West Penwith Ecohydrological Investigation and Characterisation

Phase 3 2020-21

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Further information

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Introduction

Land within West Penwith, Cornwall, is being considered for designation as a Site of Special Scientific Interest (SSSI) under the Wildlife and Countryside Act 1981. Valley mires are features of interest and 11 key mires have been identified for designation. A catchment-based approach is adopted to identify all land that may influence the ecohydrology of the mires, and to determine which areas have the most significant influence. This approach is consistent with national SSSI selection guidelines to ensure that the key areas which influence the mire are included within the SSSI boundary and to recognise pressures within the catchment to encourage future resilience of the mires.

This report

The aim of this report is to (1) identify areas of land that significantly influence the hydrology of the 11 mires in West Penwith, Cornwall identified for SSSI designated by Natural England; and (2) to identify risks in these areas of land that may impact the quality of the mire habitats. This information is designed to aid Natural England is refining the boundaries of the new SSSIs for each of the 11 mires. Therefore, the criteria for these assessments are closely link to the SSSI selection guidance for fens (JNCC, 1989). The approach in this report has three key components:

1. **Review and interpretation of the SSSI guidance** that provide the criteria for identifying the areas that significantly influence the hydrology of valley mires and the risks in the catchment may negatively impact the mire habitats.
2. **Defining hydrological risk zones** (areas of land that significantly influence the hydrology of the mires). There are multiple hydrological risk zones that may be identified for each mire that provide different levels of hydrological influence. The boundaries of the hydrological risk zones are determined using topographical, hydrological and geological information about each mire and its catchment.
3. **Catchment risk assessment** to determine pressures on each mire from land use and management, roads, historic mining, discharges and abstractions.

This report summarises a desk-based study to provide the information required for each mire. This incorporates geospatial analysis and results from field surveys where available. Field investigations will be carried out in the future for the mires where no field data was available and incorporated into this report. The report describes the approach taken below and presents a compendium of EvidenceBooks, one for each mire, detailing the catchment statistics, main site features including a conceptual model of mire functioning and a catchment risk assessment. Note that technical definitions for different ecology, geology and soil codes are provided in the Appendix to avoid repetition in the EvidenceBooks so that it may be more accessible. These are accompanied by three maps that display the proposed hydrological risk zones, the catchment risks and the land holdings within each catchment. The combination of this information will inform Natural Englandôs decision for the most appropriate hydrological risk zone for each mire. This approach has been discussed and agreed with Natural England throughout the development of the project. At this stage we are not recommending one boundary or another as this will be selected by Natural England as part of their statutory functions.

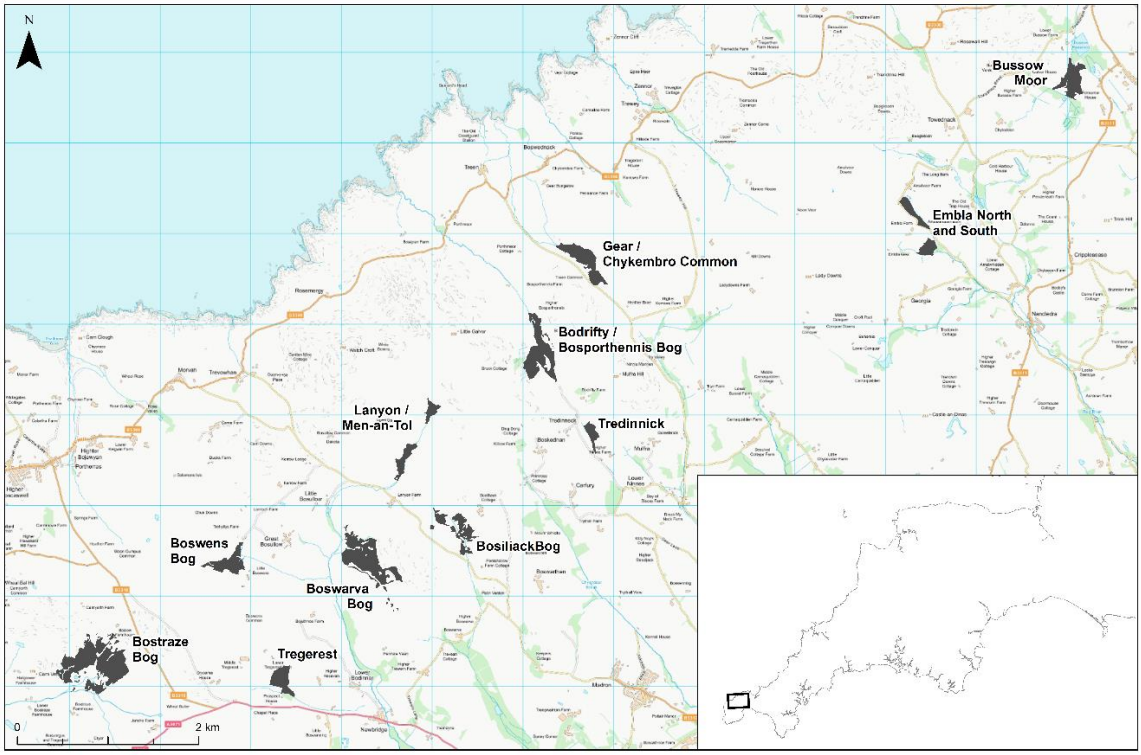


Figure 1. Location of the mires in dark grey. Mire boundaries based on NVC vegetation types from Natural England commissioned surveys.

Approach

1.. Review and interpret the available SSSI guidance

The hydrological risk zones and the catchment risk assessment are to inform SSSI boundary selection and so are developed to complement the guidance from JNCC ñGuidelines for the Selection of Biological Sites of Special Scientific Interest (SSSIs): Chapter 7, Fens" (1989). Part 1 of the SSSI Guidelines (JNCC, 2013) emphasises the importance of functionality and integrity, considering the wider hydrological and anthropogenic pressures on the mires. This includes essential criteria to define SSSI boundaries plus additional features that should also ideally be included where practical. Features that must be included are:

- The fen vegetation itself; and
- A buffer zone of land adjacent to the fen that may or may not be semi-natural. It is included to protect the fen core against potentially damaging land-use (e.g. drainage or fertilisers) that may modify or degrade the fen. The size of the buffer zone should be determined in the field and from soil evidence (JNCC, 1989, 9.2).

Part 1 of the SSSI Guidelines (JNCC, 2013) states that wetland habitats (such as mires) are often influenced by the hydrology over a much larger area. Drainage operations on the surrounding land can cause drying, or inflow of fertiliser from the catchment can result in eutrophication. These effects have led to the concept that SSSI boundaries should be drawn to encompass not only the special features of the site but also all land necessary to ensure the sustainability of those features including supporting processes such as hydrology.

To provide the highest level of protection to the mires, the SSSI boundary would capture the entire surface water catchment. However, the guidance (JNCC, 1989, 9.2) highlights that this is not always practical so where protecting the whole catchment is not possible the boundary should include:

- The steepest slopes adjacent to the fen (at least as far as the first break in slope);
- All peripheral ditches;
- All feeding springs and zones of seepage; and
- Extend part of the way along the outflow of the stream as a protection against lowering of the channel which can drain the fen.

Therefore, we identify five hydrological risk zones which capture this guidance ranging from the minimum requirement to the entire catchment (Figure 2).

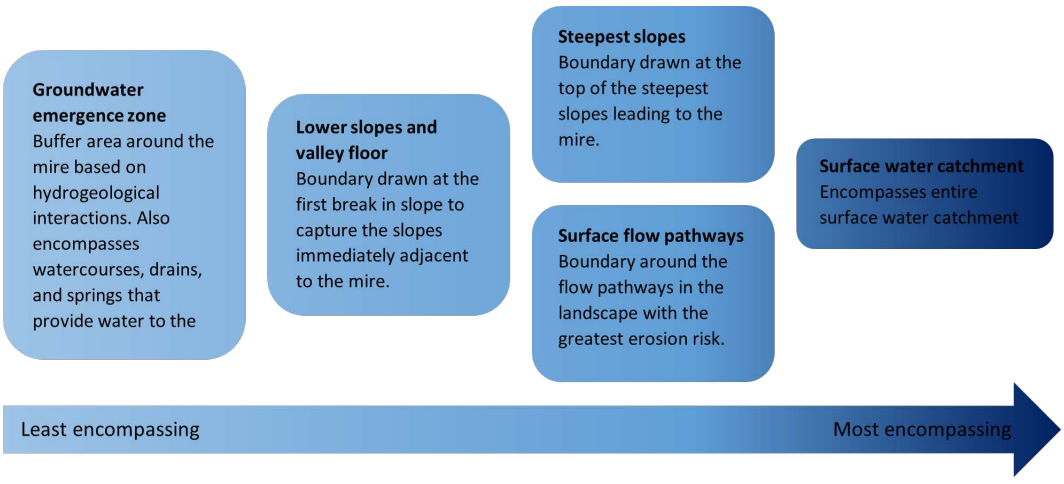


Figure 2. Scale of the five hydrological risk zones based on the SSSI guidance from least to most encompassing

SSSI designation would seek to restrict the intensity of agricultural and other land management operations within the site boundary. The hydrological risk zones reflect the inverse relationship between risk to the mires from eutrophication and drainage and the proportion of the catchment subject to protection through SSSI regulation. The fewer hydrological risk zones included within the SSSI boundary, and therefore subject to protection, the greater the residual risks to the mire and vice versa.

2. Delineating hydrological risk zones

The initial mire habitat boundaries were identified from National Vegetation Classification (NVC; Rodwell *et al*., 1991-2000) surveys to map areas of near-natural and semi-natural vegetation. The surveys were undertaken between 2012 and 2014 and in 2019. From those surveys, Natural England has identified 11 locations which support the most extensive and concentrated areas of mire vegetation (Figure 1). The mires are surrounded by semi-natural vegetation and/or intensively managed farmland.

A geospatial desk-based approach was used to delineate the five different hydrological risk zones for each of the 11 mires according to the boundary selection guidance in the published SSSI selection guidance for fens. The location, extent and nature of the zones contributing water to the mires are identified from topographical, hydrological, geological and ecological properties of the mires and their catchments. Table 1 highlights how each delineation approach (Figure 2) relates directly to specific sections of the guidance document and the data and methods used to perform the delineation. The full details of the geospatial data is provided in Appendix A and is supplemented by ecohydrological reports for four of the mires, produced in March 2018 (for Bostraze) and March 2019 (for Boswarva, Boswens and Bussow).

Table 1. Data and methods behind each hydrological risk zone delineation related directly to the relevant sections of JNCCôs (1989) SSSI selection guidance for fens. Details of datasets in Appendix A.

Hydrological risk zone	SSSI guidance	Datasets*	Method
1. Surface water catchment	ñIdeally, the site boundary of the fen should encompass the surface catchment and follow an identifiable feature in the fieldé ò(9.2)	DTM and SCIMAP flow pathways	Identified surface water catchment through topographical analysis of digital terrain model (DTM). The flow pathways from SCIMAP are used as quality control for the catchment boundary. Boundary is drawn at topographic divide in the landscape to capture all land influencing the mire. This is the largest boundary option.
2. Surface flow pathways	ñIdeally, all slopes potentially influencing the fen should be included within the site.ò(5.5)	SCIMAP flow pathways	A 5m buffer around the major flow pathways identified from SCIMAP have been included in this boundary to protect the key flow paths in the catchment that influence the mire.
3. Steepest slope	ñé boundaries should extend at least as far as the first major break of slope.ò(5.5) ñThe boundary should include the steepest slopes adjacent to the fen, at least as far as the first break of slope (i.e. where a change in angle of slope occurs).ò(9.2.1) ñThe topography of the valley often also helps to maintain a high water table.ò(Fig. 3)	Slope map derived from DTM	Slopes are classified as level, gentle, moderate and steep according to Defra guidelines for soil erosion risk (2005). The boundary is drawn at the top of the steepest slopes so that areas with a high potential for runoff are captured within the boundary.
4. Lower slopes and valley floor	ñValley fen . . . develops along the lower slopes and floor of a small valley where there is some water movement. (Fig 3)	Slope map derived from DTM	Slopes are classified according to Defra guidelines for soil erosion risk (2005). The boundary is drawn at the first break in slope nearest to the mire which captures the valley floor.
5. Groundwater emergence zone	ñBoundaries should encompass all springs and flushes upon which the fen is dependent.ò (5.5)	NVC surveys, superficial geology, soil properties, watercourses,	Boundary combines a 5m buffer around the mire habitat boundaries (identified from NVC surveys), all watercourses, drains and springs influencing the mire; and superficial geology which

	ñThe boundary should include all peripheral ditches, following the outer edge of such ditches.ò (9.2.2) ñThe boundary should encompass all feeding springs and zones of seepage.ò(9.2.3)	drains and springs.	influences the hydrological properties of the mire. This is the smallest catchment boundary option.

JNCC (1989) Guidelines for the selection of biological SSSIôs. Part 2: Detailed guidance for habitats and species groups. Chapter 7: Fens. https://jncc.gov.uk/our-work/guidelines-for-selection-of-sssis/

*Datasets supplemented for Bostraze, Boswarva, Bussow and Boswen mires by field data from the four ecohydrology reports that recorded unmapped watercourses, ditches and springs (Low, 2018, Pendleton Hydro 2019a-c).

There are assumptions made in the delineation of the hydrological risk zones which are listed below:

- The presence of other (non-mire) semi-natural habitats is not considered given that inclusion of such habitats within the SSSI boundary (including transitions between mires and other semi-natural habitats) will be determined by Natural England independent of this analysis using vegetation survey data already acquired.
- The extension of the boundary part of the way along the outflow stream of the site is based on a logical identifiable point (JNCC, 1989, 4.2.6).
- The surface water catchment matches groundwater catchment. This is based on the findings of previous ecohydrological reports from four of the mires (Low, 2018, Pendleton Hydro 2019a-c) and the fact that all the mires sit on granite bedrock that is largely unconfined.
- The presence of springs at the boundary of superficial deposits is key in identifying the groundwater emergence zone, however, the superficial geology boundaries may have been drawn based on the presence of springs, potentially making the argument circular (Low, 2018).
- Major flow pathways were identified as having an erosion risk (as calculated by SCIMAP on a scale of 0 to 1) greater than 0.5. Flow pathways with an erosion risk of less than 0.5 are considered to have limited influence on the fen.
- Catchments and surface flow pathways are determined from landscape topography. Anthropogenic modifications to the landscape such as roads and drains may intercept or redirect flow away from its natural course.

3. Assessing risks in the catchments

The catchment risk assessment is also a desk-based study using open-source (i.e. publicly available) datasets to investigate the risks to the mires from the surface water catchment hydrological risk zone (i.e. the most encompassing risk zone). The rationale for the catchment risk assessment is taken from the SSSI selection guidelines which state that *"…*adverse land-use (e.g. drainage or fertiliser application) within it [the catchment] can profoundly modify and degrade the fen*"* (JNCC, 1989, 9.2). Land cover in mire catchments is a patchwork of heathland, fen, grassland and arable land. Most arable land in West Penwith is in rotation with improved grass leys, the latter often being retained for longer periods than the arable crops.

Table 2. Hazards to the mires from catchment land-uses and features including a description of the risk (linked to the JNCC, 1989 guidelines where appropriate) and the datasets used to assess the risk. Details of datasets in Appendix A.

Risk	Description of risk	Datasets
Arable land use	ñMany valley and basin fens lying within agricultural catchments are also subject to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Most fens now have highly artificial boundaries with farmlandò(1.4)	Primarily identified with CEHôs land cover map (2007) with confirmation from CORINE land cover map (2018). Information on the types of crops in arable areas from CROME (2019).
Grassland and nutrient management	Nutrient enrichment can also result from nitrogen and phosphatic fertilisers applied to grassland alongside the use of organic manures, including slurry, any of which may be mobilised during rainfall runoff events. Nutrients may	Primarily identified with CEHôs land cover map (2007) with confirmation from CORINE land cover map (2018). The CEH

	infiltrate to the groundwater or be transported downslope by overland flow. The amount of input covers a spectrum from intensively managed grasslands with significant inputs (potentially comparable to arable land inputs) to rough grasslands with no to moderate inputs.	map differentiates between improved and rough grassland types.
Farmyards	Manure and slurry management in farmyards can also represent a nutrient source or hotspot in catchments depending on the condition of the asset and the way it is managed. SSAAFO (2010) regulations require farmers to ensure there is no leakage from slurry tanks, silage clamps etc. so these are unlikely to be a risk.	Farms, slurry pits and dairies are identified from OS MasterMap. This is quality controlled through Google Earth imagery to determine if a farm is currently active, and if there are other farms not included in the OS data.
Discharges	Discharges are potential point sources of pollutants which may cause eutrophication in the mire habitats.	Consented discharges dataset (Environment Agency) is used to identify local discharge points.
Abstractions	ñValley mires dependence upon subsurface sources of water for their essential characteristics and existence means that activities which can influence water table level, flow and pressure, such as water abstraction and damage to aquifers by quarrying, should be viewed with concern.ò(5.5)	Abstraction points dataset (Environment Agency) is used to identify local abstraction points.
Roads	Roads frequently act as a conduit for water and associated pollutants during rainstorm events. They can also be a source themselves and can sometimes be active pathways for the movement of nutrients through a catchment to natural systems such as mires.	A roads, B roads, restricted access roads identified from OS MasterMap.
Other	The landscape has a history of mining which may influence the hydrological behaviour of the area, potentially impacting the water table influencing the mires.	Mines, shafts, spoil tips and adits identified from OS MasterMap.

Intensively managed grassland and arable land are the focus of this risk assessment as both can be sources of eutrophication (Table 2), rather than semi-natural habitats which are excluded from the catchment risk assessment. Arable land is defined as cropland, freshly ploughed land or rotational set aside fallow according to the Broad Habitat definitions produced by JNCC (Jackson, 2000). Intensively managed grassland is managed as pasture or mown regularly for silage production. It is periodically re-sown and maintained with fertiliser treatments and weed control, potentially leading to the regular release of nutrients and soil loss (Jackson, 2000). Rough grassland is also considered as it is a mix of managed low-productivity grassland and semi-natural grasslands that could not be classified separately (CEH, 2011) but has a lesser risk of eutrophication than arable or intensively managed grasslands due to light-moderate inputs of manure.

Land cover type is defined in the mire catchments primarily from CEHôs land cover map 2007. While not the most recent dataset, the vector data provides a more detailed land cover map than more recent CORINE 2018 raster land cover data and more detail in grassland types. Visual assessment between the two datasets shows that arable and pasture land cover similar extents in 2007 as in 2018. The percentage of arable land, intensively managed grassland and rough grassland from the CEH dataset in each catchment is extracted using ArcGIS v10.5.

In addition to the diffuse pollution produced from nitrogen and phosphatic fertilisers on arable land and intensively managed grassland there are point sources of pollution that may cause changes to water quality or quantity in the mires, such as slurry and run-off from farmyards and roads, pollutants from discharges to the surface water and impacts from mines (Table 2).

After mapping the potential risks within the catchment, the Catchment Risk Assessment is conducted which combines the severity of the risk (e.g. the type of risk) and its likely impact on the water quality and quantity in the mire based on its proximity to the mire or flow pathways feeding the mire (Table 3). This is critical as the SSSI selection guidance states *"T*he surface catchment or contributing slopes will vary in their extent, and so

the degree of sensitivity of fens to activities taking place within the catchment will also vary." (JNCC, 1989, 9.1). A risk category has been assigned to each mire.

Table 3. Risk categories (high/ medium /low) defined by the presence of risks from Table 2 and their likely influence on the mire based on spatial extent and location.

	High	Medium	Low
Description	Risk extensive in catchment. Adjacent to the mire, within the mire itself, or intersecting major flow pathways, springs or channels flowing into the mire. Particular high risk features present e.g. arable land cover, consented discharges, abstractions.	Risk present in catchment. Intersects minor flow pathways.	No or few risks in catchment. Any present are not adjacent to mire or away from flow paths Rough grassland is considered low risk due to no or light levels of nutrient inputs.

There are some uncertainties with the Catchment Risk Assessment:

- Land cover data is derived primarily from CEHs 2007 land cover map. Each catchment risk assessment in this report is considered current at the time of writing. Although there appears to have been little change in extent between 2007 and CORINE data from 2018, land cover may significantly change in the future and with it the associated risk category assessed for each mire catchment.
- Fens may be detrimentally affected by influences derived even from outside the surface water catchment; for example, sewage pipes may be directed towards the fen from adjacent catchments. Investigations into possible sources of fen eutrophication should include an assessment of influences from outside the fen catchment.
- The presence of mine related features such as spoil tips, adits and shafts has the potential to alter the hydrological behaviour of the area. While mine and shaft locations are highlighted from the MasterMap data, the degree and extent of their effect is unknown. Mining features are also likely more widespread and extensive than OS data alone implies. Archaeological studies may provide further details in some areas, but it is outside the scope of this report to investigate this further.

The risk categorisation is central to the SSSI delineation process and is intended to help define the minimum extent of the hydrological risk zones likely to be required for the protection of each mire. Risk categories are ultimately dictated by inferred land use and catchment activities at the time of writing, and there is potential for these to change in future.

EvidenceBooks

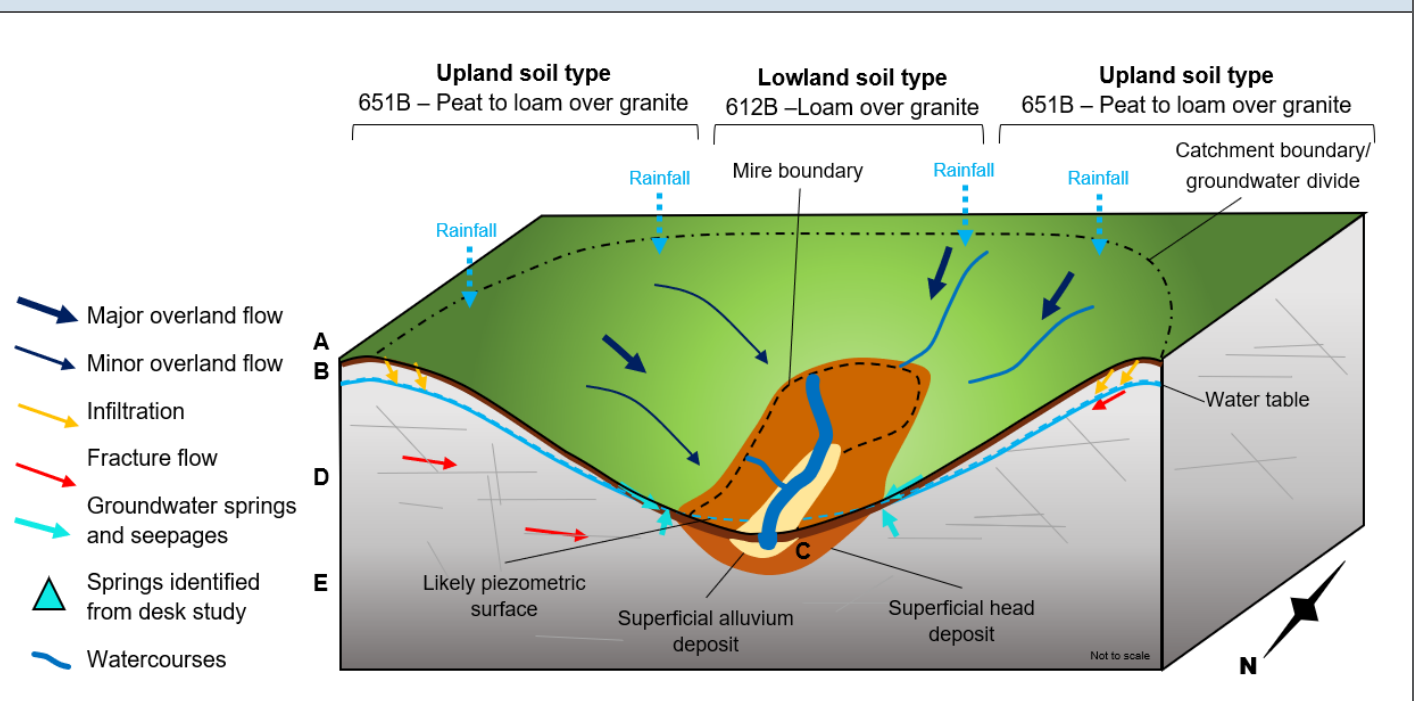
1. Bodrifty / Bosporthennis Bog

Bodrifty / Bosporthennis Bog

Catchment statistics

WFD water body catchment ID	230 (Coastal water body)	**Extent of Mire Habitat (ha)**	12.16
Water body WFD Status	Not in river water body	**Total Catchment Area (ha)**	115
NGR (approximate site centre point)	SW 44100 36000	**Number of registered landholdings (Defra Rural Land Register) in catchment**	16

Main site features

1. Ecology and Habitats	Bodrifty is predominantly (~90%) made up of variations of the NVC mire community M25 (*Molinia caerulea – Potentilla erecta* mire). M25 is usually found around seepage zones, flushes, water-tracks and topogenous mires, but may also extend onto the slightly dryer fringes of ombrogenous mires (Elkington et al. 2002). However, in this context M25 appears to be soligenous as it can be a product of drainage of wetter mires such as M21, followed by grazing. This community is found over moist but well aerated soils with low nutrient status. Two main other mire types are recorded here in smaller quantity: M21 (*Narthecium ossifragum – Sphagnum papillosum* valley mire), which is found in permanently saturated and very low nutrient conditions and M23 (*Juncus effusus/acutiflorus* ï Galium palustre rush-pasture) which occurs in wet and slightly higher nutrient conditions, sometimes at the edges of mires close to more intensively farmed areas. Other mire communities present in small quantities include M6 (*Carex echinata – Sphagnum recurvum/ auriculatum* mire) which is a soligenous community of lower nutrient conditions and M29 (*Hypericum elodes – Potamogeton polygonifolius* soakway) which is characteristic of shallow soakways and pools within mire systems. Depending on the hydroecological setting, M25 has moderate or low groundwater dependency (UKTAG, 2009), whilst M21, M23, M6 and M29 all scored as highly or moderately dependent on groundwater (UKTAG, 2009). There are also woodland/scrub (W1, W23, W24, W25) and acid grassland communities *Festuca ovina - Agrostis capillaris - Galium saxatile* grassland (U4), and *Pteridium aquilinum - Galium saxatile* (U20) present in the north and east of Bodrifty mire. Around the mire there is a mix of heathland (H4 and H8), acid grasslands (U4) and woodland/scrub communities (W24 and W1).
2. Topography and surface flow pathways	The mire habitat covers the base of the valley, 10% of the catchment area, with elevations between 165 to 185 mAOD and has a level topography (<2Á). The wider catchment has an elevation range from 165 mAOD at the valley outlet to 230 mAOD at the top of the catchment. It has a level topography extending through the centre of the catchment with gentle to moderate slopes (2-5Á) either side of the valley adjacent to the mire. The western slopes of the catchment are steeper with moderately steep to steep slopes (5-7Á). The flow pathways in the catchment are less extensive than some other mires in this report with flow being concentrated into a few pathways. The steep western slopes have a single highly erosive flow pathway (according to SCIMAP) that leads into the mire. Smaller flow pathways feed the mire from the south and east.
3. Watercourses and drainage	The mire itself sits on a headwater tributary with two other headwater tributaries feeding into the mire from the west. These tributaries should be under the main protection zone of the SSSI. While there is no evidence of artificial drains identified in the OS data, the watercourses themselves appear to be straightened and may be artificial.
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Land's End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Superficial head deposits cover the base of the valley where the mire is located, with alluvium deposits following the headwater channel downstream. The deposits are clay and silt dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body. However, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). OS open data (MasterMap, 2020) shows no evidence of springs in the catchment but they may be present along with soil seepage at the geological transition. The soil survey for SW England shows soil type 651B in the majority of the catchment and 612B lower in the mire. Both soil types are grit and loam dominated, but the upper catchment soil type is wet and peaty whereas the lower catchment soil type is well drained (Findlay, 1984).
5. Conceptual model A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff. B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils. C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = $8.64x10^{-5}$ ï 1.73 m/d D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = $6.9x10^{-4}$ ï $2.6x10^{2}$ m/d E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = $1.73x10^{-5}$ ï $2.6x10^{-9}$ m/d	

Catchment Risk Assessment

1. Arable land use	Arable land, identified from the CEH and CORINE datasets, within the Bodrifty / Bosporthennis Bog catchment is limited to small patches that cover <10% of catchment area. The arable land borders the mire on its eastern and southern boundaries. CROME data shows that crops have included perennial and maize crops in the past. Arable land intersects the major flow paths in the northern section of the catchment that leads directly to the mire and in the southern section of the catchment that leads to the stream. This may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending upon land management practices, that may increase the volume of fine eroded particles being transported to the mire.
2. Grassland and nutrient management	There are patches of intensively managed grassland throughout the catchment covering <20% of catchment area on major flow pathways leading to the mire. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths or infiltrate to groundwater into the mire, negatively impacting water quality and potentially causing eutrophication. There is a single patch of rough grassland identified from the CEH dataset that is adjacent to the mire and within the mire itself. Rough grassland poses a lower risk to the mire but may still contribute to eutrophication of the mire if the land is managed to some extent. The majority of the catchment is semi-natural heathland grass and dwarf scrub identified from the CORINE and CEH datasets.
3. Farmyards	None present in OS dataset or identified from Google Earth.
4. Discharges and abstractions	None present in Environment Agency datasets.
5. Roads	An unnamed road runs along the mire boundary along with another restricted access road near the mire. The roads, although minor, may act as conduits for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography.
6. Other	There is evidence of historical mining activity in catchment with two mining shafts identified from the OS data, <0.5 km from the mire habitat. It is not known to what extent the shaft may influence the mire habitat.
Outcome	Based on the evidence above, this site is **low-medium risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	115
2. Surface flow pathway protection	14
3. Steepest slopes	68
4. Lower slopes and valley floor	37
5. Groundwater emergence zone	23

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer. It is extended to encompass the tributaries leading into the mire which includes some of the steeper slopes. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology. This boundary covers the valley bottom of the catchment.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor. The slopes within the valley change from level/gentle to moderate/steep at this point. This boundary is not dissimilar from the groundwater emergence zone near the outlet but extends to capture some of the steeper western slopes.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography starts to plateau at the very edges of the catchment. This boundary covers over 50% of the catchment area including the majority of the main flow pathways.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer.

The **surface water catchment zone** (no. 1) is 115 ha, of moderate size compared to the other mire catchments, and offers optimum protection to the mire.

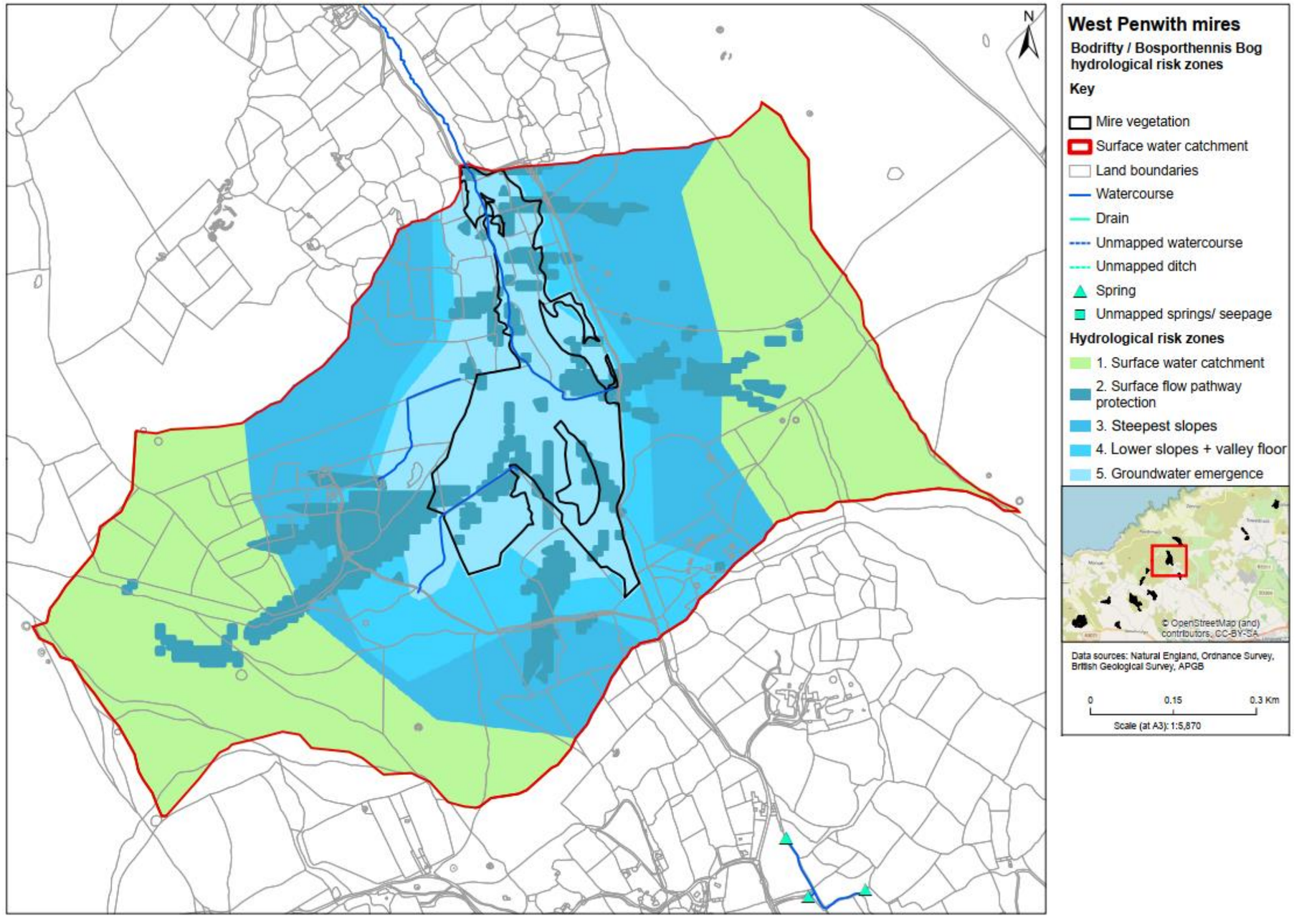


Figure 1-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	7%
Intensively managed (improved) grassland	17%
Rough low-productivity grassland	9%
Other land covers (including mire habitat)	67%

Bodrifty / Bosporthennis Bog was assigned a catchment risk of low-medium. This is primarily because of the little amount of high-risk land uses and farm features in the catchment. There are small areas of arable and intensively managed grassland that border the mire, potentially increasing nutrients, pollutants and increased fine sediments to the mire. The mine shaft and unnamed road may also pose a risk as they are in close proximity to the mire and they may influence the water table and the amount of water and pollutants transported to the mire respectively.

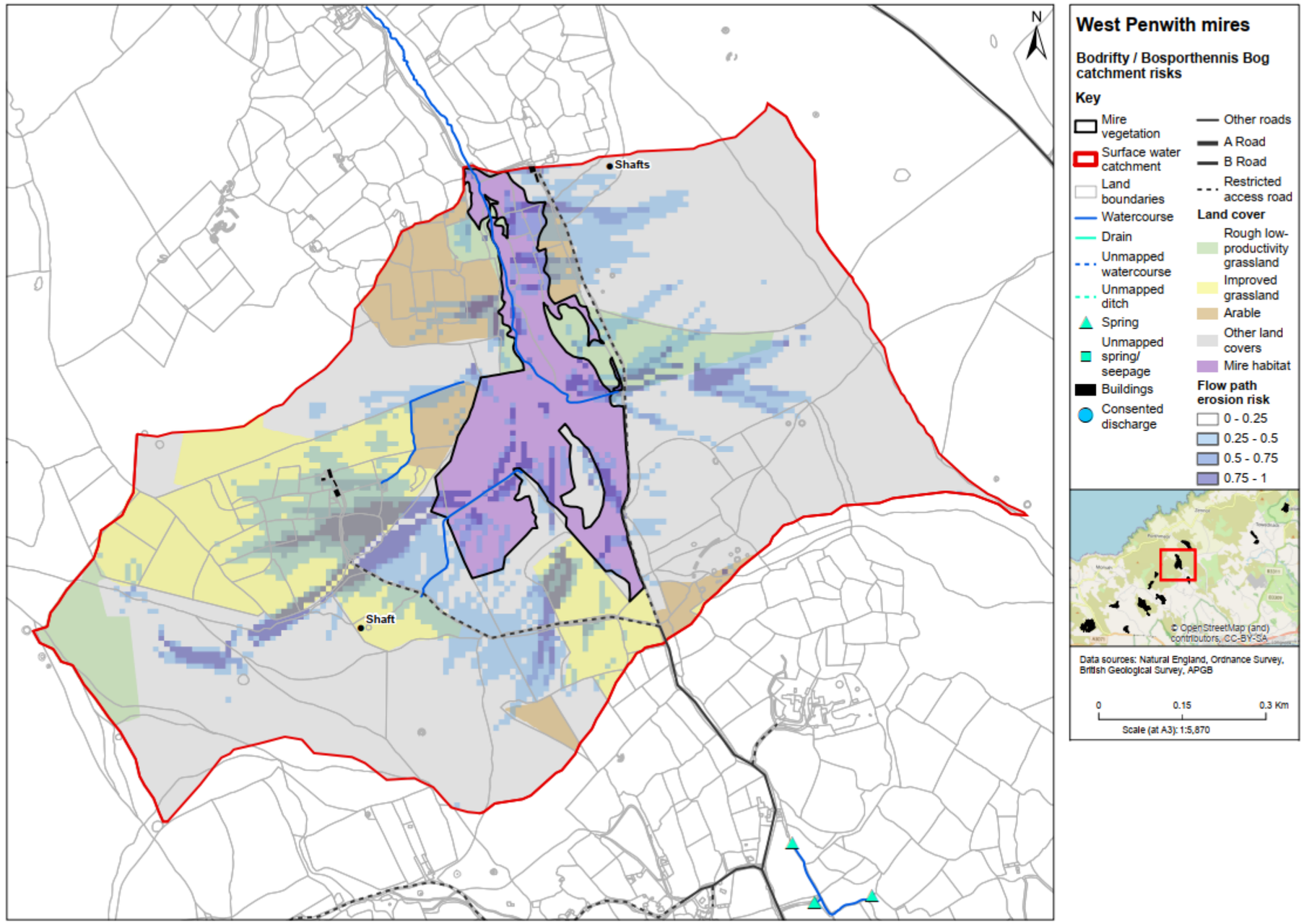


Figure 1-2. Map of catchment risks. Only land covers with a risk associated from CEHôs land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire.

Catchment land holdings

There are 16 County Parish Holding (CPH) land holdings within Bodrifty/Bosporthennis Bog surface water catchment. Those on the eastern and western edges of the catchment boundary are least likely to impact the mire as they are not on major flow pathways or steep slopes leading to the mire. The seven land holdings that intersect the mire boundary and the groundwater emergence zone may be most likely to impact the mire due to their close proximity.

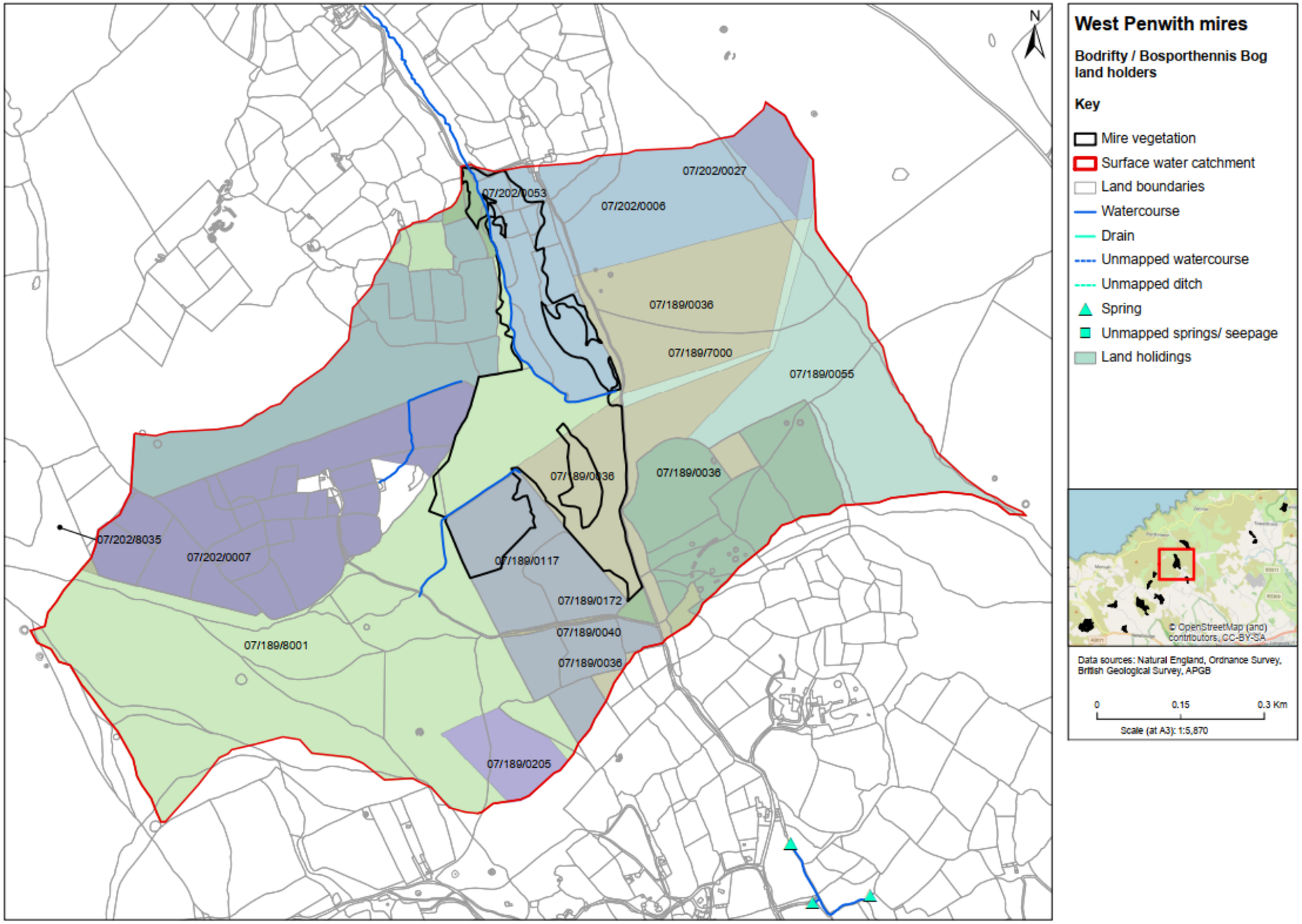


Figure 1-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

2. Bosiliack Bog

Bosiliack Bog

Catchment statistics

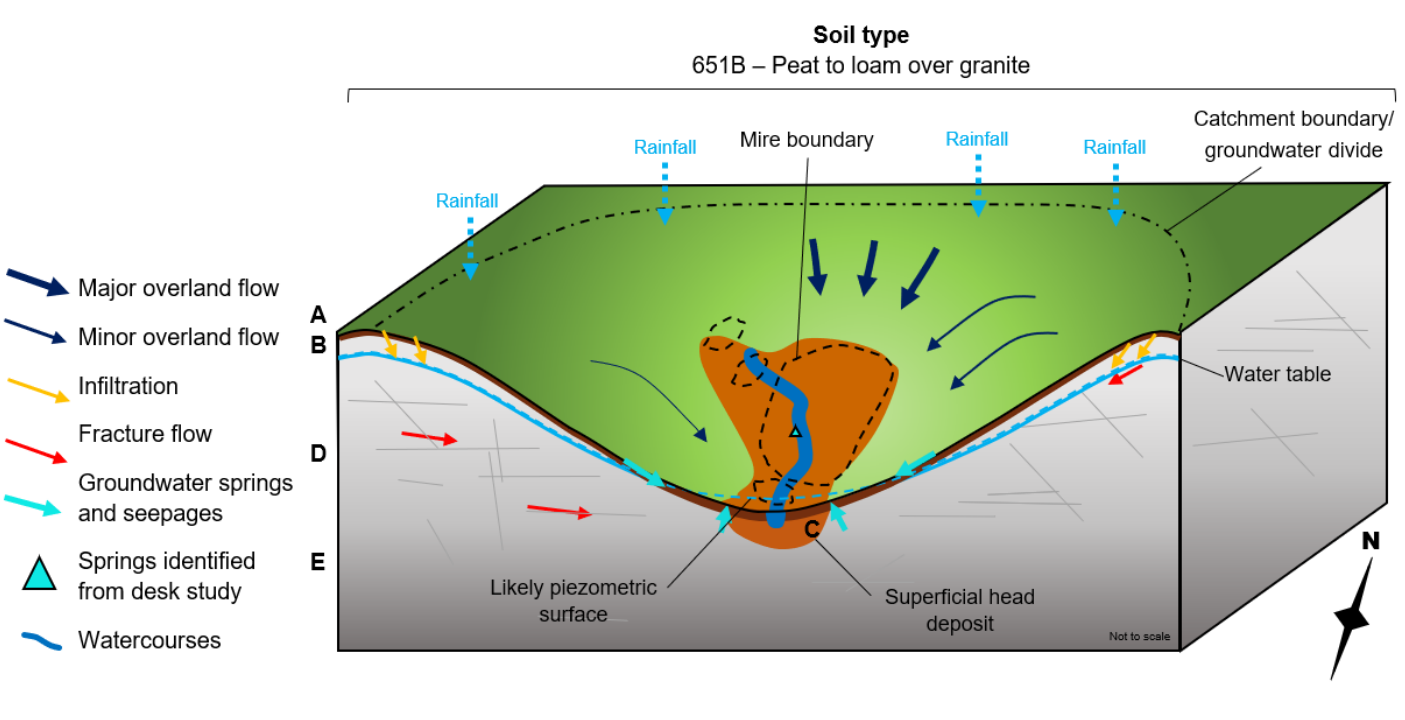
WFD water body catchment ID	405 (Coastal water body)	**Extent of Mire Habitat (ha)**	6.55
Water body WFD Status	Not in river water body	**Total Catchment Area (ha)**	85
NGR (approximate site centre point)	SW 43200 33700	**Number of registered landholdings (Defra Rural Land Register) in catchment**	6

Main site features

1. Ecology and Habitats	The most prominent NVC communities within Bosiliack bog are M25 and M23, mostly occurring in transitions with one another, making up ~90% of the mire. M25 is often found around topogenous mires that are dependent on a high local groundwater table but can also extend onto the fringes of ombrogenous mires (Elkington et al. 2002). However, in this context M25 appears to be soligenous as it can be a product of drainage of wetter mires such as M21, followed by grazing. M23 is characteristic of a range of conditions that provide fairly wet soils and moderate nutrient status (Elkington et al. 2002). The relative dependence of the communities on groundwater given by UKTAG (2009) are moderate (score of 2) for M25 and high (score of 1) for M23. Other mire communities present include M29, which is characteristic of shallow soakways and pools with fluctuating water levels and has a groundwater dependency score of 1 (high) (UKTAG, 2009). There is also a large area of wet woodland dominated by willow at the south of the mire, along with other woodland/scrub communities: W23 (*Ulex europaeus - Rubus fruticosus* scrub), W24 (*Rubus fruticosus - Holcus lanatus* underscrub) and W25 (*Pteridium aquilinum - Rubus fruticosus* underscrub). The majority of land around the mire comprises of scrub community W25.
2. Topography and surface flow pathways	The mire covers the base of the valley, <8% of the catchment area, with elevations between 170 to 190 mAOD and has a level topography (<2Á) except for one patch of mire vegetation to the west with is at the top of a gentle to moderate slope (3-5Á). The wider catchment has an elevation range from 170 mAOD at the valley outlet to 220 mAOD at the top of the catchment. It has a bowl-shaped morphology with gentle to moderate slopes (2-5Á) surrounding the mire. There are sections of moderately steep slopes (maximum 6Á) but these are limited. The flow pathways in the catchment are extensive to the north on the steeper slopes, with shorter flow pathways radiating from the mire (according to SCIMAP).
3. Watercourses and drainage	The mire itself sits on a headwater tributary and has a spring in the centre of the mire identified from OS data. These should be under the main protection zone of the SSSI. While there is no evidence of artificial drains identified in the OS data, the watercourses themselves appear to be straightened and may be artificial.
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Land's End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Superficial head deposits cover the base of the valley where the mire is located. The deposit is clay and silt dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). OS open data (MasterMap, 2020) shows evidence of one spring in the catchment but others may be present along with soil seepage at the geological transition. The soil survey for SW England shows that the majority of the catchment has soil type 651B, including the mire habitat. This is a grit and loam dominated soil with a wet peaty surface horizon (Findlay, 1984).

5. Conceptual model

AA. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff.
B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils.
C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = $8.64x10^{-5}$ ï 1.73 m/d
D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = $6.9x10^{-4}$ ï $2.6x10^{2}$ m/d
E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = $1.73x10^{-5}$ ï $2.6x10^{-9}$ m/d



Catchment Risk Assessment

1. Arable land use	Numerous patches of arable land are identified from the CEH and CORINE datasets within Bosiliack Bog catchment. The coverage is quite extensive (~25% of catchment area) with some arable land on major flow paths and within the mire boundary itself. CROME data shows that crops have included spring barley, maize, potato and fallow land in the past. This may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending on land management practices, that may increase the volume of fine eroded particles being transported to the mire.
2. Grassland and nutrient management	The catchment is predominantly intensively managed grassland which covers >60% of catchment area within and adjacent to the mire. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths and infiltrate to groundwater into the mire, negatively impact water quality and potentially causing eutrophication. There are patches of rough grassland identified from the CEH dataset spread throughout the catchment and within the mire itself. Rough grassland poses a lower risk to the mire but may still contribute to eutrophication of the mire if the land is managed to some extent.
3. Farmyards	One farm, Bosiliack Farm, was identified from Google Earth that has a manure heap. Two slurry beds were identified on this site from the OS data. They may also act as a nutrient source to the mire downstream, either via overland flow or the leaching of nutrients to the groundwater that feeds the mire, depending on the maintenance and management of the assets involved.
4. Discharges and abstractions	Two domestic abstraction points are identified from the Environment Agency dataset within the mire and adjacent to the mire which may impact the water table that the mire habitats are dependent on. No consented discharges are present in the Environment Agency dataset.
5. Roads	The B3312 road crosses the catchment along with another restricted access road near the mire. The B3312 is near to the mire habitat and crosses the outflow stream of the mire potentially with a culvert. The roads, although minor, may act as conduits for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography.
6. Other	There is evidence of historical mining activity in catchment with a mining shaft identified from the OS data near the catchment boundary, away from flow pathways. It is not known to what extent the shaft may influence the mire habitat.
Outcome	Based on the evidence above, this site is **high risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	85
2. Surface flow pathway protection	13
3. Steepest slopes	61
4. Lower slopes and valley floor	26
5. Groundwater emergence zone	13

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer which includes some of the steeper slopes and the headwater stream and spring. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology. This boundary covers the valley bottom of the catchment.

The **lower slopes and valley floor zone** (no. 4 encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor. The slopes within the valley change from level/gentle to moderate/steep at this point. This boundary is not dissimilar to the groundwater emergence zone near the outlet but extends to the west due to the gentler topography.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography starts to plateau at the very edges of the catchment. This boundary covers over 70% of the catchment area including all the main flow pathways.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer.

The **surface water catchment zone** (no. 1) is 85 ha, a small extent compared to the other mire catchments. It offers optimum protection to the mire.

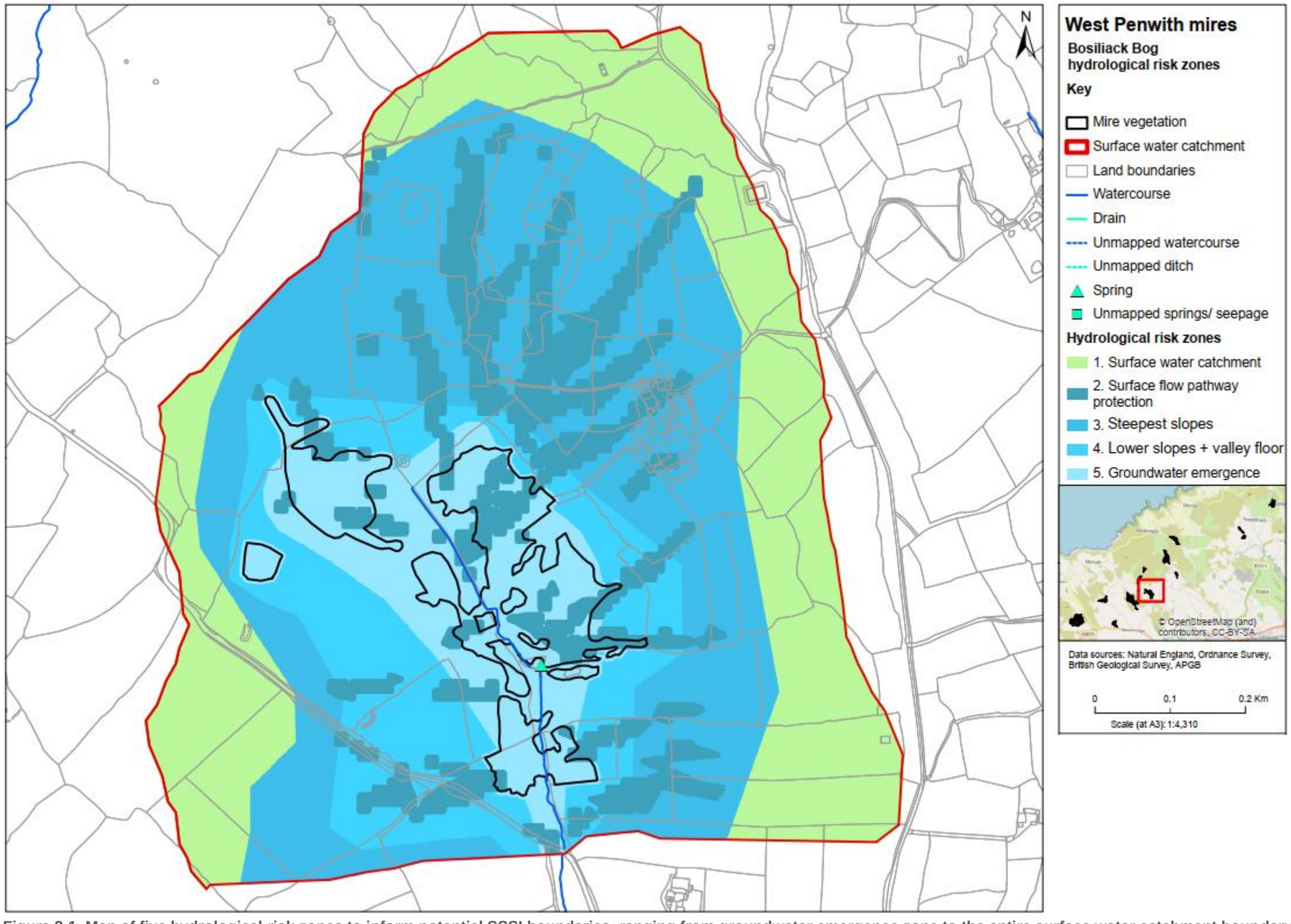


Figure 2-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	26%
Intensively managed (improved) grassland	62%
Rough low-productivity grassland	9%
Other land covers (including mire habitat)	4%

Bosiliack Bog was assigned a catchment risk of high. This is primarily because of the extensive amount of intensively managed grassland and less extensive arable land and slurry beds that intersect the main flow pathways leading to the mire and are within the mire boundary itself. These land covers are potentially high risk due to the influences of nutrients, pollutants and increased fine sediments to the mire. The abstractions within the mire (not mapped due to data protection) may also lower the water table that supports the mire habitat. The B3312 and mine shaft do not pose as much risk as they do not intersect the main flow pathways so may have limited influence on the mire.

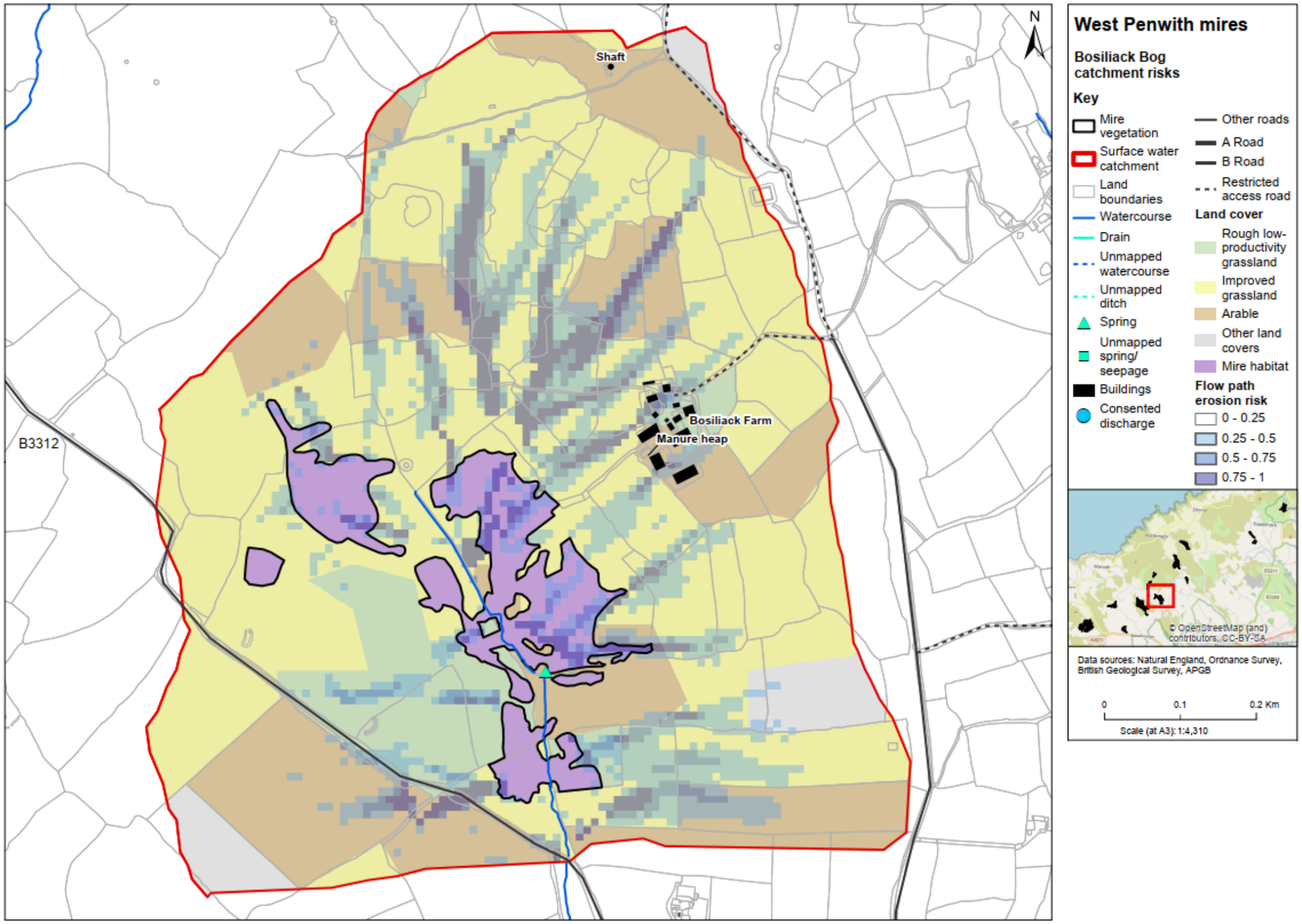


Figure 2-2. Map of catchment risks. Only land covers with a risk associated from CEHôs land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire.

Catchment land holdings

There are 6 CPH land holdings within Bosiliack Bog surface water catchment. The three land holdings that intersect the mire boundary and the groundwater emergence zone may be most likely to impact the mire due to their close proximity.

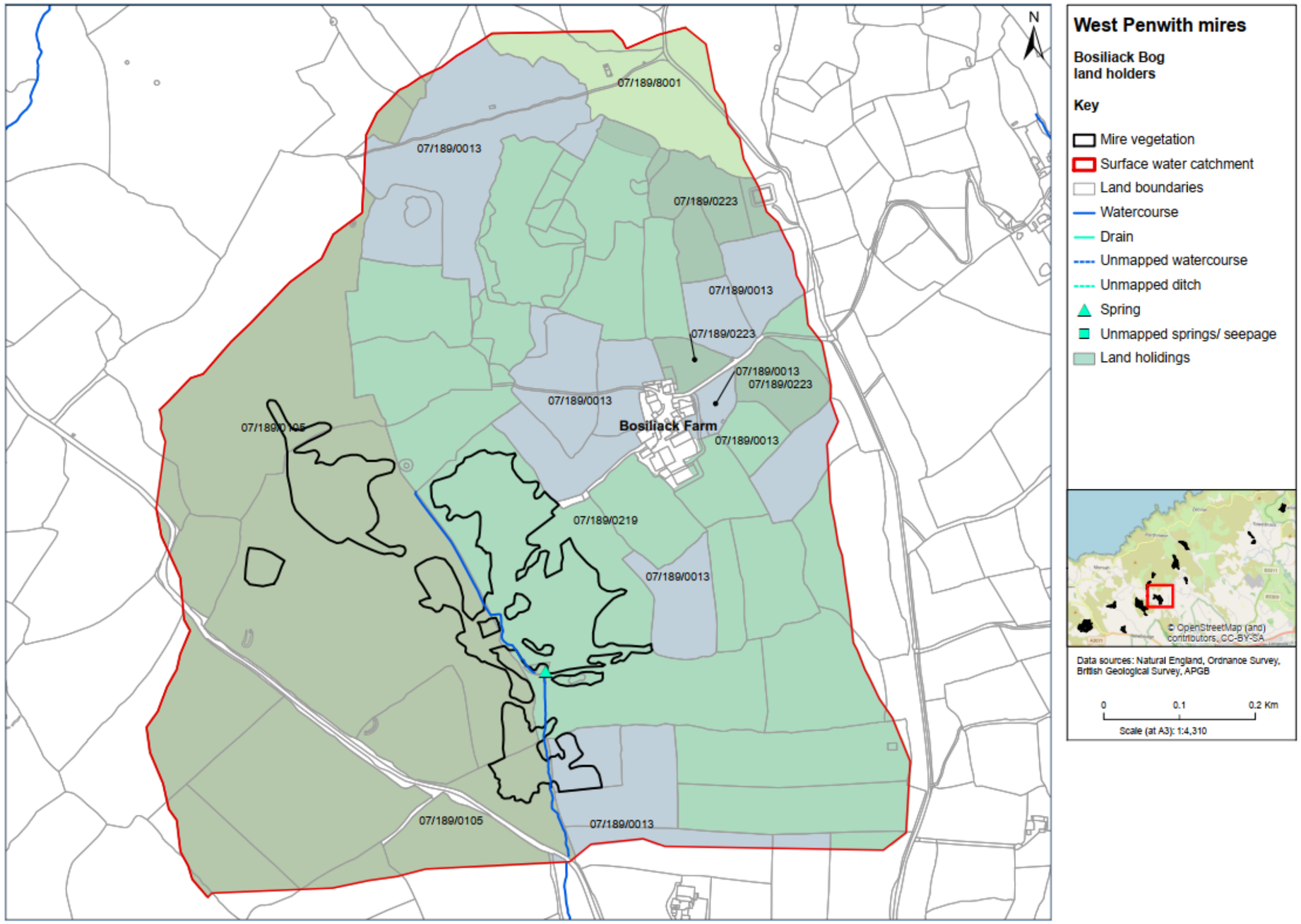


Figure 2-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

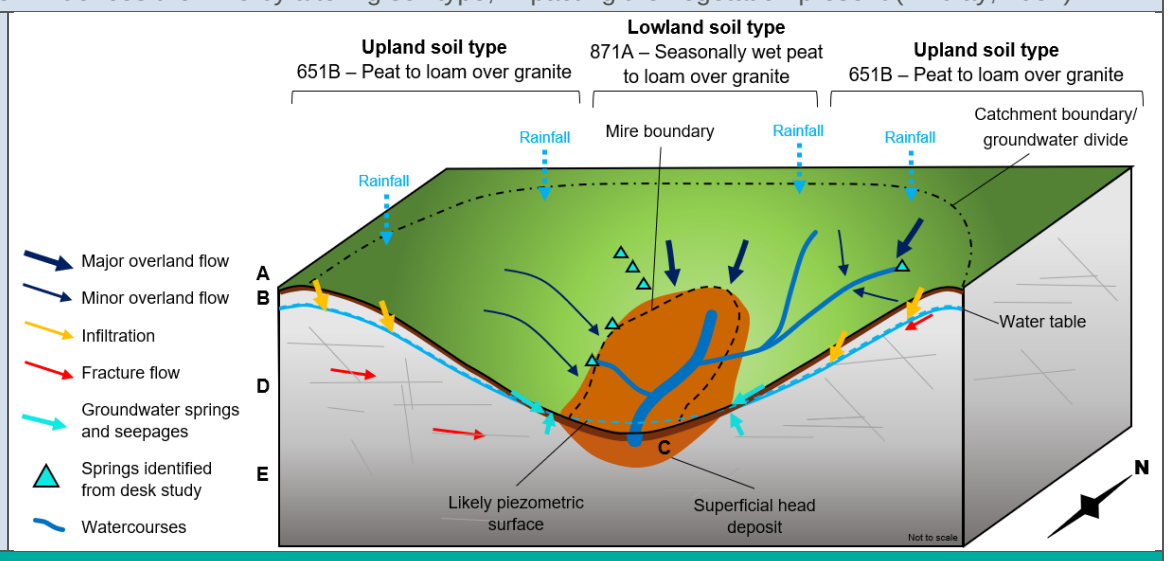
3. Bostraze Bog

Bostraze Bog

Catchment statistics

WFD water body catchment ID	230 (Coastal water body)	**Extent of Mire Habitat (ha)**	23.45
Water body WFD Status	Not in river water body	**Total Catchment Area (ha)**	300
NGR (approximate site centre point)	SW 39400 32200	**Number of registered landholdings (Defra Rural Land Register) in catchment**	13

Main site features

1. Ecology and Habitats	The most prominent NVC communities within Bostraze bog are M25, which makes up ~75% of the mire, and M23, which makes up ~20%. M25 is often found around topogenous mires that are dependent on a high local groundwater table but can also extend onto the fringes of ombrogenous mires that are rainfall dependent (Elkington et al. 2002). In this context M25 appears to be soligenous as a result of drainage of wetter mires such as M21, followed by grazing. M23 is characteristic of topogenous mires whilst also being found in areas where soligenous flows are the main source of water (Elkington et al. 2002). The relative dependence of the communities on groundwater given by UKTAG (2009) are moderate (score of 2) for M25 and high (score of 1) for M23. Other mire communities present include M6a (*Carex echinata – Sphagnum recurvum/ auriculatum* mire), M21 (*Narthecium ossifragum – Sphagnum papillosum* valley mire) and M24c (*Molinia caerulea – Cirsium dissectum* fen-meadow) ï all mires are of low nutrient conditions, and nationally less common than M25 and M23. The groundwater dependency scores for M6, M21 and M24 are 2, 1 and 1 respectively (UKTAG, 2009), however M6 is frequently soligenous. These scores are more recent and so differ from those reported in the previous ecohydrological report (Low, 2018). With a dependence on groundwater, evidence of significant groundwater storage and good hydraulic connection (Low, 2018) it can be assumed that these mire communities are at least partially groundwater fed. Some wet woodland and scrub communities, (W1 and W25b), are also present in small areas and mosaics. The area around the mire is mixed with heathland (H4) to the north-west, scrub (W25) to the south and mesotrophic grasslands (MG6) to the east.
2. Topography and surface flow pathways	The mire sits within the northern half of a valley and covers 8% of the catchment area with elevations between 145 to 165 mAOD and gently slopes (<3Á) towards the central stream. The wider catchment has an elevation range from 145 mAOD at the outlet to 225 mAOD. It has a bowl-shaped morphology with moderate to steep slopes (4-8Á) surrounding the flat valley bottom where the mire is located. The catchment has two sections, one to the north, proximate to the mire where extensive, highly erosive flow pathways (according to SCIMAP) feed the mire via overland flow. A second section of the catchment is located to the south where highly erosive flow pathways lead into streams that flow towards the mire. This suggests that the area required to protect the mire may include steep slopes in the north and land influencing the southern streams to ensure the water quality is not detrimental to the mire.
3. Watercourses and drainage	The mire sits on two headwater tributaries with artificial drains identified through OS data in the upper portions of the mire. The impact of these drains on lowering the water table may be a potential risk to the mire system. Low's (2018) report also highlights another ditch along the eastern boundary of the mire, with a bankfull width of 5-6 m, not in the OS data. The report states that the ditch is already impacting the water table, causing significant drawdown on the water table within the wetland habitat. OS data also identifies two springs located on the western edge of the mire boundary which may contribute to the hydrological condition of the mire, although other springs and overland seepage are also likely to contribute. Low's (2018) report also notes significant groundwater discharge and springs in the upper catchment. Two streams also flow towards the mire from the south (c. 3m width and free-flowing; Low, 2018), at least one of which is fed by a spring which should be in the main protection area. However, the ditch noted by Low (2018) may intercept flow from the south so it is anticipated that surface water from the southern streams may only impact the mire during floods although this is uncertain (Low, 2018).
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Landŝ End Granite bedrock. The granite has a low porosity, so main flow pathways are likely to be through weathered fractures close to the surface. Superficial head deposits cover the base of the valley where the mire is located. The deposit is clay and silt dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, that the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). There is evidence of at least two springs at the geological transition from OS open data (MasterMap, 2020), and other springs and seepages reported by Low (2018). The soil survey for SW England shows soil type 651B in the upper catchment and 871A in the lower catchment. Both soil types are grit and loam dominated with peat surface horizons, but the lower catchment soil type is permeable and affected by groundwater. This shows that groundwater influences the mire by altering soil type, impacting the vegetation present (Findlay, 1984).
5. Conceptual model A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff. B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils. C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = $8.64x10^{-5}$ ï 1.73 m/d D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = $6.9x10^{-4}$ ï $2.6x10^{2}$ m/d E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = $1.73x10^{-5}$ ï $2.6x10^{-9}$ m/d	

Catchment Risk Assessment

1. Arable land use	Arable land identified from the CEH and CORINE datasets within the Bostraze bog catchment is quite extensive (>30% of catchment area) which borders the mire and is within the mire boundary towards the north of the mire. CROME data shows that crops have included spring barley, maize, beet, potato and fallow land in the past. Arable land intersects the major flow paths in the northern section of the catchment that leads directly to the mire and in the southern section of the catchment that leads to the stream. This may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers either as overland flow or via groundwater. For example, Low's (2018) report describes the spreading of seafood processing waste on an agricultural field adjacent to the south-eastern mire boundary. Arable land cover may also be highly susceptible to erosion, depending upon land management practices, that may increase the volume of fine eroded particles being transported to the mire. Low (2018) notes the presence of erosion gullies in a ploughed field near the mire and the deposition of sediment at the mire boundary.
2. Grassland and nutrient management	There are patches of rough grassland identified from the CEH dataset spread throughout the catchment, covering 15% of the catchment area, and within the mire itself. The largest patch is in the upper catchment away from main flow paths. Rough grassland has a comparatively low risk to the mires compared to intensively managed grassland which covers >10% of catchment area in small patches, some of which are adjacent to the mire boundary. Intensively managed grasslands are associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths to the mire, negatively impacting water quality and potentially causing eutrophication.
3. Farmyards	Five farms have been identified in the catchment with Google Earth and OS data. Three of the farms, to the north and east, are on or near to major flow paths. Manure and slurry in farmyards may also act as a nutrient source to the mire downstream, either via overland flow or the leaching of nutrients to the groundwater that feeds the mire, depending on the maintenance and management of the assets involved.
4. Discharges and abstractions	None present in Environment Agency datasets.
5. Roads	The A3071 and the B3318 roads run through catchment along with other minor roads and restricted access roads leading to farms. The A3071 and the B3318 run along the top of the main flow pathways in the northern section and southern section of the catchment, respectively. There are roadside culverts that allow road run-off into the site (Low, 2018) showing how the roads may act as conduits for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography.
6. Other	There is evidence of historical mining activity in catchment with a mining shaft identified from the OS data near the spring in the southern catchment. It is not known to what extent the shaft may influence the spring that feeds into the mire.
Outcome	Based on the evidence above, this site is **high risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	300
2. Surface flow pathway protection	71
3. Steepest slopes	156
4. Lower slopes and valley floor	96
5. Groundwater emergence zone	68

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer. It is extended to encompass any identified springs and tributaries leading into the mire. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology. This boundary covers the majority of the valley bottom of the catchment.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor. The slopes within the valley change from level/gentle to moderate/steep at this point. This boundary is not dissimilar to the groundwater emergence zone boundary, again covering the valley bottom, but it does incorporate an area to the north on a main flow pathway, that has gently sloping topography.

The **steepest slopes zone** (no.3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography starts to plateau at the very top of the catchment. This boundary covers over 50% of the catchment area including the majority of the main flow pathways.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer.

The **surface water catchment zone** (no. 1) is the most extensive area (300 ha) covering both the northern and southern portions of the catchment and offers optimum protection to the mire.

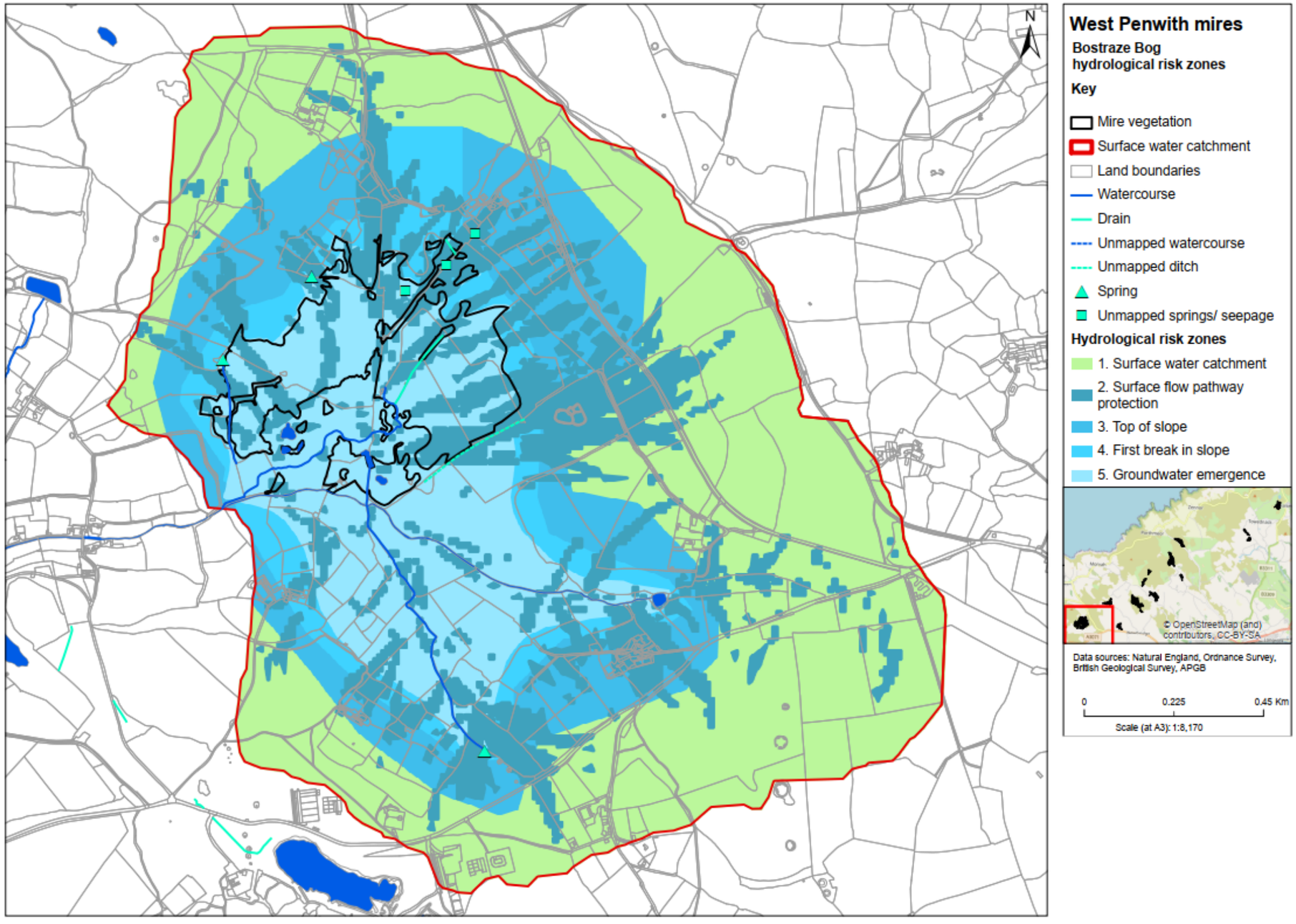


Figure 3-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	34%
Intensively managed (improved) grassland	13%
Rough low-productivity grassland	15%
Other land covers (including mire habitat)	39%

Bostraze Bog is assigned a catchment risk of high. This is primarily because to the extensive amount of arable land that intersected the main flow pathways leading to the mire. The influences of nutrient management on improved and in farmyards were also on potentially high risk as they were located on main flow pathways. The A3071 and B3318 roads which cross the catchment, although a potential high-risk feature, are further from the mire, crossing the tops of the main flow pathways. The mine shaft located near the southern spring may also potentially influence the water flowing into the mire from the south.

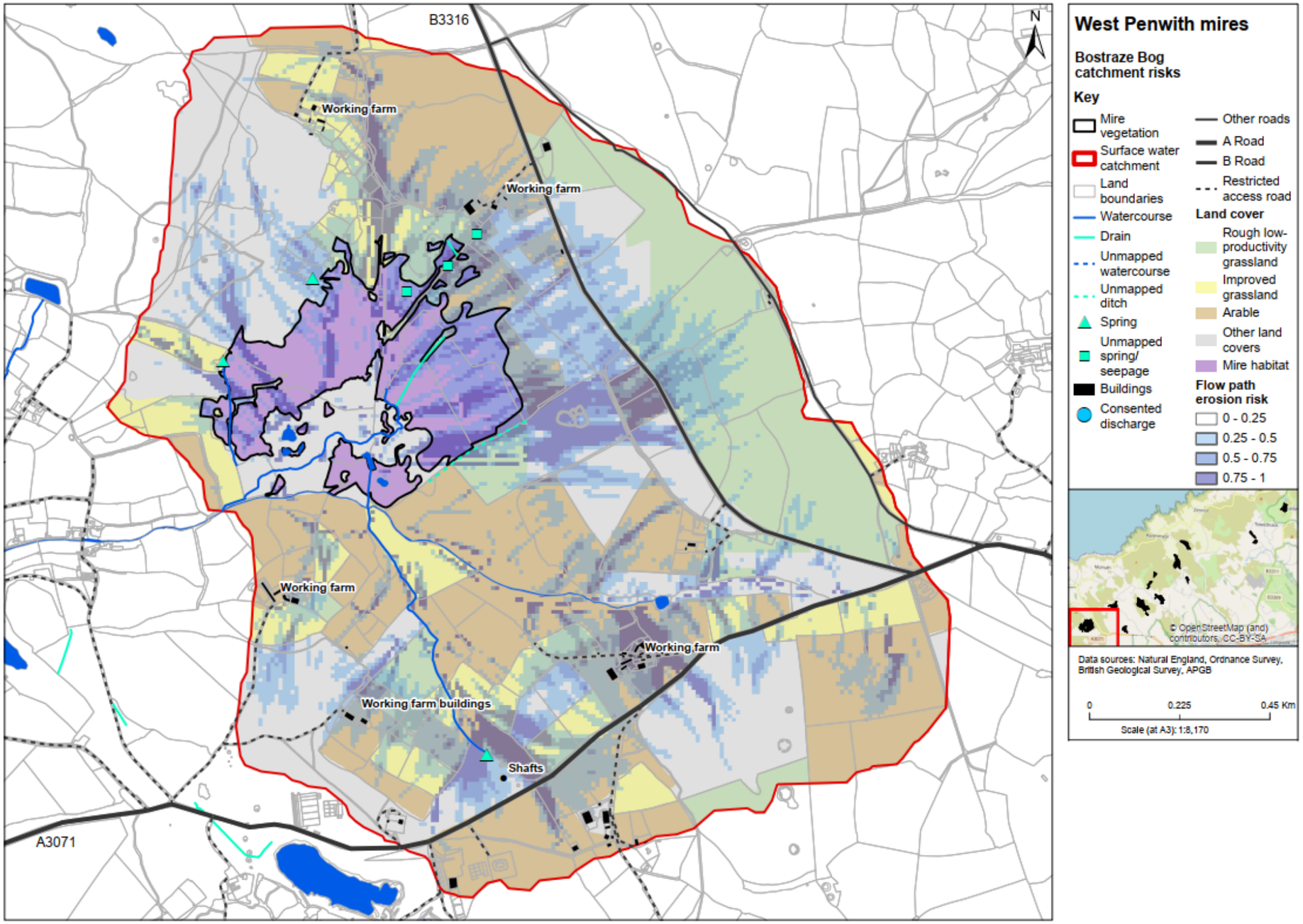


Figure 3-2. Map of catchment risks. Only land covers with a risk associated from CEHôs land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire. Unmapped features were identified in the field in Lowôs (2018) report.

Catchment land holdings

Description

There are 13 CPH land holdings within Bostraze Bog surface water catchment. Those around the peripheries and to the southern half of the catchment boundary are least likely to impact the mire as they are not on major flow pathways or steep slopes leading to the mire.
Those land holdings that intersect the mire boundary and the groundwater emergence zone which extends southwards towards the southern spring and pond may be most likely to impact the mire due to their close proximity.

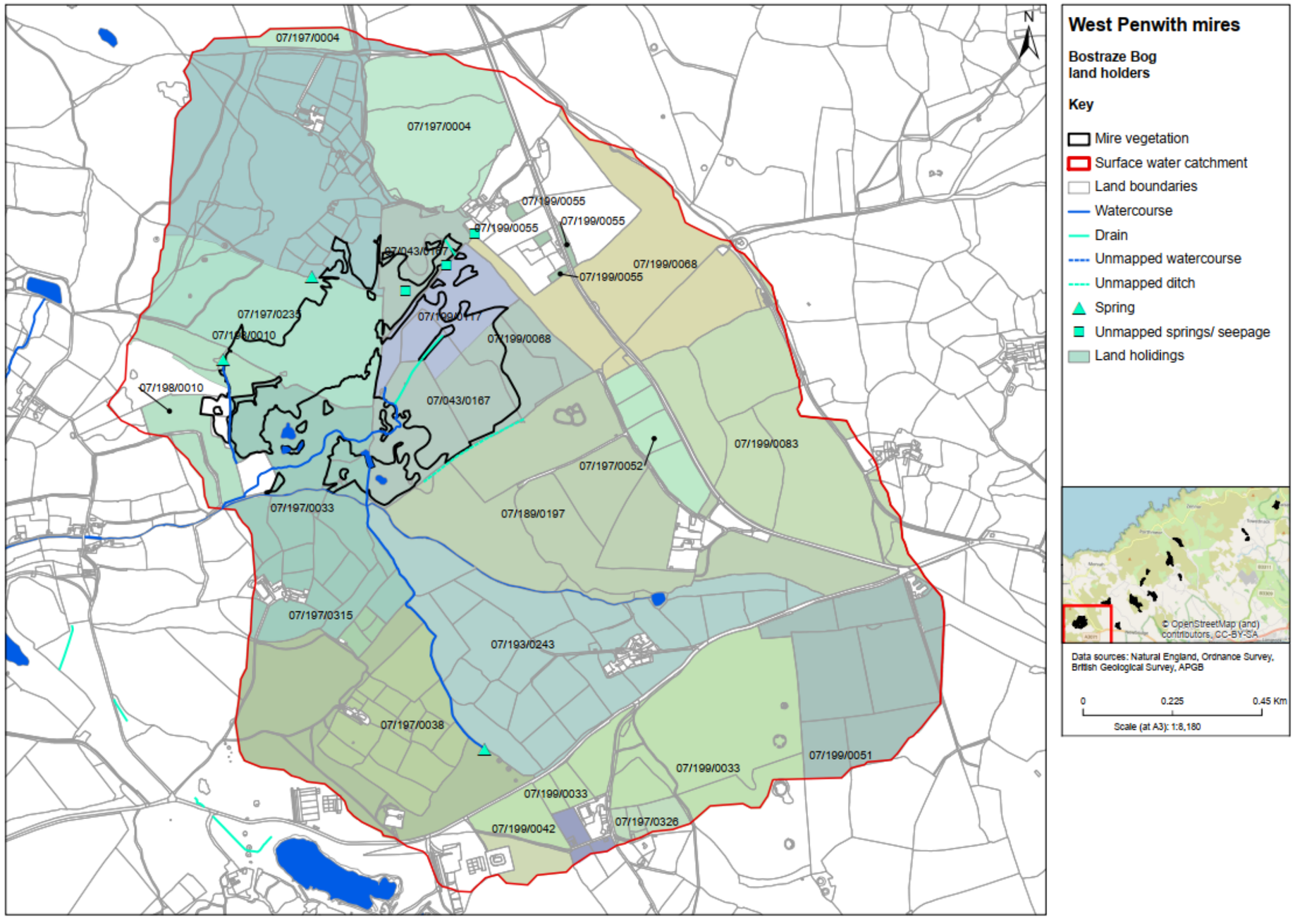


Figure 3-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

4. Boswarva Bog

Boswarva Bog

Catchment statistics

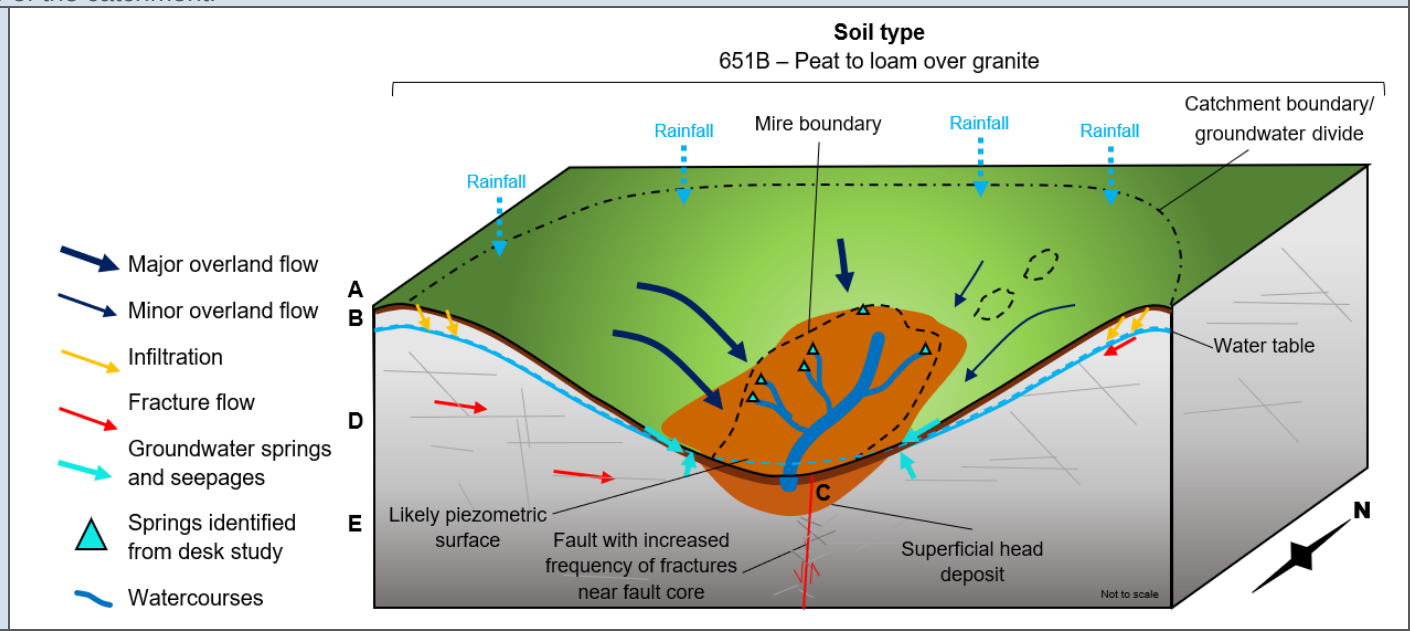
WFD WB catchment ID	GB108048002090 (Newlyn River)	**Extent of Mire Habitat (ha)**	16.38
Water body WFD Status	Overall: Moderate, Ecological: Good, Chemical: Fail due to surface water abstraction (2019)	**Total Catchment Area (ha)**	86
NGR (approximate site centre point)	SW 42200 33400	**Number of registered landholdings (Defra Rural Land Register) in catchment**	2

Main site features

1. Ecology and Habitats	Boswarva is predominantly (~90%) made up of variations of NVC mire community M25. M25 is usually found around seepage zones, flushes, water-tracks and topogenous mires, but may also extend onto fringes of ombrogenous mires that are rainfall dependent (Elkington et al. 2002). This community prefers moist but well aerated soils and depending on the hydroecological setting, has moderate or low groundwater dependency (UKTAG, 2009). However, in this context M25 appears to be soligenous as it can be a product of drainage of wetter mires such as M21, followed by grazing, and may have a higher groundwater dependency than indicated in UKTAG (2009). Other mire communities present include M23 (*Juncus effusus/acutiflorus – Galium palustre* rush-pasture), M1 (*Sphagnum auriculatum* bog pool community) and M16 (*Erica tetralix – Sphagnum compactum* wet heath), which are all maintained by a locally high water table and have groundwater dependency scores of 1, 3 and 1 respectively (UKTAG, 2009). Groundwater dependency scores differ from those reported in the previous ecohydrological report (James and King, 2019) because more recent scores have been used. Wet woodland community *Salix cinerea – Galium palustre* woodland (W1) is also present at the mire. Around the mire there is *Calluna vulgaris – Ulex gallii* heath (H8) to the south, *Ulex gallii – Agrostis curtisii* heath (H4) to the west, and *Pteridium aquilinum - Rubus fruticosus* underscrub (W25) to the north and east.
2. Topography and surface flow pathways	The mire covers the base of the valley and some of the valley side covering 20% of the catchment area. The mire habitat has elevations between 130 to 160 mAOD and has a comparatively steep topography with slopes over 7Áin some portions of the mire, although the majority has gentler slopes. The wider catchment has an elevation range from 130 mAOD at the valley outlet to 200 mAOD at the top of the catchment. There are steep slopes (maximum 10Á) adjacent to the north-eastern boundary of the mire that cross the length of the catchment, the south-western portion of the catchment has gentler slopes. The steep north-eastern slopes have extensive highly erosive flow pathways, with limited pathways on the gentler slopes (according to SCIMAP). Pendleton Hydro's (2019b) report suggests the fields around the site are relatively free draining with high infiltration with little evidence of overland flow onto the site. They suggest an additional catchment to the west with a stream leading to the mire, but this is downstream of the mire vegetation of interest in this report so is excluded.
3. Watercourses and drainage	The mire sits on a network of headwater tributaries that join the larger Newlyn River downstream of the catchment. There is no evidence of artificial drains identified in the OS data. Pendleton Hydro's (2019b) report shows unmapped watercourses that extends east towards the mire boundary. The report also shows that the network of six tributaries, which are considered to be natural, are fed by six springs/seepages, some at the boundary of the mire and some within the mire itself. Their report concludes that these are the main water source for the wetland communities in the north of the site.
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Landŝ End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Superficial head deposits cover the lowest elevations in the valley and the lower portion of the mire. The deposit is clay and silt dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling. OS open data (MasterMap, 2020) shows no springs in the catchment but Pendleton Hydro's (2019b) report shows six springs/seepage, some near the geological transition. There is a geological (normal) fault in the catchment, identified from BGS data, that follows the western edge of the mire habitat. The presence of a fault has the potential to alter the local flow regime with either increased fracture flow through open fractures or decreased flow as a result of closed fractures. The soil survey for SW England shows that the majority of the catchment has soil type 651B, including the mire habitat. This is a grit and loam dominated soil with a wet peaty surface horizon (Findlay, 1984). Pendleton Hydro's (2019b) report shows that the deepest part of the peat is near the stream at the outflow of the catchment.

5. Conceptual model

A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff.
B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils.
C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = 8.64×10^{-5} ï 1.73 m/d
D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = 6.9×10^{-4} ï 2.6×10^{2} m/d
E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = 1.73×10^{-5} ï 2.6×10^{-9} m/d



Catchment Risk Assessment

1. Arable land use	Large patches of arable land are identified from the CEH and CORINE datasets within the Boswarva Bog catchment, covering >20% of catchment area. The arable land borders the mire towards the north and intersects the major flow paths on the northern slopes of the catchment that leads directly to the mire. CROME data shows few areas of crops in this catchment. Pendleton Hydro's (2019b) report highlights that the main water source to the mire is not from overland flow but groundwater. The pollution and nutrient enrichment of the groundwater from land uses may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending upon land management practices, that may increase the volume of fine eroded particles being transported to the mire.
2. Grassland and nutrient management	The catchment has large patches of intensively managed grassland, identified from the CEH dataset, which covers >20% of catchment area to the north of the mire that intersect major flow pathways. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths to the mire or infiltrate to groundwater, negatively impacting water quality and potentially causing eutrophication. There is also a large patch of rough grassland bordering the mire to the south. Rough grassland poses a lower risk to the mire but may still contribute to eutrophication of the mire if the land is managed to some extent. The majority of the catchment to the south is semi-natural heathland grass habitat, identified from CORINE and CEH datasets.
3. Farmyards	A slurry pit is identified from the OS data associated with the building near the catchment boundary, upstream of major flow paths, but could not be confirmed on Google Earth. It may act as a nutrient source to the mire downstream depending on the maintenance and management of the assets.
4. Discharges and abstractions	None present in Environment Agency datasets.
5. Roads	No roads of note identified from OS data
6. Other	No evidence of historical mining activity in catchment identified from OS data
Outcome	Based on the evidence above, this site is **medium risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	86
2. Surface flow pathway protection	20
3. Steepest slopes	61
4. Lower slopes and valley floor	38
5. Groundwater emergence zone	22

The **groundwater emergence zone** (no.5) covers the extent of the mire vegetation and superficial geology including a 5m buffer which includes patches of vegetation to the south. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology. This boundary covers the valley bottom of the catchment.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor. This extends across all the gentle slopes to the west to the bottom of the steep eastern slopes encompassing >40% of the catchment area.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography starts to plateau at the very edges of the catchment. This boundary covers over 70% of the catchment area including the majority of the main flow pathways.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer.

The **surface water catchment zone** (no. 1) is 86 ha, a small extent compared to the other mire catchments. It offers optimum protection to the mire, although this may not be practical.

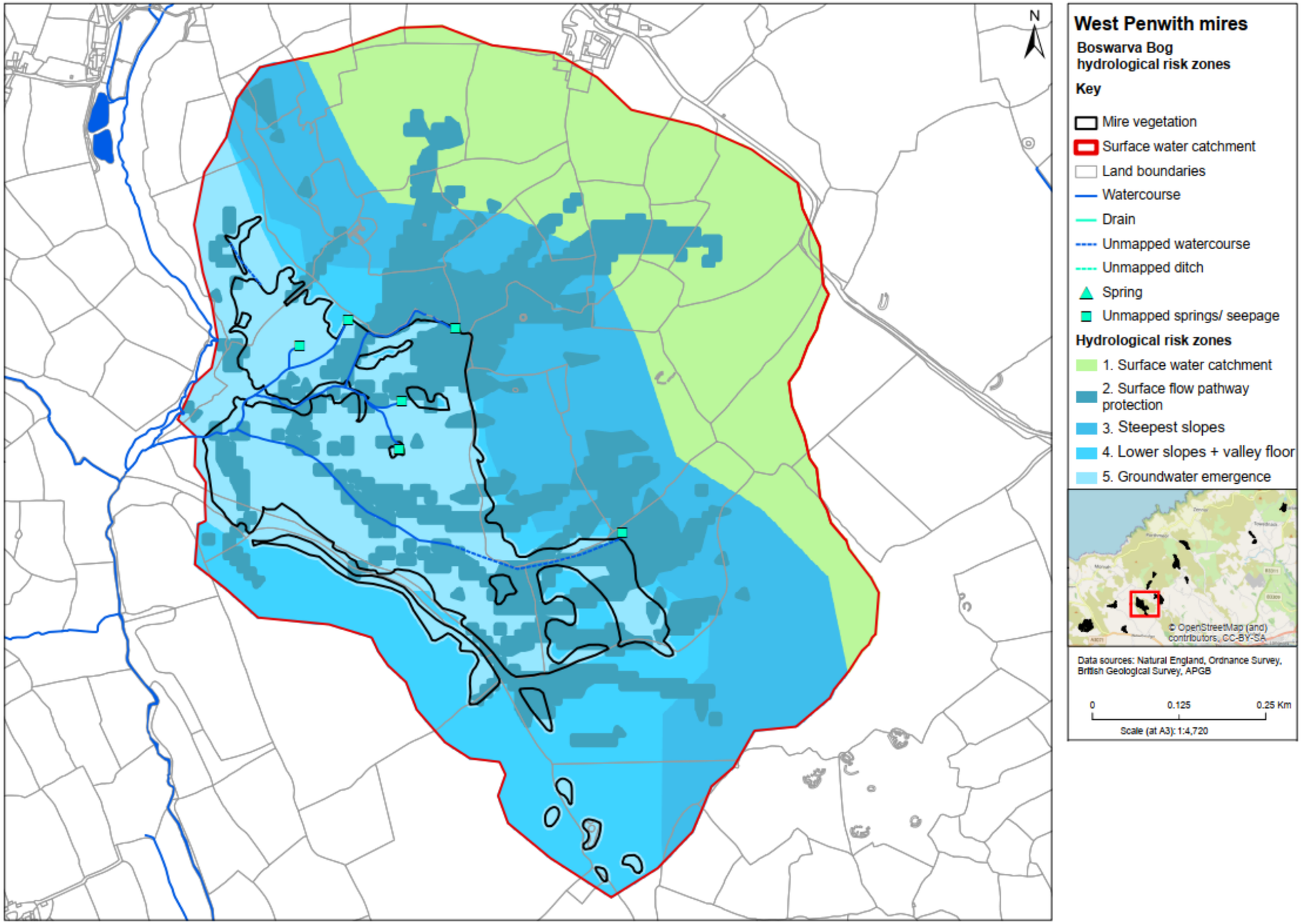


Figure 4-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	23%
Intensively managed (improved) grassland	23%
Rough low-productivity grassland	5%
Other land covers (including mire habitat)	49%

Boswarva Bog was assigned a catchment risk of medium. This is primarily because of the amount of arable land that intersected the main flow pathways leading to the mire and its close proximity to the mire. The influences of nutrient management on intensively managed grassland and the potential slurry pit are also potentially high risk but are located further from the mire boundary. There are no roads or mine features of note that may negatively influence the mire.

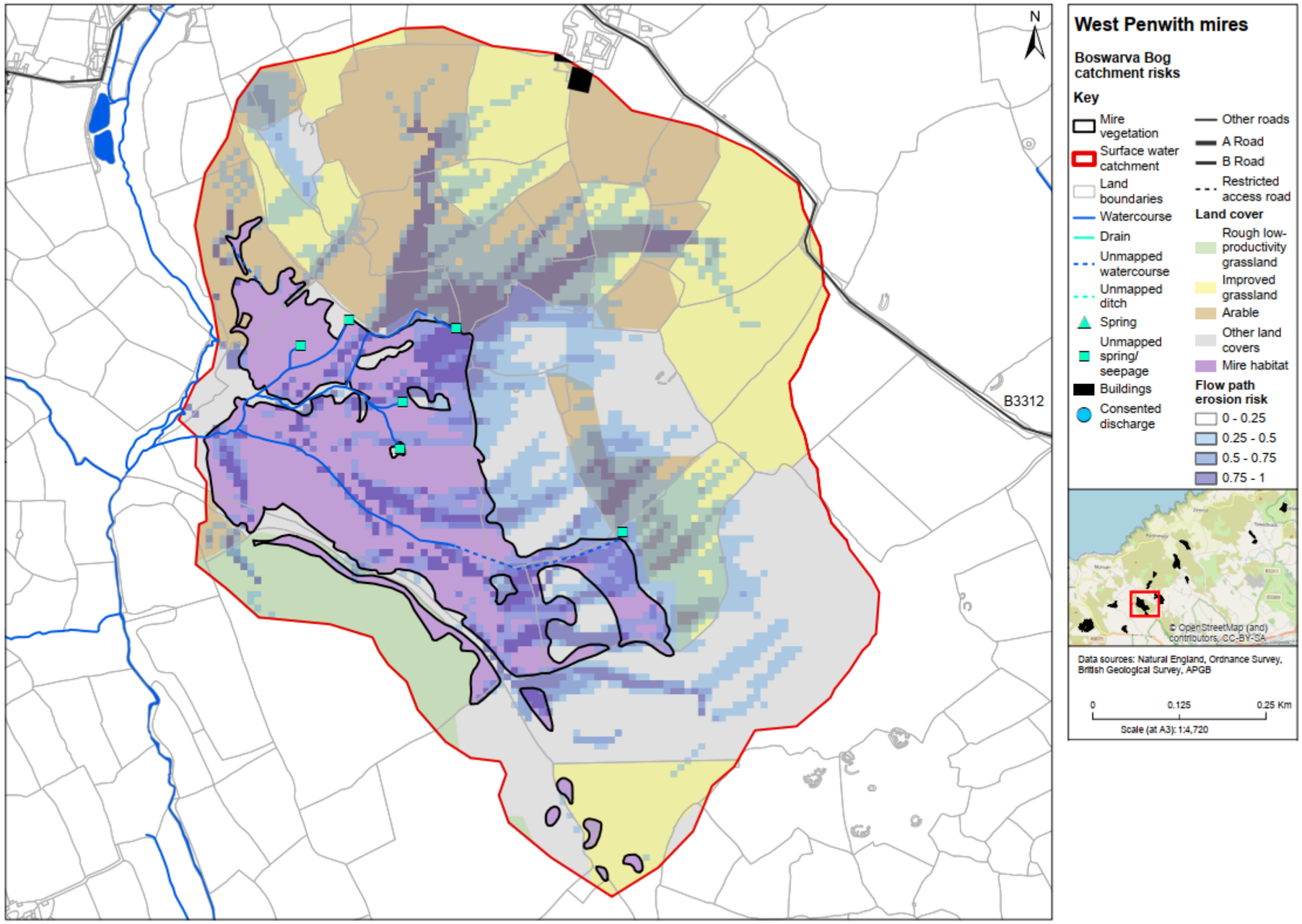


Figure 4-2. Map of catchment risks. Only land covers with a risk associated from CEHôs land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire. Unmapped features were identified in the field in Pendleton Hydroôs (2019b) report.

Catchment land holdings

There are 2 CPH land holdings within Boswarva Bog surface water catchment. Both intersect the mire boundary and the groundwater emergence zone so may be likely to impact the mire due to their close proximity.

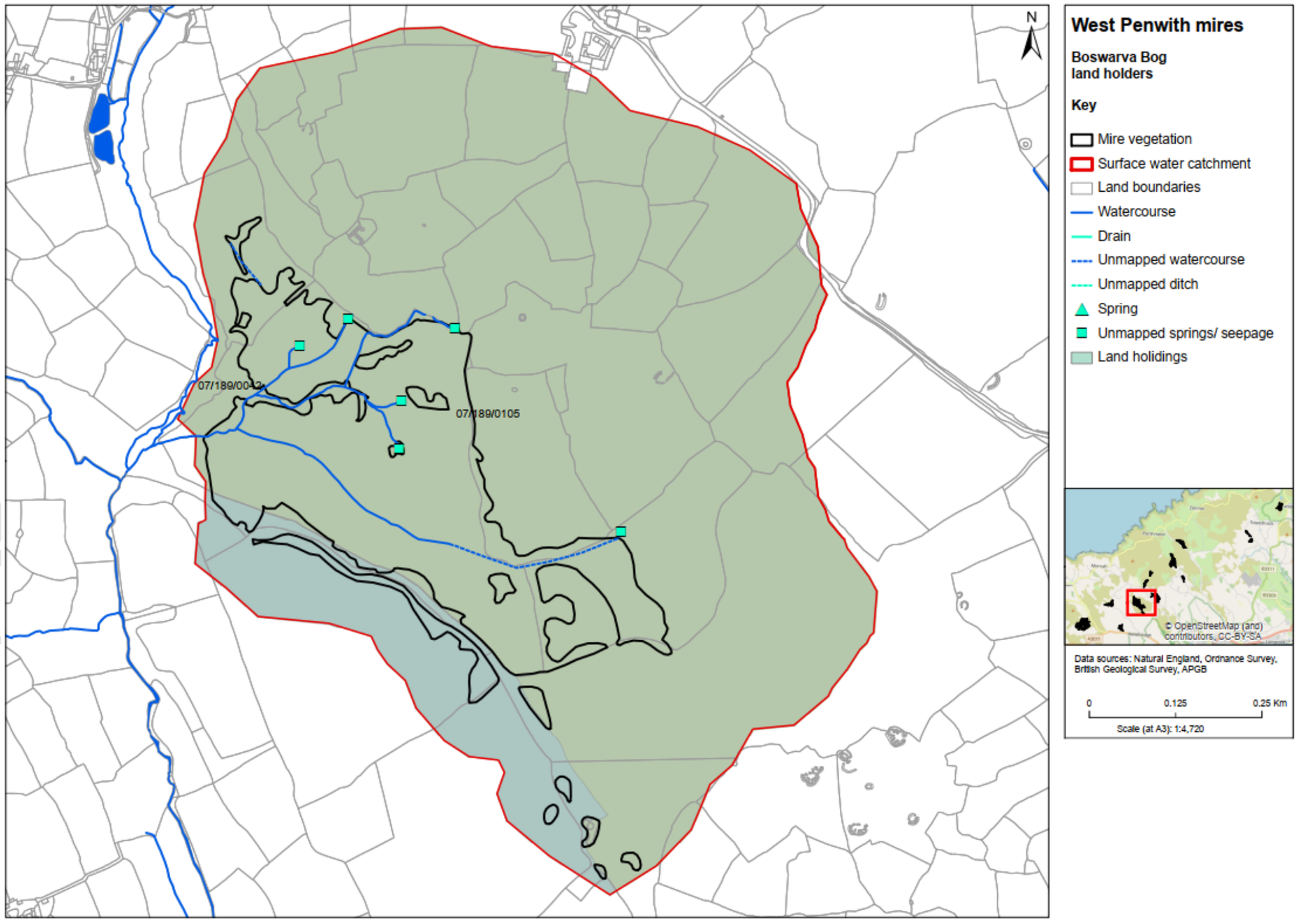


Figure 4-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

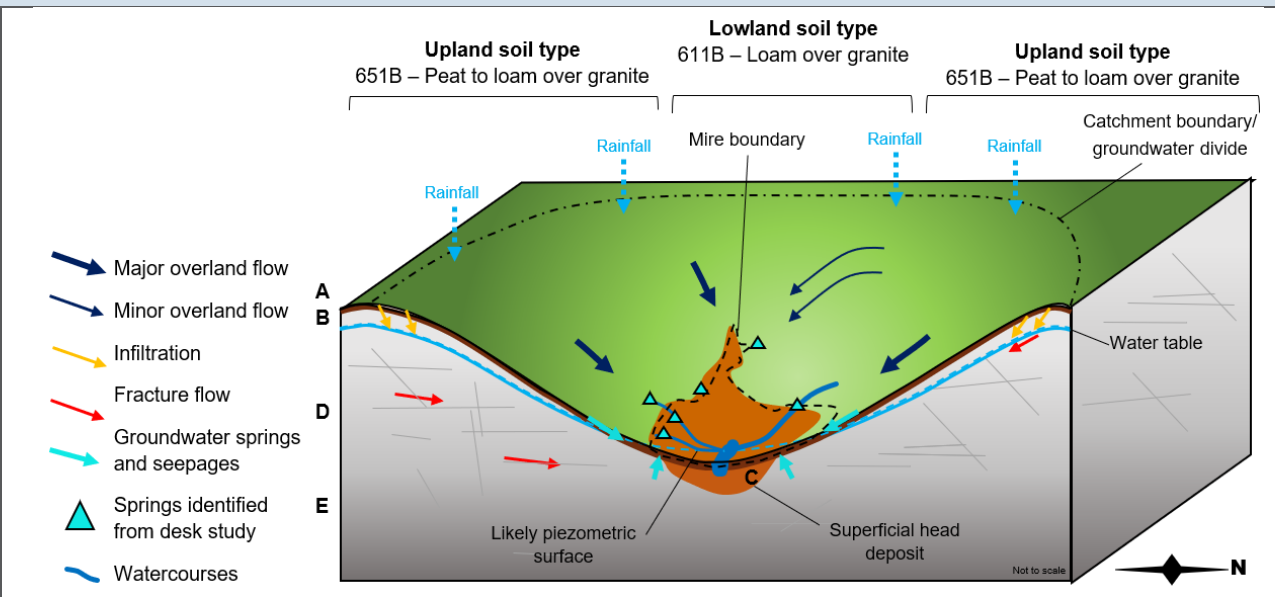
5. Boswens Bog

Boswens Bog

Catchment statistics

WFD WB catchment ID	GB108048002090 (Newlyn River)	**Extent of Mire Habitat (ha)**	6.14
Water body WFD Status	Overall: Moderate, Ecological: Good, Chemical: Fail due to surface water abstraction (2019)	**Total Catchment Area (ha)**	111
NGR (approximate site centre point)	SW 40700 33300	**Number of registered landholdings (Defra Rural Land Register) in catchment**	5

Main site features

1. Ecology and Habitats	Boswens is predominantly (~65%) made up of variations of NVC mire community M25. M25 is usually found around seepage zones, flushes, water-tracks and topogenous mires, but may also extend onto fringes of ombrogenous mires that are rainfall dependent (Elkington et al. 2002). This community prefers moist but well aerated soils and depending on the hydroecological setting, has moderate or low groundwater dependency (UKTAG, 2009). However, in this context M25 appears to be soligenous as it can be a product of drainage of wetter mires such as M21, followed by grazing, and may have a higher groundwater dependency than indicated in UKTAG (2009). Other mire communities present include M23 and M16, which are both maintained by a locally high water table and have groundwater dependency scores of 1 (high). Groundwater dependency scores may differ from those reported in the previous ecohydrological report (James and King, 2019) because more recent scores have been used. This bog also has a large covering (~15%) of wet woodland (W1), and scrub communities W22 (*Prunus spinosa - Rubus fruticosus* scrub), W23 (*Ulex europaeus - Rubus fruticosus* scrub) and W25 (*Pteridium aquilinum - Rubus fruticosus* underscrub) are also present.
2. Topography and surface flow pathways	The mire is set within a narrower valley than other mires covering 5% of the catchment area. The mire habitat has elevations between 155 to 180 mAOD and gentle to moderate slopes towards the outlet (2-5Á). The wider catchment has an elevation range from 155 mAOD at the valley outlet to 225 mAOD at the top of the catchment. It has moderate slopes (maximum 5Á) adjacent to the mire habitat with steeper slopes that may influence the mire from the north. There are extensive highly erosive flow pathways across the catchment radiating out from the mire (according to SCIMAP).
3. Watercourses and drainage	The mire encompasses multiple headwaters converging at the downstream of the mire habitat in Boswens Stream, a tributary of Newlyn River. Pendleton Hydro's (2019a) report shows that these headwaters are groundwater gaining (i.e. have groundwater inflow to the stream through the channel bed). The report also records an unmapped watercourse extending through the length of the mire habitat, and another stream on the southern boundary, all fed by springs/seepages. The southern unmapped stream may once have flowed into the site but has been redirected to the east, providing water for horses (Pendleton Hydro, 2019a). The streams are relatively confined so are unlikely to influence the mire vegetation except during flood events. The main water source the mires is from the springs/seepages directly. There is no evidence of artificial drains identified in the OS data and little evidence of overland flow from the north-western fields in Pendleton Hydro's (2019a) report which suggests that the soil is well drained and the source of water from these fields to the mire is via infiltration. However, the watercourses towards the bottom of the mire appear to be straightened and may be artificial.
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Land's End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Superficial head deposits cover the base of the valley, matching the mire vegetation boundary. The deposits are clay and silt dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). OS open data (MasterMap, 2020) shows no evidence of springs in the catchment but they may be present along with soil seepage at the geological transition. The soil survey for SW England shows that the majority of the catchment has soil type 651B including the upper mire habitat and 611B lower in the mire. Both soil types are grit and loam dominated, but the upper catchment soil type is wet and peaty whereas the lower catchment soil type is well drained with a humose surface horizon (Findlay, 1984).
5. Conceptual model A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff. B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils. C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = $8.64x10^{-5}$ ï 1.73 m/d D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = $6.9x10^{-4}$ ï $2.6x10^{2}$ m/d E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = $1.73x10^{-5}$ ï $2.6x10^{-9}$ m/d	

Catchment Risk Assessment

1. Arable land use	Patches of arable land are identified from the CEH and CORINE datasets within the Boswens Bog catchment, covering <30% of catchment area. The arable land borders the mire and intersects the main flow pathways. CROME data shows that arable land has included maize and fallow land in the past. Pendleton Hydro's (2019a) report states that fields adjacent to the mire are primarily used for grazing cattle and arable grass silage with one managed arable field on the northern boundary of the mire. The pollution and nutrient enrichment of overland flow or the groundwater from arable land uses may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending on land management practices and degree of slope, that may increase the volume of fine eroded particles being transported to the mire.
2. Grassland and nutrient management	The catchment has patches of intensively managed grassland interspersed with the arable fields, identified from the CEH dataset. It covers <30% of catchment area including fields that border the mire and intersects major flow pathways. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths to the mire or infiltrate to groundwater, negatively impact water quality and potentially causing eutrophication. There are also patches of rough grassland near the catchment's boundaries.
3. Farmyards	A farm identified as Trehyllys Farm, has been identified with Google Earth and OS data near the mire boundary on a major flow path. Manure and slurry in farmyards may also act as a nutrient source to the mire downstream, either via overland flow or the leaching of nutrients to the groundwater that feeds the mire, depending on the maintenance and management of the assets involved.
4. Discharges and abstractions	None present in Environment Agency datasets.
5. Roads	A short length of local road leading to the farm crosses the catchment on a flow pathway. Roads may act as conduits for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography.
6. Other	No evidence of historical mining activity in the catchment identified from OS data
Outcome	Based on the evidence above, this site is **medium risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	111
2. Surface flow pathway protection	25
3. Steepest slopes	84
4. Lower slopes and valley floor	31
5. Groundwater emergence zone	9

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer. It also includes a buffer around the outflow channel from the mire. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor. This extends across all the gentle to moderate slopes adjacent to the mire encompassing >25% of the catchment area.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography starts to plateau at the very edges of the catchment. This boundary covers over 75% of the catchment area including all of the main flow pathways.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer.

The **surface water catchment zone** (no. 1) is 111 ha, a moderate extent compared to the other mire catchments. It offers optimum protection to the mire, although this may not be practical.

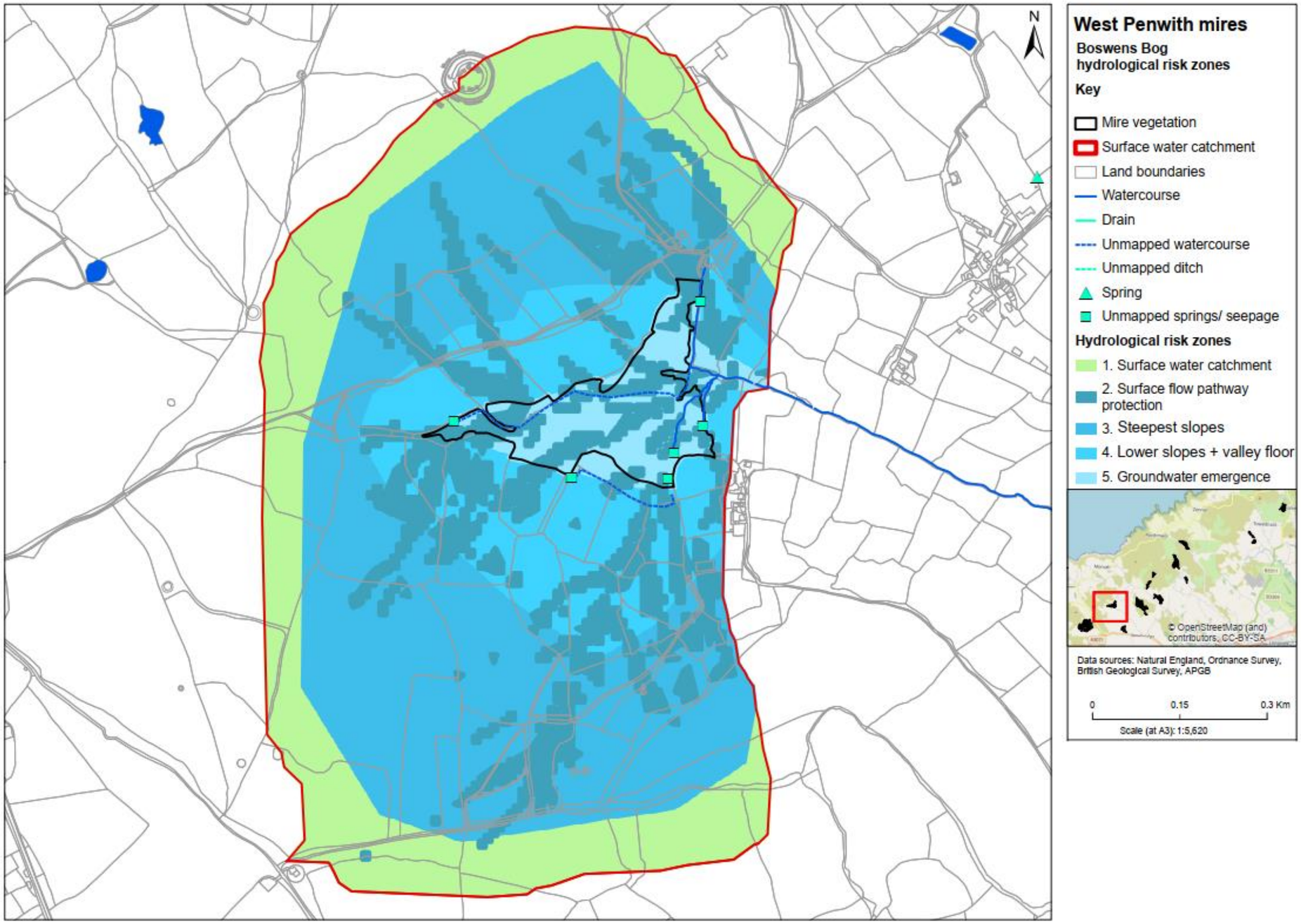


Figure 5-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	28%
Intensively managed (improved) grassland	25%
Rough low-productivity grassland	15%
Other land covers (including mire habitat)	32%

Boswens Bog was assigned a catchment risk of medium. This is primarily because of the arable land that intersected the main flow pathways leading to the mire. The influences of nutrient management on intensively managed grassland and in the farm were also potentially a risk as they were located on main flow pathways and in close proximity to the mire. The local road was not determined to be a major risk to the mire due to its short extent and there is no evidence of consented discharges or historic mining in the catchment.

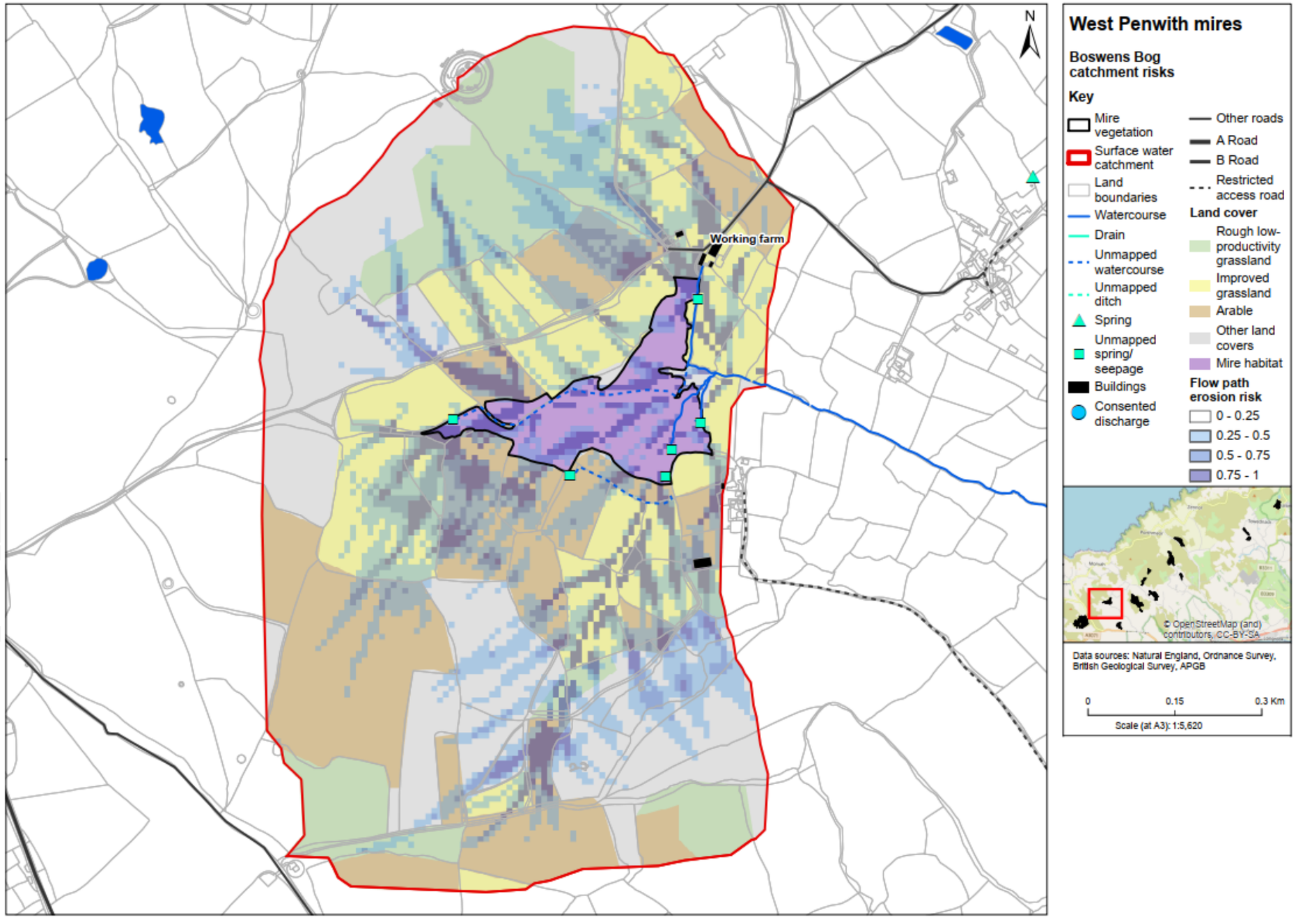


Figure 5-2. Map of catchment risks. Only land covers with a risk associated from CEHôs land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire. Unmapped features were identified in the field in Pendleton Hydroôs (2019a) report.

Catchment land holdings

There are 5 CPH land holdings within Boswens Bog surface water catchment. Three land holdings intersect the mire boundary and the groundwater emergence zone so may be most likely to impact the mire due to their close proximity.

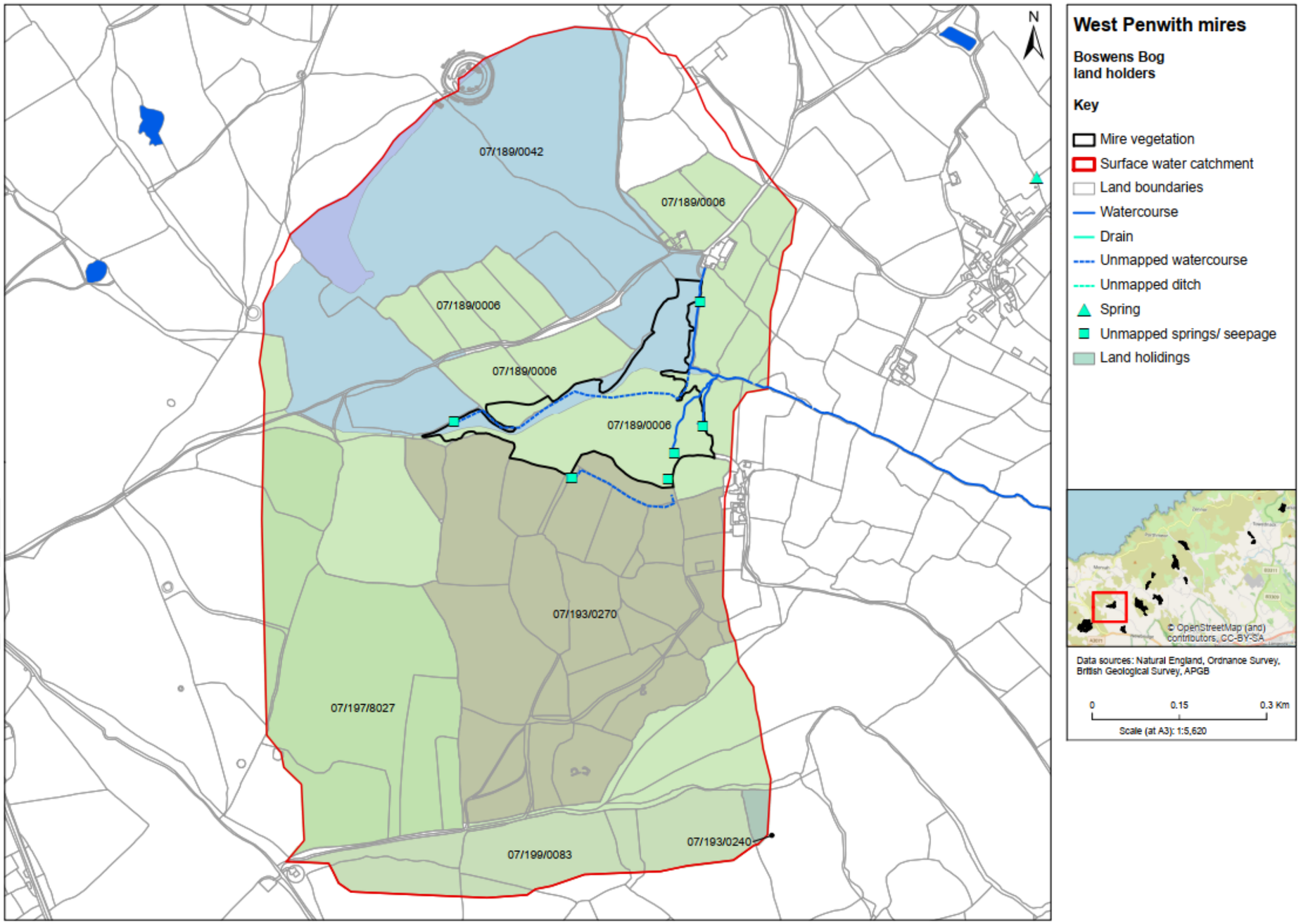
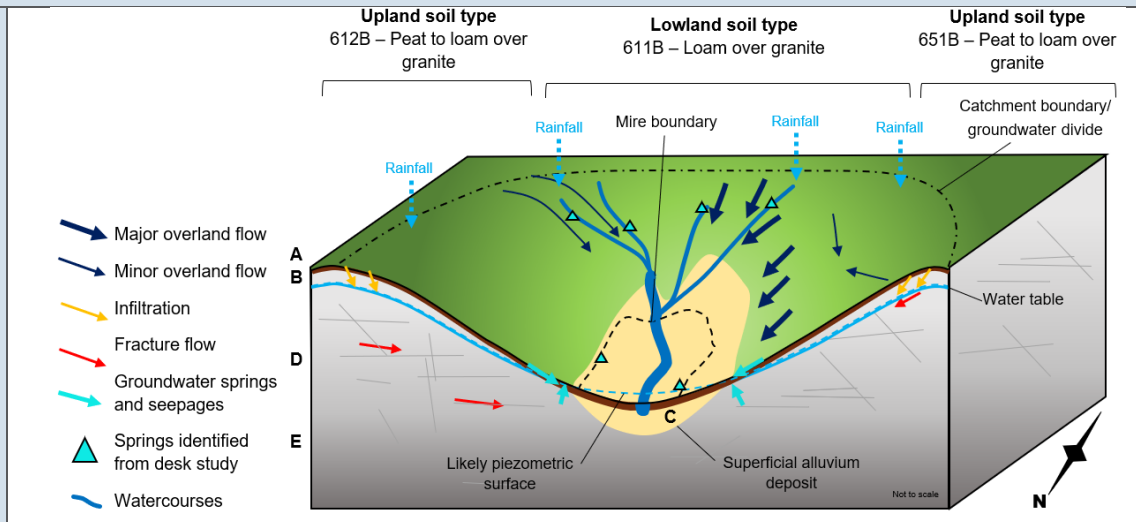


Figure 5-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

6. Bussow Moor

Bussow Moor			
Catchment statistics			
WFD water body catchment ID	230 (Coastal water body)	**Extent of Mire Habitat (ha)**	7.02
Water body WFD Status	Not in river water body	**Total Catchment Area (ha)**	160
NGR (approximate site centre point)	SW 50000 38700	**Number of registered landholdings (Defra Rural Land Register) in catchment**	8

Main site features	
1. Ecology and Habitats	The most prominent NVC community within Bussow Moor is M23, which makes up around half of the mire. A further ~25% of the mire is M25. M23 is characteristic of topogenous mires whilst also being found in areas where soligenous flows are the main source of water (Elkington et al. 2002). M25 is often found around topogenous mires that are dependent on a high local groundwater table but can also extend onto the fringes of ombrogenous mires that are rainfall dependent (Elkington et al. 2002). However, in this context M25 appears to be soligenous as it can be a product of drainage of wetter mires such as M21, followed by grazing. The relative dependence of the communities on groundwater given by UKTAG (2009) are high (score of 1) for M23 and moderate (score of 2) for M25. Groundwater dependency scores differ from those reported in the previous ecohydrological report (James and King, 2019) because more recent scores have been used. The remaining area is made up of a strip of W23 scrubland through the centre of the mire, a strip of *Lolium perenne - Cynosurus cristatus* improved, well-drained permanent grassland (MG6) to the west of the site and smaller patches of wet woodland (W1 and Willow). W23 and Willow are also found to the north and south of the site.
2. Topography and surface flow pathways	The mire only partially covers the base of the valley covering <5% of the catchment area. The mire habitat has elevations between 120 to 130 mAOD and has level topography under 2Áin slope. The wider catchment has an elevation range from 120 mAOD at the valley outlet to 220 mAOD at the top of the catchment. It has steep slopes (maximum 15Á) near the north-west boundary of the mire. There are also steep slopes further from the mire near the southern catchment boundary. The steep northern slopes have highly extensive erosive flow pathways covering the majority of the slope. Flow pathways in the rest of the catchment are more concentrated, draining towards tributaries that feed the mire (according to SCIMAP). This is supported by Pendleton Hydro's (2019c) report that suggests that overland flow is minimal in the mire and infiltrates in through the head deposit and that the network of ditches just upstream of the mire captures most overland flow from the south and east.
3. Watercourses and drainage	Multiple headwater tributaries converge into the Stennack River which runs through the mire including a number of artificial drains identified through OS data. Pendleton Hydro's (2019c) report also highlights additional watercourses which extend the tributary network upstream and seven springs/seepages that feed tributaries directly or are located within the mire habitat. They also highlight that Stennack River is modified throughout its extent and is concrete lined with sluice gates near the catchment outlet. Due its confinement it is not the primary source of water to the mire habitat during normal flow but may be during floods. Instead the two channels to the east of Stennack River fed by seepages are suggested to provide the majority of water to the mire and should be protected.
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Land's End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Superficial alluvium deposits cover the base of the valley, matching the mire vegetation boundary. The deposits are clay, silt and gravel dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). OS open data (MasterMap, 2020) shows no evidence of springs in the catchment but Pendleton Hydro's (2019c) report shows seven springs/seepages around the geological transition. The soil survey for SW England shows that the majority of the catchment has soil type 611B, 651B is on the steepest northern slopes and 612B in the upper catchment to the south. All soil types are grit and loam dominated but the 611B on the steep slopes is wet and peaty whereas the other soil types are well drained with a humose surface horizon (Findlay, 1984).
5. Conceptual model A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff. B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils. C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = $8.64x10^{-5}$ ï 1.73 m/d D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = $6.9x10^{-4}$ ï $2.6x10^{2}$ m/d E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = $1.73x10^{-5}$ ï $2.6x10^{-9}$ m/d	

Catchment Risk Assessment	
1. Arable land use	Bussow Moor has arable land, identified from the CEH and CORINE datasets, near the catchment boundary and adjacent to the mire, covering <30% of the catchment area. The arable land that borders the mire intersects the main flow pathways. CROME data shows that arable land has included spring barley in the past. The pollution and nutrient enrichment of overland flow or groundwater from arable land uses may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending upon land management practices, that may increase the volume of fine eroded particles being transported to the mire.
2. Grassland and nutrient management	There are large areas of intensively managed grassland in the catchment, identified from the CEH dataset, covering >45% of the catchment area. Intensively managed grassland is on the extensive flow paths that flow into the mire from the west and adjacent to the mire. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths to the mire or infiltrate to groundwater, negatively impacting water quality and potentially causing eutrophication. There are few patches of rough grassland or other semi-natural land covers within the catchment.
3. Farmyards	There are four farms or groups of farm buildings off Towednack Road identified as working farms from Google Earth with evidence of slurry beds from the OS data. These farms are on extensive high erosion flow pathways. Chytodeen Farm is also identified to the west of the catchment with a slurry pit identified from Google Earth and OS data. This farm is upstream of a tributary leading to a spring that may feed the mire. Manure and slurry in farmyards may also act as a nutrient source to the mire downstream, either via overland flow or the leaching of nutrients to the groundwater that feeds the mire, depending on the maintenance and management of the assets involved.
4. Discharges and abstractions	Two domestic treated sewage consented discharges are identified from Environment Agency data on major flow paths. This may be a source of pollution that may deteriorate the water quality of the mire. No abstractions are identified from the Environment Agency dataset.
5. Roads	Local roads and restricted access roads cross the catchment. Towednack Road crosses the major flow pathways leading to the mire so may act as a conduit for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography. The B3311 also crosses the catchment boundary to the east but this is not identified as a risk to the mire due to its distance from the mire habitat.
6. Other	There is evidence of historical mining activity in the catchment with five mining shafts identified from the OS data. Most of the shafts are on the extensive erosive flow pathways potentially posing a risk to the mire water table. It is not known to what extent the shafts may influence the mire habitat.
Outcome	Based on the evidence above, this site is **high risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	160
2. Surface flow pathway protection	46
3. Steepest slopes	127
4. Lower slopes and valley floor	45
5. Groundwater emergence zone	28

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer. The buffer extends around watercourses feeding the mire from the catchment. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor covering the valley bottom encompassing >25% of the catchment area.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography starts to plateau at the very edges of the catchment. The steepest slopes extend to near the catchment boundary in many cases so cover nearly 80% of the catchment area including most of the main flow pathways.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer. The flow pathways in this catchment are so extensive that this boundary covers >25% of catchment area.

The **surface water catchment zone** (no. 1) is 160 ha and is one of the catchments with the largest extents. It offers optimum protection to the mire, although this may not be practical.

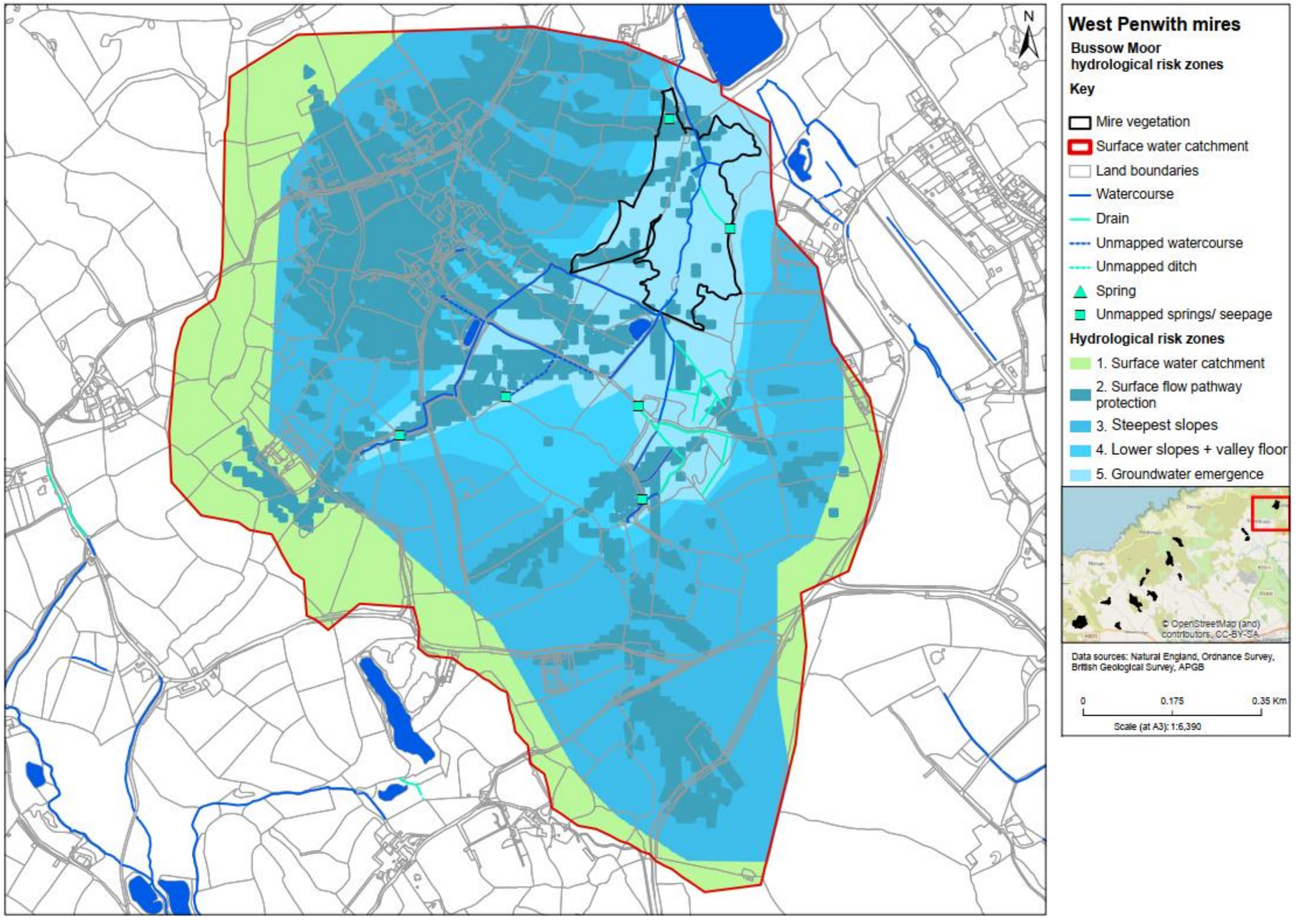


Figure 6-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	28%
Intensively managed (improved) grassland	49%
Rough low-productivity grassland	1%
Other land covers (including mire habitat)	22%

Bussow Moor is assigned a catchment risk of high. This is primarily because of the extensive amount of arable land that intersects the main flow pathways leading to the mire. The influences of nutrient management on intensively managed grassland and in the farm is also potentially high risk as they are located on main flow pathways and in close proximity to the mire. The consented discharges may also be point sources of pollutants to the mire. Towednack Road crosses the main flow paths and may also be a source of pollution to the mire. There are multiple mine shafts in the catchment that may pose a risk as they may influence the water table. The drain within the mire was shown to feed the mire, having a positive impact on the habitat (Pendleton Hydro, 2019c) but the impact of the drains upstream of the mire is unclear.

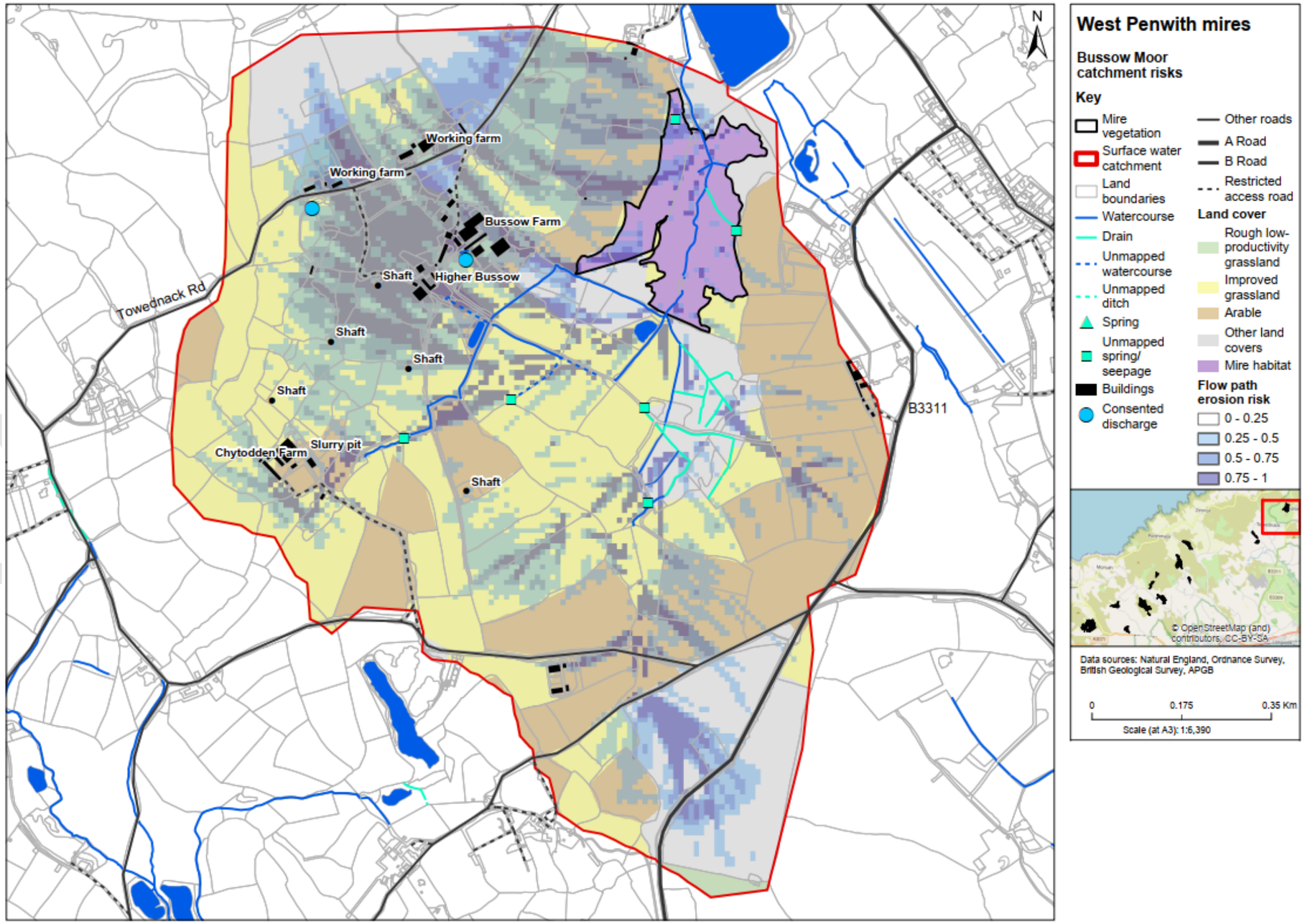


Figure 6-2. Map of catchment risks. Only land covers with a risk associated from CEHôs land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire. Unmapped features were identified in the field in Pendleton Hydroôs (2019c) report.

Catchment land holdings

There are 8 CPH land holdings within Bussow Moor surface water catchment. Those around the periphery of the catchment boundary are least likely to impact the mire as they are not on major flow pathways or steep slopes leading to the mire. One land holding covers the extent of the mire vegetation, and a second land holding covers that majority of the groundwater emergence zone so they may be most likely to impact the mire due to their close proximity.

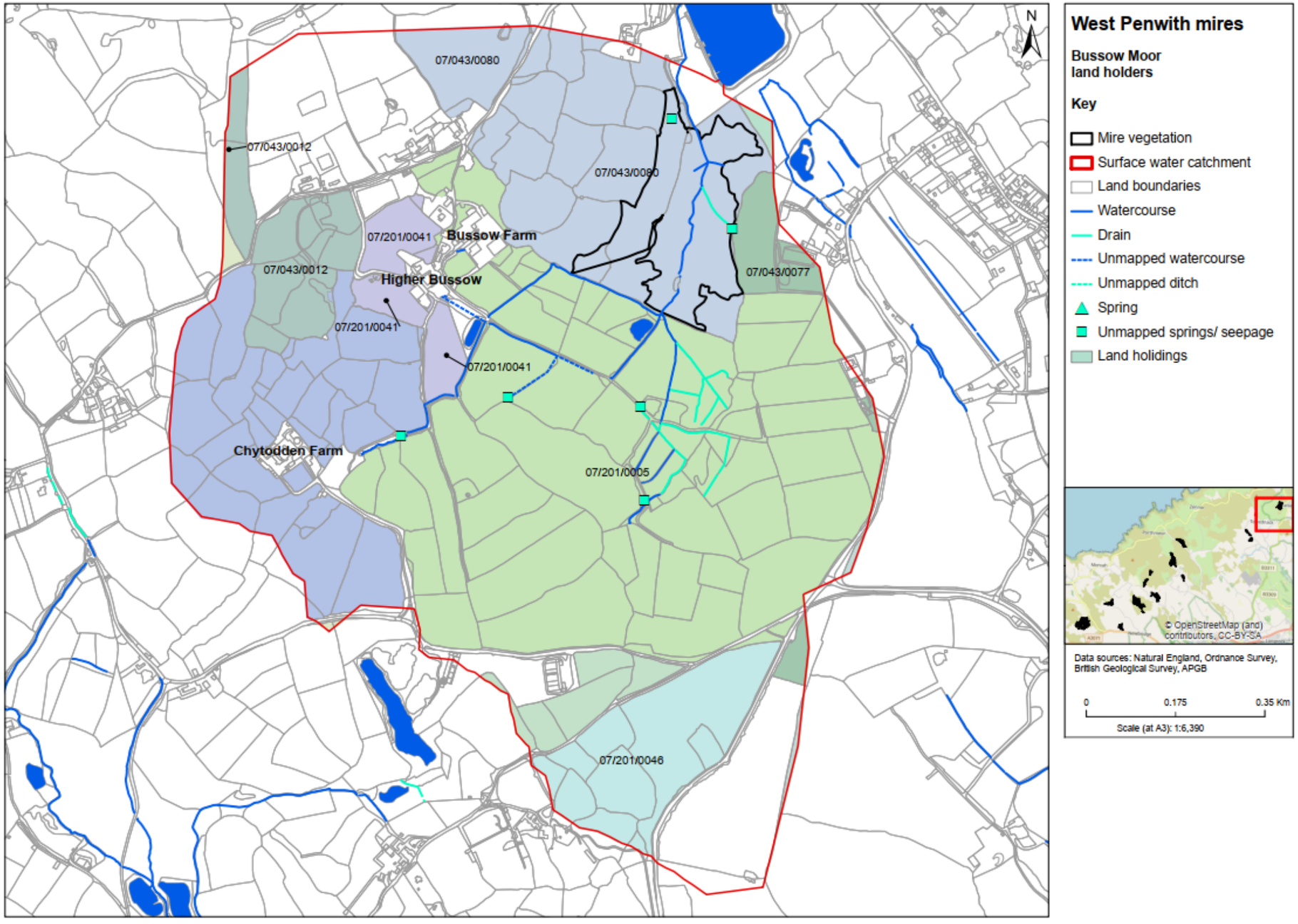


Figure 6-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

7. Embla North and South

Embla North and South

Catchment statistics

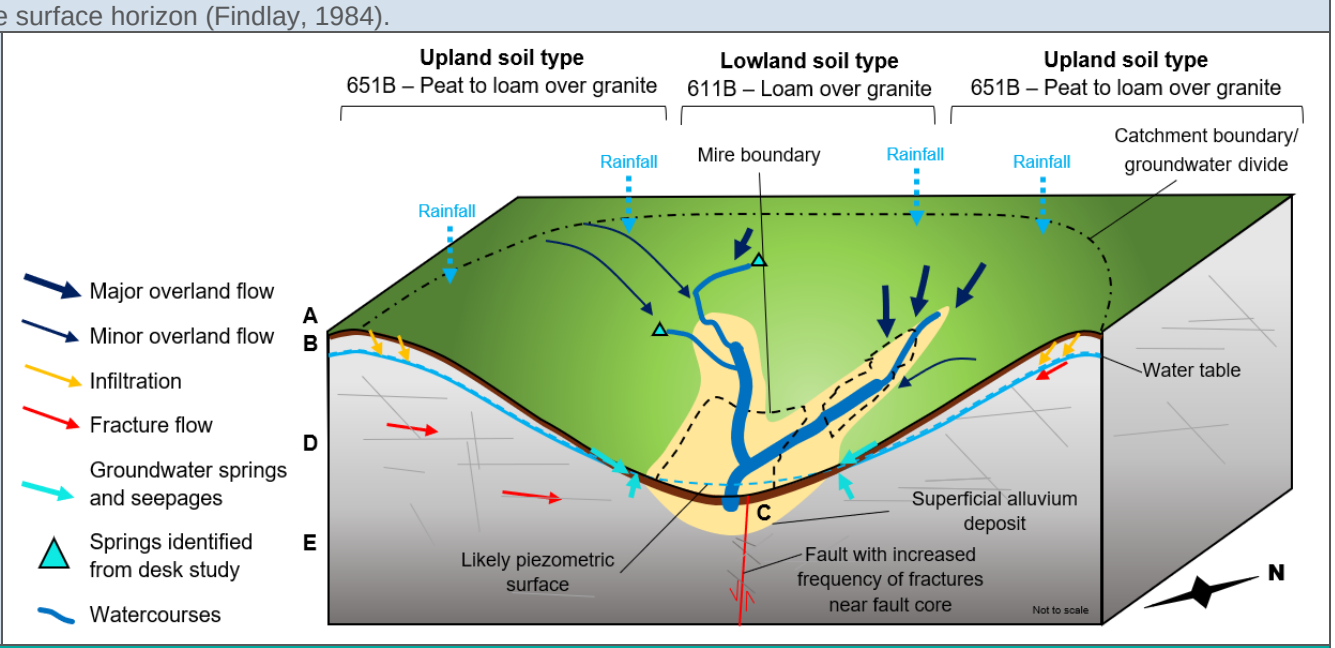
WFD water body catchment ID	GB108048002110 (Marazion River)	**Extent of Mire Habitat (ha)**	2.88 ha (North) and 2.53 ha (South)
Water body WFD Status	Overall: Moderate, Ecological: Moderate, Chemical: Fail due to diffuse and point source pollution from abandoned mine (2019)	**Total Catchment Area (ha)**	131
NGR (approximate site centre point)	SW 48200 37300 (North) and SW 48445 36862 (South)	**Number of registered landholdings (Defra Rural Land Register) in catchment**	16

Main site features

1. Ecology and Habitats	Embla North is predominantly made up of variations of NVC mire community M25 (~30%). M25 is usually found around seepage zones, flushes, water-tracks and topogenous mires, but may also extend onto fringes of ombrogenous mires that are rainfall dependent (Elkington et al. 2002). This community prefers moist but well aerated soils and depending on the hydroecological setting, has moderate or low groundwater dependency (UKTAG, 2009). However, in this context M25 appears to be soligenous as it can be a product of drainage of wetter mires such as M21, followed by grazing, and may have a higher groundwater dependency than indicated in UKTAG (2009). M25 occurs in a mosaic with wet woodland (W1) at the centre of the site, and in transition with scrubland community W25. Mire community M23 is also present as well as *Holcus lanatus - Juncus effusus* rush pasture MG10 and scrub community W22, each making up ~10-15% of the mire. Embla South is predominantly made up of variations of NVC mire community M23 (~60%). M23 is characteristic of topogenous mires whilst also being found in areas where soligenous flows are the main source of water (Elkington et al. 2002). The relative dependence of M23 on groundwater given by UKTAG (2009) is high (score of 1). A further ~20% of the mire is covered with wet woodland (W1). Mire community M25 is also present but covers a much smaller area, along with mesotrophic grassland (MG10) and scrub communities (W22 and W25).
2. Topography and surface flow pathways	The mire is in two sections partially covering the base of the valley. They cover <5% of the catchment area. The northern mire habitat has elevations between 150 to 180 mAOD and has gentle topography under 3Áin slope. The southern mire habitat has elevations between 145 to 155 mAOD and has level topography under 2Áin slope. The wider catchment has an elevation range from 140 mAOD at the valley outlet to 225 mAOD at the top of the catchment. There are limited areas of steep slopes (maximum 8.5Á) to the south of the mires with moderate slopes (<5Á) adjacent to the mires. Highly erosive flow pathways drain towards tributaries that feed the mires (according to SCIMAP).
3. Watercourses and drainage	The mires sit on a network of headwater tributaries which converge downstream of the southern mire. The northern tributary is fed by a pond at the upper end of the northern mire habitat and runs along the mire's northern boundary. The southern mire is fed by two tributaries that flow along the southern boundary of the mire habitat. The tributary from the northern mire also flows along the boundary of the southern mire habitat. OS data shows that the two southern headwaters are fed by springs which should be in the main protection area. There are no artificial drains identified through OS data in the catchment.
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Land's End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Alluvium superficial deposits cover the base of the valley. The two areas of mire vegetation sit within this deposit. The deposits are clay, silt and gravel dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). BGS data also shows a geological fault near the outlet of the catchment extending up the northern tributary on the northern edge of the mire habitat. The presence of a fault has the potential to alter the local flow regime with either increased fracture flow through open fractures or decreased flow as a result of closed fractures. OS open data (MasterMap, 2020) shows no evidence of springs at the geological transition but they may be present along with soil seepage in this region. The soil survey for SW England shows that the majority of the catchment has soil type 651B, and soil type 611B in the northern upper catchment, partially within the northern mire habitat. Both soil types are grit and loam dominated but 651B is wet and peaty whereas 611B in the upper catchment is well drained with a humose surface horizon (Findlay, 1984).

5. Conceptual model

A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff.
B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils.
C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = 8.64×10^{-5} ï 1.73 m/d
D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = 6.9×10^{-4} ï 2.6×10^{2} m/d
E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = 1.73×10^{-5} ï 2.6×10^{-9} m/d



Catchment Risk Assessment

1. Arable land use	The Embla catchment has arable land, identified from the CEH and CORINE datasets, in small isolated patches covering >10% of catchment area, with only one field bordering the mire habitats. The arable land that borders the mire intersects the main flow pathways. CROME data shows few crops present in the past. The pollution and nutrient enrichment of overland flow or groundwater from arable land uses may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending on land management practices, that may increase the volume of fine eroded particles being transported to the mire.
2. Grassland and nutrient management	The majority of the catchment is intensively managed grassland, identified from the CEH dataset, covering >50% of catchment area including the major flow paths throughout the catchment. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths to the mire or infiltrate to groundwater, negatively impacting water quality and potentially causing eutrophication. There are a few patches of rough grassland or other semi-natural land covers within the catchment, but they do not intersect the mire.
3. Farmyards	There are two farms identified as working farms from Google Earth and the OS data. These farms are not on extensive high erosion flow pathways but are in close proximity to the mire. Manure and slurry in farmyards may also act as a nutrient source to the mire downstream, either via overland flow or the leaching of nutrients to the groundwater that feeds the mire, depending on the maintenance and management of the assets involved.
4. Discharges and abstractions	One domestic treated sewage consented discharge is identified from the Environment Agency dataset near to Embla North mire boundary. This may be a source of pollution that may deteriorate the water quality of the mire habitat. No abstractions are identified from Environment Agency dataset.
5. Roads	A local road follows the western boundary of Embla North and the southern boundary of Embla South. The road has a culvert at the downstream end of the Embla North habitat. Roads may act as a conduit for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography.
6. Other	No evidence of historical mining activity in the catchment identified from OS data
Outcome	Based on the evidence above, this site is **medium-high risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	131
2. Surface flow pathway protection	37
3. Steepest slopes	62
4. Lower slopes and valley floor	25
5. Groundwater emergence zone	13

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer. The buffer extends around watercourses feeding the mire and the pond and springs feeding the tributaries. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the base of the steep slopes covering the valley bottom. This boundary encompasses >15% of the catchment area.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography becomes more moderate-gentle towards the edges of the catchment. The steepest slopes are towards the lower catchment with a large area of moderate-gentle slopes in the upper catchment. Therefore, this boundary only covers >45% of the catchment area not including the flow pathways in the upper catchment.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer.

The **surface water catchment zone** (no. 1) is 131 ha and is a moderately-sized mire catchment. It offers optimum protection to the mire, although this may not be practical.

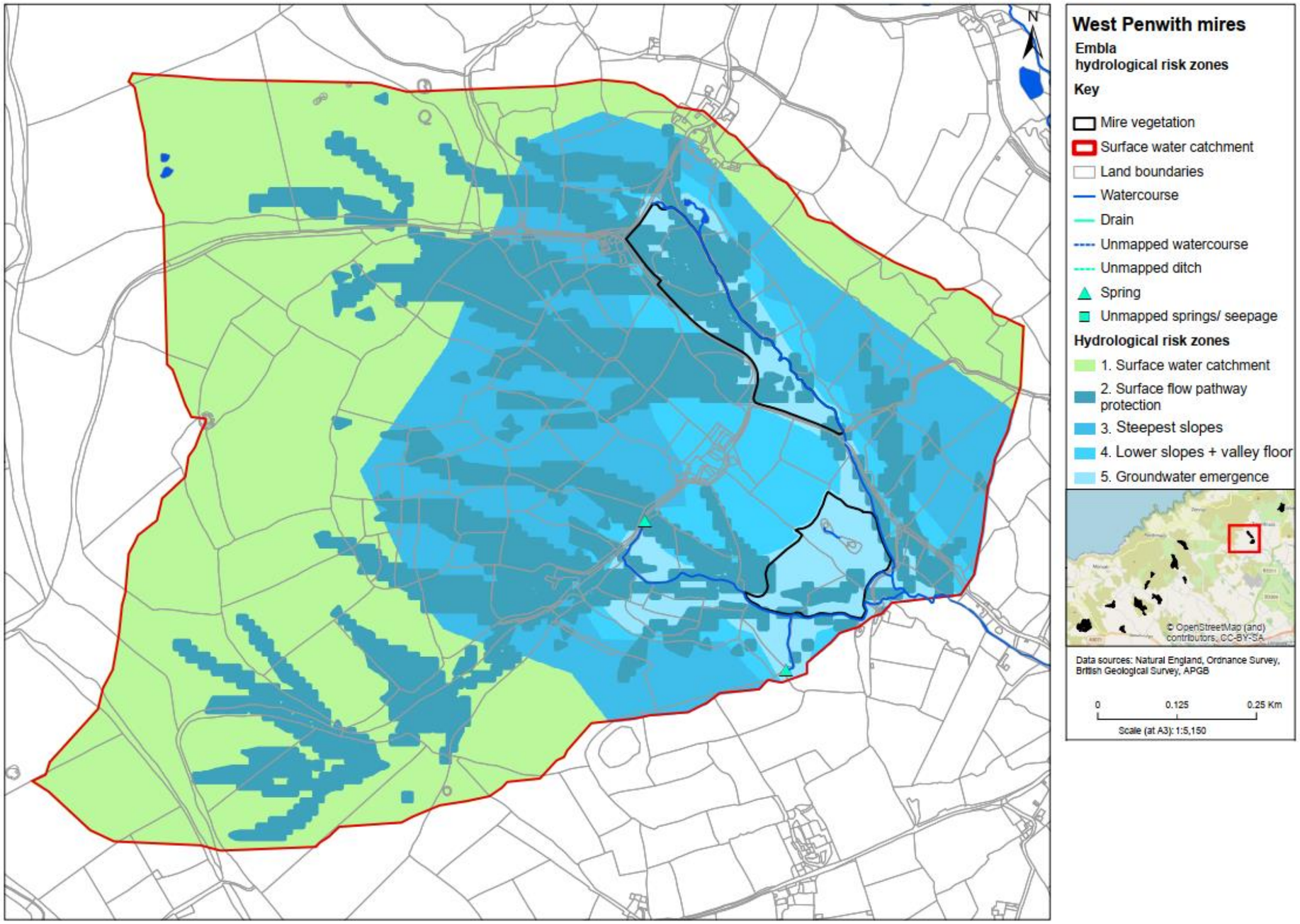


Figure 7-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	13%
Intensively managed (improved) grassland	55%
Rough low-productivity grassland	7%
Other land covers (including mire habitat)	25%

The Embla mires are assigned a catchment risk of medium-high. This is primarily because of the limited extent of arable land that is mostly far from the mire and main flow pathways. The influences of nutrient management on the extensive intensively managed grassland and in the farms are potentially high risk as they are located on main flow pathways and in close proximity to the mire. However, this is dependent on the management approaches implemented in these areas. The local road may be a risk to the mire due to its close proximity to Embla North. Embla North may also be at risk from the consented discharge upstream, which may be transported to Embla South downstream. There is no evidence of historic mining in the catchment.

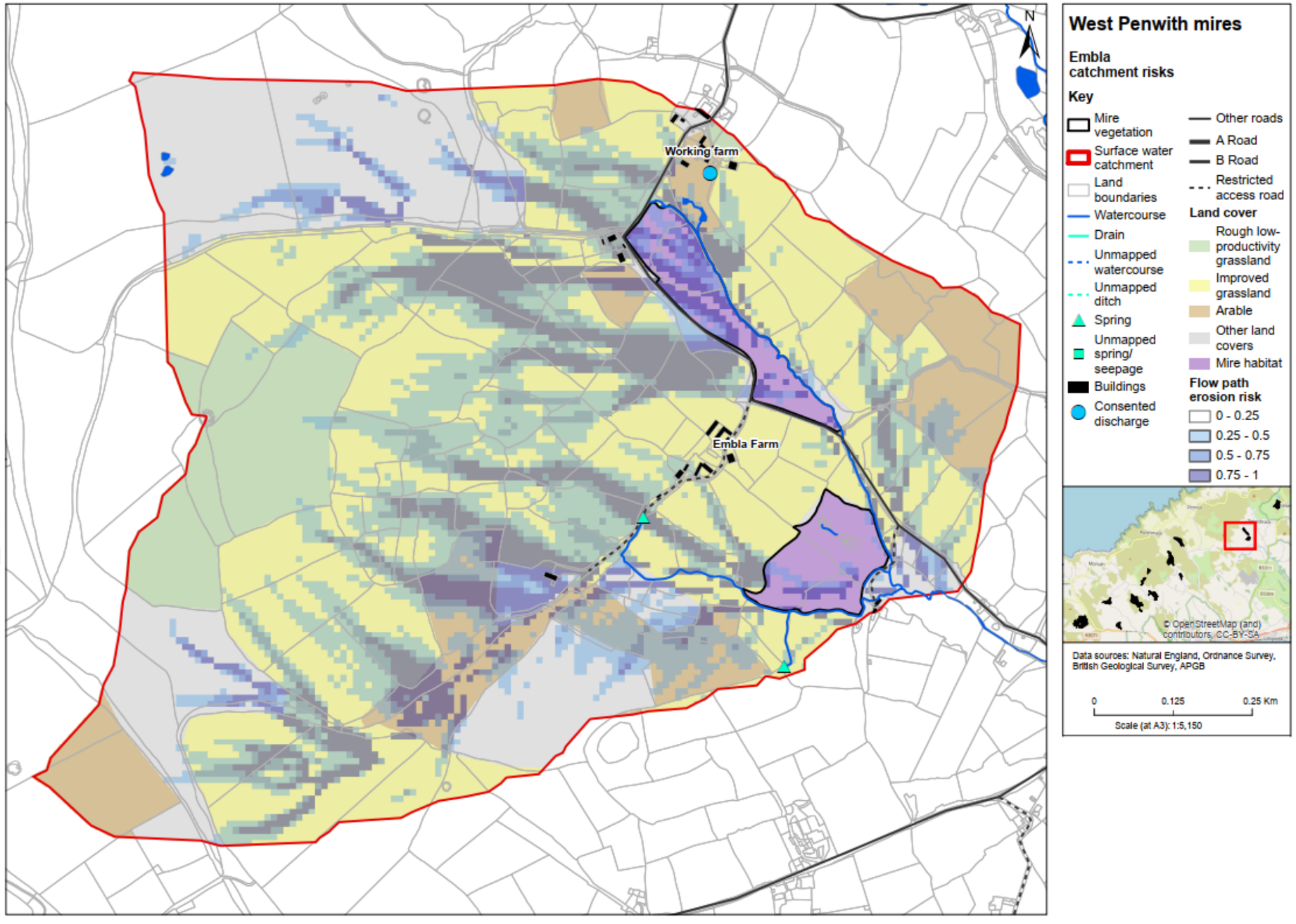


Figure 7-2. Map of catchment risks. Only land covers with a risk associated from CEHôs land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire.

Catchment land holdings

There are 16 CPH land holdings within the Embla surface water catchment. One land holding covers most of the flow pathways leading to the southern mire. There are a further three land holdings that intersect the mire boundary and/or the groundwater emergence zone of the northern mire and may be most likely to impact the mire due to their close proximity.

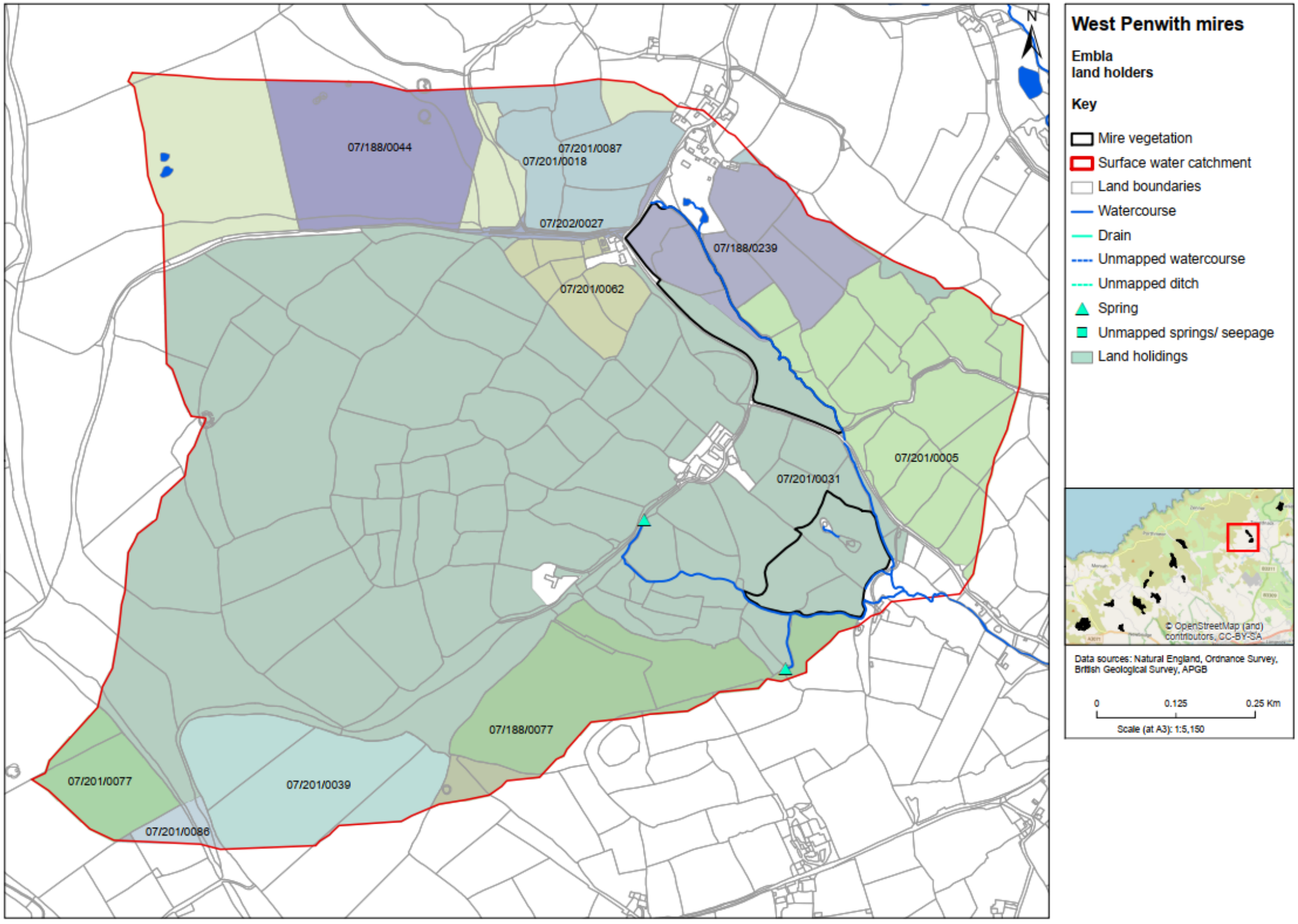


Figure 7-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

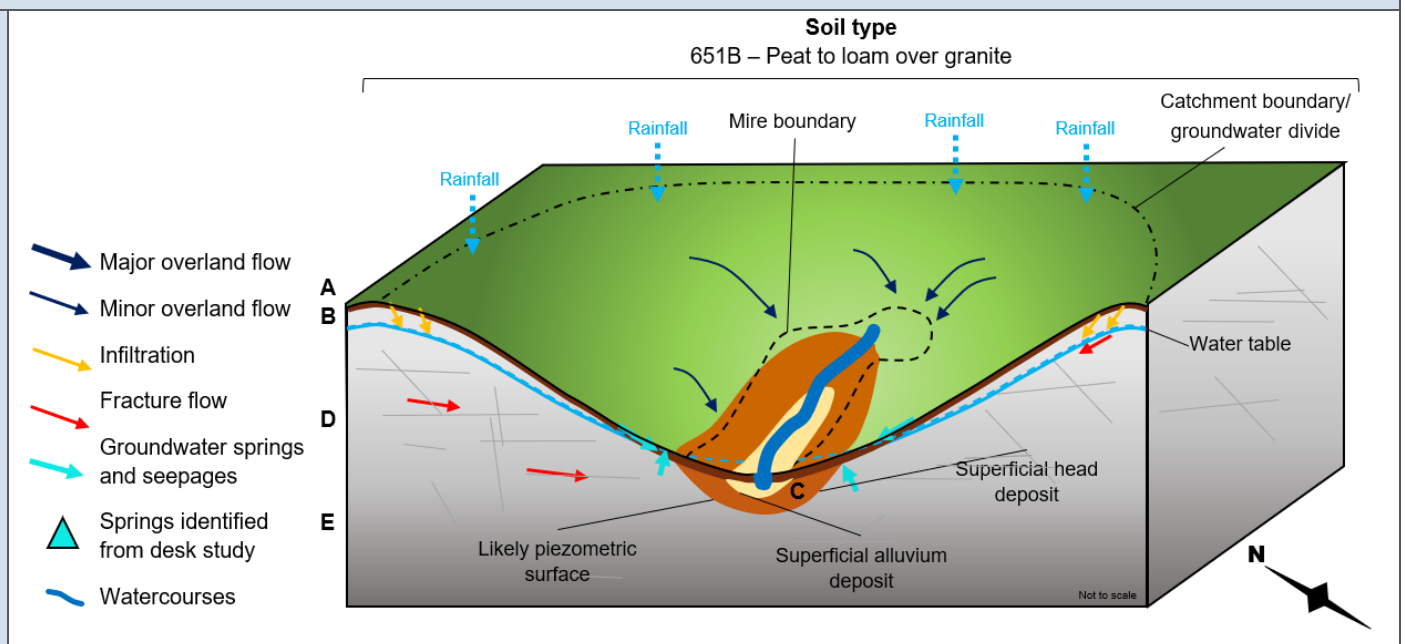
8. Gear / Chykembro Common

Gear / Chykembro Common

Catchment statistics

WFD water body catchment ID	230 (Coastal water body)	**Extent of Mire Habitat (ha)**	8.45
Water body WFD Status	Not in river water body	**Total Catchment Area (ha)**	65
NGR (approximate site centre point)	SW 44600 36700	**Number of registered landholdings (Defra Rural Land Register) in catchment**	10

Main site features

1. Ecology and Habitats	Gear Common is predominantly made up of variations of NVC mire community M25 (~60%). M25 is usually found around seepage zones, flushes, water-tracks and topogenous mires, but may also extend onto fringes of ombrogenous mires that are rainfall dependent (Elkington et al. 2002). This community prefers moist but well aerated soils and depending on the hydroecological setting, has moderate or low groundwater dependency (UKTAG, 2009). However, in this context M25 appears to be soligenous as it can be a product of drainage of wetter mires such as M21, followed by grazing, and may have a higher groundwater dependency than indicated in UKTAG (2009). M16 mire community is also present, covering around 25% of the mire. This community is maintained by a locally high water table and found on soils that are at least seasonally waterlogged. The community is considered highly dependent on groundwater (UKTAG, 2009). Other communities present over smaller areas include M21, M1 and wet woodland (W1). The site is surrounded by a mix of heathland communities (H4 and H8).
2.Topography and surface flow pathways	The mire habitat is set within an area of comparatively level topography (<2Á), with elevations between 170 to 185 mAOD. The habitat covers <15% of catchment area. The wider catchment has an elevation range from 170 mAOD at the valley outlet to 200 mAOD at the top of the catchment. The catchment has a level topography with the steepest slopes at a maximum of 4.5Áadjacent to the southern boundary of the mire. The flow pathways in the catchment are the least extensive of any of the mires being considered by this report, being located primarily within the mire habitat (according to SCIMAP).
3. Watercourses and drainage	The mire sits on a headwater tributary. There are no artificial drains identified through OS data in the catchment.
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Landõs End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Superficial head deposits cover the lower portion of the mire, with alluvium deposits following the headwater channel downstream. The deposits are clay and silt dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). OS open data (MasterMap, 2020) shows no evidence of springs in the catchment but they may be present along with soil seepage at the geological transition. The soil survey for SW England shows soil type 651B for the entire catchment, which is grit and loam dominated with a wet and peaty surface horizon (Findlay, 1984).
5. Conceptual model A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff. B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils. C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = $8.64x10^{-5}$ ï 1.73 m/d D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = $6.9x10^{-4}$ ï $2.6x10^{2}$ m/d E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = $1.73x10^{-5}$ ï $2.6x10^{-9}$ m/d	

Catchment Risk Assessment

1. Arable land use	The Gear catchment has two small isolated patches of arable land, identified from the CEH and CORINE datasets, covering <5% of catchment area away from main flow paths. The pollution and nutrient enrichment of overland flow or groundwater from arable land uses may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending on land management practices that may increase the volume of fine eroded particles being transported to the mire. However, due to the limited extent of the arable land, and its distance from the mire and flow pathways, the arable land is relatively low risk.
2. Grassland and nutrient management	There are two isolated patches of intensively managed grassland identified from the CEH dataset that covers ~10% of catchment area. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths to the mire or infiltrate to groundwater, negatively impacting water quality and potentially causing eutrophication. Again, due to their location in the catchment, these land covers are considered relatively low risk. There are few patches of rough grassland, but the majority of the catchment is heathland grass vegetation.
3. Farmyards	None present in OS dataset or identified from Google Earth.
4. Discharges and abstractions	None present in Environment Agency datasets.
5. Roads	Gear Hill road follows the south-western boundary of the mire crossing a flow pathway. Roads may act as a conduit for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography.
6. Other	There is evidence of historical mining activity in catchment with a mining shaft identified from the OS data. The shaft is near the catchment boundary away from flow pathways. It is not known to what extent the shaft may influence the mire habitat.
Outcome	Based on the evidence above, this site is **low risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	65
2. Surface flow pathway protection	5
3. Steepest slopes	56
4. Lower slopes and valley floor	37
5. Groundwater emergence zone	10

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor. As the catchment has a relatively level topography, this boundary encompasses >55% of the catchment area.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography plateaus at the edges of the catchment. The steepest slopes are towards south of the mire habitat, capturing the majority of the remaining catchment not covered by the lower slopes and valley floor boundary. Therefore, this boundary covers >85% of the catchment area including all flow pathways in the catchment.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer.

The **surface water catchment zone** (no. 1) is 65 ha and is one of the smallest catchments considered by this report. It offers optimum protection to the mire.

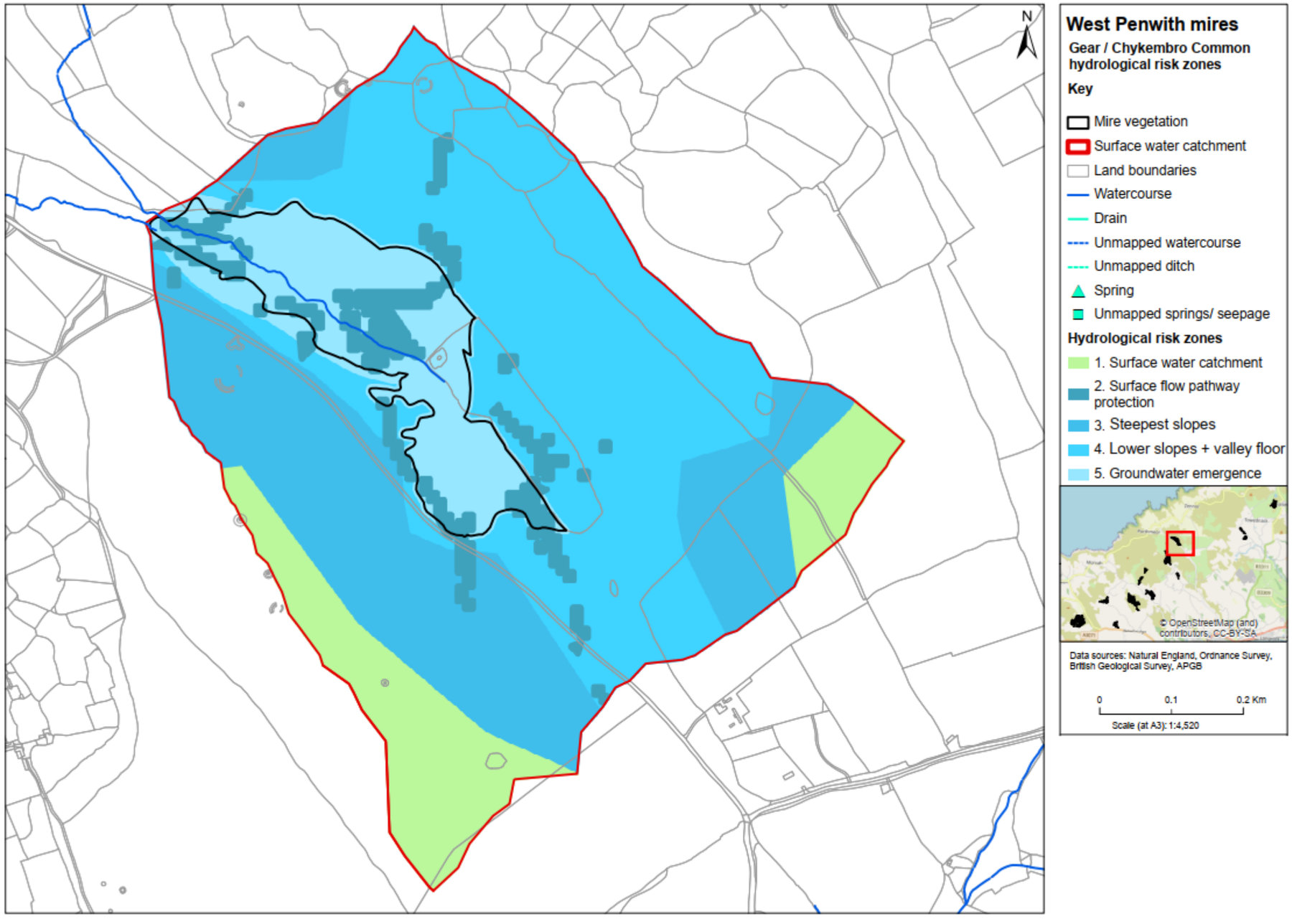


Figure 8-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	4%
Intensively managed (improved) grassland	10%
Rough low-productivity grassland	0%
Other land covers (including mire habitat)	86%

Gear / Chykembro Common mire is assigned a low catchment risk. This is primarily because of the limited extent of arable land and intensively managed grassland that is far from the mire and main flow pathways. Gear Hill road may be a risk to the mire due to its close proximity to mire boundary. The mine shaft may cause a risk to the mire habitat, but its impact is unknown.

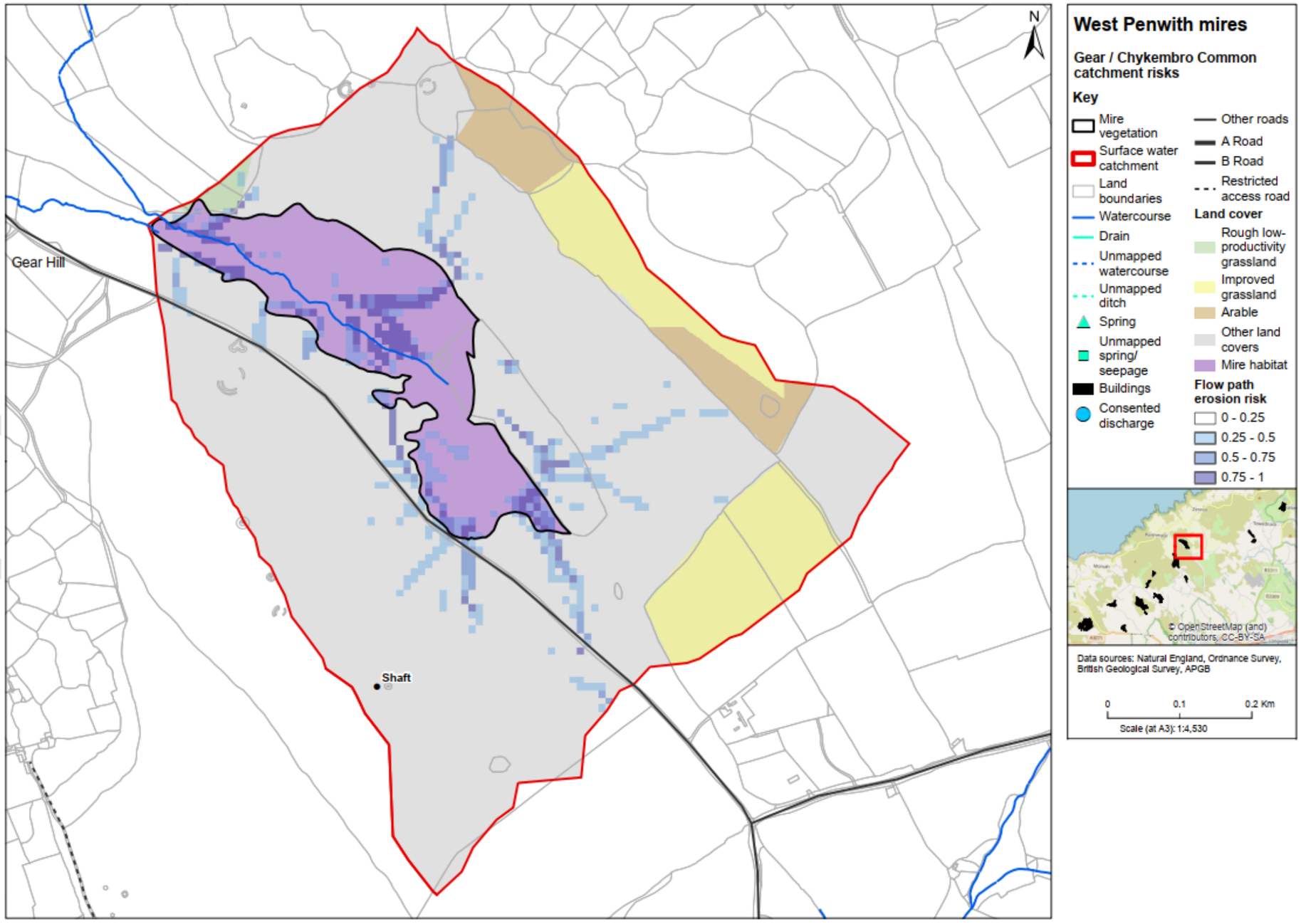


Figure 8-2. Map of catchment risks. Only land covers with a risk associated from CEHôs land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire.

Catchment land holdings

There are 10 CPH land holdings within Gear/Chykembro Common surface water catchment. The majority are likely to impact the mire as they are on steep slopes leading to the mire. Two land holdings intersect the mire boundary and the groundwater emergence zone, they may be most likely to impact the mire due to their close proximity.

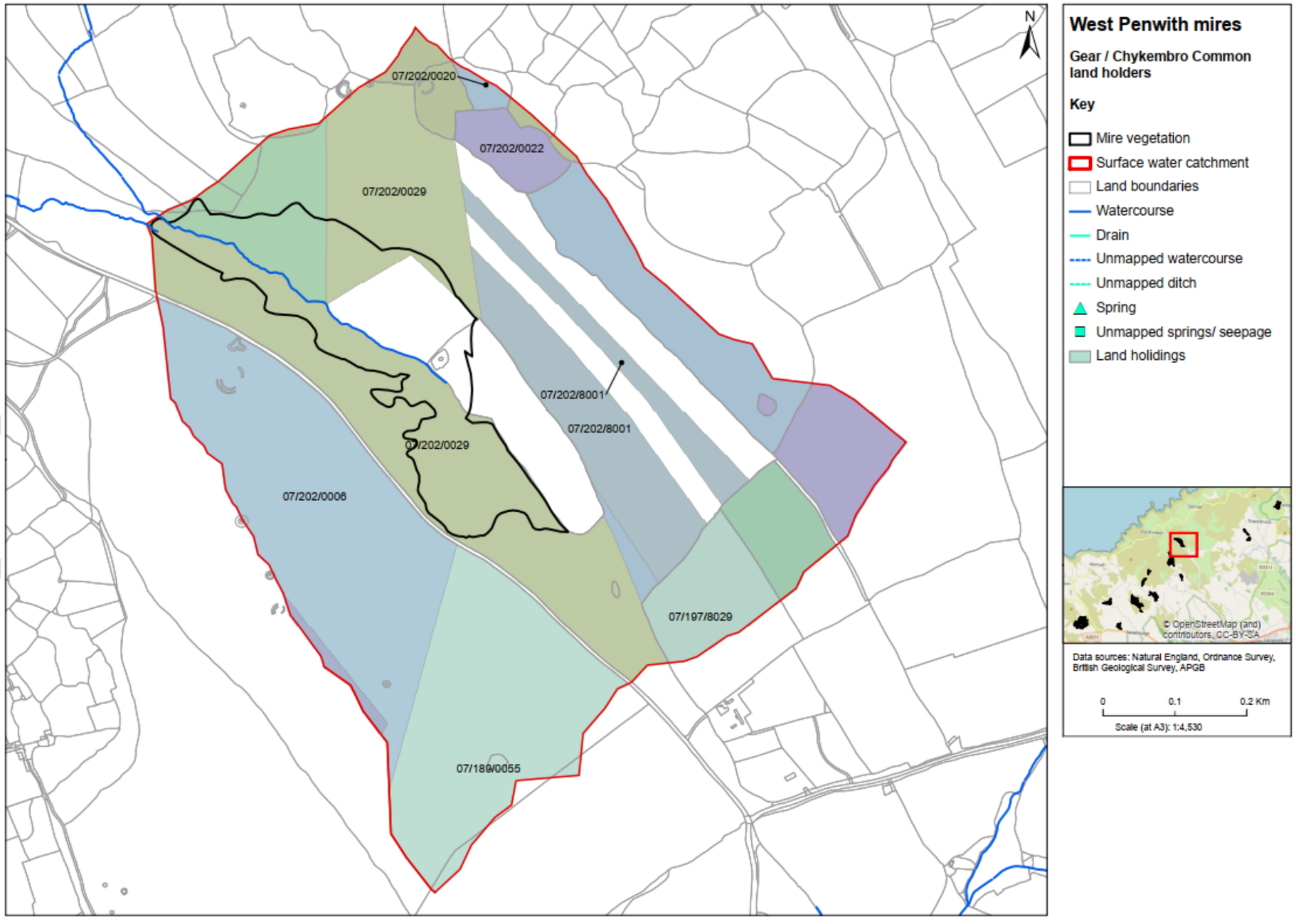
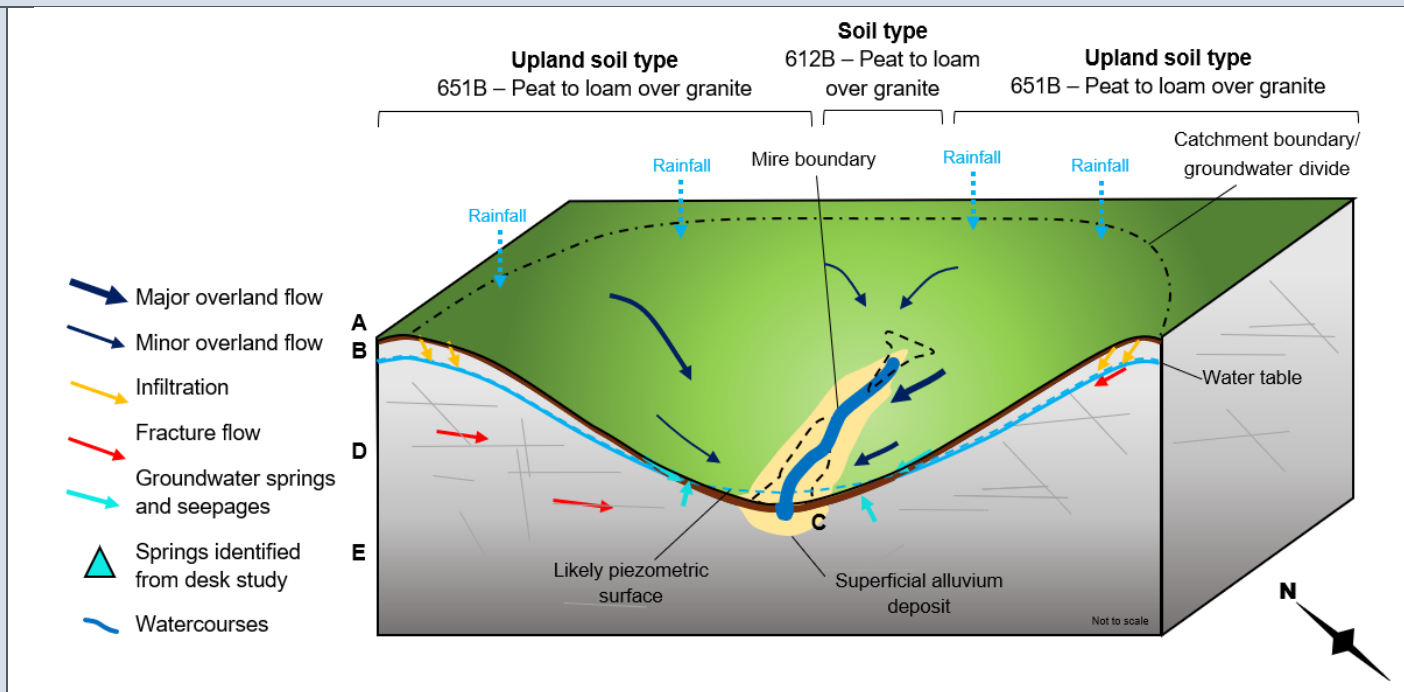


Figure 8-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number. Note: there are gaps in the CPH data.

9. Lanyon / Men-an-Tol

Lanyon / Men-an-Tol			
Catchment statistics			
WFD WB catchment ID	GB108048002090 (Newlyn River)	**Extent of Mire Habitat (ha)**	2.01 ha (north) and 3.31 (south)
Water body WFD Status	Overall: Moderate, Ecological: Good, Chemical: Fail due to surface water abstraction (2019)	**Total Catchment Area (ha)**	180
NGR (approximate site centre point)	SW 43000 35100 and SW 42500 34300	**Number of registered landholdings (Defra Rural Land Register) in catchment**	10
Main site features			
1. Ecology and Habitats	Lanyon mire is predominantly made up of variations of NVC mire community M25. In the northern section of the mire, M25 covers over 95% of the mire, with only 3 small areas of Willow. M25 also covers ~90% of the southern section of the mire, with small areas of M23, M29 and Willow. M25 is usually found around seepage zones, flushes, water-tracks and topogenous mires, but may also extend onto fringes of ombrogenous mires that are rainfall dependent (Elkington et al. 2002). This community prefers moist but well aerated soils and depending on the hydroecological setting, has moderate or low groundwater dependency (UKTAG, 2009). However, in this context M25 appears to be soligenous as it can be a product of drainage of wetter mires such as M21, followed by grazing, and may have a higher groundwater dependency than indicated in UKTAG (2009). The mire is mostly surrounded by scrub (W25) and heathland (H8).		
2. Topography and surface flow pathways	The mire vegetation is split into two sections in the same valley, one upstream to the north and one downstream to the south. They cover <3% of the catchment area. The northern mire habitat has elevations between 190 to 200 mAOD and has gentle topography under 3Áin slope. The southern mire habitat has elevations between 170 to 185 mAOD and has level topography under 2Áin slope. The wider catchment has an elevation range from 170 mAOD at the valley outlet to 250 mAOD at the top of the catchment. It has moderate-steep slopes (maximum 6Á) on both sides of the valley, with the steepest slopes on the western valley face near to the mire habitats. Highly erosive flow pathways are concentrated, flowing down the valley faces towards the tributaries in the mires (according to SCIMAP).		
3. Watercourses and drainage	A headwater tributary starts in the northern mire habitat at the top of the valley. The southern habitat is downstream on the same stream, which runs along the eastern edge of the mire. The channel that connects the mire habitats has a gentle-moderate slope. There are no artificial drains identified through OS data in the catchment although straight drains to the north east of the mires have been identified from aerial photographs.		
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Landís End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Alluvium superficial deposits cover the base of the valley including the majority of the southern mire habitat extending up to, but only covering a fraction of the northern mire. The deposits are clay and silt dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). OS open data (MasterMap, 2020) shows no evidence of springs in the catchment but they may be present along with soil seepage at the geological transition. The soil survey for SW England shows that the majority of the catchment has soil type 651B which is grit and loam dominated with a wet and peaty surface horizon. The lowest portion of the southern mire habitat, and on the eastern slopes there is the well-drained 612B soil type (Findlay, 1984).		
5. Conceptual model A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff. B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils. C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = $8.64x10^{-5}$ ï 1.73 m/d D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = $6.9x10^{-4}$ ï $2.6x10^{2}$ m/d E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = $1.73x10^{-5}$ ï $2.6x10^{-9}$ m/d			
Catchment Risk Assessment			
1. Arable land use	Arable land identified from the CEH and CORINE datasets in the Lanyon / Men-an-Tol catchment covers >25% of catchment area. It is on flow pathways that lead to both sections of the mire and borders the north section of the mire habitat. The pollution and nutrient enrichment of overland flow or groundwater from arable land uses may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending on land management practices, that may increase the volume of fine eroded particles being transported to the mire.		
2. Grassland and nutrient management	There are patches of intensively managed grassland identified from the CEH dataset that covers ~30% of catchment area on the main flow pathways leading to the mires, especially the southern mire. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths to the mire or infiltrate to groundwater, negatively impacting water quality and potentially causing eutrophication. There are few patches of rough grassland between the mires and in the upper catchments, but this has a lower eutrophication risk to the mires than intensively managed grassland. The majority of the flow pathways leading to the northern section of the mire drain semi-natural heather and dwarf shrub habitat.		
3. Farmyards	None present in OS dataset or identified from Google Earth.		
4. Discharges and abstractions	A South West Water Sewage pumping station is identified from the Environment Agency dataset adjacent to the southern mire boundary. This may be a source of pollution to the mire habitat. No abstractions identified from Environment Agency dataset.		
5. Roads	A restricted access road crosses the main flow pathways leading to the mire from the north-west. Roads may act as a conduit for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography.		
6. Other	There is evidence of historical mining activity in the catchment with three mining shafts identified from the OS data. The shafts are in the east of the catchment with two on flow paths leading to the northern and southern mires. It is not known to what extent the shafts may influence the mire habitat. The OS data also highlights two fords on the stream between mires.		
Outcome	Based on the evidence above, this site is **medium-high risk**		

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	180
2. Surface flow pathway protection	30
3. Steepest slopes	72
4. Lower slopes and valley floor	29
5. Groundwater emergence zone	8

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer. The buffer extends around the stream that connects the two mire habitats. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor along the valley bottom. This boundary encompasses >15% of the catchment area.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography becomes more moderate-gentle towards the edges of the catchment. This catchment has multiple areas of steeper slopes that reduce in gradient before becoming steep again. The boundary is drawn around the steepest slopes nearest to the mire. Therefore, this boundary only covers <40% of the catchment area not including the flow pathways in the upper catchment.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer.

The **surface water catchment zone** (no. 1) is 160 ha and is one of the larger catchments. It offers optimum protection to the mire.

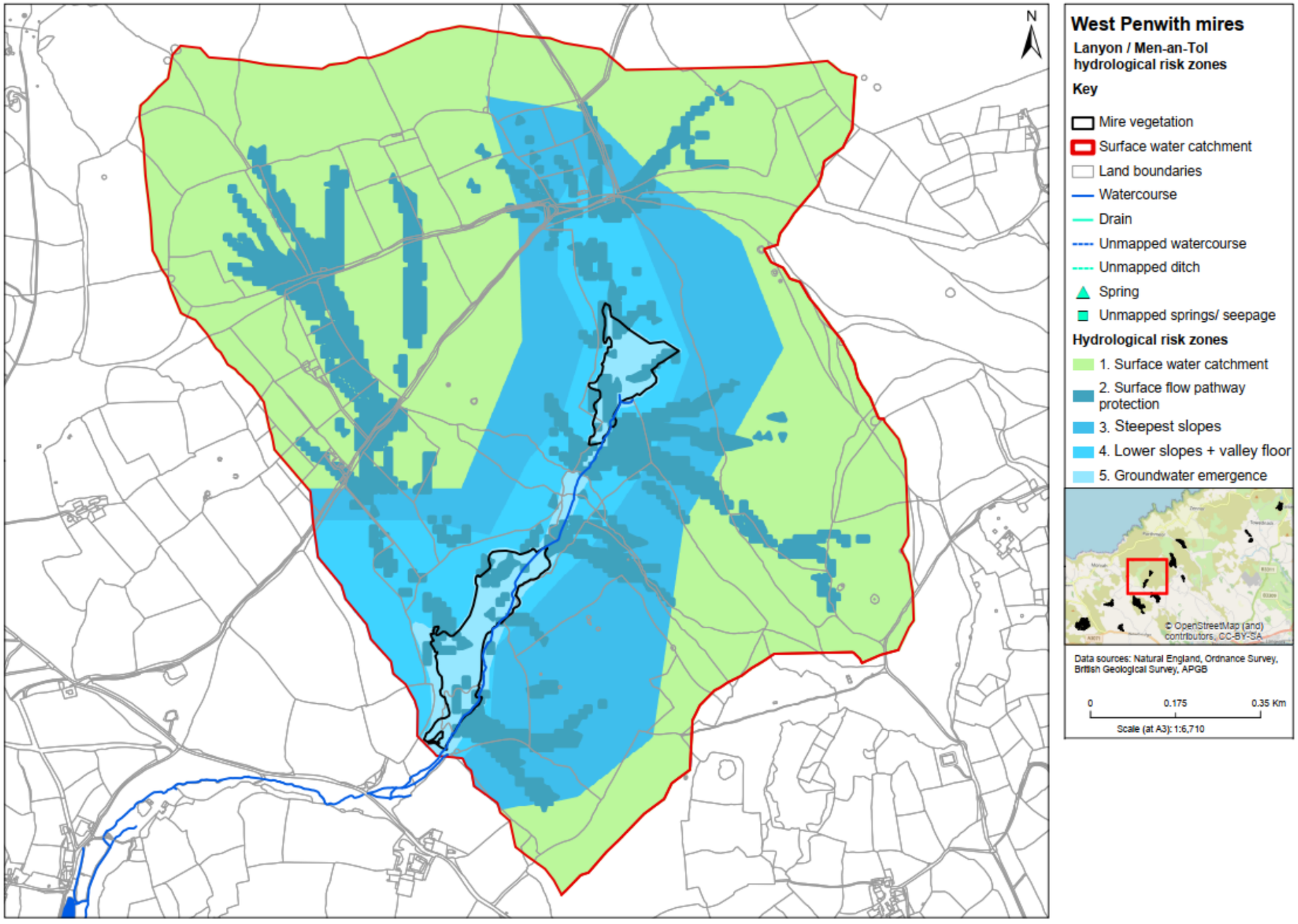


Figure 9-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	27%
Intensively managed (improved) grassland	31%
Rough low-productivity grassland	11%
Other land covers (including mire habitat)	31%

Lanyon / Men-an-Tol mires are assigned a medium-high catchment risk. This is primarily because of the presence of arable land on key flow pathways. Intensively managed grassland is also extensive within the catchment and on the main flow pathways. The southern mire is considered higher risk than the northern mire due to the landcovers on the main flow pathways leading to the mire, the restricted access road that crosses the flow pathway and the consented discharge in close proximity to the mire boundary. The northern mire is lower risk because the majority of the flow pathways leading to the northern mire drain semi-natural land, although some cross arable land. The mine shafts may also cause a risk to the mire habitat, but its impact is unknown.

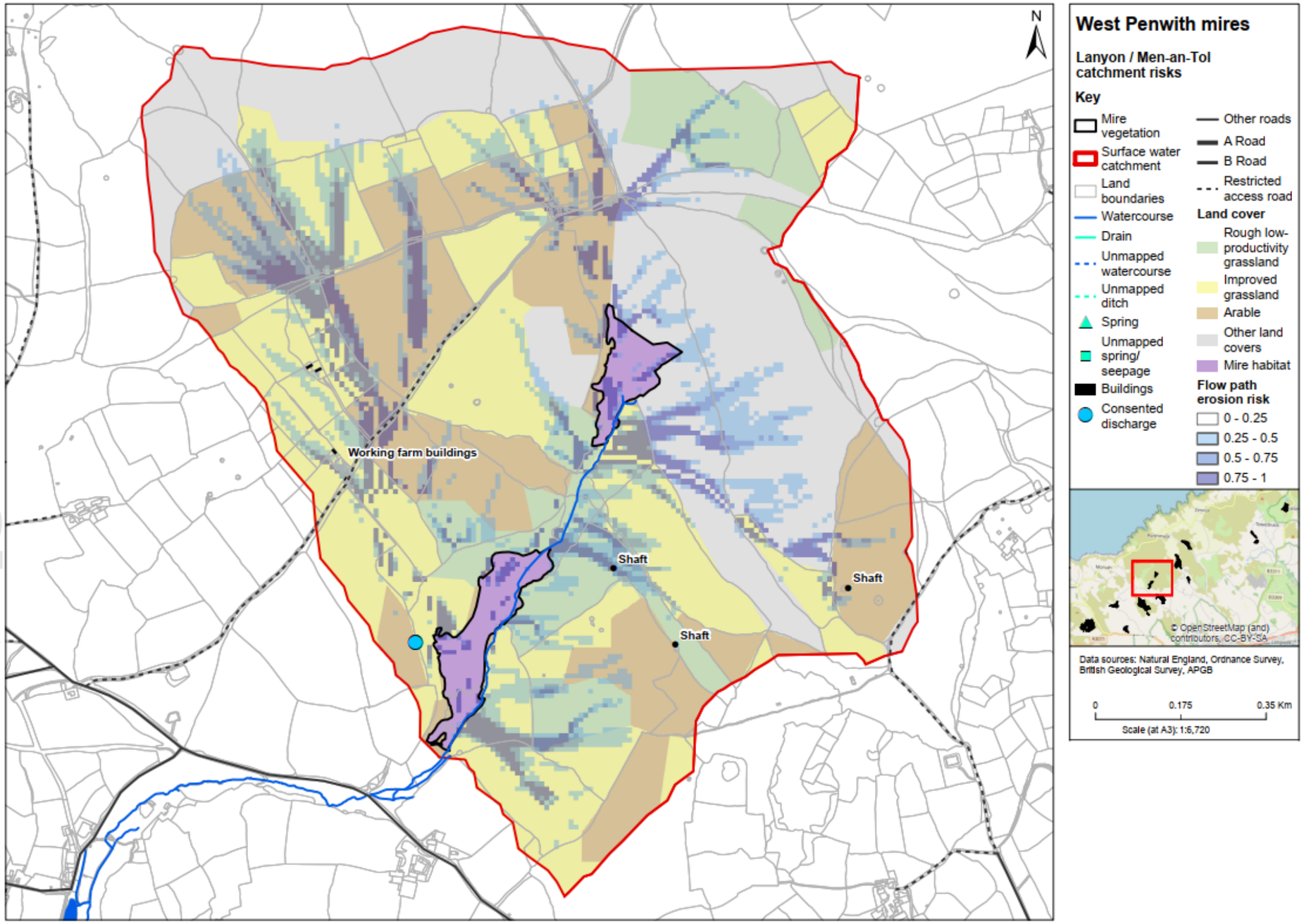


Figure 9-2. Map of catchment risks. Only land covers with a risk associated from CEHô land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire.

Catchment land holdings

There are 10 CPH land holdings within Lanyon/Men-an-Tol surface water catchment. Two land holdings cover the majority of the groundwater emergence zone and flow pathways for both mires, so they are most likely to impact the mires due to their close proximity. Other land holdings also cover the main flow pathway leading to the southern section of the mire.

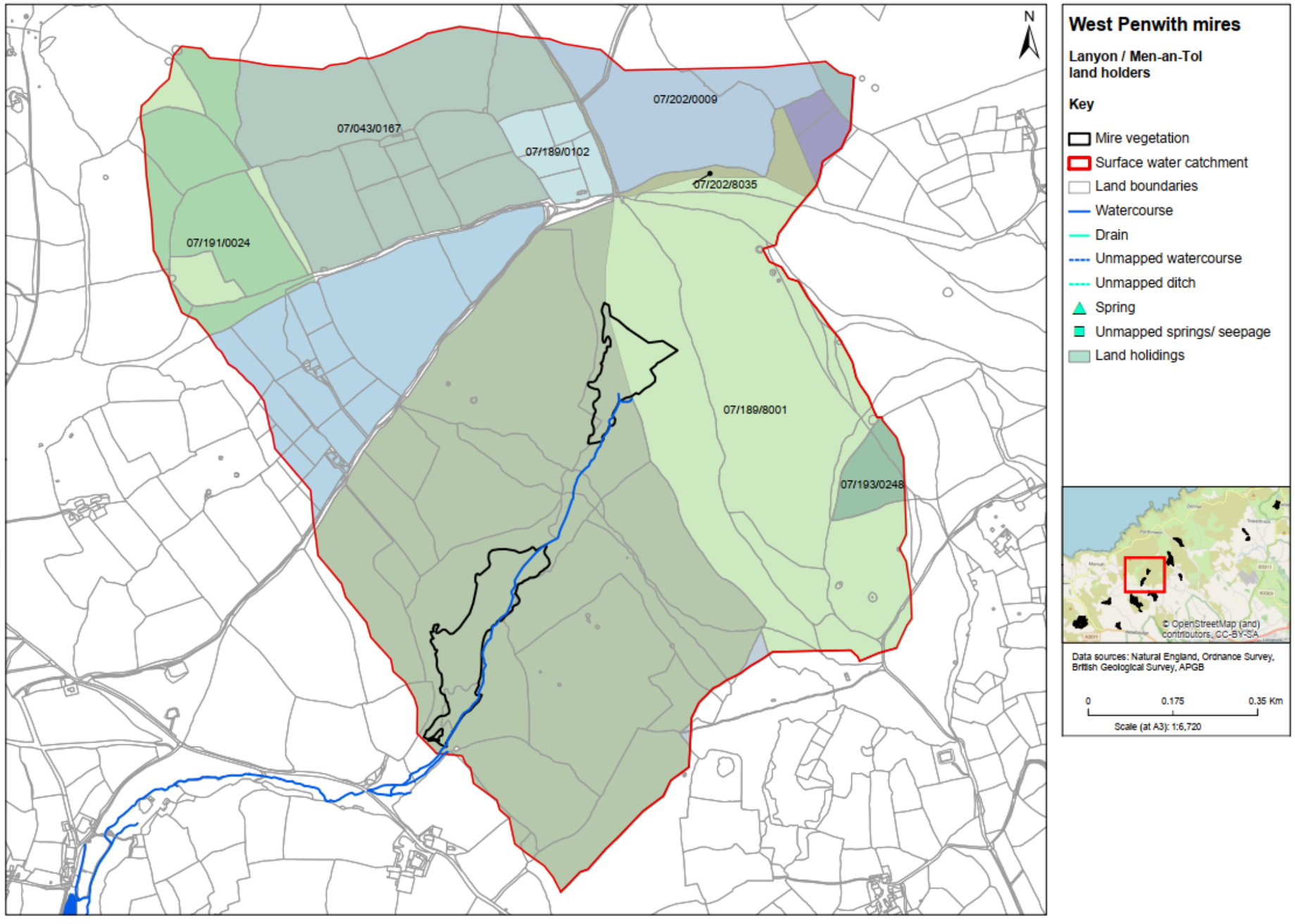


Figure 9-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

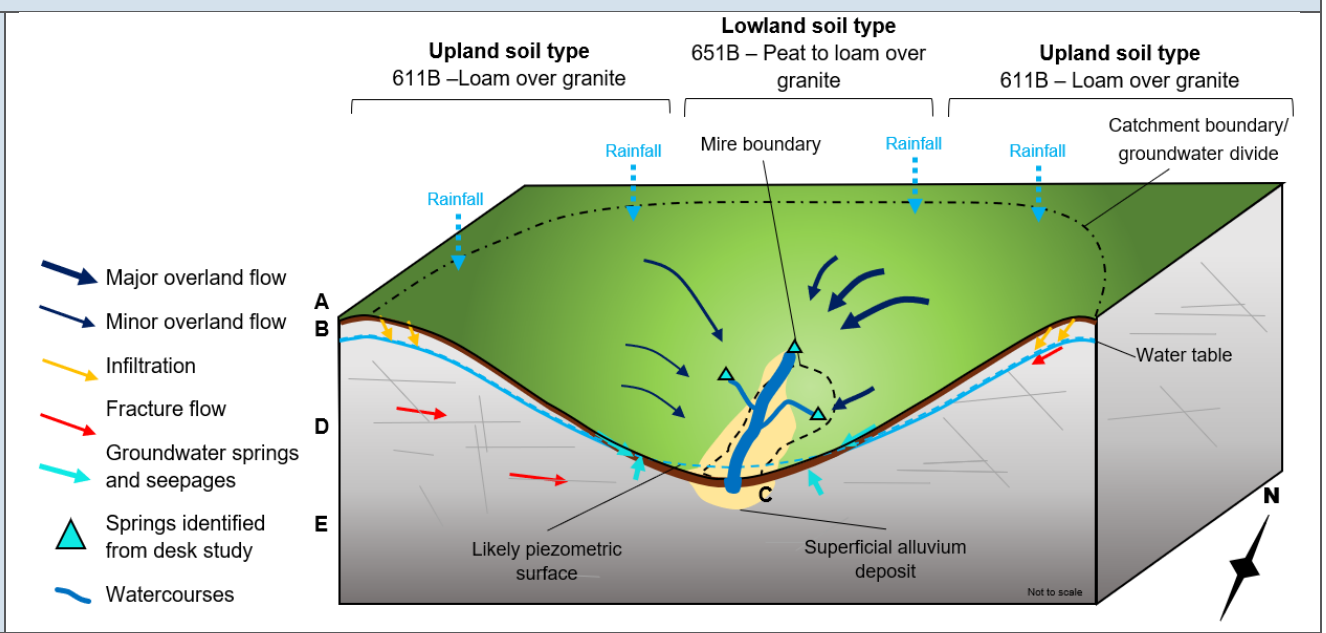
10. Tredinnick

Tredinnick

Catchment statistics

WFD water body catchment ID	GB108048002100 (Trevaylor Stream)	**Extent of Mire Habitat (ha)**	2.33
Water body WFD Status	Overall: Moderate, Ecological: Good, Chemical: Fail (2019)	**Total Catchment Area (ha)**	60
NGR (approximate site centre point)	SW 44700 34800	**Number of registered landholdings (Defra Rural Land Register) in catchment**	10

Main site features

1. Ecology and Habitats	The NVC communities within Tredinnick are predominantly M23 (~45%) and M25 (~20%). M23 is characteristic of topogenous mires whilst also being found in areas where soligenous flows are the main source of water (Elkington et al. 2002). M25 is often found around topogenous mires that are dependent on a high local groundwater table but can also extend onto the fringes of ombrogenous mires that are rainfall dependent (Elkington et al. 2002). However, in this context M25 appears to be soligenous as it can be a product of drainage of wetter mires such as M21, followed by grazing. The relative dependence of the communities on groundwater given by UKTAG (2009) are high (score of 1) for M23 and moderate (score of 2) for M25, although M25 may have a higher groundwater dependency than indicated in UKTAG (2009) in this context. *Lolium perenne - Cynosurus cristatus* improved well-drained permanent grassland (MG6) is present at the north of the site, with woodland (W1) and scrub (W22, W23, W25) communities present at the south of the site.
2. Topography and surface flow pathways	The mire covers the base of the valley, <4% of the catchment area, with elevations between 155 to 170 mAOD and has a level topography (<2Á). The wider catchment has an elevation range from 155 mAOD at the valley outlet to 220 mAOD at the top of the catchment. It has gentle to moderate slopes (2-5Á) adjacent to the mire with moderately steep slopes (maximum 8Á) in the upper catchment. The flow pathways in the catchment are extensive, radiating out from the mire habitat (according to SCIMAP).
3. Watercourses and drainage	The mires sit on a network of three headwater tributaries which converge within the southern mire. The tributaries are all fed by springs identified from the OS data around the edges of the mire habitat which should be in the main protection area. There are no artificial drains identified through OS data in the catchment.
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Landôs End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Alluvium superficial deposits partially cover the base of the valley and part of the mire habitat. The deposits are clay, silt and gravel dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). OS open data (MasterMap, 2020) shows three springs around the geological transition but there may be more present along with soil seepage in this area. The soil survey for SW England shows that the majority of the catchment has soil type 611B with 651B near the catchment boundary. All soil types are grit and loam dominated but the 651B in the upper catchment is wet and peaty whereas the other soil type is well drained with a humose surface horizon (Findlay, 1984).
5. Conceptual model A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff. B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils. C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = $8.64x10^{-5}$ ï 1.73 m/d D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = $6.9x10^{-4}$ ï $2.6x10^{2}$ m/d E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = $1.73x10^{-5}$ ï $2.6x10^{-9}$ m/d	

Catchment Risk Assessment

1. Arable land use	Arable land identified from the CEH and CORINE datasets in the Tredinnick catchment covers >25% of catchment area in the lower catchment. It covers fields adjacent to the mire and on the major flow paths leading to the mire. CROME data shows that crops have been spring barley and wheat in the past. The pollution and nutrient enrichment of overland flow or groundwater from arable land uses may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending on land management practices, that may increase the volume of fine eroded particles being transported to the mire.
2. Grassland and nutrient management	The majority of the catchment is intensively managed grassland, identified from the CEH dataset, that covers >40% of the catchment area on the main flow pathways leading to the mires. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths to the mire or infiltrate to groundwater, negatively impacting water quality and potentially causing eutrophication. There is no rough grassland in the catchment and the upper catchment is dominated by semi-natural heathland grass and dwarf shrub habitat.
3. Farmyards	There are two farms and a dairy identified from the OS data although only one of these, Tredinnick Farm, had evidence that it was currently in use on Google Earth. The farms are on extensively erosive flow pathways leading to the mire. Manure and slurry in farmyards may also act as a nutrient source to the mire downstream, either via overland flow or the leaching of nutrients to the groundwater that feeds the mire, depending on the maintenance and management of the assets involved.
4. Discharges and abstractions	Three domestic treated sewage consented discharges are identified from the Environment Agency dataset on major flow pathways. They may be a source of pollution that may deteriorate the water quality of the mire habitat. No abstractions identified from the Environment Agency dataset.
5. Roads	Local roads cross the catchment along with some restricted access roads. The roads are in close proximity to the mire crossing flow pathways. Roads may act as a conduit for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography.
6. Other	No evidence of historical mining activity in catchment identified from OS data.
Outcome	Based on the evidence above, this site is **medium-high risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	60
2. Surface flow pathway protection	18
3. Steepest slopes	36
4. Lower slopes and valley floor	11
5. Groundwater emergence zone	5

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer. The buffer extends around the springs that feed the mire. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor along the valley bottom. This boundary encompasses >18% of the catchment area.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography becomes more moderate-gentle towards the edges of the catchment. This boundary covers <60% of the catchment area including many of the flow pathways in the catchment.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer. The flow pathways in this catchment are so extensive, the boundary covers >30% of the catchment area.

The **surface water catchment zone** (no. 1) is 60 ha and is the smallest catchment considered in this report. It offers optimum protection to the mire.

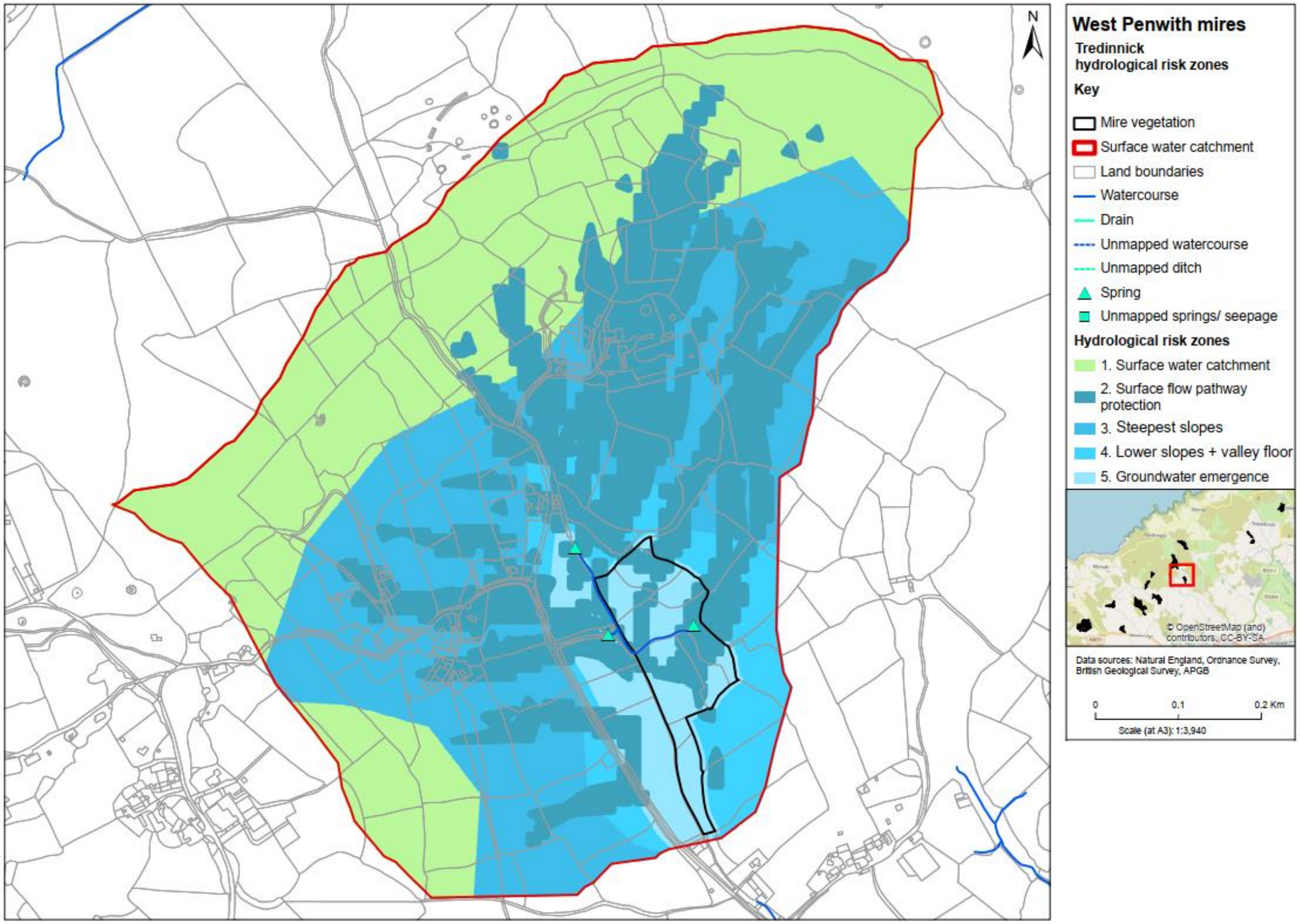


Figure 10-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	27%
Intensively managed (improved) grassland	31%
Rough low-productivity grassland	11%
Other land covers (including mire habitat)	31%

Tredinnick mire is assigned medium-high catchment risk. This is primarily because of the presence of farms, arable land and intensively managed grassland on extensive, highly erosive flow pathways that lead to the mire. These features may, depending on their management, be a risk to the water quality of the mire. The roads and consented discharges on the flow pathways may also be a threat to the mire habitat.

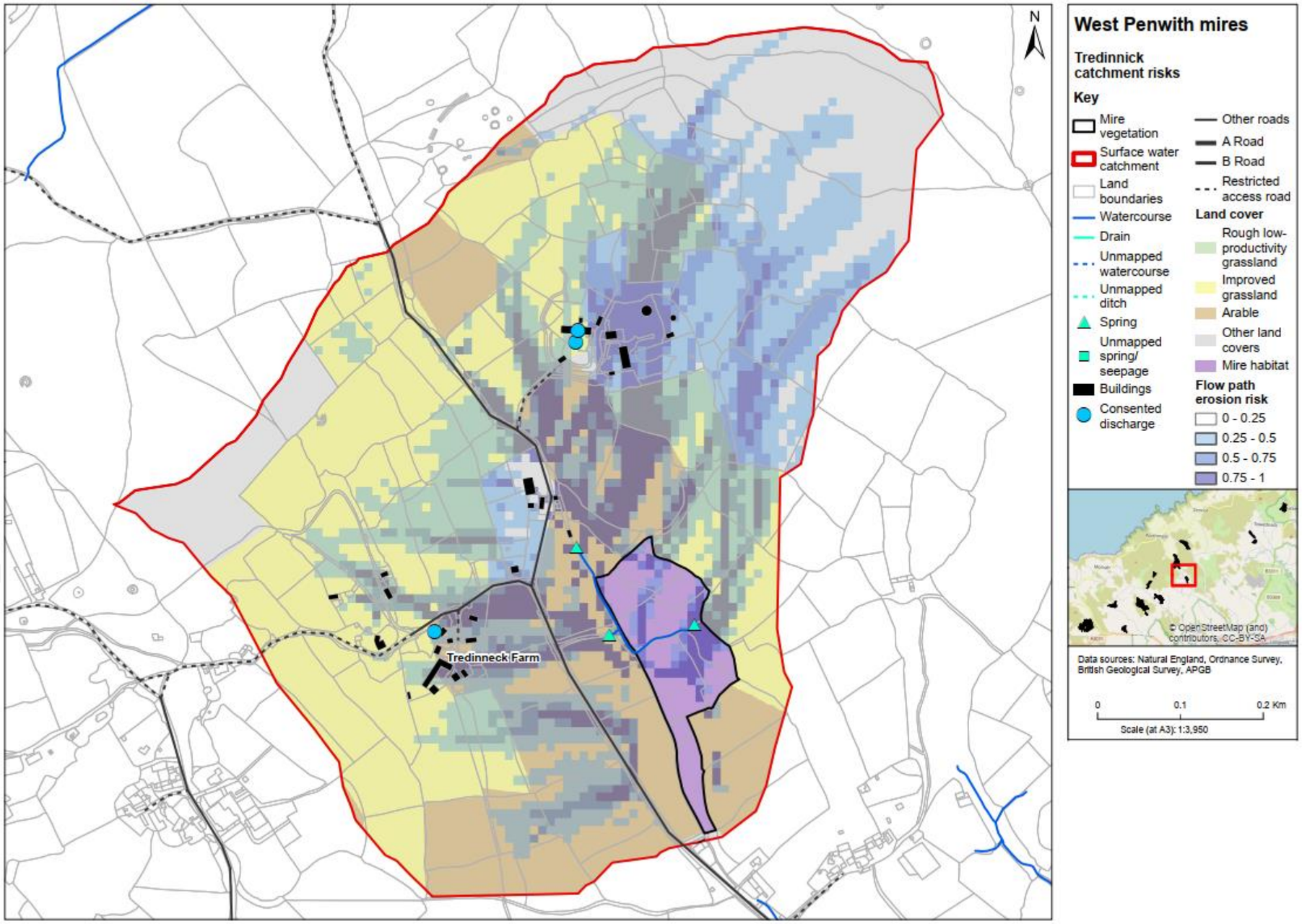


Figure 10-2. Map of catchment risks. Only land covers with a risk associated from CEHô land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire.

Catchment land holdings

There are 10 CPH land holdings within Tredinnick surface water catchment. Those towards the edges of the catchment boundary are least likely to impact the mire as they are not on major flow pathways or steep slopes leading to the mire. The five land holdings that intersect the mire boundary and the groundwater emergence zone may be most likely to impact the mire due to their close proximity.

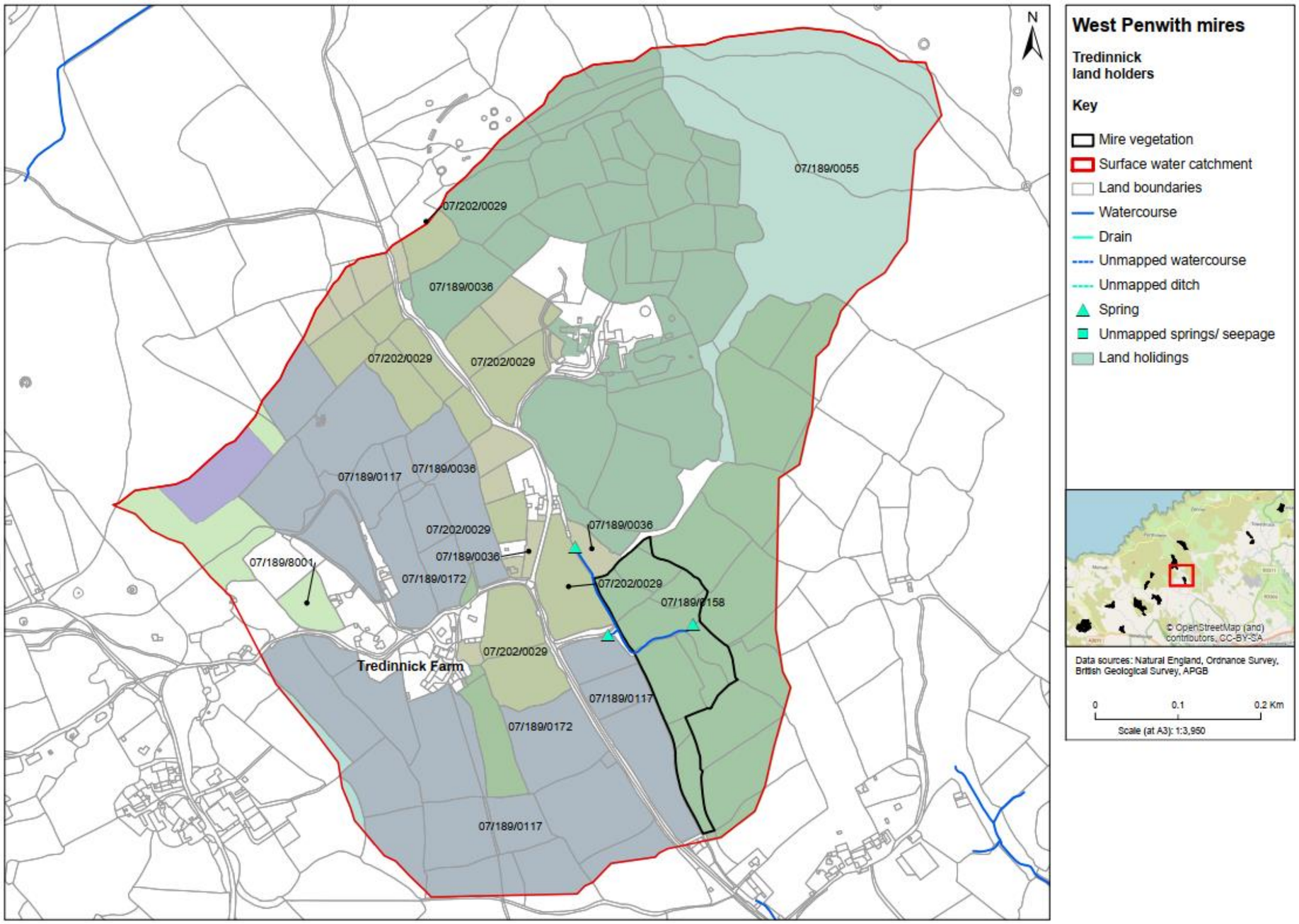


Figure 10-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

11. Tregerest

Tregerest

Catchment statistics

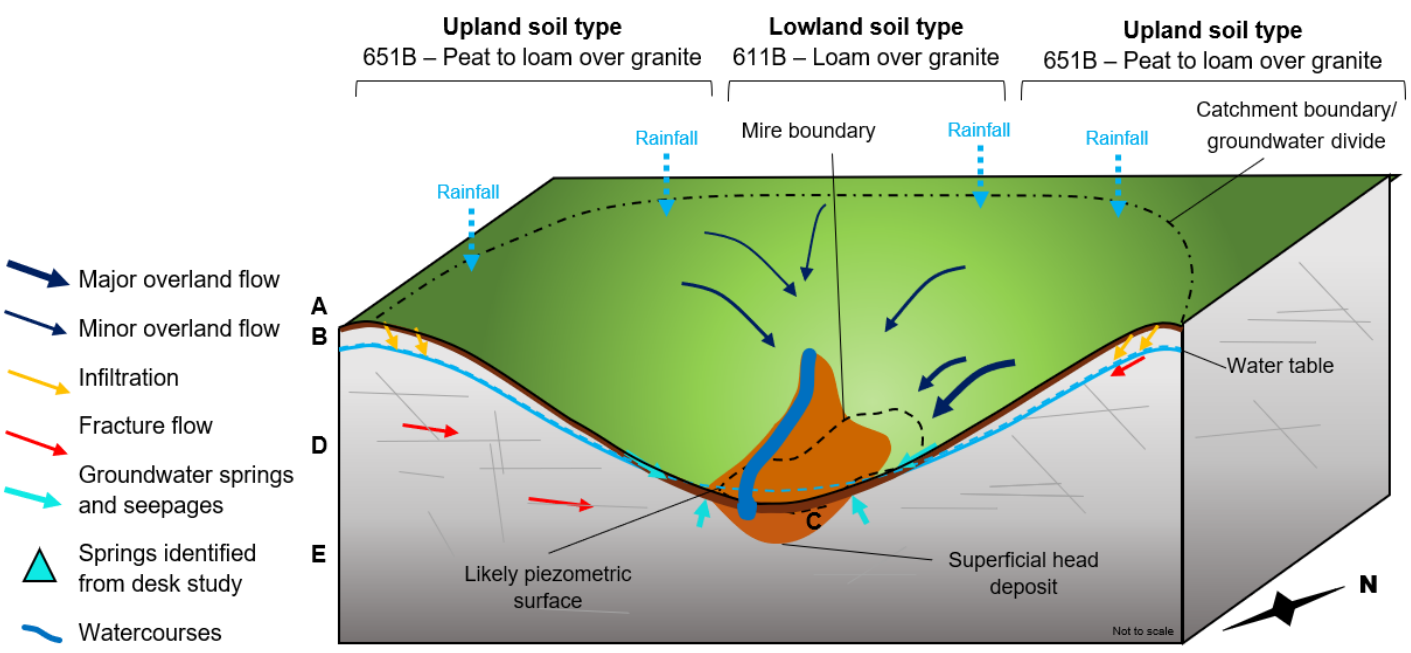
WFD WB catchment ID	GB108048002090 (Newlyn River)	**Extent of Mire Habitat (ha)**	4.89
Water body WFD Status	Overall: Moderate, Ecological: Good, Chemical: Fail due to surface water abstraction (2019)	**Total Catchment Area (ha)**	97
NGR (approximate site centre point)	SW 41300 32000	**Number of registered landholdings (Defra Rural Land Register) in catchment**	3

Main site features

1. Ecology and Habitats	Tregerest is predominantly made up of variations of NVC mire community M23 and *Holcus lanatus - Juncus effusus* rush pasture community (MG10). Both cover about 35% of the mire. M23 is characteristic of topogenous mires whilst also being found in areas where soligenous flows are the main source of water (Elkington et al. 2002). The relative dependence of M23 on groundwater given by UKTAG (2009) is high (score of 1). There is a very small amount of M25 also present on the site and the south of the site is comprised mostly of scrub and woodland (W1, W24) and *Glycerio - Sparganion* water margin vegetation (S23).
2. Topography and surface flow pathways	The mire covers the base of the valley, <5% of the catchment area, with elevations between 150 to 170 mAOD and has a level topography near the outlet (<2Á) extending the moderate steep slopes at higher elevations (<6Á). The wider catchment has an elevation range from 150 mAOD at the valley outlet to 225 mAOD at the top of the catchment. It has gentle to moderate slopes (2-5Á) in the majority of the catchment but the northern slopes adjacent to the mire are steep (maximum 8.5Á). The flow pathways in the catchment are extensive on the steep northern slopes leading into the mire habitat and more concentrated into distinct flow pathways in the remainder of the catchment (according to SCIMAP).
3. Watercourses and drainage	The mire sits adjacent to a headwater stream which flows along the southern boundary of the mire. There are no artificial drains identified through OS data in the catchment.
4. Soils, geology and hydrogeology	BGS open datasets (BGS, 2020) show that the mire sits on Landôs End Granite bedrock. The granite has a low porosity, so the main flow pathways are likely to be through weathered fractures close to the surface. Head superficial deposits partially cover the base of the valley and part of the mire habitat. The deposits are clay, silt and gravel dominated with low permeability that prevents the direct infiltration of rainfall to the groundwater body, however, the properties of superficial deposits are highly spatially variable. The change in flow regime between the fractured bedrock and low permeable superficial means that at the geological transition there is the potential for groundwater upwelling (springs). OS open data (MasterMap, 2020) shows no springs around the geological transition but there may be more present along with soil seepage in this area. The soil survey for SW England shows that the catchment has soil type 611B in the majority of the catchment including the mire and 651B upper catchment. Both soil types are grit and loam dominated but the upper catchment soil type is wet and peaty whereas the lower catchment soil type is well drained with a humose surface horizon (Findlay, 1984).

5. Conceptual model

A. Surface - Receipt of rainfall. High proportion infiltrates into soils with some surface runoff.
B. Soil - Freely draining soils with infiltration of rainfall towards water table. Thin on slopes and thicker in shallow topography. Groundwater exfiltration through thin soils.
C. Superficial deposits - Locally confined creating a disconnection between surface and groundwater exfiltration at perimeter of deposits. Hydraulic conductivity = $8.64x10^{-5}$ ï 1.73 m/d
D. Fractured granite - Hydrogeologically conductive throughout shallow depths with interconnected fractures acting as pathways for flow. Steep hydraulic gradient. Decreasing conductivity with depth. Hydraulic conductivity = $6.9x10^{-4}$ ï $2.6x10^{2}$ m/d
E. Solid granite - Negligible flow, hydrologically insignificant. Effective base of aquifer. Hydraulic conductivity = $1.73x10^{-5}$ ï $2.6x10^{-9}$ m/d



Catchment Risk Assessment

1. Arable land use	Arable land, identified from the CEH and CORINE datasets, in the Tregerest catchment covers the majority (~60%) of the catchment area. It covers fields adjacent to the mire and on the major flow paths leading to the mire. The pollution and nutrient enrichment of overland flow or groundwater from arable land uses may lead to eutrophication effects from the inward drainage of water enriched by nitrogenous and phosphatic fertilisers. Arable land cover may also be highly susceptible to erosion, depending on land management practices, that may increase the volume of fine eroded particles being transported to the mire.
2. Grassland and nutrient management	The catchment has large areas of intensively managed grassland, identified from the CEH dataset, that covers ~25% of the catchment area on the main flow pathways leading to the mires. Intensively managed grassland is associated with the application of fertilisers containing nitrates and phosphates, organic manures and slurry that may be mobilised during heavy rainfall and travel along flow paths to the mire or infiltrate to groundwater, negatively impacting water quality and potentially causing eutrophication. There is little rough grassland in the catchment.
3. Farmyards	There are four farms identified from Google Earth and the OS data, with a slurry pit identified in Middle Tregerest Farm. Two of the farms are on extensively erosive flow pathways leading to the mire. Manure and slurry in farmyards may also act as a nutrient source to the mire downstream, either via overland flow or the leaching of nutrients to the groundwater that feeds the mire, depending on the maintenance and management of the assets involved.
4. Discharges and abstractions	None present in Environment Agency datasets.
5. Roads	The A3071 and restricted access roads run through the catchment. The A3071 intersects one flow pathway but is relatively far from the mire habitat posing a moderate risk. One restricted access road leading to Lower Tregerest Farm crosses the river feeding the mire at a culvert. Roads may act as a conduit for nutrients and other pollutants during heavy rain events, potentially connecting separate portions of the landscape together outside of the main flow pathways based on topography.
6. Other	No evidence of historical mining activity in catchment identified from OS data
Outcome	Based on the evidence above, this site is **medium-high risk**

Hydrological risk zones

Delineation approaches	Area (ha)
1. Surface water catchment	97
2. Surface flow pathway protection	24
3. Steepest slopes	46
4. Lower slopes and valley floor	17
5. Groundwater emergence zone	9

The **groundwater emergence zone** (no. 5) covers the extent of the mire vegetation and superficial geology including a 5m buffer. The buffer extends around the headwater that flows along the southern boundary of the mire. This boundary is designed to protect the key hydrological influences on the mire, such as the springs and seepage expected at the boundary of the superficial geology.

The **lower slopes and valley floor zone** (no. 4) encompasses the groundwater emergence zone and extends up-catchment to the lower slopes and valley floor along the valley bottom. This boundary encompasses >17% of the catchment area.

The **steepest slopes zone** (no. 3) is the minimum requirement for a SSSI boundary from the SSSI guidance (JNCC, 1989). It extends from the top of the steepest slopes leading to the mire, before the topography becomes more moderate-gentle towards the edges of the catchment. This boundary covers >45% of the catchment area including many of the flow pathways in the catchment, although the flow pathways in the upper catchment are not included.

The **surface flow pathway protection zone** (no. 2) is designed to be used in conjunction with the previous boundaries to protect the main contributing areas to the mire. The flow pathways are identified from SCIMAP and main flow pathways are identified as pathways with an erosion risk score >0.5 with a 5m buffer. The flow pathways in this catchment are fairly extensive so the boundary covers <25% of catchment area.

The **surface water catchment zone** (no. 1) is 97.03 ha and offers optimum protection to the mire.

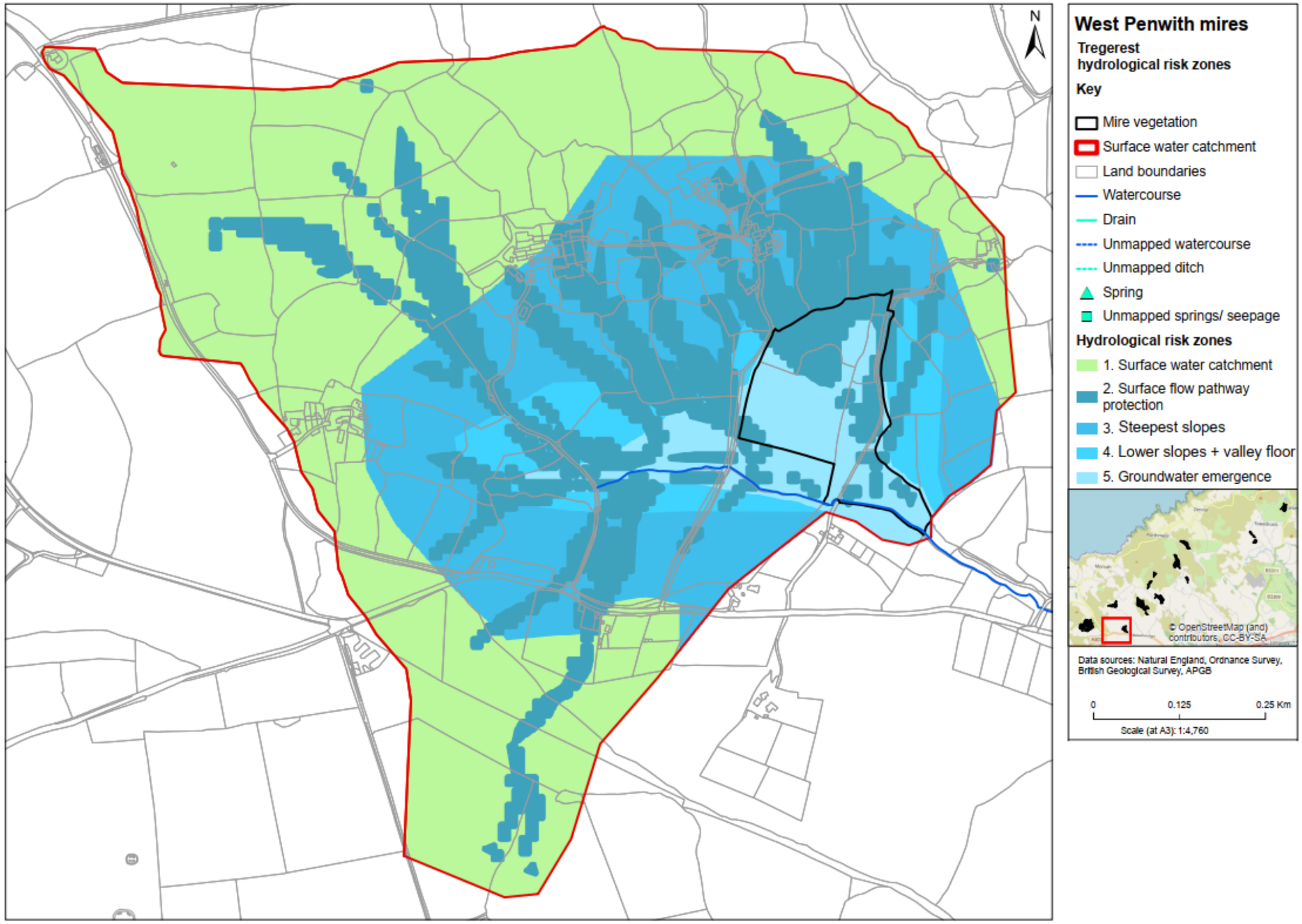


Figure 11-1. Map of five hydrological risk zones to inform potential SSSI boundaries, ranging from groundwater emergence zone to the entire surface water catchment boundary.

Catchment Risk Assessment

Land cover	Percentage catchment cover
Arable land	607%
Intensively managed (improved) grassland	25%
Rough low-productivity grassland	2%
Other land covers (including mire habitat)	13%

Tregerest mire is assigned medium-high catchment risk. This is primarily because of the presence of farms, arable land and intensively managed grassland on extensive, highly erosive flow pathways that lead to the mire. These features may, depending on their management, be a risk to the water quality of the mire. The A3071 road on the flow pathways may also be a threat to the mire habitat.

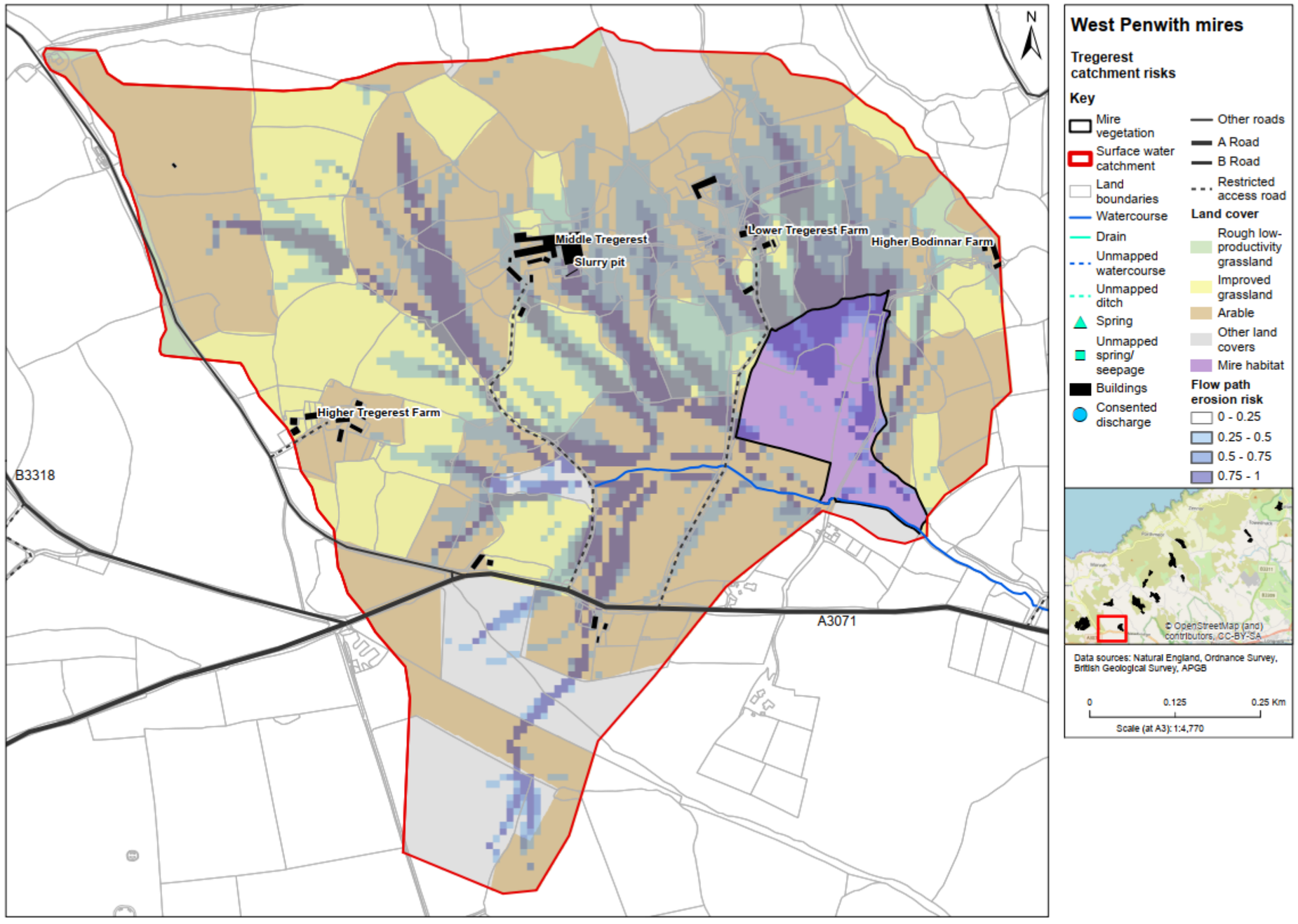


Figure 11-2. Map of catchment risks. Only land covers with a risk associated from CEHs land cover map 2007 shown for clarity. Farm features that have been verified with Google Earth are labelled including the farm name where available. Mine features identified from OS data also labelled. Flow pathways from SCIMAP superimposed to assess potential impact of risks on the mire.

Catchment land holdings

There are 3 CPH land holdings within Tregerest surface water catchment. Two land holdings cover the majority of the catchment and intersect the mire boundary and the groundwater emergence zone so may be most likely to impact the mire due to their close proximity.

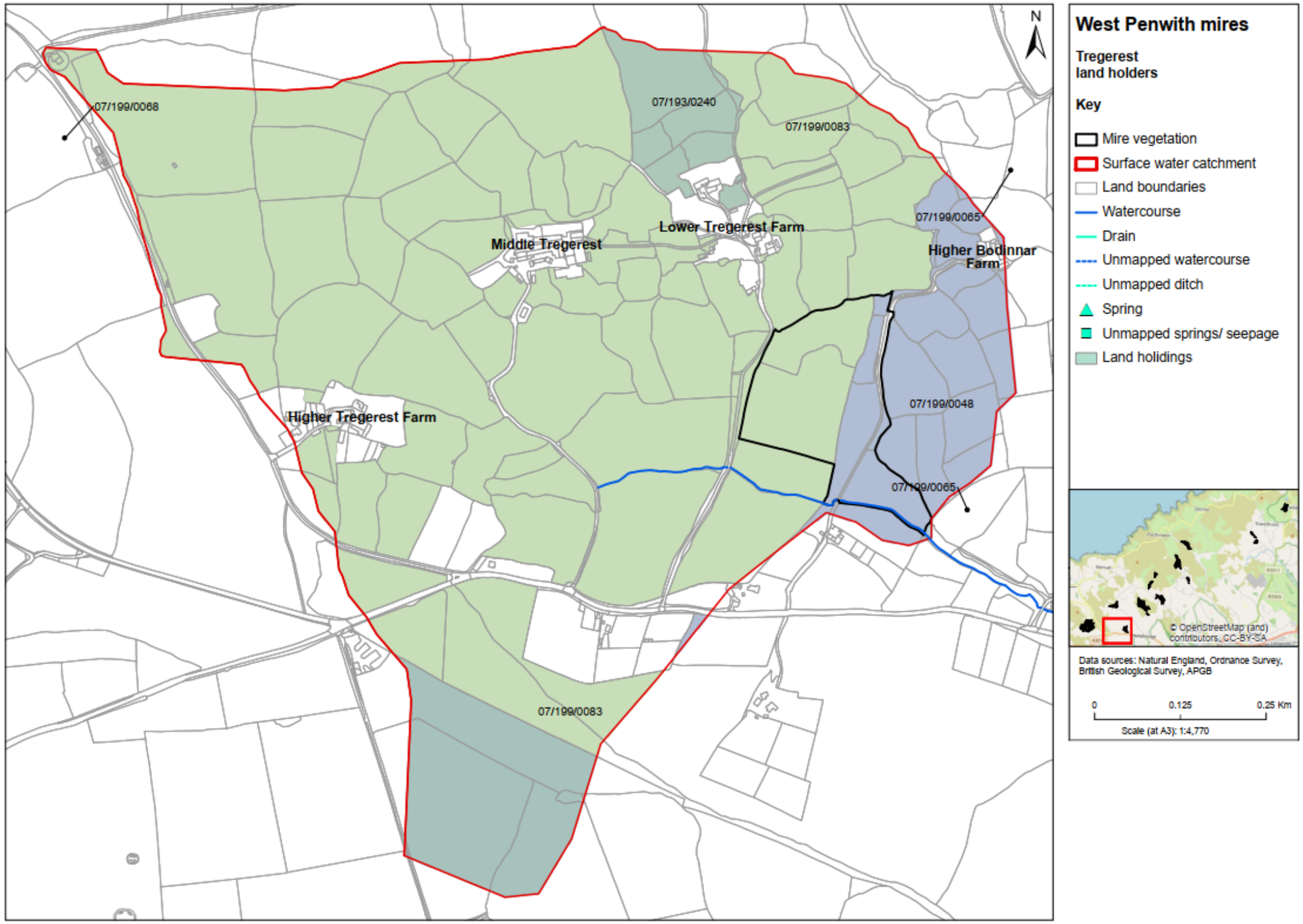


Figure 11-3. Map of land holdings in the catchment. Due to the high number of CPH numbers the same shades of green and purple may be used for the same CPH number. Therefore, each land holding is also labelled with the CPH number.

Conclusions

This report identifies hydrological risk zones for 11 mires in West Penwith, Cornwall to inform Natural England in refining SSSI boundaries. Five hydrological risk zones are identified for each mire based on available topographical, hydrological and geological information, increasing in spatial coverage from the groundwater emergence zone to the surface water catchment zone. The groundwater emergence zone captures the main groundwater inputs and surface watercourses that feed each mire. The lower slopes and valley floor is the minimum area that should be protected by the SSSI to protect mire functioning according to the JNCC guidelines. However, the catchment risk assessment that identifies the hazards to mire hydrology, water quality and ecology in the catchments highlights features that may pose a risk to the mire are often positioned outside of the groundwater emergence or lower slopes and valley floor zones, connected to the mire via flow pathways on steep slopes in the catchment. The key features and catchment risk category are summarised for the 11 mires in Table 4. The catchment risk category inferred from land use and catchment activities at the time of writing, should be considered when selecting which hydrological risk zone is most appropriate to offer the mire protection and to inform SSSI boundary definition.

Table 4. Summary of the characteristics of each mire and catchment including the risks identified for each mire.

Mire	Mire habitats (NVC codes)	Extent of mire habitat (ha)	Total catchment area (ha)	Number of land holdings in catchment	Risks in catchment	Risk category
Bodrifty / Bosporthennis Bog	M25B, M6C, M29, M25A, M23B, M21, M6D, M23A, W1	12.16	115	16	• Small areas of arable and intensively managed grassland that border the mire • Close proximity road • Mine shaft	Low-medium
Bosiliack Bog	M25B, M25C, M23A, M25A, M23B, M25B, M29	6.55	85	6	• Arable land adjacent to mire • Extensive intensively managed grassland and farmyards on flow pathways • Abstractions within mire • Mine shaft	High
Bostraze Bog	M21, M23B, M24C, M25A, M25B, M25C, M6A, W1	23.45	300	13	• Extensive arable land and farmyards on flow pathways • Large roads on flow pathways • Mine shaft near spring	High
Boswarva Bog	M23B, M25A, M25C, M25B, *M23A, M16B,* M1, W1	16.38	86	2	• Arable land on main flow pathways and in close proximity to mire	Medium
Boswens Bog	M23B, M25C, M25A, M23A, M16B, W1	6.14	111	5	• Arable land, intensively managed grassland and farmyard on main flow pathways and adjacent to the mire	Medium

Mire	Mire habitats (NVC codes)	Extent of mire habitat (ha)	Total catchment area (ha)	Number of land holdings in catchment	Risks in catchment	Risk category
Bussow Moor	M23B, M23A, M25, M23, W1	7.02	160	8	• Arable land, intensively managed grassland and farmyards on main flow pathways and adjacent to the mire • Consented discharges on flow pathways • Road crossing main flow pathways • Multiple mine shafts	High
Embla North and South	M25C, M23B, M23A, W1 (NORTH) M25B, M23A, M23B, W1 (SOUTH)	5.41	131	16	• Intensively managed grassland and farmyards on main flow pathways and adjacent to the mire • Local road in close proximity • Consented discharge	Medium-high
Gear / Chykembro Common	M1, M16A, M21, M25A, W1	8.45	65	10	• Limited extent of arable and intensively managed grassland • Road in close proximity • Mine shaft	Low
Lanyon / Men-an-Tol	M23B, M25C, M25A, M29	5.32	180	10	• Arable land, intensively managed grassland and farmyards on flow pathways and adjacent to mire. • Consented discharge • Multiple mine shafts	Medium-high
Tredinnick	M23A, M25A, W1	2.33	60	10	• Extensive arable land, intensively managed grassland and farmyards on flow pathways and adjacent to mire • Roads in close proximity to mire • Consented discharge	Medium-high
Tregerest	M23A, M23B, M25, W1	4.89	97	3	• Extensive arable land, intensively managed grassland and farmyards on flow pathways and adjacent to mire • Roads in close proximity to mire	Medium - high

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Appendices

A. Dataset glossary

Dataset	Source	Description
Digital Terrain Model (DTM)	Get mapping (https://www.getmapping.com/products/height-data/height-data-getmapping)	5m resolution gridded elevation derived from aerial photography that is comparable to LiDAR which was not available in many of the catchments of interest.
Flow pathways	SCIMAP (http://www.scimap.org.uk/)	Model that predicts connectivity of surface water in the landscape based on topography, soil moisture and saturation.
Superficial geology	British Geological Society (BGS)	Map of superficial geology deposits at 1:50,000 scale
Geological faults	British Geological Society (BGS)	Map of linear geological features including faults at 1:50,000 scale
Soil properties	NATMAP (http://www.landis.org.uk/data/nmvector.cfm)	Digitised national soil map at 1:250,000 scale.
Land boundaries	OS MasterMap	Mapped point, line and polygon features watercourses, drains and springs, farm, slurry bed, roads, mines, shafts, adits and spoil heaps.
Land cover map 2018	CORINE (https://land.copernicus.eu/pan-european/corine-land-cover/clc2018)	Gridded land cover inventory of 44 land cover classes derived from satellite data. Minimum mapping unit of 25 ha.
Land cover map 2007	Centre for Ecology and Hydrology (CEH) (https://www.ceh.ac.uk/services/land-cover-map-2007)	Vector dataset derived from digital cartography to delineate around real-world boundaries. Minimum mapping unit is 0.5 ha.
Crop map 2018	Crop Map of England (CROME) published by Rural Payments Agency	Vector dataset classifying 20 main crop types within hexagons. Derived from Sentinel 1 and 2 satellite imagery.
Consented discharges	Environment Agency	Shapefile of consented discharges
Abstraction points	Environment Agency	Shapefile of abstraction points

B. Ecology glossary

NVC code	Community name	Description	Groundwater dependency score*	Ecology requirements
Fen meadows/rush pastures				
M1	*Sphagnum auriculatum* bog pool community	This community is confined to pools and wetter hollows on ombrogenous and topogenous mires with base-poor and oligotrophic raw peat soils in the more oceanic parts of Britain. In the South West, it is associated with valley mires where there is a high-water table.	3 (2)	
M6	*Carex echinata – Sphagnum recurvum/*	This mire is the major soligenous community of peats and peaty gleys irrigated by rather base-poor waters in the sub-montane zone of northern and western Britain. The soils and water are	2 (1)	- Base-poor waters

	auriculatum mire	quite acidic with a superficial pH usually between 4.5 and 5. It typically occurs as small stands among other mire communities, grassland and heaths and sometimes with swamp and spring vegetation. It is commonly found in tracts of unenclosed pasture on upland fringes, particularly between 200 m and 400 m (although it may be found much higher) and is ubiquitous in the upland fringes of Britain. The community is frequently grazed. This, especially where combined with drainage, can convert the community to grassland.		- Acidic soils and water (4.5 – 5 pH)
M16	*Erica tetralix* – *Sphagnum compactum* wet heath	This wet heath community is found on acid and oligotrophic mineral soils or shallow peats that generally have a surface pH of between 3.5 and 4.5 and that are at least seasonally waterlogged. It is characteristic of the south of lowland England, being particularly associated with the surrounds of valley mires maintained by a locally high water table.	1 (2)	- Soils with a surface pH of between 3.5 and 4.5. - At least seasonally waterlogged. - High water table
M21	*Narthecium ossifragum* – *Sphagnum papillosum* valley mire	This is a community of permanently waterlogged, acid and oligotrophic peats, especially characteristic of valley mires maintained by a locally high-water table. The peat on which this community is found is usually not very deep (20-150 cm) with a surface pH mostly in the range of 3.5-4.5, and a water table at or very close to the surface. Burning and grazing are likely to have little effect in the absence of drainage.	1 (2)	- Permanently waterlogged - Acidic soils (3.5-4.5 pH) - Locally high water table
M23	*Juncus effusus/ acutiflorus* – *Galium palustre* rush-pasture	This rush-pasture occurs over a variety of moist, moderately acid to neutral, peaty and mineral soils in the cool and rainy lowlands of western Britain. It is a community of gently sloping ground around the margins of soligenous flushes, as a zone around topogenous mires and wet heaths, and especially widespread in wet, comparatively unimproved or reverted pasture. It can be found on a variety of moderately acid to neutral soils that are kept moist to wet for most of the year with a pH in the range of 4-6. Artificial drainage and other kinds of soil modifications such as fertilising and reseeding have reduced its former extent.	1 (2)	- Moderate to neutral acidity (4-6 pH) - Peaty and mineral soils - Soils that are kept moist to wet for most of the year.
M24	*Molinia caerulea* – *Cirsium dissectum* fen-meadow	This is generally a species-rich community of moist to fairly dry peats and peaty mineral soils which are circumneutral, generally having a pH within the range 5-6.5. It can be found in association with both soligenous and topogenous mires, typically marking out the better-drained fringes of bogs and fens, or the margins of wet hollows and flushes. Although climate and soil together both influence the floristics of this community it is essentially a secondary vegetation type, derived from a variety of wetland vegetation types and maintained by mowing or grazing. In the absence of any kind of treatment all the stands of the	1	- Moist to fairly dry peats - 5 – 6.5 pH

		community would probably progress to scrub or woodland. It has been reduced in extent by agricultural modification. Other stands have become rank and scrubby with neglect.		
M25	*Molinia caerulea – Potentilla erecta* mire	This mire is a community of moist, but well-aerated, acid to neutral peats and peaty mineral soils in the wet and cool western lowlands of Britain. It occurs over gently sloping ground, marking out seepage zones and flushed margins of sluggish streams, water-tracks and topogenous mires, but also extends onto the fringes of ombrogenous mires. Soil and drainage conditions of this community have similarities to those of M23 and M24 and geographically this community can be seen as a northern/western replacement of M24. Treatments such as burning, grazing and drainage are likely to be largely responsible for the development of this community over ground that would naturally carry some other kind of mire, often M21 in valley mire situations, or wet heath vegetation. In the lowlands, other tracts of the community together with neighbouring vegetation have been lost to agricultural intensification.	2 (3) In the context of West Penwith, M25 is generally highly dependent on groundwater	- Moist but well aerated soils - Acid to neutral soils
M29	*Hypericum elodes – Potamogeton polygonifolius* soakway	This community is characteristic of shallow soakways and pools in peats and peaty mineral soils, such as seepages and runnels around mires and in heathland pools, at moderate altitudes. The water is typically clear, still or gently flowing, moderately acid to neutral, with a pH between 4 and 5.5, and probably quite oligotrophic.	1 (2)	
Neutral grasslands				
MG6	*Lolium perenne - Cynosurus cristatus* improved permeant grassland	The major permanent pasture type in lowland Britain, often brought about by the action of fertilisers, herbicides and drainage on many other MG types or by agricultural rundown of MG7. May also be used for silage or haymaking.		
MG10	*Holcus lanatus - Juncus effusus* rush pasture	This occurs throughout the British lowlands, commonly developing following drainage and eutrophication of mire vegetation, and/or the reversion of agriculturally modified grassland to a more natural state.	2	
Woodlands and scrub				
W1	*Salix cinerea – Galium palustre* woodland	A woodland community of wet mineral soils on the margins of standing or slow-moving water and in moist hollows, mainly in the lowlands. It often occurs as a narrow fringe or as scattered fragments around ponds, lakes, dune slacks etc.	2	- Wet mineral soils
W22	*Prunus spinosa - Rubus fruticosus* scrub	Blackthorn is overwhelmingly dominant. Found around woodland margins and abandoned grassland. Generally associated with mesotrophic soils. Absent from peat.		

W23	*Ulex europaeus - Rubus fruticosus* scrub	Gorse scrub. Widespread, absent from peat.		
W24	*Rubus fruticosus - Holcus lanatus* underscrub	Bramble scrub. Widespread.		
W25	*Pteridium aquilinum - Rubus fruticosus* underscrub			
Acid grasslands				
U4	*Festuca ovina - Agrostis capillaris - Galium saxatile* grassland	Principally a grassland community of upland (sub-montane) areas of north and western Britain associated with a range of acidic soils on lime-poor substrates. Examples do occur in lowland situations (<300m).	3	
U20	*Pteridium aquilinum - Galium saxatile*	This community favours slightly richer soils and occurs particularly after burning, and in the absence of grazing or cutting management.		
Heathlands				
H4	*Ulex gallii – Agrostis curtisii* heath	This community occurs on a variety of moist, acid soils, that are too moist for dry heath but not so consistently waterlogged as to be able to sustain wet heath.		
H8	*Calluna vulgaris – Ulex gallii* heath	This community is found on free-draining, generally acid to circumneutral soils. It can be found over a wide range of arenaceous sedimentaries and acid igneous and metamorphic rocks as well as on silty and sandy superficials like loess and aeolian sands. The superficial pH underneath this community is usually from 3.5 to 4.5.	3	
Swamps and tall-herb fens				
S23	*Glycerio - Sparganion* water margin vegetation	Miscellany of Glycerio-Sparganion vegetation from unshaded silty margins of lowland streams and pools. These communities generally contain no rare or scarce plants but are significant in providing diversity, sometimes in quite modified landscapes, that is important floristically but also for associated invertebrate and bird faunas. Widespread and still quite common.	3	

*May vary for different hydro-ecological settings (UKTAG, 2009).

Sources: Elkington *et al.* (2002); Environment Agency (2009); Natural England (1999); Rodwell *et al.* (1991 – 2000); Whitbread *et al.* (1992); (UKTAG, 2009).

C. Fertiliser glossary

Fertiliser	Properties
Phosphatic fertiliser	Fertilizer compound or mixture containing available (soluble) phosphate; examples are phosphate rock (phosphorite), superphosphates or triple superphosphates, nitrophosphate, potassium phosphate, or N-P-K mixtures.
Nitrogenous fertiliser	Fertiliser materials, natural or synthesized, containing nitrogen available for fixation by vegetation, such as potassium nitrate or ammonium nitrate.
Farmyard manure	Manure can be used as an organic nitrogen fertiliser as it breaks down slowly over time to release its nutrients.
Slurry	Mixture of organic waste from farming including some or all of animal waste, hay, water runoff from washing down dairies, stables and barns that is converted over time into fertiliser.

Sources: EEA (2020)

D. Soil glossary

Soil code	Properties
651B	Gritty, loamy and very acidic with a wet peaty surface horizon and thin ironpan often present.
871A	Permeable, gritty, coarse and loamy with a wet humose or peaty surface horizon affected by groundwater
612B	Well drained humose gritty loamy soils. Occasionally with thin ironpan.
611B	Well drained gritty loamy soils with a humose surface horizon in places.

Sources: Findlay (1984).

E. Geology glossary

Code	Type	Properties
Land's End Granite (and microgranite)	Bedrock	Medium-coarse grained biotite granite. Granite typically has a low porosity and the main flow pathways are likely to be through weathered fractures close to the ground surface. Fracture frequency is generally considered to decrease with depth leading to negligible flow at depth. Therefore, the 'base' of the aquifer is generally considered to be approx. 30-40m below the surface. Due to the largely unconfined nature of the granite, the groundwater catchment is considered to reflect surface catchment.
Alluvium	Superficial	Typically unconsolidated sand, silt, clay and gravel formed in a river/stream environment. Proportions of sand, silt, clay and gravel is spatially variable throughout the lithology.
Head	Superficial	Poorly sorted, angular and poorly stratified rock debris, clayey hillwash and soil creep. Usually deposited by solifluction or gelifluction processes as a result of waterlogged deposits and the thawing of frozen ground.

Sources: BGS (2020); Defra (2020).

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