Penderyn Quarry: East Twyn-y-Glog Ridge Hydrogeological Impact Assessment

19 December 2018

T1.01

Penderyn Quarry: East Twyn-y-Glog Ridge Hydrogeological Impact Assessment

Prepared for

Hanson UK
Hanson House
14 Castle Hill
Maidenhead
SL6 4JJ

Report reference:
61190R13, December 2018

Report status:
Final Report (redacted)

CONFIDENTIAL

New Zealand House, 160-162 Abbey Foregate,
Shrewsbury, Shropshire
SY2 6FD

Telephone: +44 (0)1743 276 100
Facsimile: +44 (01743 248 600

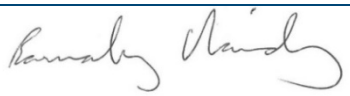
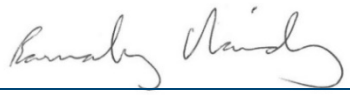
Registered Office:
Stantec UK Ltd
Buckingham Court
Kingsmead Business Park
Frederick Place, London Road
High Wycombe HP11 1JU
Registered in England No. 1188070

Penderyn Quarry: East Twyn-y-Glog Ridge Hydrogeological Impact Assessment

This report has been prepared by Stantec UK Ltd (Stantec) in its professional capacity as environmental specialists, with reasonable skill, care and diligence within the agreed scope and terms of contract and taking account of the manpower and resources devoted to it by agreement with its client and is provided by Stantec solely for the internal use of its client.

The advice and opinions in this report should be read and relied on only in the context of the report as a whole, taking account of the terms of reference agreed with the client. The findings are based on the information made available to Stantec at the date of the report (and will have been assumed to be correct) and on current UK standards, codes, technology and practices as at that time. They do not purport to include any manner of legal advice or opinion. New information or changes in conditions and regulatory requirements may occur in future, which will change the conclusions presented here.

This report is confidential to the client. The client may submit the report to regulatory bodies, where appropriate. Should the client wish to release this report to any other third party for that party's reliance, Stantec may, by prior written agreement, agree to such release, provided that it is acknowledged that Stantec accepts no responsibility of any nature to any third party to whom this report or any part thereof is made known. Stantec accepts no responsibility for any loss or damage incurred as a result, and the third party does not acquire any rights whatsoever, contractual or otherwise, against Stantec except as expressly agreed with Stantec in writing.

	Name	Signature
Author	Chris Woodhouse	
Checked by	Barnaby Harding	
Reviewed by	Barnaby Harding	

Revision record:

Issue	Date	Status	Comment	Author	Checker	Reviewer
1	15/06/2018	Draft for external review	61190R13 D1	CDW	BCH	BCH
2	23/08/2018	Draft for external review	61190R13 D2	CDW	BCH	BCH
3	12/10/2018	Draft for external review	61190R13 D3	CDW	BCH	BCH
4	8/11/2018	Draft for external review	61190R13 D4	CDW	BCH	BCH
5	15/11/2018	Draft for external review	61190R13 D5	CDW	BCH	BCH
6	3/12/2018	Final Report (Official Sensitive)	61190R13	CDW	BCH	BCH
7	18/12/2018	Final Report (Official Sensitive)	61190R13Rev01	CDW	BCH	BCH
8	18/12/2018	Final Report (redacted)	61190R13Rev01	CDW	BCH	BCH

Contents

FIGURES

TABLES

APPENDICES

1 Introduction

1.1 Background

Hanson UK (Hanson) is submitting a planning application to extract limestone from the eastern half of the Twyn-y-Glog Ridge at the existing Penderyn Quarry. Penderyn Quarry is an active limestone quarry located immediately east of the village of Penderyn and 5.5 km north-west of Aberdare in Rhondda Cynon Taf, South Wales.

Hanson is proposing to give up rights to work the western half of the Twyn-y-Glog ridge as part of the planning application and instead quarry the eastern part of the ridge. The application area covers approximately 1.77 ha and lies within the existing Penderyn Quarry land ownership boundary. Figure 1.1 shows a map of the area around Penderyn Quarry with the eastern Twyn-y-Glog Ridge application area marked in red ("the Site"). The western ridge area which is to be preserved ("the Preserved Area") (i.e. where Hanson is proposing to give up the rights to quarry) is shown in green and has an area of 2.35 ha with the Penderyn Quarry land ownership boundary shown in blue. An assessment has been made of the impacts of working the Site, with a comparison made between the loss of effective catchment area in working the Site versus that in working of the Preserved Area.

At the Site, Hanson proposes to work the limestone resource to a level of not less than 265 m Above Ordnance Datum (AOD). Confining working to this level will mean groundwater dewatering will not be required within the Site. Details of the proposed development are set out in the development plans in Appendix A. Following mineral working, the Site will be included in the overall Penderyn Quarry restoration plan, where a lake is proposed in the quarry void. Appendix C contains the proposed restoration plan for Penderyn Quarry.

This report constitutes a Hydrogeological Impact Assessment (HIA) that has been prepared on behalf of Hanson in support of the planning application. A Flood Consequence Assessment (FCA) has also been produced as a separate document (Stantec, 2018).

1.2 Scope of Work

Hanson instructed Stantec UK Ltd. (Stantec) in April 2018 to undertake an HIA in support of the planning application for mineral extraction within the Site. This report focusses on the hydrogeological impacts of the mineral working and subsequent restoration at the Site and has been written in line with the Planning Policy Wales (PPW) guidance.

The scope of work undertaken for this HIA includes the following:

- Review of the baseline hydrogeology for the Site and surrounding area;
- identification of receptors and assessment of potential impacts;
- recommendations for appropriate Site inspection and mitigation measures; and
- preparation of an HIA for the proposed development (this report).

Stantec has also undertaken a Flood Consequence Assessment (FCA), which is the subject of a separate report (Stantec, 2018).

1.3 Data Sources

The information and assessments in this report are predominantly based on secondary data analysis associated with both the Site itself and the surrounding land area. The main sources of data are summarised below:

- Proposed development plans provided by Hanson (Appendix A);
- previously consented development for the Preserved Area (Appendix A);
- proposed restoration plan provided by Hanson (Appendix B);
- geological data from monitoring well drilling;

- previous monitoring, conceptualisation and impact assessment reports for Penderyn Quarry by SRK and ESI Ltd (ESI);
- groundwater level, stream flow and rainfall data collected as part of the Penderyn Quarry monitoring regime;
- British Geological Survey (BGS) mapping;
- Ordnance Survey mapping; and
- data from Natural Resources Wales (NRW) including rainfall, historic landfill data, LiDAR data and abstraction licences.

1.4 Report Outline

This report constitutes the HIA for the planning application, and includes the following:

- A review of the relevant baseline conditions and conceptual model for the Site (Section 2);
- an outline of the proposed quarry development (Section 3);
- an assessment of the potential impacts of the development, including a comparison of impacts through loss of catchment area of working the Preserved Area, and recommendations for any appropriate Site inspection and mitigation measures (Section 4); and
- a summary of the results and key conclusions (Section 5).

The technical approach of this HIA is in accordance with the requirements of GP3 (Groundwater Protection: Principles and Practice, EA, 2013) (the guidance adopted by NRW) to ensure the protection of groundwater in the Site vicinity.

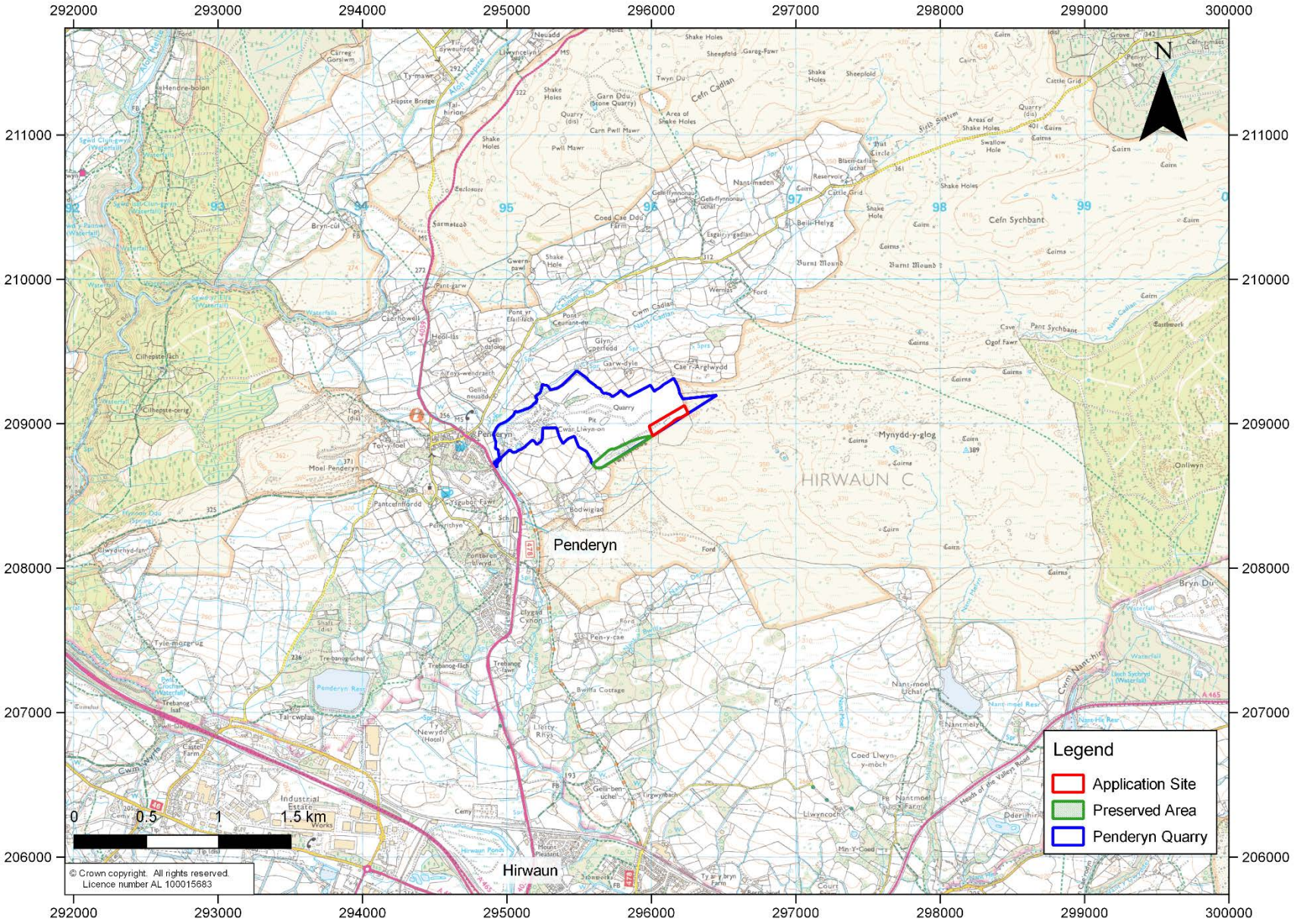


Figure 1.1 Site location showing surrounding area

2 Baseline Conditions

2.1 Site Setting

The Site is located approximately 1.1 km east of Penderyn village and 2.8 km north of Hirwaun in Rhondda Cynon Taf (postcode: CF44 0TX and NGR: SN 961090). The Site, and all of Penderyn Quarry, lie within Brecon Beacons National Park, the southern boundary of which lies 2.8 km south of the Site. Penderyn Quarry is accessed from the A4059 which lies immediately west of the quarry and 1 km west of the Site.

The Site is within Penderyn Quarry which covers an area of 49.8 ha and is an operational limestone quarry. Other than Penderyn Quarry, land use in the area around the Site is predominantly rural, comprising various small settlements, agricultural land, woodland and moorland. Land immediately around the Site to the north and west forms part of Penderyn Quarry, and to the south and east is moorland forming the western slopes of the hill Mynydd-y-Glog. A number of small industrial developments are located in the surrounding area, the closest of which is Penderyn Distillery located 1 km south-west of the Site. The Cwm Cadlan Special Area of Conservation (SAC) is located 440 m north of the Site. Section 2.7.4 contains more information about this SAC.

Settlements surrounding the Site include Bodwigiad (725 m south-west), Penderyn (1.1 km west of the Site), Pontbren Llwyd (1.3 km south-west) and Hirwaun (2.8 km south). A number of isolated dwellings and farms are located in the area around the Site, including Cae'r-Arglwydd (340 m north of the Site), Garw-dyle (400 m north) and Glyn-perfedd (650 m north).

Figure 2.1 shows a map of LiDAR topography data around the Site. Ground levels at the Site itself, range from 350 – 362 m AOD. The Site forms part of the Twyn-y-Glog ridge, and topography slopes away from the Site to the north and south. There is a much steeper drop to the north due to the presence of the Penderyn Quarry void and the quarry is currently being worked to an elevation of 250 m AOD. To the south, topography falls towards the westward flowing Bodwigiad Stream which is at an elevation of approximately 320 m AOD at its closest approach. East of the Site, ground levels rise gradually to the summit of Mynydd-y-Glog (at 390 m AOD). Regionally, topography is dominated by elevated moorland areas including Mynydd-y-Glog, Moel Penderyn (up to 360 m AOD) and Cadair Fawr (485 m AOD). North of the Site are the Brecon Beacons and land is generally topographically much higher. River valleys cut through this high land including Cwm Cadlan, the valleys of the River Cynon and River Hepste.

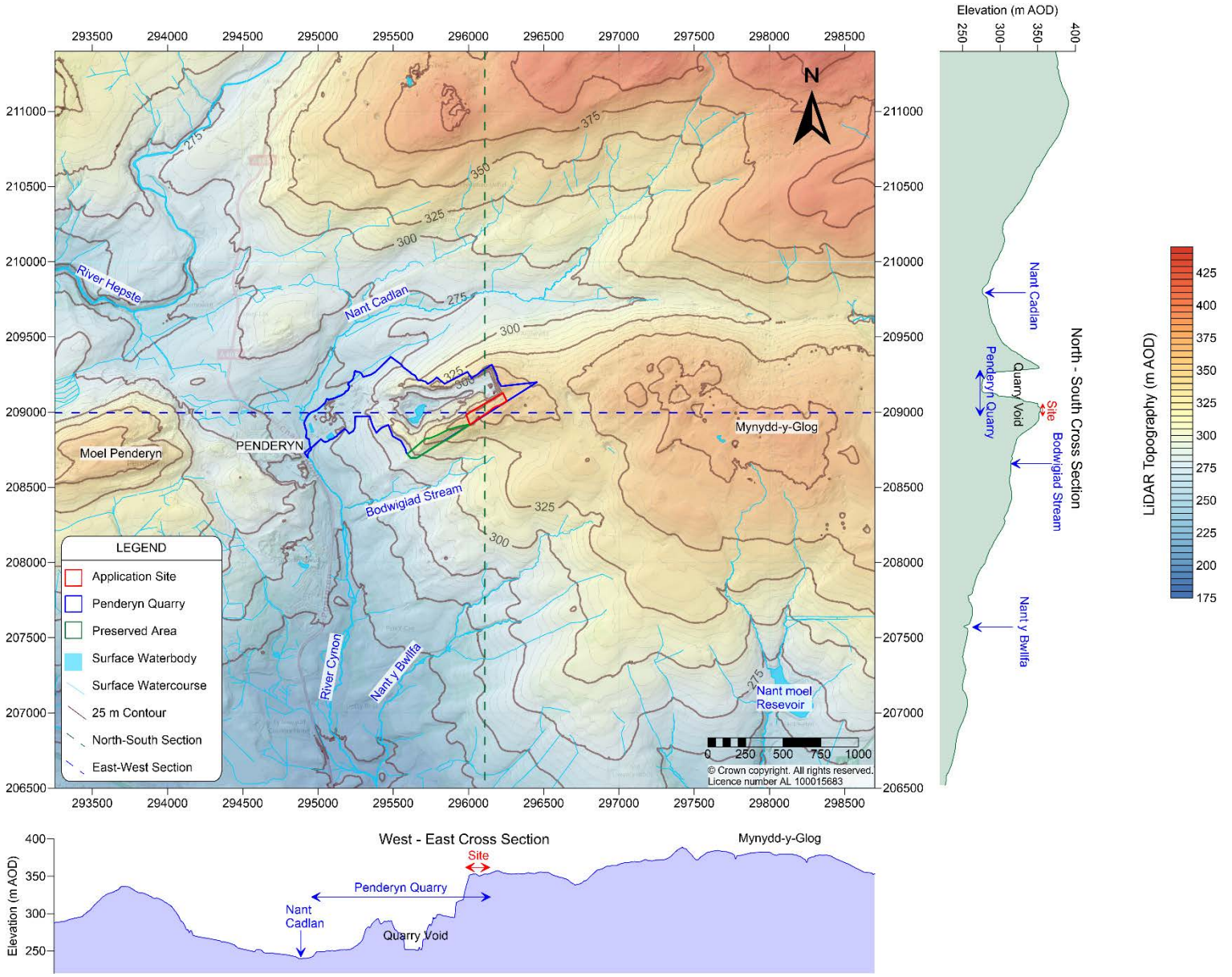


Figure 2.1 LiDAR topography data around the Site

2.2 Geology

2.2.1 Regional geology

Bedrock

The bedrock geology of the area around the Site consists of Carboniferous strata. Figure 2.2 shows the bedrock geology as taken from the 1:50,000 scale geological map of the area (BGS, 1979). A summary of the regional geological sequence is provided in Table 2.1 and is discussed in greater detail in this section.

The Carboniferous Oxwich Head Limestone Formation of the Pembroke Limestone Group and younger Twrch Sandstone Formation of the Marros Group crop out at the Site. The Oxwich Head Limestone Formation is comprised of fine to coarse grained packstone limestone and includes the Penderyn Oolite (cropping out 60 m north of the Site towards the base of the Oxwich Head Limestone) and Honeycombed Sandstone members. These members are comprised of ooidal limestone and calcareous sandstones respectively. The Twrch Sandstone Formation unconformably overlies the Oxwich Head Formation and is formed of quartz arenites and conglomerates.

The older Carboniferous Dowlais Limestone Formation crops out within the Penderyn Quarry void, 125 m to the north of the Site. This unit is comprised of various grainstone, packstone and wackestone limestones with some interbedded shale strata. The age of the bedrock strata gets progressively younger moving southwards from the Site. The Bishopston Mudstone Formation crops out 2 km south of the Site and the younger still South Wales Lower Coal Measures crops out 1.9 km south-west of the Site. The older Devonian Grey Grits Formation and Carboniferous Cwmyniscoy Mudstone (also part of the Pembroke Limestone Group) formations crop out 700 m north-east and 950 m north-east of the Site respectively.

The geological structure around the Site is complex. Structural features in the area largely date to the late Carboniferous – early Permian Variscan orogeny. Bedrock strata in the southern part of Penderyn Quarry (including the Site) dip gently at 10 - 25^{o} to the south-east and form part of the southern limb of a regional east-west trending antiformal anticline. The Site lies on the southern limb of this anticline strata become progressively younger southwards of the anticlinal axis. The Dinas Fault is a regionally significant steeply northerly dipping normal fault, and this runs north-east to south-west 400 m north of the Site. The Coed Hir Fault lies 1.5 km north of the Site and is a southerly dipping fault with a normal displacement running along a similar orientation to the Dinas Fault. These major faults are cross-cut by a series of north-west to south-east orientated faults. These cross-faults mostly downthrow westwards (Barclay, Taylor, & Thomas, 1988).

Table 2.1 Regional lithological sequence[1]

Period	Group	Formation	Description	Thickness (m)	Local presence
Carboniferous	South Wales Coal Measures	South Wales Middle Coal Measures	Coal-bearing mudstones/siltstones, with seatearths and minor sandstones	120 – 240	3.9 km south-west
		South Wales Lower Coal Measures		80 - 300	1.9 km south-west
	Marros	Bishopston Mudstone	Mudstones, with some interbedded siltstones and sporadic, minor quartzitic sandstones	750	1.2 km north-west
		Twrch Sandstone	Quartz arenites and quartz conglomerates with minor mudstones	190	Present
	Pembroke Limestone	Oystermouth	Argillaceous limestones and mudstones	< 61	275 m west
		Oxwich Head Limestone (containing Penderyn Oolite and Honeycombed Sandstone)	Thick bedded fine to coarse grained, recrystalised, packstones with ooidal limestones	125 - 183	Present
		Dowlais Limestone	Thick-bedded, grainstone, packstone and wackestone limestones with shale interbeds; minor micritic and ooidal limestones and some sandstones	Up to 120	At depth
		Cwmynyscoy Mudstone	Interbedded mudstones and thin- to medium-bedded skeletal packstones	10 - 60	At depth
Devonian	Upper Old Red Sandstone	Grey Grits	Fluvial sandstones and conglomerates	45 - 350	At depth

[1]Unconformities shown by undulating lines

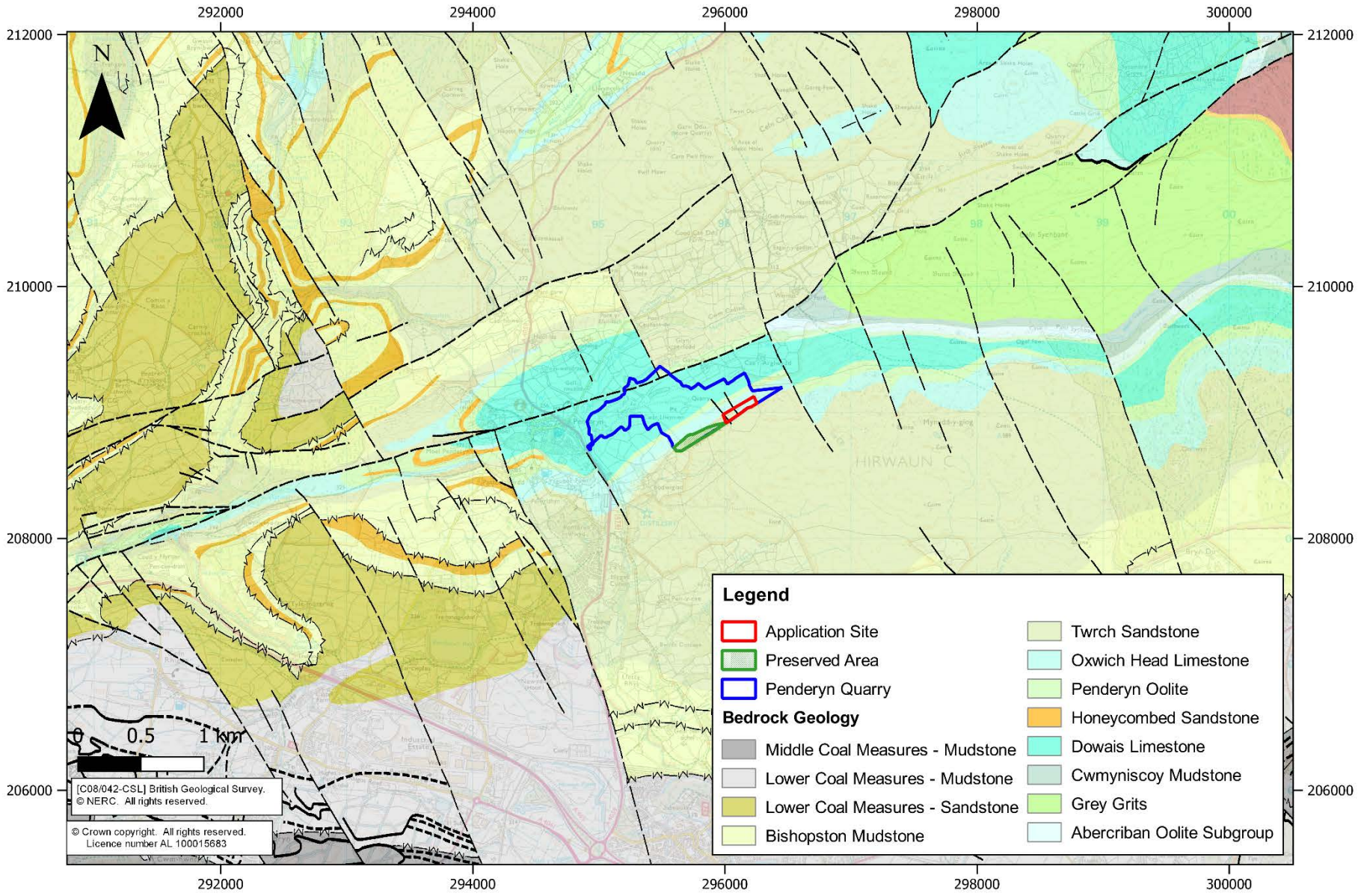


Figure 2.2 Bedrock geology

Superficial Deposits

Figure 2.3 shows the superficial deposits that overlie the bedrock strata around the Site. Quaternary deposits cover the bedrock geology across much of the surrounding region, however no superficial deposits are mapped at the Site. Superficial deposits are largely absent at Penderyn Quarry, likely because they have been stripped away by quarrying activities.

Glacial till is the primary superficial lithology and this covers most of the surrounding area with the closest deposit being 140 m south of the Site. Approximately 150 m to the south and at various other locations in the surrounding region, peat deposits crop out in isolated patches. Peat appears to be associated with high ground in moorland settings.

Approximately 600 m north and 1 km west of the Site, alluvium deposits of sand, silt and muds crop out along Nant Cadlan. Alluvium also crops out 1.3 km to the south-west along the River Cynon.

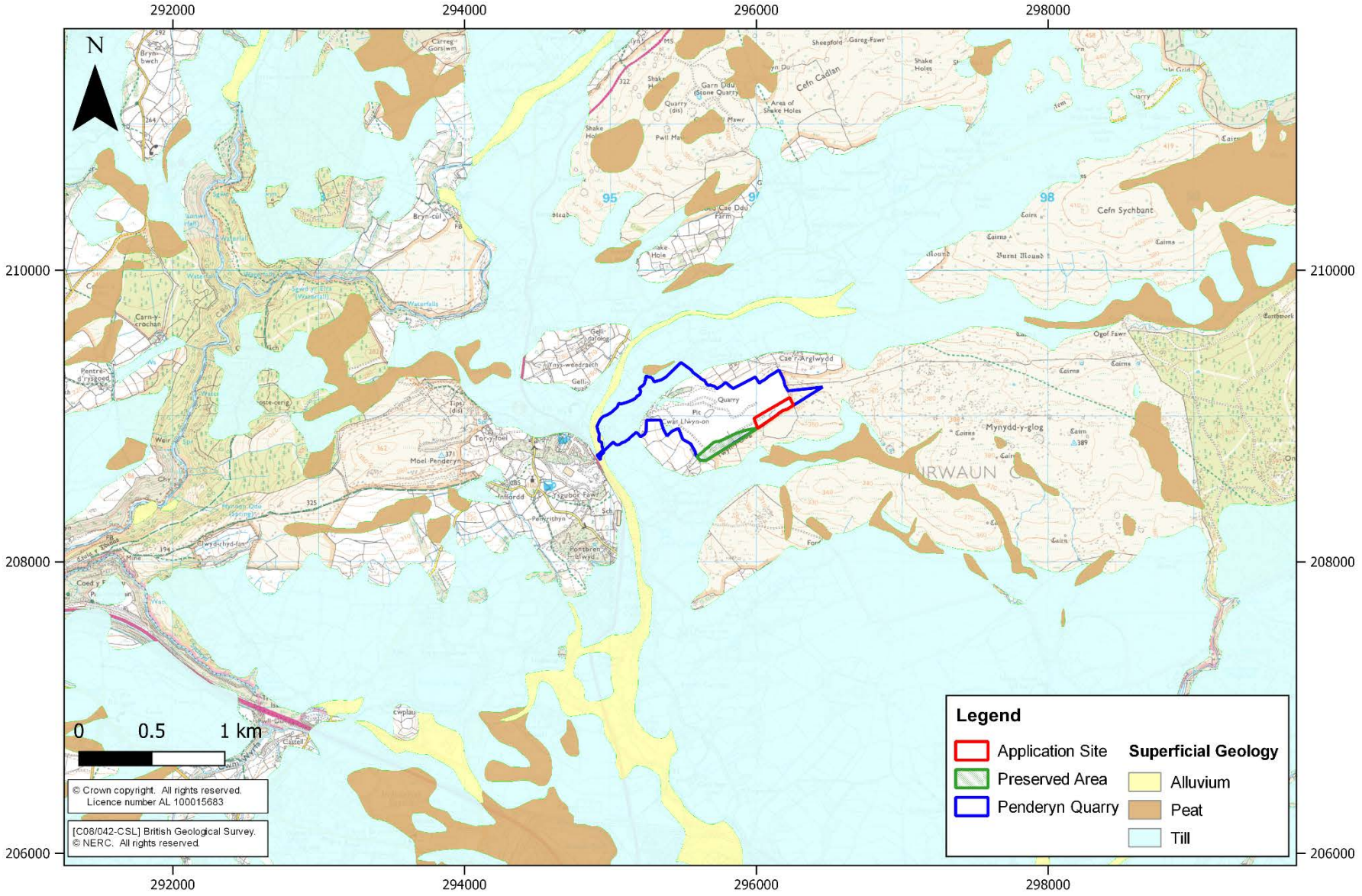


Figure 2.3 Superficial geology

2.2.2 Local geology

Information on the geology in the vicinity of the Site has been obtained from the following sources:

- Monitoring well drilling at the Site;
- previous reports written for the Site and surrounding areas; and
- publicly available geology maps.

Seventeen monitoring boreholes have been drilled around Penderyn Quarry as well as a number of shallow piezometers within the Cwm Cadlan SAC located north of the Site, as shown in Figure 2.4. However, no monitoring boreholes have been drilled within the Site itself.

Figure 2.4 summarises the geology around the Site and Penderyn Quarry based on borehole log data. At Penderyn Quarry, superficial deposits are absent having been removed by quarrying. Superficial deposits increase in thickness northwards to in excess of 69 m at OB14 (note OB1, OB2 and OB14 did not penetrate the full thickness of the superficial strata). Here, the superficial deposits infill a deep glacial channel. Surficial superficial units are predominantly comprised of glacial till. Deeper superficial strata (beneath the glacial till) north of Penderyn Quarry around Cwm Cadlan SAC are comprised of glaciofluvial and glaciolacustrine deposits comprised of sand and gravel and clays with sand and gravel respectively. These deeper units were encountered in OB14.

Twrch Sandstone Formation was only encountered in OB7. This was described as a pebble conglomerate in a cemented sand matrix. The full thickness of the Twrch Sandstone was penetrated at this location and found to be 18 m thick. At the Site, the Twrch Sandstone has a faulted contact (along a cross-fault) with the Oxwich Head Limestone. This unit is expected to be relatively thin across the Site (i.e. < 30 m) with the precise thickness dependent on the fault displacement which is uncertain. Based on the dip, the thickness of the Twrch Sandstone will increase to the south of the Site.

At OB7, the Oxwich Head Limestone is described as dark grey and hard. At OB5, the unit is described as weathered with sand and gravel fissure fills which are presumably within palaeokarst features. The full thickness of the unit was not penetrated at either borehole location. This unit is in turn underlain by the Dowlais Limestone. The full thickness of Dowlais Limestone has not been proven by any of the boreholes at and around Penderyn Quarry. The Penderyn Oolite and Oystermouth Limestone have not been identified in any of the borehole logs however, this may not necessarily mean these lithologies are absent at other locations including the areas of outcrop.

Figure 2.4 shows that superficial deposits directly overlie the Dowlais Limestone to the north of the Site and the overlying bedrock units are absent. In the case of OB16, the absence of Penderyn Oolite conflicts with the geological map for the area and could imply that the fault lies north of OB16 and hence further north than mapped. The difference in elevation of the upper Dowlais Limestone contact between OB16 (263.4 m AOD) and OB10 (287 m AOD) could be due to fault displacement but may also be due to erosion.

Karst is mostly developed in the upper horizons of the limestone strata close to the ground surface and is discussed in more detail in Section 2.5.

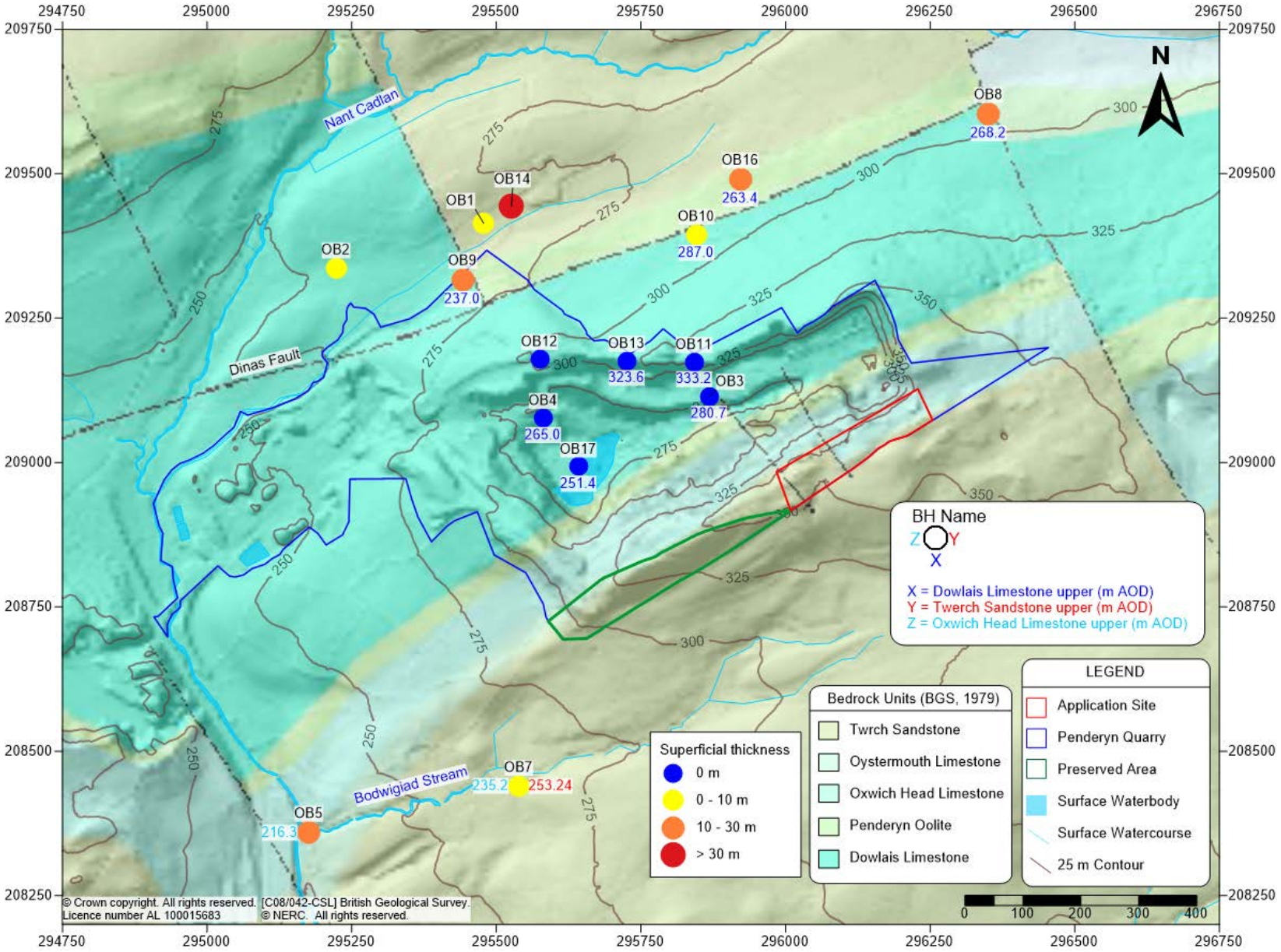


Figure 2.4 Geology around Penderyn Quarry

2.2.3 Infilled ground/landfilling

Three historical landfills lie within 4 km of the Site. These landfills are shown in Figure 2.5 and further details are provided in Table 2.2.

All three historical landfills are located south of the Site. Hirwaun Ironworks accepted household waste and Hirwaun Waste Disposal Site accepted liquid sludge, whilst the Hugh Patches Site accepted various waste types and closed in 1980. The operators of both the Hirwaun Ironworks and Hirwaun Waste sites are unknown.

Table 2.2 Historical landfills within 4 km of the Site

Landfill	Operator	Status	Distance from Site	Waste Accepted
Hirwaun Ironworks Domestic Refuse Tip	Unknown	Historical	2.8 km south	Household
Hirwaun Waste Disposal Site	Unknown	Historical	3.4 km south-west	Liquid Sludge
Hugh Patches Site	Cynon Valley Borough Council	Historical: 1970 - 1980	4 km south-west	Inert, industrial, commercial & household

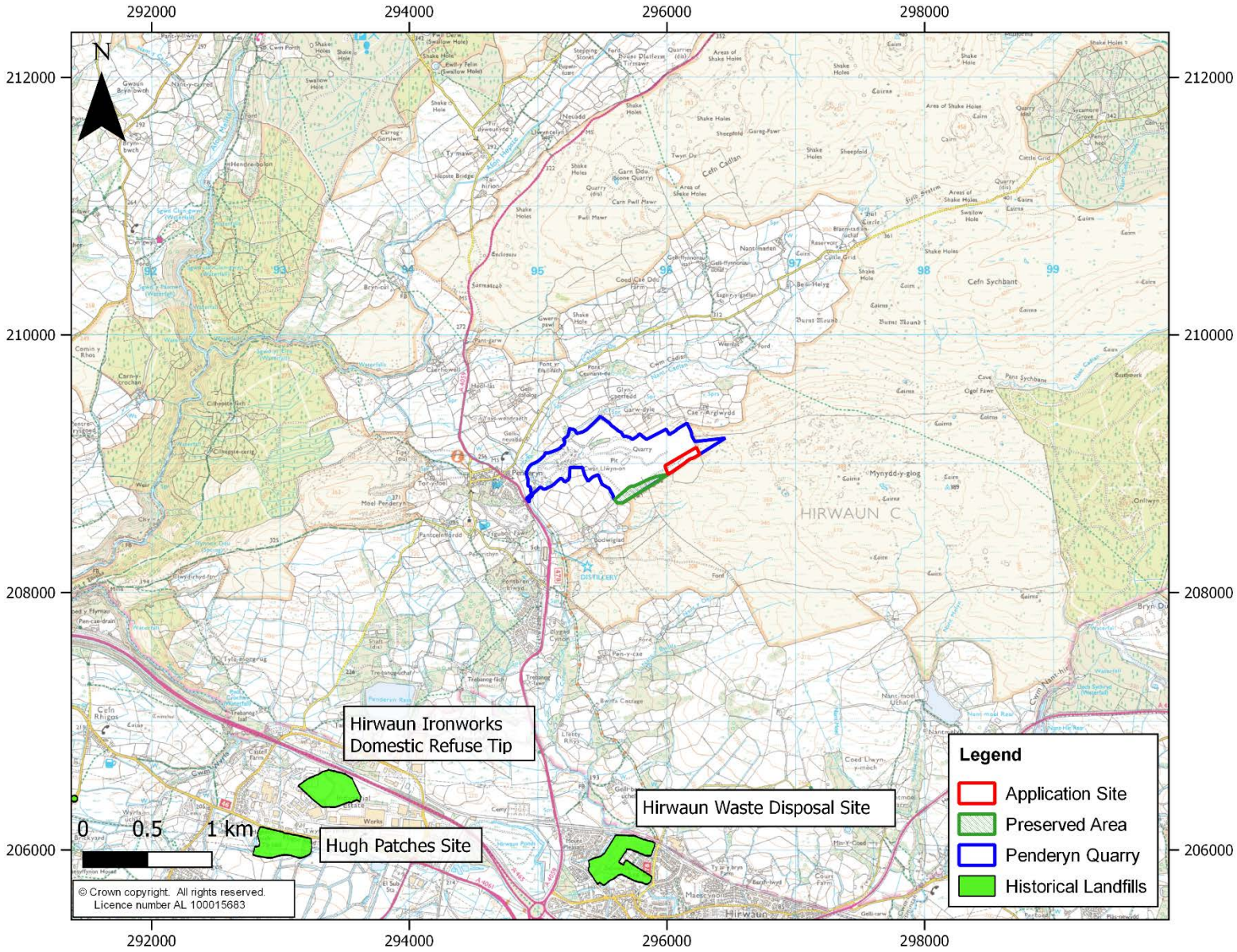


Figure 2.5 Neighbouring historical landfills around the Site

2.3 Hydrology

2.3.1 Rainfall

Rainfall data is available from the following sources:

- Hirwaun STW (3.3 km south-west of the Site) provided by NRW;
- Cwm Cadlan (1 km north) (data available between May 2007 and July 2015 only) provided by NRW;
- SSSI gauge (800 m north-west) maintained and operated by Hanson; and
- Penderyn Quarry rain gauge (900 m west) maintained and operated by Hanson.

Rainfall data from these gauges is cross checked by Stantec (formerly ESI) on a biannual basis using the methodology given in ESI (2014). Using all rain gauges for which data is available and the methodology set out in ESI (2014), a combined sythetic dataset from 1998 - 2018 has been produced.

Table 2.3 summarises annual rainfall data for the synthetic dataset and the full dataset is presented graphically in Figure 2.6. This indicates that annual rainfall varies from 1,300 mm (2003) to 2,516 mm (1996). Mean monthly rainfall ranges between 105 and 222 mm and summer months are typically, but not always, drier than winter months. Annual rainfall fluctuates between years and has fallen since 2014 however, annual rainfall since that time has remained within the expected range based on historical data.

The Standard Average Annual Rainfall (SAAR) for the Site is 1,690 mm which lies within the data range but is below the mean rainfall of 1,854 mm.

Table 2.3 Synthetic annual data statistics (1998 – 2017)

Statistic	Value (mm)
Mean annual rainfall	1,854
Median annual rainfall	1,875
Minimum annual rainfall	1,300
Maximum annual rainfall	2,516

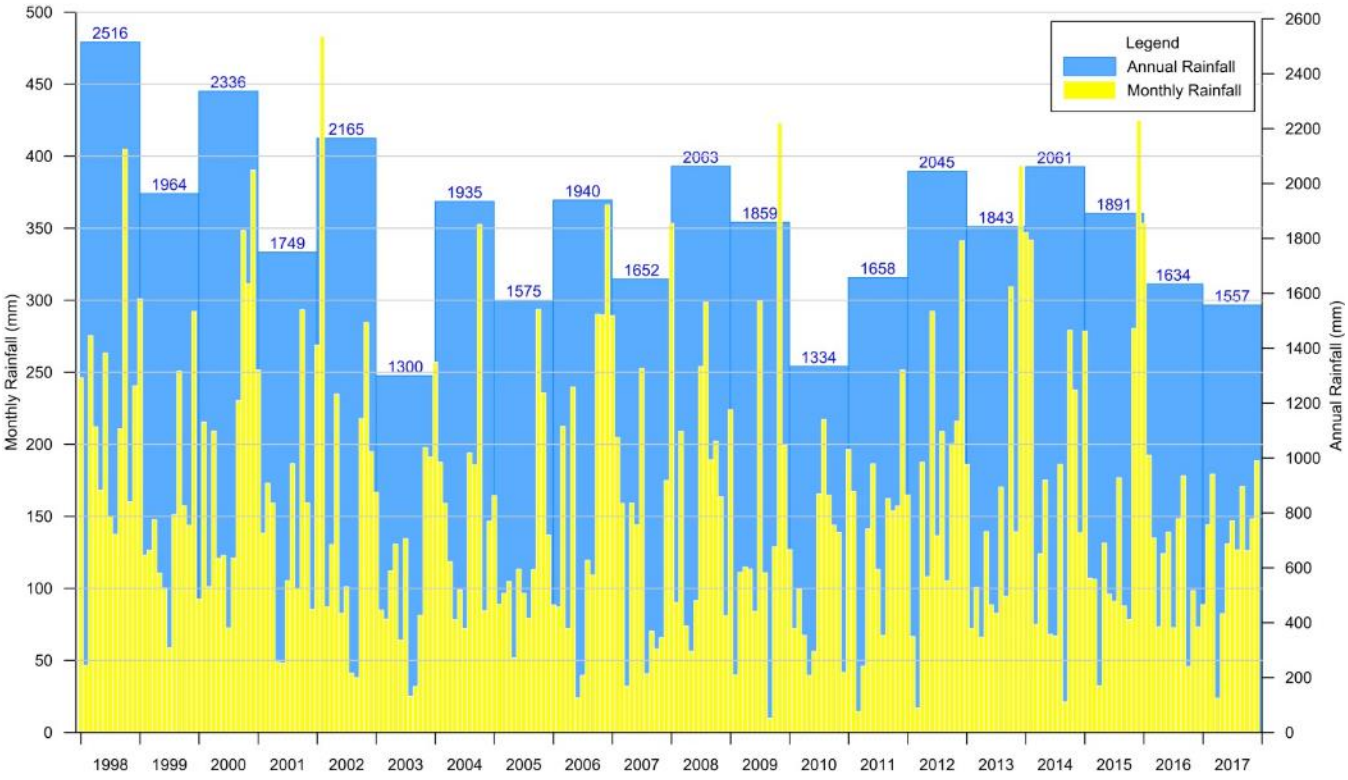


Figure 2.6 Synthetic rainfall record

2.3.2 Surface water features

Watercourses

Figure 2.7 shows neighbouring surface watercourses in the Site vicinity.

Bodwigiad Stream is the most proximal watercourse to the Site. This is sourced from an area of moorland south and east of the Site and the Site itself is included in its catchment. The Bodwigiad Stream flows south-westwards to its confluence with the River Cynon approximately 1 km to the south-west of the Site. Another un-named stream is located 550 m north-west of the Site and immediately north of Penderyn Quarry and flows south-westwards to its confluence with the River Cynon.

Nant Cadlan is located 700 m to the north; this is sourced 2.8 km north-east of the Site on the southern flank of Cadair Fawr and flows north-west and west along Cwm Cadlan. Nant Cadlan becomes the River Cynon south-west of the Site. OS mapping shows a series of springs and tributaries which contribute to flow in the Nant Cadlan/River Cynon at various points along its course. These tributaries include the Bodwigiad Stream which meets the River Cynon 1 km south-west of the Site.

The River Cynon flows south-east towards the River Taff which it joins at Abercynon 22.5 km from the Site. Around 1.6 km south-west of the Site, the River Cynon features a series of anastomosing channels. Nant y Bwllfa is located approximately 1.4 km south of the Site. A tributary of the Nant y Bwllfa, the Nant y Deri, is located 1.2 km south of the Site. The Nant y Bwllfa is a tributary of the River Cynon and joins this watercourse north of Hirwaun around 2.4 km south of the Site.

Nant Melyn is another tributary of the River Cynon. This is sourced 1.7 km west of the Site and flows southwards through Nant-moel Reservoir to its confluence approximately 4.5 km south-east of the Site.

Further from the Site is the River Hepste, which lies 2 km north-west of the Site and is sourced from high up in the Brecon Beacons 10 km north of the Site. The River Hepste flows south-west and then westwards to its confluence with the River Mellte 3.7 km west of the Site. The River Mellte flows southwards and becomes the River Neath 5 km west of the Site.

There are a number of other small streams and farm drains that drain to these larger rivers in the area around the Site. Areas of limestone outcrop at and around the Site have a lower density of watercourses compared to areas underlain by Marros Group and Coal Measures strata. This is particularly apparent around Nant Cadlan, where almost all tributaries are sourced from Marros Group strata rather than limestone strata. The density of streams is greater west of the quarry with most flowing broadly southwards in line with the regional topographic slope.

Waterbodies

Figure 2.7 shows neighbouring surface waterbodies in the Site vicinity.

The closest major waterbodies to the Site are as follows:

- Waterbodies associated with water management at Penderyn Quarry (see Section 2.4.1);
- Penderyn Reservoir 2.5 km south-west of the Site; and
- Nant-moel Reservoir 2.5 km south-east of the Site.

Penderyn Reservoir is an artificial reservoir and does not have an outlet but is used for a water supply abstraction. Nant-moel Reservoir is fed by inflows from watercourses further up the catchments with outflows from a dam.

The most proximal waterbodies are a pond in woodland near Pontbren Llwyd, approximately 1.4 km south-west of the Site and a series of small ponds on the moorland of Mynydd-y-Glog, the closest of which is 700 m east. These small ponds may occupy dolines and sinkholes (see Section 2.5).

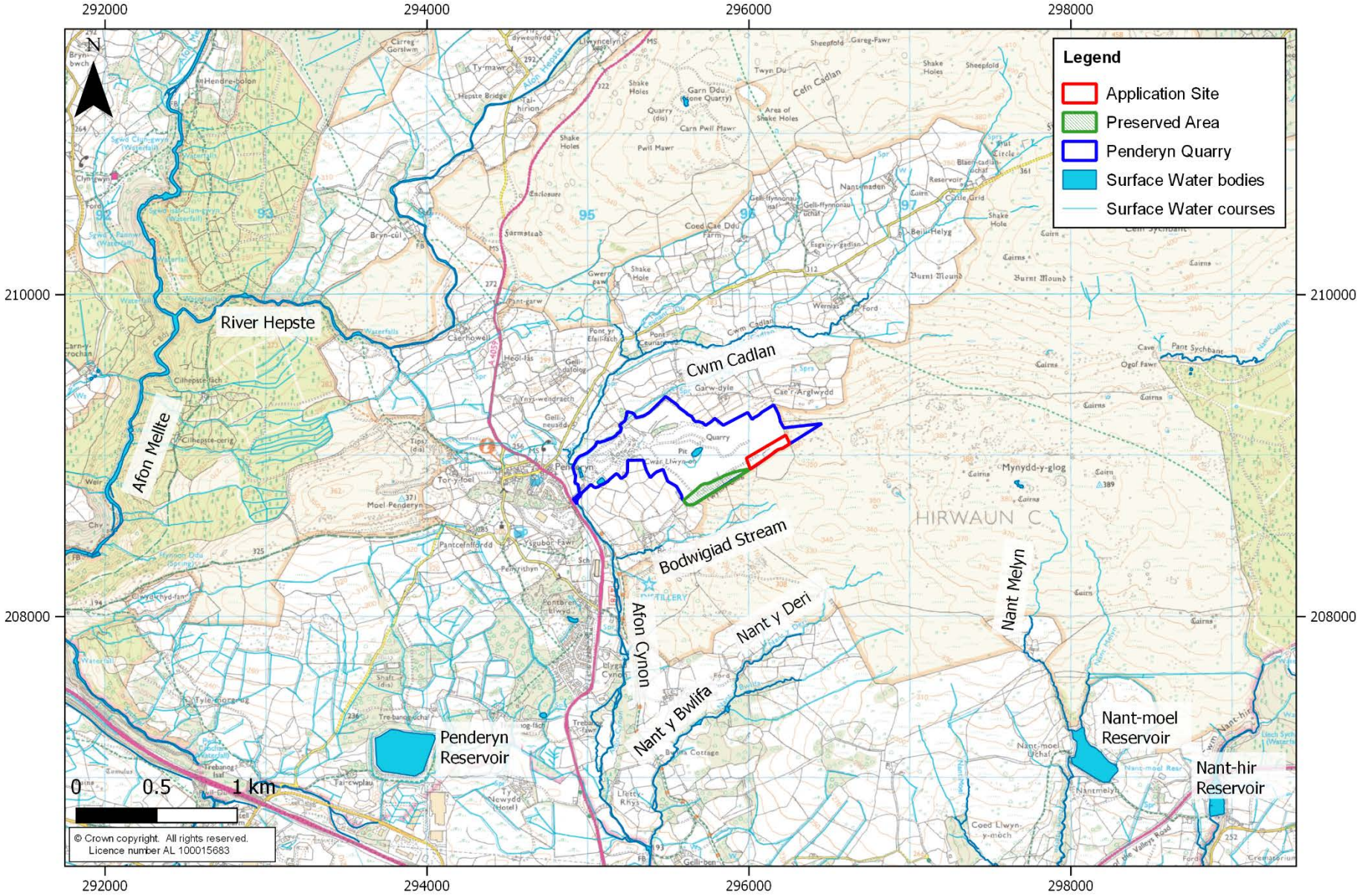


Figure 2.7 Surface water features in proximity to the Site

2.3.3 Surface water flow and levels

The Centre for Ecology and Hydrology (CEH) does not operate any gauging stations within 4 km of the Site (CEH, 2018). NRW records river stage in the River Cynon at Hirwaun, located 3.4 km south of the Site. As part of the monitoring regime at Penderyn Quarry, stage is recorded in the Nant Cadlan 1 km west of the Site (see Figure 2.10). An empirical relationship between stage and flow has been derived and, from this, flows have been calculated. Recording began in May 1996 and flow statistics for the period May 1996 – April 2018 are presented in Table 2.10 together with stage statistics for the NRW gauge at Hirwaun.

Recording of stage at Nant Cadlan has been of variable frequency during the monitoring period and is currently at 15 minute intervals. The flow record since 2008 is provided in Figure 2.8 where it is also compared to monthly rainfall totals. As is expected, there is a strong relationship between flow in the Nant Cadlan and rainfall. Flow in the watercourse is flashy because the gauging location is high up in the catchment. Other watercourses in the surrounding area are expected to behave in a similar manner.

Data for stage of the River Cynon at Hirwaun suggests that water levels fluctuate over a relatively narrow range. This could be due to the greater width and depth of the river at this downstream location and, being further downstream in the catchment, the river will be less flashy in character.

During the June and August 2018 monitoring rounds, no flow was observed in the Bodwigiad Stream. During the April 2018 monitoring round, a significant portion of flow was observed to be lost through a “fissure” in the Bodwigiad Stream bed (see Section 2.5.1 for a discussion of this).

Table 2.4 Statistics for recorded flows at Nant Cadlan (May 1996 – April 2018) and stage in the River Cynon at Hirwaun (2008 – 2017)

Statistic	Flow in Nant Cadlan (l/s)	Stage in River Cynon at Hirwaun (m AOD)
95% Exceedance (Q_{95})	0.581	174.40
70% Exceedance (Q_{70})	4.66	174.49
50% Exceedance (Q_{50})	10.6	174.54
10% Exceedance (Q_{10})	69.6	174.72
Mean	27.2	174.56

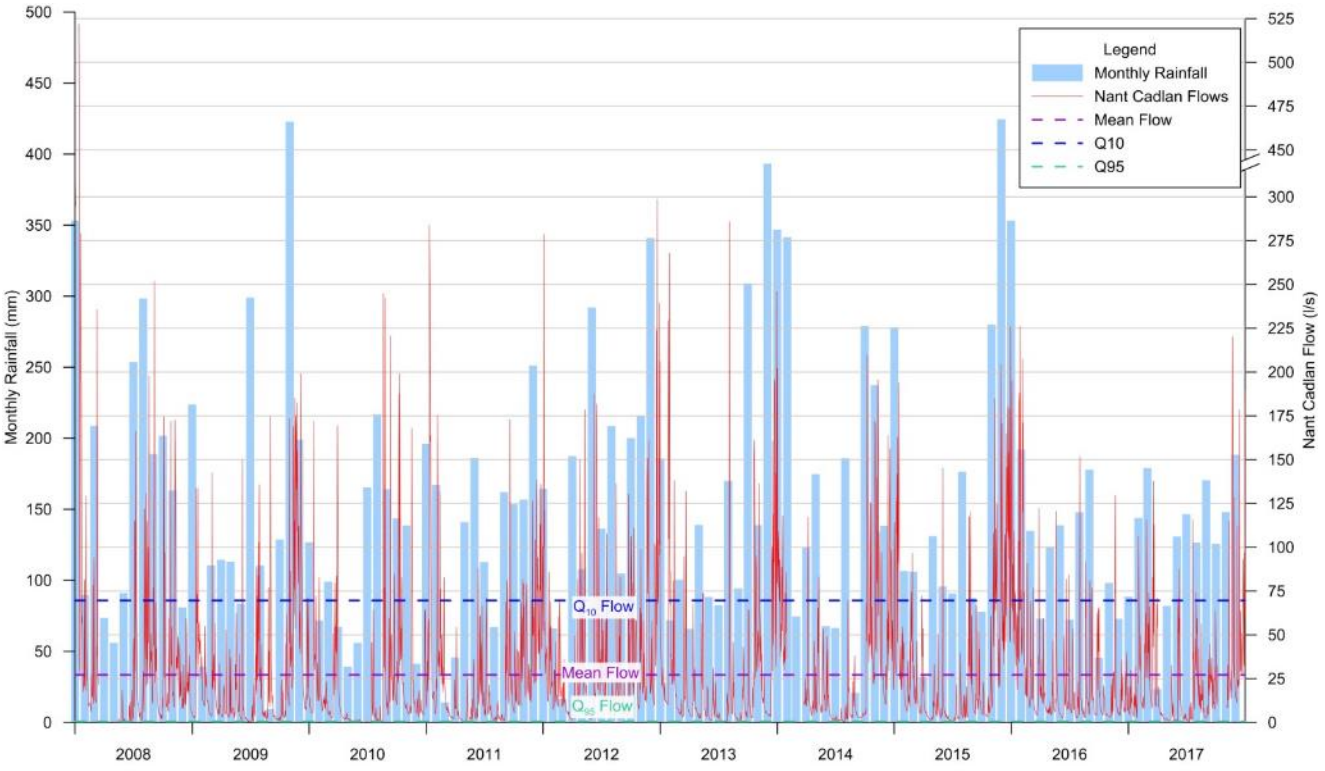


Figure 2.8 Flow record for Nant Cadlan compared to rainfall (2008 – 2017)

2.4 Site Drainage and Water Management

2.4.1 Site water management plan

Runoff from the northern part of the Site discharges towards Penderyn Quarry where it is managed by the existing quarry water management scheme. Runoff in the southern part of the Site discharges to the south. Some of this southward flowing runoff recharges the underlying limestone aquifer, whilst the remainder discharges to the Bodwigiad Stream. The existing Penderyn Quarry water management scheme is described below and Figure 2.9 shows the aspects of the water management scheme applicable to the Site.

The quarry sump collects surface water runoff from the quarry void catchment (including the northern part of the Site) and some groundwater ingress. The portion of groundwater is considered to be a minor component of dewatering relative to surface water runoff. Water abstracted from the quarry sump is transferred to the Nant Cadlan and is discharged under consent AN0272901 (Appendix C). This discharge passes through a 300 mm diameter pipe. A manually adjustable stopcock allows this flow to be diverted to a series of storage tanks from which water is used for dust suppression and wheel washing purposes.

Post restoration, runoff from the Site will attenuate in the large open water feature which constitutes part of the proposed restoration scheme for Penderyn Quarry (see Appendix B).

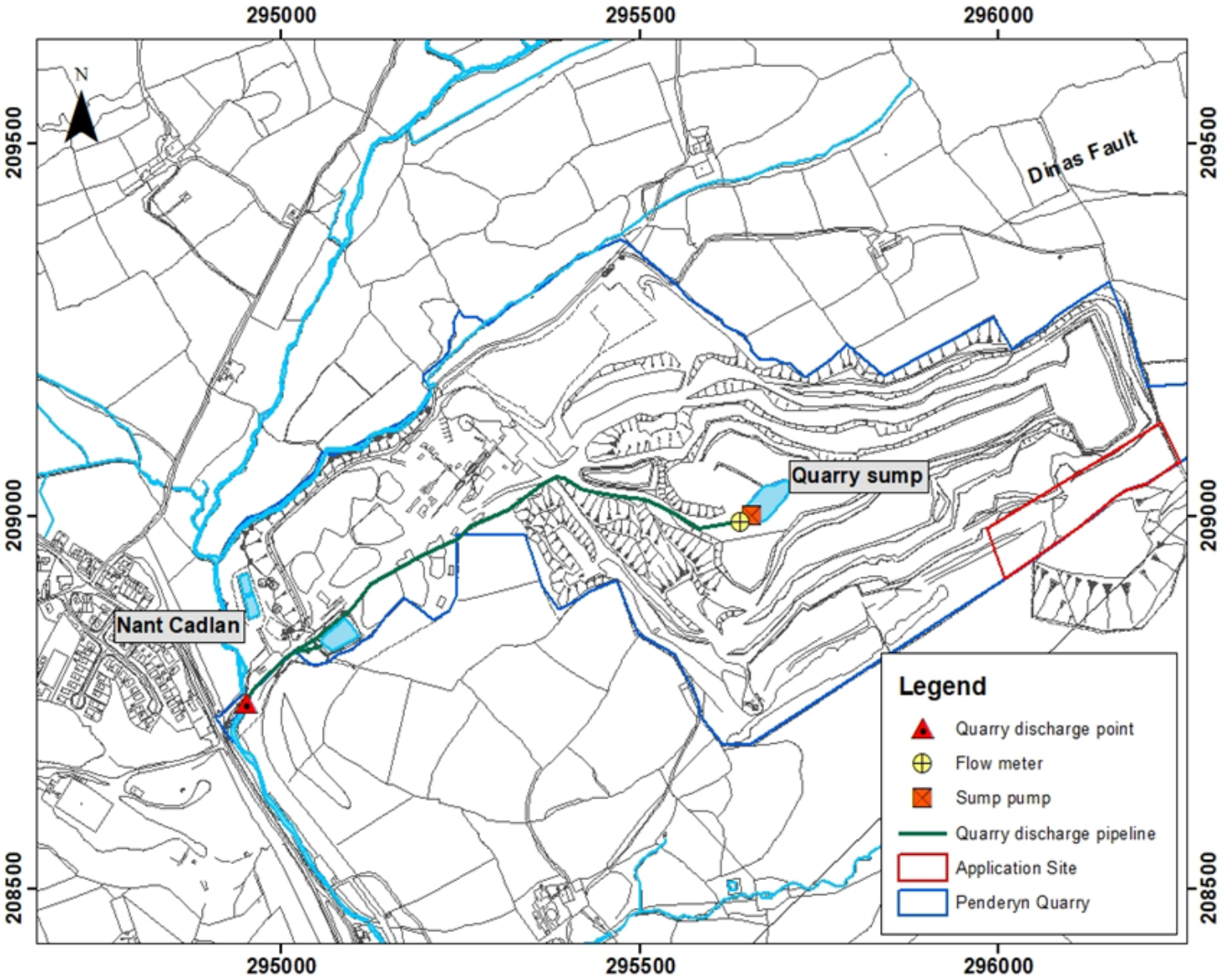


Figure 2.9 Penderyn Quarry water management plan

2.5 Hydrogeology

2.5.1 Groundwater levels and flow

Available Data

As part of the monitoring regime at Penderyn Quarry, groundwater levels are monitored at 29 monitoring locations. These locations are listed in Table 2.5 and are shown in Figure 2.10. Ten of these locations monitor groundwater levels within the limestone aquifer (formed of the Dowlais Limestone and Oxwich Limestone) while the remainder monitor levels within the superficial deposits. The different limestone units are thought to behave in a similar way and, therefore, are treated as one aquifer unit for the remainder of the report.

Table 2.5 Monitoring borehole summary

Name	Screened Lithology	Reading type	Location
OB1	Superficials	auto/manual	In SSSI
OB2	Superficials	auto/manual	In SSSI
OB5	Oxwich Limestone	manual	Along Bodwigiad Stream
OB7	Oxwich Limestone	auto/manual	Along Bodwigiad Stream
OB8a	Dowlais Limestone	auto/manual	Edge of SSSI
OB8b	Superficials	auto/manual	Edge of SSSI
OB9a	Dowlais Limestone	auto/manual	Edge of SSSI
OB9b	Superficials	auto/manual	Edge of SSSI
OB10a	Dowlais Limestone	auto/manual	Edge of SSSI
OB10b	Superficials	manual	Edge of SSSI
OB12	Dowlais Limestone	auto/manual	On quarry site
OB13	Dowlais Limestone	auto/manual	On quarry site
OB14	Superficials	auto/manual	In SSSI
OB15	Dowlais Limestone	auto/manual	South of Dinas Fault
OB16	Dowlais Limestone	auto/manual	Edge of SSSI
OB17	Dowlais Limestone	auto/manual	On quarry site
P1	Superficials	auto/manual	In SSSI
P1a	Superficials	manual	In SSSI
P1b	Superficials	manual	In SSSI
P7	Superficials	auto/manual	In SSSI
P7a	Superficials	manual	In SSSI
P7b	Superficials	manual	In SSSI
P7l	Superficials	manual	In SSSI
P15a	Superficials	manual	In SSSI
P15b	Superficials	manual	In SSSI
P15c	Superficials	manual	In SSSI
P15d	Superficials	auto/manual	In SSSI
P17	Superficials	auto/manual	In SSSI
P17l	Superficials	manual	In SSSI

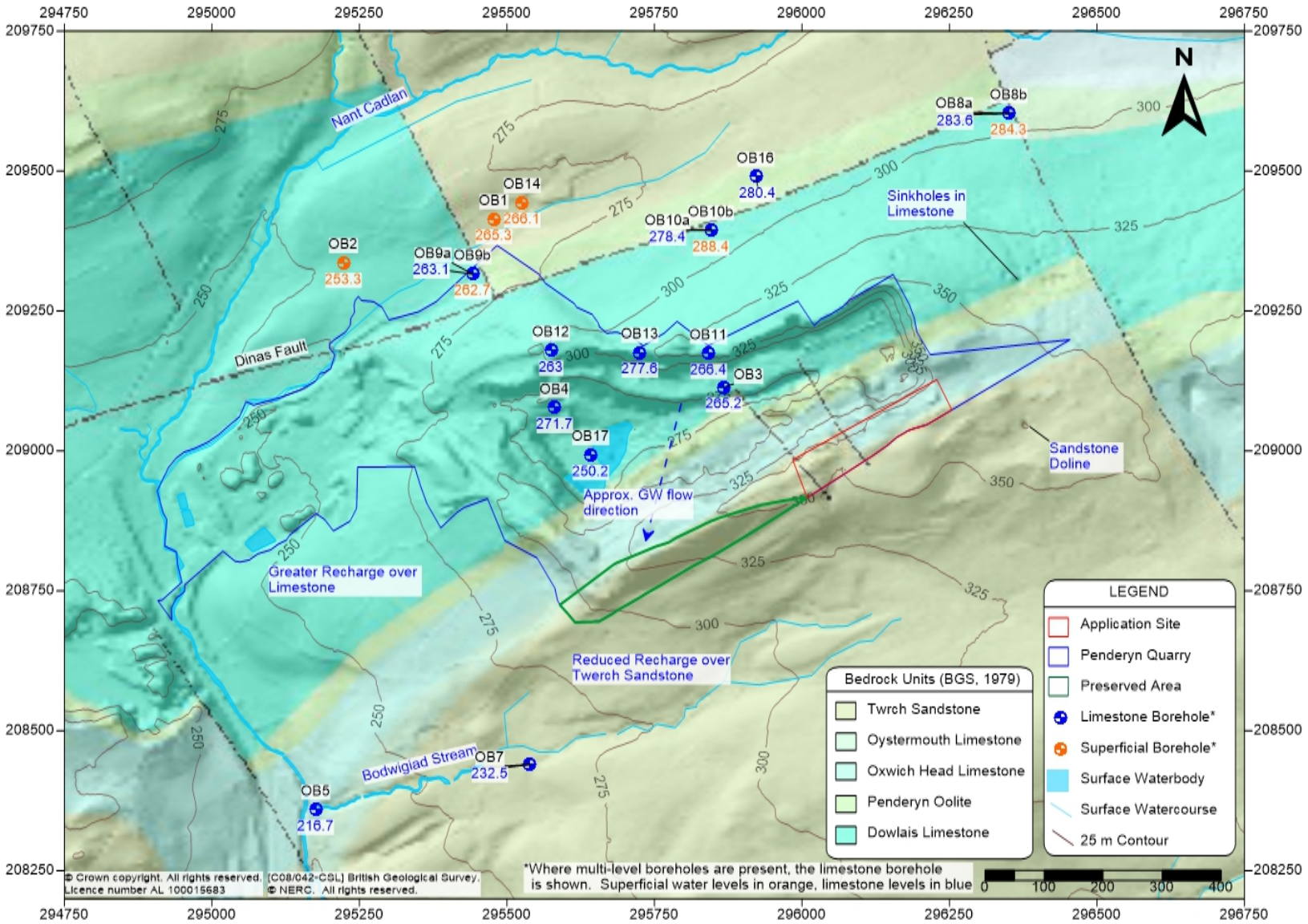


Figure 2.10 Monitoring locations at Penderyn Quarry

Groundwater levels and flow

Table 2.6 provides a statistical summary of groundwater levels recorded in the Penderyn Quarry monitoring wells. Figure 2.11 shows the recent mean recorded groundwater levels. In the limestone aquifer, groundwater levels are generally highest north of Penderyn Quarry at OB8, OB10 and OB16 and are lowest to the south of Penderyn Quarry recorded in OB5 and OB7. This indicates that there is a broadly south-west hydraulic gradient.

Table 2.6 Groundwater Level Summary[1]

Name	Monitoring Period[2]	Minimum (m AOD)	Mean (m AOD)[3]	Maximum (m AOD)
OB1	1996 - 2018	263.0	265.2	265.6
OB2	1996 - 2018	251.0	253.2	253.8
OB3	1996 – 2003	251.1	265.1	266.0
OB4	1996 – 2004	263.0	270.4	277.4
OB5	1996 – 2018	202.8	216.3	229.4
OB7	1996 – 2018	230.6	233.0	234.8
OB8a	1996 – 2018	259.5	283.1	284.2
OB8b	1996 – 2018	278.0	283.9	285.0
OB9a	1996 – 2018	234.4	262.9	264.2
OB9b	1996 – 2018	254.8	262.6	264.1
OB10a	1997 - 2018	265.3	279.3	285.4
OB10b	2001 - 2018	278.8	287.7	292.0
OB11	2003 – 2011	228.2	268.7	288.4
OB12	2004 - 2018	260.4	263.1	267.3
OB13	2015 - 2018	270.3	276.9	292.5
OB14	2015 - 2018	264.4	265.7	267.6
OB15	2015 - 2018	278.6	292.4	305.0
OB16	2015 - 2018	278.3	279.8	281.3
OB17	2015 - 2018	246.9	250.5	254.0

[1]Dark blue indicates boreholes screened within the Dowlais Limestone, light blue are boreholes screened in the Oxwich Head Limestone and yellow boreholes are screened in the superficial strata
[2]Different monitoring ranges for different boreholes. All locations where monitoring has been discontinued has been agreed with NRW
[3]This value is the mean of mean annual groundwater levels based on logger data only. Minimum and maximum levels include manual and logger data

Hydrographs for the boreholes screened within the limestone aquifer around Penderyn Quarry can be classified into two groups: those with larger amplitude seasonal variations (particularly OB13 (annual range approximately 20 m) and OB15) and those with smaller amplitude variations (ESI, 2017). Larger amplitude variations are present in areas of limestone outcrop or thin superficial deposits, whilst smaller amplitude variations are present in areas of superficial cover. Based on this, it is inferred that where superficial deposits overlie the limestone, particularly to the north and east of Penderyn Quarry, recharge to the limestone aquifer is reduced or attenuated thereby producing a reduced amplitude of seasonal fluctuation (ESI, 2017).

The Twrch Sandstone is thought to be unsaturated at the Site and is not saturated at OB7. Owing to the cemented nature of the constituent sandstone and conglomerate units, this stratum is less

permeable than the limestone and the degree of hydraulic connectivity between the two is thought to be limited.

Where watercourses directly overlie the limestone aquifer, there could be some discharge from the aquifer to features including the Bodwigiad Stream and Nant Cadlan. Such connectivity will be reduced and may be absent where the limestone is overlain by Twrch Sandstone or glacial till. A vertically upwards hydraulic gradient between the limestone aquifer and overlying superficial deposits exists around Nant Cadlan at OB9, this suggests that groundwater from the limestone discharges to Nant Cadlan in this area.

During the April 2018 monitoring round, flow in the Bodwigiad Stream was observed to be lost in the stream through a “fissure” in the stream bed. Figure 2.12 shows the location of this “fissure”, which is thought to be either a new epikarst feature or reactivation of palaeokarst within the limestone strata. Such dissolution features could form naturally at any given time due to weathering and/or erosion and, dependent on underlying groundwater levels, could lead to loss of flows to groundwater or stream flows gaining from groundwater.

Baseflow to watercourses could be locally sourced from perched layers within the limestone. Seasonal fluctuations in groundwater levels in boreholes monitoring the superficial deposits are generally small. This may be due to a strong hydraulic connection with the surface (ESI, 2017). Consequently, superficial deposits are thought to be in hydraulic continuity with surface water. At OB10 the hydraulic gradient is vertically downwards and this is more consistent with a recharge area.

The limestone aquifer is expected to have a negligible primary porosity and groundwater flow within the aquifer will be largely dependent upon secondary features such as joints, faults and karstic fissures and conduits. Bedding planes may often act as inception horizons for development of karst features.

Hydrograph data from OB10a and OB13 suggests that there could be some perching within the limestone aquifer, likely due to intervening lower hydraulic conductivity stratigraphic horizons (ESI, 2017). Levels in OB13 are much higher than in adjacent boreholes (see Figure 2.11) and this level is approximately coincident with the elevation at which seepages are observed in the quarry face above a thin mudstone layer. This is suggestive of perched groundwater. There may, therefore, be a significant degree of hydraulic separation perpendicular to bedding planes within the limestone. Groundwater levels at OB13 show a large degree of fluctuation (20 m) and may, in part, represent an ephemeral perched or semi-perched horizon within the limestone sequence. This may be linked to karstic features within the limestone (ESI, 2017).

At OBH10a, the limestone hydrograph has been interpreted to show some effect of dewatering with a small drawdown occurring from around 2009 onwards but this has stabilised since 2014 (ESI, 2017). This is not reflected in the upper horizon (OBH10b) and this supports the conclusion that there is a weak connection between the shallow and deep limestone aquifer at this location. This small drawdown is absent in other neighbouring monitoring boreholes. The connectivity between the shallow superficial strata and deeper limestone will likely vary spatially and temporally dependent on local lithological and hydrogeological characteristics.

Historical recorded groundwater levels in OB3 suggest that prior to the onset of dewatering at Penderyn Quarry, natural groundwater levels in the quarry void were at around 265 m AOD during the winter, dropping to around 263 m AOD during the summer (Steffen, Robertson and Kirsten (UK), 1998). The Site is located south, and downgradient, of the main quarry void. Given that the Site is downgradient, groundwater levels will be lower than at Penderyn Quarry itself and those levels historically recorded in OB3. The natural water table at the Site would therefore be less than 265 m AOD.

Recharge to the limestone is from direct rainfall and runoff through solutional features. Particularly on the southern face of the Penderyn Quarry void, karst has developed though limestone dissolution by acidic runoff from areas of Twrch Sandstone outcrop. Solution features are most prominent at the contact between the Twrch Sandstone and the limestone and represent preferential recharge pathways to the limestone.

LiDAR data shows a number of sinkholes formed directly on the limestone outcrop and dolines formed on the overlying Twrch Sandstone. Dolines are thought to have formed through dissolution of the underlying limestone strata which causes collapse of the overlying Twrch Sandstone. Dolines likely provide a direct recharge pathway to the limestone aquifer. These dolines are sited proximal to the contact between the Twrch Sandstone and the limestone where the overlying Twrch Sandstone is relatively thin and are located in the east of the Site.

Recharge to the limestone aquifer at Penderyn Quarry and the Site occurs directly through the limestone as superficial deposits are absent. Upper horizons within the limestone aquifer are often directly connected to the surface, possibly by karstified horizons close to the water table. This produces a greater amplitude of seasonal groundwater variability with some flashy responses.

Areas of limestone, particularly to the north of Penderyn Quarry, are covered by glacial till which impedes recharge to the limestone aquifer. This causes perched springs to form in some areas north of Penderyn Quarry (ESI, 2017).

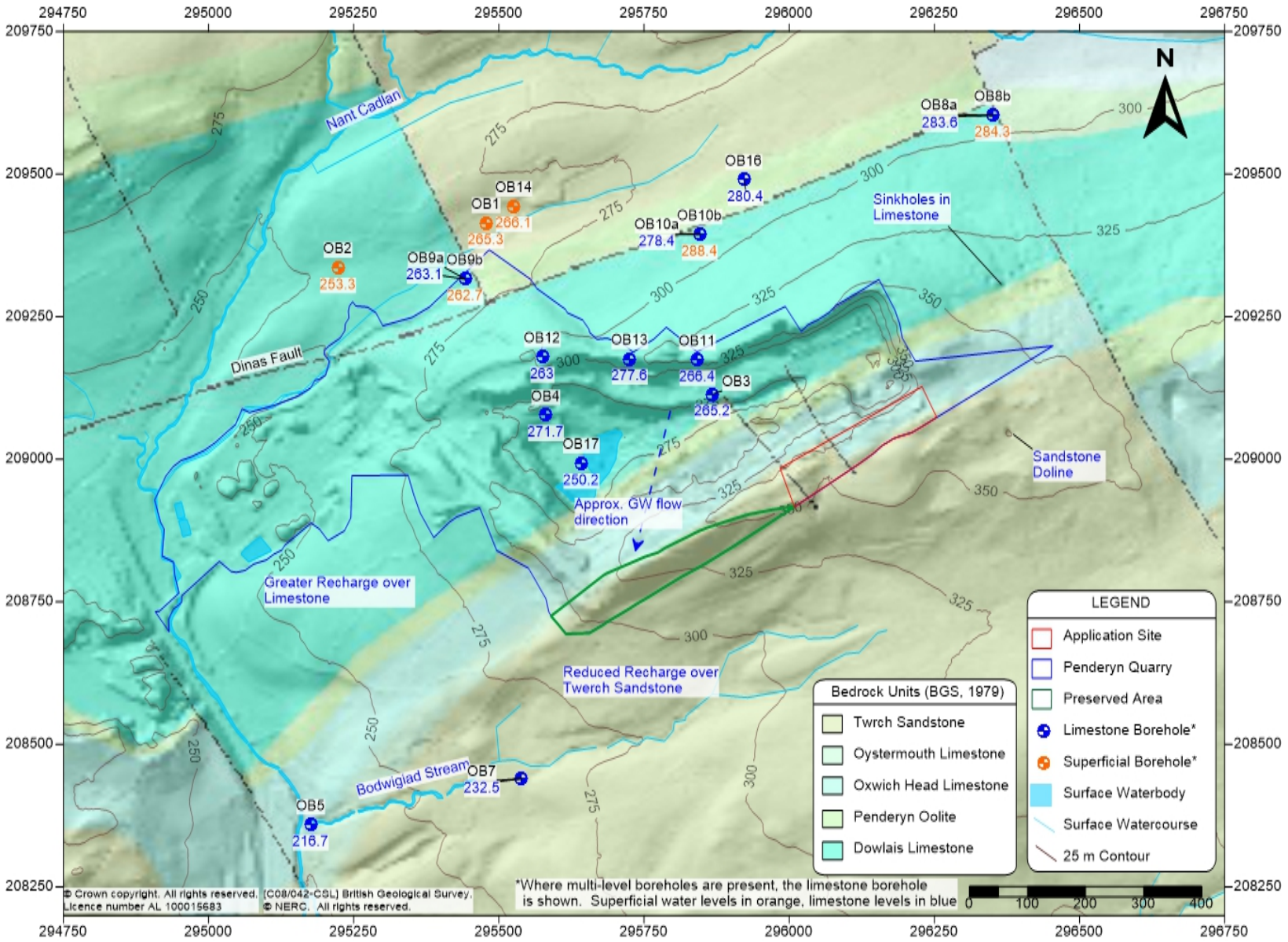


Figure 2.11 Conceptual hydrogeology

2.5.2 Aquifer properties

Aquifer property testing has not been undertaken at the Site or in the monitoring boreholes around Penderyn Quarry. However, estimates of the likely hydraulic properties can be made from borehole log descriptions of the encountered strata and literature sources.

Glacial till and the glaciofluvial and glaciolacustrine superficial strata will have spatially heterogeneous aquifer properties dependent on the relative proportions of clay and sand and gravel lithologies. Where clay comprises a greater proportion of the unit, permeability will be lower. Based on the lithological descriptions, it is generally expected that the glaciofluvial deposits (mostly sand and gravel) will be the most permeable, whilst glaciolacustrine deposits (clay dominated) will be the least permeable. The geological composition of the glacial till is highly variable, and the permeability of this unit is also expected to vary.

Hydraulic properties of the limestone are expected to vary spatially and with depth. Limestone will be most permeable where karst is present and this is expected to be the case at shallow depths. Permeability will also be enhanced along fractures, although may be lower than might be expected due to fracture infills from later sedimentation.

A transmissivity of 20 m^2/day has been recorded for a borehole located 20 km east of the Site (Allen, et al., 1997). This low transmissivity is where the limestone aquifer is confined and is inferred to be due to poor solution development. This value could be representative of the matrix of the aquifer and where karst is less well developed.

The Twrch Sandstone is reported to be well cemented meaning that intergranular permeability is likely to be low. Permeability may be enhanced around fractures and faults.

2.6 Surface Water and Groundwater Quality

2.6.1 Surface water quality

Surface water quality monitoring was undertaken by Hanson at two locations (along the Nant Cadlan and in its tributary located north of Penderyn Quarry) for field parameters (pH, Electrical Conductivity (EC), dissolved oxygen and alkalinity). This was undertaken as part of the annual monitoring regime until September 2014 when water quality monitoring ceased after agreement with NRW. This was because no effect on the receptor was anticipated whilst quarrying is above 250 m AOD and a good baseline dataset had been established (ESI, 2015). Results collected during the monitoring period suggest that water quality is good.

2.6.2 Groundwater quality

Groundwater quality monitoring was undertaken by Hanson between 1996 and 2014 as part of the annual monitoring regime. Groundwater quality monitoring ceased following agreement with NRW for the same reasons highlighted above. Groundwater quality monitoring was undertaken at 11 monitoring locations as follows:

- Shallow superficial deposits (OB2);
- deep superficial deposits (OB9b and OB10b);
- limestone locations (OB7, OB9a, OB10a, OB11 and OB12); and
- shallow drift locations within in Cwm Cadlan SSSI (P1, P7 and P15).

Full groundwater quality results are appended in Appendix D, Table 2.7 shows mean groundwater quality results for the monitoring period at each monitored location. Groundwater quality in the aquifer units around Penderyn Quarry is generally good and the only exceedances of Drinking Water Standards (DWS) are for manganese and iron. These exceedances are mostly (with the exception of manganese in OB7) in the superficial deposits overlying the limestone aquifer. Elevated concentrations of manganese and iron are not unusual in groundwater environments.

Table 2.7 Mean groundwater quality results[1,2]

Location	Calcium (mg/l)	Potassium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Manganese (mg/l)	Iron (mg/l)	pH (-)	EC (µS/cm)	Alkalinity (mg/l)	Chloride (mg/l)	Sulphate (mg/l)	Nitrate (mg/l)	Ammonium (mg/l)
OB2	96.1	2.66	3.38	8.85	0.042	0.054	7.34	427	217	9.54	10.2	3.97	0.16
OB7	81.9	2.97	2.06	9.15	**0.197**	0.523	7.44	371	191	8.95	9.35	1.58	0.16
OB9a	79.4	1.45	12.3	8.23	0.022	0.039	9.01	437	241	9.44	11.2	0.77	0.16
OB9b	89.0	1.88	6.37	25.9	**0.478**	**0.446**	7.57	452	237	10.9	15.9	0.73	0.13
OB10a	69.3	1.00	18.4	7.05	0.016	0.042	7.35	427	234	10.9	10.1	1.65	0.24
OB10b	133	6.13	5.77	8.96	**0.132**	**0.592**	7.28	540	274	13.6	10.9	10.0	0.13
OB12	91.0	2.40	14.3	7.23	0.011	0.032	7.47	521	233	9.05	18.4	4.39	0.06
P1b	65.8	1.06	1.45	6.07	**0.138**	**2.75**	7.48	297	147	6.17	5.55	1.08	0.13
P7a	58.4	1.46	1.60	5.71	**0.119**	**4.30**	7.23	297	159	7.50	4.53	1.25	5.63
P15b	22.7	1.25	0.58	4.84	**0.210**	**2.62**	7.32	187	86	13.3	6.38	0.87	0.04

[1]Rows are colour coded according to the sampled aquifer: yellow is shallow superficial deposits, orange is deep superficial deposits and blue is limestone
[2]Results in **bold** indicate exceedances of DWS

2.7 Potential Receptors

2.7.1 Surface water features

The primary surface water receptors in the vicinity of the Site that could potentially be influenced by the proposed development, are:

- Bodwigiad Stream;
- Nant Cadlan; and
- River Cynon

2.7.2 Licenced water abstractions

NRW provided details of three abstraction licences within 4 km of the Site. Details of these are provided in Table 2.8 and the locations are shown in Figure 2.12. The closest licenced abstraction to the Site is operated by Hanson for use within Penderyn Quarry. The licence allows for water to be abstracted from the un-named tributary of the Nant Cadlan at a point adjacent to the northern boundary of Penderyn Quarry (as shown on Figure 2.12). This licence allows for abstracted water to be utilised in the manufacture of ready-mixed concrete.

[redacted]. [redacted] [*Welsh Water (DCWW) is licenced to abstract*] from the Bodwigiad Stream and Nant y Bwllfa [redacted] [*Abstracted water*] is transferred to Penderyn Reservoir (which has no natural inlet or outlet) where water is taken for public water supply purposes. The [redacted] Bodwigiad Stream and Nant y Bwllfa are shown in Figure 2.12 (both marked in blue). [redacted]

The third licenced abstraction is also operated by DCWW for public water supply purposes from a groundwater borehole located [redacted] south-west of the Site. The borehole from which the supply is sourced takes groundwater from the limestone aquifer (SRK, 2011).

Table 2.8 Information on licenced abstractions within 4 km from NRW

Licence Holder	Licence ID	Distance from Site	Source	Purpose	Mean Permitted Daily Rate (m^3/day)
Hanson	21/57/23/0051	500 m west	Surface water	Mineral processing	29.9
DCWW	2/57/23/0002	[redacted]	Surface water	Public water supply	3,271
DCWW	2/57/23/0060	[redacted]	Groundwater borehole	Public water supply	3,112

The Site is mapped as lying within a Source Protection Zone (SPZ) of a licenced abstraction. Information from NRW indicates that this was related to an abstraction from Penderyn Distillery, located 1 km south-west of the Site. However, the distillery is reported to abstract no more than 20 m^3/day and this abstraction is therefore exempt from licencing. This is listed as a private water supply (see below).

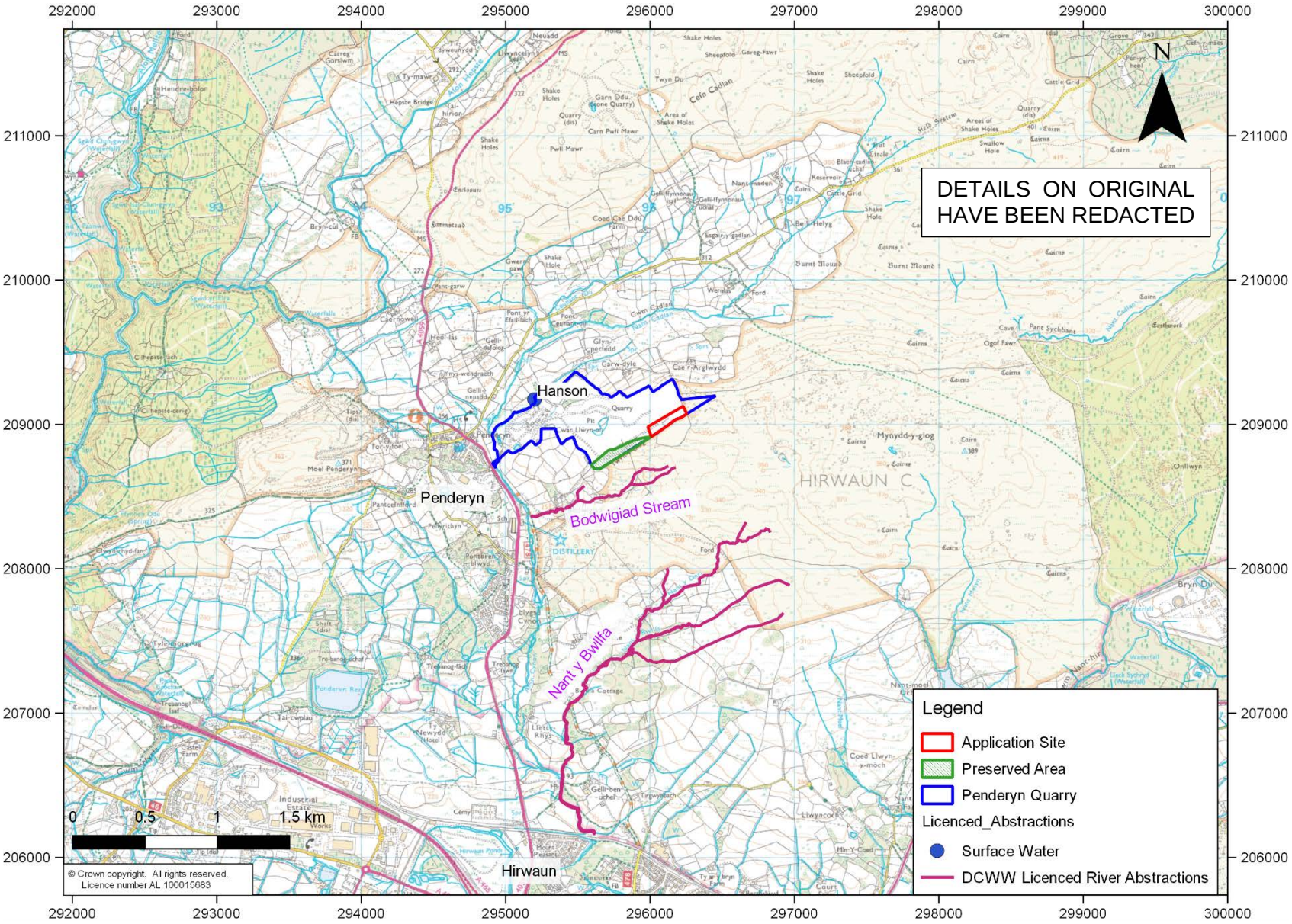


Figure 2.12 Neighbouring licenced abstractions

2.7.3 Private water supplies

Details on private water supplies within 4 km of the Site were requested from Rhondda Cynon Taf Council in April 2018. Rhondda Cynon Taf Council provided data for ten supplies in June 2018 and this is presented in Table 2.9. The mapped locations of the private water supplies are shown in Figure 2.13. Some water supplies are from a mixed source, from Rhondda Cynon Taf Council has advised that supplies where springs are thought to be susceptible to intermixing with runoff from surrounding land have been assigned to this category.

The closest private water supplies to the Site are sourced from the hamlet of Bodwigiad from a spring and mixed source. It is probable that this supply is from the limestone aquifer. The Penderyn Distillery abstraction is from a borehole installed within the limestone aquifer (Hull, 2013). Based on location, it is expected that the other supplies are sourced from younger strata, mostly the Marros Group. With the exception of the Penderyn Distillery abstraction, all supplies are utilised for domestic purposes. The Tyle-Morgrug private water supply is understood to be used to supply holiday accommodation.

Table 2.9 Details of private water supply abstractions within 4 km of the Site

Name[1]	Distance	Source	Use	Mean Daily Rate (m^3/day)
Bodwigiad Spring	775 m south-west	Spring	Domestic	1.8
Bodwigiad	775 m south-west	Mixed	Domestic	1.8
Penderyn Distillery	1 km south-west	Borehole	Commercial	Unknown but reported to be < 20 m^3/day
Coed Car Ddu Farm	1.25 km north	Spring	Domestic	1.8
Gelli-ffynnonau-uchaf	1.4 km north	Spring	Domestic	1.8
Nant Maden	1.7 km north	Spring	Domestic	0.6
Caerhowell	1.9 km north-west	Spring	Domestic	1.8
Tirgwynbach	2.5 km south	Borehole	Domestic	0.4
Nantmoel Farm	3 km south-east	Mixed	Domestic (may no longer be in use)	1.8
Tyle-Morgrug	3.7 km south-west	Spring	Commercial/Domestic	Unknown

[1]Based on OS mapping of the location. All other information provided by Rhondda Cynon Taf Council

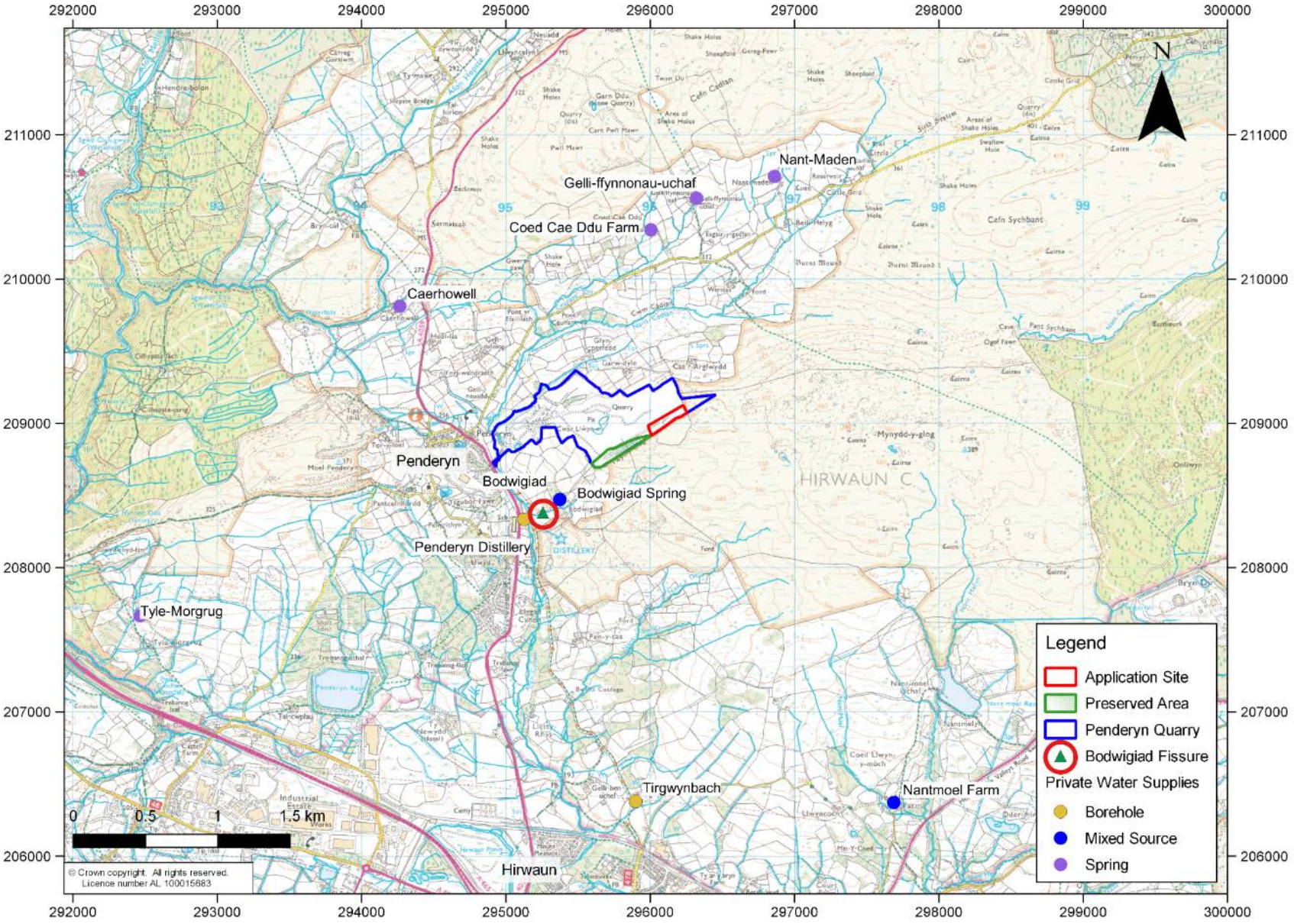


Figure 2.13 Private water supplies

2.7.4 Designated environmental sites

Designated sites within 4 km of the Site are summarised in Table 2.10 and the locations of these are shown in Figure 2.14. All of these designated sites support various habitats and therefore could be water dependent. The closest designated site to the Site is Cwm Cadlan National Natural Reserve (NNR). Much of the NNR is also designated as a SSSI and Special Area of Conservation (SAC). Cwm Cadlan is designated for the species-rich grassland habitats at the site which include molina meadows. These habitats are primarily supported by surface water with some spring flushes.

The next closest designated site is the Blaen Cynon SAC (including component Woodland Park and Pontpren and Cors Bryn – Y – Gaer SSSIs). These sites are primarily designated for a diverse range of habitats that support the Mash fritillary butterfly. Dyffrynoedd Nedd a Mellte SSSI also lies within 2 km of the Site and is designated for geological outcrops showing structural features and the geological sequence as well as a diverse range of habitats and vegetation.

Table 2.10 Neighbouring designated sites

Name	Designation	Distance from Site	Reason(s) for designation(s)
Cwm Cadlan	NNR	170 m north	Molina meadows, marsh grassland and species-rich fen land
Cwm Cadlan	SSSI/SAC	440 m north	
Blaen Cynon	SAC	1.4 km south	Designated for Marsh fritillary butterfly
Woodland Park and Pontpren	SSSI (part of Blaen Cynon SAC)	1.4 km south	Designated for Marsh fritillary butterfly, marshy, dry acid and neutral grassland and woodland habitats
Dyffrynoedd Nedd a Mellte	SSSI	1.8 km west	Diverse range of semi-natural woodland, including a diverse range of plants, mosses and lichens. Also geological features.
Cors Bryn – Y – Gaer	SSSI (part of Blaen Cynon SAC)	2.4 km south-east	Marsh fritillary butterfly and various acid grassland habitats
Coedydd Nedd a Nellte	SAC/SSSI	3.2 km west	Old sessile oak woods in deeply incised valleys with forests of slopes, screes and ravines.
Tir Mawr a Dderi Hir	SSSI	3.3 km south-east	Various grassland habitats

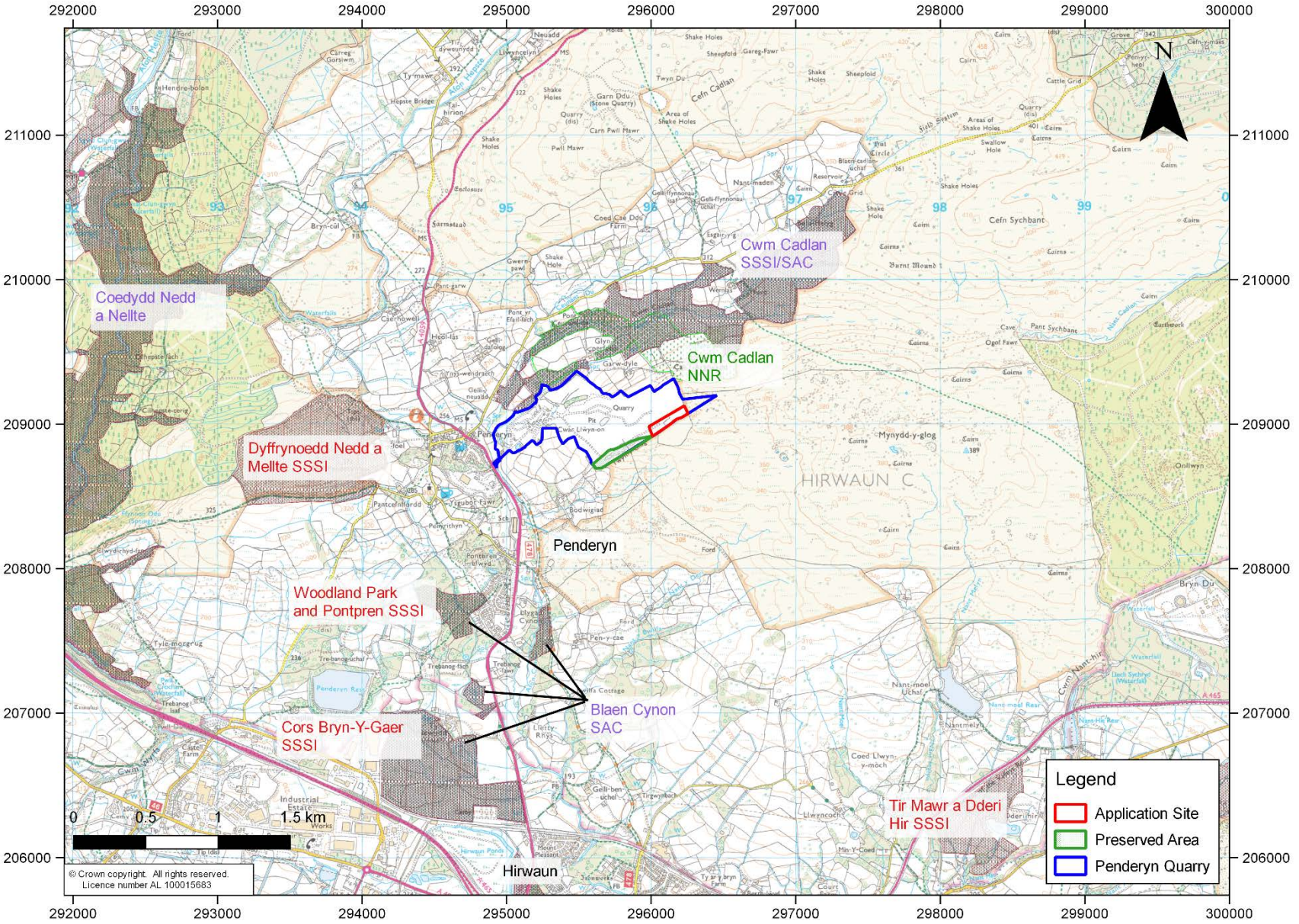


Figure 2.14 Neighbouring designated sites

2.8 Hydrogeological Conceptual Model

Figure 2.15 shows a cross section summarising the hydrogeological conceptual model through the Site and Penderyn Quarry. This conceptualisation is described in more detail below.

Superficial deposits are absent at the Site and Penderyn Quarry, but elsewhere are mostly comprised of glacial till with some peat and alluvium. The bedrock geological sequence at the Site features Twrch Sandstone comprised of cemented sandstone and conglomerate overlying a sequence of Carboniferous Limestone of the Pembroke Limestone Group. This sequence is described in more detail in Section 2.2.

The Bodwigiad Stream is the closest watercourse to the Site being situated 300 m south at its closest approach. Due to the lower permeability of the unit, surface watercourses tend to be mostly sited over areas of Twrch Sandstone (compared to limestone) or where the limestone is overlain by superficial deposits such as glacial till. The Bodwigiad Stream joins the Nant Cadlan west of the Site and this becomes the River Cynon south-west of the Site.

The Twrch Sandstone is not thought to be saturated at the Site. Owing to the cemented nature of the constituent sandstone and conglomerate units, this stratum is less permeable than the limestone and the degree of hydraulic connectivity between the two is thought to be limited.

The limestone aquifer has a negligible primary porosity and groundwater flow within the aquifer will be largely dependent upon secondary features such as joints, faults and karstic fissures and conduits. Bedding planes may often act as inception horizons for development of karst features and where lower permeability mudstone units are present, perched groundwater layers may form. Groundwater flow in these perched layers will likely be southwards in line with the stratigraphic dip.

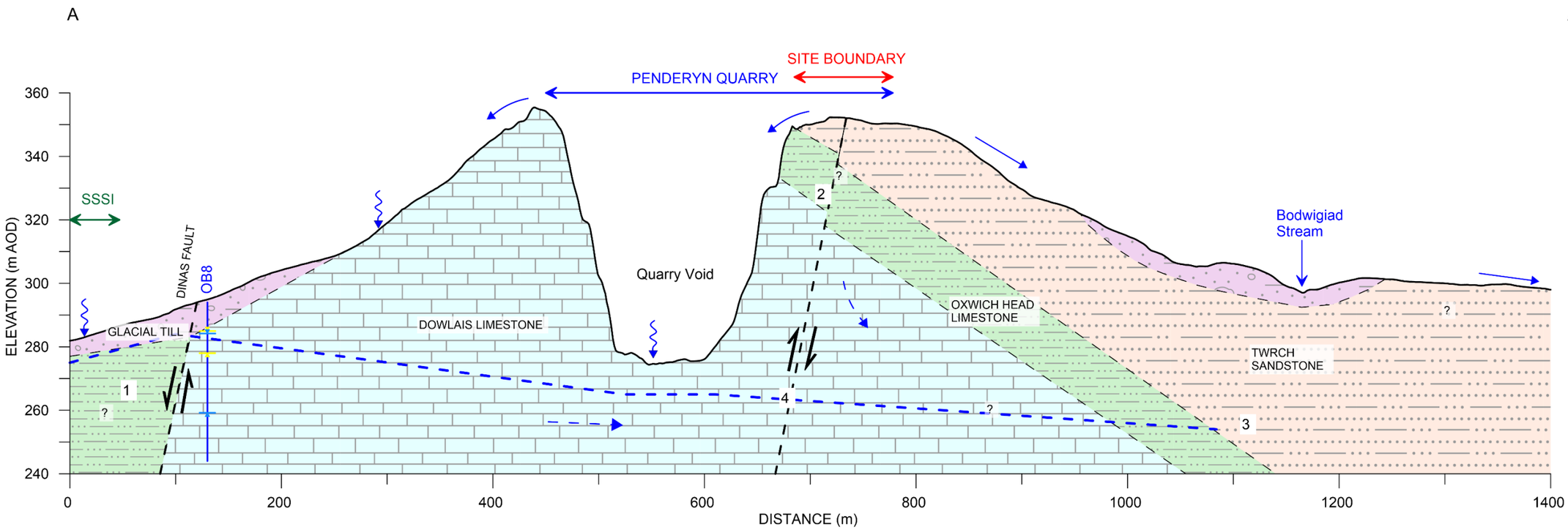
There could be some discharge from the limestone aquifer to surface water features including the, Bodwigiad Stream and Nant Cadlan, where the watercourse directly overlies the limestone aquifer. Such connectivity will be reduced and may even be absent where the limestone is overlain by Twrch Sandstone or glacial till. Dependent on location, the watercourses could be gaining or losing to groundwater. Epikarst features may locally enhance connectivity with the underlying aquifer, such as along the Bodwigiad Stream.

Based on groundwater levels, groundwater flow within the limestone aquifer appears to be flowing south and westwards. However, groundwater flow will vary spatially dependent on the density of fractures and karst formation. Flow in perched layers will likely flow down stratigraphic dip. There is some drawdown due to quarry dewatering evident in monitoring boreholes at Penderyn Quarry, but this appears to have largely stabilised since 2014 and groundwater is thought to comprise only a minor component of quarry dewatering.

Recharge to the limestone is from direct rainfall and runoff through solutional features. Particularly on the southern face of the Penderyn Quarry void, karst has developed though limestone dissolution by acidic runoff from areas of Twrch Sandstone outcrop. Solution features are most prominent at the contact between the Twrch Sandstone and the limestone and represent preferential recharge pathways to the limestone outcrop.

A series of sinkholes are present on the limestone outcrop around Penderyn Quarry. Dolines have formed on the Twrch Sandstone. These represent preferential recharge pathways to the limestone aquifer and act to limit surface water runoff.

Cwm Cadlan SSSI (also designated as NNR and SAC) is the closest designated site to the Site. This site is designated for its grassland habitats and is thought to be primarily dependent on surface water. Licenced and private abstractions sourced from groundwater are thought to be abstracting groundwater from the limestone aquifer.



Glacial Till
Twerch Sandstone Formation
Oxwich Head Formation
Dowlais Limestone Formation

Fault
Piezometer
Limestone GWL
Superficial Maximum*

Superficial Minimum*
Limestone Maximum*
Limestone Minimum*

Explanatory Notes

1. Presence of Oxwich Head Limestone uncertain - could be glacial superficial strata present
2. Sense and direction of fault displacement uncertain. Geology based on exploration borehole drilling and BGS mapping.
3. Groundwater in Limestone not thought to be in hydraulic continuity with that in Twrch Sandstone
4. Groundwater levels beneath the Site expected to be < 265 m AOD

Groundwater flow direction
Surface water flow direction
Recharge/percolation
? Uncertainty

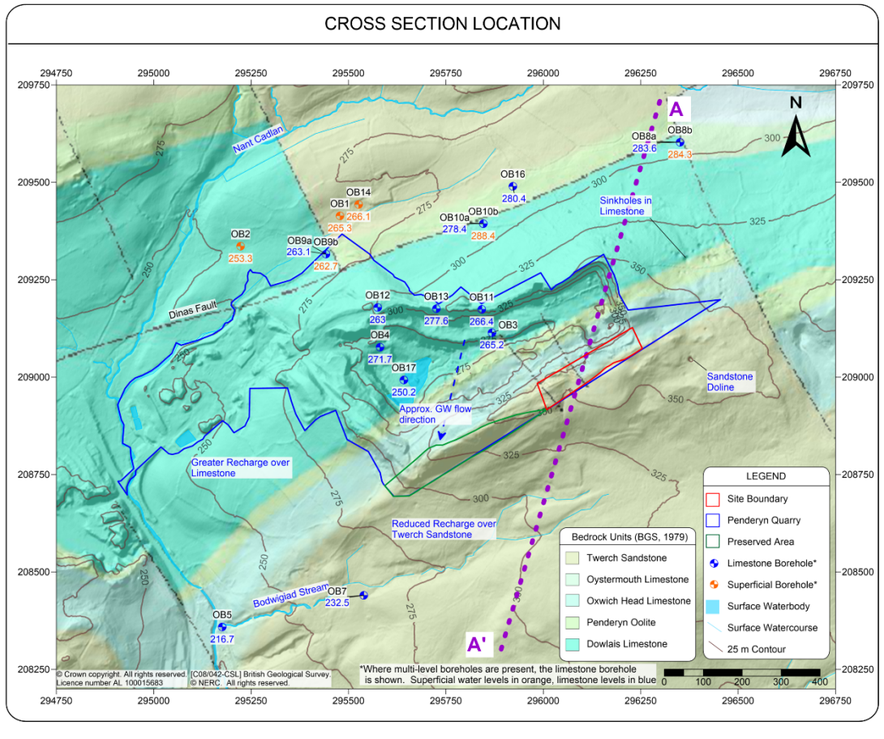


Figure 2.15 Conceptual cross section

3 Proposed Development

3.1 Operational Stage

It is proposed to extract Carboniferous Limestone (both Dowlais Limestone and Oxwich Head Limestone) at the Site. Appendix A contains the quarry design for the Site. It is proposed to work the Site down to an elevation of not less than 265 m AOD (corresponding to a depth of around 85 m). Based on historical groundwater elevation data presented by Steffen, Robertson and Kirsten (UK) (1998), the water table would not be encountered even if the existing Penderyn Quarry had not been formed north of the Site.

As the Carboniferous Limestone is excavated, a series of shallow benches will be formed. This will modify the topography at the Site and that portion of the surface water runoff from the Site that currently drains southwards, would be redirected into the quarry void.

3.2 Restoration Stage

Appendix B contains the proposed restoration plan for Penderyn Quarry including the Site. Penderyn Quarry as a whole is to be restored to a series of habitats centred around a lake which will be allowed to form in the quarry void. These habitats include woodland, calcareous grassland, wetland areas and riparian vegetation. Riparian vegetation will form around the margins of the lake and will feature a mixed variety of species.

The restoration plan showing the restoration proposals for Penderyn Quarry was included as part of the Review of Old Mineral Permissions (ROMP) application submitted in March 2011. The ROMP application has yet to be determined.

4 Potential Impacts and Mitigation Measures

4.1 General Impacts of the Proposed Development

The array of potential impacts from quarrying activities associated with limestone extraction and subsequent quarry void restoration is well understood. A well designed quarry and standard mitigation measures can avoid many of these potential impacts. Table 4.1 lists potential impacts and the typical mitigation measures applied.

In the following sections the potential for the general hydrogeological impacts listed in Table 4.1 to apply to the receptors identified in Section 2.7 is discussed for the operational and restoration phases at the Site. The impact assessment methodology applied is set out in Appendix E.

Each of the identified receptors has been assigned a value from low to high and, along with the magnitude of effect at each receptor, an associated degree of impact has been deduced. Where the degree of impact is more than minor, the potential impact is considered significant and mitigation measures have been proposed. These mitigation measures are detailed in Section 4.5.

Table 4.1 Potential impacts of quarry development

No.	Type of Impact	Typical Mitigation Measures
A	**Impacts from quarry operation on water levels and flows**	
A1	Impacts on nearby abstractions	Avoid working nearby, wet working, cut off walls, recharge trenches, discharge of compensation flows to drains
A2	Impacts on habitats	
A3	Impacts on nearby watercourses and waterbodies	
B	**Impacts from quarry operation on water quality**	
B1	Impacts on water quality from standard plant operation	Settlement lagoons, standard planning conditions regarding bunding of fuel tanks, appropriate spill response procedures etc.
C	**Impacts from discharge of water**	
C1	Impacts on receiving watercourse quality	Settlement lagoons, controlled by discharge consent to be applied for
C2	Impacts on receiving watercourse flows	Covered by FCA
C3	Diversion of baseflow from one catchment to another	Relocation of discharge point, discharge of compensation flows to drains
D	**Impacts from restoration**	
D1	Long-term impact on groundwater levels and baseflow	Appropriate design of restoration, particularly the materials used to restore slopes and the level and location of the overflow point
D2	Faster runoff and increased flood risk	SuDS-style overflow channels to minimise peak flows

4.2 Assessment of Water Quantity Impacts

4.2.1 Changes to groundwater recharge

As dewatering at the Site will not be required, groundwater-dependent receptors could only be impacted by a reduction in recharge to Carboniferous Limestone body. At present, the eastern part of the Site is underlain by limestone (comprising approximately 38% of the Site's surface area), whilst the western and southern parts of the Site is underlain by the Twrch Sandstone [redacted].

The conceptual model indicates that, based on aquifer characteristics, recharge to the limestone is expected to be greater than recharge to the Twrch Sandstone. Runoff from the Twrch Sandstone is aggressive and causes dissolution features to form around the contact between the Twrch Sandstone and limestone. These karstic features represent a preferential recharge pathway.

Quarrying at the Site will cause the following competing effects that will impact recharge:

1. Removal of the Twrch Sandstone overburden from the western and southern part of the Site progressively exposing deeper layers of limestone; and
2. quarrying of limestone extant at the surface leading to the removal of shallow karstic dissolution features located at shallow levels within the limestone.

The effect of the first process will be to increase the area of exposed limestone which will lead to an increase in recharge. The second will expose deeper limestone that may be less receptive to recharge than the shallower limestone but will still likely be more receptive to recharge from the Twrch Sandstone. These two effects will counteract one another. The extent to which this occurs is dependent on the extent to which the deeper limestone is receptive to recharge and the existing degree of karstification at the surface.

As the Site is worked, any water that does not recharge at the Site itself would runoff and enter Penderyn Quarry void north of the Site. This water would then either recharge the aquifer at a more northerly location (upgradient) than previous or runoff to the quarry sump.

Given these competing effects, their small magnitude, any reduction in recharge at the Site would be small and, as the area of Twrch Sandstone is greater than the limestone area at the Site, total recharge to the aquifer could increase. Overall, given the small area of the Site compared to the entire limestone aquifer the net effect on recharge to the limestone aquifer will be negligible.

The effect of the change in groundwater recharge patterns on neighbouring receptors is discussed in the following sections.

4.2.2 Interception of perched water table(s)

The hydrogeological conceptual model for Penderyn Quarry, that has been developed over many years of study indicates that there may be some perched groundwater tables within the limestone aquifer above low permeability stratigraphic horizons such as mudstone layers. Based on the conceptual model, perched water tables may be present above low permeability layers in the limestone. Stratigraphic horizons dip to the south and it is expected that much of the flow will be conveyed southwards down dip. Given this, it is not expected that seepage into the quarry void from these perched layers will occur. However, there will be a reduction in catchment area of these layers equivalent to the quarried area. Given the small size of the Site in relation to the groundwater catchment as a whole, any effects would be expected to be negligible.

4.2.3 Changes to surface water catchment

A catchment divide runs north-east to south-west through the Site. Section 2.4.1 states that runoff from the Site either flows into the Penderyn Quarry void (north of the catchment divide) or discharges to the Bodwigiad Stream (south of the catchment divide [redacted]). Quarrying will push the catchment divide further south-westwards and all runoff from the Site will discharge to the quarry void.

An assessment of how this change will impact on neighbouring receptors is outlined in the following sections.

4.3 Impacts from the Operational Phase

4.3.1 A1 Impacts on nearby abstractions

Licenced public water supply abstractions operated by DCWW are classified as highly sensitive receptors. Private groundwater supplies are classed as low sensitivity receptors. Potential impacts on groundwater and surface water abstractions are considered separately below.

Groundwater abstractions

Based on the discussion in Section 4.2.1, there will be a negligible change in recharge to groundwater due to the development. The degree of effect on neighbouring licenced and private groundwater abstractions (including those from springs) is therefore classified as negligible producing a negligible degree of impact. This includes the licenced DCWW public water supply groundwater abstraction.

Surface water abstractions

Only the Bodwigiad Stream catchment will be affected by the development and these effects are considered further below. DCWW is licenced to abstract water from locations on the Bodwigiad Stream and Nant y Bwllfa watercourse under the same licence and this abstraction is classified as a highly sensitive receptor. There will be negligible effects on abstractions sited outside the Bodwigiad Stream catchment and the degree of impact on other such abstractions would similarly be negligible.

The abstraction locations are shown in Figure 2.12. Approximately 199 ha of catchment area (upstream of the abstraction locations) is available to DCWW for the abstractions, comprised of 49.1 ha from the Bodwigiad Stream and 150 ha from the Nant y Bwllfa. Details of the derivation of these catchment areas are outlined below.

The Bodwigiad Stream catchment area (upstream of the DCWW abstraction) of 49.1 ha has been drawn based on LiDAR data and BGS geological mapping. The catchment area is truncated to the east because, even though topographically the catchment appears to drain westwards, LiDAR data shows that a series of sinkholes and dolines are present on the areas of limestone and Twrch Sandstone respectively. It is expected that runoff from these eastern areas [redacted] will be captured by these solutional features. Groundwater sourced from subsequent infiltration of this runoff is likely to support flows in the Bodwigiad Stream as baseflow. Our approach, in not considering the doline and sinkhole part of the catchment, is therefore conservative.

The Nant y Bwllfa catchment area upstream of the DCWW abstraction is 150 ha and is based on LiDAR topography. There are no identifiable doline or sinkhole features in this catchment, likely because the entire area is underlain by Twrch Sandstone.

[redacted]. Combined, these catchments represent the total available catchment area for the licenced DCWW abstraction. As each of these locations is covered by a single licence, any reduction in catchment area should be considered in relation to the total catchment (i.e. Bodwigiad Stream plus Nant y Bwllfa).

[redacted]

Table 4.2 summarises the anticipated reduction in catchment area that would be available for the DCWW abstraction licence from working the Site. There will be no reduction in catchment area of the Nant y Bwllfa catchment which lies south of the Bodwigiad Stream catchment.

Table 4.2 shows that the predicted loss of total available catchment area to the licenced DCWW abstraction due to quarrying is 0.48% of the total available 199 ha from both the Bodwigiad Stream

and Nant y Bwllfa watercourses. It is expected that the existing area underlain by limestone at the Site that currently drains to the Bodwigiad Stream (i.e. 0.18 ha) contributes a negligible amount of runoff to the Bodwigiad Stream. This is because there will be more recharge to groundwater rather than runoff over the limestone outcrop. Therefore, the effective loss of catchment area (i.e. loss of Twrch Sandstone catchment alone) available to the DCWW abstraction licence is 0.39%. This is considered to be a negligible level of effect and impact.

Some runoff from the Twrch Sandstone outcrop within the Site boundary then passes over the limestone outcrop before it reaches the Bodwigiad Stream. Some of this runoff portion will infiltrate to the limestone under existing conditions. Therefore, at present, this portion of runoff will not reach the Bodwigiad Stream and removing this part of the Bodwigiad Stream catchment will have a lesser impact on the total effective catchment area. Therefore, the total loss of effective catchment available for the DCWW abstraction is likely to be < 0.39%.

Recent monitoring visits indicate that the Bodwigiad Stream has been dry over the 2018 summer period. This information, together with the much greater catchment area of the Nant y Bwllfa (over three times greater) means it is probable that DCWW relies more on the abstraction from the Nant y Bwllfa than from the Bodwigiad Stream. Abstraction from the Nant y Bwllfa is hence inferred to be much more significant for topping up levels in the Penderyn Reservoir than abstraction from the Bodwigiad Stream. [redacted]

A private water supply from a spring partly dependent on surface water runoff is also located at Bodwigiad. The total reduction in catchment area would be 0.95 ha (i.e. both Twrch Sandstone and Limestone). The loss of effective catchment area for the private supply would be 0.77 ha (i.e. Twrch Sandstone catchment only). The total catchment available to the Bodwigiad private water supply is estimated to be approximately 57 ha. The loss of effective catchment in relation to the available catchment area for the private abstraction is small (1.4%). Therefore, particularly as the private water supply is partly dependent on a spring (which would be unaffected) as well as the stream, the degrees of effect and impact are expected to be negligible.

Table 4.2 Change in catchment area available for the DCWW surface water abstraction as a result of working the Site

Catchment	Area (ha)	Percentage of total catchment for DCWW abstraction
Bodwigiad Stream Catchment upstream of DCWW abstraction	49.1	24.7%
Nant y Bwllfa Catchment upstream of DCWW abstraction	150	75.3%
Total available catchment for DCWW abstraction	**199.1**	**100%**
Twrch Sandstone Area lost	0.77	0.39%
Limestone Area lost	0.18	0.09%
Total Area Lost	**0.95**	**0.48%**
Effective catchment area loss	**0.77**	**0.39%**

REDACTED

Figure 4.1 DCWW licenced abstraction catchments and anticipated losses in catchment area

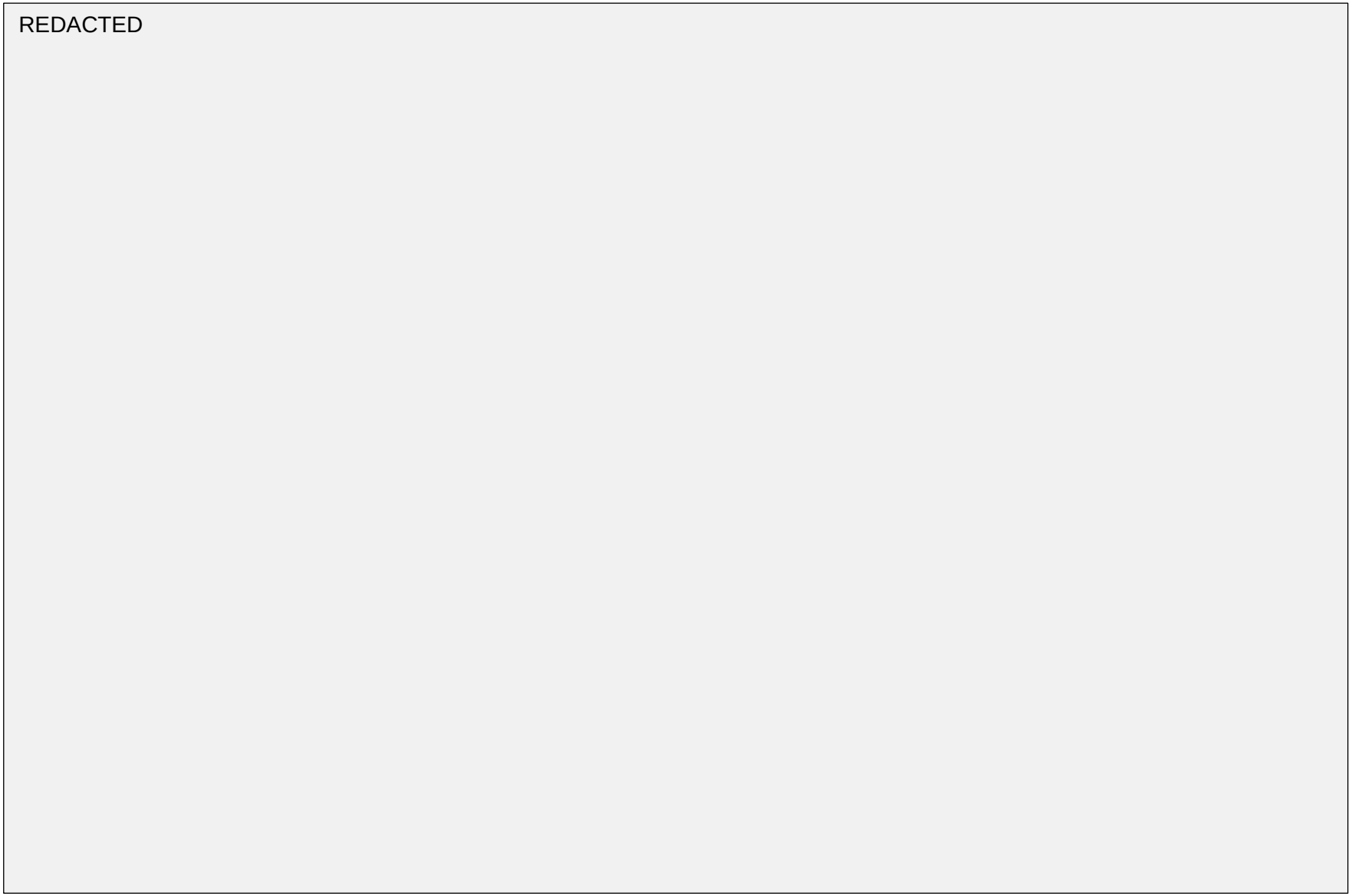


Figure 4.2 Twyn-y-Glog ridge, existing catchment divide and geology

4.3.2 A2 Impacts on sensitive sites

All sensitive sites are classified as highly sensitive receptors. Cwm Cadlan SSSI/SAC is the closest designated site to the Site. Surface water does not drain northwards towards Cwm Cadlan and the groundwater flow direction is to the south away from the SAC and all proposed quarrying within the Site is to take place above the natural water table level. There is also no direct pathway between the Site and the SAC. No effects will therefore occur on the SAC and, whilst in accordance with the Impact Assessment Methodology in Appendix E the degree of impact is classified as 'negligible', there will in fact be zero impact. Effects and impacts on more distant designated sites will be similarly classified as negligible.

4.3.3 A3 Impacts on watercourses and waterbodies

Changes in baseflow could affect watercourses that are downgradient of the Site. This includes the Bodwigiad Stream and Nant y Bwllfa. However, any changes in recharge that may occur will be slight and the conceptual model suggests that these watercourses are flashy and sourced primarily from surface runoff, as the catchments are mostly sited on the Twrch Sandstone outcrop. Therefore, effects on neighbouring watercourses are considered to be negligible resulting in a negligible degree of impact.

Changes in the entire catchment area of the Bodwigiad Stream are expected to reduce flows in this watercourse (i.e. looking at effects on flows rather than effects of the abstraction). However, the change in effective catchment area (0.77 ha) in relation to the Bodwigiad Stream catchment area as a whole (estimated to be approximately 60 ha) is small (< 1.3%). Therefore, the degrees of effect and impact are expected to be negligible.

4.3.4 B1 Impacts on water quality from standard plant operation

Water quality could be affected by chemical spillages or mobilisation of suspended solids. The limestone aquifer is utilised for private and licenced water supply abstractions and has been assigned as a high value receptor. The Twrch Sandstone is considered to be hydraulically connected to the limestone (albeit in a relatively limited way) and these two units have been considered together.

Spills at the Site could feasibly occur from the accidental loss of fluids from mobile or fixed plant equipment. However, in accordance with existing practices at Penderyn Quarry, drainage systems at the Site will be regularly inspected to ensure that visible oil is not present. An ISO 14001 certified environmental management system is operated by Penderyn Quarry, and will also be applied at the Site, to ensure that all procedures follow best practice.

Potential water quality impacts will be addressed by standard planning conditions applied to the planning permission. In the unlikely event of a spill, the spillage would be retained within the active quarry void for a sufficient length of time to allow it to be collected using oil absorbent materials, with standard operational procedures. Contaminated material would then be disposed of in accordance with current industry best practices. Discharge from the quarry void would cease during this time.

Any facilities for the storage of soils, fuels or chemicals will be sited within Penderyn Quarry (rather than the Site) in accordance with best practice and existing planning conditions.

Given that the aforementioned mitigation measures already in place at Penderyn Quarry will also be applied at the Site, the degree of effect on the limestone aquifer system from a chemical spill is considered to be negligible, meaning that the degree of impact is also expected to be negligible. Further mitigation measures, in addition to those already in place at Penderyn Quarry, are therefore not required.

4.3.5 C1 Impacts on receiving watercourse quality

Runoff from the Site will flow northwards into the Penderyn Quarry void and will be dealt with in accordance with the existing water management system for Penderyn Quarry. Discharges from Penderyn Quarry to Nant Cadlan will be in accordance with the existing discharge licence. Therefore, the degrees of effect and impact will be negligible.

4.3.6 C2 Impacts on receiving watercourse flows

There is to be no water discharge from Penderyn Quarry as a whole above greenfield runoff rates, and all excess runoff will be attenuated within the boundaries of Penderyn Quarry. Further information regarding this is found in the accompanying FCA (Stantec, 2018).

4.3.7 C3 Diversion of baseflow from one catchment to another

There will be no dewatering within the Site and there will be no diversion of baseflow between catchments.

4.4 Impacts from Restoration

4.4.1 D1 Long-term impact on groundwater levels and baseflow

Any effects on recharge (see Section 4.2.1), which are expected to be negligible, will remain. As dewatering is not proposed, there will be no effects on groundwater levels.

4.4.2 D2 Faster runoff and increased flood risk

Runoff from the Site will increase due to climate change. This runoff will be attenuated by the restored lake and as such there would not be an increased flood risk. The accompanying FCA contains a detailed drainage strategy to demonstrate that runoff from the Site will not increase above the greenfield runoff rates (Stantec, 2018).

4.5 Summary

Table 4.3 summarises the impacts of the operational phase. No significant impacts have been identified that result from the proposed quarry restoration.

Table 4.3 Summary of impacts from working the Site – operational phase

No.	Type of Impact	Receptor	Receptor Value	Degree of Effect	Degree of Impact pre mitigation	Mitigation Required	Degree of Impact post mitigation
A	**Impacts on water quantity**						
A1	Neighbouring abstractions	DCWW licenced surface water abstraction	High	Negligible	Negligible	No	Negligible
		DCWW licenced groundwater abstraction	High	Negligible	Negligible	No	Negligible
		Private water supplies (both groundwater and surface water dependent)	Low	Negligible	Negligible	No	Negligible
A2	Impacts on sensitive sites	Cwm Cadlan SSSI/SAC	High	Negligible[1]	Negligible[1]	No	Negligible
		Other identified designated sites	High	Negligible	Negligible	No	Negligible
A3	Impacts on watercourses and waterbodies	Bodwigiad Stream	Medium	Negligible	Negligible	No	Negligible
		Nant Cadlan	Medium	Negligible	Negligible	No	Negligible
B	**Water quality impacts**						
B1	Spillage of fuels and release of suspended solids.	Limestone aquifer	High	Negligible	Negligible	No	Negligible
		Twrch Sandstone	Medium	Negligible	Negligible	No	Negligible
C	**Impacts from discharge of water from dewatering operations**						
C1	Impacts on receiving watercourse water quality	Nant Cadlan	Medium	Negligible	Negligible	No	Negligible
C2	Impacts on receiving watercourse flows	Nant Cadlan	See Stantec (2018)				
C3	Diversion of baseflow between catchments	Bodwigiad Stream / Nant Cadlan	Medium	Negligible	Negligible	No	Negligible

[1]See Section 4.3.2 – whilst the classification is shown as 'Negligible' there will in this case be no effect and no impact, as there will be no dewatering within the Site.

4.6 Comparison Between the Site and Preserved Area

As described in Section 1.1, it is proposed that an area of Penderyn Quarry with existing planning permission is to be preserved in favour of working the Site. An assessment has been made of the impacts of working the Preserved Area on catchment areas that could affect the surface water abstractions from the Bodwigiad stream and the Bodwigiad Stream itself.

Working the Preserved Area would remove a slightly greater area of the Bodwigiad catchment underlain by Twrch Sandstone than the Site and none of the catchment area underlain by limestone. The changes are summarised in Table 4.4. Whilst the total catchment area lost is 0.08 ha smaller (0.87 ha compared with 0.95 ha for the Site), Section 4.3.1 demonstrates that the area underlain by limestone at the Site (0.18 ha) is expected to contribute a negligible amount of runoff to the Bodwigiad stream. Therefore, the loss of effective catchment area from working the Preserved Area is actually 0.1 ha greater (i.e. 0.87 ha compared with 0.77 ha) than that for working the Site. Additionally, none of the runoff from the Twrch Sandstone in the Preserved Area currently passes over limestone prior to discharging to the Bodwigiad Stream. As is mentioned in Section 4.3.1, at the Site it is probable that some runoff over the Twrch Sandstone which then passes over the limestone will be lost to the limestone. This means that an even lower proportion of runoff from the Site will reach the Bodwigiad Stream compared to that from the Preserved Area.

Table 4.4 Change in catchment area available for the DCWW surface water abstraction resulting from working the Preserved Area

Catchment	Area (ha)	Percentage of total catchment
Bodwigiad Stream Catchment upstream of DCWW abstraction	49.1	24.7%
Nant y Bwllfa Catchment upstream of DCWW abstraction	150	75.3%
Total available catchment for DCWW abstraction	199.1	**100%**
Twrch Sandstone Area lost	0.87	0.44%
Limestone Area lost	0	0%
Total Area Lost	**0.87**	**0.44%**
Effective catchment area loss	**0.87**	**0.44%**

Total loss of catchment to the Bodwigiad Stream and Bodwigiad private water supply due to working the Preserved Area is predicted to be 1.86 ha, all of which is Twrch Sandstone and is therefore equivalent to the effective catchment area. This represents 3.1% of the total Bodwigiad Stream catchment area as a whole (estimated to be approximately 60 ha) and 3.3% of the catchment available to the private water supply (estimated to be approximately 57 ha). Such a reduction in catchment would be unlikely to result in a significant impact on flow in the Bodwigiad Stream. Effects

on flows in the Bodwigiad Stream and the private Bodwigiad abstraction dependent on the stream are therefore assessed as negligible.

The assessment outlined above demonstrates that there are benefits from working the Site rather than the Preserved Area. This is due to a lesser reduction in effective catchment area to the Bodwigiad Stream from working the Site which, in turn, results in a lesser impact on the Bodwigiad Stream itself, the private water supply at Bodwigiad and the licenced DCWW abstraction. Table 4.5 summarises the losses of effective catchment area (i.e. catchment underlain by Twrch Sandstone) for the two scenarios of working the Site and the Preserved Area. Although there is a net relative benefit of working the Site, impacts of both scenarios are considered to be negligible.

Table 4.5 Comparison of loss of effective catchment of working the Site versus working the Preserved Area

Receptor	Loss of effective catchment from working the Site	Loss of effective catchment from working the Preserved Area	Net relative benefit from working the Site?
DCWW Licenced Surface water abstraction	0.77 ha (0.39%)	0.87 ha (0.44%)	Yes – lesser reduction in effective catchment area of 0.1 ha (0.05%)
Bodwigiad private water supply abstraction	0.77 ha (1.4%)	1.86 ha (3.3%)	Yes – lesser reduction in effective catchment area of 1.09 ha (1.9%)
Bodwigiad Stream	0.77 ha (1.3%)	1.86 ha (3.1%)	Yes – lesser reduction in effective catchment area of 1.09 ha (1.8%)

4.7 Inspection and Mitigation Measures

4.7.1 Proposed mitigation measures

No significant impacts have been identified at the Site and further mitigation measures are not required. Flood risk and drainage mitigation measures are presented separately by Stantec in the accompanying FCA (2018).

4.7.2 Proposed monitoring

Based on the findings of this report, most notable that working will be above the water table, it is not considered necessary for any changes to the existing water monitoring regime at Penderyn Quarry.

5 Conclusions

Hanson is proposing to extract limestone from the eastern part of Twyn-y-Glog ridge at the existing Penderyn Quarry. The Site is to be worked to a level of not less than 265 m AOD and the excavations at the Site will not require groundwater dewatering. As part of this application, the western part of the ridge, which Hanson has planning permission to work, is to be preserved ("the Preserved Area").

Stantec has reviewed the potential hydrogeological and hydrological impacts of the development at the Site and subsequent restoration. Potential impacts to neighbouring abstractions, surface water bodies, water quality and sensitive sites have been assessed. The most proximal receptors include a licenced DCWW surface water abstraction, the Bodwigiad Stream, a private water supplies at Bodwigiad) and the limestone aquifer.

Impacts from working the Site are expected to be negligible and, hence, not significant. Impacts from working the Preserved Area would be expected to be similarly negligible and not significant; however, the loss of effective catchment area from working the Site is less than that lost from working the Preserved Area. Therefore, working the Site is expected to yield a slight net relative benefit, i.e. a lesser (but still negligible) impact on neighbouring receptors when compared with working the Preserved Area.

REFERENCES

Allen, D. J., Brewerton, L. J., Coleby, L. M., Gibbs, B. R., Lewis, M. A., MacDonald, A. M., . . . Williams, A. T. (1997). *The Physical Properties of Major Aquifers in England and Wales.*

Barclay, W. J., Taylor, K., & Thomas, L. P. (1988). *Geology of the South Wales Coalfield, Part V, the country around Merthyr Tydfil.*

BGS. (1979). Geological Survey of England and Wales 1:50,000 geological map series. Merthyr Tydfil. Sheet number 231.

CEH. (2018). *National River Flow Archive*. Retrieved November 2017, from https://nrfa.ceh.ac.uk/data/search

ESI. (2015). *Penderyn Quarry Annual Monitoring Report - Oct 2014 to Sept 2015.*

ESI. (2017). *Penderyn Quarry Geological/Hydrogeological Reconceptualisation.*

Hull, D. (2013). *A Geoenvironmental assessment of the Penderyn Distillery Site.* University of Cardiff Masters' Thesis.

SRK. (2011). *Penderyn Quarry ROMP Hydrological Impact Assessment.*

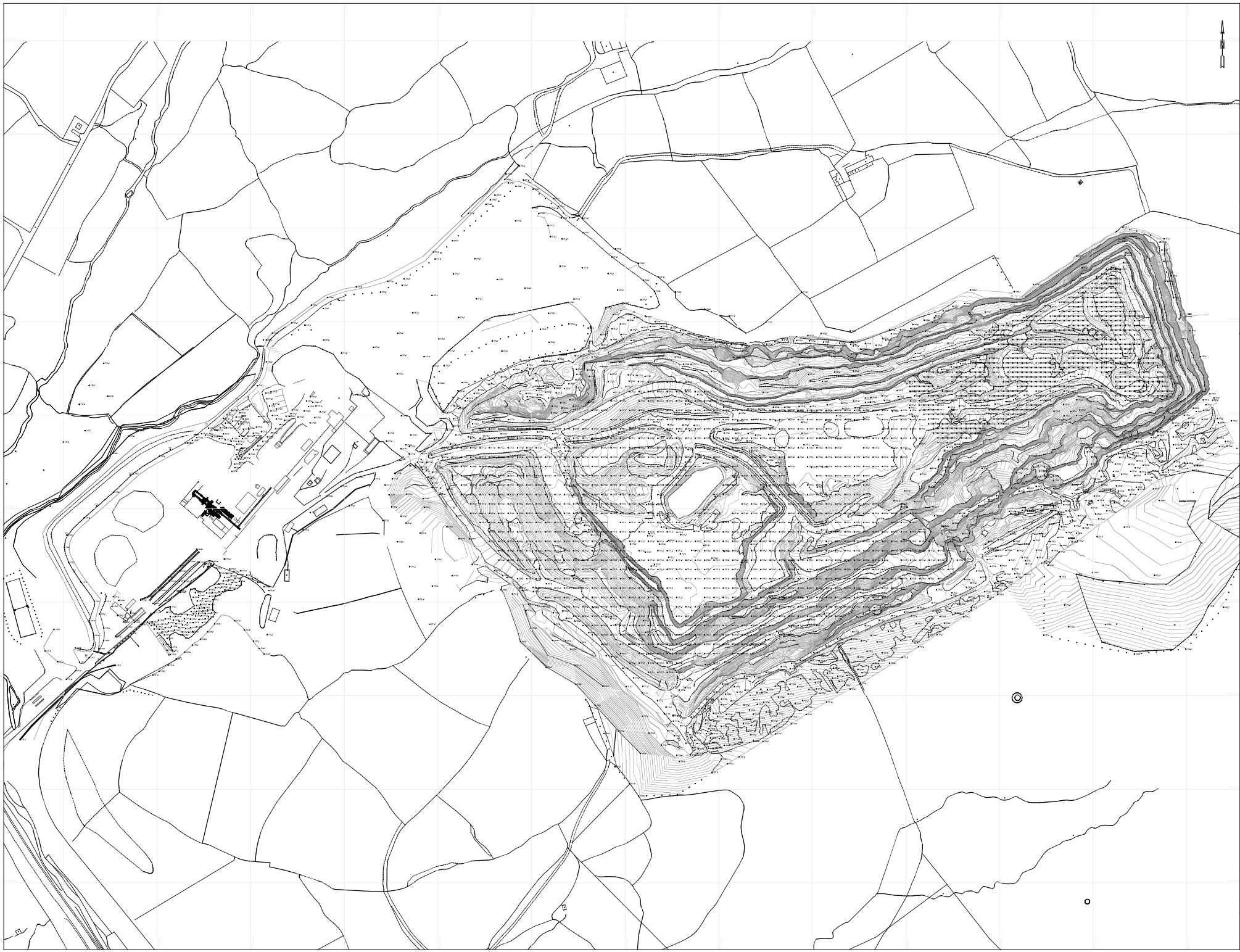
Stantec. (2018). *Penderyn Quarry Twyn-y-Glog Flood Consequence Assessment.*

Steffen, Robertson and Kirsten (UK). (1998). *Penderyn Quarry Hydrogeological Monitoring Annual Review .*

APPENDICES

Appendix A

Topographic Survey and Planning Areas

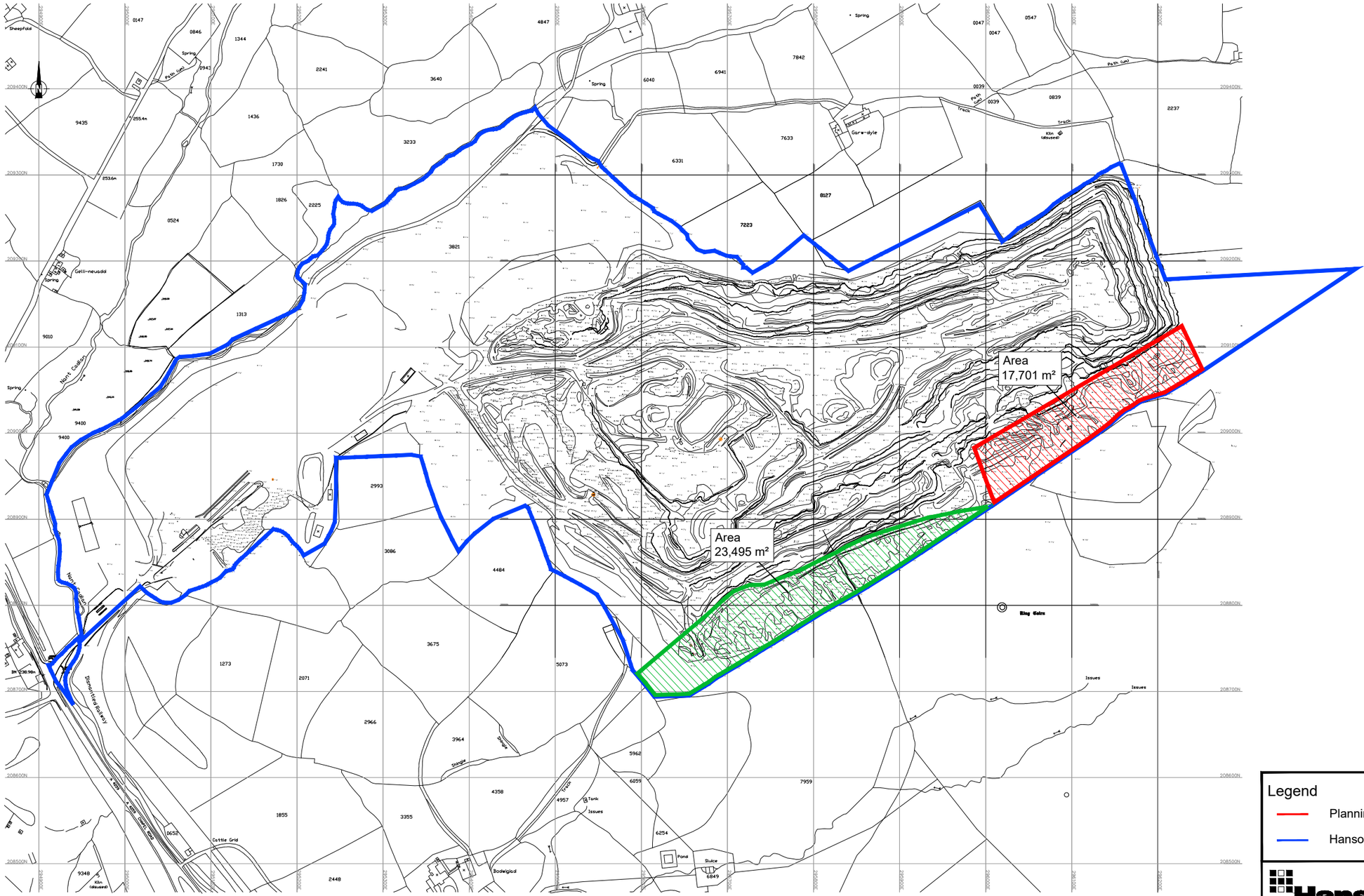


Hanson HEIDELBERGCEMENT Group

Site: Penderyn Quarry

Title: Site Survey

Scale	Date	Drawing No
1:1250	Mar2018	
Drawn by: C	Revised	



Legend

- Planning application boundary
- Hanson freehold land ownership

Hanson
HEIDELBERGCEMENT Group

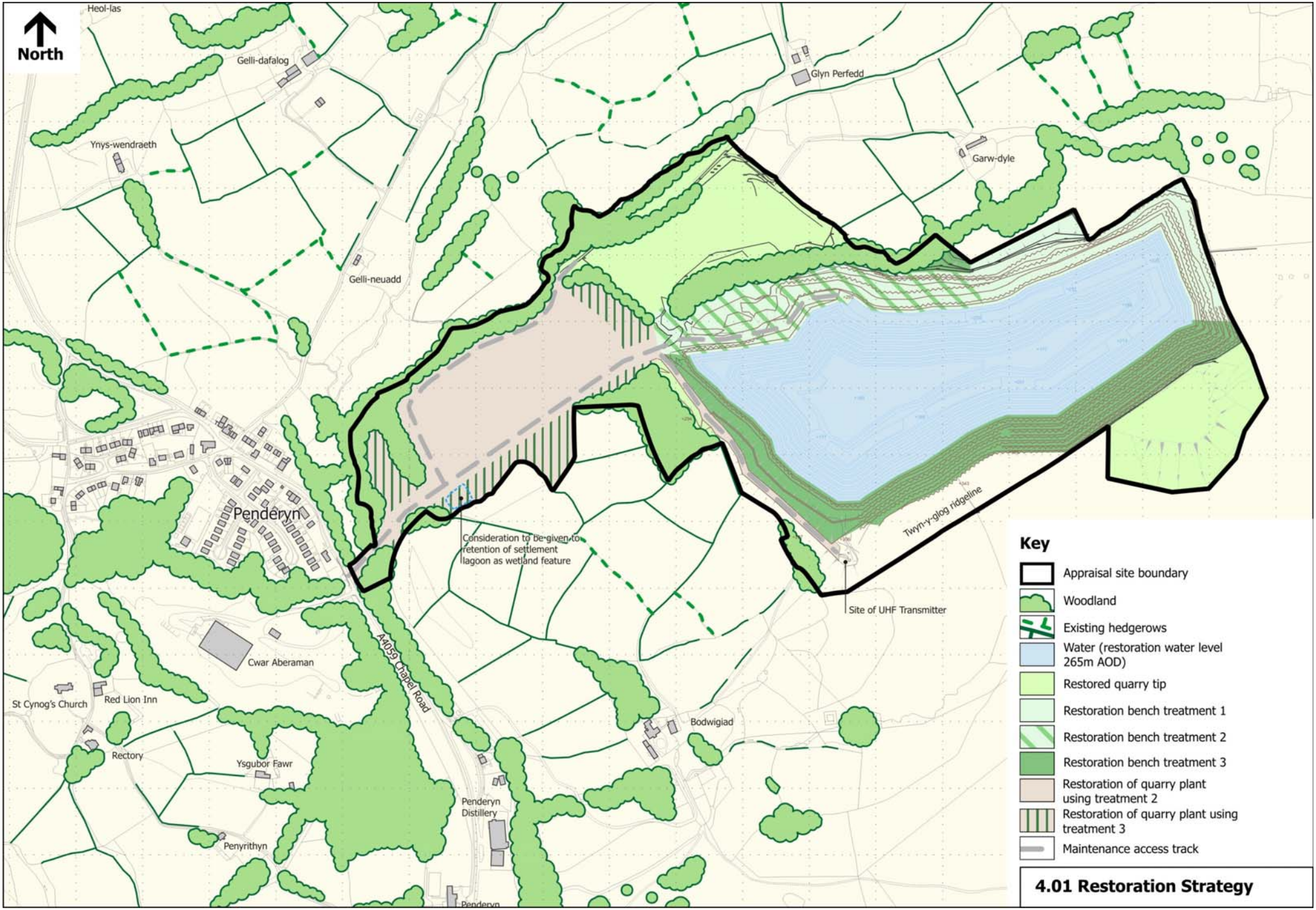
Site: Penderyn Quarry

Title: East Twyn-Y-Glog Ridge Planning Application Boundary

Scale	Date	Drawing No.
1:5000@A3	Aug 2018	P7m/108
Drawn by: MP	Checked by: MF	

Appendix B

Penderyn Quarry Restoration Plan


North
Heol-las
Gelli-dafalog
Glyn Perfedd
Ynys-wendraeth
Garw-dyle
Gelli-neuadd
Penderyn
Consideration to be given to retention of settlement lagoon as wetland feature
Twyn-y-glog ridgeline
Site of UHF Transmitter
Cwar Aberaman
A4059 Chapel Road
St Cynog's Church
Red Lion Inn
Rectory
Ysgubor Fawr
Penyrithyn
Penderyn Distillery
Bodwigiad
Penderyn
Key
Appraisal site boundary
Woodland
Existing hedgerows
Water (restoration water level 265m AOD)
Restored quarry tip
Restoration bench treatment 1
Restoration bench treatment 2
Restoration bench treatment 3
Restoration of quarry plant using treatment 2
Restoration of quarry plant using treatment 3
Maintenance access track
4.01 Restoration Strategy

Appendix C

Discharge Permit

creating a better place

Environment Agency

Mr R Griffiths
Principal Geologist South
The Ridge
Chipping Sodbury
Bristol
BS37 6AY

Our ref: AN0238501
Your ref:

Date: 13 June 2011

Dear Mr Griffiths

Copy of information sent to your client about an application received under the Environmental Permitting (England and Wales) Regulations 2010

Permit reference: AN0238501
Applicant: Hanson Quarry Products
Facility: Penderyn Quarry

I enclose for your information, copies of a letter and permits sent to your client about their application for an environmental permit. The information is important and should be kept safe.

Please quote our reference if you contact us. If you have any questions please phone me on 03708 506 506 or email psc-waterquality@environment-agency.gov.uk.

Yours sincerely

Kathy Nowell
Permitting Support Advisor

MCROW.

creating a better place

Environment Agency

15 JUN 2011

lgae.

Mr R Tyson
Hanson House
14 Castle Hill
Maidenhead
Berkshire
SL6 4JJ

Our ref: AN0238501
Your ref:

Date: 13 June 2011

Solve Phillips
Shepherd

Dear Mr Tyson

Issue of variation notice

Permit reference: AN0238501
Applicant: Hanson Quarry Products
Facility: Penderyn Quarry

I enclose a variation notice that gives legal information about the variation and shows the changes to your permit.

If you are not already familiar with our document 'How to comply with your environmental permit' please look at it, as this will help you understand how to meet the conditions of the permit. You can find this on our website at http://www.environment-agency.gov.uk/business/topics/permitting/32320.aspx
If you do not have internet access please telephone our Customer Contact Centre.

Please look at the table below and note any of the information or actions that apply to your permit.

If...	then..
the variation means you now need to submit quarterly waste returns on waste movements	you can get the forms you need from our website http://www.environment-agency.gov.uk/business/topics/waste/32176.aspx If you do not have web access phone our Customer Contact Centre
you need to submit other returns	send these to your area office. Speak to your area officer to check local arrangements.
your variation has added an installation to your permit for the first time	we've enclosed the pollution inventory letter, notice and fact sheet

Permitting Support Centre, Quadrant 2, 99 Parkway Avenue,
Parkway Business Park, Sheffield, S9 4WF
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

Rights of appeal

If you are not happy with any permit condition that has been imposed by the variation you may appeal to the Secretary of State for permits in England or Welsh Ministers for permits in Wales. You must make your appeal by 9 December 2011. If you are appealing against conditions imposed as a result of your application you must make your appeal by 9 December 2011. If you are appealing against any other conditions we have added at the same time as an Environment Agency initiated variation you must make your appeal by 9December 2011.

Further information about making an appeal and the forms you will need are available from the Planning Inspectorate website or from the contact details below.

For England:

The Planning Inspectorate, Room 4/04 Kite Wing, Temple Quay House,

2 The Square, Temple Quay, Bristol, BS1 6PN. Phone: 0117 3728726

Email: environment.appeals@pins.gsi.gov.uk

For Wales:

The Planning Inspectorate, Crown Buildings, Cathays Park, Cardiff, CF10 3NQ.

Phone: 029 2082 3866 / 389, Fax: 029 2082 5150, Email: wales@pins.gsi.gov.uk

You must send written notice of the appeal and the documents listed below to the Secretary of State or Welsh Ministers to the respective Planning Inspectorate address above. At the same time you must send us a copy of the notice and documents.

The documents are:

- a statement of the grounds of appeal;
- a copy of any relevant application;
- a copy of any relevant environmental permit;
- a copy of any relevant correspondence between the appellant and the regulator;
- a copy of any decision or notice which is the subject matter of the appeal; and
- a statement indicating whether you wish the appeal to be in the form of a hearing or dealt with by way of written representations.

You may withdraw an appeal by notifying the Secretary of State or Welsh Ministers in writing and sending a copy of that notification to us.

If you have any questions about this permit please phone our Customer Contact Centre on 08708 506 506. They will put you in touch with a local area officer.

Yours sincerely

Kathy Nowell
Permitting Support Advisor

Notice of variation and consolidation with introductory note

Environmental Permitting (England & Wales) Regulations 2010

Hanson Quarry Products Europe Limited

Penderyn Quarry site drainage
Penderyn
Near Aberdare
Mid Glamorgan
CF44 0TX

Variation application number
AN0238501/V001

Permit number
AN0238501

Penderyn Quarry site drainage
Permit number AN0238501

Introductory note

This introductory note does not form a part of the notice.

The following notice gives notice of the variation and consolidation of an environmental permit.

This variation is to add a storm overflow on to the attenuation lagoon.

The schedules specify the changes made to the permit.

The status log of a permit sets out the permitting history, including any changes to the permit reference number.

Status log of the permit		
Description	**Date**	**Comments**
Permit determined AN0238501	02/11/92	
Application AN0238501/V001 (variation and consolidation)	Duly made 13/01/11	Application to add a storm discharge
Variation determined AN0238501	09/06/11	Varied and consolidated permit issued in modern condition format and to include storm overflow.

End of introductory note

Notice of variation and consolidation

Environmental Permitting (England and Wales) Regulations 2010

The Environment Agency in exercise of its powers under regulation 20 of the Environmental Permitting (England and Wales) Regulations 2010 varies and consolidates

Permit number
AN0238501

issued to:
Hanson Quarry Products Europe Limited ("the operator")

whose registered office is

Hanson House
14 Castle Hill
Maidenhead
Berkshire
SL6 4JJ

company registration number **00300002**

to operate a regulated facility at

Penderyn Quarry
Penderyn
Near Aberdare
Mid Glamorgan
CF44 0TX

to the extent set out in the schedules.

The notice shall take effect from 9th June 2011

Name	Date
Christopher Hall	**9th June 2011**

Authorised on behalf of the Environment Agency

Schedule 1

All conditions have been varied by the consolidated permit as a result of the application made by the operator.

Schedule 2 – consolidated permit

Consolidated permit issued as a separate document.

Permit

The Environmental Permitting (England and Wales) Regulations 2010

Permit number
AN0238501

This is the consolidated permit referred to in the variation and consolidation notice for application AN0238501 authorising,

Hanson Quarry Products Europe Limited ("the operator"),

whose registered office is

Hanson House
14 Castle Hill
Maidenhead
Berkshire
SL6 4JJ

company registration number **00300002**

to operate a regulated facility at

Penderyn Quarry
Penderyn
Near Aberdare
Mid Glamorgan
CF44 0TX

to the extent authorised by and subject to the conditions of this permit.

Name	Date
Christopher Hall	**9th June 2011**

Authorised on behalf of the Environment Agency

Conditions

1 Management

1.1 General management

1.1.1 The operator shall manage and operate the activities:

(a) in accordance with a written management system that identifies and minimises risks of pollution, including those arising from operations, maintenance, accidents, incidents, non-conformances and those drawn to the attention of the operator as a result of complaints; and

(b) using sufficient competent persons and resources.

1.1.2 Records demonstrating compliance with condition 1.1.1 shall be maintained.

1.1.3 Any person having duties that are or may be affected by the matters set out in this permit shall have convenient access to a copy of it kept at or near the place where those duties are carried out.

2 Operations

2.1 Permitted activities

2.1.1 The operator is only authorised to carry out the activities specified in schedule 1 table S1.1 (the "activities").

2.2 The site

2.2.1 The activities shall not extend beyond the site, being the land shown edged in green and the discharge shall be made at the point marked on the site plan at schedule 7 to this permit and as listed in table S3.2 (discharge points).

3 Emissions and monitoring

3.1 Emissions to water

3.1.1 There shall be no point source emissions to water except from the sources and emission points listed in schedule 3.

3.1.2 The limits given in schedule 3 shall not be exceeded.

3.2 Emissions of substances not controlled by emission limits

3.2.1 Emissions of substances not controlled by emission limits (excluding odour) shall not cause pollution. The operator shall not be taken to have breached this condition if appropriate measures, including, but not limited to, those specified in any approved emissions management plan, have been taken to prevent or where that is not practicable, to minimise, those emissions.

3.2.2 The operator shall:

(a) if notified by the Environment Agency that the activities are giving rise to pollution, submit to the Environment Agency for approval within the period specified, an emissions management plan;

(b) implement the approved emissions management plan, from the date of approval, unless otherwise agreed in writing by the Environment Agency.

3.3 Monitoring

3.3.1 Permanent means of access shall be provided to enable sampling/monitoring to be carried out in relation to the emission points specified in schedule 3 tables S3.1, S3.2 and S3.3 unless otherwise agreed in writing by the Environment Agency.

4 Information

4.1 Records

4.1.1 All records required to be made by this permit shall:

(a) be legible;

(b) be made as soon as reasonably practicable;

(c) if amended, be amended in such a way that the original and any subsequent amendments remain legible, or are capable of retrieval; and

(d) be retained, unless otherwise agreed in writing by the Environment Agency, for at least 6 years from the date when the records were made.

4.1.2 The operator shall keep on site all records, plans and the management system required to be maintained by this permit, unless otherwise agreed in writing by the Environment Agency.

4.2 Reporting

4.2.1 The operator shall send all reports and notifications required by the permit to the Environment Agency using the contact details supplied in writing by the Environment Agency.

4.3 Notifications

4.3.1 The Environment Agency shall be notified without delay following the detection of:

(a) any malfunction, breakdown or failure of equipment or techniques, accident, or emission of a substance not controlled by an emission limit which has caused, is causing or may cause significant pollution;

(b) the breach of a limit specified in the permit; or

(c) any significant adverse environmental effects.

4.3.2 Any information provided under condition 4.3.1 shall be confirmed by sending the information listed in schedule 5 to this permit within the time period specified in that schedule.

4.3.3 Where the Environment Agency has requested in writing that it shall be notified when the operator is to undertake monitoring and/or spot sampling, the operator shall inform the Environment Agency when the relevant monitoring and/or spot sampling is to take place. The operator shall provide this information to the Environment Agency at least 14 days before the date the monitoring is to be undertaken.

4.3.4 The Environment Agency shall be notified within 14 days of the occurrence of the following matters, except where such disclosure is prohibited by Stock Exchange rules:

Where the operator is a registered company:

(a) any change in the operator's trading name, registered name or registered office address; and

(b) any steps taken with a view to the operator going into administration, entering into a company voluntary arrangement or being wound up.

Where the operator is a corporate body other than a registered company:

(a) any change in the operator's name or address; and

(b) any steps taken with a view to the dissolution of the operator.

4.3.5 Where the operator proposes to make a change in the nature or functioning, or an extension of the activities, which may have consequences for the environment and the change is not otherwise the subject of an application for approval under the Regulations or this permit:

(a) the Environment Agency shall be notified at least 14 days before making the change; and

(b) the notification shall contain a description of the proposed change in operation.

4.4 Interpretation

4.4.1 In this permit the expressions listed in schedule 6 shall have the meaning given in that schedule.

4.4.2 In this permit references to reports and notifications mean written reports and notifications, except where reference is made to notification being made "without delay", in which case it may be provided by telephone.

Schedule 1 - Operations

Table S1.1 Activities		
Activity reference	**Description of activity**	**Limits of specified activity**
A1	Discharge of trade effluent consisting of site drainage via outlet A or A1	
A2	Discharge of trade effluent consisting of storm site drainage via outlet 1	The discharge shall only occur when all the attenuation volume is utilised and only for as long as the flow passed forward as part of Activity reference A1is equal to or greater than the overflow setting indicated in table S3.1.

Schedule 2 - Waste types, raw materials and fuels

Wastes are not accepted as part of the permitted activities and there are no restrictions on raw materials or fuels under this schedule.

Schedule 3 – Emissions and monitoring

Table S3.1 Point Source emissions to water (other than sewer) – emission limits and monitoring requirements

Discharge source and discharge point ref. & location	Parameter	Limit (including unit)	Reference Period	Limit of effective range	Monitoring frequency	Compliance Statistic
A1:Discharge of trade effluent consisting of site drainage via outlets A and A1	Suspended solids (measured after drying at 105° C)	100 mg/l	Instantaneous (spot sample)	N/A		Maximum
A1:Discharge of trade effluent consisting of site drainage via outlets A and A1	pH	5 to 9	Instantaneous (spot sample)	N/A		Minimum and maximum
A1:Discharge of trade effluent consisting of site drainage via outlets A and A1	Visible oil or grease	No significant trace present	Instantaneous (spot sample)	N/A	N/A	No significant trace
A2:Discharge of trade effluent consisting of storm site drainage via outlet 1	Attenuation lagoon volume	550 m^3	Instantaneous (spot sample)	N/A	N/A	Minimum
A2:Discharge of trade effluent consisting of storm site drainage via outlet 1	Overflow setting	368 l/s	Instantaneous (spot sample)	N/A	N/A	Minimum
A2:Discharge of trade effluent consisting of storm site drainage via outlet 1	Visible oil or grease	No significant trace present	Instantaneous (spot sample)	N/A	N/A	No significant trace

Table S3.2 Discharge points			
Effluent Name	**Discharge Point**	**Discharge point NGR**	**Receiving water/Environment**
Discharge of trade effluent consisting of site drainage	Outlet A	SN 94912 08906	Nant Cadlan
Discharge of trade effluent consisting of site drainage	Outlet A1	SN 94923 08858	Nant Cadlan
Discharge of trade effluent consisting of storm site drainage	Outlet 1	SN 94953 08758	Nant Cadlan

Table S3.3 Monitoring points		
Effluent(s) and discharge point(s)	**Monitoring type**	**Monitoring point NGR**
Discharge of trade effluent consisting of site drainage via outlet A	Effluent sample point	SN 94912 08906
Discharge of trade effluent consisting of site drainage via outlet A1	Effluent sample point	SN 94923 08858
Discharge of trade effluent consisting of storm site drainage via outlet 1	Storm effluent sample point	SN 94953 08758

Schedule 4 – Reporting

There is no reporting under this schedule.

Schedule 5 - Notification

These pages outline the information that the operator must provide.

Units of measurement used in information supplied under Part A and B requirements shall be appropriate to the circumstances of the emission. Where appropriate, a comparison should be made of actual emissions and authorised emission limits.

If any information is considered commercially confidential, it should be separated from non-confidential information, supplied on a separate sheet and accompanied by an application for commercial confidentiality under the provisions of the EP Regulations.

Part A

Permit Number	
Name of operator	
Location of Facility	
Time and date of the detection	

(a) Notification requirements for any malfunction, breakdown or failure of equipment or techniques, accident, or emission of a substance not controlled by an emission limit which has caused, is causing or may cause significant pollution	
To be notified within 24 hours of detection	
Date and time of the event	
Reference or description of the location of the event	
Description of where any release into the environment took place	
Substances(s) potentially released	
Best estimate of the quantity or rate of release of substances	
Measures taken, or intended to be taken, to stop any emission	
Description of the failure or accident.	

(b) Notification requirements for the breach of a limit	
To be notified within 24 hours of detection unless otherwise specified below	
Emission point reference/ source	
Parameter(s)	
Limit	
Measured value and uncertainty	
Date and time of monitoring	
Measures taken, or intended to be taken, to stop the emission	

Time periods for notification following detection of a breach of a limit	
Parameter	**Notification period**

(c) Notification requirements for the detection of any significant adverse environmental effect	
To be notified within 24 hours of detection	
Description of where the effect on the environment was detected	
Substances(s) detected	
Concentrations of substances detected	
Date of monitoring/sampling	

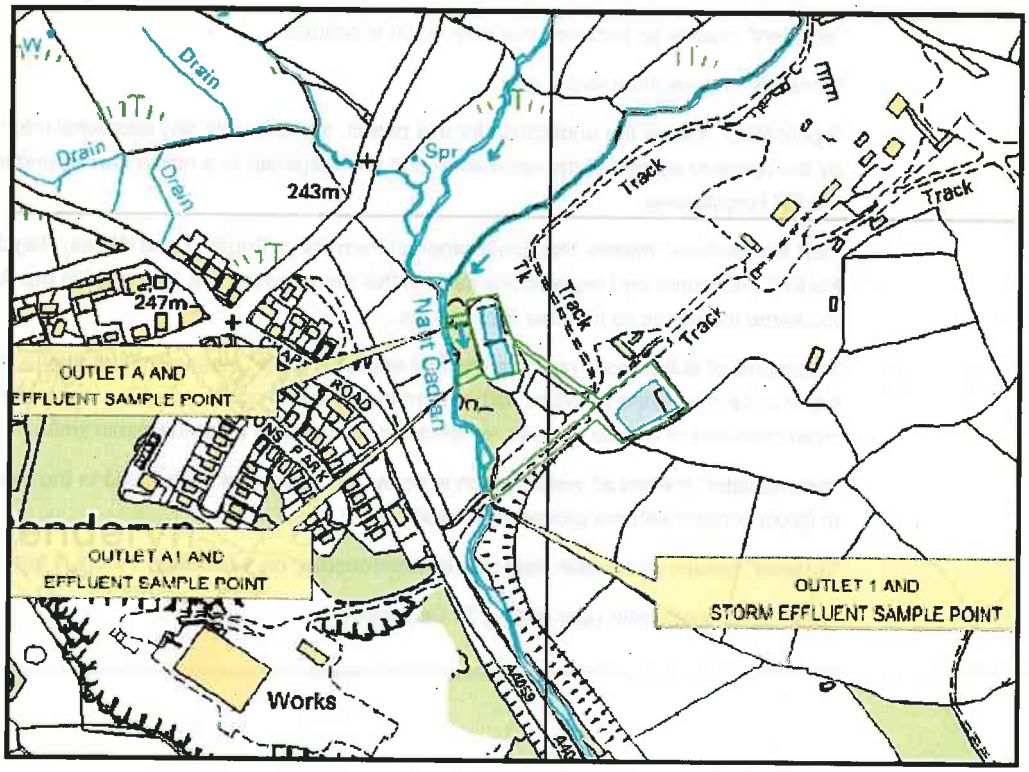
Part B - to be submitted as soon as practicable

Any more accurate information on the matters for notification under Part A.	
Measures taken, or intended to be taken, to prevent a recurrence of the incident	
Measures taken, or intended to be taken, to rectify, limit or prevent any pollution of the environment which has been or may be caused by the emission	
The dates of any unauthorised emissions from the facility in the preceding 24 months.	

Name*	
Post	
Signature	
Date	

* authorised to sign on behalf of the operator

Schedule 7 - Site plan



END OF PERMIT

Schedule 6 - Interpretation

"accident" means an accident that may result in pollution.

"annually" means once every year.

"application" means the application for this permit, together with any additional information supplied by the operator as part of the application and any response to a notice served under Schedule 5 to the EP Regulations.

"EP Regulations" means The Environmental Permitting (England and Wales) Regulations SI 2010 No.675 and words and expressions used in this permit which are also used in the Regulations have the same meanings as in those Regulations.

"emissions of substances not controlled by emission limits" means emissions of substances to air, water or land from the activities, either from the emission points specified in schedule 3 or from other localised or diffuse sources, which are not controlled by an emission limit..

"groundwater" means all water, which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil.

"quarter" means a calendar year quarter commencing on 1 January, 1 April, 1 July or 1 October.

"year" means calendar year ending 31 December.

Water Resources Act 1991
as amended by the Environment Act 1995
Consent to Discharge
Certificate of Holder

ENVIRONMENT AGENCY

Part A

To: HANSON QUARRY PRODUCTS EUROPE LTD
THE COMPANY SECRETARY
THE RIDGE CHIPPING SODBURY
BRISTOL
BS37 6AY

NB: For a body corporate the job title is a point of contact.
Holder Start Date: 26/08/00

The **Environment Agency** ("the Agency") hereby confirm that the above named person is a/the registered holder of consent AN0272901 Consent Issued: 06/06/97

Nature of Discharge(s); TMWC Trade - Minewater - Continuous
at SN9494008710 PENDERYN QUARRY PENDERYN ABERDARE

Note: This certificate should be kept with the consent document for future reference. If you transfer responsibility for the discharge to somebody else you must pass the consent to them and tell the Agency within 21 days. **Responsibility for the consent cannot be disclaimed by the holder but the registration of holder may be transferred to a successor.** To do this please complete the form below, then tear it off and return it to the address shown. If you fail to transfer the consent, even though you are no longer on the site, you may still be liable for prosecution for pollution. If you transfer the consent but do not tell us, you will be committing an offence. In case of any queries please contact your local Environment Agency office.

Part B **Please complete in block capitals or type.**

To:

Water Resources Act 1991: Notice of transfer of consent to discharge

Consent: AN0272901
Consent Issued: 06/06/97

Name: HANSON QUARRY PRODUCTS EUROPE LTD
Address: THE COMPANY SECRETARY
THE RIDGE CHIPPING SODBURY
BRISTOL
BS37 6AY

I/We* hereby serve notice on the Agency that I/we* am/are* no longer a/the* Holder of the above consent which will be/was* transferred to: * delete as appropriate

Name(s) of new holder(s):
Address:

Post Code:

Date of Transfer to new Holder(s); .....

Signed: ..... **Dated:** .....

Name (block capitals): ..... **Position:** .....
(to be completed when signing on behalf of corporate bodies)

JWE/5/96

RECYCLED

Deddf Adnoddau Dwr 1991
fel y'i diwygiwyd gan Ddeddf yr Amgylchedd 1995
Caniatâd Gollwng
Tystysgrif Daliwr

ASIANTAETH YR AMGYLCHEDD

Rhan A

At: HANSON QUARRY PRODUCTS EUROPE LTD
THE COMPANY SECRETARY
THE RIDGE CHIPPING SODBURY
BRISTOL
BS37 6AY

DS: I gorff corfforedig mae teitl y swydd yn bwynt cysylltu.
Dyddiad Cychwyn Daliwr: 26/08/00

Mae **Asiantaeth yr Amgylchedd** ("yr Asiantaeth") yn cadarnhau drwy hyn mai/bod y sawl a enwyd uchod yw/yn ddaliwr cofrestredig uy caniatâd AN0272901 Cyhoeddwyd Caniatâd: 06/06/97

Natur y gollwng:
yn TMWC Trade - Minewater - Continuous
SN9494008710 PENDERYN QUARRY PENDERYN ABERDARE

Nodyn: Dylid cadw'r dystysgrif hon gyda'r ddogfen ganiatâd i gyfeirio ati yn y dyfodol. Os byddwch yn trosglwyddo cyfrifoldeb y gollwng i rywun arall, rhaid i chi gyflwyno'r caniatâd iddo ef neu hi a dweud wrth yr Asiantaeth cyn pen 21 diwrnod. **Ni all y daliwr wadu cyfrifoldeb y gollwng, ond gall cofrestriad y daliwr gael ei drosglwyddo i olynydd.** I wneud hynny, byddwch cystal â llenwi'r ffurflen isod, ei datgysylltu a'i dychwelyd i'r cyfeiriad a nodir. Os methwch drosglwyddo'r caniatâd, hyd yn oed os nad ydych ar y safle mwyach, gallwch fod yn agored yr un fath i gael eich erlyn am lygru. Os trosglwyddwch y caniatâd ond heb ddweud wrthom, byddwch yn cyflawni trosedd. Os bydd gennych ymholiadau, byddwch cystal â chysylltu â swyddfa Asiantaeth yr Amgylchedd yn lleol.

Rhan B **Llenwch mewn priflythrennau bras neu deipio.**

At:

Deddf Adnoddau Dwr 1991: Hysbysiad am drosglwyddo caniatâd gollwng

Caniatâd: AN0272901

Cyhoeddwyd Caniatâd: 06/06/97

Enw:
Cyfeiriad: HANSON QUARRY PRODUCTS EUROPE LTD
THE COMPANY SECRETARY
THE RIDGE CHIPPING SODBURY
BRISTOL
BS37 6AY

Yr wyf fi/Yr ydym ni* drwy hyn yn hysbysu'r Asiantaeth nad fi/ni/nad wyf/ydym mwyach yw/yn* Ddeiliad y caniatâd uchod. Caiff/Cafodd hwnnw ei drosglwyddo i: *dilewch yn ôl yr angen

Enw(au) y Daliwr/Dalwyr newydd:
Cyfeiriad:

Cod Post:

Dyddiad Trosglwyddo i'r Daliwr/Dalwyr newydd: .....

Llofnodwyd:..... **Dyddiedig:** .....

Enw Enw (priflythrennau bras):..... **Safle:** .....

JWE/5/96

(i'w lenwi wrth lofnodi ar ran cyrff corfforaethol)

RECYCLED

CONSENT NO.	AN0272901

ASIANTAETH YR AMGYLCHEDD
ENVIRONMENT AGENCY

WATER RESOURCES ACT 1991

SECTION 88 - SCHEDULE 10

(AS AMENDED BY THE ENVIRONMENT ACT 1995)

CONSENT TO DISCHARGE

TO: THE COMPANY SECRETARY
ARC SOUTH WALES LTD
CANAL ROAD
CWMBACH
ABERDARE
CF44 0AG

The **ENVIRONMENT AGENCY** ("The Agency") in pursuance of its powers under the Water Resources Act 1991 **HEREBY CONSENTS** to the making of a discharge **OF TRADE EFFLUENT**, as follows:

PUMPED GROUNDWATER /SITE DRAINAGE

FROM: **EFFLUENT TREATMENT PLANT**

AT: PENDERYN QUARRY, PENDERYN ABERDARE

TO: THE RIVER CYNON

SUBJECT TO the conditions set out in the following schedule:

PUMPED GROUNDWATER/SITE DRAINAGE SCHEDULE NO. AN027290101

Subject to the provisions of Paragraphs 7 and 8 of Schedule 10 of the Water Resources Act 1991, no notice shall be served by the Agency, altering this consent, without the agreement in writing of the consent holder, during a period of 4 years from the date this consent takes effect.

This consent is issued and takes effect on the 6th day of June 1997

Signed .....
Area Water Quality Manager

Asiantaeth yr Amgylchedd
Plas yr Afon, Parc Busnes Llaneirwg, Llaneirwg, Caerdydd CF3 0LT. Ffon 01222 770088, Ffacs 01222 798555

Environment Agency
Rivers House, St. Mellons Business Park, St. Mellons, Cardiff CF3 0LT. Tel 01222 770088, Fax 01222 798555

CONSENT NO.	**AN0272901**
SCHEDULE NO.	**AN027290101**
DATE ISSUED	6/6/97

ASIANTAETH YR AMGYLCHEDD
ENVIRONMENT AGENCY

CONDITIONS OF CONSENT TO DISCHARGE

PUMPED GROUNDWATER /SITE DRAINAGE ("the Discharge")

FROM: EFFLUENT TREATMENT PLANT, PENDERYN QUARRY

1. (a) The Discharge shall not contain any poisonous, noxious or polluting matter or solid waste matter.

(b) Provided that the Discharge hereby consented is made in accordance with the following conditions of this consent, such discharge shall not be taken to be in breach of condition (a) above by reason of containing substances or having properties identified in and controlled by those conditions.

NATURE

2. The Discharge shall consist solely of trade effluent comprising of pumped groundwater and site drainage from a total drainage area of 202300 square metres for the prevention of interference with quarrying.

LOCATION

3. The Discharge shall be made in the manner and at the place specified as:

(a) discharging via a 300mm dia pipe set in concrete headwall.

(b) discharging to the River Cynon

(c) at National Grid Reference SN 9494 0871

(d) shown marked "Consent Point" on Drawing No P7d/2 attached as Annex 1

SAMPLE POINT

4. The outlet to the watercourse shall be constructed and maintained so that a representative sample of the Discharge may be obtained at National Grid Reference SN 9494 0871 as shown marked 'Consent Point' on Drawing No P7d/2

CONSENT NO	**AN0272901**
SCHEDULE NO	**AN027290101**
DATE ISSUED	6/6/97

ASIANTAETH YR AMGYLCHEDD
ENVIRONMENT AGENCY

VOLUME

5. The volume of the Discharge shall be dependant on rainfall.

6. The rate of discharge shall not exceed 50 litres per second.

COMPOSITION

7. The discharge shall not contain more than:

   (a) 25 milligrammes per litre of suspended solids (measured after drying at 105°C.);

   (b) 10 milligrammes per litre of mineral oil.

   (c) a pH value of 9.0pH units or less than a pH value of 6.0 pH units.

   (d) 2 milligrammes per litre of total iron (as Fe)

8. The effluent treatment facility shall be maintained in an efficient operational manner at all times.

9. As far as is reasonably practicable, the effluent treatment area shall be operated to prevent:

   (i) any matter being present in the Discharge to such an extent as to cause the receiving waters, or any waters of which the receiving waters are a tributary, to be poisonous or injurious to fish in those waters, or to the spawning grounds, spawn or food of fish in those waters, or otherwise cause damage to the ecology of those waters; and

   (ii) the Discharge from having any other adverse environmental impact.

Appendix D

Groundwater Quality Results

Hydrochemical Baseline Data - OB2
Drift layer

OB2	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l $CaCO_3$	mg/l $CaCO_3$	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Total Mn	Mn	Total Fe	Fe	lab pH	Field pH	lab EC	Field EC	Lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	PO4	NO2	TDS	TOC	Mg/Ca
PENDOB2	Apr-96	89.50	0.43	2.13	5.55	0.00	0.00	0.02	0.01	7.9		430		189	240					10.80	10.80	1.66		0.25	0.00	413.93	1.60	0.04
PENDOB2	Aug-96	90.70	0.50	2.00	5.54	0.05	0.02	0.25	0.05	7.8		450		195	240					22.00	11.10	0.90		0.05	0.01	425.67	2.10	0.04
PENDOB2	Nov-96	91.10	0.50	1.94	6.47	0.41	0.01	28.50	0.05	7.5	7.6	433	460	183	250				9.9	5.00	8.50	1.00		1.52	0.01	421.09	2.10	0.04
PENDOB2	Apr-97	56.40	1.00	2.08	5.78	0.05	0.00	1.40	0.05	7.2	7.3	410	423	195	300				9.0	5.00	7.40	1.30		0.14	0.01	445.16	0.80	0.06
PENDOB2	Jun-97	95.10	0.05	1.90	5.10	0.00	0.01	0.03	0.01	8.60	7.3	460	451	213	300			210.2	14.2	10.00	9.00	6.00		0.05	0.25	493.46	0.80	0.03
PENDOB2	Oct-97	116.00	1.25	8.55	6.19	1.58	0.01	39.00	0.02	7.8	7.5	430	367	235	240				12.0	12.00	5.00	31.18	0.13	0.03	0.07	473.22	1.00	0.12
PENDOB2	Feb-98	85.10	0.70	2.47	72.7	0.12	0.03	1.28	0.03	7.3	7.3	505	508	280	280	61		275.9	9.3	16.00	17.00	8.90		0.03	0.02	544.57	3.00	0.05
PENDOB2	Jun-98	108.30	0.50	2.55	12.50	0.03	0.03	0.19	0.05	7.5	6.5	469	463	260	260	68.3			11.4	8.00	11.00	8.50		0.04	0.01	468.67	2.00	0.04
PENDOB2	Oct-98	87.46	0.60	2.16	12.50	0.03	0.03	0.03	0.06	7.6	7.5	422	330	210	140	76	8	192.7	13.7	7.00	9.00	9.00		0.01	9.70	308.31	3.00	0.04
PENDOB2	Feb-99	101.00	0.50	1.20	7.54	4.50	0.07	105.00	0.33	7.5		711	182	255	351			205.0	9.2	20.20	8.02	6.19		1.53	0.43	575.22	1.00	0.02
PENDOB2	Jun-99	102.00	0.50	2.40	6.54	0.05	0.01	1.48	0.05	8.2		348	448	240	139	51.5		58.5	11.9	13.50	8.36	8.84		0.15	0.02	311.94	1.00	0.04
PENDOB2	Oct-99	114.00	0.50	1.73	19.60	0.05	0.05	0.62	0.05	7.4	7.9	398	518	228	197	19	1.67	185.5		14.70	9.30	0.89		0.05	0.02	401.22	12	0.03
PENDOB2	Jan-00	99.10	0.50	2.10	7.02	0.01	0.00	0.13	0.05	7.2	7.1	429	354	150	225			258.0		9.30	8.50	5.85	0.06	0.15	1.48	408.55	15.5	0.04
PENDOB2	May-00	108.00	0.50	2.09	9.74	25	0.01	1210.00	0.05	7.8	7.5	463	463	232	223	39	3.84		12.6	9.80	9.60	9.15		0.05	0.02	421.07	1.00	0.03
PENDOB2	Oct-00	104.00	0.50	1.99	10.50	2.78	0.01	23.40	0.14	7.7	6.9	766	333	252	300	70.5	7.19	182.0	14.0	9.80	9.20	0.00		0.05	0.00	502.19	1.00	0.03
PENDOB2	Jan-01	96.10	0.50	1.93	6.78	2.81	0.01	55.00	0.05	7.7	7.2	461	307	240	240			247.0	6.6	9.70	9.30	11.38		0.05	0.13	428.73	1.00	0.03
PENDOB2	May-01	99.70	0.44	2.06	8.13	1.80	0.01	38.00	0.05	7.8	7.3	394	483	172	207	33	2.63	228.0	11.7	9.40	9.50	9.37		0.15	0.13	391.48	2.88	0.03
PENDOB2	Sep-01	103.00	0.38	2.03	11.00	3.38	0.00	118.00	0.01	7.4	7.3	441	406	248	205	45	5.05	255.0	12.1	10.30	9.80	3.65	0.40	0.15	0.32	390.73	1.00	0.03
PENDOB2	Jan-02	68.60	55.80	1.74	70.00	2.77	0.02	64.80	0.39	8.2	7.4	397	392	242	223			255.0	9.5	10.20	0.35	1.34	0.40	0.16	0.13	432.13	1.00	0.04
PENDOB2	May-02	91.40	0.35	1.83	10.00	0.64	0.00	28.40	0.04	7.2	7.9	395	468	180	360	33.7	3.57	151.0	14.3	6.50	58.90	0.54	0.30	0.57	0.04	609.38	1.00	0.03
PENDOB2	Sep-02	109.00	0.30	2.00	7.94	4.70	0.01	226.00	0.02	7.50	7.20	449	453	246	203	46.3	4.73	284.0	10.7	8.50	9.30	6.60	0.39	0.15	0.13	391.61	7.00	0.03
PENDOB2	Jan-03	111.00		8.24							6.90	450	378	254	270													0.12
PENDOB2	May-03	124.00		2.58						7.30	7.37	458	354	123	211													0.03
PENDOB2	Sep-03	101.00	0.59	2.03	8.30	0.08	0.0005	2.61	0.005	7.80	6.80	371	429	190	225	34	3.11	255.0	15.3	8.62	8.70	1.53	0.30	0.05	0.04		2.50	0.03
PENDOB2	Jan-04	113.00		3.14							7.00	646	320	219	234			240.0	6.3									0.05
PENDOB2	May-04	118.00		16.40							7.29	435	520	319	154	37.4	2.70	291.0	15.8									0.23
PENDOB2	Sep-04	113.00	0.41	2.20	6.55	3.54	0.0005	208.00	0.005	7.47	7.44	447	471	256	171	27.0	2.71	268.3	11.4	4.36	10.60	0.94	0.03	0.05	0.04	261.00	2.50	0.03
PENDOB2	May-05	114.00		6.55							7.36	615	402	193		54.4	5.85	318.5	10.9									
PENDOB2	Sep-05	114.00	1.46	3.79	7.03	0.25	0.0015	9.94	0.015	7.38	7.09	460	528	232	216	46.6	4.84	264.3	15.4	10.00	12.00	3.99	0.29	0.15	0.13		2.50	0.05
PENDOB2	May-06	117.00		10.90							7.25	454	502	216	224	39.3	4.47	221.5	9.7									
PENDOB2	Sep-06	110.00	6.32	11.50	6.92	1.85	0.025	15.10	0.05	7.34	7.35	459	531	237	237	34.0	3.25	16.6	13.7	10.00	11.70	0.61	0.03	0.05	0.04		0.75	0.17
PENDOB2	May-07	113.00		12.50							6.78	461	492	276	226	46.6	5.03	278.2	11.8									
PENDOB2	Sep-07	90.00	0.60	2.10	6.00	0.51	0.0005	25.00	0.02	8.08	7.42	410	573	220	198	19.9	2.10	251.0	11.1	9.00	9.00	4.40	0.10	0.36	0.03		2.00	0.04
PENDOB2	May-08	103.00		2.00							7.29	482	479	249	115	57.8	5.80	195.0	11.8									
PENDOB2	Sep-08	101.00	0.50	2.00	5.00	0.04	0.005	1.55	0.01	7.80	7.17	424	438	213	203	31.1	3.21	315.0	12.6	6.00	9.00	1.50	0.07	0.005	0.03		2.30	0.03
PENDOB2	May-09	62.00		2.00							7.58	364	366	195	150	69.4	8.10	167.0	9.4									0.28
PENDOB2	Sep-09	90.00	0.50	2.00	5.00	0.01	0.01	0.12	0.01	7.60	7.04	361	333	210	116	73.8	8.20	151.0	10.9	8.00	7.00	1.20	0.02	0.01	0.01		1.30	0.04
PENDOB2	May-10	96.00		2.00							8.62	440	401	171	155	44.3	8.70	112.0	10.2									0.03
PENDOB2	Sep-10	91.00	1.00	2.00	4.00	0.05	0.02	0.55	0.01	7.50	7.39	453	429	178	209	62.1	7.78	100.0	11.1	7.00	7.00	1.10		0.01	0.01		1.70	0.02
PENDOB2	May-11	97.00		1.00							7.32	384	476	248	208	50.6		31.0	10.7									0.03
PENDOB2	Sep-11	72.00	1.00	2.00	4.00	0.01	0.01	0.01	0.01	7.60	6.76	343	396	180	181	22.9		13.0	12.2	8.00	6.00	1.10	0.20	0.01	1.10		1.50	0.03
PENDOB2	May-12																											
PENDOB2	Sep-12	16.00	1.00	1.00	1.00	0.01	1	0.01	0.01	7.90	8.25	110	83	44	65	72.1		127.0	10.5	4.00	3.00	1.30	0.01	0.01	0.01		0.20	0.10
PENDOB2	May-13	112.00	1.00	3.00	5.00	0.06	<0.002	5.37	<0.01		7.80		507		277		4.12		12.4	6.00	7.00		0.01	0.01			<0.2	
PENDOB2	Nov-13	85.00	3.00	7.00	4.00	0.75	0.003	34.20	<0.01	7.60	7.09	441	380	264	200	42.0	4.99		8.4	6.00	7.00	2.60	0.02	0.05	<0.01		<0.2	
PENDOB2	May-14	82.00		3.00							8.17	387	490	205	258				12.9									
PENDOB2	Oct-14	20.00	1.00	1.00	3.00	0.07	0.004	1.27	0.02	8.50	7.34	318	0	80	75		4.43		14.2	6.00	4.00	1.60	0.03	<0.01	<0.01		0.30	0.05
BASELINE STATISTICS																												
PENDOB2	2 std deviation	18.06	0.15	0.60	5.02	2.95	0.04	563.64	0.15	0.5	0.7	73	135	69	97					9.19	4.69	7.39	0.36	0.94	0.74	137.32	1.63	0.01
PENDOB2	Average	99.42	0.50	2.04	7.93	1.04	0.02	90.13	0.06	7.6	7.3	434	421	221	234					11.25	9.47	5.79	0.20	0.25	0.18	434.73	1.58	0.03
PENDOB2	Lower Limit	81.36	0.36	1.44	2.91	0.00	0.00	0.00	0.00	7.1	6.6	361	286	152	138	13.5	0.3	94.6		2.06	4.77	0.00	0.00	0.00	0.00	297.41	0.00	0.02
PENDOB2	Upper Limit	117.48	0.65	2.65	12.95	3.99	0.05	653.77	0.21	8.2	8.0	507	556	290	331	85.3	8.9	332.2		20.44	14.16	13.18	0.55	1.19	0.92	572.05	3.21	0.04

Rogue values removed from statistical calculation
Half detection limit

BASELINE EXCEEDANCES
Lower than baseline
Higher than baseline

Hydrochemical Baseline Data - OB7
Limestone layer

OB7	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l $CaCO_3$	mg/l $CaCO_3$	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Total Mn	Mn	Total Fe	Fe	lab pH	Field pH	lab EC	Field EC	lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	PO4	NO2	TDS	TOC	Mg/Ca
PENDOB7	Apr-96	39.1	1.97	3.02	16.50	0.09	0.01	0.22	0.01	8.1		326		128	160					10.50	11.70	0.17		0.25		278.43	1.50	0.13
PENDOB7	Aug-96	49.80	2.26	3.68	18.10	0.05	0.03	0.24	0.05	7.2		303		130	160					5.00	12.50	0.05		0.05	0.01	286.72	6.10	0.12
PENDOB7	Nov-96	64.50	2	3.58	9.50	1.06	0.70	3.68	0.05	7.6	7.0	332	352	141	200				8.8	5.00	5.80	0.40		0.28	0.01	335.81	9.30	0.09
PENDOB7	Apr-97	73.10	1.69	2.93	6.21	0.78	0.53	0.05	0.05	7.3	7.4	321	347	144	250				10.9	5.00	2.50	0.10		0.17	0.01	397.28	4.20	0.07
PENDOB7	Jun-97	67.90	1.3	2.30	5.40	0.00	0.00	0.00	0.01	8.7	7.6	360	345	176	240			56.0	14.0	9.00	7.00	0.50		0.05	0.25	386.51	3.80	0.06
PENDOB7	Oct-97	65.10	0.94	1.70	5.49	0.01	0.01	0.09	0.05	7.6	7.6	292	303	149	220				13.1	10.00	14.00	4.16	0.06	0.06	0.07	370.04	1.00	0.04
PENDOB7	Feb-98	71.80	3.3	2.52	45.3	0.45	0.36	2.04	1.50	7.9	7.1	253	381	210	200				9.4	12.00	7.00	3.20		0.07	0.14	391.19	4.00	0.06
PENDOB7	Jun-98	77.05	1.8	1.94	8.00	0.15	0.14	0.67	0.10	7.3	7.7	419	378	220	180	91.8			13.7	10.00	18.00	1.00		0.10	0.01	347.73	2.00	0.04
PENDOB7	Oct-98	73.55	1.5	2.12	16.50	0.14	0.37	0.51	1.72	7.5	7.3	408	343	200	120			-105.0	11.6	5.00	13.00	1.30		0.02	0.03	261.51	4.00	0.05
PENDOB7	Feb-99	81.10	1.17	1.17	5.63	0.51	0.26	3.35	0.11	7.7		421	94	208	174			-335.7	9.9	14.20	7.39	0.10		0.05	0.01	323.46	2.13	0.02
PENDOB7	Jun-99	83.50	1.62	1.85	5.94	255.00	0.02	1.14	0.05	7.7	7.5	291	373	194	183	19.7		201.0	13.5	10.50	8.36	4.42		0.15	0.02	339.69	1.00	0.04
PENDOB7	Oct-99	21.8	1.96	2.12	7.08	0.00	0.09	0.13	0.05	7.2	7.8	373	425	187	192	12	0.82	12.0	12.9	12.20	9.30	0.89		0.05	0.10	289.87	2.24	0.16
PENDOB7	Jan-00	61.30	1.48	1.59	11.10	0.45	0.00	4.24	0.05	7.8		286		136	180					8.40	7.60	5.98	0.06	0.15	0.05	317.30	1.00	0.04
PENDOB7	May-00	83.60	1.73	1.80	7.28	0.39	0.01	4.19	0.05	7.8	7.7	397	388	188	183	16.1	1.75	305.0	10.7	9.10	10.50	5.81		0.05	0.04	343.23	1.00	0.04
PENDOB7	Oct-00	85.30	1.36	1.96	9.13	0.25	0.01	1.01	0.05	7.9	7.2	373	118	204	223	40.7	4.18	241.0	14.1	19.50	23.7			0.05		413.12	1.00	0.04
PENDOB7	Jan-01	77.00	1.36	1.92	9.39	0.30	0.01	2.67	0.05	7.8	7.3	409	357	208	78	22.6	2.73	248.0	6.0	8.40	10.30	0.85		0.05	0.13	204.62	1.00	0.04
PENDOB7	May-01	81.40	1.65	2.05	10.70	0.03	0.01	3.02	0.02	7.0	7.5	330	400	330	237	73.3	7.69	240.0	10.8	7.60	11.50	4.65		0.15	0.13	409.00	1.00	0.04
PENDOB7	Sep-01	85.20	1.80	2.46	12.90	0.00	0.00	0.05	0.01	7.5	7.4	388	364	224	185	26	2.6	253.0	12.4	7.00	11.90	4.27	0.40	0.15	0.13	351.52	1.00	0.05
PENDOB7	Jan-02	54.00	36.40	2.25	49.80	0.03	0.01	1.07	0.08	8.3	7.5	303	351	214	192	69	7.25	319.0	9.5	8.90	4.20	0.66	0.40	0.16	0.13	348.99	1.00	0.07
PENDOB7	May-02	72.60	6.88	2.00	15.00	0.19	0.01	2.50	0.04	7.5	8.2	393	191	180	208	33.6	3.62	182.0	12.6	7.90	11.00	0.75	0.30	0.05	0.04	370.02	3.00	0.05
PENDOB7	Sep-02	91.80	1.43	2.24	7.70	0.03	0.00	0.05	0.01	7.7	7.6	370	312	220	196	37.1	3.91	291.0	10.6	7.90	11.10	2.97	0.39	0.15	0.13	364.55	1.00	0.04
PENDOB7	Jan-03	83.80		2.03							7.10	375	313	194	212													0.04
PENDOB7	May-03	93.50		2.13						7.50	7.50	374	148	99	136													0.04
PENDOB7	Sep-03	82.30	1.46	1.87	6.92	0.27	0.00	2.97	0.02	8.20	7.40	338	328	164	181	26.1	2.45	330.0		8.20	10.90	1.26	0.30	0.05	0.04		2.50	0.04
PENDOB7	Jan-04	83.20		1.80							7.20	323	275	184	164			217.0	9.0									0.04
PENDOB7	May-04	75.70		1.25							7.34	307	416	182	174	38.6	3.7	120.0	12.2									0.03
PENDOB7	Sep-04	76.00	1.16	1.42	6.54	0.06	0.00	0.16	0.005	7.54	7.36	345	366	179	124	52.6	5.23	251.8	10.8	7.52	11.30	0.85	0.05	0.05	0.04	166.00	2.50	0.03
PENDOB7	May-05	87.40		1.44							7.83	315	380	182		65	6.7		11.6									
PENDOB7	Sep-05	137.00	1.67	2.20	5.83	0.31	0.22	0.33	0.015	7.70	7.32	369	494	170	157	23.6	2.53	153.1	11.3	10.00	13.50	0.97	0.29	0.15	0.13		2.50	0.03
PENDOB7	May-06	89.00		2.02							7.41	375	440	186	170	20.5	2.15	-21.2	10.5									
PENDOB7	Sep-06	86.50	2.35	1.49	5.47	0.32	0.30	1.01	0.164	7.39	7.40	370	444	175	189	24.3	2.44	-18.0	11.6	24.60	13.10	0.96	0.03	0.05	0.04		0.75	0.03
PENDOB7	May-07	84.50		2.02							7.11	405	430	244	175	13.5	1.48	327.0	11.9									
PENDOB7	Sep-07	82.00	1.70	2.00	5.00	0.08	0.00	0.25	0.0025	8.03	7.07	400	479	200	162	29.9	3.1	105.0	10.6	7.00	11.00	2.00	0.10	0.04	0.03		1.00	0.04
PENDOB7	May-08	89.00		2.00							7.39	417	437	209	181	29.4	3	126.0	11.0									
PENDOB7	Sep-08	88.00	2.00	2.00	5.00	0.05	0.005	0.15	0.005	7.80	7.05	391	437	206	172	62	6.37	68.0	12.5	7.00	10.00	0.40	0.02	0.005	0.02		1.80	0.04
PENDOB7	May-09	78.00		2.00							6.52	423	411	219	233	22.1		-69.0	9.0									0.05
PENDOB7	Sep-09	92.00	2.00	2.00	5.00	1.25	1.24	5.38	0.01	7.40	6.78	379	456	232	161	7.5	1	158.0	10.1	7.00	6.00	0.20	0.17	0.01	0.01		1.40	0.04
PENDOB7	May-10	92.00		2.00							8.68	466	404	200	174	7.1	4.9	-83.0	10.1									0.04
PENDOB7	Sep-10	86.00	1.00	2.00	4.00	0.68	0.69	8.87	9.26	7.40	7.11	399	438	182	221	30.8	7.3	157.0	10.2	7.00	9.00	0.20	0.02	0.01	0.01		1.70	0.02
PENDOB7	May-11	89.00		2.00							7.20	329	465	221	212	31.5	7.2	-70.0	10.4									0.04
PENDOB7	Sep_11	93.00	2.00	2.00	4.00	0.18	0.39	1.23	0.01	7.40	7.31	453	402	159	107	10.9		-98.0	11.0	7.00	7.00	0.20	0.02	0.01	0.20		1.40	0.04
PENDOB7	May-12	97.00		2.00							8.70	426	301	167	320	11.8		-37.0	12.0									0.03
PENDOB7	Sep-12	97.00	2.00	2.00	4.00	2.00	0.40	0.78	0.01	7.80	7.30	426	471	229	241	20.1		-65.0	10.3	5.00	7.00	0.20	0.02	0.01	0.01		0.20	0.03
PENDOB7	May-13	89.00	2.00	2.00	4.00	0.39	0.313	6.09	<0.01		8.00		442		243		5.17		9.9	7.00	5.00	0.70					0.36	
PENDOB7	Nov-13	86.00	2.00	2.00	4.00	0.51	0.196	8.94	<0.01	7.80	8.15	446	470	277	237	53.2	6.05		8.8	7.00	6.00	1.90	0.14	0.05	<0.01		0.61	
PENDOB7	May-14	92.00		2.00						8.23		413	420	225	240		6.46		12.7									
PENDOB7	Oct-14	98.00	2.00	2.00	5.00	0.43	0.36	5.11	3.14	8.20	6.96	451	420	227	384		2.76		15.9	7.00	4.00	0.20	0.11	<0.01	<0.01		0.44	0.02

BASELINE STATISTICS

PENDOB7	2 std deviation	20.12	0.98	1.34	8.24	120.08	0.42	3.16	1.02	0.6	0.5	104	61	68	66					7.38	7.28	4.38	0.39	0.15	0.14	112.11	4.54	0.05
PENDOB7	Average	73.83	1.76	2.26	9.70	14.43	0.14	1.52	0.22	7.6	7.4	349	366	179	193					9.36	9.90	2.23	0.18	0.11	0.07	335.95	2.63	0.05
PENDOB7	Lower Limit	53.71	0.78	0.92	1.46	0.00	0.00	0.00	0.00	7.0	6.9	245	305	112	127					1.98	2.63	0.00	0.00	0.00	0.00	223.83	0.00	0.00
PENDOB7	Upper Limit	93.94	2.74	3.60	17.93	134.51	0.57	4.68	1.24	8.2	7.9	453	427	247	260					16.74	17.18	6.61	0.56	0.26	0.21	448.06	7.16	0.10

Rogue values removed from statistical calculation
Half detection limit

BASELINE EXCEEDANCES
Lower than baseline
Higher than baseline

Hydrochemical Baseline Data - OB9a

LIMESTONE

OB9a	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l $CaCO_3$	mg/l $CaCO_3$	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Total Mn	Mn	Total Fe	Fe	lab pH	Field pH	lab EC	Field EC	lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	PO4	NO2	TDS	TOC	Mg/Ca
PENDOB9a	Apr-96	74.80	1.26	12.40	6.84	0.01		0.05	0.02	8.1		425		205	250					10.80	8.96	0.05		0.25	0.01	420.39	0.50	0.28
PENDOB9a	Aug-96	69.50	1	10.30	18.6	0.05	0.20	0.24	0.05	7.4		440		192	240				9.4	5.00	8.29	0.10		0.05	0.05	405.94	1.90	0.25
PENDOB9a	Nov-96	71.20	1	11.40	6.75	0.05	0.01	0.58	0.05	7.6	8.6	432	429	182	250					5.00	41.30	0.05		0.19	0.01	441.95	2.30	0.27
PENDOB9a	Apr-97	72.10	0.5	11.80	6.50	0.05		0.72	0.05	7.3	7.6	393	426	190	300		6.2	134.0	10.2	5.00	6.10	0.05		0.24	0.01	468.35	0.90	0.27
PENDOB9a	Jun-97	77.00	0.9	13.60	6.30	0.02		0.09		8.5	7.2	440	422		280			162.5	7.8		0.00					439.40	1.00	0.29
PENDOB9a	Oct-97	72.90	1.1	11.80	1.10	0.01	0.01	0.33	0.01	7.9	7.5	358	359	250	260			128.7		10.00	5.00	0.11	0.13	0.03	0.08	419.47	0.00	0.27
PENDOB9a	Feb-98	71.90	1.5	15.10	52.5	0.03	0.03	0.03	0.03	7.6	7.1	450	382	260	260	24	2.99	-63.0	8.1	14.00	21.00	0.03		0.04	0.04	493.36	1.00	0.35
PENDOB9a	Jun-98	82.45	1.3	14.74	12.00	0.03	0.03	0.10	0.07	7.5	7.0	463	434	270	240			-12.8	14.0	6.00	8.00	0.50		0.06	0.01	417.95	3.00	0.30
PENDOB9a	Oct-98	73.23	1.1	13.15	17.5	0.03	0.03	0.05	0.11	7.6	6.9	466	344	250	160	46.2			13.6	6.00	6.00	0.25		0.03	0.03	312.62	2.00	0.30
PENDOB9a	Feb-99	3.51	0.5	0.64	3.83	0.05	0.03	0.72	0.05	7.6	7.2	509	300	244	205	15.9		124.0	9.9	10.30	7.02	0.10		0.05	0.01	276.14	1.00	0.30
PENDOB9a	Jun-99	74.40	1.09	14.40	7.64	21.10	0.01	0.49	0.05	8.2	7.5	334	407	228	209	31.3	3.22	78.0	12.1	11.00	6.64	0.44		0.15	0.02	370.82	1.00	0.32
PENDOB9a	Oct-99	88.60	1.48	14.40	9.99	0.02	0.05	0.24	0.05	7.4	7.1	378	514	229	209	17.2	1.84	60.0	12.0	10.20	6.87	0.44		0.05	0.02	387.13	5.76	0.27
PENDOB9a	Jan-00	78.00	1.73	13.30	9.26	0.02	0.01	0.19	0.05	6.1	7.3	394	335	187	211				9.5	8.80	7.30	2.31	0.06	0.15	0.02	378.35	19.90	0.28
PENDOB9a	May-00	76.60	1.19	12.40	8.00	0.05	0.02	1.16	0.05	7.8	7.6	445	447	238	220				12.9	9.10	7.20	4.44		0.05	0.12	387.57	2.08	0.27
PENDOB9a	Oct-00	81.10	0.50	12.20	8.55	0.05	0.02	0.05	0.05	7.9	7.0	425	221	252	213	66	6.6	135.2	13.1	9.00	7.20			0.05		378.53	1.00	0.25
PENDOB9a	Jan-01	80.80	0.50	12.50	7.67	0.05	0.01	0.26	0.13	7.1	7.3	434	497	244	210	15.2	1.21	-180.3	13.2	9.60	7.70	0.85		0.05	0.14	376.15	1.00	0.26
PENDOB9a	May-01	81.50	1.04	12.40	10.00	0.03	0.03	0.19	0.02	7.5	7.4	350	445	236	224	20.3	2.15	-49.0	12.7	11.70	7.60	0.88		0.15	0.13	398.73	1.00	0.25
PENDOB9a	Sep-01	83.00	1.16	13.10	11.80	0.00	0.02	0.15	0.04	7.6	6.6	432	415	258	217	17	1.7	48.4	16.6	10.40	8.30	0.90	0.40	0.15	0.13	393.74	1.00	0.26
PENDOB9a	Jan-02	52.50	15.00	10.70	24.60	0.03	0.02	0.64	0.03	8.3	7.3	300	402	240	282	25.8	3.09	159.0	7.8	12.10	0.35	0.88	0.40	0.16	0.13	398.87	1.00	0.34
PENDOB9a	May-02	69.90	1.04	10.80	9.90	0.03	0.02	0.10	0.04	7.4	8.0	405	461	232	259	26	2.56	17.0	15.6	5.60	56.30	0.20	0.30	0.05	0.04	469.87	1.00	0.25
PENDOB9a	Sep-02	81.50	0.88	12.50	8.30	0.12	0.05	0.05	0.04	7.7	7.5	412	380	253	217	13.8	1.46	23.0	10.6	11.50	8.10	0.89	0.39	0.15	0.13	388.78	1.00	0.26
PENDOB9a	Jan-03	78.20		13.00							6.7	430	382	240	225													0.27
PENDOB9a	May-03	92.30		15.40						7.60	74.0	430	315	402	215													0.28
PENDOB9a	Sep-03	81.30	0.98	12.80	9.00	0.025	0.00	0.05	0.005	8.10	7.2	367	394	216	229	26.7	2.19	124.0	13.5	10.80	9.20	0.20	0.30	0.05	0.04		2.50	0.26
PENDOB9a	Jan-04	83.10		13.10							7.2	425	318	234	218			137.0	7.2									0.26
PENDOB9a	May-04	96.40		12.50							7.6	475	495	205	224	27.1	2.2	326.0	16.4									0.21
PENDOB9a	Sep-04	78.40	0.91	11.90	8.67	0.025	0.0005	0.05	0.005	7.69	7.7	430	455	236	186	25.3	2.55	122.1	11.4	10.70	9.28	0.20	0.03	0.05	0.04	255.00	2.50	0.26
PENDOB9a	May-05	82.50		11.30							7.8	383	500	244		45.7	4.56		11.9									
PENDOB9a	Sep-05	84.20	0.95	13.10	7.92	0.025	0.0015	0.05	0.0015	7.85	7.5	442	542	222	209	29.9	3.23	225.7	13.6	10.00	10.40	1.47	0.64	0.15	0.13		2.50	0.26
PENDOB9a	May-06	84.40		13.10							7.8	432	497	222	223	66.2	7.39	215.0	10.1									
PENDOB9a	Sep-06	75.00	1.45	11.40	7.25	0.025	0.025	0.615	0.05	7.67	7.6	439	501	232	236	29.2	2.76	149.6	10.9	10.00	10.40	0.20	0.07	0.05	0.04		0.75	0.25
PENDOB9a	May-07	91.30		14.10							7.4	461	485	260	221	56.5	6.06	250.6	11.4									
PENDOB9a	Sep-07	77.00	0.90	13.00	7.40	0.005	0.002	0.072	0.02	8.61	7.6	460	581	200	207	26.1	2.5	16.0	13.6	10.00	8.00	0.40	0.10	0.04	0.03		2.00	0.28
PENDOB9a	May-08	81.00		13.00							7.9	472	455	238	217	78.4	7.8	158.0	16.0									
PENDOB9a	Sep-08	108.00	1.00	6.00	8.00	0.01	0.005	0.2	0.01	7.70	7.2	482	541	255	240	32.1	3.36	308.0	13.1	6.00	16.00	1.30	0.02	0.005	0.005		2.00	0.09
PENDOB9a	May-09	99.00		5.00							7.1	514	531	260	375	14.2		136.0	9.2									0.24
PENDOB9a	Sep-09	112.00	1.00	6.00	8.00	0.05	0.01	0.2	0.02	7.40	9.6	469	519	274	193	43	4.8	148.0	11.1	7.00	17.00	0.90	0.01	0.01	0.01		1.90	0.09
PENDOB9a	May-10	82.00		13.00							8.4	512	420	248	178	40.9	6.8	117.0	10.4									0.32
PENDOB9a	Sep-10	79.00	1.00	13.00	6.00	0.02	0.01	0.39	0.01	7.50	7.4	471	458	245	250	60	6.9	107.0	11.7	11.00	10.00	0.30	0.01	0.01	0.01		1.60	0.17
PENDOB9a	May-11	81.00		13.00							7.8	382	454	248	247	46.6	4.9	47.0	10.1									0.26
PENDOB9a	Sep-11	83.00	1.00	14.00	6.00	0.01	0.01	0.01	0.01	7.60	6.9	510	434	253	229	47.9		58.0	12.8	12.00	11.00	3.40	0.01	0.01	3.40		1.40	0.09
PENDOB9a	May-12	88.00		15.00							8.5	485	336	241	273	58.3		110.0	12.8									0.28
PENDOB9a	Sep-12	89.00	1.00	15.00	7.00	14	0.01	0.01	0.01	8.10	7.7	489	485	250	267	41.4		78.0	11.6	10.00	11.00	0.20	0.01	0.01	0.01		0.20	0.02
PENDOB9a	May-13	90.00	1.00	15.00	7.00	0.011	<0.002	0.27	<0.01		8.1		495		275		9.08		9.7	11.00	10.00	0.30	0.01		<0.01		0.24	
PENDOB9a	Nov-13	70.00	<1	13.00	6.00	0.006	0.003	0.1	<0.01	8.00	7.94	483	520	297	228	61.3	7.13		9.3	11.00	12.00	2.00	0.02	0.06	<0.01		0.66	
PENDOB9a	May-14	64.00		12.00							8.1	458	460	251	258		6.46		13.1									
PENDOB9a	Oct-14	86.00	1.00	16.00	8.00	0.016	0.006	0.43	0.09	8.20	7.25	498	460	244	225		2.91		13.7	11.00	10.00	0.30	0.04	0.02	<0.01		0.20	0.19

BASELINE STATISTICS

PENDOB9a	2 std deviation	10.43	0.72	2.56	5.67	9.93	0.10	0.62	0.06	0.6	0.9	80	139	57	57					5.29	4.11	0.67	0.36	0.15	0.10	101.14	9.01	0.05
PENDOB9a	Average	77.00	1.05	12.88	7.75	1.20	0.03	0.31	0.05	7.6	7.3	415	391	230	227					8.94	6.76	0.34	0.20	0.10	0.05	398.14	2.57	0.28
PENDOB9a	Lower Limit	66.57	0.32	10.32	2.08	0.00	0.00	0.00	0.00	7.1	6.4	335	252	174	170					3.64	2.65	0.00	0.00	0.00	0.00	297.00	0.00	0.23
PENDOB9a	Upper Limit	87.44	1.77	15.45	13.42	11.13	0.13	0.93	0.11	8.2	8.2	495	529	287	284					14.23	10.87	1.00	0.55	0.25	0.15	499.29	11.59	0.33

Rogue values removed from statistical calculation
Half detection limit

BASELINE EXCEEDANCES
Lower than baseline
Higher than baseline

Hydrochemical Baseline Data - OB9b
Drift layer

OB9b	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l $CaCO_3$	mg/l $CaCO_3$	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Total Mn	Mn	Total Fe	Fe	lab pH	Field pH	lab EC	Field EC	lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	PO4	NO2	TDS	TOC	Mg/Ca
PENDOB9b	Apr-96	49.40	2.94	5.67	43.50	0.93	0.00	0.04	0.01	8.3		466		143	180					39.2	37.40	0.03		0.25	0.00	398.00	0.70	0.19
PENDOB9b	Aug-96	46.40	2.71	4.87	60.30	0.90	1.01	0.17	0.05	7.6		493		158	200					33	36.20	0.05		0.05	0.01	428.65	5.40	0.17
PENDOB9b	Nov-96	44.50	2.72	4.66	68.20	0.46	0.39	0.05	0.05	7.7	8.5	482	515	151	220				8.9	30.00	11.60	0.05		0.21	0.01	430.79	6.60	0.17
PENDOB9b	Apr-97	31.10	1.95	4.31	73.10	0.47	0.05	15.10	0.05	7.8	7.4	485	526	175	260				8.2	25.00	34.80	0.05		0.46	0.01	488.08	3.20	0.23
PENDOB9b	Jun-97	50.00	1.3	4.50	51.00	1.28	0.00	0.02	0.00	8.80	7.8	455	190		240			71.1	14.3		22.00					399.60	1.20	0.15
PENDOB9b	Oct-97	49.80	1.56	4.21	58.40	0.88	0.87	0.08	0.01	8.3	7.7	428	347	215	240				12.6	14.00	30.00	0.20	0.01	0.02	0.01	451.89	0.00	0.14
PENDOB9b	Feb-98	48.50	2.6	4.79	80.20	11.40	0.85	0.03	0.03	7.6	6.5	432	508	250	260		8.5		10.2	19.00	25.00	1.30		0.09	0.11	499.67	2.00	0.16
PENDOB9b	Jun-98	65.58	1.6	5.78	37.00	0.00	0.03	0.80	0.09	7.6	7.2	481	465	250	260	68.3			12.1	85	22.00	0.80		0.17	0.01	535.25	3.00	0.15
PENDOB9b	Oct-98	60.83	1.7	5.34	49.50	0.18	0.37	0.41	0.05	7.6	6.5	478	393	250	300	63	6.3	173.8	15.0	33.00	12.00	0.60		0.09	2.60	532.08	4.00	0.15
PENDOB9b	Feb-99	59.40	1.63	4.89	35.30	1.50	0.38	21.90	0.05	7.5	7.4	507	420	244	265			179.0	6.5	12.30	10.30	0.10		0.37	0.03	448.05	1.00	0.14
PENDOB9b	Jun-99	71.60	1.66	6.44	21.80	785.00	0.01	12.70	0.05	8.1	8.4	336	450	228	192	36.5	3.45	164.9		10.60	7.43	1.77		0.15	0.02	355.77	1.00	0.15
PENDOB9b	Oct-99	88.50	2.05	6.51	30.10	2.36	1.64	20.50	0.05	7.6	8.1	365	482	232	205			32.2		11.30	10.30	0.44		0.05	0.10	401.14	6.20	0.12
PENDOB9b	Jan-00	74.00	1.55	5.95	22.10	0.25	0.00	0.63	0.05	6.9	7.6	404	336	200	206			225.0		7.30	7.00	1.49	0.06	0.15	0.02	370.93	17.5	0.13
PENDOB9b	May-00	80.70	1.67	6.07	23.70	0.24	0.04	1.91	0.05	7.8	7.6	452	451	236	225	16.1	1.7	100.0	11.6	7.90	8.6	2.26		0.05	0.03	405.57	1.00	0.13
PENDOB9b	Oct-00	83.60	1.06	5.62	19.80	2.78	1.38	49.30	0.26	7.8	7.0	409	135	260	280	18.2	1.91	10.0	13.5	7.30	6.5			0.68	0.00	467.80	1.00	0.11
PENDOB9b	Jan-01	75.60	1.46	5.64	18.00	134.00	0.29	5300.00	0.05	7.8	7.2	413	516	230	228	15.71	1.82	141.0	8.4	6.50	9.3	0.85		0.05	0.14	396.04	1.00	0.12
PENDOB9b	May-01	87.80	1.26	6.28	16.50	0.00	0.15	0.00	0.01	7.2	7.5	370	444	235	230	21.6	2.22	187.0	10.9	9.10	8.5					410.20		0.12
PENDOB9b	Sep-01	88.60	1.13	6.06	17.30	3.72	1.75	83.70	1.26	7.6	7.4	436	400	297	217	33	3.38	151.0	14.3	6.60	9.80	0.90	0.40	0.15	0.13	382.38	1.00	0.11
PENDOB9b	Jan-02	53.50	13.50	4.88	27.80	20.60	0.01	331.00	0.04	8.4	8.5	305	384	244	222	54.9	6.32	247.0	11.3	8.20	0.35	0.88	0.40	0.16	0.13	331.85	1.00	0.15
PENDOB9b	May-02	77.50	1.83	5.23	16.80	27.10	0.85	265.00	0.01	7.4	8.3	392	263	240	120	21.8	1.95	13.0	15.0	5.80	58.90	0.20	0.30	0.23	0.04	313.78	1.00	0.11
PENDOB9b	Sep-02	92.90	0.98	6.16	11.60	9.85	1.39	40.40	0.06	7.8	7.6	433	395	247	246	10.1	1.07	75.0	12.6	8.60	8.20	0.89	0.39	0.15	0.13	431.18	1.00	0.11
PENDOB9b	Jan-03	104.00		9.18							6.80	436	369	248	242													0.15
PENDOB9b	May-03	103.00		9.93						7.50	7.60	437	363	375	210													0.16
PENDOB9b	Sep-03	97.90	0.97	8.04	9.77	0.18	0.0005	0.05	0.005	7.70	7.20	376	427	215	261	40.1	3.59	218	15.0	8.96	8.10	0.43	0.30	0.05	0.04		2.50	0.14
PENDOB9b	Jan-04	113.00		3.27						7.10		490	325	245	218			137	7.2									0.05
PENDOB9b	May-04	209.00		12.30							7.50	440	540	405	246	22.6	2	328	15.3									0.10
PENDOB9b	Sep-04	100.00	0.95	5.26	7.98	4.63	0.0005	189.00	0.005	7.51	7.66	441	465	245	178	34.1	3.62	198	10.8	6.88	9.60	0.73	0.03	0.18	0.04	242.00	2.50	0.09
PENDOB9b	May-05	154.00		8.86							7.64	405	460	252		23	2.52		11.4									
PENDOB9b	Sep-05	104.00	1.01	6.13	9.58	0.10	0.02	0.21	0.005	7.76	7.34	460	555	188	254	19.7	2.11	235	12.8	10.00	14.80	0.89	0.29	0.15	0.13		2.50	0.10
PENDOB9b	May-06	114.00		6.17							7.45	480	548	254	220	11	1.33	214	9.9									
PENDOB9b	Sep-06	99.30	1.61	4.98	8.63	0.32	0.37	0.83	0.05	7.48	7.43	465	528	233	239	40.9	4.04	159	12.0	10.00	16.60	0.20	0.03	0.05	0.04		0.75	0.08
PENDOB9b	May-07	104.00		5.73							6.99	512	534	304	245	26.6	2.75	203	12.9									
PENDOB9b	Sep-07	99.00	0.90	5.50	7.70	0.09	0.0005	0.19	0.036	8.35	7.40	480	605	220	207	12	1.2	26	12.6	7.00	14.00	2.60	0.10	0.04	0.03		2.00	0.09
PENDOB9b	May-08	110.00		6.00							7.39	535	151	265	238	61.2	6.1	530	12.6									
PENDOB9b	Sep-08	82.00	1.00	13.00	7.00	0.005	0.005	0.07	0.03	8.00	7.34	434	458	232	238	61.3	6.43	292	11.7	8.00	8.00	0.40	0.005	0.005	0.005		1.60	0.26
PENDOB9b	May-09	78.00		13.00							8.50	463	488	243	188	13.1		119	9.3									0.33
PENDOB9b	Sep-09	82.00	1.00	14.00	7.00	0.05	0.03	2.96	0.04	7.60	7.13	419	471	274	204	29.5	3.3	-85	11.3	9.00	9.00	0.20	0.01	0.01	0.01		1.90	0.28
PENDOB9b	May-10	106.00		5.00							8.45	547	454	195	187	10.7	5.4	66	10.4									0.08
PENDOB9b	Sep-10	78.00	1.00	6.00	6.00	3.48	2.73	15.20	11.7	7.40	7.45	411	432	218	249	39.6	5.1	172	11.3	7.00	3.00	0.02		0.01	0.01		1.70	0.08
PENDOB9b	May-11	110.00		5.00								426	505	277	251	27.9		28	10.2									0.07
PENDOB9b	Sep_11	113.00	1.00	6.00	7.00	0.12	0.01	0.35	0.01	7.60	7.06	568	492	155	245	4.1		50	12.0	8.00	17.00	0.20	0.01	0.01	0.20		1.50	0.28
PENDOB9b	May-12	120.00		6.00							8.57	537	375	192	300	15.8		98	13.2									0.08
PENDOB9b	Sep_12	118.00	1.00	6.00	7.00	5.00	0.06	0.01	0.01	7.70	7.58	465	533	247	312	32.5		110	11.8	7.00	17.00	0.20	0.01	0.01	0.01		0.20	0.01
PENDOB9b	May-13	120.00	<1	5.00	7.00	0.58	<0.002	4.39	<0.01		7.70		558		269		7.03		11.6	7.00	16.00	1.30	0.03		<0.01			
PENDOB9b	Nov-13	90.00	<1	5.00	6.00	0.82	<0.002	3.22	<0.01	7.70	7.95	468	490	237	234	55.1	6.4		9.6	7.00	16.00	2.40	0.02	0.05	<0.01		<0.2	
PENDOB9b	May-14	74.00		4.00							7.96	533	550	279	285		4.5		12.5									
PENDOB9b	Oct-14	120.00	1.00	6.00	7.00	1.80	0.624	2.79	0.12	7.90	7.44	523	520	262	273		2.18		13.6	8.00	16.00	0.20	0.04	<0.01	<0.01		<0.2	0.05

BASELINE STATISTICS

PENDOB9b	2 std deviation	32.49	1.15	1.49	41.97	370.88	1.19	2493.08	0.58	0.7	1.1	97	123	33	60					17.94	22.14	1.42	0.43	0.36	0.10	106.20	4.22	0.05
PENDOB9b	Average	66.17	1.81	5.42	40.32	52.57	0.51	305.96	0.12	7.7	7.5	438	447	236	237					14.28	17.15	0.73	0.16	0.19	0.04	433.44	2.39	0.14
PENDOB9b	Lower Limit	33.68	0.66	3.93	0.00	0.00	0.00	0.00	0.00	7.0	6.3	342	324	202	177					0.00	0.00	0.00	0.00	0.00	0.00	327.23	0.00	0.09
PENDOB9b	Upper Limit	98.65	2.95	6.91	82.29	423.45	1.70	2799.04	0.70	8.4	8.6	535	570	269	297					32.22	39.30	2.14	0.58	0.54	0.14	539.64	6.61	0.19

Rogue values removed from statistical
Half detection limit

BASELINE EXCEEDANCES
Lower than baseline
Higher than baseline

Hydrochemical Baseline Data - OB10a
Limestone layer

OB10a	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l $CaCO_3$	mg/l $CaCO_3$	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Total Mn	Mn	Total Fe	Fe	lab pH	Field pH	lab EC	Field EC	lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	PO4	NO2	TDS	TOC	Mg/Ca
PENDOB10a	Oct-97	72.60	1.46	18.00	7.75	0.01	0.01	0.67	0.06	7.9	7.4	445	340	202	260				11.5	12.00	17.00	58.46	0.26		0.07	504.86		0.41
PENDOB10a	Feb-98	64.30	1.30	19.90	62	0.11	0.03	0.54	0.03	7.4	6.5	464	471	270	300		6.2		8.8	18.00	26.00	1.90		0.06	0.06	559.57	1.00	0.52
PENDOB10a	Jun-98	65.33	0.40	17.15	8.80	0.03	0.03	0.25	0.03	7.4	7.4	483	451	240	240	14.7			11.1	8.00	14.00	0.25		0.01	0.05	406.83	2.00	0.44
PENDOB10a	Oct-98	64.36	1.10	17.31	11.00	0.03	0.03	0.68	0.03	7.5	7.7	481	340	240	160	62	6.6	194.0	10.8	37	18.00	3.50		0.03	3.00	350.55	3.00	0.45
PENDOB10a	Feb-99	64.20	0.05	17.20	4.28	0.05	0.01	0.29	0.05	7.4	7.2	498	90	236	131			150.0	8.4	15.20	7.90	2.65		0.05	0.01	271.41	1.00	0.45
PENDOB10a	Jun-99	65.30	1.08	19.70	5.76	26.50	0.01	0.51	0.05	8.1	7.4	340	416	232	208	25		137.0	14.3	12.30	7.68	1.77		0.15	0.02	367.58	1.00	0.50
PENDOB10a	Oct-99	82.40	1.22	20.70	6.78	0.00	0.01	0.64	0.05	7.4	8.1	371	474	228	194	11.2	1.03	184.5	11.5	15.00	7.93	0.44		0.11	0.02	371.34	2.08	0.42
PENDOB10a	Jan-00	69.40	1.12	18.80	6.44	0.03	0.00	0.26	0.05	6.2	7.0	404	314	216	212			255.0	0.0	8.20	8.10	2.17	0.06	0.15	0.02	373.09	15.00	0.45
PENDOB10a	May-00	73.00	1.14	18.20	6.13	0.05	0.05	0.05	0.05	7.9	7.3	431	442	224	220	42.8	4.81	274.0	10.1	8.80	7.10	3.13		0.05	0.06	386.11	1.00	0.42
PENDOB10a	Oct-00	71.70	0.50	17.60	6.50	0.05	0.02	0.05	0.05	7.8	6.9	403	484	256	268	30.1	3.2	162.0	12.4	8.60	7.80	0.00		0.05	0.00	439.78	1.00	0.41
PENDOB10a	Jan-01	71.90	0.50	18.20	5.99	0.05	0.01	0.35	0.05	7.4	7.6	432	513	242	263	26.4	3.05	180.0	8.6	8.60	8.10	0.85		0.05	0.13	435.24	1.00	0.42
PENDOB10a	May-01	66.60	1.16	17.70	6.46	0.11	0.01	0.68	0.05	8.2	7.8	384	433	204	260	39.8	3.47	166.0	11.4	7.50	9.40	2.20		0.15	0.13	428.56	1.00	0.44
PENDOB10a	Sep-01	69.80	1.05	18.10	8.72	0.00	0.00	0.46	0.01	7.6	7.2	416	370	254	263	32.6	3.36	158.5	11.7	8.90	8.60	0.90	0.40	0.15	0.13	437.22	1.00	0.43
PENDOB10a	Jan-02	44.70	10.20	15.10	16.80	0.03	0.00	0.53	0.01	8.3	7.6	287	368	232	213	36.9	4.1	197.0	9.7	9.20	0.35	0.88	0.40	0.16	0.13	310.93	1.00	0.56
PENDOB10a	May-02	61.80	0.95	16.00	7.95	0.03	0.01	0.32	0.005	7.4	8.2	385	483	230	295	58.5	5.92	141.0	14.6	3.80	105.00	0.20	0.30	0.05	0.04	555.70	1.00	0.43
PENDOB10a	Sep-02	68.00	0.75	17.20	5.87	0.03	0.01	0.05	0.005	7.7	7.4	412	488	223	219	42.8	4.68	234.0	9.6	8.50	8.90	2.30	0.30	0.15	0.13	378.99	3.80	0.42
PENDOB10a	Jan-03	73.10		17.60							6.6	388	353	242	260													0.40
PENDOB10a	May-03	81.60		18.90						7.6	7.5	260	354	140	205													0.38
PENDOB10a	Sep-03	61.90	0.90	15.50	6.34	0.025	0.0005	0.66	0.005	8.4	7.6	396	453	200	223	56	5.33	271.0	19.6	8.83	89.80	0.87	0.30	0.05	0.04		2.50	0.41
PENDOB10a	Jan-04	114.00		7.05								440	317	276	222			222.0	8.0									0.10
PENDOB10a	May-04	74.30		15.60							7.2	361	515	228	237	28.1	2.54	161.0	12.7									0.35
PENDOB10a	Sep-04	74.40	0.88	15.70	6.88	0.025	0.0005	0.05	0.005	7.6	7.6	432	452	227	170	46.7	4.88	269.8	9.5	8.32	9.36	0.94	0.03	0.05	0.04	261.00	2.50	0.35
PENDOB10a	May-05	79.60		15.00							7.7	402	450	228	228	38	3.75		11.6									
PENDOB10a	Sep-05	77.80	1.05	17.10	6.27	0.0509	0.0015	0.807	0.0015	7.6	7.2	451	492	218	209	20.8	2.29	180.1	12.0	10.00	11.60	4.87	0.29	0.15	0.13		2.50	0.36
PENDOB10a	May-06	79.10		17.00							7.4	436	497	224	236	21.3	2.56	202.7	10.0									
PENDOB10a	Sep-06	79.30	0.88	16.30	5.54	0.025	0.0015	0.625	0.015	7.7	7.3	498	452	229	222	24.7	2.48	186.1	11.3	10.00	10.80	1.15	0.07	0.05	0.04		2.78	0.34
PENDOB10a	May-07	62.40		12.80							6.9	820	484	290	219	32.1	3.9	252.5	11.4									
PENDOB10a	Sep-07	73.00	1.10	16.00	5.70	0.05	0.01	0.12	0.0038	8.6	7.8	220	549	220	205	20.4	2.7	288.0	9.2	8.00	9.00	5.00	0.10	0.04	0.03		1.00	0.36
PENDOB10a	May-08	79.00		16.00							7.4	481	479	242	224	38	3.8	556.0	11.5									
PENDOB10a	Sep-08	80.00	1.00	16.00	6.00	0.46	0.005	5.19	0.03	7.7	7.4	453	462	241	222	40.1	4.32	260.0	11.2	7.00	9.00	1.60	0.02	0.005	0.01		2.20	0.33
PENDOB10a	May-09	72.00		15.00							7.1	476	474	240	204	30.6		175.0	8.8									0.05
PENDOB10a	Sep-09	80.00	1.00	16.00	6.00	0.01	0.01	0.12	0.04	7.4	6.6	428	470	250	171	46.4	5.32	164.0	9.5	10.00	9.00	1.20	0.01	0.03	0.01		2.30	0.33
PENDOB10a	May-10	82.00		16.00								527	430	250	190	27	6.5	119.0	12.7									0.32
PENDOB10a	Sep-10	77.00	1.00	16.00	5.00	0.09	0.01	0.65	0.01	7.4	7.4	481	457	249	256	62	5.94	134.0	9.9	9.00	11.00	1.50	0.01	0.010	0.01		1.60	0.20
PENDOB10a	May-11	80.00		15.00								388	462	253	246	40.5		40.0	10.2									0.31
PENDOB10a	Sep_11	83.00	1.00	16.00	5.00	0.01	0.01	0.02	0.01	7.7	7.3	522	438	252	116	36.3		59.0	11.0	9.00	10.00	1.60	0.01	0.010	1.60		1.50	0.33
PENDOB10a	May-12	85.00		16.00							8.8	488	340	232	282	14.4		127.0	10.9									0.31
PENDOB10a	Sep_12	86.00	1.00	16.00	5.00	12	0.01	0.01	0.01	8.0	7.6	495	473	252	251	43.7		135.0	10.6	9.00	11.00	0.80	0.05	0.020	0.04		0.20	0.02
PENDOB10a	May-13	86.00	1.00	16.00	5.00	12	0.01	0.01	0.01	8.0	7.6	495	473	252	251	43.7		135.0	10.6	9.00	11.00	0.80	0.05	0.020	0.04		0.20	0.02
PENDOB10a	Nov-13	81.00	2.00	15.00	6.00	0.053	<0.002	1.11	<0.01	7.8	8.0	502	510	285	240	63	7.4		8.1	9.00	12.00	2.90	0.03	0.090	0.01		0.53	
PENDOB10a	May-14	84.00		14.00							7.6	469	480	257	219				13.2									
PENDOB10a	Oct-14	93.00	1.00	14.00	6.00	0.06	0.003	0.57	0.09	8.2	7.6	499	450	252	267		3.54		12.3	7.00	7.00	1.10	0.06	<0.01	<0.01		<0.2	0.15

BASELINE STATISTICS

PENDOB10a	2 std deviation	10.38	0.68	2.24	3.53	14.68	0.03	0.45	0.03	1.0	0.8	94	130	40	95					7.01	7.76	2.31	0.34	0.11	1.64	143.71	7.98	0.07
PENDOB10a	Average	69.30	1.00	18.35	7.05	2.08	0.02	0.42	0.04	7.5	7.3	427	421	234	229					10.93	10.13	1.65	0.24	0.08	0.28	410.16	2.51	0.44
PENDOB10a	Lower Limit	58.92	0.32	16.11	3.52	0.00	0.00	0.00	0.01	6.6	6.5	333	291	195	134					3.92	2.37	0.00	0.00	0.00	0.00	266.46	0.00	0.37
PENDOB10a	Upper Limit	79.68	1.69	20.59	10.58	16.75	0.04	0.87	0.07	8.5	8.2	521	551	274	325					17.93	17.90	3.95	0.58	0.19	1.92	553.87	10.48	0.51

Rogue values removed from statistical calculation
Half detection limit

BASELINE EXCEEDANCES
Lower than baseline
Higher than baseline

Hydrochemical Baseline Data - OB10b

DRIFT LAYER

OB10b	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l $CaCO_3$	mg/l $CaCO_3$	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Total Mn	Mn	Total Fe	Fe	lab pH	Field pH	lab EC	Field EC	lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	PO4	NO2	TDS	TOC	Mg/Ca
PENDOB10b	Oct-97	37.00	4.77	7.14	36.5	0.04	0.03	0.08	0.03	8.1	7.2	567	516	270	270				14.4	17.00	5.00	33.66	0.06	0.03	0.59	471.21		0.32
PENDOB10b	Feb-98	87.60	4.50	5.84	88.5	0.34	0.03	0.03	0.03	7.3	7.4	564	608	320	300		8.5		6.8	17.00	26	18.40		0.27	0.01	614.16	3.00	0.11
PENDOB10b	Jun-98	102.10	3.00	3.31	8.80		0.03	0.00	0.03	7.2	7.1	564	532	270		17			11.8	12.00	32	11.40		0.12	0.01	172.79	2.00	0.05
PENDOB10b	Oct-98	124.90	3.20	4.46	13.50	0.48	0.03	2.91	0.03	7.5	7.0	639	518	320	260	74	7.6	241.6	12.1	49	46	19.90		0.24	26.4	604.85	3.00	0.06
PENDOB10b	Feb-99	116.00	4.11	3.56	5.91	1.65	0.06	38.40	0.20	7.1	7.1	602	163	272	210			236.0	8.2	26.70	9.34	14.14		2.96	0.69	439.88	1.00	0.05
PENDOB10b	Jun-99	112.00	3.56	3.74	6.87	3060.00	0.01	29.50	0.05	8.1	7.6	395	514	254	230	51		204.0	13.6	12.60	8.12	17.24		0.15	0.02	444.96	1.00	0.06
PENDOB10b	Oct-99	136.00	2.94	3.69	7.46	1.31	0.01	27.50	0.05	7.4	7.9	464	608	274	248	36.9	3.15	200.0	12.1	17.50	6.86	14.62		0.53	0.13	492.35	2.13	0.05
PENDOB10b	Jan-00	129.00	2.95	3.72	7.48	1.72	0.00	0.90	0.05	6.7	7.5	503	427	200	243			300.0	0.0	8.20	6.70	10.85	0.06	0.15	0.02	465.59	18.70	0.05
PENDOB10b	May-00	113.00	3.27	3.00	6.59	0.05	0.05	0.05	0.05	7.8	7.2	508	520	248	232	63.9	7.28	255.0	0.0	9.80	7.10	21.16		0.05	0.02	447.13		0.04
PENDOB10b	Oct-00	144.00	8.17	4.11	13.70	1.94	0.03	10.20	0.56	7.6	6.5	593	209	348				203.0	14.5	13.70	15.40	0.00		0.15		199.82	2.72	0.05
PENDOB10b	Jan-01	109.00	6.97	3.08	8.13	5.27	0.04	82.80	0.05	7.5	7.0	525	616	262				195.0	7.0	15.80	7.70	15.23		0.10	0.32	166.42	2.19	0.05
PENDOB10b	May-01	119.00	3.23	3.21	6.37		0.03	0.00	0.24	8.1	7.4	372	530	220		56.1	5.23	220.0	9.3	10.60	7.40					150.08		0.04
PENDOB10b	Sep-01	123.00	3.69	3.37	12.30	5.44	0.01	146.00	0.02	7.4	6.8	561	503	320	263	36.1	3.93	289.9	11.3	13.40	8.30	15.84	0.40	0.15	0.64	501.58	1.00	0.05
PENDOB10b	Jan-02	102.00	16.70	3.66	22.30	5.01	0.00	136.00	0.01	8.4	7.2	480	538	296		48.6	9.85	250.0	9.7	16.60	0.35	5.52	0.40	0.16	0.13	167.83	1.00	0.06
PENDOB10b	May-02	94.80	5.08	2.71	10.00	22.80	0.05	454.00	0.31	7.1	7.8	465	481	220	262	56	5.47	185.0	13.3	5.20	78.10	3.48	0.30	2.11	0.04	521.52	3.10	0.05
PENDOB10b	Sep-02	125.00	7.06	3.48	9.02	13.80	0.03	343.00	0.06	7.3	7.0	561	587	271	380	37.5	4.09	260.0	9.7	14.30	9.70	28.80	0.30	1.01	0.13	662.18	10.80	0.05
PENDOB10b	Jan-03	194.00		10.70							6.8	513	424	298	308													0.09
PENDOB10b	May-03	130.00		3.49						7.40	7.3	191	387	174	261													0.04
PENDOB10b	Sep-03	112.00	3.46	3.02	8.28	9.84	0.0005	226.00	0.005	8.10	7.3	441	571	204	164	61.2	5.92	268	20.1	11.60	7.50	4.62	0.03	0.05	0.08		2.50	0.04
PENDOB10b	Jan-04	79.00		17.00							6.8	416	371	230	232			166	8									0.35
PENDOB10b	May-04	255.00		25.90							6.7	476	632	238	220	26.5	2.21	183	12.28									0.17
PENDOB10b	Sep-04	141.00	8.79	3.42	12.80	1.32	0.0005	31.70	0.005	7.17	6.8	641	642	318	202	33.4	3.44	293.6	11.1	19.50	11.30	6.91	0.03	0.05	0.04	399.00	11.10	0.04
PENDOB10b	May-05	242.00	15.20								7.2	495	500	300		48	5		10.2									
PENDOB10b	Sep-05	174.00	19.00	10.00	16.00	1.97	0.0015	45.70	0.015	7.07	6.7	684	768	311	247	35.2	3.73	258.3	12.4	36.30	26.90	26.30	0.29	0.31	0.13		9.45	0.09
PENDOB10b	May-06	213.00		15.60							7.2	518	593	235	233	45.5	5.31	2460	8.6									
PENDOB10b	Sep-06	163.00	7.14	8.44	8.33	3.83	0.00373	73.30	0.0075	7.29	7.0	647	624	303	271	40.8	3.97	187.4	13.3	10	12.20	4.12	0.07	0.05	0.04		2.30	0.09
PENDOB10b	May-07	127.00		6.08								559	571	280	247	20.1	2.22	233.7	12.1									
PENDOB10b	Sep-07	110.00	4.20	2.80	6.00	0.84	0.01	14.00	0.015	8.37	7.3	520	539	250	260	19.7	2	278	10.4	11	6.00	11.00	0.10	0.21	0.05		5.00	0.04
PENDOB10b	May-08	115.00		4.00							7.4	527	535	265	250	38.3		704	11.4									
PENDOB10b	Sep-08	120.00	4.00	3.00	7.00	0.39	0.005	4.27	0.02	7.60	6.9	558	725	282	261	30.5	3.2	291	12	11	8.00	3.50	0.06	0.005	0.01		2.80	0.04
PENDOB10b	May-09	117.00		4.00							6.8	598	584	304	231	37.9		187	8.5									0.05
PENDOB10b	Sep-09	146.00	4.00	4.00	7.00	0.07	0.01	1.19	0.03	7.00	6.5	595	657	352	203	43.4	4.8	101	11.2	12	6.00	2.30	0.03	0.03	0.01		0.80	0.05
PENDOB10b	May-10	132		3							8.02	648	535	244	210	17.1	5.4	124	9.9									0.04
PENDOB10b	Sep-10	120.00	5.00	3.00	6.00	3.54	0.02	17.30	0.01	7.10	7.1	592	576	290	237	52.4	6.6	119	10.8	12	6.00	2.20		0.01	0.06		2.90	0.03
PENDOB10b	May-11	126.00		4.00							7.1	537	602	270	574	37		31	8.7	12								0.05
PENDOB10b	Sep-11	144	6	4	6	0.09	0.01	1.34	0.01	7.1	6.72	692	583	241	496	26.7		68	11.4	12	6	2.7	0.01	0.01	2.7		2.3	0.05
PENDOB10b	May-12	129.00		4.00							8.6	582	397	292	335	29.4		161	10.2									0.05
PENDOB10b	Sep-12	141.00	5.00	4.00	6.00	4.00	0.2	0.01	0.07	7.70	10.7	637	628	335	381	60.2		174	10.7	8	6.00	2.00	0.07	0.03	0.01			0.06
PENDOB10b	May-13	165	6	9	6	1.094	<0.002	35.8	<0.01		7.7		552		313					7	5	1.7	0.01	0.05	<0.01		0.35	
PENDOB10b	Nov-13	154.00	8.00	12.00	6.00	4.00	<0.002	61.10	<0.01	7.50	7.7	605	590	311	348	69.2	8.06		9.4	9	7.00	4.00	0.02	0.09	<0.01		0.68	
PENDOB10b	May-14	88.00		3.00							7.6	497	510	264	258	7.67			11.3									
PENDOB10b	Oct-14	195.00	5.00	7.00	8.00	4.21	2.878	18.22	14.05	8.00	7.2	613	600	297	330		4.23		12.7	12	4.00	2.80	0.04	0.05	<0.01		0.41	0.04
BASELINE STATISTICS																												
PENDOB10b	2 std deviation	24.59	2.31	1.56	5.84	1844.15	0.03	86.75	0.31	0.7	0.7	157	112	84	53					9.74	5.56	6.75	0.39	1.63	0.58	133.24	10.68	0.01
PENDOB10b	Average	120.73	3.85	3.76	8.83	279.84	0.03	26.03	0.11	7.6	7.2	527	536	275	251					14.53	8.19	15.88	0.18	0.41	0.24	497.97	3.67	0.05
PENDOB10b	Lower Limit	96.14	1.54	2.20	2.99	0.00	0.00	0.00	0.00	6.9	6.5	370	424	191	198					4.79	2.63	9.13	0.00	0.00	0.00	364.73	0.00	0.04
PENDOB10b	Upper Limit	145.32	6.16	5.32	14.67	2123.99	0.06	112.78	0.41	8.3	7.9	685	647	360	303					24.26	13.75	22.63	0.56	2.04	0.83	631.20	14.35	0.06

Rogue values removed from statistical
Half detection limit

BASELINE EXCEEDANCES
Lower than baseline
Higher than baseline

Hydrochemical Baseline Data - OB12

LIMESTONE

OB12	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l $CaCO_3$	mg/l $CaCO_3$	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Total Mn	Mn	Total Fe	Fe	lab pH	Field pH	lab EC	Field EC	Lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	PO4	NO2	TDS	TOC	Mg/Ca
PENDOB12	Sep-04	82.90	2.74	17.80	14.30	0.12	0.03	2.30	<0.01	7.4	7.2	525	575	245	217	43.5	4.78	253	10	18.50	32.20	2.33	0.09	0.05	<0.08	320.00	<5	0.35
PENDOB12	May-05	113.00		12.80							7.4	540	454	258		43.0	4.70		11									
PENDOB12	Sep-05	109.00	1.80	15.20	6.68	<0.05	<0.003	<0.1	<0.003	7.8	7.2	535	597	192	242	40.3	4.13	201	14	<20	21.00	16.00	<0.58	<0.31	<0.26		<5	0.23
PENDOB12	May-06	116.00		15.10							7.1	589	644	224	290	44.5	4.80	188	11									
PENDOB12	Sep-06	108.00	2.36	13.80	6.24	0.03	0.025	0.24	0.05	7.2	7.1	521	616	260	252	43.1	4.74	241	13	10.00	22.60	4.46	0.03	0.05	0.04		0.75	0.21
PENDOB12	May-07	95.20		14.20							6.7	538	536	292	235	42.7	4.75	241	16									
PENDOB12	Sep-07	94.00	1.50	14.00	5.30	0.00	0.002	0.04	0.05	8.0	6.8	520	365	220	269	24.6	2.40	105	13	8.00	20.00	9.50	0.10	0.04	0.03		1.00	0.25
PENDOB12	May-08	99.00		15.00							7.4	565	550	260	230	72.5	7.30	860	13									
PENDOB12	Sep-08	102.00	2.00	15.00	5.00	0.005	0.005	0.02	0.005	7.7	7.3	526	560	270	253	34.7	4.12	192	10	7.00	17.00	2.40	0.005	0.005	0.005		1.90	0.24
PENDOB12	May-09	95.00		14.00							7.2	570	560	282	278	36.8	4.20	128	10									0.04
PENDOB12	Sep-09	103.00	2.00	15.00	5.00	0.010	0.01	0.90	0.040	7.3	6.7	488	549	292	197	41.6	4.75	43	10	8.00	14.00	1.00	0.020	0.020	0.010		2.70	0.24
PENDOB12	May-10	24.00		1.00							8.5	145	470	67	223	20.2	5.40	71	14									0.07
PENDOB12	Sep-10	99.00	3.00	14.00	5.00	0.020	0.01	3.76	0.010	7.3	7.7	558	520	229	271	48.8	4.77	123	12	8.00	15.00	1.20	0.010	0.010	0.010		1.90	0.14
PENDOB12	Sep_11	77.00	2.00	16.00	7.00	0.010	0.01	1.11	0.010	7.5	7.4	535	438	177	103	14.8		107	13	8.00	16.00	1.60	0.010	0.010	1.600		1.20	0.24
PENDOB12	May-12	95.00		16.00							8.4	535	384	174	278	26.4		128	10									0.28
PENDOB12	Sep-12	88.00	3.00	16.00	8.00	15.000	0.01	0.01	0.010	7.9	7.1	693	628	254	381	60.2		174	11	7.00	14.00	0.60	0.130	0.010	0.010		0.20	0.06
PENDOB12	May-13																											
PENDOB12	Nov-13	87.00	3.00	15.00	7.00	0.193	0.003	17.90	<0.01	7.7	8.17	545	600	246	279	70.9	8.25		9.3	8.00	19.00	4.80	0.150	0.060	0.080		0.71	
PENDOB12	May-14	76.00		13.00							8.89	510	380	264	168		4.80		12.7									
PENDOB12	Oct-14	67	3	18	10	0.084	0.007	3.57	0.08	8.1	7.87	460	0.42	213	195		3.06		11.4	8	12	<0.2	0.11	0.03	<0.01		1.3	0.269

Half detection limit

Hydrochemical Baseline Data - P1b

SURFACE LAYER

P1b	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l CaCO3	mg/l CaCO3	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Mn	Fe	lab pH	Field pH	lab EC	Field EC	lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	NO2	TDS	Mg/Ca
P1B	Nov-96	12.90	1.32	0.90	11.00	0.00	0.05	9.3	9.6	50	121	43	90				9.0	5.00	2.50				143.47	0.12
P1B	Apr-97	46.30	5.03	1.53	6.48	0.00	0.05		8.1		171	98	120				13.3	5.00	5.90				216.69	0.06
P1B	Jun-97	69.20	48.4	1.60	7.30	0.00	0.01	8.3	7.7	525	340	184	240			-106.4	16.7	9.00	6.00				434.30	0.04
P1B	Aug-97	45.00	0.47	1.10	6.00	0.00	0.00		7.6		603	102	300			103.7	18.4	7.00	6.00				431.57	0.04
P1B	Oct-97	24.40	7.07	0.95	6.07	0.15	0.01	7.8	8.1	149	159	66	100				14.1	5.00	5.00				170.65	0.06
P1B	Feb-98	35.20	2.9	1.33	29.40	0.14	0.03	7.9	6.5	233	203	110	110				5.9	17.00	5.00				225.20	0.06
P1B	Jun-98	60.75	1.00	1.85	11.50	0.51	0.08	7.9	6.9	348	315	210	240	24			14.0	6.00	3.00				377.49	0.05
P1B	Oct-98	46.11	0.80	1.34	10.00	0.46	0.03	7.7	6.9	438	343	80	120	61	6.1	-82.0	16.0	75	4.00				284.14	0.05
P1B	Jan-00	44.20	0.50	1.11	7.18	0.00	0.00	7.5	7.8	220	204	104	104			-180.0	5.4	6.10	0.90	5.18	0.06	0.02	192.07	0.04
P1B	May-00	101.00	0.50	2.04	6.80	0.01	0.05	7.5	7.7	443	513	230	45	44.5		210.0	15.7	7.00	5.40	2.46		0.04	180.20	0.03
P1B	Oct-00	26.70	0.50	0.81	5.18	0.08	3.17	8.2	7.3	160	280	148	163			-307.0	14.6	1.05	1.30				237.65	0.05
P1B	May-01	41.60	0.50	1.53	5.36	0.02	0.05	8.2		186		112						4.70	3.00				56.76	0.06
P1B	Sep-01	20.10	0.72	0.78	5.95	0.00	0.00	8.4		168		88						6.10	1.40	0.90		0.13	36.09	0.07
P1B	Jan-02	57.70	0.34	1.24	5.60	0.05	0.01	7.7		217		160						5.70	0.35	0.88		0.13	231.83	0.04
P1B	May-02	20.70	0.77	1.05	5.84		0.01	7.4		138		68						3.65	0.90	1.02		0.04	33.98	0.08
P1B	Sep-02	64.40	0.59	1.25	5.63	0.07	0.91	7.8		286		197	203					5.30	1.80	0.89		0.13	328.63	0.03
P1B	Jan-03	101.00		1.23					8.30	299	66	212	196											0.02
P1B	May-03	62.90		1.46				7.3		180		181												0.04
P1B	Sep-03	62.60	1.31	1.31	6.11			7.6		277		166						5.02	9.20	0.2		0.04		0.03
P1B	Jan-04	72.50		2.06					7.20	283	312	161	222			-76	7.2							0.05
P1B	May-04	109.00		1.90						279		164												0.03
P1B	Sep-04	45.80	0.69	2.10	5.58	0.01	0.01	7.5		347		110						5.74	4.85	0.02	0.03	0.04	214.00	0.08
P1B	May-05	55.60		1.15						457		177												
P1B	Sep-05	109.00	0.89	2.25	6.08	0.05	0.002	7.4		427		210						10.00	1.63	0.20		0.04		0.03
P1B	May-06	133.00		1.60					7.33	430	368	146	165.00	64.7	6.51	-131	13.5							
P1B	Sep-06	163.00	1.73	2.22	7.20	0.07	0.547	7.9	7.18	459	380	171	190.00	44.2	3.85	-94.1	19.4	10.00	20.10	0.02		0.04		0.02
P1B	May-07	99.60		1.91					7.13	397	411	246	180.00	43.2	4.02	-146	15.4							
P1B	Sep-07																							
P1B	May-08	59.00		2.00					7.02	328.00	242.00			93.10	9.30	291.00	9.30							
P1B	Sep-08																							
P1B	May-09	18.00		0.50						125.00	117.00	53.00	30.00	46.30		111.00	8.90							0.04
P1B	Sep-09	33.00	3.00	1.00	3.00	0.80	0.01	6.80	6.48	174.00	342.00	104.00	114.00	21.20	2.20	-56.00	16.80	5.00	5.00	0.20	1.00	0.01		0.05
P1B	May-10	7.00		1.00						100.00	363.00	13.00	169.00	49.70	8.30	-6.00	12.70							0.24
P1B	Sep-10	84.00	3.00	1.00	4.00	0.31	7.72	7.80	7.25	363.00	362.00	163.00	221.00	67.20	8.56	98.00	12.70	5.00	20.00	0.40	0.01	0.01		0.01
P1B	May-11	80.00		1.00						332.00	445.00	237.00	187.00	173.00		88.00	11.00							0.02
P1B	Sep_11	74.00	1.00	1.00	4.00	0.01	0.33	7.70	6.20	360.00	523.00	135.00	232.00	60.50		59.00	13.40	6.00	8.00	1.60	0.01	1.60		0.05
P1B	May-12	77.00		1.00					8.41	355.00	294.00	154.00	243.00	47.30		218.00	16.00							0.02
P1B	Sep_12	85.00	1.00	1.00	4.00	0.01	0.02	7.90	7.80	344.00	436.00	173.00	199.00	61.60		161.00	11.10	5.00	8.00	1.00	0.01	0.01		0.02
P1B	May-13	94.00	1.00	2.00	4.00	0.27	24.40		8.00		398.00	191.00			7.99		11.60	6.00		0.80	0.02	<0.01		
P1B	Nov-13	95.00	2.00	3.00	4.00	0.33	33.90	7.90	7.58	399.00	470	199.00	201.40		14.99		4.7	6.00	7.00	2.00	0.02	<0.01		
P1B	May-14	82.00		2.00					8.89	347.00	380	184.00	168.00		4.8		13.7							
P1B	Oct-14	115.00	1.00	2.00	4.00	0.10	0.14	8.10	7.53	382.00	0.41	184.00	195.00		3.75		14.7	3.00	8.00	0.60	0.03	<0.01		0.02

BASELINE STATISTICS

PENDP1b	2 std deviation	29.73	0.39	0.80	4.38	0.35	1.74	0.6	1.1	236	167	112	149					3.94	3.78	4.34	-	0.12	209.99	0.02
PENDP1b	Average	41.78	0.62	1.30	7.40	0.11	0.27	7.9	7.5	261	237	121	159					5.63	3.80	2.85	0.06	0.06	263.04	0.05
PENDP1b	Lower Limit	12.05	0.23	0.50	3.02	0.00	0.00	7.3	6.4	24	70	9	10					1.70	0.02	0.00		0.00	53.05	0.03
PENDP1b	Upper Limit	71.51	1.02	2.10	11.78	0.46	2.01	8.6	8.5	497	405	234	307					9.57	7.58	7.18		0.18	473.02	0.07

Rogue values removed from statistical calculation
Half detection limit

BASELINE EXCEEDANCES
Lower than baseline
Higher than baseline

Hydrochemical Baseline Data - P7a

Surface layer

P7a	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l CaCO3	mg/l CaCO3	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Mn	Fe	lab pH	Field pH	lab EC	Field EC	lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	NO2	TDS	Mg/Ca
PENDP7a	Nov-96	10.20	0.60	0.35	7.42	0.00	0.05	9.5	8.3	50		43	60				7.4	5.00	2.50				99.32	0.06
PENDP7a	Apr-97	36.40	8.72	0.92	5.01	0.00	0.05		8.3		100	69	80				13.5	11.00	2.50				162.20	0.04
PENDP7a	Aug-97	28.00	0.25	0.63	5.10	0.00			8.0		203	78	120			37.8	18.0	6.00	3.00				189.38	0.04
PENDP7a	Oct-97	11.50	1.09	0.77	5.63	0.09	0.01	7.4	7.3	210	202	105	120				12.9	5.00	5.00				175.49	0.11
PENDP7a	Feb-98	33.90	0.70	0.84	29.90	0.03	0.23	7.8	6.9	213	189	110	140		9.8		6.5	5.00	2.00				243.40	0.04
PENDP7a	Jun-98								7.1		161		120	91.2									146.40	
PENDP7a	Oct-98	5.47	0.90	0.48	11.80	0.09	0.03	7.0	7.3	201	164	120	100	62	6.3	-78.5	15.8	2.50	4.00				147.26	0.15
PENDP7a	Feb-99	11.70	0.50	0.83	4.47	0.18	1.99	6.4	5.8	120	685	44	70			-92.7	8.2	15.30	0.25				120.62	0.12
PENDP7a	Jun-99	35.60	0.50	1.14	5.35	0.12	3.92	6.5	6.6	180	216	88	73	86.6	6.7	-56.7	13.3	5.00	2.50				142.95	0.05
PENDP7a	Jan-00	36.10	0.50	0.80	5.61	0.00		7.5	7.7	179	148	92	78			-197.0	4.1	3.90	1.50	4.07	0.06	0.02	147.66	0.04
PENDP7a	May-00	54.60	0.50	0.91	4.01	0.04	0.89	7.5	7.5	278	194	134	93	119	12.14	-283.0	13.3	6.80	3.70	2.05		0.02	186.60	0.03
PENDP7a	Oct-00	37.90	0.50	0.40	4.87	0.10	6.53	7.8	6.8	211	48	116	160			-208.0	15.0	0.89	1.90				248.29	0.02
PENDP7a	Jan-01	44.10	0.50	0.99	5.61	0.04	0.81	7.1		235			112					5.30	2.30	4.15		0.13	200.57	0.04
PENDP7a	May-01	49.40	0.50	0.85	5.32	0.06	1.97	7.9		216		104						6.60	3.60				68.30	0.03
PENDP7a	Sep-01	52.40	0.89	0.81	8.51	0.00	0.00	7.3		223		140						5.20	4.90	0.90		0.38	73.99	0.03
PENDP7a	Jan-02	46.10	0.32	0.90	5.30	0.07	0.01	7.3		189		120						5.00	0.35	0.88		0.13	178.73	0.03
PENDP7a	May-02	48.50	0.37	0.96	7.17	0.08	0.01	7.1		258		152						7.30	1.80	0.90		0.04	67.12	0.03
PENDP7a	Sep-02	56.80	0.65	0.97	5.97	0.11	0.01	7.3		245		173						9.20	2.60	0.89		0.13	77.32	0.03
PENDP7a	Jan-03	59.30		1.16					7.1	269	146	162												0.03
PENDP7a	May-03	60.30		1.12				7.1		217		183												0.03
PENDP7a	Sep-03	59.40	1.29	0.97	6.25			7.1		289		161						12.00		0.2		0.04		0.03
PENDP7a	Jan-04	91.30		7.53					7.2	255	196	187	146			-143	2							0.14
PENDP7a	May-04	78.70		4.16						265		219												0.09
PENDP7a	Sep-04	49.30	0.47	0.92	5.71	0.06	0.005	7.5		302		173						8.60	2.58	0.2		0.04	155.00	0.03
PENDP7a	May-05	45.80		0.74						346		129												
PENDP7a	Sep-05	66.60	0.48	1.20	4.94	0.16	0.0015	7.4		308		169						10.00	1.30	0.2		0.04		0.03
PENDP7a	May-06	71.60		0.75					7.2	290	331	135	136	71.5	7.85	-66	10.5							
PENDP7a	Sep-06	78.30	1.40	3.12	5.22							125												0.07
PENDP7a	May-07	97.40		9.61					7.0	331	296	270	112	60.9	6.22	68.2	16.8							
PENDP7a	Sep-07	57.00	9.90	0.92	6.50	0.13	1,7	7.7	7.1	340	479	350	162	29.9	3.2	105	10.6	16.00	4.00	0.15		0.03		0.03
PENDP7a	May-08	58.00		1.00					7.0	338	298	167		22.3	2.2	89	8.1							
PENDP7a	Sep-08	74.00	7.00	1.00	7.00	0.55	2.03	7.6	6.8	335	398	180		66.4	7	14	13.2	8.00	4.00	0.8	0.01	0.03		0.02
PENDP7a	May-09	71.00		1.00						364	372	177	149	64.6	7.6	167	9							0.03
PENDP7a	Sep-09	76.00	1.00	2.00	6.00	0.22	0.02	7.6	6.6	305	413	175	146	65.6	6.7	-54	15.1	10.00	7.00		0.03	0.01		0.04
PENDP7a	May-10	82.00		1.00						399	61	194	37	49.3	7.2	83	13.2							0.02
PENDP7a	Sep-10	81.00	1.00	2.00	5.00	0.19	2.99	7.3	5.9	389	443	179	228	38.5	4.4	66	12.4	8.00	8.00	0.7	0.01	0.01		0.02
PENDP7a	May-11	79.00		1.00						298	404	199	180	74.9		-54	11.9							0.02
PENDP7a	Sep_11	72.00	1.00	1.00	5.00	0.04	0.74	7.5	6.2	360	384	137	177	45.8		-45	12.6	8.00	4.00	0.8	0.12	0.80		0.04
PENDP7a	May-12	84.00		2.00					7.8	521	325	210	263	13.8		142	16.1							0.04
PENDP7a	Sep_12	92.00	1.00	1.00	5.00	0.01	0.29	7.9	7.5	386	396	165	242	43		-1	12.4	7.00	24.00	1.7	0.01	0.01		0.02
PENDP7a	May-13	43.00	<1	1.00	5.00	0.19	14.3		7.8		251		121		10.32		9.7	8.00		0.9	0.03	<0.01		
PENDP7a	Nov-13	89.00	6.00	3.00	7.00	0.49	45.6	7.6	7.9	831	820	385	305				5.5	10.00	11.00	1.7	50.40	<0.01		
PENDP7a	May-14	77.00		2.00					8.4	417	440	217	198		1.99		13.3							
PENDP7a	Oct-14	120.00	1.00	4.00	6.00	0.30	25.06	7.9	7.3	423	0	199	219		2.96		17	7.00	12.00	<0.2	0.03	<0.01		0.03

BASELINE STATISTICS

PENDP7a	2 std deviation	17.62	0.45	0.41	2.48	0.11	4.03	1.6	1.2	78	72	62	60					4.09	2.25	3.18	-	0.34	106.76	0.02
PENDP7a	Average	40.84	0.61	0.74	5.58	0.05	1.37	7.5	7.4	206	175	96	102					5.61	3.03	2.79	0.06	0.14	156.83	0.03
PENDP7a	Lower Limit	23.22	0.16	0.32	3.10	0.00	0.00	5.9	6.3	128	103	34	42					1.52	0.78	0.00		0.00	50.07	0.01
PENDP7a	Upper Limit	58.46	1.06	1.15	8.05	0.17	5.41	9.1	8.6	284	248	157	162					9.70	5.28	5.98		0.48	263.59	0.05

Rogue values removed from statistical calculation

Half detection limit

BASELINE EXCEEDANCES

Lower than baseline

Higher than baseline

Hydrochemical Baseline Data - P15b

Surface layer

P15b	Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	su	su	microS/cm	microS/cm	mg/l CaCO3	mg/l CaCO3	%	ppm	mV	C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l
Site	Sample Period	Ca	K	Mg	Na	Mn	Fe	lab pH	Field pH	lab EC	Field EC	lab Alk	Field Alk	DO	DO	Redox	Temp	Cl	SO4	NO3	NH4	NO2	TDS	Mg/Ca
PENDP15b	Aug-97	33.00	0.43	0.43	6.20	0.00	0.00		7.5		272	94	140			-151.0	16.0	7.00	1.00				218.86	0.02
PENDP15b	Oct-97	33.90	0.36	1.04	5.21	0.19	1.32	2.6	7.2	186	240	1	160				13.4	11.00	5.00				253.22	0.05
PENDP15b	Feb-98	25.50	1.6	0.75	31.2	0.07	0.03	7.3	7.1	217	205	90	90	61			8.0	20.00	1.50				190.45	0.05
PENDP15b	Jun-98	36.74	0.40	0.70	8.80	0.17	2.67	7.0	6.6	245	266	140	220				12.8	22.00	1.50				341.38	0.03
PENDP15b	Oct-98	24.18	1.20	0.52	8.50	0.09	0.03	7.4	7.0	197	164	130	80	86	6.6	33.4	16.1	14.00	1.50				147.62	0.04
PENDP15b	Feb-99	23.90	0.50	0.05	2.95	0.02	0.23	7.2		181	68	80	39			-200.3	8.7	15.20	2.50				92.93	0.003
PENDP15b	Jun-99	10.40	2.70	0.31	3.95	0.24	2.06		6.5		468		100			-18.0	13.5	5.00	40.60				187.26	0.05
PENDP15b	Oct-99	28.30	0.50	0.33	3.36	0.12	0.94	7.5	8.6	157	219	86	45			11.0	17.4	12.80	2.50				103.75	0.02
PENDP15b	Jan-00	12.70	0.50	0.19	3.25	0.00	0.00	6.7		111	276	35	44			-32.0		9.30	0.60	1.81	0.06	0.02	82.05	0.02
PENDP15b	May-00	20.20	0.50	0.05	3.59	0.08	1.69	6.9	7.0	205	242	110	97	19.5	1.97	-370.0	14.0	9.50	0.10	2.39		0.04	155.94	0.004
PENDP15b	Oct-00					0.06	0.43																	-
PENDP15b	Jan-01	10.60	0.50	0.42	3.28	0.06	0.05	6.9		222		66	274					9.20	5.10	0.85		0.13	364.47	0.07
PENDP15b	May-01	22.60	0.79	2.5E-04	4.26	0.13	2.99	6.9		133		55	83					10.70	1.10	1.76		0.13	145.72	1.8E-05
PENDP15b	Sep-01	17.30	0.63	2.5E-04	3.67	0.12	4.14	7.2		197		96	117					17.90	0.35	2.11		0.13	189.09	2.4E-05
PENDP15b	Jan-02	14.40	0.31	3.0E-04	2.21	0.20	0.01	6.9	7.4	258		104	73					77.00	0.35	0.88		0.13	168.49	3.5E-05
PENDP15b	May-02	9.35	0.39	0.21	2.78	0.05	0.03	7.6		162		64	70					9.90	0.35	0.20		0.04	108.70	0.04
PENDP15b	Sep-02	19.00	0.45	2.5E-04	3.43			7.1		239		129						18.20	0.80	0.89		0.13	43.15	2.2E-05
PENDP15b	Jan-03	25.20		0.12					6.4	139	133	78	144											0.01
PENDP15b	May-03	26.20		0.20				6.4		199		166												0.01
PENDP15b	Sep-03	21.10	1.13	0.40	4.64			7.0		178		178						13.80	0.60	0.2		0.04		0.03
PENDP15b	Jan-04	19.00		0.057					6.8	168	212	174	92			46	5.6							0.00
PENDP15b	May-04	13.10		0.65						101		57												0.08
PENDP15b	Sep-04	18.20	0.80	0.39	4.57	0.10	0.005	7.0		230		124						16.30	0.15	0.2		0.04	125.00	0.04
PENDP15b	May-05	21.00		0.05						465		57												
PENDP15b	Sep-05	25.20	1.13	0.91	8.43	1.99	0.0015	6.6		278		115						10.00	0.743	0.2		0.04		0.06
PENDP15b	May-06	29.30		0.18					7.0	261	330	66	124	68.7	7.31	-104.1	11.9							
PENDP15b	Sep-06	24.60	3.11	0.37	9.34	0.27	17.6	7.0	6.8	5	355	87	160	46.8	4.14	-68.9	17.2	10.00	1.92	0.2		0.04		0.02
PENDP15b	May-07	28.80		0.72					6.3	243	297	168	122	41	4.2	-106.1	15.2							
PENDP15b	Sep-07	30.00	12.00	0.67	12.00	0.28	21	7.5	6.9	270	385		139	36.4	3.6	-82	12.5	13.00		0.15		0.03		0.04
PENDP15b	May-08	36.00		0.05					6.9	240	272	117	120	101.7		-53	17.7							
PENDP15b	Sep-08	8.00	0.50	0.50	2.00	0.06	1.6	7.6	7.2	50	79	18	25	80.5	8.38	285	13.1	3.00	3	0.5	0.06	0.04		0.10
PENDP15b	May-09	14.00		0.50					7.9	100	91	37	36	66.7		170	10.4							0.09
PENDP15b	Sep-09	21.00	1.00	1.00	4.00	0.11	3.25	7.6	7.0	121	143	58	53	67.3	7.3	98	11.9	6.00	7	0.9	0.00	0.01		0.04
PENDP15b	May-10	15.00		1.00						129	108	41	35	79.4	8.9	90	11.6							0.11
PENDP15b	Sep-10	20.00	1.00	1.00	2.00	0.22	1.65	7.8	7.6	100	116	18	73	68	7.3	64	12	5.00	6	0.7	0.01	0.01		0.05
PENDP15b	May-11	86.00		2.00						367	252	242	221	62.5		28	11.7							0.04
PENDP15b	Sep-11	11.00	1.00	1.00	4.00	0.02	0.19	7.8	7.4	99	0	30	68	75.1		46	13.3	8.00	6	0.8	0.01	0.80		0.04
PENDP15b	May-12	5.00		1.00					10.1	100	99	6	79	61.9		109	14.6							0.33
PENDP15b	Sep-12	19.00	1.00	1.00	3.00	0.01	0.01	8.0	7.3	118	108	45	92	73		121	11	5.00	5	0.6	0.01	0.01		0.09
PENDP15b	May-13	14.00	<1	<1	4.00	0.21	2.89		7.9		123		58		10.2		16.6	8.00		0.8	0.01	<0.01		
PENDP15b	Nov-13	15.00	<1	1.00	4.00	0.99	6.48	7.3	7.5	174	160	33	20	88.3	11.03		7	8.00	58	1.9	0.17	<0.01		
PENDP15b	May-14	17.00		2.00					8.4	164	140	40	25		6.62		14.9							
PENDP15b	Oct-14	48.00	1.00	2.00	8.00	0.01	2.08	8.1	7.3	301	310	112	171		5.23		16.4	10.00	19	0.2	0.03	<0.01		0.04

BASELINE STATISTICS

PENDP15b	2 std deviation	14.59	0.48	0.48	4.08	0.14	2.69	0.5	1.3	79	77	62	137					10.12	3.29	1.16	-	0.11	174.76	0.03
PENDP15b	Average	25.30	0.57	0.38	4.75	0.10	1.18	7.1	7.2	186	236	89	121					12.58	1.90	1.78	0.06	0.09	190.21	0.02
PENDP15b	Lower Limit	10.71	0.10	0.00	0.67	0.00	0.00	6.6	5.9	107	159	28	0					2.46	0.00	0.62		0.00	15.45	0.00
PENDP15b	Upper Limit	39.90	1.05	0.86	8.83	0.24	3.88	7.6	8.5	266	312	151	258					22.71	5.19	2.95		0.20	364.97	0.05

Rogue values removed from statistical calculation

Half detection limit

BASELINE EXCEEDANCES

Lower than baseline

Higher than baseline

Appendix E

Impact Assessment Methodology

1 Introduction

1.1 Background and Objectives

Stantec UK Limited (Stantec) has developed an impact assessment methodology for determining the degree of impact of quarrying activities on neighbouring receptors. The objective of this technical note is to outline a methodology for assigning a degree of impact to potential effects on neighbouring receptors that have been identified in a Hydrogeological Impact Assessment (HIA). This methodology will also determine whether an effect is significant and if any mitigation measures are required. This methodology is to be applied across all HIAs undertaken by Stantec to ensure a consistent approach.

2 Impact Assessment Methodology

2.1 Overview

A source-pathway-receptor methodology has been applied to the impact assessment. In the context of the impact assessment for the Site these elements may be defined as:

Source: Activities associated with mineral extraction, including dewatering, water quality effects, and the quarry discharge;

Pathways: The groundwater flow pathways or hydrogeological linkages identified in the conceptual model;

Receptors: Abstractions, designated sites, rivers, aquifers and other key water features. The risk assessment process can be subdivided into a number of steps as described below.

2.2 Identification of Receptors

The identification of a risk requires the presence of all three elements in the source-pathway-receptor chain. The source for this assessment is, by definition, the proposed extraction activities within the Application Area. The first task in the risk assessment process is therefore to identify any relevant receptors. As a minimum, the following should be considered:

- Neighbouring groundwater and surface water abstractions including both licenced and private supplies;
- Underlying aquifers;
- Neighbouring surface water features (including waterbodies and watercourses); and
- Neighbouring water-dependent designated sites.

2.3 Identification of Pathways

Having established all potential impact sources and receptors, it is necessary to identify potential pathways between the quarry (the source) and each receptor (i.e. determine all source-pathway-receptor linkages). The assessment process must establish whether the quarrying activities could potentially affect any of the identified receptors. This is achieved by considering each potential source-pathway-receptor chain in the context of the conceptual model. Where there is believed to be no significant groundwater pathway between the quarry and a given receptor, this receptor can be removed from the impact assessment process. Where a pathway linkage is unclear, possibly due to uncertainty in the conceptual model, the pathway is assumed to exist at this stage of the assessment process.

This risk assessment approach serves to filter the list of potential receptors, and only those that are considered vulnerable (i.e. within the radius of influence or with a linking pathway) are considered in the impact assessment.

2.4 Quantification of Effects

The presence of a hydrogeological pathway between the quarry and receptor does not indicate that an effect will occur at the receptor. The next step in the impact assessment process must therefore be to address whether or not there is likely to be an effect at each potential receptor resulting from quarry development and restoration. This may require quantification, for example of the degree of groundwater level change at a receptor. As a minimum a qualitative assessment will be provided.

2.5 Assessment of Level of Impact and Significance

The demonstration and quantification of a potential effect does not necessarily indicate that the impact will be significant. The significance of potential effects is assessed individually for each receptor. There are two aspects to the assessment of significance.

- The size of the potential effect should be compared with a criterion that indicates the smallest significant impact. If the size of effect is smaller than the criterion then the effect does not represent a significant impact. In some cases it may be more appropriate to determine this on a qualitative basis.
- If the size of effect is potentially greater than the relevant criterion, it is necessary to assess the significance that the potential impact represents. The significance of an impact is dependent on the magnitude of the effect and the importance of the receptor.

2.5.1 Importance of receptors

Receptors have been assigned to one of three status categories; low, medium or high. The methodology for assigning to a particular category is based on the following criteria:

- Low Status: Unlikely to be of significant ecological or societal value (e.g. small ephemeral pond); surface water and groundwater abstractions that supply or impact on an individual or small number of people (e.g. farm or home supply), although this may be locally significant;
- Medium Status: Of local ecological or societal value or supporting medium or high status ecological features (e.g. springs); surface water or groundwater abstractions that supply or impact on a local community (e.g. local water supply or water supply to a local amenity);
- High Status: Nationally and internationally designated ecological sites (e.g. SACs) or features supporting these (e.g. springs); surface or groundwater abstractions that are utilised for public water supply. Also includes aquifers that are defined as Source Protection Zones (SPZs) or similar.

2.5.2 Degree of effect

The degree of effect at each receptor is to be evaluated separately on the basis of the conceptual model. The degree of effect is assessed without the application of mitigation measures. To assist in this evaluation, the following conservative guidelines have been adopted for screening purposes.

- For licensed groundwater abstraction boreholes a predicted groundwater level reduction in excess of 0.5 m is taken to indicate a medium to high degree of effect, with the exact category dependent on the magnitude of the predicted change and the available drawdown.
- For shallow wells and ponds, a predicted reduction in level in excess of 0.25 m is taken to indicate a medium to high degree of effect, with the exact category dependent on the magnitude of the predicted change and the available drawdown or degree to which levels fluctuate.
- For spring flows or baseflow-dependent watercourses, a derogation of flow in excess of 10% of mean low flows is taken to indicate a medium to high degree of effect. The exact category is dependent on the magnitude of the predicted change and the degree to which flows are groundwater dependent.
- Potential water quality effects will be greatest in the shallowest aquifer. Deeper aquifers will be less likely to be affected, and the level of effect will also be correspondingly lower, given the increased capacity for dilution and attenuation with depth. Effects on surface water will be dependent on the distance between the quarry and the relevant surface water feature.

Where an effect falls below the threshold criteria described above, it is taken to be negligible. Where it exceeds the critical thresholds, the degree of effect (low, medium, or high) is assessed, based on the particular conditions at that receptor. This assessment should relate the predicted effect to measured baseline conditions. For example, for groundwater levels, the effect should be compared to seasonal variability, and for stream flows, the change should be compared to measured baseflows.

2.5.3 Degree of impact

Table 2.1 shows how the receptors value and degree of effect are brought together to determine the degree of impact. A moderate or major degree of impact is considered to be significant. When a degree of impact is significant, mitigation measures are required.

Table 2.1 Impact assessment matrix

		Receptor Value		
		Low	**Medium**	**High**
Degree of Effect	**Negligible**	Negligible	Negligible	Negligible
	Low	Minor	Minor	**Moderate**
	Medium	Minor	**Moderate**	**Major**
	High	**Moderate**	**Major**	**Major**