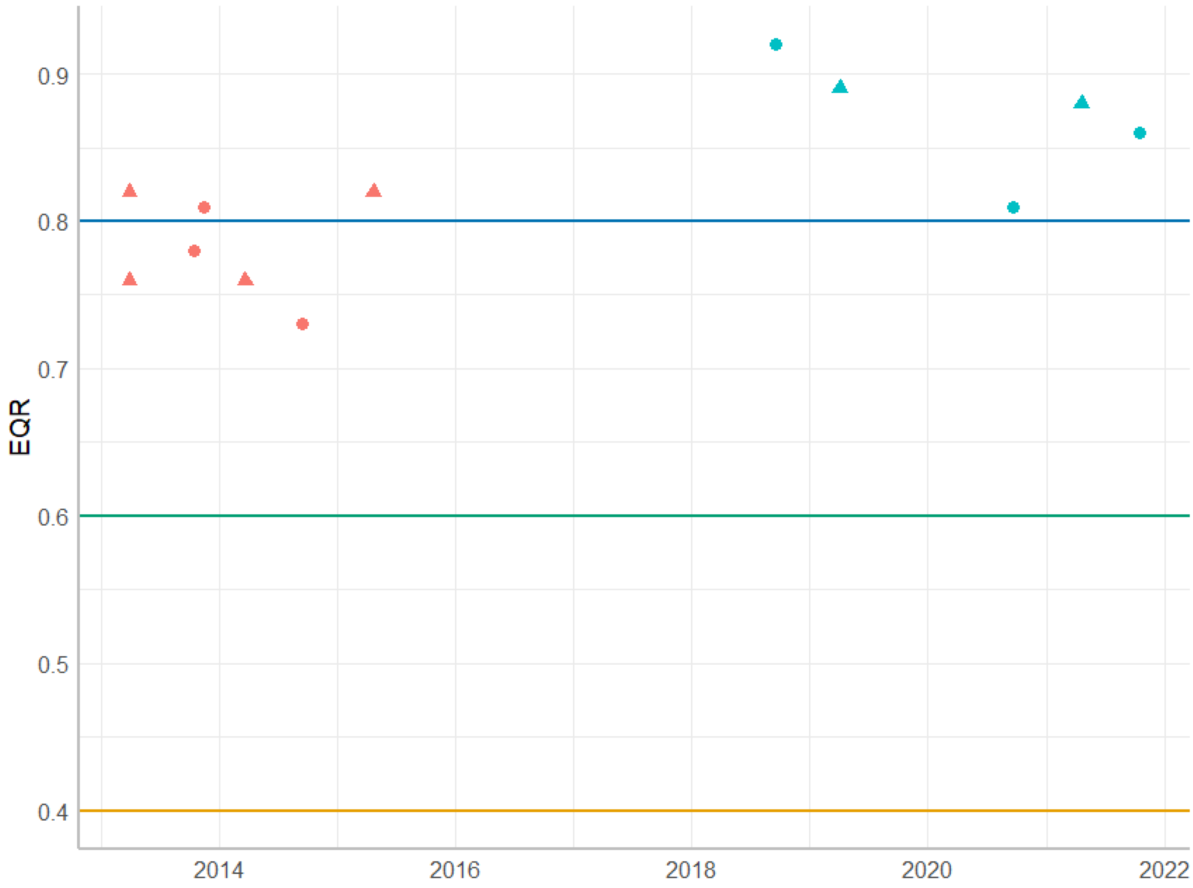

Figure 5.1 Trophic Diatom Index EQR values. Red points TDI4, blue points are derived from next generation DNA sequencing. Triangle = spring, Circle = Autumn. Ecological status boundaries denoted by blue (High/Good), green (Good/Moderate), gold (Moderate/Poor) horizontal lines.

Table 5.9 Historical WFD Classifications for phytobenthos in the Warleggan River as reported on the Environment Agency's Catchment Data Explorer.

WFD Status	2014	2015	2016	2019
	Good	Good	Good	Good

Macrophyte data is absent in the Warleggan River, though monitoring is conducted further downstream on the River Fowey, upstream of Lostwithiel, at Restormel Castle (10714). And, in the downstream neighbouring reach Cardinham Water (10705) at the confluence with the River Fowey. Both sites are considered outside of the zone of influence.

5.3.4 Impact Assessment

The available baseline data show that the diatom community in the associated reaches of the Warleggan River is indicative of clear undisturbed water with low nutrient concentrations (Figure 4.28Figure and Figure 4.29Figure).

Diatoms are sensitive to changes in water quality, though flow regime can impact assemblage structures also. In the case of Hawk's Tor, phytobenthos scores are relatively stable across seasons and years (good/high ecological status). The impact of changes in the flow regime on diatom assemblages is closely tied to that of water quality, reduction in the dilution of nutrients, as such the **sensitivity** is tied to that reported in Section 0.

The lifecycle of diatoms is relatively short, making them ideal proxies for quantifying short term changes in water quality. In headwaters, communities change rapidly to reflect environmental conditions of the preceding weeks, while in lower reaches assemblages can change more slowly, due to the accumulation of multiple stressors, and are considered to reflect the preceding few months. As the Warleggan River is consistently of good ecological status, phytobenthos will likely recover quickly to reflect environmental conditions shortly after the pre abstraction flow regime is resumed. The phytobenthos receptor will have **low sensitivity** to the proposed flow alterations and the significance is considered to be **minor**. Overall confidence in the assessment is **high.**

Confidence in the assessment of macrophytes is **low**, given the lack of data in the Warleggan River. However, the risk posed by reduction in wetted width or the rise of conditions that favour filamentous algae is a concern, so the **sensitivity** has been assessed as **high**. Although, part of the reason for assessing the sensitivity as high is that macrophyte communities change more slowly, and so would the recovery from a major disturbance, especially if the community shifts to one dominated by filamentous algae. Given that the timing and duration of the proposed drought permit interventions, the **significance** of the impact is assessed as **medium** as a conservative estimate.

Table 5.10 Summary of diatom impact assessment

Receptor	Sensitivity	Significance of impact	Confidence level
Phytobenthos	Low	Minor	High
Macrophytes	High	Moderate	Low

5.4 Macroinvertebrates

5.4.1 *Background*

This assessment focusses on potential effects of the proposed licence on macroinvertebrate communities associated with the Warleggan River (GB108048007630) downstream of Hawk's Tor, including consideration of potential effects on WFD status. The impact assessment for this study focuses on the WFD status of macroinvertebrate communities present in the Warleggan River, and the potential for impacts due to implementation of the proposed abstraction licence.

Table 5.11 - WFD macroinvertebrate classification

Target area	Classification year	WB ID	WB Name	Overall	Macroinvertebrates
Hawk's Tor	2019	GB108048007630	Warleggan River	Moderate	High

5.4.2 *Potential pathways of impact*

A reduction in flow from Hawk's Tor to the Warleggan River could impact macroinvertebrate communities by contributing to a loss of wetted habitat and reduced stream velocity, which may in turn lead to an increase in predation pressures and reduction in dilution for water quality elements. Macroinvertebrate communities are considered resilient to single season low flow periods (typically during summer), though can be more sensitive to low flows in groundwater-fed and upland watercourses. Proposed flow reduction is scheduled for the winter months, when macroinvertebrates are not studied, but timings of flow can be important throughout the macroinvertebrate life cycle. However, the reach may experience reduced flows until the following Autumn depending upon the recharge rate of Hawk's Tor.

5.4.3 *Baseline Macroinvertebrate*

Table 5.12 Macroinvertebrate monitoring sampling locations

River	BIOSYS ID	Monitoring location name	NGR	Data period	Data included in assessment
Warleggan	10707		SX 15830 68100	2013-2021	**Y**
Warleggan	**79079**		**SX 14550 73080**	**2013-2014**	**N**

Site 10707 is approximately 8km downstream of Hawk's Tor Pit, whilst site 79079 is circa 1.5km downstream and is the closest representative of location for the drought permit, however this sample site was limited to only four samples over two years.

Macroinvertebrate data is summarised as a suite of biotic indices (Table 5.13Table 5.13), calibrated to detect the biological effects of low flows and water pollution:

- Lotic Invertebrate index for Flow Evaluation (LIFE; Extence *et al.*, 1999) is the average of abundance-weighted flow groups that indicate the preferences of each taxon for higher water velocities and clean gravel/cobble substrata or slow/still water velocities and finer substrata. LIFE is used to index the effect of flow variations on macroinvertebrate communities.
- Whalley Hawkes Paisley Trigg (WHPT) method (UKTAG 2014) is an index of overall biological water quality using macroinvertebrates similar to the BMWP index. WHPT responds to the same environmental pressures as the Biological Monitoring Working Party (BMWP) though, unlike BMWP, it is abundance-sensitive and it can detect moderate changes in water quality that would previously have been undetected. WHPT NTAXA also responds to the same environmental pressures as BMWP NTAXA. WHPT and WHPT NTAXA are the current indices used to determine WFD status for macroinvertebrates and a comparison of LIFE and WHPT scores are useful for distinguishing the direct effects of water abstraction from the effects of water pollution.
- Proportion of Sediment Sensitive Invertebrates (PSI) (Extence et al, 2013): The PSI is used to determine the degree to which a site is impacted by sediment. Each species has been assigned a sensitivity rating for sediment which is used to calculate the PSI. The scores range from 0 (heavily sedimented) to 100 (minimally sedimented).
- Community Conservation Index (CCI) (Chadd and Extence, 2004): The CCI is used to evaluate the conservation value of macroinvertebrate communities. The CCI is calculated based on rarity values assigned to invertebrate species, from 1 (very common) to 10 (endangered), based on the Chadd and Extence 2004 Conservation Score Definitions. Low CCI scores indicate low conservation value and high scores indicate high conservation value, these values can exceed 10.

Table 5.13 Macroinvertebrate monitoring summary

Location ID	NGR	Sample Date	WHPT NTAXA	WHPT ASPT	LIFE NTAXA	LIFE FAMILY	PSI FAMILY	CCI
Warleggan River (79079)	SX 1455073080	28/03/2013	31	7.5	28	7.93	72.88	23.23
		15/10/2013	26	6.83	24	7.38	68.29	
		18/03/2014	22	7.25	19	7.79	77.5	9.52
		10/09/2014	28	6.57	24	7.58	65.31	8.82
Warleggan River (10707)	SX 1583068100	28/03/2013	24	7.88	20	8.35	83.72	8.75
		15/11/2013	23	8.05	19	8.16	89.19	
		04/04/2014	30	7.68	26	8.04	83.67	14.54
		05/09/2014	27	8.13	23	8.22	84.62	15.27
		22/04/2015	30	7.8	26	8.27	82.76	10.85
		20/10/2015	22	7.54	20	8.1	84.62	10.28
		08/04/2016	31	7.56	29	7.69	73.58	21.56
		30/09/2016	22	7.54	20	7.85	88.57	10
		24/04/2017	30	7.98	27	8.07	79.31	15.17
		12/10/2017	21	7.87	19	8.16	86.49	10.42
		26/04/2018	27	7.83	22	8.23	86.96	13.65
		17/09/2018	28	7.64	23	7.91	79.55	14.64
		03/04/2019	33	7.95	29	8.03	83.93	22
		29/06/2020	26	7.79	21	8.1	80.49	15.12
		22/09/2020	27	7.74	21	8.05	80	18.57
		12/05/2021	31	7.83	27	8.15	83.05	15.87
		17/10/2021	29	7.57	25	7.84	82.61	13.67
		04/04/2022	30	7.74	26	8.04	83.64	16.55

Observed WHPT, ASPT, NTAXA, family LIFE (LIFE F) and PSI were provided for all samples. Expected values were generated using site information (source: Defra) to inform the River Invertebrate Predictions and Classification System (RIVPACS) model via the River Invertebrate Classification Tool (RICT) web application. The ratio for observed to expected scores are presented in Figure 5.2 Figure 5.2, expected scores were generated separately for each season. The Warleggan invertebrate dataset is temporally well distributed but not spatially, with only one site with more than three years monitoring data available.

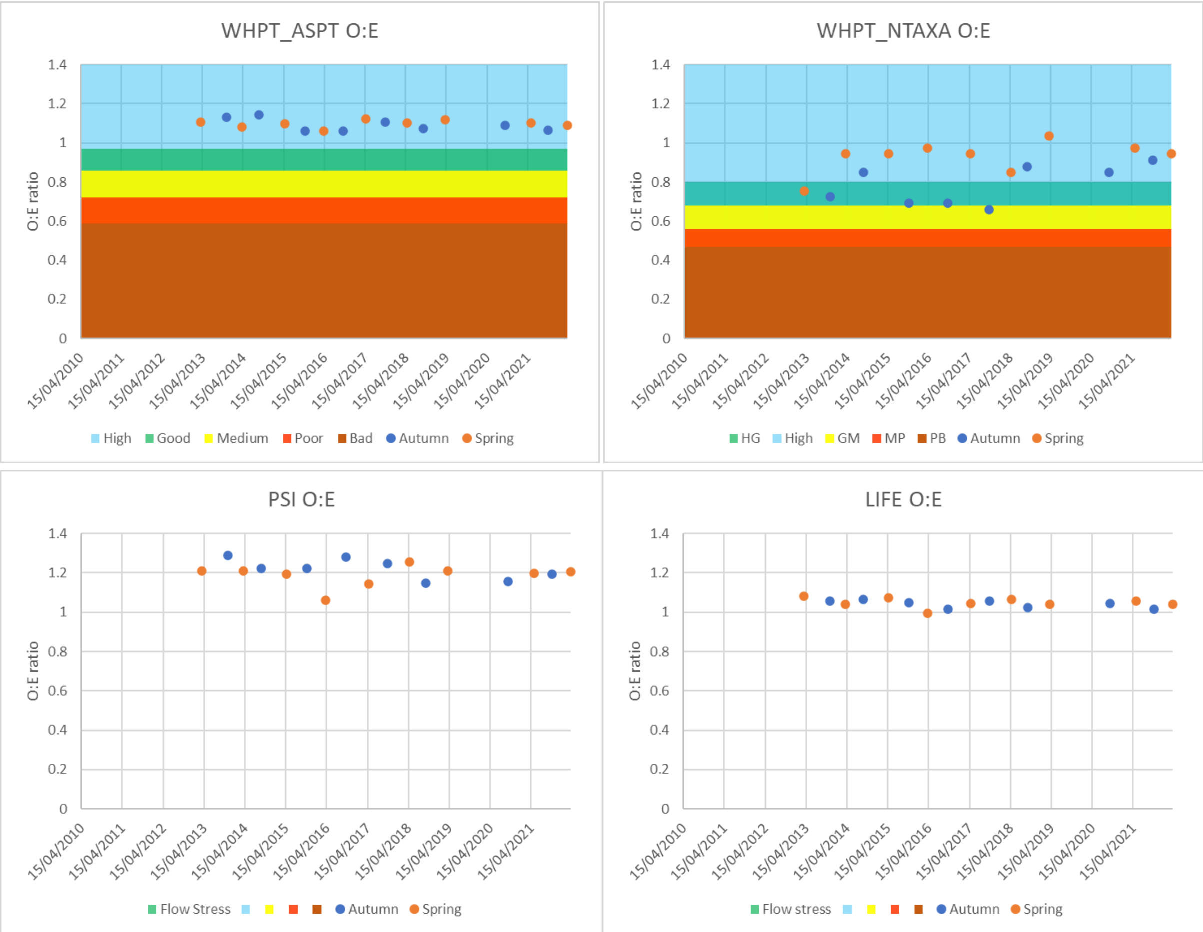

Figure 5.2 Invertebrate indices at monitoring location 10707. Only sites with 3 years monitoring, within the reaches between Hawk's Tor and the Fowey have been considered

The macroinvertebrate community of the Warleggan was found to be diverse and indicative of good ecological water quality (Figure 5.2), with NTAXA and ASPT Observed:Expected (O:E) ratios found to be consistently high and indicative of Good status. NTAXA O:E ratios fell in the autumn months for a three-year period between 2015 and 2017 but has since recovered. This may indicate that Autumn is a particularly sensitive time to changes in water quality.

LIFE O:E ratios demonstrated that there was no indication of an impact of low flow on the macroinvertebrate community, with LIFE O:E ratios consistently above an O:E ratio of 1. Similarly, PSI O:E ratios, with ratios are consistently above an O:E ratio of 1 which indicates that the reach is not subject to sediment stress.

The majority of the CCI scores exceed 10, this indicates that the macroinvertebrate communities are of high conservation value.

5.4.4 Impact assessment

Baseline data did not indicate significant flow, pollution, or sediment stress on the macroinvertebrate community. The macroinvertebrate community in the Warleggan River is diverse and contains species sensitive changes in flow conditions. Macroinvertebrates are typically resilient to change and generally recover rapidly from short term fluctuations in environmental conditions. The impact of the proposed drought permit on macroinvertebrate communities is tied to physical and chemical pathways discussed in Sections 4.1 and 0.

The diversity of a sample is a general reflection of the diversity of available habitat, as such NTAXA O:E is thought to provide the best indication of habitat diversity. Potential impacts of the proposed drought permit on physical habitat were deemed to be medium, considering the flow scenarios outlined in Sections 4.1. As the baseline macroinvertebrate data showed NTAXA O:E to consistently fall within the WFD boundary of Good status or better, with the exception of Autumn samples between 2015-17, it is considered that the proposed drought permit, with the flow compensation measures, will have a limited adverse impact on the macroinvertebrate community in terms of diversity.

During the baseline assessment, good water quality is reflected in the ASPT O:E scores. Impact to ASPT O:E will be tied to that of water quality (0), the impact of which is predicted to be low . Given the expected impact of water quality (low) and hydrology (medium), it is considered unlikely that the expected changes in physical habitat or water quality would cause a deterioration of the macroinvertebrate element WFD status. As such the **sensitivity** of macroinvertebrate element is **Medium**, the **significance** of impacts is **Moderate**, and due to the limited spatial distribution of the data, **confidence** in this assessment is **medium**.

Table 5.14 Summary of macroinvertebrate impact assessment

Receptor	Sensitivity	Significance of impact	Confidence level
Macroinvertebrates	Medium	Moderate	Medium

5.5 Fish

5.5.1 Background

Under WFD the Environment Agency (EA) Catchment data explorer classifies the Warleggan River waterbody (GB108048007630) as 'moderate' for fish based on the most recent Cycle 3 2019 classification (Table 5.15).

This classification is based on 2 survey sites within the waterbody, Carne Wood (SX1581868422) and West Wood (SX1543065880). At a site level these assessment points are classified as 'Poor' and 'Good' respectively. At Carne Wood, the absence of bullhead (*Cottus gobio*) is the primary reason for failure. Absence of European eel (*Anguilla Anguilla*) also contributes to the classification.

5.5.2 Potential pathways of impact

Fish species may respond differently to flow variation given their spatial and temporal habitat requirements. As such, impacts of flow upon fish would depend upon timing, duration, and magnitude. Key considerations are therefore the changes in the quality or extent of habitat as well as impacts on habitat accessibility; individual species and life stages require access to a variety of habitats (and associated environmental conditions, such as water temperature and dissolved oxygen concentration) at different times of the year for successful recruitment. In addition, predicted impacts to macroinvertebrate populations are also considered in terms of potential changes in availability of food sources.

Abstraction from Hawk's Tor pit will reduce the top water level and (unmitigated) would result in cessation of flow from the lake outfall. Additionally, following the drought permit there will be a period of time where the water level in Hawk's Tor pit recharges following draw down of water level. This period is likely to extend through the Spring and Summer months in 2023 and potentially beyond.

Reduction in flow in the downstream catchment could result in the following issues for the recorded fish population:

- Sedimentation of spawning habitat – Reduced flows/velocity result in deposition of fine sediment, which would normally be carried downstream during times of high flow. Fine sediment compromises the quality of gravel / cobble spawning habitat by reducing flow of water through the substrate, starving incubating eggs of oxygen. Sedimentation can also compact or armour the gravel bed, making it more difficult for salmonid fish to cut redds into.
- Reduced physical flow for upstream migration of salmonid fish– Increased difficulty for fish to access headwater spawning habitat (as far as Hawk's Tor Pit) due to lack of flow at natural and artificial barriers. Reduced flow for downstream migration of smolts during Spring 2023.

- Potential exposure of habitat used to by fish to spawn – Low flows may result in gravel substrate that has been used as spawning habitat by salmonid fish becoming exposed to the air, resulting in egg mortality.
- Loss of wetted area within the channel – Reduction in habitat quantity as well as quality, potential reduction in productivity of the Warleggan River in terms of salmonid fish during Summer 2023.

A reduction in water level in Hawk's Tor Pit could lead to:

- Isolation of fish in Hawk's Tor Pit – limiting coarse and salmonid fish migration downstream (there is no upstream migration out of Hawk's Tor Pit)
- Unfavourable water quality conditions for fish within Hawk's Tor Pit

5.5.3 Baseline

Ecological status for the Warleggan River waterbody is moderate, and fish populations are the only failing ecological element. As the fish failure is due to natural causes (natural barriers), an alternate less stringent objective has been set of moderate for the fish element and overall ecological status. Therefore, although the waterbody does not meet the standard objective of good status, it is meeting its requirement set in the River Basin Management Plan.

Table 5.15 WFD status for fish

Target area	Classification year	WB ID	WB Name	Overall	Fish
Hawk's Tor	2019	GB108048007630	Warleggan River	Moderate	Moderate

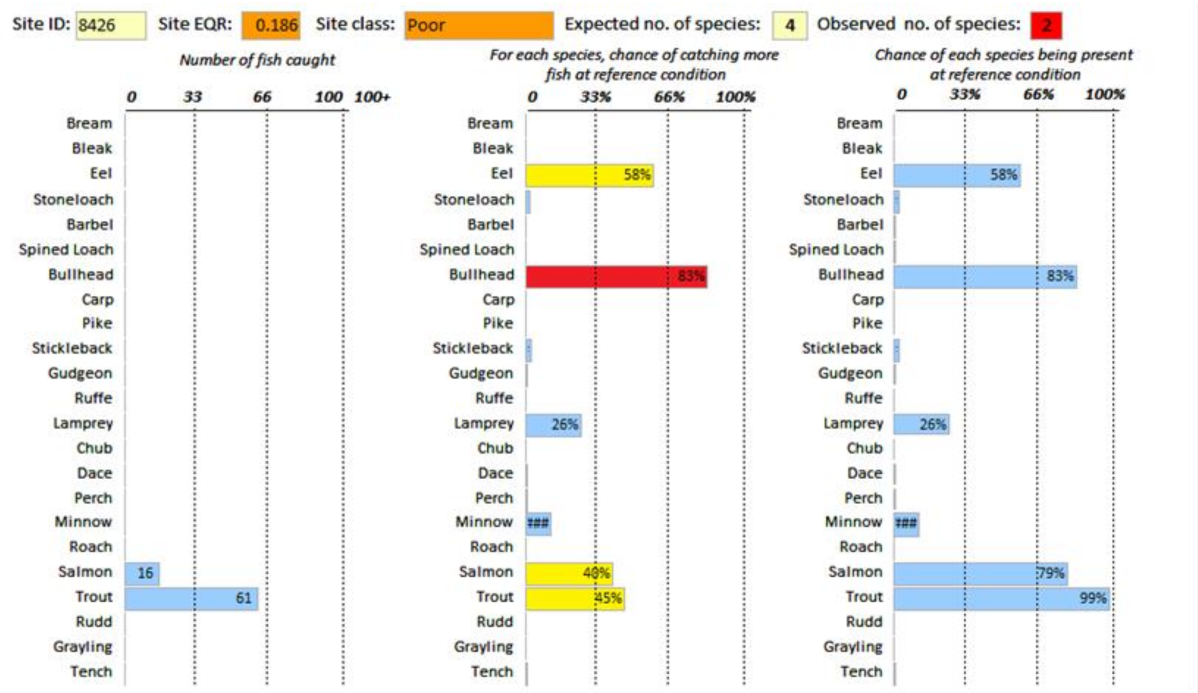

Figure 5.3 - FCS2 Classification information for the Carne Wood site on the Warleggan. Source – Environment Agency

The Reasons for Not Achieving Good (RNAG) dataset identifies 'Barriers - ecological discontinuity' as the reason for the fish failure in the Warleggan waterbody. The SWMI (significant water management issue) for the RNAG is 'Natural', suggesting that natural barriers to migration impact the catchment[4].

The Environment Agency has monitored fish populations on the Warleggan at numerous locations since 1977 (Table 5.16, Figure 5.28). There is one site (site ID) upstream of Hawk's Tor Pit; Hawk's Tor (25162), which was sampled once in 1999. The remaining sites in Table 5.16 Table 5.16 are listed in order downstream. West Wood (8430) has the longest record, with 19 surveys conducted between 1977 and 2018, but the greatest sampling effort occurs at Carne Wood (8426), with 25 surveys conducted from 1994 to present.

Table 5.16 Monitoring locations between Hawk's Tor and the Fowey confluence

Site ID	Site Name	NGR	Nº Surveys	1st Survey	Last Survey
25162	Hawk's Tor	SX1500075400	1	20/09/1999	20/09/1999
22991	Tank Bridge	SX1506473770	1	31/10/2006	31/10/2006
8423	Temple	SX1477273180	12	04/08/1994	18/10/2018
8424	u/s Maidenwell	SX1464871576	11	27/07/1994	26/07/2012
8425	Wooda Bridge	SX1485068842	9	02/08/1994	28/09/2004

[4] https://environment.data.gov.uk/catchment-planning/WaterBody/GB108048007630/rnag?cycle=3&element=55, accessed 29th October 2022

8426	Carne Wood	SX1581868422	25	29/07/1994	17/09/2021
8432	Lantewey (*tributary)	SX1594968205	11	04/08/1994	27/06/2018
8427	Panters Bridge	SX1585068060	18	09/08/1977	08/09/2011
8429	Warleggan Gauging Station	SX1598167396	9	04/08/1994	07/09/2004
8430	West Wood	SX1543065880	19	10/08/1977	13/07/2018

Considering data from 1994 to 2021 taken from the Fish and Ecology Data Explorer (source: https://environment.data.gov.uk/ecology/explorer/, accessed 29th October 2022) shows that 4 species have been recorded in these surveys; Atlantic salmon (*Salmo salar*), Brown trout (*Salmo trutta*), bullhead and European eel. Table 5.17shows a summary of species distribution in the catchment.

Table 5.17 - Summary of species recorded in Environment Agency electric fishing surveys

Site Name	NGR	Atlantic salmon	Brown trout	Bullhead	European eel
Hawk's Tor	SX1500075400	n	y	n	n
Tank Bridge	SX1506473770	y	y	n	n
Temple	SX1477273180	y	y	n	y
u/s Maidenwell	SX1464871576	y	y	n	y
Wooda Bridge	SX1485068842	y	y	n	y
Carne Wood	SX1581868422	y	y	y	y
Lantewey (*tributary)	SX1594968205	y	y	n	y
Painters Bridge	SX1585068060	y	y	y	y
Warleggan Gauging Station	SX1598167396	y	y	n	y
West Wood	SX1543065880	y	y	y	y

Figure 5.4 - Location of Environment Agency electric fishing survey sites in the Warleggan catchment

The most recent surveys in 2018, at West Wood (8430) and Temple (8423), and in 2021 at Carne Wood (8426) record the following species: Atlantic salmon (*Salmo salar*), brown / sea trout (*Salmo trutta*), Bullhead (*Cottus gobio*), and European eel (*Anguilla anguilla*). The upstream limit of Atlantic salmon records is at Tank Bridge (22991)/ Temple (8423) in 2006/2005. In 2012, salmon were present as far upstream as Maidenwell (8424), but there are no records of salmon extending past Carne Wood (8426) in recent years. However, sea/brown trout are considered to be present throughout, as far upstream as Hawk's Tor (25162)

Overall, the electric fishing data shows that brown trout are well distributed throughout the Warleggan River catchment, they are recorded at all sites and during all surveys. Trout populations are supported further upstream than salmon, although only one survey was conducted at Temple post-2010.

Atlantic salmon have been recorded throughout the majority of the catchment, with the exception of the most upstream site, Hawk's Tor, and are not often recorded in large numbers beyond Carne Wood. Recorded densities of Atlantic salmon are highest in the surveys in the middle and lower reaches of the catchment.

A previous Environmental Monitoring Plan for Hawk's Tor Pit (APEM, 2007) noted that some records of Atlantic salmon in the upper reaches of the Warleggan catchment are likely to be linked to stocking – historically hatchery reared fish have previously been introduced to the upper reaches of the catchment. Therefore, identifying areas of the catchment naturally utilised by Atlantic salmon is difficult as records of stock fish distort the data. Bullhead distribution is limited to 3 sites towards the downstream end of the catchment, and European eel have been recorded at most survey sites, with the exception of the two furthest upstream (Hawk's Tor and Tank Bridge).

A review of Environment Agency electric fishing data for the Warleggan catchment confirms that records of bullhead are sporadic, however of note they were recorded at the Carne Wood survey site in the most recent 2021 electric fishing survey, confirming that migratory access is possible to the site for the species.

Baseline data for the fish population in Hawk's Tor Pit is limited. Seine netting was carried out in October 2022 by RSK Biocensus as part of wider invasive non-native species surveys at the site. The only species recorded was brown trout, in low densities. Visual observations at the lake have additionally confirmed the presence of brown trout.

Based on the baseline data for the wider catchment, Atlantic salmon and European eel have also been recorded in the vicinity of the lake. The habitat in the lake is suitable for European eel and it is assumed that the species is present. In recent years Atlantic salmon have been absent from the upper reaches of the Warleggan catchment, and it has been noted that historic records may be as a result of stocking from hatchery sites. It is therefore thought to be unlikely that Atlantic salmon are present or utilise Hawk's Tor Pit as temporary habitat.

5.5.4 Impact Assessment

Baseline data shows that salmonid fish, both brown trout and Atlantic salmon, are present within the Warleggan River, although records of Atlantic salmon are largely in the middle and lower reaches in recent years. Both species have similar life cycles, with spawning typically occurring from October to December. During spawning, salmonid fish lay eggs in 'redds' which are excavations made in the gravel bed of streams and rivers. These eggs will remain within the redds for roughly 10 to 12 weeks (Scott and Beaumont, 1993), known as the incubation period, however this timeframe is heavily dependent on water temperature. Both spawning and incubation are sensitive times for salmonid fish, there is a requirement for clean gravel with low concentration of fine sediment both to facilitate the cutting of redds and allow a flow of water through the substrate to maintain supply of oxygen to eggs within the redds (Greig et al., 2005).

Prior to spawning, salmonid fish typically complete migratory movements to locate suitable habitats - fish will move upstream into headwater or tributary areas to spawn. For brown trout, the species has varying life cycles, with some fish remaining in freshwater habitats for their whole life (resident trout) and others migrating to sea to reach maturity (sea trout). It isn't possible to differentiate whether juvenile brown trout captured in electric fishing surveys are resident trout present year-round or the offspring of migratory sea trout. Records from the previous Environmental Monitoring Plan document produced by APEM (2007) suggest that sea trout do use the Warleggan, with anecdotal records of spawning within headwater areas. In order to reach their spawning habitats, salmonid fish require sufficient flow to overcome migratory obstacles (i.e., weirs, natural cascades), the requirement for high flow spate events is emphasised in small tributary / headwater streams which are often steep and present challenges for fish passage. Upstream migration of salmonid fish into tributary and headwater areas typically takes place shortly prior to spawning; the timeframe for this migratory movement is typically from September through to December (Solomon and Lightfoot, 2008).

Downstream migration of adult migratory salmonid fish (sea trout and Atlantic salmon, post spawning they are known as kelts) occurs post spawning (Moore, Privitera and Riley, 2013), typically through December and January. The survival rate of Atlantic salmon after spawning is low, however for sea trout fish are often able to return to spawn multiple times. Drawing down Hawk's Tor Pit from top water level for the drought permit will coincide with the latter stages of downstream migration of salmonid kelts, when the risk is reduced. Once the pit is below top water level natural hydrological connectivity with the downstream Warleggan catchment no longer exists, flow will be required to be provided artificially through pumps. It is our current understanding that migration upstream of Hawk's Tor pit via the lake is unlikely given the nature of inflow channel morphology, though there is potential that sea trout could be trapped in the lake. Baseline data review has shown that records for Atlantic salmon in the upper reaches of the Warleggan catchment are limited, and there are no records of the species upstream of Hawk's Tor Pit (although only one survey has taken place).

Following on from the Drought Permit, the time when Hawk's Tor pit will be recharging to top water level is likely to coincide with the downstream migration of salmonid smolts (typically April and May). Smolts typically use elevated water levels during the Spring to ease their migration downstream (Solomon and Lightfoot, 2008). The operation of the Drought Permit, unmitigated, could affect smolt emigration from the Warleggan downstream of Hawk's Tor Pit due to impact on the flow regime. As discussed above for salmonid kelts, reduction in the water level of Hawk's Tor Pit will also mean that the lake itself is disconnected from the downstream Warleggan catchment, with flow being provided artificially by pumped compensation flow. Therefore, any smolts entering the pit from the upstream reaches of the Warleggan River will be unable to proceed beyond the pit, though the morphology of inlet channels upstream of Hawk's Tor, as detailed about suggest that smolt migration into the pit is unlikely due to barriers present.

Depending on length of time for Hawk's Tor Pit to recharge to top water level (see Section 4.1), **upstream migration** of salmonid fish in 2023, as far as Hawks Tor Pit, may also be impacted by reduced flows. An Environment Agency resistivity fish counter on the River Fowey at Restormel gauging station records upstream movements of salmonid fish into the catchment. Data from the counter shows that May to November are the most important months for upstream migration of salmonid fish. The counter is located in the lower reaches of the main River Fowey, it is likely that migration of salmonid fish into the upper reaches of the smaller Warleggan River tributary takes place later in the year than results recorded at Restormel.

The ongoing **sensitivity** of salmonid fish as a receptor to prolonged reduction in flow due to reduction in water level at Hawk's Tor Pit is thought to be **high;** this receptor is highly sensitive to changing environments due to an inability to tolerate and recover from changes. However, the Warleggan is a sub-catchment of the wider river Fowey and as such impact on salmonid fish is not expected to extend to an operational catchment scale. Hydrological assessment of the zone of influence has also identified that the primary area of risk is in the headwaters of the Warleggan River as far as the Blacktor Downs tributary, and that at Tregoffe gauging station accretion of flow has largely mitigated impacts, suggesting a limited geographical extent to the risk.

European eel and bullhead are also recorded in the Warleggan catchment. Bullhead are only present in the lower reaches of the catchment (see baseline data above), the impact on flow from abstraction at Hawk's Tor Pit will be negligible by this point. Therefore, is anticipated that the **sensitivity** of bullhead to reduced flow within the Warleggan waterbody will be **minor**.

For European eel, the most flow sensitive life stage is downstream migration of silver eels, which takes place during the Autumn. Implementation of the drought permit will take place after this migration has taken place in 2022, however there is a risk that Hawk's Tor Pit will not have recharged to top water level by Autumn 2023. As discussed, linked to the downstream migration of smolts above, reducing the pit below top water level will mean there is no natural hydrological connection with the downstream watercourse (flow provided by pumps), which is likely to restrict natural emigration of silver eels from the pit. The current **sensitivity** of European eel to the drought permit is thought to be **minor**, however if impact extends into the silver eel run in Autumn 2023 this will be elevated. Further information on the population of European eel in Hawk's Tor Pit will help to quantify this risk.

Risk to fish population in the lake - Hawk's Tor Pit is known to hold brown trout – confirmed by RSKBiocensus seine netting survey and visual assessment. It is also assumed that European eel are present in the pit as they have been identified in the surrounding catchment. Presence of other species is thought to be unlikely – Atlantic salmon and bullhead are present within the catchment, however they are predominantly recorded in the middle and lower reaches, and the habitats within Hawks Tor Pit are not considered suitable to support either species.

Pumps used for both abstraction of water for supply and provision of a downstream compensation flow pose a risk to fish within the lake through entrainment, however this will be mitigated with best practice screening. It is likely that brown trout resident in Hawk's Tor Pit use tributary streams as spawning habitat, particularly the upper Warleggan River, which enters from the north. However, walkovers completed in November 2023 by SWW and EA highlighted a disconnect in terms of fish passage between the headwaters of the Warleggan

River and the upstream end of Hawk's Tor Pit, therefore it is unlikely the channel is of a suitable form for fish movements.

In terms of the fisheries impact pathways, the sensitivity of various fish species and likely impacts are discussed in detail above. Currently the outfall is gravity fed, this flow route will not be naturally maintained once water levels are drawn down. The loss of natural downstream flow, following reduction in the water level at Hawk's Tor Pit, is likely to impact brown trout most significantly, which are present in the upper reaches of the Warleggan catchment. Impacts of draw-down of Hawk's Tor Pit on fish migratory movements through the lake. If water levels remain below top water level through to Autumn 2023, downstream migration of European eel from the pit could also be impacted. Further knowledge of the fish population and understanding of how draw down of lake levels will impact on migratory access for fish to tributaries is required.

5.5.5 Summary

For all salmonid species, and potentially European eels, the likely **sensitivity** regarding flow reductions in the reach below Hawk's Tor, and the draw-down risk of the pit to the resident and migratory populations, is considered to be **high**. Bullhead are only present in the lower reaches of the Warleggan catchment, where accretion of flow will limit any impacts, therefore, **sensitivity** is assessed as **low.**

However, the Warleggan River above Hawk's Tor Pit is a small catchment and is the very headwaters of the stream. It is unknown to what extent sea trout utilise the catchment for spawning and therefore it's productivity both in terms of kelts and smolts. Similarly, the population of European eel in the pit itself is currently unknow. Therefore, **confidence** in this assessment is also **low** and mitigation and monitoring will be proposed (Section 6 and 7) to overcome these issues. Furthermore, since 2009/10, the river has directly entered the pit and the inlet channel morphology precludes the movement of fish through/out of the pit into the head waters of the catchment.

The impact to migration of salmonid fish is similar at both life stages (smolts and kelts). The reduced flow, and the draw down in the lake, poses a consistent risk albeit at different points in the year. Downstream migration of smolts between April and May, and the upstream migration of kelts between May and November, will be impacted by reduced flows, should the natural flow regime not be re-established in time post drought permit. The re-establishment of the natural flow regime is dependent upon the recharge rate of the pit and the timing of water levels reaching top water level. Resident fish populations and migratory fish within the lake during the drought permit will become isolated from the main reach, tributaries, for the duration of any lake draw down.

The negative impact on productivity for fish is not expected to extend beyond 2023, although there is a risk that reduced spawning success in 2022/23 could see fewer adult migratory salmonid fish returning to the Warleggan River in future years. The magnitude can therefore be characterised as a medium-sized, substantial, medium-term and/or frequent change. As such, the **significance** is deemed to be **moderate.**

Table 5.18 Summary of Fish impact assessment

Receptor	Sensitivity of receptor to impact	Significance of impact	Confidence level
Fish			
Atlantic salmon	High	Moderate	Low
Sea/Brown trout	High	Moderate	Low
Bullhead	Low	Minor	Medium
European eel	Low	Minor	Medium

5.6 NERC and Other Notable Species and Habitats

5.6.1 Background

A baseline ecological walkover was completed on 11th November 2022 to determine the suitability of Hawk's Tor Pit for Natural England and the Commission for Rural Communities (NERC), Section 41 species and habitats and for any other notable species or habitats, that may be impacted as a result of the proposed Drought Permit. Along with desk-based data, this walkover provides an overview of the site's sensitivity for these species and habitats.

The baseline survey included Hawk's Tor Pit, the immediate surrounding habitats and a section of the Warleggan River, downstream to the A30.

5.6.2 Potential pathways to impact

A reduction in water level at Hawk's Tor Pit, as a result of the proposed drought permit may lead to the following potential impacts for species and habitats:

- Temporary reduction of foraging and commuting habitat
- Exposure of marginal vegetation – drying of habitat, succession of habitat to unfavourable habitat type(s)

5.6.3 Baseline

5.6.3.1 Mammals

Signs of otter were found during the survey, in the form of a fresh spraint at the top of the outfall channel on the southern tip of the lake. The lake itself reportedly supports larger fish species which would provide a good foraging resource. The outfall channel as well as the sunken channel of the Warleggan River both provide suitable movement corridors for otter, connecting the lake, via the A30 culvert, to other suitable foraging habitats downstream. Habitats including undercut banks, dense tussocky vegetation, willow scrub and exposed rocks around the edge of the waterbody provide suitable cover for potential otter lay-ups, however no further evidence of the presence of otter was found in these locations.

Given the sparse and patchy tree and shrub cover and the position of the lake within the moorland landscape, resting areas and holt sites are considered more likely to be located downstream of the A30 within the more sheltered river valley. Depending on the amount of draw-down lowering the water level of the lake may affect the suitability of the lake for foraging otters by separating the water from fringing habitats that provide cover. This will however depend on the nature of the newly exposed shoreline, as if large rocks and boulders become exposed these may provide some cover and potentially alternative resting sites.

No field signs of other mammals were noted; however, surrounding habitats including the small areas of woodland and scrub provide suitable sett-building habitat for badger (*Meles meles*) and the taller, tussocky grasslands have suitability for Harvest Mouse (*Micromys minutus*) which are known from the Bodmin Moor SSSI and to the south of the A30. Crevices within the rocky cliff may provide suitable roosting sites for bats, and the lake and surrounding habitats provide moderate suitability foraging habitat. Beaver (*Castor fiber*) are present within the Warleggan River catchment c. 2.5km to the south within Cabilla Estate. Water vole (*Arvicola amphibius*) is considered to be absent in the catchment, given their restricted range in Cornwall, at a small number of reintroduction sites.

5.6.3.2 Reptiles

Habitats immediately around the lake and the wider areas of heathland, fen and taller acid grassland provide suitable habitat for more commonly occurring reptiles including Common Lizard (*Zootoca vivipara*), Slow Worm (Anguis fragilis), Grass Snake (*Natrix helvetica*) and Adder (*Vipera berus*). Changes to the water level in the lake would not be expected to directly affect these species because the habitat in the draw-down zone is not particularly suitable and refugia for reptiles.

5.6.3.3 Amphibians

The lack of marginal and emergent vegetation and largely sandy/gravelly shores formed by wave action limit the suitability of the lake for amphibians as breeding habitat.

5.6.3.4 Invertebrates

The observed habitats are likely to support a range of invertebrates of heathland, acid grassland, fen and aquatic marginal habitats which could include notable species. Habitats that appear hydrologically dependant on the lake water level are geographically restricted, which will limit their suitability for specialist species. Areas of tall and tussocky acid grassland to the north and around the ditch and river channel along the south-eastern side of the lake, together with fringing fens, provide suitable habitat for rarities such as Marsh Fritillary (*Euphydryas aurinia*) which are known to be present on Bodmin Moor.

5.6.3.5 Birds

During the ecology walkover survey, a single Cormorant (*Phalacrocorax carbo*) was noted flying over the lake, and a Snipe (*Gallinago gallinago*) was flushed from the Warleggan River channel. A possible Sand Martin (*Riparia riparia*) or kingfisher (*Alcedo atthis*) nesting site was noted on a section of the northern cliff, where sandy substrates were exposed and excavated holes seen.

The expanse of open water has suitability to attract waterfowl such as gulls, ducks and geese and may provide some foraging for piscivorous species. The steep lake profile and lack of macrophytes and emergent vegetation would limit foraging opportunities for other species.

The lack of marginal and emergent vegetation, other than as occasional sparse or very narrow strips, limits the suitability for breeding birds associated with open water habitats and it is likely that only low numbers of open water or wetland species would successfully breed or forage at Hawks Tor Pit.

Lowering the lake water level has the potential for temporary adverse impacts on such species through separating the vegetated bankside habitats from the water’s edge, however this foraging and open water habitat will be retained throughout the operation of the Drought Permit.

There is a lack of both breeding bird and wintering bird data available for Hawks Tor Pit however based on the habitat availability and presence of more suitable open water bodies in the wider landscape it is anticipated that the Drought Permit would not impact this receptor.

5.6.3.6 Habitats

Baseline surveys identified the presence of the following Habitats of Principle Importance:

- Upland flushes, fens, and swamps
- Lowland fen
- Purple moor grass and rush pastures
- Mountain heaths and willow scrub
- Lowland dry acid grassland

Scattered willow scrub was noted around the southern end of the lake, willow scrub and dry heathland on steep slopes of sand and gravels from past quarrying activities, while habitats around the north-eastern edge of the lake comprised a mixture of acid grassland. Around the very northern end of the lake: Purple Moor-grass (*Molinia caerulea*) dominated acid grassland. Around the south-eastern edge to the southern tip of the lake, the bank was found to vary from c. 1.5 – 0m in height and supported dry heathland and acid grassland in between the wetter channels of a shallow ditch and Warleggan River, which ran parallel to the water’s edge. Small areas of fen on low-lying areas by the water’s edge were occasionally present.

The location would have once been occupied by and extensive valley mire, the remains of which are present all around the lake, but at an elevated level, due to the pit having been dug through them. At various points around the edges were peat masses up to one metre -thick, with dry exposed edges, well above the lake level and sitting on mineral and clay materials. Peat masses, and the majority of priority habitats, are above the water level of the lake (often more than 50cm) and appear not to be hydrologically dependant on the lake water level. This peat is not representative of the surrounding mire habitat, which is dominated by soft rush and moorgrass with no sphagnum, again due to the pit disturbance to the valley mire. So there is only a limited risk of lower lake levels damaging any mire communities on these already dry peats.

5.6.4 Impact assessment

Based on the baseline assessment otter and habitats of principle importance are subject to impact assessment, other species are judged not to be impacted by the proposed drought permit.

Otter

The magnitude of impact, the draw-down of water on Hawk's Tor Pit, on potential foraging habitat for otter is considered to be **High** (as described in 4.1.8) and the sensitivity of the otter, based on their mobility and the availability of other food and refuge sources within the landscape, as well as the volume of water within Hawk's Tor Pit which will remain for foraging is considered to be **Not Sensitive.** The significance of impact on otter is therefore predicted to be **Minor**, with **Medium** confidence.

Habitats

The surface vegetation on areas of lowland fen peats was dominated by moorgrass. This is likely due to the presence of a ditch running parallel with the south-eastern lake shore, 10m back from the edge. This creates a thin peat strip stranded and drying from both sides. Towards the top end of the ditch the peat bank lowers and water comes over it from the ditch to the lake shore creating the only small patch of healthy mire vegetation with Sphagnum seen on the lake shore (15m x10m). The draw down will partially affect this.

The magnitude of impact on water level is predicted to be **High**, as described in Section 4.1.7. The sensitivity of habitat is predicted to be **Low**, based on the potential for recovery over a short period of time. Other supporting water sources will be maintaining ground saturation and size and scale of the wider habitats, away from Hawk's Tor Pit water level interaction. The overall significance of impact is predicted to be **Moderate** with a **Medium** confidence level.

5.6.5 Summary

Table 5.19 Summary of impact to NERC habitats and species

Receptor	Sensitivity	Significance of impact	Confidence level
Otter	Not sensitive	Minor	Medium
NERC habitats	Low	Moderate	Medium

5.7 Invasive Non-Native Species

5.7.1 Background

INNS flora and fauna are considered a significant threat to biodiversity worldwide and have been identified as one of the most serious and rapidly growing threats to biodiversity, ecosystem services and food, health and livelihood security. The annual cost of INNS to the Great Britain economy was estimated in 2010 to be £1.7 billion per year, of which around £5 million was attributed to the water industry management of INNS. New and existing INNS also pose a threat to achieving Water Framework Directive (WFD) objectives. The UKWIR project completed by Ricardo Energy & Environment (UKWIR, 2016), provided further evidence of the implications of INNS to the water industry.

Subsequently, the Environment Agency (EA) (2017) set out a position paper on the assessment of the risks of spreading INNS through existing water transfers. The position paper set out the scope, outcomes and timelines expected for risk assessments of raw water transfers and options appraisal that water companies should deliver in their Asset Management Plans (AMP) 7 (2020-2025).

As a result, INNS became a new "driver" within the 2019 Price Review (PR19). In previous price reviews, there was some scope for limited INNS work, justified within the biodiversity drivers. Having a separate driver recognised the increasing evidence and understanding of the risks posed by INNS. The guidance supporting this driver is explicit in stating that "the most cost-beneficial and least damaging way to manage invasive species is to prevent their arrival and spread." This highlights the need to understand the pathways by which INNS can be transferred and hence be spread. Furthermore, the EA has specifically identified raw water transfers (RWTs) as a subgroup of pathways that should have priority risk assessments (RAs) to assess the potential for INNS to spread. The INNS guidance indicates that all water companies will need to consider:

- Pathways of spread (understanding and reducing the risk from different pathways).
- Preventing spread (controlling, eradicating, or managing INNS to prevent spread where this will contribute to WFD prevention of deterioration); and
- Action on INNS to achieve conservation objectives of Sites of Special Scientific Interest (SSSI) and sites protected under the Habitats Directive.

This has led to INNS being considered in the Water Industry National Environmental Programme (WINEP) across the water industry with a particular focus on investigating the risks of spreading INNS through options appraisal for mitigation and companywide biosecurity plans to reduce the risk of distributing INNS through new existing activities and operations. A high-level risk assessment approach has been developed in line with the Environment

Agency's guidelines for INNS assessment, to provide a consistent, rapid approach to identifying INNS risks[5].

5.7.2 Baseline

A review of available baseline data located with the National Biodiversity Network (NBN) Atlas was undertaken to understand the current known INNS community within proximity to Hawk's Tor Pit, the infrastructure route and Colliford reservoir.

A review of available INNS records within 1km of Hawk's Tor Pit returned no INNS records within the last 20 years. Similarly, a review of available INNS records within a 500m wide strip between Hawk's Tor Pit and Colliford reservoir (undertaken to highlight species that may be present in the area of a potential pipeline route), showed no records in the past 20 years had been recorded within this area.

A review of available INNS records within 1km of Colliford reservoir within the last 20 years returned four species, shown in Table 5.20 below. The most common species recorded is the aquatic macrophyte species swamp stonecrop (*Crassula helmsii*) which occurred five times. The second most common species is the terrestrial plant species Japanese knotweed (*Fallopia japonica*) recorded three times. Two elodea species were also recorded once respectively, Nuttall's waterweed (*Elodea nuttallii*) and Canadian pondweed (*Elodea canadensis*).

Project-specific monitoring for native crayfish species was undertaken at Hawk's Tor Pit in autumn 2022. During these surveys, no invasive species of crayfish were recorded over the 3 nights of trapping. There was also no indication of invasive plants or invertebrates observed on site, and the monitoring concluded that invasive mussels were considered likely to be absent.

It must be noted that it was not the optimal time of year for plant surveys, so certain species may not have been represented. Aquatic invertebrate kick samples were also collected at the site and are currently undergoing analysis.

The data presented provides an indication of the INNS which have been recorded within the search areas, however, the accuracy in determining the actual density of INNS is dependent upon sampling effort. Therefore, the data is not a definitive list of all INNS within the search area, there may be INNS which have not yet been recorded and/or the distribution of recorded INNS may be more extensive than reported.

[5] Environment Agency (2017). Managing the Risk of Spread of Invasive Non-Native Species Through Raw Water Transfers. Position 1321_16.

Table 5.20 NNS recorded with 1 km of Colliford reservoir between 2002 and 2022, data from NBN Atlas.

Common Name	*Scientific Name*	Occurrences
Swamp Stonecrop	*Crassula helmsii*	5
Japanese Knotweed	*Fallopia japonica*	3
Nuttall's waterweed	*Elodea nuttallii*	1
Canadian Pondweed	*Elodea canadensis*	1

5.7.3 Potential pathways of impact

The assessment is based on a simple pre-mitigation questionnaire which was informed by the descriptions and scheme design information for numerous other water resource options including drought permits (and their associated components). The questionnaire covers three major aspects of a water resource option:

- The construction of the option/element
- The operation of the option/element
- The maintenance of the option/element

The questionnaire is visible in Table 5.21. Questions are answered based on high level descriptions of the construction, operation, and maintenance elements. The results of the questionnaire will provide pre-mitigation risk categorisation into High, Medium or Low risk.

Table 5.20 Summary of the questionnaire used in the high-level risk assessment (excluding mitigation measures)

Construction Questionnaire			
Q1	Does the option require the construction of new infrastructure	**Yes = Q2**	**No = No Risk**
Q2	Are construction activities limited to within the confines of existing infrastructure? (e.g. Improvements to an existing WTW).	**Yes = Q4**	**No = Q3**
Q3	Are construction activities likely to involve the transport of materials such as transport of soils, vegetation or raw water.	**Yes = High Risk**	**No = Medium Risk**
Q4	Are construction activities likely to involve the transport of materials such as soils, vegetation or raw water to/from outside of the existing site.	**Yes = Medium Risk**	**No = Low Risk**
Operation Questionnaire			
Q1	Does the option/element involve the transfer/abstraction of raw water?	**Yes = Q2**	**No = Q3**
Q2	Does the option/element utilise an open-channel transfer mechanism (e.g. river, canal) AND/OR does the option terminate at an open reservoir/channel?	**Yes = High Risk**	**No = Low Risk**
Q3	Does the option/element utilise an open-channel transfer mechanism (e.g. transfer channel) AND/OR does the option terminate at an open reservoir?	**Yes = Medium Risk**	**No = No Risk**
Maintenance Questionnaire			
Q1	Does the maintenance activity require the movement of machinery, eg dredging, excavators, haulage?	**Yes = Q2**	**No = Q3**
Q2	Does the maintenance activity require the removal/transport of biological material? (e.g. screen debris, pipeline fouling)	**Yes = High Risk**	**No = Medium Risk**
Q3	Does the maintenance activity require the removal/transport of biological material? (e.g. screen debris, pipeline fouling)	**Yes = High Risk**	**No = Low Risk**

The outcomes of the pre-mitigation risk questionnaire were then reviewed/updated to reflect the residual risk after the implementation of mitigation measures or consideration of other factors not captured within the pre-mitigation questionnaire. In updating/reviewing the risk assessment, in light of available mitigation measures, standard (best practice) mitigation measures were considered. This included those measures that can reduce the spread and distribution of INNS and limit the pathways of distribution during construction, operation and maintenance of the scheme. These standard measures include (for example):

- Pre-construction considerations:
    - Ensuring detailed checks and risk assessments are carried out for INNS within initial site feasibility assessments and surveys.
    - Where any INNS are present, ensure contractors understand the risks and implications of managing it, as well as your legal requirements.
    - Where any INNS are identified as a risk of being introduced, spread within, or moved off-site, ensure mitigation measures are considered at the early planning stage, and ensure enough time is given to implement them.
    - Consider phasing construction to allow time to deal with the presence and/or risk of the spread of INNS.
    - Ensure INNS and locations (mapped) are incorporated within all relevant site method statements, including the site Ecological Protection Plan and Species Protection Plans, where appropriate.
    - Where a species requires long-term management (e.g. Japanese knotweed), ensuring a site management plan is put together that addresses all issues associated with it
    - Nominating a designated Clerk of Works/ecologist to manage the issue of INNS on your site from an early stage.
- Equipment / machinery used in construction or maintenance of options
    - Clear signs/markings should be used to warn staff working there that a site/area contains INNS (where known).
    - Where contaminated soil, materials or water are located, signage should be erected to indicate them.
    - Personnel working on or between sites should ensure their clothing and footwear are cleaned where appropriate to prevent spread
    - Tracked vehicles should not be used within areas known to contain INNS (especially where plan fragments are known to be present).
    - All vehicles leaving the construction and or operational sites and / or transporting infested soil/materials must be thoroughly pressure-washed in a designated wash-down area before being used for other work.
    - Where cross-contamination is possible (i.e. from one site to another), consider designating vehicles or machinery to specific sites where possible to prevent spread.

- Material/water left after vehicles have been pressure-washed must be contained, collected and disposed of appropriately
- All wash facilities including wastewater from washing vehicles, equipment or personnel should be managed in a responsible way so as not to not cause harm to the environment

In addition to those standard measure listed above, it is noted that South West Water has company-wide biosecurity protocols and standard operating procedures in place to ensure that all operations are tied to biosecurity practices. Only standard (best practice) mitigation measures (as listed above), which would not require a re-design of the scheme or additional scheme-specific infrastructure, have been considered.

5.7.4 Impact assessment

Pre- and post-mitigation risk scores are provided within

below. There is a high pre-mitigation risk of INNS transfer occurring at the construction phase, as the option is likely to require the construction of new infrastructure such as pumping equipment and pipelines, which may involve the transport of biological material such as soils and vegetative fragments.

This would be a particular concern regarding the construction of the Hawk's Tor Pit infrastructure, as the site currently appears to currently be completely free of INNS. Particular care should therefore be taken in regard to the use of vehicles, plant equipment and the transfer of materials used on the site, to ensure that INNS are not transported to and from Hawk's Tor Pit or Colliford reservoir or construction compounds and sites.

Several INNS species are recorded within proximity to Colliford reservoir which may pose a risk during construction activities, in particular Japanese Knotweed (*Fallopia japonica*). Standard biosecurity measures should be implemented during the construction phase, which would reduce the risk of transfer of INNS to a negligible level.

There is currently a high pre-mitigation risk of INNS transfer occurring during the operation of this scheme, as the option involves a raw water transfer from the source to an open reservoir. However, Hawk's Tor Pit is located within a very small watershed area which consists predominantly of open moorland agricultural grazing to the north and south, with amenity woodland along the southwestern boundary. Therefore, the most likely pathways for INNS to the site include recreational users, SWW employees or contractors and animal vectors (birds/livestock). According to records, there are currently no INNS recorded within the source of the transfer, however the absence of INNS records within the search area at Hawk's Tor Pit may be a consequence of sampling effort, and as such INNS may be present at the site but have not yet been recorded.

Given the apparent absence of INNS within 1km of Hawk's tor Pit, the operational frequency (infrequent to rare) and the relatively short distance of the transfer (approximately 2km) to Colliford Reservoir within the same catchment area, the use of INNS screening and treatment of the raw water prior to transfer would be considered disproportionate relative to the perceived risk in this instance, however as a precautionary measure 2mm 2d screening has been installed on both the abstraction and compensation pumps. Further mitigation focuses on secondary pathways to prevent the establishment of INNS within Hawk's Tor Pit which may then be transferred to Colliford reservoir, as a consequence of the scheme's operation. This mitigation to include wash down facilities for leisure activities, SWW staff and contractors and signage to inform users of the consequences of INNS transfer. Implementation of these mitigation measures during the operation of the scheme would likely reduce risk to a negligible level.

There is a major pre-mitigation risk of INNS transfer occurring during maintenance with the assumption that plant machinery such as dredges, or excavators will be required to complete maintenance. Additionally, there may be a requirement to transport biological material such as screen debris and pipeline fouling. It is assumed that maintenance will be undertaken in accordance with best practice mitigation measures in view of the company-wide biosecurity plan. The aim of such mitigation should be to prevent the transfer of biological material to and from the site. Implementation of mitigation during the maintenance activities would likely reduce risk to a negligible level.

Table 5.22 Risk Scores pre and post mitigation

Activity Based Risk Score			
Construction Activity Risk			
Pre mitigation	**Major Risk**	**Post Mitigation**	**Negligible**
Operational Activity Risk			
Pre mitigation	**Major Risk**	**Post Mitigation**	**Negligible**
Maintenance Activity Risk			
Pre mitigation	**Major Risk**	**Post Mitigation**	**Negligible**

5.7.5 Summary

Overall, the perceived INNS transfer risk relating to the construction, operation and maintenance of the Hawk's Tor Pit drought permit is assessed as negligible assuming the mitigation described above is employed. The source of the transfer being within a small watershed area (~3km2) that is predominantly agricultural grazing is a low-risk raw water source supported by a lack of INNS occurrence records. The major INNS-specific risks relating to the scheme are from secondary pathways to and from Hawk's Tor Pit, Colliford reservoir and constructions sites or compounds. Mitigation, as described above, should aim to prevent the spread of INNS through the application of best-practice biosecurity protocols and stakeholder engagement.

Currently, our understanding of the INNS community within proximity to the abstraction location and scheme infrastructure is limited by the availability of occurrence records within

NBN Atlas and from onsite observations. In most instances, these records are not captured as part of targeted INNS monitoring but are instead the product of site observations during various ecological surveys or citizen science programmes. Therefore, additional, systematic monitoring prior to implementation would provide additional confidence in the above assessment and inform any requirement for additional mitigation.

Table 5.23 Summary of impact (INNS) post-mitigation

Receptor	Sensitivity	Significance of impact	Confidence level
Invasive non-native species	Not sensitive	Minor	Medium

5.8 Geology, Palaeoenvironmental Sequences and Slope Stability

5.8.1 Baseline

As with all projects concerning new abstractions from lakes or reservoirs, it usual to consider the impacts of the water level draw down on side slope stability within the waterbody. Further data on bank composition and structural integrity was required to progress this assessment.

In addition, and as above, the site partially falls within the Hawk's Tor Pit Site of Special Scientific Interest (SSSI). This was designated as a geological SSSI in 1993 due to the presence of superficial Late Quaternary and Early Holocene waterlogged deposits, containing well preserved pollen sequences important in demonstrating and interpreting landscape responses to rapid climate change for the period in upland south-west England.

There is a requirement that proposed works should consider potential impacts on alluvial and peat deposits in the locality of the Site; because water level changes in the landscape could affect the preservation of peat deposits and any associated palaeoenvironmental and archaeological assets within them preserved by the waterlogged, anaerobic environment offered.

Superficial deposits of peat are shown on the geological map surrounding the eastern side of the reservoir, and extending upslope onto the moors, forming the bed of the Warleggan River. It is known to have formed between 2.5 million years ago and the present. There are no superficial deposits shown beneath the northern, southern or western parts of the site.

Although not shown on geological maps, the BGS (catalogue of Artificial Ground) shows artificial ground covering the whole western, southern and western margins of the reservoir. It is assumed this is spoil from the processing of the kaolinized granite at the site. Historic map regression carried out for this EAR did not yield further evidence of type and location of spoil material.

The site shows exposures of peat deposits of varying thicknesses, grading into and underlain by unconsolidated gravels/solifluxion deposits, which are in turn underlain by the weathering products of the Bodmin Moor Granite. To the west and north-west of the site, there is a near vertical granite cliff with only thin covering deposits of peat and gravels. The cliff face looks to be relatively unstable and prone to slumping as there are debris piles at the base.

Ground levels fall to the north and east, and in these areas, the peat and underlying gravels thicken. The peat here is slumped over the gravels and in some limited areas extends down to the water's edge.

Along the water edge beneath the north and east sides of the pit is a beach comprised of an angular grit of coarse sand/fine gravel. From the profile of the granite bedrock, it is expected to grade into intact granite at shallow depth.

The British Geological Survey (BGS) online viewer shows the bedrock geology beneath the whole district comprises the Bodmin Granite Intrusion, an igneous bedrock formed between 330.9 and 272.3 million years ago during the Carboniferous and Permian periods.

5.8.2 Impact assessment

Lake level draw down due to the operation of the Drought Permit may be a critical factor in the stability of slopes that are currently partially or totally submerged. The lake side sand/gravel beaches would be expected to be secure against rapid drawdown as the water level inside the slope will quickly equalize with that outside the slope (i.e. the lake water level); draw-down is not expected to result in slope instability in this material.

The underlying granite is intact and is standing near vertical where it is exposed in the quarry. This suggests it would also not be affected by draw down even where it is currently submerged. Anecdotally, the Drought Order abstractions during 1996 resulted in a maximum water level draw down within Hawk's Tor Pit of 11.78m (Table 4.8 above) without reported accounts of associated bank instability.

In addition, as described under Designated Sites above, the geological SSSI has no dependence on water level within the pit and no equivalent sequences have been recorded within Hawk's Tor quarry pit that could be directly impacted by dewatering or carving during draw-down.

Based on this the sensitivity of the geology, Quaternary geology and slope stability is deemed to be **Not sensitive** and the overall significance of impact from the Drought Permit is predicted to be (worst case) **Minor,** with **Medium** confidence of the assessment.

5.9 Tourism and Recreation

Public access to Hawk's Tor Lake is very limited, as there are no footpaths or roads available to the public that can be accessed around it. However, the land to the east of the lake is part of Brockabarrow Common Registered Common Land, and therefore is accessible to the public, despite the lack of formalised paths or roads.

There are no notable settlements or communities in the immediate vicinity of the site. The nearest is the small village of Temple, approximately 1km south. The artificial barrier of the A30 would make Brockabarrow Common and the Hawk's Tor Pit area a less likely local walking/dog walking spot than other locations near to the village. The nature of the proposals are such that any impacts on visitors and users would be limited.

Sensitivity to tourism and recreation is therefore considered to be **low**, the magnitude of impact is **low** and the overall significance of the impact **minor**.

The receiving Colliford reservoir offers numerous leisure activities such as lakeside walks, fishing, and picnic areas. Works should endeavour to avoid any negative impact to the public accessing and enjoying these facilities.

5.10 Aesthetics and Landscape

The site is located in the Bodmin Moor Landscape Character Area (LCA). The LCA description states that:

"this is a tranquil and variable area, from intimate enclosed valleys to wide high moorland. The granite tors and wild moorland have a genuine sense of wilderness where, despite the unique remains of extensive relict landscapes and the influence of thousands of years of human manipulation of the landscape, the forces of nature are still dominant".

All proposed development should consider potential impacts on this landscape, aesthetics and also, as above, the nearby palaeoenvironmental sequences which hold a record of that past use and landscape.

The sensitivity of the receptor is considered to be **medium**.

Notably, a previous planning application to turn the lake into an aqua park, with associated facilities, was rejected primarily due to the negative impact the scheme would have on the landscape.

The most significant expected visual impact is the lowering of the water levels due to the increased abstraction. An additional visual impact is the creation of two floating pontoons on the lake, as well as orange buoys to identify the associated floating pipework. A small compound has been created for construction purposes on the site of pre-existing parking/infrastructure.

Hawk's Tor Pit has relatively restricted views from the surrounding landscape, with impact to visual amenity affecting a relatively low number of people using the common land to the east. The changes to the lake surface and water level would also be visible briefly for drivers on the A30.

The abstraction would not exceed the maximum drawdown limit of 12m (that was permitted in the 1995/96 drought orders), therefore the magnitude of impact is **low,** and overall significance of impact on the wider landscape receptor is considered to be **minor**.

5.11 Archaeology and Heritage

5.11.1 Approach to Archaeological and Heritage Assessment

This assessment considers the potential for physical change or harm to buried archaeological assets, as well as any change to setting, character and significance (both tangible and intangible) to heritage assets. This captures both designated and non-designated heritage assets in accordance with current best practice and standard guidance.

A 500m buffer area around the site has been used as the study area.

The assessment has drawn on the following data sources, though does not constitute a detailed examination:

- Review and summary of Cornwall and Isles of Scilly Historic Environment Record (HER) data pertaining to the study area;

5.11.2 Review of Historic Landscape Characterisation data relevant to the study area. Baseline evidence

The site is located within an area which is rich in both designated and non-designated heritage assets. These illustrate that there is both potential and evidence for the survival of a wide range of assets including:

- Prehistoric occupation, several hillforts, isolated artefacts and evidence of agricultural practice.
- Medieval settlement (including a submerged settlement within Colliford Lake itself and several examples of Deserted Medieval Villages), ecclesiastic structures, alluvial/stream works/reservoirs, evidence of peat extraction and evidence of agricultural practice.
- Post medieval industrial practice, variable scales of settlement and agricultural structures.

A range of Listed Buildings are known in the area, largely reflecting the post medieval agricultural landscape of small clusters of farmsteads.

5.11.3 Summary of impacts

Because of the presence of designated (Listed) structures in the wider landscape, presence of waterlogged alluvial and peat sequences, and in particular the range of likely well preserved and coherent prehistoric remains, intrusive works in the area have the potential to impact upon the historic environment. The sensitivity of the receptor is therefore considered to be **medium**.

Water level changes in the landscape could affect the preservation of peat deposits (and any archaeological assets within them) while intrusive works could lead to the loss (in whole or in part) of buried archaeological assets. The proposed works considered within the EAR are not expected to involve any intrusive excavations (as existing pipework infrastructure will be used within the terrestrial environment for pumped flows to Colliford Reservoir), therefore the magnitude of impact to nearby heritage assets is considered to be **minor**, although the potential impacts arising from wider construction and enabling works should also be considered by SWW and their agents, including power supply installation should be considered separately by the designers and Principal Contractor.

The drawdown of water from Hawk's Tor Pit will not be to a level below that of the 1995/1996 abstractions and a lack of hydrological connection between significant and designated waterlogged sequences to the north (within the geological SSSI) has been described. Overall, the magnitude of impact to submerged heritage features is considered to be **minor**.

Wider changes have the potential to change how built heritage assets are appreciated, and in particular the submerged structures in Colliford Lake may be disturbed/exposed by changes to the level of water flow. This aspect of the project may require further evaluation and mitigation, whilst recognising that the annual draw-down of water level with Colliford reservoir would be expected as a result of normal operational use.

5.12 Impact Assessment on Receptors Summary

This report measured and modelled lake level and river flow data together with walkover and bathymetric survey data to predict hydrological impacts under the proposed drought permit. The results of the hydrological modelling and other analyses have been used to assess baseline data and predict potential impacts, a summary of all receptor impacts is provided in Table 5.21.

Table 5.21 – Summary of assessment of unmitigated impact on pathways and receptors for the proposed Hawk's Tor Pit Drought Permit.

Feature	Description	Magnitude of impact / Significance of impact on receptor	Level of confidence	Monitoring required? (Y/N)	Mitigation required? (Y/N)
Pathways	Lake water level	High	Medium		
	Flow on the Warleggan River	High	Medium		
	Lake Hydromorphology	Negligible	Medium		
	Water Quality	Medium	Medium		
Receptors	Designated sites				
	Hawk's Tor Pit SSSI	Minor	Medium	N	N
	Bodmin Moor North SSSI	Minor	Medium	N	N
	Cabilla Manor Wood SSSI	Minor	Low	Y	N
	Bodmin Moor North CWS (NC/CN7/N)	Minor	Medium	N	N
	South West Moor (NC/CN7/S1)	Minor	Low	Y	N
	Blacktor Downs (NC/CN7/S3)	Minor	Low	Y	N
	Hardhead Down and Warleggan Down (NC/CN7/S2)	Minor	Low	Y	N
	WFD Status				
	GB108048007630 WFD ecological status	Moderate	Medium	Y	Y
	GB108048007630 WFD chemical status	Minor	High	N	N
	Macrophytes and Phytobenthos				
	Phytobenthos	Minor	High	N	N
	Macrophytes	Moderate	Low	Y	Y
	Macroinvertebrates				
	Macroinvertebrates	Moderate	Medium	Y	Y
	Fish				
	Atlantic salmon	Moderate	Low	Y	Y
	Sea/Brown trout	Moderate	Low	Y	Y
	Bullhead	Minor	Medium	N	N
	European eel	Minor	Medium	N	N
	NERC and other notable species and habitats				
	Otter	Minor	Medium	N	N
	NERC habitats (Lowland Fen/peatland/wet woodland)	Moderate	Medium	Y	Y
	INNS				
	Invasive Species	Minor	Medium	N	N
	Geology and slope stability				
	Impact to lakeside slope stability	Minor	Medium	Y	N
	Tourism and recreation				
	Impact to public and visitors	Minor	High	N	N
	Aethetics and landscape				
	Impact on wider landscape	Minor	High	N	N
	Archaeology and heritage				
	Heritage Assets in the surrounding area	Minor	High	N	N
	Submerged and waterlogged Heritage Assets in and around Hawk's Tor Pit	Minor	Medium	Y	N

6. Mitigation Measures

There is a risk of **Moderate** impacts on the Warleggan River for resident Atlantic salmon, sea/brown trout, macrophytes and macroinvertebrates under the drought permit scenario. There is also a **Moderate** risk of impacts from the reduction of water level within Hawk's Tor Pit on the surrounding NERC habitats including limited areas of wet woodland, lowland fen and other peatland under the Drought Permit scenario.

A number of mitigation options have been agreed with the Environment Agency that are embedded and secured within the Drought Permit application, these include:

- Provision of a compensation flow of 32 l/s (Dec-Apr inclusive) through natural gravity overflow and/or temporary pumps from Hawk's Tor Pit into Warleggan River.
- Provision for two artificial spates (on written request from the EA) for twelve hours duration during December 2022 at 96 l/s to aid migration of salmonid fish.
- Provision of a post drought permit compensation flow of 18 l/s (Mar-Sept inclusive) until 30 September 2023 or until recovery of Hawk's Tor Pit to TWL, whichever is sooner.
- Provision of three artificial spates for twelve hours during May 2023 at 32 l/s to aid migration of salmonid smolts.
- Provision of two artificial spates for twelve hours between October and December inclusive 2023 at 96 l/s to aid migration of salmonid fish.
- Compensation flows will be increased should environmental monitoring identify a need for increased flows, or should the Environment Agency require, at their discretion.
- Provision for fish rescue team to support migration of fish around Hawk's Tor Pit and in the Warleggan River as TWL is drawn down.
- A commitment to provide further compensation and artificial spates in the autumn of 2023, in the event that of Hawk's Tor Pit does not return to TWL.
- A commitment to maintaining a 'Hands-Off' Water Level of TWL-12m (i.e. 220.5m AOD) as part of its Drought Permit operation in order to minimise any risks to slope stability around Hawk's Tor Pit.
- Best practice screening will be implemented to mitigate the risk to fish and any potential INNS transfer from within the lake for both the abstraction of water for supply and provision of a downstream compensation.
- Installation of continuous (15 minute interval) water quality monitoring on the outlet of Hawk's Tor Pit to assess changes in water quality and provide trigger levels for actions in the event of any deterioration in water quality.
- Provision of ditch management, to restrict flow and hold water within the peatland habitat. Parallel to the south-eastern shore of Hawk's Tor Pit is a ditch that runs parallel to the lake edge and merges with the marsh habitats at the outflow from the lake. Atop the ridge of this ditch is an outcrop of peat. It is proposed that blocking the ditch along its length at intervals and at the exits, so that it fills with water, some level of protection for the peatland area behind the stranded strip can be achieved. This

strip will then act as a bund keeping the mire community further back wet, during draw downs.

- Increase sand bank provision on the south-western end of Hawk's Tor Pit to retain water in the saturated wet fenland habitat, that would otherwise be drained during the drought permit operation.
- Walkover surveys will be used to assess any risks to fish and in particular salmonids in the Warleggan River and Hawk's Tor Pit, once water levels are drawn down and hydrological connectivity with the downstream Warleggan is lost and during the pit recovery period.
- Screening of pumps to avoid entrainment of fish – 2mm screening to be applied to all pumps for abstraction and compensation flow.

Additional mitigation measures may include the following, based on site observations during the drought permit:

- Provision of ditch management, to restrict flow and hold water within the peatland habitat. Parallel to the south-eastern shore of Hawk's Tor Pit is a ditch that runs parallel to the lake edge and merges with the marsh habitats at the outflow from the lake. Atop the ridge of this ditch is an outcrop of peat. It is proposed that blocking the ditch along its length at intervals and at the exits, so that it fills with water, some level of protection for the peatland area behind the stranded strip can be achieved. This strip will then act as a bund keeping the mire community further back wet, during draw downs.
- Increase sand bank provision on the south-western end of Hawk's Tor Pit to retain water in the saturated wet fenland habitat, that would otherwise be drained during the drought permit operation.
- Observation of the quarry pit section as drawdown takes place to gauge sedimentary sequence and effects on stability or hydrological/ physical interconnections with the peatlands.
- Feedback and improved calibration of the hydrological model in light of measured flow/ recovery rates during abstraction
- Walkover surveys will be used to assess any risks to fish and in particular salmonids in the Warleggan River and Hawk's Tor Pit, once water levels are drawn down and hydrological connectivity with the downstream Warleggan is lost and during the pit recovery period.
- If low lake levels extend to downstream migration of silver eels (Autumn 2023), fyke nets will be used to trap fish prior to transport to the downstream catchment. (NB: need for additional survey to confirm presence of silver eel in Hawk's Tor Pit).
- Screening of pumps to avoid entrainment of fish – 2mm screening to be applied to all pumps for abstraction and compensation flow.
- All pumping equipment to be retained on site to avoid spread of INNS. Compensation flow pump screens are self-cleansing (rota-flush) and the abstraction pump screens would be backflushed into the pit.

The development of mitigation recommendations has been based upon the assessment of sensitive receptors identified and are tailored to the characteristics of the study area and is informed by the assessment of environmental sensitivity presented in Sections 4 and 5 of this EAR.

Walkover surveys and other in-drought monitoring will provide information on the effects of the drought and drought permit/order implementation (Section 7) to inform decisions on the application of any mitigation measures. Further targeted surveys would then be required following implementation of mitigation measures to assess their success and to enable adjustment, as may be necessary (or to suspend the mitigation measure if it is shown to have an adverse effect).

As part of the construction and management of the abstraction works a construction environmental management plan (CEMP) should be produced to manage risk to the environment during installation and operation of the works, this will include measures to reduce the risk of INNS at Hawks Tor.

SWW has made a commitment to fisheries habitat enhancement in the reach of the Warleggan River between Hawk's Tor Pit and eth A30. Funding will be provided for a habitat assessment and enhancement project, the aim of which is to improve habitat for brown trout. The proposed scale may be extended beyond Water Company owned land with landowner permission.

- SWW will work with a delivery partner to deliver enhancement work on the Warleggan River targeting brown / sea trout habitat. The area targeted on the main river channel extends between the pit outflow (SX 15130 74373) and A30 bridge (SX 15109 74126) on the main Warleggan River. The west bank tributary stream in the vicinity of NGR SX 15027 74122 will also be targeted for enhancements. Both areas fall within SWWs land ownership.
- Specific proposals for habitat enhancement will be finalised and agreed with the Environment Agency prior to delivery. All proposals will be subject to relevant consents being provided, principally land drainage consent.
- Habitat works will need to align with SWWs long term management plan for the pit and will be developed to ensure they are complimentary to future plans for the routing of the Warleggan River. A budget up to £20K will be available for the work, which we will deliver during Summer 2023.

To achieve a full assessment of the potential and to draw up a restoration plan there is a holding line in PR24 WINEP for an investigation that EA requested and SWW support. This will look into peatland restoration, BNG and the natural capital potential of the site.

No further on-site monitoring of the water levels in the peat (as previously suggested by use of piezometers) is necessary under the Drought Permit. This will not provide any further useful eco-hydrological data

6.1 Assessment of impacts previously deemed moderate with implementation of mitigation measures

Table 6.1: Summary of impact with mitigation measures

Pathway/Receptor name	Mitigation description	Significance of impact on receptor before mitigation	Significance of impact on receptor after mitigation
Atlantic salmon	Artificial spate events where compensation flow is increased for a 12 hr period during key times of year for migration. Winter (2 x 96 l/s), spring (3 x 32l/s), and autumn (3 x 96 l/s) If fish are observed to be trapped, or in distress, during the proposed drought permit a number of measures could be taken. The decision on which method to deploy should be taken in discussion with the Environment Agency, and according to the specific nature of the problem. Options may include: a) Deployment of localised aeration; b) Installation of fish refugia in spatially limited areas; c) Fish rescue and relocation if no other suitable alternative is available.	Moderate	Minor
Sea/Brown trout		Moderate	Minor
Macrophytes (WFD Ecological Status)		Moderate	Minor
Macroinvertebrates (WFD Ecological Status)		Moderate	Minor
NERC Habitats	Blocking a ditch so that it fills with water so that the strip can then act as a bund keeping the mire community further back wet, during draw downs. Additional measures may include alteration to sand bank to retain saturated lowland fen habitat on the southern corner of Hawk's Tor Pit, to be confirmed through monitoring of habitat change and risk during permit.	Moderate	Minor

7. Environmental Monitoring Plan

7.1 Introduction

An EMP has been developed which includes baseline, pre-drought permit implementation, during-drought permit implementation and post-drought permit implementation monitoring.

It is important to note that the level of monitoring is risk-based. The environmental assessment indicates that the proposed drought permit presents a low risk to the environment (negligible or minor negative impacts are predicted for most receptors) with the exception of fish populations, NERC habitats and macrophytes, where moderate impacts are possible depending on the success of the compensation flows and the reactive of communities during the drought event. Given the latter moderate effects, and uncertainties inherent in some of the assessments, monitoring has been recommended, to check the predicted degree of impact, and identify any unexpected impacts in order to trigger further mitigation measures, if needed.

7.1.1 Baseline monitoring

Baseline monitoring is required to formulate a description of the existing ecological conditions, from which the impacts of the drought permit over and above the effects of other pressures, such as natural drought, can be identified. Baseline monitoring can also help to establish the sensitivity of the environment to changes in flow and improve the level of confidence in the assessment of likely impacts. Due to the short timeline to apply for and implement the drought permit, in this case baseline monitoring can be merged with pre-drought permit monitoring.

7.1.2 Pre-drought permit monitoring

Pre-implementation monitoring should be triggered by SWW drought permit preparations and undertaken prior to implementation of a drought permit. Pre-implementation data can be important to demonstrate the precise baseline conditions ahead of the proposed changes.

7.1.3 During-drought permit monitoring

During-drought permit monitoring is required to assess any impacts from the implementation of the drought management action and for the management of mitigation measures.

It is recommended that monitoring during drought permit period continues as per the pre-implementation period, except where, in consultation with the EA, it is deemed that such monitoring may be environmentally damaging.

7.1.4 Post-drought permit monitoring

Post-drought permit monitoring aims to assess a site's recovery and to check that there are no long-term effects on any environmental features. This is important as results are needed to assess the success of mitigation measures. It can also feed back into the assessment of sensitivity and likely impact and inform the management of future drought/licensed abstractions.

The implementation and duration of post drought permit monitoring will depend upon the severity of the natural drought and of any detected impacts on the environment but will cover the period of recovery and will be carried out in consultation with the regulator.

7.2 Hawk's Tor Pit Environmental Monitoring Plan

A summary of the EMP for Hawk's Tor Pit drought permit is presented in Table 7.1.

Table 7.1 Summary of monitoring and mitigation pre, during and post drought permit

Pathway/ Receptor	Potential Impact identified in EAR	Gaps in Baseline Monitoring	On-set of requirement of Drought Permit	During Drought Permit Implementation Period		Post Drought Permit
				Trigger and monitoring to inform mitigation action	Mitigation actions triggered by monitoring	Monitoring and post-drought mitigation (where applicable)
Hydrology: Groundwater level	Risk of groundwater draw down and a lack of groundwater level data	SWW has initiated a field monitoring programme as part of a programme of longer-term monitoring of groundwater levels within both the peat deposits, wet fenland habitat and at depth within the granite strata; the results from this ongoing monitoring will help determine the extent to which groundwater feeds the lake; the depth at which this occurs within its c.30m water column depth; and its relative significance within the context of the overall hydrological balance of the lake.	Continue monitoring the groundwater levels for the sites listed in the field programme.	Continue monitoring the groundwater levels for the listed observation sites	Not applicable	Continue monitoring the groundwater levels for the listed observation sites
Hydrology	Reduction in water level of Hawk's Tor Pit and a reduction in flow in the Warleggan River	SWW has implemented an enhanced hydrological monitoring programme, which will measure water level and flow on a 15-minute interval over a 12-month period within the lake, its outflow channel and on the Warleggan River, just downstream of its confluence with the lake outflow channel. These data will be used to refine the understanding of the hydrological balance of the lake and the Warleggan River. At the locations listed below. National Grid References to be agreed in writing with the Agency: Continuous flow measurement at the following locations: • Site 1: Hawk's Tor Pit outlet at NGR SX 15128 74369 • Site 2: River Warleggan, downstream of the pit confluence at NGR SX 15130 74182C Compensation flow from magflow metre at NGR SX 15134 74445 Spot flow gauging at the following locations: • Site 3: River Warleggan (Brockabarrow Common), upstream of pit confluence at NGR SX 15155 74212 • Site 4: Pit inflow 1, East Bank at NGR SX 15225 74485 • Site 5: Pit inflow 2, North bank at NGR. SX 15094 74865 • Site 6: Pit inflow 3, North bank at NGRSX 15085 74871 • Site 7: Pit inflow 4 at NGR SX 15063 74879	Lake in-flow and out-flow volumes measured monthly via manual gauging Flow upstream of the Warleggan River north of the A30 (new temple bridge) by monthly manual gauging Continuous levels of Hawk's Tor Pit measured and recorded via telemetry. Continuous compensation flow readings to Warleggan River; reported weekly for the daily average, based on pumped rates and/or stage discharge relationship in pit outflow channel. Daily abstraction volume via installed meter on the pump pontoon collated as daily a total and reported weekly.	Continue monitoring lake water levels and river flow regime Weekly walkovers during drawdown period. Wetland areas to include mapping/photographs of how the Drought Permit impacts on the hydrology of the wetland area.	Water level monitoring to trigger hands off level at TWL-12m. Compensation flow SWW will provide further compensation and artificial spates in the autumn of 2023 in the event that of Hawk's Tor Pit not returning to TWL	Continue monitoring lake water levels and river flow regime
Water Quality	Potential reductions in water quality due to reductions in flow.	Limited spatial coverage of data for this reach.	Regular monitoring: Parameters to be sampled for are soluble reactive phosphorous (SRP), dissolved oxygen,	Carry out water quality monitoring at the baseline survey sites during low flow conditions to assess impacts of	Consider measures to address identified point sources of nutrient	Repeat water quality sampling activity for 3

Hawk's Tor Pit **Warleggan River**		In-situ spot water quality monitoring at two locations of Warleggan River; downstream of Hawk's Tor outflow (SX1514374312) and at Cabilla Wood/Warleggan River road bridge (SX1478968927) Water quality multiparameter logging instrument – sondes - will be used to measure dissolved oxygen, conductivity, turbidity and temperature in the field using calibrated handheld equipment/or in situ continuous (15 minute interval) water quality sonde in the Hawk's Tor Pit outlet channel	ammoniacal nitrogen (freshwater), pH, turbidity, conductivity, and water temperature in the field using calibrated handheld equipment. Appropriate trigger values would be set for level and/or flow based on local circumstances, timing, seasonality and expert opinion	drought permit. Parameters to be sampled for are soluble reactive phosphorous (SRP), dissolved oxygen, ammoniacal nitrogen (freshwater), pH, turbidity, conductivity, and water temperature. Frequency to be determined in agreement with EA.	loading if SRP readings are high. Alert trigger levels • dissolved oxygen (DO) <50% • temperature (dec C) >20 • turbidity (NTU) >100 Compensation measures/monitoring should be set aside where the agreed trigger levels are exceeded as a result of: • artificial spate events requested in writing • natural spate/adverse weather events • fisheries habitat enhancement work	months after cessation of the drought permit or until Hawk's Tor pit returns to TWL after 30/04/2023 Frequency to be determined in agreement with EA.
Macrophytes **Downstream of Hawk's Tor Pit**	Reduction in abundance or distribution as a result of reduced water quality / habitat.	Carry out macrophyte surveys at 2 sites downstream of Hawk's Tor Pit, between June and September 2023. Complete one survey on a suitable control site.	Seasonal walkover and carry out macrophyte surveys at the baseline survey sites (if during plant growing season) Carry out water quality sampling at same time including samples for Soluble Reactive Phosphate (SRP). Appropriate triggers: Significant impacts of ecological distress, and/ or if reduced flows are considered to be having serious detrimental environmental consequences on downstream waterbodies	Survey to be undertaken and macrophytes identified (if drought permit implemented in plant growing season) Walkover survey to identify any key sources of nutrient loading. Carry out water quality sampling at the baseline sites including samples for SRP.	Presence of algal blooms or establishment/expansion of filamentous green algae. Consider measures to address identified point sources of nutrient loading. Consider scope for addressing any identified sources of nutrient loading from walkover survey, if this would help address water quality risks. Consider possible in-stream measures or adjustments to improve habitat conditions.	Carry out post-drought permit implementation surveys at the baseline monitoring sites for 2 consecutive summers after the permit to understand the extent of recovery from any adverse impacts. No specific post-drought permit mitigation measures identified.
Macroinvertebrates **Downstream of Hawk's Tor Pit**	Reduction in abundance or distribution as a result of reduced water quality / habitat.	Carry out multi-seasonal macroinvertebrate surveys each year. Sampling to occur at 2 sites downstream of Hawk's Tor Pit and suitable control site(s). Identify specimens to species/mixed taxonomic level.	Seasonal monitoring of macroinvertebrates at the baseline survey sites. Samples to be collected and identified to species level.	Seasonal monitoring of macroinvertebrates at the baseline survey sites. Samples to be collected and identified to species level.	Consider possible in-stream measures or adjustments to improve habitat conditions.	Carry out post-drought permit implementation surveys at the baseline monitoring sites for 2 consecutive summers after the permit to understand the extent of recovery from any adverse impacts.

Fish community, including sea/brown trout, Atlantic salmon, European eel, and Bullhead **Within Hawk's Tor Pit** **Within Warleggan River**	Sedimentation of spawning habitat Reduced physical flow for upstream migration of salmonid Potential exposure of habitat used to by fish to spawn Loss of wetted area within the channel Reduction in abundance or distribution as a result of reduced water quality.	Baseline walkover surveys to identify and map salmonid spawning and juvenile and lamprey ammocoete habitat quality and geomorphology. Fish populations within Hawks Tor pit. The target area is between Hawk's Tor outflow (SX1514374312), downstream to the confluence with the Blacktor Downs tributary (SX1502673571) and to the accessible limit approaching Cabilla Woods from Cabilla Wood/Warleggan River road bridge (SX1478968927)	Weekly walkover survey of lake for fish in distress, specifically to target times of downstream migration and should pooling occur in the lake. Salmon redds at risk of exposure, downstream of Hawk's Tor Pit.	Weekly habitat walkovers To include: walkover survey of the same reaches to identify signs of environmental stress (fish in distress, dry channel in identified spawning areas, etc.). Particular attention needs to be given to known lamprey ammocoete habitat and salmonid spawning areas/mapped redds to ensure there is sufficient flow over them and that they are not at risk of exposure. It will be necessary to recognise and report redds mapped during previous weeks. These walkover surveys will be undertaken at least three times before their need is reviewed (over the first month of the drought permit implementation) if climatic conditions should change (heavy rainfall), but by default should be carried out throughout the duration of the DP. Frequency will reduce to monthly if null impact shown Redd counting and mapping conducted weekly Dec -Jan – inclusive. Reports to IEP inbox (ieppdevonandcornwall@environment-agency.gov.uk) within one week of survey. Liaison will be required between the consultant undertaking this work and EA Fisheries prior to work commencing. Targeted observation walkover surveys – Assess fish passage from the lake to the northern Warleggan River tributary as the lake level draws down. Timing to be agreed with the EA. Visual assessment of sea trout accumulation within Hawk's Tor pit to be delivered in January (2 x surveys). Visual assessment of smolt accumulation within Hawk's Tor pit to be delivered in April and May (3 x surveys) eDNA sampling of Hawks Tor pit to understand fish populations.	Consider deployment of aeration equipment in key reaches/water bodies with critically low oxygen levels. Consider possible in-stream measures or adjustments to improve habitat conditions. In extreme cases, consider capture/rescue surveys for fish. It is noted these will need sufficiently sized aerated holding tanks as it is unlikely that they can be moved to elsewhere in the catchment. [to be agreed with EA if this should be a mitigation measure] Consider additional releases either from Hawk's Tor Lake to the Warleggan via temporary augmentation Provision of artificial spates (on written request from eth EA) to aid migration of salmonid smolts at key times between November to December 2022, and April to May 2023 will be informed by surveys.	Weekly habitat walkovers to include: walkover survey of the same reaches to identify signs of environmental stress (fish in distress, dry channel in identified spawning areas, etc.). Particular attention needs to be given to known spawning areas/mapped redds to ensure there is sufficient flow over them and that they are not at risk of exposure. Should this be indicated compensation flow from Hawk's Tor Pit will be required. Juvenile Electric Fishing Surveys – Fully quantitative surveys. 2023 electric fishing surveys on EA sites known as: Temple (8423), u/s Maidenwell (8424) and Tank Bridge (22991 A final report will be produced after the spawning run providing a review of the 'potential spawning population' data gathered during the walkovers and subsequent analysis against flow/level/rainfall data with consideration of a) fish/redd

						counts, patterns and trends, b) the influence of the DP on migration during implementation
Designated sites	Reduction of wetted width or river flow impacting on habitat features downstream of Hawk's Tor	Confidence is low in assessments for: South West Moor (NC/CN7/S1), Blacktor Downs (NC/CN7/S3), and Hardhead Down and Warleggan Down (NC/CN7/S2) Walkover Surveys to identify condition of habitat and any vegetation change, including taking a baseline photo record and site notes at: Peatland in the vicinity of SX 15200 74400; Wetland fen at SX 15130 74373; and Warleggan River Flood Plain at SX 15118 73995. to be carried out weekly between December 2022 and April 2023 and then monthly thereafter until October 2023.	None	Flow gauging and flow accretion modelling	Not applicable	Following the wetland monitoring we require a report on how the drought permit has impacted on the wetland area. Post Drought Permit follow up wetland habitat mapping to be done to NVC standard.
Invasive non-native species (INNS)	Risk of increasing the potential for this species to spread along watercourse	Collate available local records to improve baseline datasets.	Visual monitoring at agreed locations during walkovers.	Presence detected of INNS at key sites. Ensure all site operators follow check, clean, dry protocols to reduce spread to Hawk's Tor Pit.	Depending on findings of walkover survey and risk assessment, agree with EA any appropriate risk reduction or control measures taking account of national INNS advice prevailing at the time on control and risk management measures. Establishment and/or expansion of invasive non-native species	Complete walkover survey of impacted reaches post drought to understand any changes to the coverage of species. Carry out clearance where appropriate to do so in dialogue with the EA and taking account of national INNS advice prevailing at the time on control and risk management measures.
Geology	Risk of bank collapse as water level in the lake is drawn down.	Implement weekly assessment of bankside stability of Hawk's Tor SSSI exposed faces during draw-down.	Continue weekly assessment of bankside stability of Hawk's Tor SSSI exposed faces during draw-down	Continue weekly assessment of bankside stability of Hawk's Tor SSSI exposed faces during draw-down		
Tourism and Recreation	Potential reduction in river flows having adverse effect on water-dependent features of this site	Discuss potential impacts on any water-dependent features of this heritage asset with the site owner and understand how the drought permit might impact on these features. Agree scope for any monitoring or mitigation measures.	None.	Regular contact with site owner to understand how the drought permit may be affecting local residents.	Supplementary flows downstream to maintain river flow.	None

Aesthetics and Landscape	Minor visual impact to walkers on common land to east and drivers on A30.	Visual amenity of Hawks Tor Pit should be monitored during drawdown.	None	None	n/a	Any unsightly visible structures should be removed from Hawks Tor Pit after the completion of the permit period.
Archaeology and Heritage	Minor risk to submerged heritage features resulting from drawdown, and changes to flow to Colliford Lake.	Further evaluation should be done on the effects of drawdown and increased water flow to Colliford Lake on heritage features in the area.	None			None needed.

8. References

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Appendices

Appendix A: Hawk's Tor Peat Study Field Notes (D. M. Smith (SWW))

(Figure denotes locations of field notes at Hawks Tor pit)

Field Notes on Map

1. Marginal vegetation flooded (upto 30cm) by raised water levels in lake due to recent rains. Molinia*, Juncus acutiflora, Rubus* sp, *Circium* sp and common grass species. Nothing of note.
2. peatland horizons exposed by clay pit being dug through them, upto 3m above the lake level, on 70cm+ of clay and granite rubble, with at least 1m of peat on top of it. Dry collapsing face.
3. Soft rush and Molinia tussocks on top of the remnant dry peats, no Sphagnum, not a mire vegetation

4. Remant peat mass west of the stream going from leat to the lake is dry with non mire veg, but stream side has some aquatic species and Mesotrophic Sphagna.
5. Main flow of stream fast, oxygenated and not acidic, Potomagetons etc in flow. Incised channel, dropping of and channel head eroding back. Some peatland restoration opportunities from diverting the flow back in to the dry mire and channel blocking. For future assessment, not within scope of the visit, which was focused on draw down impacts.
6. West side of the stream the peat body is dominated by large Molinia and Juncus tussocks, with stream flow from the leat spreading between them. Again would benefit from blocking to reduce flow speeds and encourage more oxygen poor mire conditions. Not botanical interest currently. The lake edge margin of this large stranded peat mass is a cliff face covered with brambles. Already dry so no further draw down impacts
7. Wet woodland on steeply sloping banks above the lake level. Trees growing in the stranded peat, independent of the water level. Wetness in the wood is provided by surface run-off and streams (springs?) running down the slope. This is sustaining some woodland Sphagna which runs down to a thin lakeside strip which is inundated by higher lake levels. This would be impacted by lower lake levels, but it's a very small (negligible) area.
8. Foreshore all sands and limited vegetation other than rush inundated by higher water levels. One single small patch of wet heath extending to the shore on a shallow gradient area, with some Sphagnum- only $1m^2$.
9. Low lying wet willow clump that will be affected by draw down 10m x2m strip with Sphagnum present.
10. Further small wet patch on shoreline, with a single willow tree and a small amount of Sphagnum
11. Straight run of exposed peat face which is lower than the other sides and just in contact with the water of the lake by 10cm at normal lake levels. Draw down will dry this zone, hastening the decay of the peat face backwards to a small increased degree. The current vegetation on this historic peat deposit is non mire (rush and Molinia), indicating its already dry and decaying peat. Behind this peat face 5m back is a parallel ditch. A simple mitigation to the draw down would be blocking this ditch.
12. Low lying patch of wet mire on shore line, due to the ditch behind the face being shallow and over spill of water to the shore. This can be protected from draw down with a bund that could be put in place when the ditch is also blocked.
13. Dry beach
14. Wetland area behind informal low ridge of sand and gravels. This is low enough as a hollow to be wet all the time, but it is also inundated by lake levels when high. It will need to be protected from drawdown. This could be done by dragging up some of the lake edge sands and gravels to block the gaps in the ridge.
15. X2 snipe seen on site, one in the wetland above, the other near the leat breach.

Appendix B: Breakdown of Hawk's Tor Pit Water Quality Analysis

	ID	6205102	6219232
	Sampled Date	12/10/2022	20/10/2022
Parameter	**Unit**		
Benzo[a]Pyrene	ng/l	<0.5	
Benzo[b]Fluoranthene	ng/l	<0.5	
Benzo[ghi]Perylene	ng/l	<0.5	
Benzo[k]Fluoranthene	ng/l	<0.5	
Indeno[1 2 3-cd]Pyrene	ng/l	<0.5	
Total PAH	ng/l	0	
Bromodichloromethane	ug/l	<0.2	
Dibromochloromethane	ug/l	<0.3	
Tetrachloroethene	ug/l	<0.2	
Tetrachloromethane	ug/l	<0.2	
Tribromomethane	ug/l	<0.2	
Trichloroethene	ug/l	<0.2	
Trichloromethane	ug/l	<0.2	
Total THM	ug/l	0	
Benzene	ug/l	<0.2	
1 2-Dichloroethane	ug/l	<0.2	
Total Trichloroethene +Tetrachloroethene	ug/l	0	
Mass Spec Comments: No Significant organics detected	ug/l	<1	
Geosmin	ng/l	3	
2-Methylisoborneol	ng/l	<1	
Atrazine	ng/l	<7	
Bentazone Tot	ng/l	<2	
Bromoxynil Tot	ng/l	<6	

Chlorotoluron	ng/l	<5	
Chlorpyrifos	ng/l	<2	
2 4-D Tot	ng/l	<10	
2 4-DB Tot	ng/l	<7	
Diazinon	ng/l	<7	
Dicamba Tot	ng/l	<10	
Dichlobenil	ng/l	<3	
Dieldrin	ng/l	<4	
Diuron	ng/l	<7	
HCH (gamma-) (Lindane)	ng/l	<11	
Ioxynil Tot	ng/l	<4	
Isoproturon	ng/l	<4	
Linuron	ng/l	<12	
MCPA Tot	ng/l	<6	
MCPB Tot	ng/l	<8	
Mecoprop Tot	ng/l	<7	
Pendimethalin	ng/l	<3	
Pentachlorophenol Tot(PCP)	ng/l	<7	
Propyzamide	ng/l	<5	
Simazine	ng/l	<7	
Triclopyr Tot	ng/l	<4	
Fluroxypyr Tot	ng/l	<7	
Fenpropimorph	ng/l	<3	
Carbendazim	ng/l	<3	
Azoxystrobin	ng/l	<5	
Clopyralid Tot	ng/l	<9	
Dichlorprop Tot	ng/l	<9	
Epoxyconazole	ng/l	<16	
Asulam (Total)	ng/l	<12	
Picloram Tot	ng/l	<4	
Tebuconazole	ng/l	<7	
Diflufenican	ng/l	<3	
Cyprodinil	ng/l	<10	
Metaldehyde	ng/l	<1	
Boscalid	ng/l	<7	
Cyromazine	ng/l	<12	
Metamitron	ng/l	<10	
Propamocarb	ng/l	<9	
Quinmerac (Total)	ng/l	<2	
Total Pesticides	ng/l	0	
PFBS (375-73-5)	ng/l		
5:3 FTCA (914637-49-3)	ng/l		
3:3 FTCA (356-02-5)	ng/l		
7:3 FTCA (812-70-4)	ng/l		

6:2 FTAB (34455-29-3)	ng/l		
8:2 FTS (39108-34-4)	ng/l		
4:2 FTS (757124-72-4)	ng/l		
PFHxS (355-46-4)	ng/l		
PFDA (335-76-2)	ng/l		
PFBA (375-22-4)	ng/l		
PFHpS (375-92-8)	ng/l		
PFNA (375-95-1)	ng/l		
6:2FTS (27619-97-2)	ng/l		
PFEESA (113507-82-7)	ng/l		
PFPA (2706-90-3)	ng/l		
PFHxA (307-24-4)	ng/l		
PFHpA (375-85-9)	ng/l		
PFOA (335-67-1)	ng/l		
PFUnA (2058-94-8)	ng/l		
PFDoA (307-55-1)	ng/l		
PFOSA (754-91-6)	ng/l		
Linear PFOS(1763-23-1)	ng/l		
Ibuprofen Tot	ng/l		
Diclofenac Tot	ng/l		
Naproxen Tot	ng/l		
NFDHA (151772-58-6)	ng/l		
PFMOBA (863090-89-5)	ng/l		
PFMOPrA (377-73-1)	ng/l		
PFecHS (133201-07-7 / 646-83-3)	ng/l		
PFDS (335-77-3)	ng/l		
PFPeS (2706-91-4)	ng/l		
PFDoS (79780-39-5)	ng/l		
PFNS (68259-12-1)	ng/l		
PFTrDA (72629-94-8)	ng/l		
PFUnDS (749786-16-1)	ng/l		
HFPO-DA (Gen X) (13252-13-6)	ng/l		
HFPO-TA (13252-14-7)	ng/l		
DONA (919005-14-4)	ng/l		
EtFOSA (4151-50-2)	ng/l		
EtFOSE (1691-99-2)	ng/l		
NEtFOSAA (2991-50-6)	ng/l		
6:2 Cl-PFESA (756426-58-1)	ng/l		
8:2 Cl-PFESA (763051-92-9)	ng/l		
MeFOSA (31506-32-8)	ng/l		
NMeFOSAA (2355-31-9)	ng/l		
MeFOSE (24448-09-7)	ng/l		

PFTeA (376-06-7)	ng/l		
PFHxDA (67905-19-5)	ng/l		
PFODA (16517-11-6)	ng/l		
FBSA (30334-69-1)	ng/l		
FHxSA (41997-13-1)	ng/l		
Coliform (Pres) by MF	no/100ml	~80	~2500
E.coli (Pres) by MF	no/100ml	<10	~200
F.strep (Pres) by MF	no/100ml	~10	~50
Intestinal Enterococci (2 Dil) Pres	no/100ml	~10	~50
TVC at 22/3 Day	no/ml	135	
TVC at 37/2 Day	no/ml	31	
C.perfringens (Pres) by MF	no/100ml	3	~10
No of oocysts/l	no/l	0	
Blue Green Algae Total	cells/ml	0	
Green Algae Total	cells/ml	30	
Diatoms Total	cells/ml	<10	
Chryspophytes Total	cells/ml	170	
Unicell Flagellates Total	cells/ml	120	
Other Algae Total	cells/ml	1100	
Total Algae	cells/ml	1420	
Transmittance (Filtered) at 254 nm	%	85.1	82.1
Transmittance at 254 nm	%	80	80.7
pH (Langelier Index)	pH units	10.5	
pH in Water	pH units	6.8	6.8
Cond in Water	uS/cm	62.9	62.2
Dry Residue	mg/l	44	
Alk Bicarb HCO3	mg/l	9	9
Alk Carb HCO3	mg/l	0	0
Alk Hydr HCO3	mg/l	0	0
Alk at pH 8.3 HCO3	mg/l	0	0
Alk at pH 4.5 HCO3 Water	mg/l	9	9
CO2 Free	mg/l	1.96	2.25
Hardness Ca	mg/l	1.8	1.9
Hardness Carb	mg/l	2.9	2.8
Hardness Mg	mg/l	1.9	2
Hardness Non Carb	mg/l	0.9	1.1
Hardness Tot Ca	mg/l	3.8	3.9
Colour as Pt/Co	mg/l		8.7
Turbidity	NTU	0.12	0.46
DOC L/L	mg/l		
TOC L/L	mg/l	2.52	
N Tot Water&Waste C-O	mg/l		

TON NO3 Water	mg/l	<1.6	<1.6
NH4 Tot Water	mg/l	<0.08	<0.08
NO3 NO3 Water Calc	mg/l	<1.6	<3.51
NO2 NO2 Water	mg/l	<0.017	<0.017
Chloride Water	mg/l	14	17
PO4 Ortho P Water	ug/l	<16.5	
SiO2 Diss Water	mg/l	4.7	4.7
F Tot	ug/l	<100	<100
SO4 Diss Water	mg/l	<2.4	3.8
BrO3 Total	ug/l	<0.15	
Al Diss Water	ug/l	22.2	22.1
Al Tot Water	ug/l	33.9	29
As Tot Water	ug/l	1.5	
B Tot Water	ug/l	<7.1	
Ba Tot Water	ug/l	2.86	
Ca Tot Water	mg/l	1.8	1.9
Cd Diss Water	ug/l	<0.06	<0.06
Cd Tot Water	ug/l	<0.06	<0.06
Cr Diss Water	ug/l	<0.8	<0.8
Cr Tot Water	ug/l	<0.8	<0.8
Cu Diss Water	ug/l	4.47	<1.9
Cu Tot Water	ug/l	<1.9	<1.9
Fe Diss Water	ug/l	71.9	62.3
Fe Tot Water	ug/l	112	105
Hg Tot Water	ug/l	<0.04	
K Tot Water	mg/l	1	1
Mg Tot Water	mg/l	1.2	1.2
Mn Diss Water	ug/l	16.4	8.08
Mn Tot Water	ug/l	22.6	21.9
Na Tot Water	mg/l	8.2	8.4
Ni Diss Water	ug/l	<3.3	<3.3
Ni Tot Water	ug/l	<3.3	<3.3
Pb Diss Water	ug/l	<0.08	<0.08
Pb Tot Water	ug/l	<0.08	<0.08
Sb Tot Water	ug/l	<0.05	
Se Tot Water	ug/l	<0.52	
Zn Diss Water	ug/l	<21	<21
Zn Tot Water	ug/l	<21	<21
Rn-222 Tot Water	Bq/l		
Gross Alpha Tot Water	Bq/l	<0.02	
Gross Beta Tot Water	Bq/l	<0.054	
Tritium Water	Bq/l		
CN Tot Clean CO	ug/l		

Appendix C: Expanded Ecological Data

Location ID	NGR	Sample Date	WHPT NTAXA	WHPT ASPT	LIFE NTAXA	LIFE FAMILY	PSI FAMILY	CCI
Warleggan River (79079)	SX 1455073080	28/03/2013	31	7.5	28	7.93	72.88	23.23
		15/10/2013	26	6.83	24	7.38	68.29	
		18/03/2014	22	7.25	19	7.79	77.5	9.52
		10/09/2014	28	6.57	24	7.58	65.31	8.82
Warleggan River (10707)	SX 1583068100	28/03/2013	24	7.88	20	8.35	83.72	8.75
		15/11/2013	23	8.05	19	8.16	89.19	
		04/04/2014	30	7.68	26	8.04	83.67	14.54
		05/09/2014	27	8.13	23	8.22	84.62	15.27
		22/04/2015	30	7.8	26	8.27	82.76	10.85
		20/10/2015	22	7.54	20	8.1	84.62	10.28
		08/04/2016	31	7.56	29	7.69	73.58	21.56
		30/09/2016	22	7.54	20	7.85	88.57	10
		24/04/2017	30	7.98	27	8.07	79.31	15.17
		12/10/2017	21	7.87	19	8.16	86.49	10.42
		26/04/2018	27	7.83	22	8.23	86.96	13.65
		17/09/2018	28	7.64	23	7.91	79.55	14.64
		03/04/2019	33	7.95	29	8.03	83.93	22
		29/06/2020	26	7.79	21	8.1	80.49	15.12
		22/09/2020	27	7.74	21	8.05	80	18.57
		12/05/2021	31	7.83	27	8.15	83.05	15.87
		17/10/2021	29	7.57	25	7.84	82.61	13.67
		04/04/2022	30	7.74	26	8.04	83.64	16.55
Fowey (10706)	SX 1766064880	03/04/2013	25	7.4	21	8.14	78.26	
		10/10/2013	27	7.15	24	7.79	81.4	
		20/04/2015	31	7.3	26	7.96	77.78	8.84
		03/04/2019	32	7.21	27	7.89	75	15.56
		15/10/2020	23	6.65	21	7.76	69.77	10
		12/05/2021	27	7.51	23	7.87	76	14.78
		17/10/2021	32	6.88	28	7.36	65.45	14.88
St Neot River (10704)	SX 1810070710	17/04/2013	23	6.41	20	7.2	55.81	
		12/09/2013	24	6.05	20	7.3	60.98	
		20/03/2014	28	6.16	24	7.21	56	15.88
		05/09/2014	22	5.93	19	7	45.71	9.64
		10/04/2015	24	6.58	19	7.05	54.05	10
		19/10/2015	20	5.55	16	6.88	48.39	7
St Neot River (10690)	SX 1842067990	15/04/2010	26	7.92	23	8.04	75.44	
		15/09/2010	32	7.47	28	7.57	76.36	
		07/04/2011	31	7.8	27	8	74.24	
		27/09/2011	26	7.17	22	7.82	76.6	
		16/05/2012	33	7.65	28	8	80	
		20/09/2012	27	7.64	24	8.04	77.19	
		17/04/2013	27	7.62	23	8.04	78.85	
		15/10/2013	32	7.03	28	7.68	69.09	
		21/03/2014	26	7.17	23	7.87	77.08	14.95
		05/09/2014	32	7.33	27	8.11	73.02	15.12

		15/04/2015	35	7.56	30	7.8	73.02	19.33
		17/09/2015	29	7.33	25	7.96	72.73	14.37
		11/04/2016	27	7.95	23	8.13	86	14
		25/10/2016	27	7.15	24	7.54	69.77	13.26
		24/04/2017	29	7.58	24	8.13	82.14	14.7
		26/10/2017	27	7.14	23	7.78	73.47	14.32
		24/04/2018	30	7.07	26	7.58	72.73	10.82
		10/09/2018	22	6.4	18	7.44	67.5	12.78
		03/04/2019	31	7.51	27	7.89	75.86	14
		26/09/2019	30	7.23	25	7.88	75	14
		15/10/2020	23	6.72	20	7.5	70.27	10
		12/05/2021	30	7.53	25	8.12	83.64	14.68
		17/10/2021	25	7.29	20	7.65	75.61	10.94
St Neot River (160961)	SX 1851665481	17/04/2013	32	7.21	27	7.85	73.68	
		01/11/2013	27	6.84	24	7.71	67.44	
		20/04/2015	31	7.61	27	8.15	81.03	11.05
		14/09/2015	25	6.6	22	7.77	71.74	8.44
Fowey (78516)	SX 1863064900	17/04/2013	24	7.28	22	7.95	80	
		26/09/2013	25	7.45	21	7.95	85.37	
		25/03/2014	31	7.35	25	7.92	75	12.54
		05/09/2014	31	7.16	24	7.88	82.35	17.5S