

Vaynor Quarry: Flood Consequence Assessment and Drainage Strategy





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Prepared for
Hanson UK
Hanson House
Castle Hill
Maidenhead
SL6 4JJ

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

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

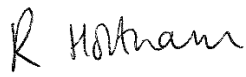
Registered Office:
Stantec UK Ltd
Buckingham Court
Kingsmead Business Park
Frederick Place, London Road
High Wycombe HP11 1JU
Registered in England No. 1188070

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	Name	Signature
Author	Maris Sunaitis Richard Holtham	
Checked by	Henry Kelly & Chris Woodhouse Barnaby Harding	
Reviewed by	Barnaby Harding Andrew Tait	

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Contents

1	INTRODUCTION	1
1.1	Background	1
1.2	Scope of Work	1
1.3	Data Sources	2
1.4	Report Structure	2
2	SITE DESCRIPTION	4
2.1	Site Setting	4
2.2	Geology	7
2.2.1	Bedrock geology	7
2.2.2	Superficial geology	7
2.2.3	Hydrogeology	7
2.3	Hydrology	8
2.3.1	Rainfall	8
2.3.2	Surface water features	9
2.3.3	Surface water flow	14
2.3.4	Surface water levels and infiltration rate calculations	22
2.3.5	Catchment descriptors	26
2.4	Site Drainage and Water Management	26
3	PROPOSED DEVELOPMENT	28
3.1	Operational Stage	28
3.2	Restoration	28
4	FLOOD RISK TO THE PROPOSED DEVELOPMENT	29
4.1	Sources of Flooding	29
4.2	Flood Zones	29
4.3	Flood Map for Planning	30
4.4	Historical Fluvial Flooding	31
4.5	Flood Defences	31

4.6	Surface Water (Pluvial) Flooding	31
4.7	Groundwater Flooding	33
4.8	Flooding in the Event of Reservoir Failure	33
5	SUITABILITY OF THE PROPOSED DEVELOPMENT	34
5.1	Justification Test	34
5.2	Merthyr Tydfil Local Development Plan	34
6	FLOOD RISK FROM THE PROPOSED DEVELOPMENT	35
6.1	Identified Receptors	35
6.1.1	Water features	35
6.1.2	Property	35
6.1.3	Infrastructure	35
6.1.4	Designated sites	35
6.2	Climate Change	35
6.3	Runoff Calculations	36
6.3.1	Runoff destinations	36
6.3.2	Runoff calculations – greenfield	39
6.3.3	Runoff calculations – operational & restored sites	40
6.4	Flood Risk During the Operational Phase	42
6.5	Flood Risk Post Restoration	42
6.6	Flood Risk Mitigation Measures	43
7	FLOOD RISK CONSIDERATIONS	44
7.1	Key Considerations	44
7.2	Remain Safe in Times of Flooding	44
7.3	No Net Loss of Floodplain Storage	44
7.4	No Impediment to Flood Water Flows	44
7.5	Surface Water Runoff	44
7.6	Risks to People	44
8	DRAINAGE STRATEGY	45
8.1	Operational Phase	45

8.1.1	Overview	45
8.1.2	Performance requirements	45
8.1.3	Water quality	45
8.1.4	Proposed drainage strategy – operation phase from Year 0 to Year 10	46
8.1.5	Proposed drainage strategy – operational phase from Year 10 to final development	47
8.2	Restoration Phase	49
8.3	Maintenance	49
8.4	Biodiversity and Amenity	50
9	CONCLUSIONS	51

FIGURES

Figure 1.1	Site location showing surrounding area	3
Figure 2.1	Topography around the Site	6
Figure 2.2	Surface water features in proximity to the Site	12
Figure 2.3	Surface water features identified at the Site in November 2019	13
Figure 2.4	Nant y Glais gauging locations, springs and dry reaches	18
Figure 2.5	Stream flow rate along Nant y Glais compared to groundwater levels at VAYNOB07a and rainfall at Pontsticill Upper station	19
Figure 2.6	Synthetic Nant y Glais flow rate at the three gauging locations	20
Figure 2.7	Stream flow rate variation over time along Nant y Glais	21
Figure 2.8	Spillover points for eastern and western arm of the quarry	23
Figure 2.9	Gauge board levels at south-east pond	24
Figure 2.10	Pond water stage, precipitation and 3-hour averaged infiltration rate relationships	25
Figure 4.1	TAN15 flood zone map for planning	31
Figure 4.2	NRW pluvial flood risk data	33
Figure 6.1	Runoff catchments – greenfield	36
Figure 6.2	Runoff catchments – current	37
Figure 6.3	Runoff catchments – operational and post-restoration	38
Figure 8.1	Results for 48-hour 1-in-100-year storm event plus climate change	49

TABLES

Table 2.1	Rainfall data statistics (May 2013 – September 2019)	9
Table 2.2	Flow statistics for neighbouring flow gauging locations (CEH, 2019)	14
Table 2.3	Flow statistics for modelled flow rates at Nant y Glais (between March 2018 and August 2019)	17
Table 2.4	Nant y Glais catchment descriptors	26
Table 2.5	Discharge permit details	27
Table 4.1	Potential sources of flooding	29

Table 4.2	TAN 15 Flood Zones	29
Table 6.1	Site catchment areas over time	39
Table 6.2	Hydrological catchment descriptors (CEH, 2019)	40
Table 6.3	Greenfield runoff	40
Table 6.4	Predicted runoff from the Site (1 in 1 year event)	41
Table 6.5	Predicted runoff from the Site (1 in 30 year event)	41
Table 6.6	Predicted runoff from the Site (1 in 100 year event)	42
Table 8.1	Summary of calculation results	48
Table 8.2	General management and maintenance requirements for infiltration basins	50

APPENDICES

Appendix A	Development plans
Appendix B	Restoration plan
Appendix C	Greenfield runoff calculation output reports
Appendix D	Technical Note on Calculation of CBAC
Appendix E	Discharge permit

1 Introduction

1.1 Background

Hanson Quarry Products Europe Limited (Hanson) is submitting applications for the Review of Old Mineral Permissions (ROMP) from at Vaynor Quarry, the purpose of which is to review and update the planning conditions that apply at the site. Vaynor Quarry is an inactive limestone quarry located approximately 1 km north of the outskirts of Merthyr Tydfil, lying partly within the administrative area of Merthyr Tydfil County Borough Council and partly within that of the Brecon Beacons National Park Authority, in South Wales.

Hanson is proposing to recommence extraction of limestone at Vaynor Quarry site (“the Site”) and extract the remaining economic limestone resource. Figure 1.1 shows the location of the Site relative to the surrounding area. The current quarry void is split into two “limbs” lying east and west of a central ridge. The part of the Site that has extant planning permission for minerals extraction will be the subject of separate ROMP applications, one to Merthyr Tydfil County Borough Council and the other to the Brecon Beacons National Park Authority.

The Site considered in this report is comprised of the areas covered by each of the two ROMP applications as well as an area to the south which contained the former quarry processing plan, which together cover an area of approximately 65.4 ha. The black hatched area on Figure 1.1 is the full extraction area once all mineral is exhausted (expected to be after 100 years). The maximum proposed extent of the extraction area is 38.3 ha.

The quarry void will be passively dewatered and quarrying is expected to take at least 100 years. Once limestone extraction is complete, the quarry void will be restored to nature (see Section 3.2). Details of the proposed development are set out in the development and restoration plans in Appendix A and Appendix B, respectively.

This report constitutes a Flood Consequence Assessment (FCA) that has been prepared on behalf of Hanson in support of the ROMP applications. Stantec has also undertaken a Hydrogeological Impact Assessment (HIA), which is included as Chapter 9 of the Environment Statement (SLR Consulting, 2022).

1.2 Scope of Work

Hanson instructed Stantec UK Ltd. (Stantec) in April 2018 to undertake an FCA in support of the ROMP application for the review of planning conditions at the Site. This FCA has been written in line with Technical Advice Note (TAN) 15 (Welsh Assembly Government, 2004), Good Practice Guide (GPG) 101 (NRW, 2015), and Guidance Note (GN) 008 (NRW, 2017) to satisfy both Natural Resources Wales (NRW) and the Lead Local Flood Authority (LLFA) (Merthyr Tydfil County Borough Council) that all potential flood risks to and from the proposed development have been considered.

This assessment includes site-specific flood risk consideration and calculations to estimate surface water runoff for the greenfield, current, operational and restored Site. These calculations also account for the effect of climate change using relevant advice provided in the Planning Policy for Wales. A drainage strategy is presented for the proposed development and restoration of the Site. The purpose of the drainage strategy is to ensure that runoff from the operational or restored site does not adversely affect flood risk at the Site or elsewhere, as well as ensuring that the water

leaving the Site has been suitably treated, if required. Site-specific flood risk mitigation measures have been included with recommendations for a strategy to manage and mitigate flood risks posed to the Site.

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);
- proposed restoration plan provided by Hanson (Appendix B);
- geological data from monitoring well and exploration drilling;
- flow gauging and water quality monitoring undertaken by Stantec;
- former conceptualisation and impact assessment reports for the Site by ESI (now Stantec);
- site visits undertaken by ESI (now Stantec) on 31 March 2016 and by Stantec on 21 November 2019 and 9th July 2021;
- groundwater and surface water level monitoring data provided by Hanson;
- hydrological descriptor and flow data obtained for the Centre for Ecology and Hydrology (CEH);
- British Geological Survey (BGS) mapping;
- Ordnance Survey mapping; and
- data from NRW including rainfall, historical landfill data, LiDAR digital terrain model (DTM) data and abstraction licences.

1.4 Report Structure

This report constitutes the FCA for the proposed development, and includes the following:

- a description of the Site conditions (Section 2);
- an outline of the proposed development (Section 3);
- a summary of potential flooding sources and an assessment of flood risk to the development (Section 4);
- an assessment of the Site's suitability for the proposed development (Section 5);
- an assessment of flood consequences from the development to the surrounding area (Section 6);
- a summary of flood risk considerations (Section 7); and
- the proposed drainage strategies for the Site to alleviate any potential increase in flood consequences under the developed and restored Site scenarios (Section 8).

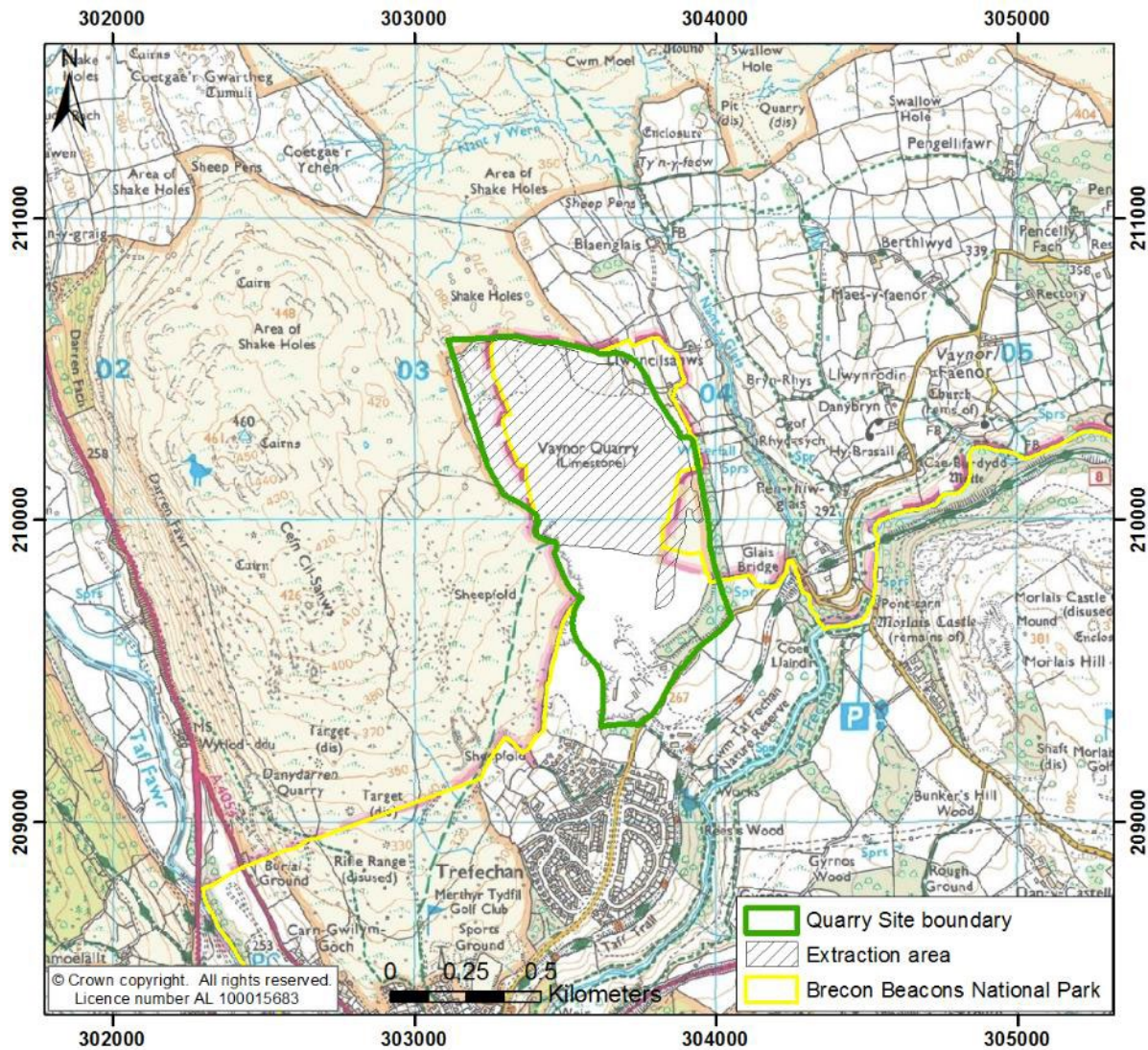


Figure 1.1 Site location showing surrounding area

2 Site Description

2.1 Site Setting

The Site is an inactive limestone quarry and is located approximately 3.2 km north-north-west of the centre of Merthyr Tydfil town and 100 m north of Trefechan village in Merthyr Tydfil County Borough (nearest postcode: CF48 2LA and NGR: SO 035103). The Site is accessed from Vaynor Road, which lies to the south-east. Vaynor Road is accessed 1.6 km from the Site from the A4054. The Heads of the Valleys Road (A465) lies 850 m south of the Site.

The Site was operational as a limestone quarry since at least the 1940s, with the first planning permission granted in 1947 (IDO permission, now lapsed), with four subsequent mineral planning permissions granted from 1959 onwards. The Site ceased mineral extraction and was mothballed in 2007 though the main phase of past production at the Site finished in the 1990s.

Other than Vaynor 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 is moorland and forms the eastern slopes of the hill Cefn Cil-Sanws, which peaks 750 m west of the Site at 461 m AOD. The ground falls to the south and east of the Site, where to the immediate south of the Site is the village of Trefechan, built in the 1950s. In the east there is widespread, predominantly pastoral, agricultural land on the slopes while the steep-sided gorges are dominated by deciduous woodland. Several farms are located in the surrounding area, the closest of which is LlwynCILsanws Farm located 160 m north-east of the Site.

Approximately 16 ha of the Site lies within the BBNP in the north-west and east (Figure 1.1). Cwm Taf Fechan Site of Special Scientific Interest (SSSI) follows the Taf Fechan river gorge to the south-east of Site. Nant y Glais SSSI lies in the gorge of the Nant y Glais 140 m north-east of the Site.

Settlements surrounding the Site include Trefechan (100 m south), Llwyn-on (1.9 km north-west) and Pontsticill (1.9 km north-east). A number of isolated dwellings and farms are located in the area around the Site, including LlwynCILsanws (160 m north-east), Aberglais Inn (330 m east), Blaenglais (370 m north), Pen-rhiw-glais (440 m east), Llwynrodin (650 m east), Hy-Brasail (680 m east), and Berthlwyd (850 m north-east). Regionally, the outskirts of Merthyr Tydfil lie 1 km south of the Site and Vaynor (comprised of a small number of widely spread dwellings) lies 1 km east.

Figure 2.1 shows a map of LiDAR topography data around the Site. Ground levels at the Site itself range from 260 to 400 m AOD, with the lowest elevation at the processing area to the south of the Site. Topography rises above the Site to the west and north, and slopes away from the Site to the east and south. There are steep changes in topography within the Site boundary due to the presence of the quarry void that was worked historically to a minimum elevation of 270 m AOD in the south-east of the void. The maximum depth of the void is around 50 m in the north-west. The current base of the quarry void varies between 270 m AOD and 360 m AOD in elevation depending on location. East of the Site, topography falls towards the southward-flowing Nant y Glais, which is at an elevation of between 250 and 281 m AOD along its closest approach.

Regionally, topography is dominated by the elevated moorland areas to the north of the Site within BBNP, including Garn Ddu (up to 462 m AOD), Twyn Croes (442 m AOD) and Gwaun y Pynt (528 m AOD). River valleys cut through this high land including Cwm Taf which holds Llwyn-onn

Reservoir (2.1 km north-west of the Site) and Cwm Taf Fechan which holds the Pontsticill Reservoir (2.6 km north-east) and Pentwyn Reservoir (4.3 km north-east).

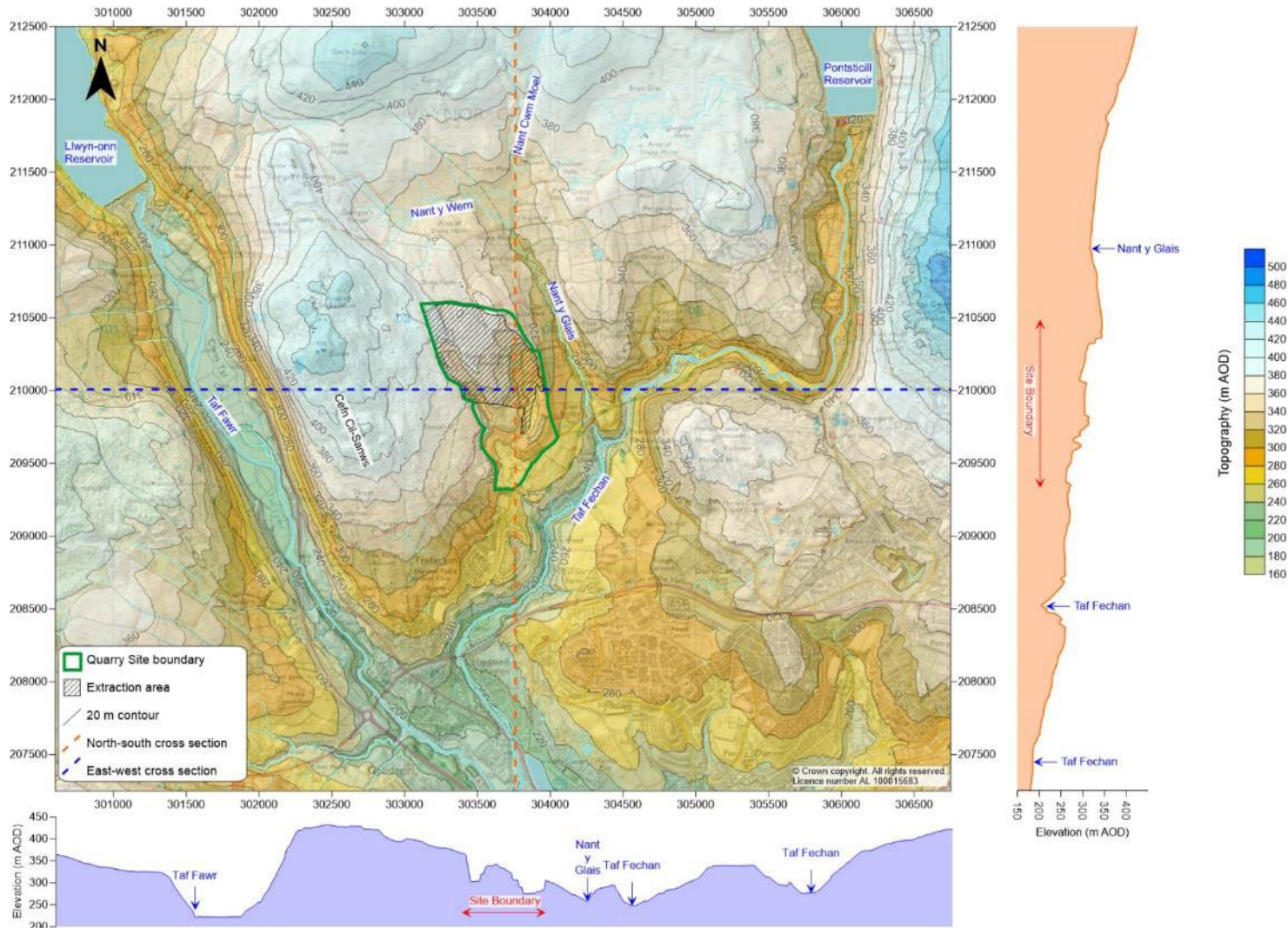


Figure 2.1 Topography around the Site

2.2 Geology

Information on the regional and local geology data in the vicinity of the Site is available from the BGS 1:50,000 scale maps (BGS, 1979), and from geological logs of boreholes drilled at the Site. This section provides a summary of collated geological data; a more detailed geological description can be found in the accompanying HIA (Stantec, 2020).

2.2.1 Bedrock geology

The bedrock geology of the area around the Site consists of Carboniferous strata. Carboniferous Dowlais Limestone Formation of the Pembroke Limestone Group is the economic mineral at the Site. This unit crops out over the majority of the Site and is described as hard, grey, fine to medium-grained limestone with occasional thin calcareous mudstone or shelly bands throughout. The maximum proven thickness of the Dowlais Limestone Formation is 79 m.

Cropping out in the south-west of the Site is the younger Oxwich Head Limestone which unconformably overlies the Dowlais Limestone Formation. The Llanelly Formation underlies the Dowlais Limestone Formation at depth, which is in turn unconformably underlain by the Abercriban Oolite Subgroup. These units crop out north of the Site.

The geological structure of the area is complex and heavily faulted, with the main structural elements in the area largely dating to the late Carboniferous – early Permian Variscan orogeny. Bedrock strata at the Site dip gently at 5 - 10° to the south-east and form part of a regional, gently dipping stratigraphic succession on the northern limb of the synclinal basin of the South Wales Coalfield.

2.2.2 Superficial geology

Quaternary deposits cover the bedrock geology across much of the surrounding region, with glacial till mapped across the eastern part of the Site and on higher ground to the east and south of the Site. Much of the till mapped at the Site roughly follows the alignment of the Nant y Glais and Taf Fechan but at the Site these deposits are now partially absent, having been stripped away by quarrying activities.

Peat is also present 1 km to the north of the Site, along with alluvium associated with watercourses. Glaciofluvial deposits, head, river terrace deposits and alluvium occupy a strip of land 1.4 km west of the Site, close to the Afon Taf Fawr. Superficial deposits are absent from much of the land immediately to the north of the Site, along with the high ground to the west of the Site.

2.2.3 Hydrogeology

The sequence of the Abercriban Oolite Subgroup, Llanelly Formation, Dowlais Limestone Formation, Penderyn Oolite Member, Oxwich Head Limestone Formation are defined as principal aquifers. Principal aquifers are defined as layers of rock or drift deposits that have high intergranular and/or fracture permeability – meaning they usually provide a high level of water storage. They may support water supply and/or river baseflow on a strategic scale.

Groundwater levels at the Site have been monitored since 1998 until the present time and these data show that groundwater flows broadly south-eastwards. Groundwater is shallowest in the south (approximately 10 m bgl (m below ground level)) and deepest in the north (up to 73 m bgl). Most of the boreholes show a typical seasonal change in groundwater level (being higher over winter and lower over summer) with seasonal changes varying by between 2 and 16 m. Groundwater is

recharged through rainfall and is understood to discharge to the Nant y Glais and Cwm Taf Fechan, to springs around the Site and to various waterbodies within the quarry void. As a karstic limestone environment, groundwater recharge and flow are predominantly through fractures. The hydrogeological system at the Site is described in more detail in the HIA (Chapter 9 of SLR Consulting, 2022).

2.3 Hydrology

2.3.1 Rainfall

Rainfall data provided by NRW for April 2013 to October 2019 is available from the following sources:

- Llwyn-on Main gauge (2.2 km north-west of the Site);
- Pontsticill Upper WTW gauge (2.5 km north-east of the Site).

Table 2.1 summarises annual rainfall data for both the Llwyn-on Main and Pontsticill Upper gauges. This indicates that annual rainfall varies from 1,499 mm (Pontsticill Upper, 2017) to 2,055 mm (Llwyn-on Main, 2015). Mean monthly rainfall ranges between 77 mm (April, Pontsticill Upper and Llwyn-on Main) and 284 mm (December, Llwyn-on Main). There is a strong seasonality and summer months are typically much drier than winter months. Annual rainfall fluctuates between years and at Pontsticill Upper generally decreased between 2014 and 2017 but the same trend is not present at Llwyn-on Main.

Table 2.1 shows that rainfall is higher at Llwyn-on Main than at Pontsticill Upper. Llwyn-on-Main is at around 240 m AOD, whilst Pontsticill Upper is at approximately 350 m AOD. Although it might be expected that rainfall would be higher on higher ground, rainfall is lower at Pontsticill Upper because it is further east and is in the orographic rain shadow formed by higher ground to the west.

The Standard Average Annual Rainfall (SAAR) for the Site is 1,659 mm (CEH, 2019), which lies within the data range and is consistent with the mean rainfall recorded at Pontsticill Upper (1,657 mm) but is below the mean rainfall at Llwyn-on Main (1,928 mm). This is likely to be because of its geographic location being further south and east of Llwyn-on Main. Given this, rainfall data from Pontsticill Upper is considered most representative of rainfall at the Site.

Table 2.1 Rainfall data statistics (May 2013 – September 2019)

Period		Llwyn-on Main (mm)	Pontsticill Upper (mm)
Mean monthly rainfall	January	247	203
	February	176	165
	March	141	148
	April	77	77
	May	101	99
	June	102	83
	July	100	87
	August	165	143
	September	137	124
	October	163	154
	November	230	180
	December	284	231
Mean annual rainfall (2014 - 2018)		1,928	1,657
Median annual rainfall (2014 - 2018)		1,970	1,553
Minimum annual rainfall (2014 - 2018)		1,748	1,499
Maximum annual rainfall (2014 - 2018)		2,055	1,936

2.3.2 Surface water features

Watercourses

Figure 2.2 shows neighbouring surface watercourses in the Site vicinity. The hydrology of the area around the Site is dominated by the south-westerly draining Taf Fechan 270 m to the south-east of the Site and the southerly draining Afon Taf Fawr, approximately 1.4 km to the west. These watercourses are sourced from the Llwyn-onn Reservoir and Pontsticill Reservoir respectively, which are sourced in turn from watercourses and further reservoirs higher in the catchments (see

waterbodies section below). The Taf Fechan and the Afon Taf Fawr are confluent 2.1 km south of the Site, where they continue southwards as the Afon Taf/River Taff. The estuary of the River Taff is at Cardiff Bay approximately 38 km south of the Site. The Site is located high in the River Taff catchment, with its constituent tributaries draining steep hillsides.

The Nant y Glais is the most proximal watercourse to the Site and lies 160 m east at its closest approach. This is sourced from the Nant Cwm-moel and Nant y Wern, both of which drain an area of moorland north of the Site and join to form the Nant y Glais approximately 600 m north of the Site. The Nant y Glais flows southwards, at times through the Nant y Glais cave system (Section 2.2.2), to its confluence with the Taf Fechan approximately 300 m to the south-east of the Site. The Site sits within the catchments of the Nant y Glais and the Taf Fechan, into which surface runoff from the Site under pre-development (greenfield) conditions would have drained.

OS mapping shows a series of springs along the hillsides on the true right (western) bank of the Nant y Glais, east of the Site. These contribute to the flow in the Nant y Glais at various points along its course. An unnamed tributary of the Nant y Glais catchment flows into a swallow hole 1 km north-east of the Site and its location of re-emergence is unknown. Areas of Dowlais Limestone Formation and Marros Group which crop out at and around the Site have a lower density of watercourses compared to areas underlain by older Avon Group and Old Red Sandstone strata. The density of streams is greater north of the Site with most flowing broadly southwards in line with the regional topographic slope.

Watercourses are generally absent to the west of the Site on the high ridge of Cefn Cil-Sanws and to the north on high ground at Garn Ddu. OS mapping and LiDAR data indicate the presence of sinkholes in the limestone, and geological maps show that these sinkholes are not covered by glacial till. These sinkholes will capture runoff and increase recharge to the underlying limestone aquifer and, in so doing, will limit surface water runoff that could then form streams. The presence of sinkholes in these areas is considered further in the hydrogeology section of the HIA (Stantec, 2020).

Although not shown on OS mapping, a series of minor watercourses was identified at the Site during a site visit by Stantec in November 2019 and were present during the July 2021 site visit (see Figure 2.3). These are sourced from a series of seepages in the quarry faces and from springs in the quarry floor. Water from these sources in the eastern arm drains from the north-eastern upper part of the quarry along the quarry floor and cascades in a series of waterfalls over the quarry benches to a pond in the south-eastern part of the quarry (see below). Photographs of these features are provided in Appendix 9.5 of the ES Chapter (SLR Consulting, 2022).

Springs in the north-western part of the western arm of the quarry drain to a series of ponds along the western edge. In the south a spring forms a watercourse which drains to a culvert that passes beneath Vaynor Road to a heavily vegetated settlement lagoon. Stantec (2022) has undertaken tracer testing and water quality analyses to determine the source of this spring. Based on the analyses, it is considered most likely that this spring is at least partially sourced from the ponds in the western arm of the quarry void. There is an outlet from the settlement lagoon to the Taf Fechan; however, at the time of the site visit this was not flowing.

Waterbodies

Figure 2.2 shows neighbouring surface waterbodies in the Site vicinity. The closest major waterbodies to the Site are as follows:

- Pontsticill Reservoir 2.6 km north-east of the Site; and
- Llwyn-onn Reservoir 2.1 km north-west of the Site.

Both Pontsticill Reservoir and Llwyn-onn Reservoir are fed by inflows from watercourses further up the catchments and have outflows from dams into Afon Taf Fawr and Taf Fechan, respectively. The most proximal waterbodies are a series of small ponds 700 m north-east of the Site and several small ponds occupying dolines and sinkholes on the upper slopes of Cefn Cil-Sanws, 500 m west of the Site. These mostly do not appear to have outlets and likely drain to the limestone aquifer.

A series of water features were identified at the Site during the site visit (Figure 2.3). In the western arm, a number of small ponds are located adjacent to the western quarry faces. These do not have any clear surface water outlet and appear to drain to groundwater. In the eastern arm, most runoff and groundwater ingress drains to a pond in the south-east (referred to as the “south-east pond” throughout the remainder of this report). This also has no outlet and drains to the limestone aquifer. A number of much smaller ponds are also present in the eastern arm.

In the southern part of the Site around the former processing plant area, a pond is present which discharges through a culvert beneath Vaynor Road to a settlement lagoon.

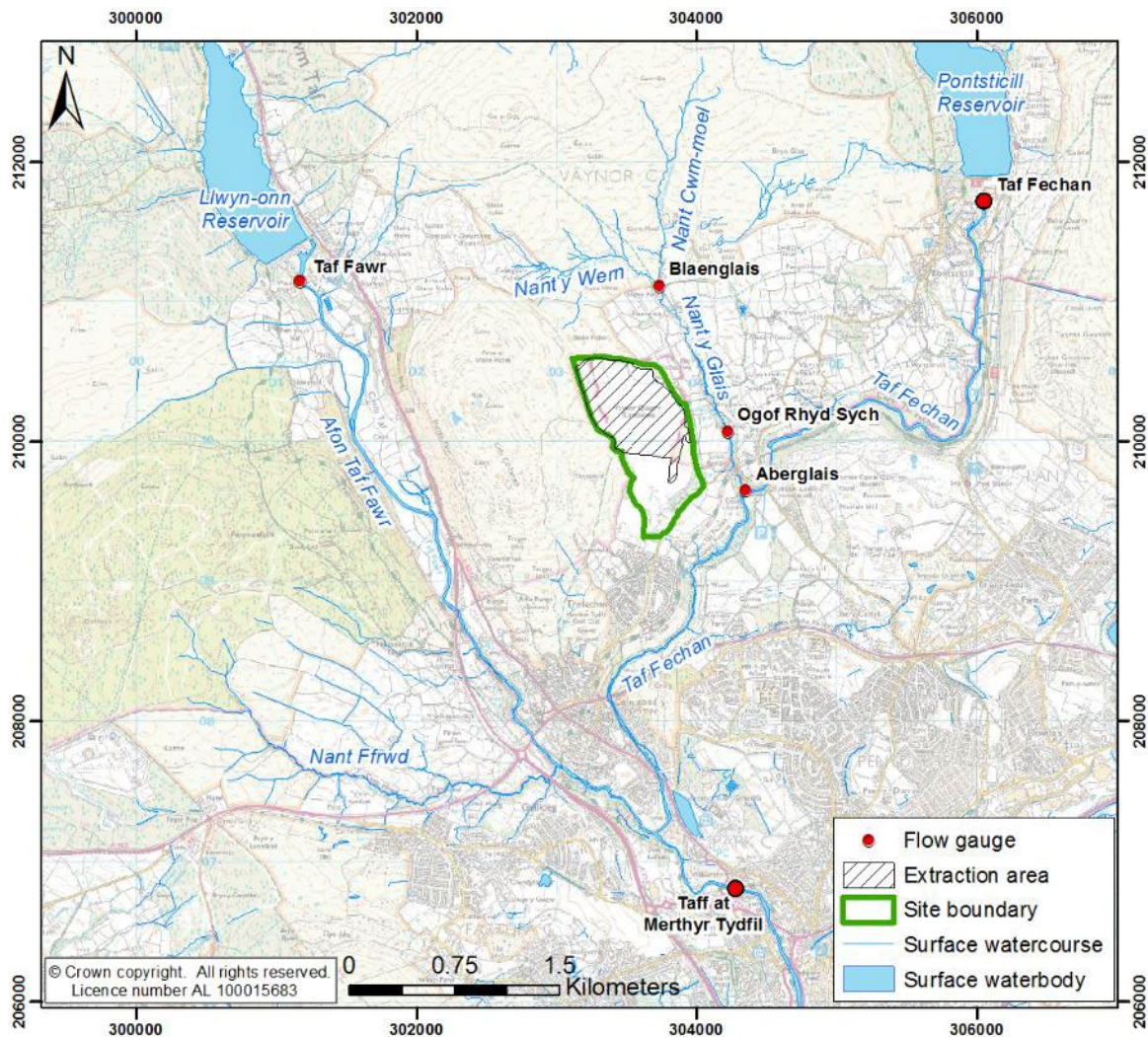


Figure 2.2 Surface water features in proximity to the Site

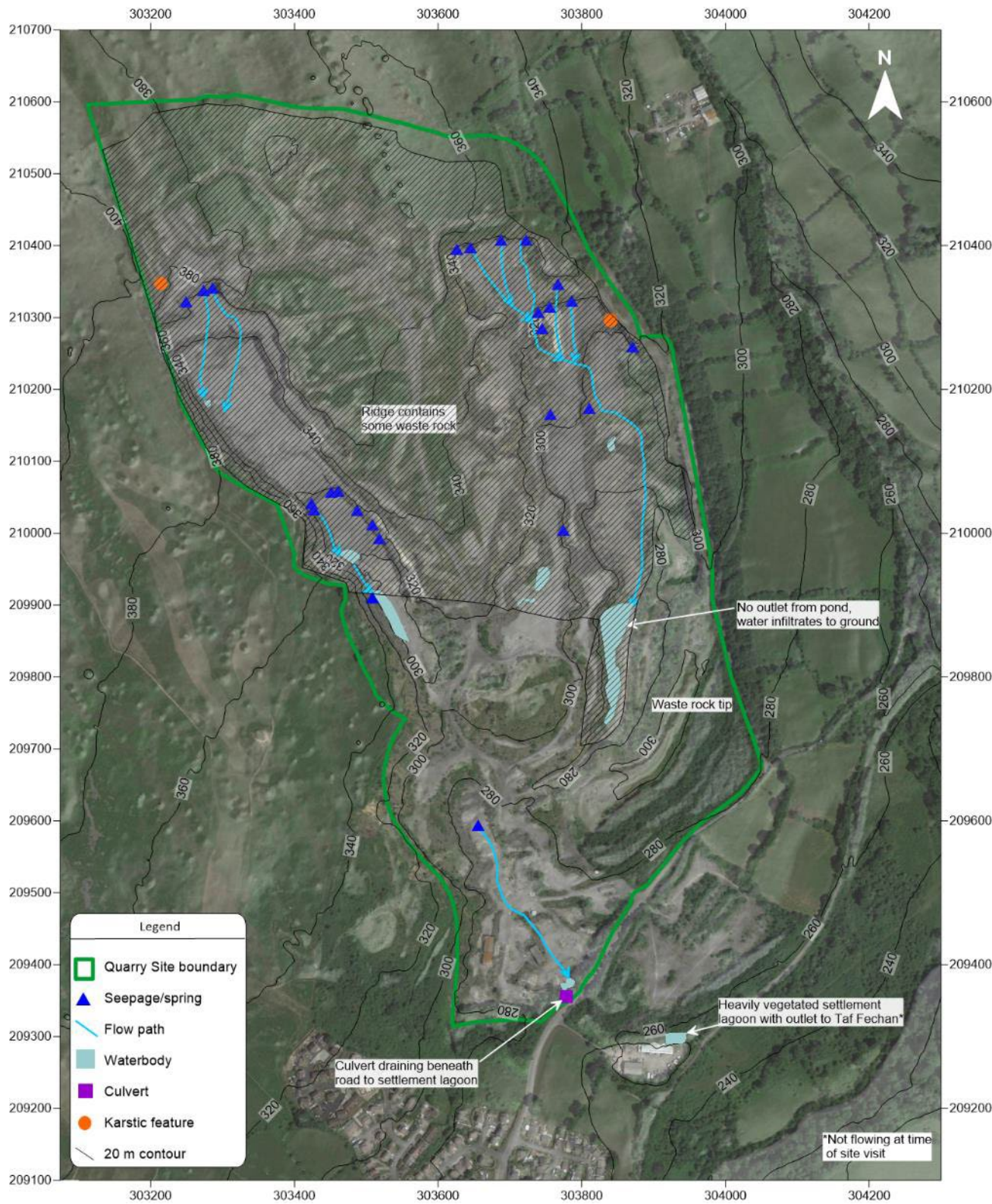


Figure 2.3 Surface water features identified at the Site in November 2019

2.3.3 Surface water flow

Taf Fawr, Taf Fechan and River Taff

The National River Flow Archive holds surface water flow data at the following locations (CEH, 2019):

- Taf Fawr at Llwynon Reservoir (2 km west-north-west of the Site);
- Taf Fechan at Taf Fechan Reservoir (2.5 km north-east); and
- Taff at Merthyr Tydfil (2.6 km south).

Table 2.2 summarises the catchment characteristics and measured flows from each of these gauging locations. However, the degree to which these statistics are representative of natural flow is uncertain due to the controlling influence of the reservoirs on flows in the Taf Fawr and Taf Fechan. The two gauges at the reservoirs are thought to measure reservoir outflows and hence will not represent a natural flow regime. The Taff at Merthyr Tydfil is located downstream of the two reservoirs and hence will also be influenced by the dammed outflows. The baseflow indices for these watercourses are relatively low and indicate that the contribution to flow from groundwater in these catchments is less significant than surface water.

Table 2.2 Flow statistics for neighbouring flow gauging locations (CEH, 2019)

Parameter	Taf Fawr at Llwynon Reservoir	Taf Fechan at Taf Fechan Reservoir	Taff at Merthyr Tydfil
Available record	1931 – 2019	1936 – 1973	1978 – 2019
Location and distance from Site	2 km west-north-west	2.5 km north-east	2.6 km south
Baseflow Index	0.34	0.46	0.37
Catchment area (km²)	43.0	33.7	104.1
95% exceedance (m³/s)	0.178	0.221	0.749
70% exceedance (m³/s)	0.265	0.252	1.12
50% exceedance (m³/s)	0.374	0.360	1.49
10% exceedance (m³/s)	2.738	2.053	9.44
Mean flow (m³/s)	1.093	0.783	3.824
Estimated effective rainfall (mm)	802	733	1,158

Nant y Glais

The Nant y Glais flows southwards approximately 160 m east of the Site at its closest approach. The hydrology of the Nant y Glais is complex due to the karstic nature of the terrain. Stantec

Report Reference: 64789R2

Report Status: Final

collected monthly flow gauging data at three locations along the Nant y Glais between March 2018 and June 2019 (inclusive). As shown in Figure 2.2 (and in greater detail in Figure 2.4), the gauging points are located at:

- Blaenglais (560 m north of the Site), which is approximately 1.7 km downstream of the river source and immediately downstream of the confluence between the Nant Cwm Moel and the Nant y Wern;
- Ogof Rhyd Sych (260 m east of the Site), which is downstream of the river's emergence from the Nant y Glais cave system; and
- Aberglais (300 m east of the Site), which is immediately upstream of the river's confluence with the Taf Fechan.

During a site visit by ESI Ltd (now Stantec) in March 2016, the Nant y Glais was flowing along its full length, although flow appeared to decrease in the reach between Blaenglais and the waterfall and caves further to the south. Monthly field observations made between March 2018 and June 2019 indicate the stream is usually dry in:

1. the reach starting approximately 200 m downstream from the Blaenglais gauging location to the NG03 spring; and
2. the reach approximately 210 m upstream of the NG02 spring, i.e. upstream of the caves.

These reaches are marked as dry reaches in Figure 2.4. Flow continues underground across these reaches through the underlying cave system and fractures in the limestone.

During the monthly 2018/2019 monitoring visits, flow was observed in these reaches only on 14 November 2018 and 14 June 2019 (i.e. two out of seventeen visits). Both occasions were associated with relatively heavy rainfall events totalling 45 - 50 mm in the preceding five day period. Anecdotal evidence obtained from a local resident in March 2016 corroborates the observation that the downstream reach is dry for most of the time.

The gauging data (see Figure 2.5) indicates that the flow rate in the monitored time period was highest in the winter months (November - March) with a maximum flow of 200 l/s recorded in December 2018 at the downstream monitoring point (Aberglais). The flow rate is significantly lower between April and October with the minimum measured value of 5.7 l/s at the upstream monitoring point (Blaenglais) recorded in June 2018.

Flow rate appears to be primarily controlled by antecedent rainfall (see Figure 2.5); for example, peak flow rates recorded on 14 November and 11 December 2018 correlate to high rainfall events on 9 November and 6 December 2018, respectively. Due to the relatively small size of the catchment (approximately 500 ha) and steepness of the slopes, water passes through the system quickly. However, delayed inflows from the limestone aquifer recharged through sinkholes could be significant.

Figure 2.6 shows synthetic flow rates calculated at Blaenglais, Ogof Rhyd Sych and Aberglais gauging locations using a transient water balance model. The methodology is based on ESI (2007). Climate Based Assessment Criteria (CBAC) calculations have also been used by ESI Ltd (now Stantec) successfully at Cornelly Quarry, another limestone quarry in South Wales (ESI, 2007). These assessments were used as part of the 2015 public inquiry for Cornelly Quarry prior to receipt of planning approval and a copy of the technical note from the inquiry explaining the

methodology is included in Appendix D. Note that the technical note refers to sites in the vicinity of Cornelly Quarry, but the methodology is transferable.

The analytical equations used are the same as in (Streetly, 2008) and the parameters were calibrated to fit the monthly gauging data. The modelled flows achieved an overall good fit, though there is less confidence in the predicted peak flows due to an absence of spot flow gauging measurements during high flow events.

Modelled flow rate statistics are presented in Table 2.3 for the period between March 2018 and August 2019. The mean flow rate increases by 31.8 l/s (33% increase) between Blaenglais and Ogof Rhyd Sych thus suggesting overall gaining conditions between these locations. Meanwhile, the flow rate between Ogof Rhyd Sych and Aberglais monitoring points increases only by 5.6 l/s (4.4% increase) which is consistent with the upslope catchment area increase (33% and 4.2%, respectively).

Groundwater levels in the Dowlais Formation (as recorded in VAYNOB7a approximately 280 m from Nant y Glais, see Figure 2.5) show a rainfall signature. Between September 2018 and April 2019, groundwater levels have a monthly fluctuation of 2 to 4 m indicating a highly responsive system typical of karstic aquifers. Furthermore, during this period both the groundwater levels and stream flow rates are elevated compared to the low levels and flows between July to September 2018 and April to July 2019. Although the correlation between the groundwater levels and the stream's flow rates is not strong, the stream may be in hydraulic connection with groundwater but this may not be evident with the monthly stream flow gauging frequency and the complexities of the karst system.

Figure 2.7 shows Nant y Glais flow rate variation over time; in all cases the flow rate increases between Blaenglais and Ogof Rhyd Sych monitoring points. Flow in this reach is, in part, controlled by the karstic nature of the faulted and exposed limestone. There are no tributaries present in this reach and instead the water is gained through several springs (in the sides of the gorge), interactions with the limestone aquifer and runoff from adjacent agricultural land and moorland scrub. The Nant y Glais cave system through which the stream passes can be seen in Figure 2.4.

Meanwhile, the change in flow rate between Ogof Rhyd Sych and Aberglais is much more variable; the reach alternates between losing and gaining conditions without a discernible pattern or correlation with either rainfall or groundwater levels. This could be caused by complexities of the karstic system and/or inaccuracies in the Aberglais flow gauging measurements. The monitoring location is located in a pebble/boulder-rich reach which creates non-ideal gauging conditions due to turbulent and non-lateral flow.

Table 2.3 Flow statistics for modelled flow rates at Nant y Glais (between March 2018 and August 2019)

Parameter	Blaenglais	Ogof Rhyd Sych	Aberglais
Catchment area (km²)	3.6	4.8	5.0
95% exceedance (l/s)	6.8	9.0	9.4
70% exceedance (l/s)	27.4	32.9	33.8
50% exceedance (l/s)	44.8	9.0	9.4
10% exceedance (l/s)	141.2	155.6	173.4
Mean flow (l/s)	94.9	126.7	132.3

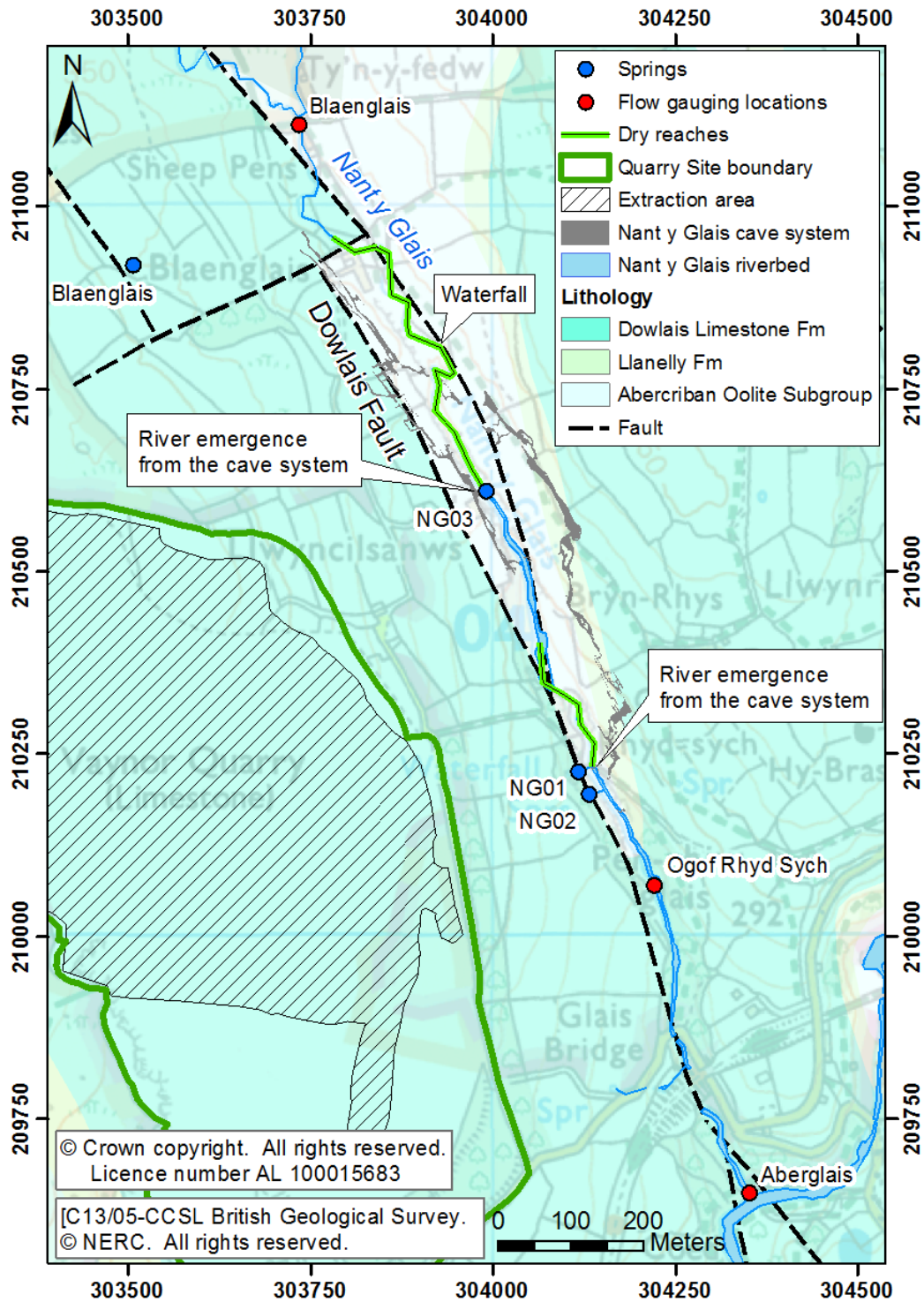


Figure 2.4 Nant y Glais gauging locations, springs and dry reaches

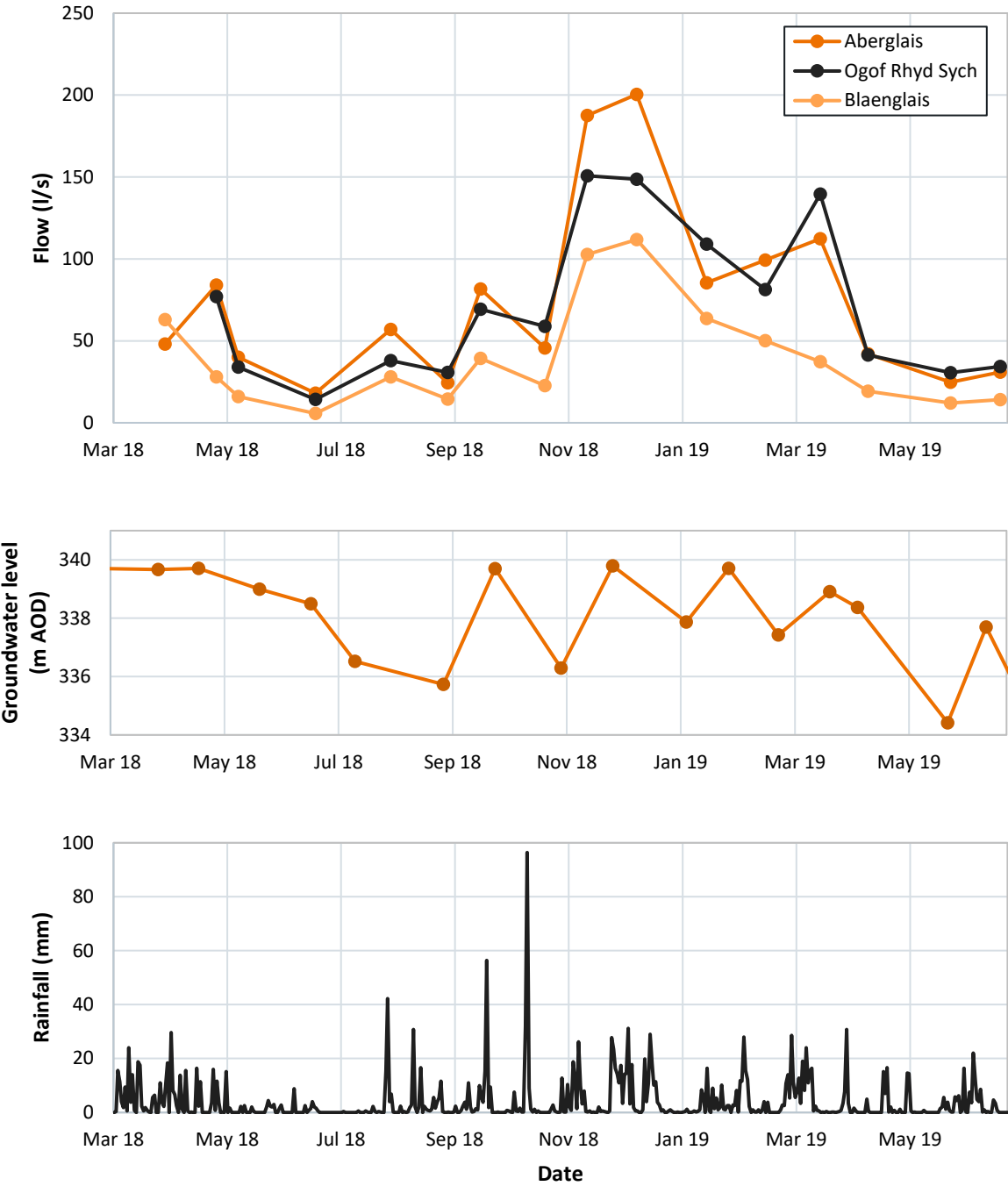


Figure 2.5 Stream flow rate along Nant y Glais compared to groundwater levels at VAYNOB07a and rainfall at Pontsticill Upper station

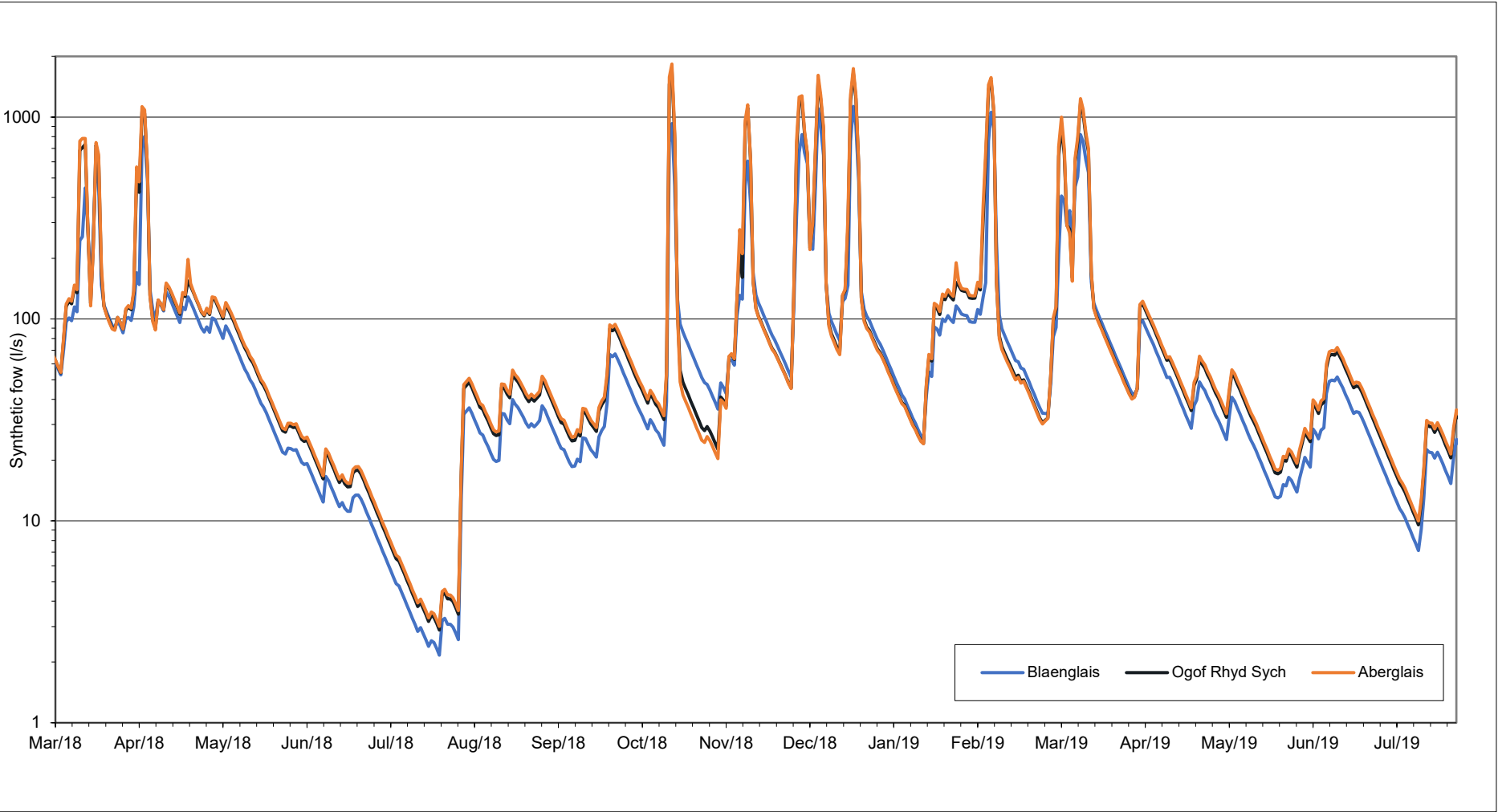


Figure 2.6 Synthetic Nant y Glais flow rate at the three gauging locations

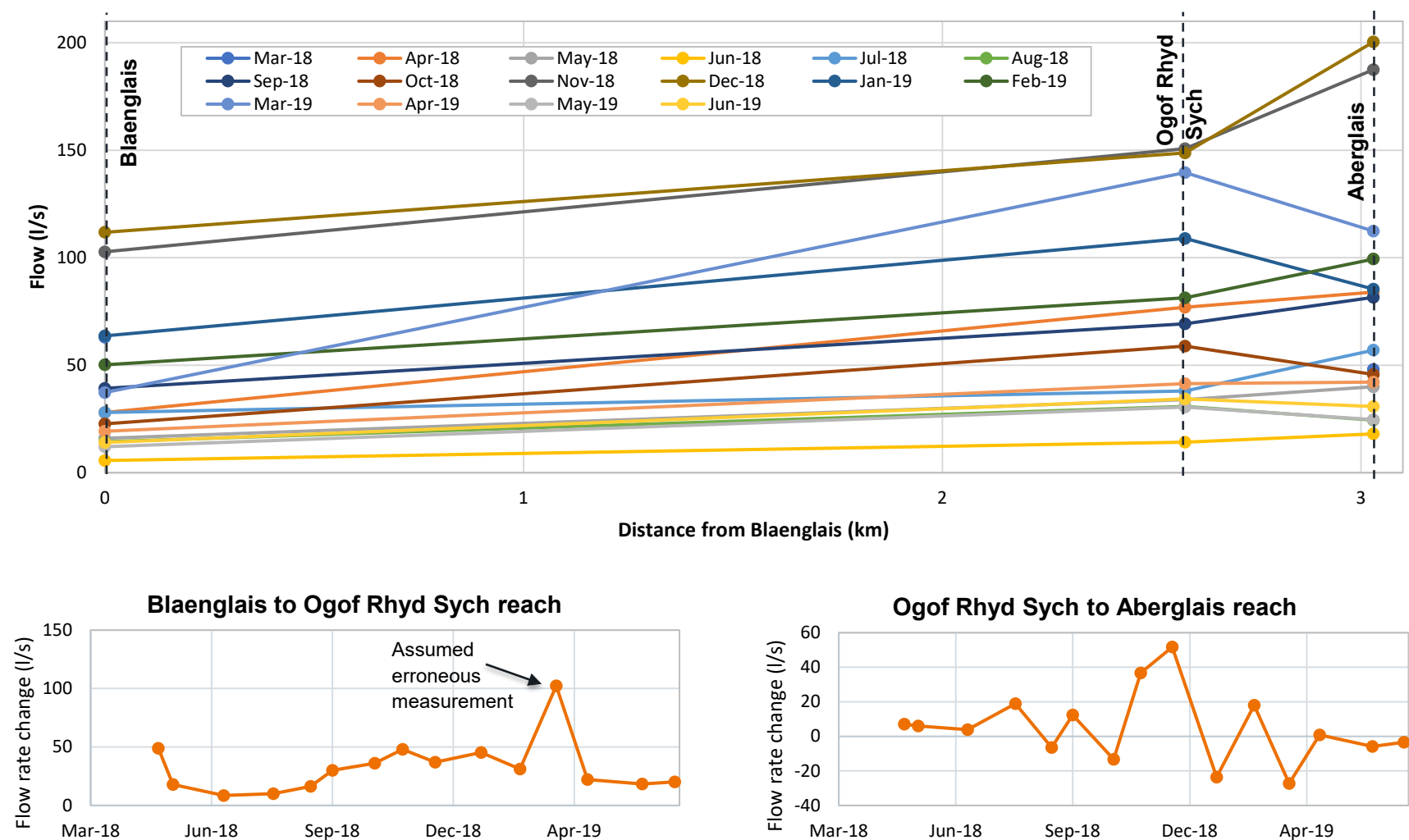


Figure 2.7 Stream flow rate variation over time along Nant y Glais

2.3.4 Surface water levels and infiltration rate calculations

A gauge board and water level logger (recording at hourly intervals) were installed in the south-east pond in August 2018 by BCL Ltd (BCL). Results of this monitoring are shown in Figure 2.9. The gauge board datum has not been surveyed, however, based on LiDAR topography, the gauge board zero datum elevation is thought to be around 270.5 m AOD.

Monitoring results show that surface water levels in the south-east pond are mostly static at around 0.2 m. Levels rise rapidly in response to rainfall events by up to 2 m and recede more steadily, but still relatively quickly. Water discharges to the south-east pond from groundwater that feeds a small stream that flows through the quarry void (Figure 2.3). During rainfall events, runoff from most of the eastern arm will discharge to the south-east pond. Due to the topography of the Site, south-east pond levels would have to rise by approximately 9.3 m to 280 mAOD before overtopping and discharging to surface water. This rise is much greater than would occur in response to rainfall events and therefore, all water must infiltrate to the underlying aquifer. The spill over points for the eastern and the western arms of the quarry are shown on Figure 2.8. In the western arm, water levels would have to rise by approximately 1.4 m to 301.4 mAOD before they could overflow into the southern part of the Site. Given the flat relief in this area, this pond is still able to hold significant volumes of water (see Section 8.1.4). There are no reports of water overtopping from the western void and therefore all groundwater inflows and runoff from the western void must also infiltrate.

The infiltration rate for the south-east pond has been estimated by calculating the rate at which the runoff volume stored within the pond infiltrates through the underlying basal area over time. The volume of water stored within the south-east pond and the basal wetted pond area available for infiltration were calculated by producing a stage vs area and stage vs volume relationship. This was calculated using LiDAR data at 0.01 m intervals in Surfer 17 (Golden Software, 2021).

Three rainfall events with a distinct rainfall-stage relationship and various runoff inputs were selected for infiltration rate analysis (see Figure 2.10). Rainfall events with clear water input signals and recession curves were preferentially selected in order to better quantify the runoff input into the pond. Daily rainfall data was taken from the Pontsticill Upper WTW gauge (2.5 km north-east of the Site). The hourly infiltration rate was taken as an average of every three hours to smooth out artificial variation caused by data frequency. Each rainfall event's average infiltration rate was estimated as the mean infiltration rate between 25 - 75% range of the pond stage recession curve as this is most representative of typical conditions. This is consistent with the approach outlined in BRE Digest 365 Soakaway guidance (Garvin, 2016). The calculated infiltration rates range between 0.0035 to 0.0094 mm/s with an average of 0.0056 mm/s (0.48 m/day). Though this infiltration rate is dependent upon the hydraulic head in the pond and hence is an approximation, it is deemed to be reasonably representative as an average as it is calculated using rainfall events covering a wide range of water input rates.

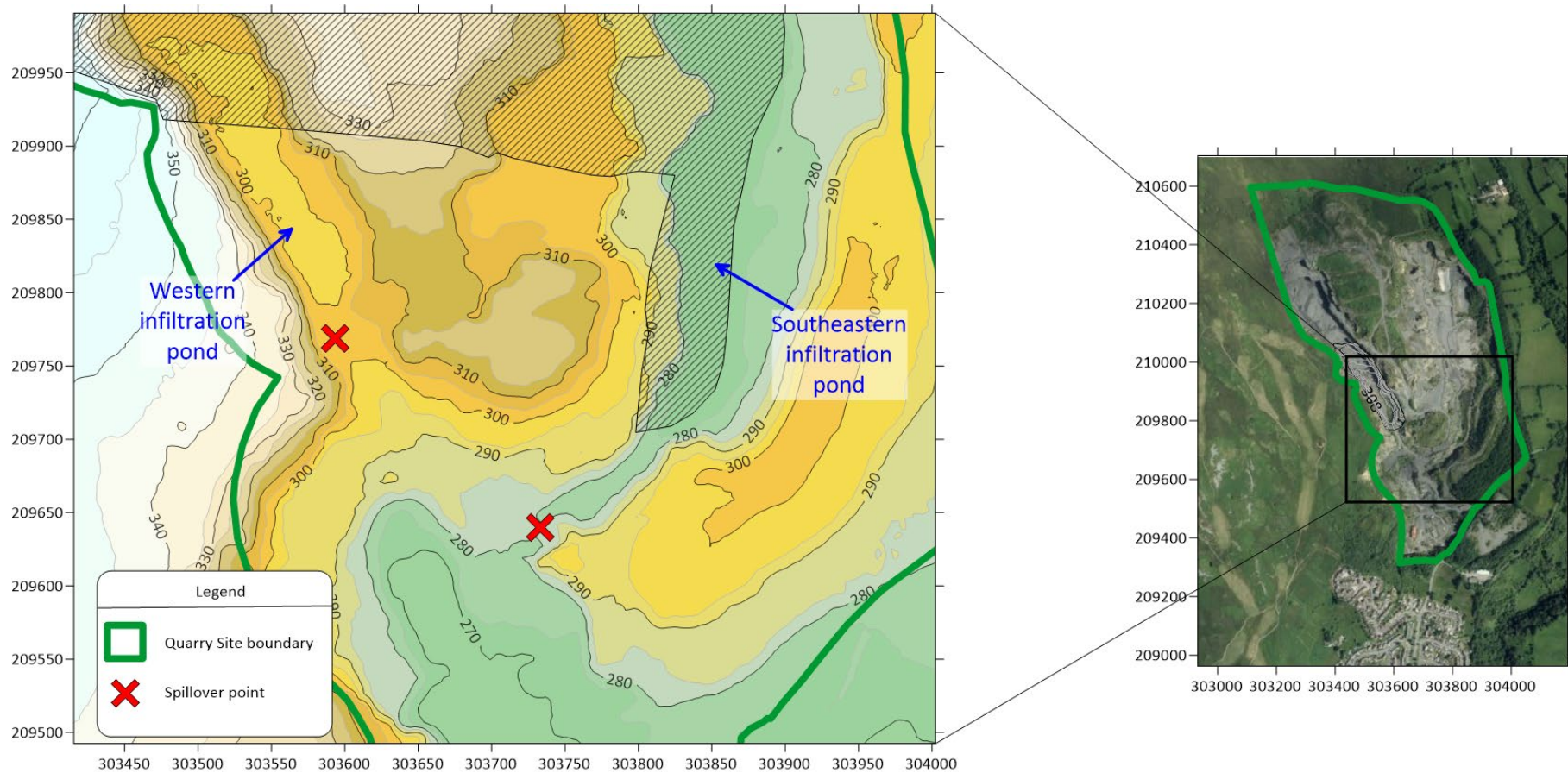


Figure 2.8 Spillover points for eastern and western arm of the quarry

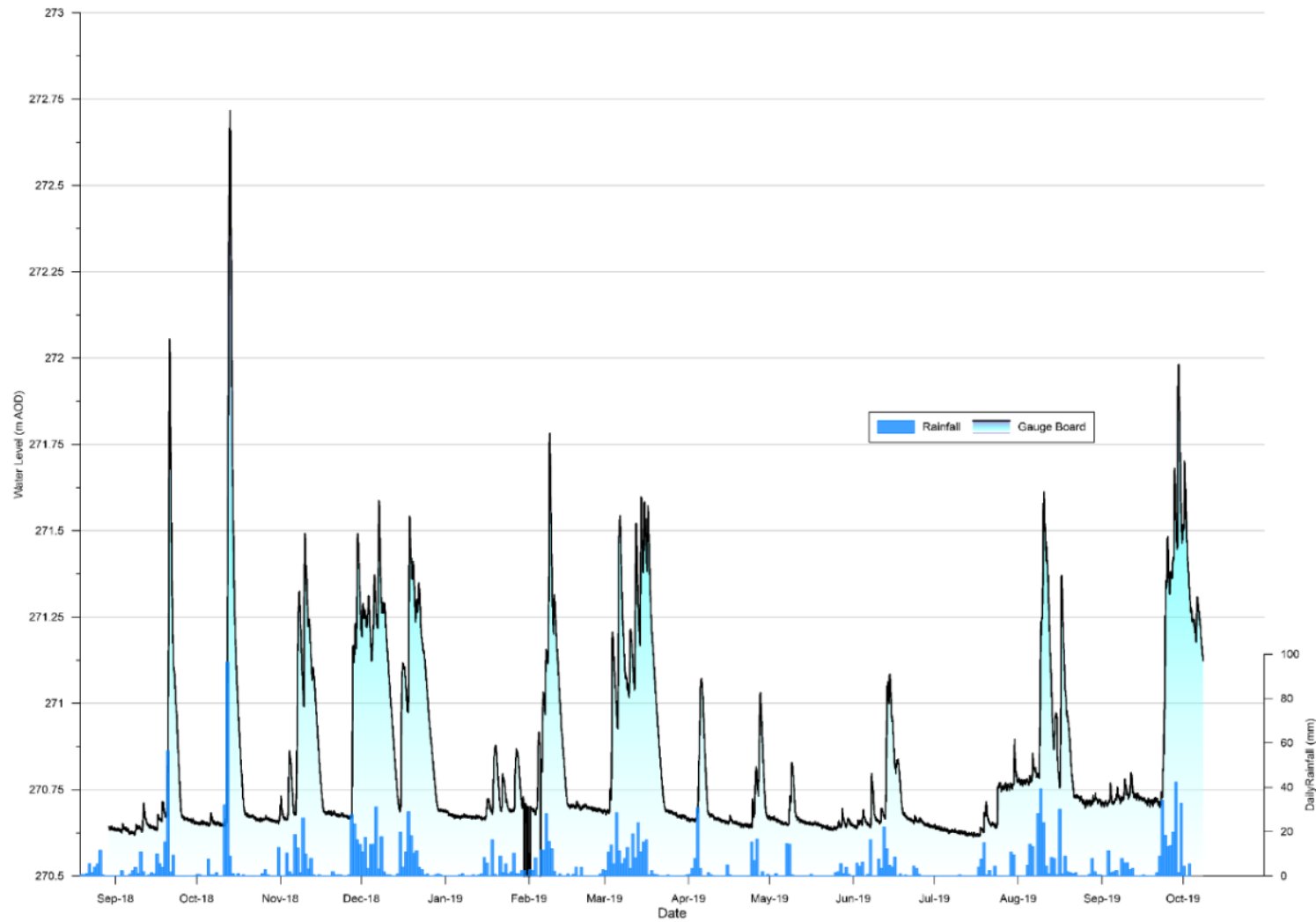


Figure 2.9 Gauge board levels at south-east pond

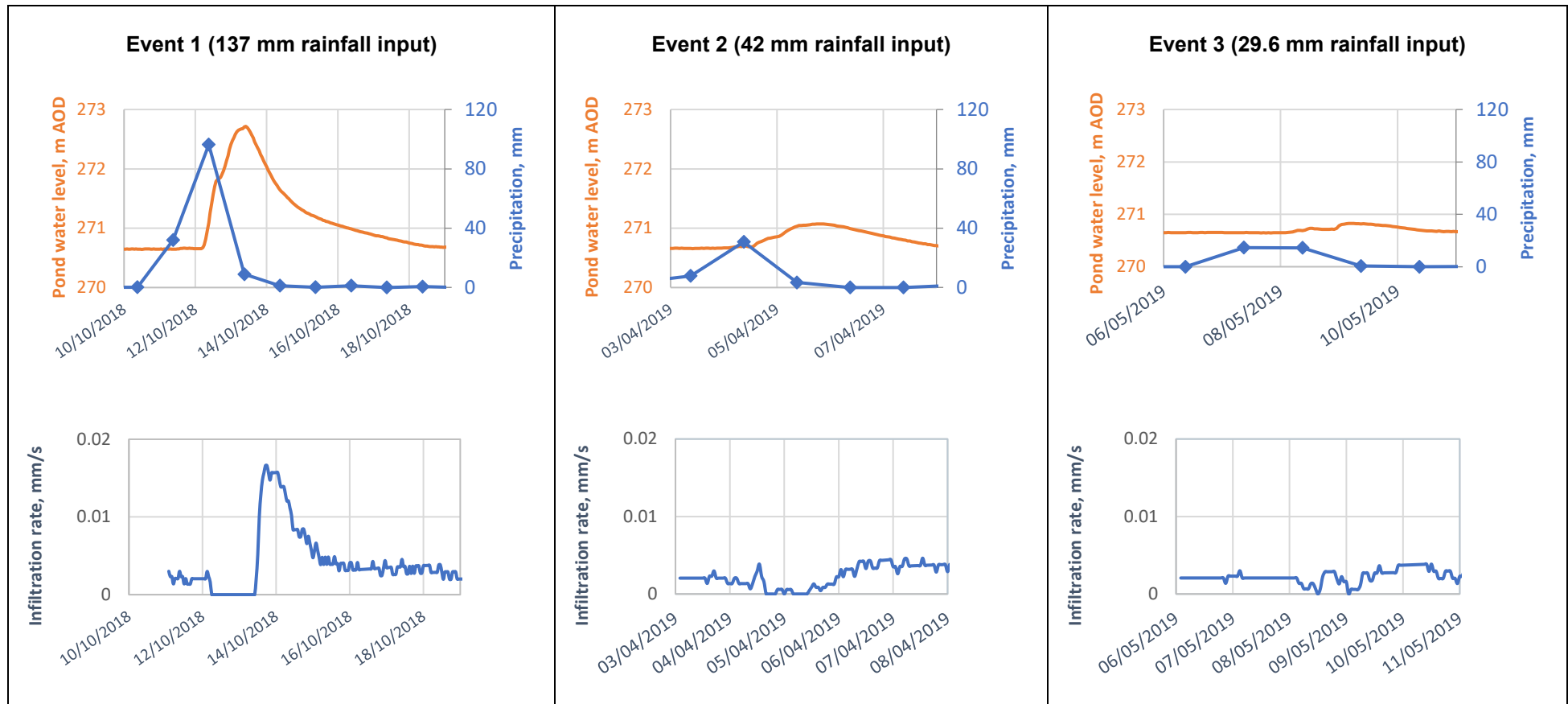


Figure 2.10 Pond water stage, precipitation and 3-hour averaged infiltration rate relationships

2.3.5 Catchment descriptors

Representative hydrological catchment descriptors for the Nant y Glais catchment have been derived from the online Flood Estimation Handbook (FEH) and are provided in Table 2.4 (CEH, 2020).

Table 2.4 Nant y Glais catchment descriptors

Descriptor	Abbreviation	Value
Area (of catchment)	AREA	5.4 km ²
Mean Altitude	ALTBAR	376 m
Mean direction of all drainage path slopes	ASPBAR	South-east (143°)
Base Flow Index associated with each HOST soil class	BFIHOST	0.389
Proportion of time when soil moisture deficit was equal to, or below, 6 mm during 1961 – 1990	PROPWET	0.54
Average Annual Rainfall (1961 – 1990)	SAAR	1,659 mm
Standard Percentage Runoff associated with each HOST soil class	SPRHOST	46.33%
Extent of urban and suburban land within catchment	URBEXT ₂₀₀₀	0.000

2.4 Site Drainage and Water Management

There is no site water management plan in place at the Site. Most runoff currently drains to the limestone aquifer beneath the Site following the pathways shown in Figure 2.3 and described above. Some runoff also drains to the Nant y Glais and Taf Fechan. The extant quarry floor is interpreted to intercept the groundwater surface causing seepages and this is classified as passive dewatering. This is the subject of a transfer abstraction licence application that was submitted under the transitional abstraction licencing arrangements on 11 December 2019.

The Site holds a discharge permit for the discharge of site drainage to the Taf Fechan in the south. The details of the permit are summarised in Table 2.5 and the permit itself is provided in Appendix E. The permit allows the discharge of groundwater and surface water runoff, which has passed through the Site's settlement lagoon system south of the Vaynor Road. This includes groundwater seepages from the spring in the northern part of the former processing area. The discharge permit does not specify a maximum discharge rate or volume, which is instead dependent upon the rainfall. It does, however, specify selected quality requirements.

Table 2.5 **Discharge permit details**

Discharge location	NGR	Limits	Permit ID
Taf Fechan	SO 03960 093110	Suspended solids 60 mg/l Oil/grease 10 mg/l pH 5 - 9	AF4026001/T002

3 Proposed Development

3.1 Operational Stage

Hanson has produced a series of operational plans that are provided in Appendix A.

In the first five years of the development, quarrying will occur in the western arm only, with some extraction up to 4.5 m below the water table. All of this additional groundwater inflow, along with surface water runoff, will be contained within the western arm and will infiltrate to ground (as per current conditions). The surface water runoff catchment area for the western arm will increase slightly.

From Year 5 to 10, quarrying will occur mainly in the central area between the two quarry arms to provide a connection for water from the western arm to flow into the south-east pond. Flow from the western arm will occur once water levels reach 300 mAOD. This connection is expected to be effective before Year 10.

From Year 10 to Year 15, quarrying continues in the central area to develop the south-east pond to its final depth across the width of the quarry by Year 15. This is to accommodate an increase in passive dewatering and runoff volumes as the catchment area to the south-east pond increases and the quarry is deepened. Quarrying will also continue in the north of the western arm. From Year 15 onwards, quarrying continues across the full quarry area to final development.

A site water management plan has been developed for the operational and restoration phases and more details are provided in Section 8.

3.2 Restoration

It is proposed to restore the Site to nature as shown by the restoration plan appended in Appendix B.

4 Flood Risk to the Proposed Development

4.1 Sources of Flooding

Flooding can occur from a number of sources as shown in Table 4.1. Each of these sources of flood risk is considered in detail below.

Table 4.1 Potential sources of flooding

Source	Description
Flooding from rivers	River flows which exceed the flow capacity of the river channel (or culverts) can cause fluvial flooding.
Flooding from the sea	High tides and/or storm surges can inundate coastal areas.
Flooding from land	Intense rainfall that cannot soak into the ground or enter drainage systems can quickly runoff the land and result in local flooding.
Flooding from groundwater	Groundwater flooding occurs when groundwater levels rise above surface elevations.
Flooding from sewers	Sewer flooding can occur when piped systems are overwhelmed by heavy rainfall, when sewers become blocked or when sewers are of inadequate capacity.
Flooding from reservoirs, canals and other artificial sources	Non-natural or artificial sources of flooding can include reservoirs, canals and lakes where water is retained above natural ground level.

4.2 Flood Zones

Technical Advice Note (TAN) 15 defines three fluvial or tidal/coastal flood zones (with two further sub-categories) as shown in Table 4.2. The flood zones provide a high-level overview of the likely flood risk to a specific area or region, although do not necessarily account for the presence of existing flood defences or the likely impacts of climate change.

Table 4.2 TAN 15 Flood Zones

Flood Zone	Description of Zone	Use within planning framework
A	Considered to be at little or no risk of fluvial or tidal/coastal flooding.	Used to indicate that justification test is not applicable and no need to consider flood risk further.
B	Areas known to have been flooded in the past evidenced by sedimentary deposits.	Used as part of a precautionary approach to indicate where site levels should be checked against the extreme (0.1%) flood level. If site levels are greater than the flood levels used to define adjacent extreme flood outline there is no need to consider flood risk further.
C	Based on NRW extreme flood outline, equal to or greater than 0.1% annual	Used to indicate that flooding issues should be considered as an integral part of decision making by

Flood Zone	Description of Zone	Use within planning framework
	exceedance probability (river, tidal or coastal).	the application of the justification test including assessment of consequences.
C1	Areas of the floodplain that are developed and served by significant infrastructure, including flood defences.	Used to indicate that development can take place subject to application of justification test, including acceptability of consequences.
C2	Areas of the floodplain without significant flood defence infrastructure.	Used to indicate that only less vulnerable development should be considered subject to application of justification test, including acceptability of consequences. Emergency services and highly vulnerable development should not be considered.

4.3 Flood Map for Planning

The Development Advice Map (DAM) is a screening tool for determining which sites may be in areas where flood risk may be of concern. The respective zones included in the map are defined in Table 4.2.

Figure 4.1 shows that the Site lies entirely within Zone A, i.e. it is considered to be at little or no risk of flooding from fluvial or coastal flooding. This is expected given its elevated position above the valley floor. Areas designated as Zone C2 (an area within a floodplain but not benefitting from flood defence infrastructure) and Zone B (an area known to have flooded in the past, based upon the presence of fluvially-derived sedimentary deposits) in the vicinity of the Site are limited to the floodplains of the Taf Fawr, the Nant y Glais and the Taf Fechan.

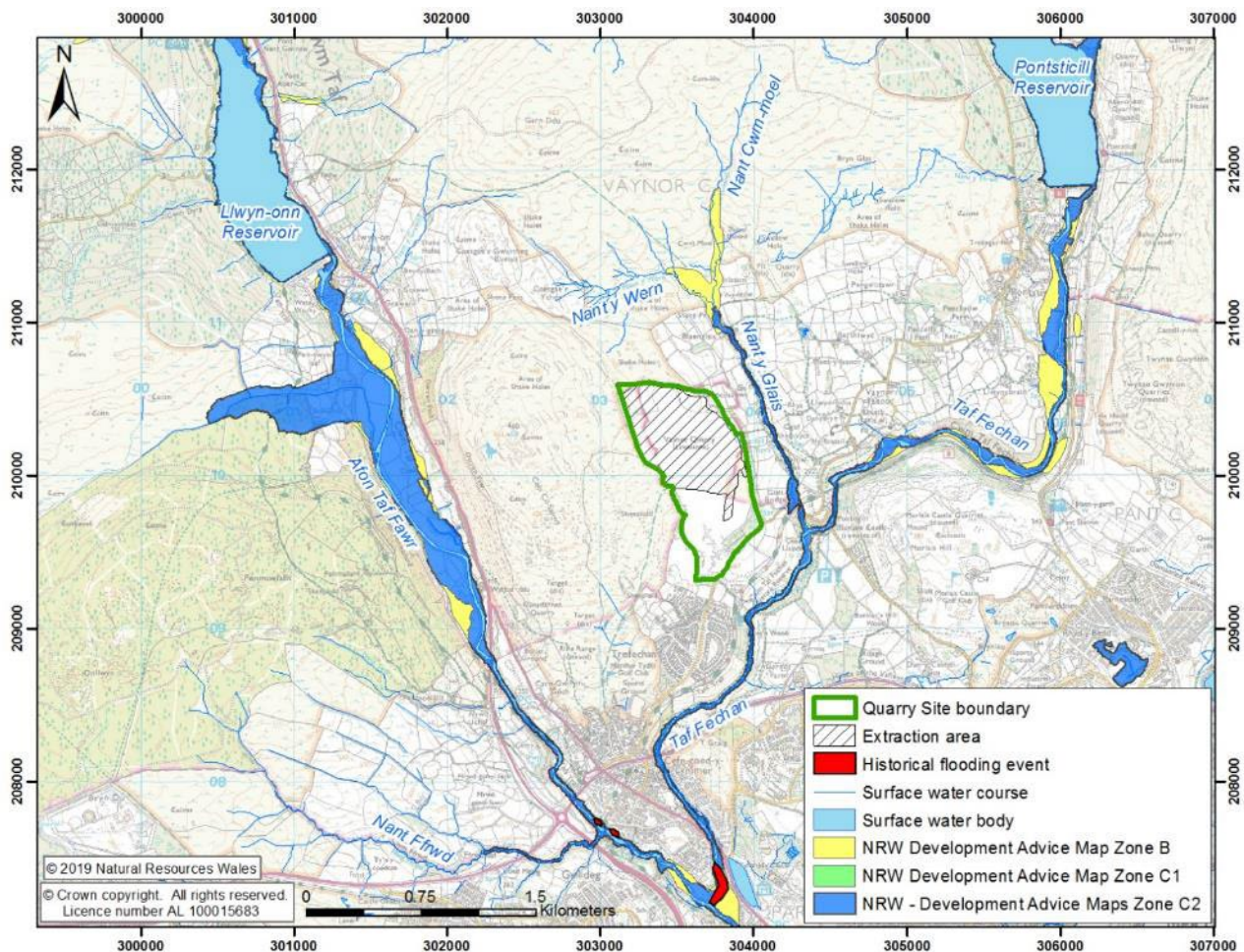


Figure 4.1 TAN15 flood zone map for planning

4.4 Historical Fluvial Flooding

The Site has not experienced any historical flooding according to NRW data. The closest historical flooding events have been recorded as December 1979 at the convergence of the Afon Taf Fawr and the Nant Ffrwd approximately 1.7 km south-south-west of the Site, as well as at the convergence of the Taf Fechan and the Afon Taf Fawr around 1.9 km south of the Site (see Figure 4.1).

4.5 Flood Defences

The Site does not benefit from any flood defences according to NRW data. The closest flood defences are located approximately 8.5 km south-east of the Site at Aberfan, surrounding the banks of the River Taff.

4.6 Surface Water (Pluvial) Flooding

Surface water (pluvial) flooding is usually associated with extreme rainfall events but can also occur when rain falls on land that is already saturated or is of low permeability. Rainfall that is unable to infiltrate, either due to high rainfall intensity or ground conditions, generates overland flow. Overland flow can cause flooding or ponding in localised topographic depressions before runoff can infiltrate or enter a drainage system or watercourse.

The NRW surface water flood risk map in Figure 4.2 shows that the risk of surface water flooding varies from very low (light blue) to high (dark blue) across the Site and its immediate vicinity. Areas identified as high risk have a chance of flooding of greater than 1 in 30 (3.3%), whilst medium risk (medium blue) areas are susceptible to flooding from between 1 in 100 (1%) and a 1 in 30 (3.3%). Low risk means that each year the area has a chance of flooding between 1 in 1,000 (0.1%) and 1 in 100 (1%).

Pluvial flood risk at the Site is predominantly limited to localised depressions within the quarry void and several overland flow channels which approximately follow the runoff channels observed during the site visits. Figure 4.2 shows three main overland channels located within the extraction area; terminating at the southern end of the extraction area at three separate infiltration ponds with no outlets. Only the south-east pond is thought to be a permanently water-filled feature, the other ponds may be ephemeral, forming following storm events.

Figure 4.2 shows another major surface drainage channel in the southern part of the Site that appears to collect storm runoff from the Cefn Cil-Sanws hill to the west and drain south-eastwards beneath Vaynor Road via a culvert towards the Taf Fechan. During the site visit, a drainage feature was observed in the south of the Site draining to the culvert; however, this was sourced by a spring in the north of the processing area and not from runoff. No stream features on the Cefn Cil-Sanws hill were observed during a walkover in July 2021 and they are not apparent on online satellite imagery. Some runoff from the Cefn Cil-Sanws hill is possible, but due to the thick vegetation and sink holes, this is expected to only occur after the largest storm events.

Where possible, site water management will direct runoff towards the infiltration ponds to ensure plant equipment is not affected. Surface runoff will be managed by a suitable drainage strategy (see Section 8).

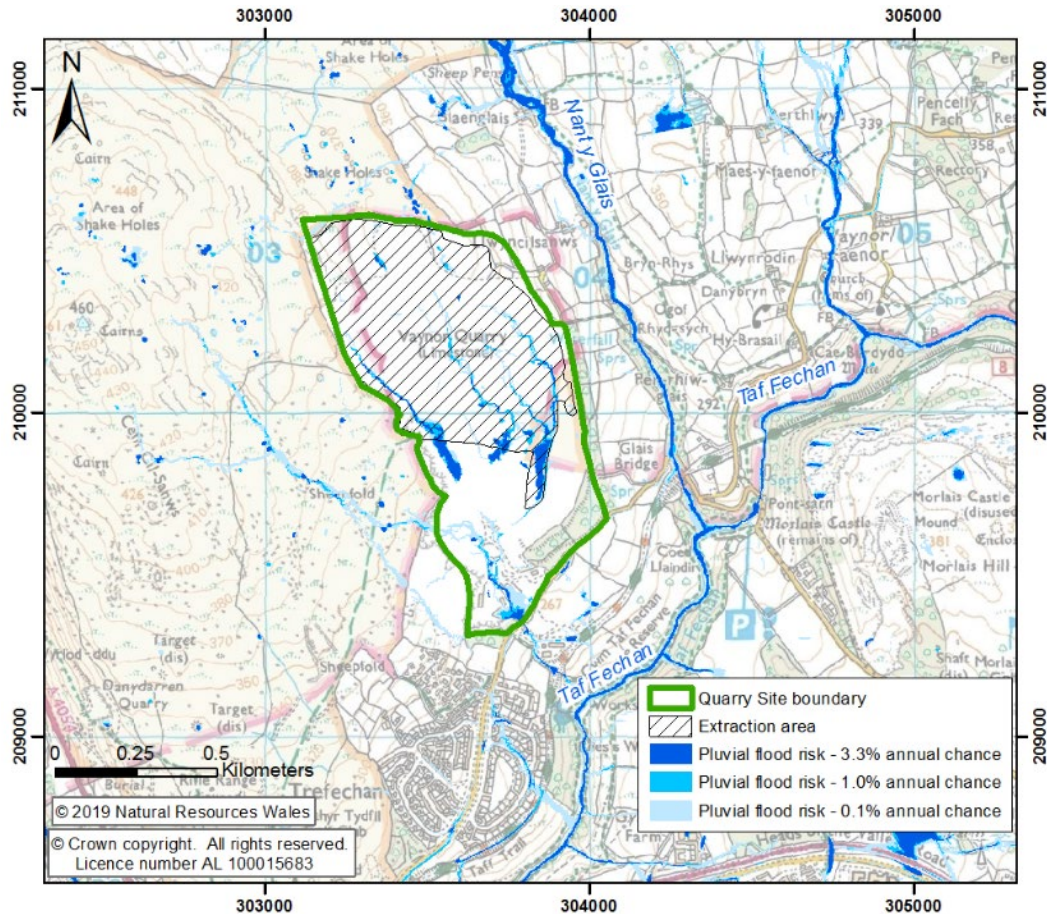


Figure 4.2 NRW pluvial flood risk data

4.7 Groundwater Flooding

Groundwater flooding occurs when the water table rises above the ground surface or into man-made ground.

Merthyr Tydfil County Borough Council's (MTCBC's) Strategic FCA defines the risk of groundwater flooding as low to moderate as both the soils and underlying geology are shown to be permeable to an extent (MTCBC, 2018).

The quarry void at the Site intercepts the groundwater table causing seepages along the bedding plane. As the groundwater seepages are confined to within the Site boundaries and are channelled towards the infiltration ponds whereupon it either evaporates or infiltrates into the ground, it does not create an off-site flood risk. The flood risk to the Site can be managed using the drainage strategy (Section 8).

4.8 Flooding in the Event of Reservoir Failure

According to the strategic FCA, there are five reservoirs in the Taff catchment upstream of Merthyr Tydfil in the Brecon Beacons (MTCBC, 2018). The two closest to the Site are the Llwyn-on Reservoir 2.1 km north-west and the Pontsticill Reservoir 2.5 km north-east of the Site.

According to the NRW data there is no flood risk to the Site in the unlikely event of reservoir failure. Flood risk from reservoir failure is limited to the floodplains of the Taff Fechan and the Taff Fawr.

5 Suitability of the Proposed Development

5.1 Justification Test

Welsh planning policy aims to direct development towards zones at low risk of flooding. This is principally achieved through application of the Justification Test.

Given that the Site is within Flood Zone A, the Site is considered appropriate for all types of development and no Justification Test is required in this case.

The only constraint for development in this area is that it does not increase off-site flood risk. This is addressed in sections 6 to 8.

5.2 Merthyr Tydfil Local Development Plan

The Local Development Plan (LDP) states the following (MTCBC, 2011):

“Part of the drive for a more efficient use of resources also involves adopting an integrated approach to the use of finite mineral resources and the LDP provides positively for the working of local mineral resources to meet the needs of the wider region.”

The LDP states that before the Site was closed in 2007, it was one of only two aggregate quarries within the LDP area, therefore its continued mineral extraction was necessary to meet the aggregate mineral requirements:

“The Council is satisfied that with the continued working at current production levels, the existing quarries [Vaynor Quarry and Gelligaer Quarry] in the County Borough will continue to meet Merthyr’s proportional level of contribution to the estimated regional need for aggregate minerals.”

6 Flood Risk from the Proposed Development

6.1 Identified Receptors

6.1.1 Water features

Runoff from the southern part of the Site follows the topographical gradient (see Figure 2.1) and predominantly drains towards the Taf Fechan to the south. The remainder of the area drains into three closed sub-catchments of the existing quarry void where it either evaporates or infiltrates into the underlying aquifer via surface depressions and ponds (including the south-east pond) (see Figure 2.3). Upon recharging the aquifer, much of the infiltrating water likely contributes to baseflow in the Taf Fechan and spring flow in the Cwm Taf Fechan SSSI.

6.1.2 Property

Land use in the area around the Site is predominantly rural with only several small settlements in its vicinity. The closest settlements surrounding the Site are Trefechan (100 m south), Llwyn-on (1.9 km north-west) and Pontsticill (1.9 km north-east).

A number of isolated dwellings and farms are located in the area around the Site, including Llwynsilanws (160 m north-east), Aberglais Inn (330 m east), Blaenglais (370 m north), Pen-rhiw-glais (440 m east), Llwynrodin (650 m east), Hy-Brasail (680 m east), and Berthlwyd (850 m north-east). Regionally, the outskirts of Merthyr Tydfil lie 1 km south of the Site and Vaynor (comprised of a small number of wide-spread dwellings) lies 1 km east.

Morlais Castle Golf Course lies 900 m south-east of the Site, and Merthyr Tydfil Golf Course lies 25 m west at its closest approach.

6.1.3 Infrastructure

Vaynor Road (oriented north-east to south-west) is located adjacent to the Site's southern boundary. Set beneath Vaynor Road lies a culvert which channels surface runoff and groundwater from the Site southwards towards the Taf Fechan. Glais Bridge is located 250 m east of the Site along Vaynor Road. Heads of the Valleys Road (A465) lies 850 m south of the Site traversing in an east-west direction.

6.1.4 Designated sites

Cwm Taf Fechan SSSI follows the Taf Fechan river gorge 150 m south-east of Site. Nant y Glais SSSI lies in the gorge of the Nant y Glais 140 m north-east of the Site.

6.2 Climate Change

Projections of future climate change in the UK suggest that short-duration, high-intensity rainfall and long-duration rainfall events will become more frequent. Guidance drafted by the Welsh government recommends that the effects of climate change are incorporated into FCAs (Welsh Assembly Government, 2004). Recommended precautionary sensitivity ranges for peak rainfall intensities and peak river flows and climate change allowances have been set out in the guidance for FCAs (Welsh Government, 2021).

The operational period of the proposed development is anticipated to be at least 100 years. Due to the long operational period, a conservative climate change uplift of 40% has been considered in this runoff assessment for both the operational and post-restoration phases.

6.3 Runoff Calculations

6.3.1 Runoff destinations

Greenfield

Figure 6.1 shows inferred surface water flow directions and catchment areas under greenfield conditions labelled for identification in the following rainfall runoff calculations.

Under greenfield conditions, surface runoff at the Site was part of a single principal catchment (G1) as it flowed south-east towards the Taf Fechan and east towards its tributary, the Nant y Glais.

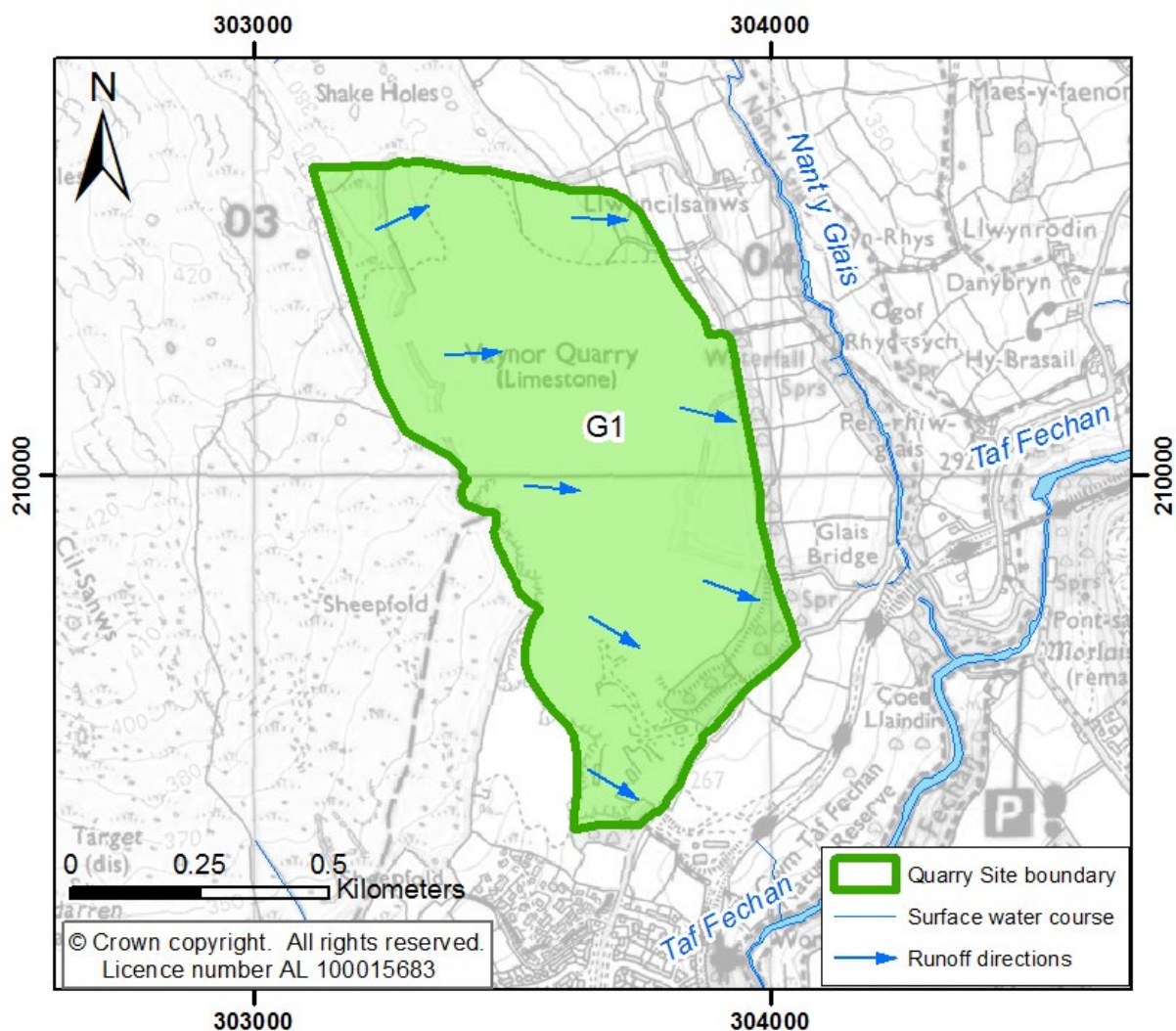


Figure 6.1 Runoff catchments – greenfield

Current

Figure 6.2 shows inferred surface water flow directions and catchment areas under the current conditions labelled for identification in the following rainfall runoff calculations. These catchments have been derived using LiDAR data.

Under current conditions, there are four principal sub-catchments within the Site (prefixed “C”). Sub-catchment C1 is split into two non-contiguous northern and southern parts and remains largely unaltered from greenfield conditions and its surface runoff is routed either south-east towards the Taf Fechan or east towards the Taf Fechan’s tributary the Nant y Glais. In catchment C1’s southern part, some of the runoff is channelled through a culvert beneath Vaynor Road, where it discharges to the Taf Fechan via a settlement pond (Figure 2.3).

Previous quarrying activities at the Site have resulted in the creation of three closed sub-catchments (C2-C4) wherein surface runoff in each sub-catchment flows downgradient ponds which have no outlet. Water within these ponds is inferred to infiltrate.

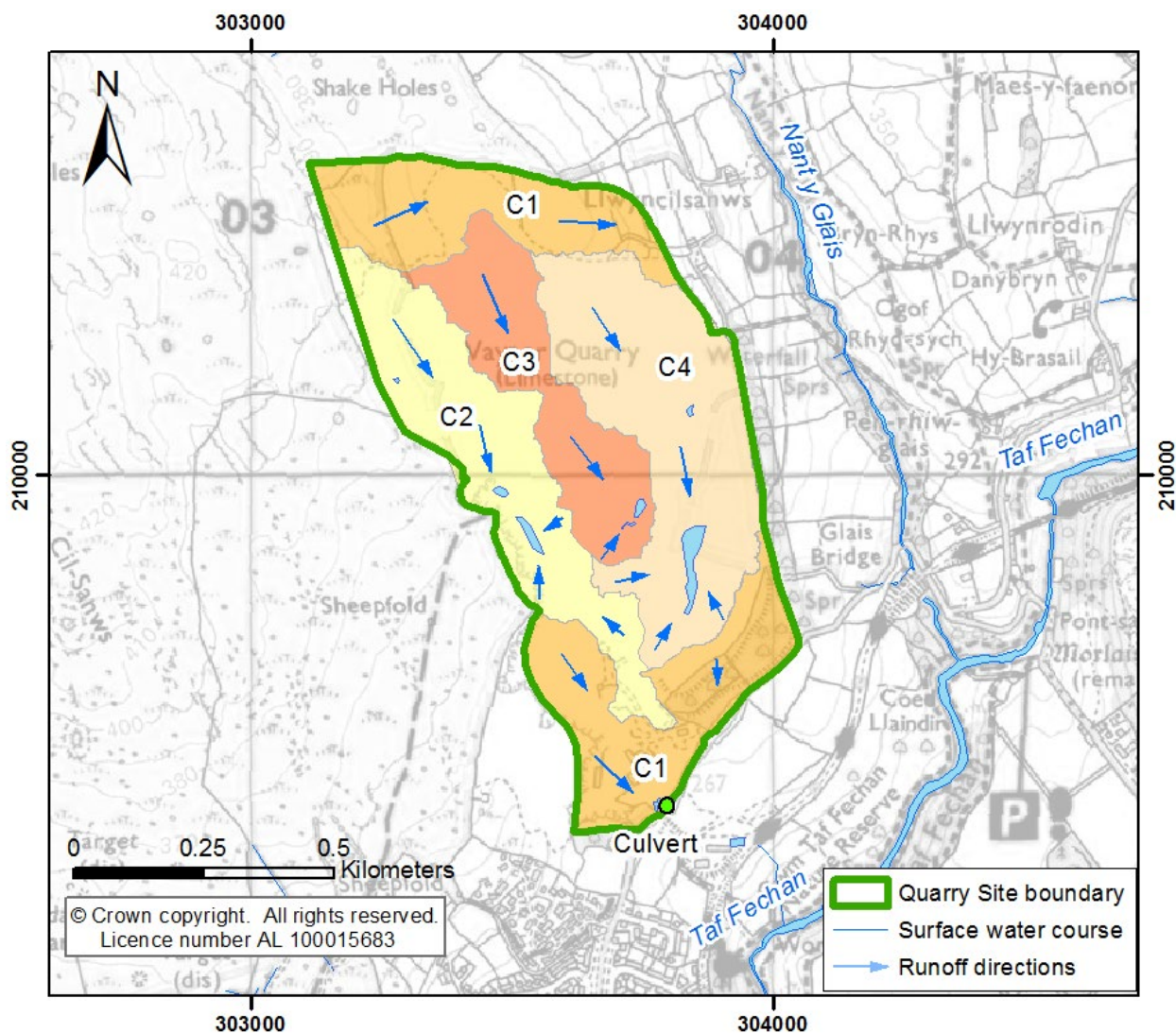


Figure 6.2 Runoff catchments – current

Operational

The quarry will be worked over 100 years in six phases whereupon the central ridge will be removed and the quarry void will be both expanded and deepened. Catchment C1 (north) will be largely excavated away leaving only small areas at the north-west and north-east corners of the Site (catchment “OR1”) draining north-east and east towards the Nant y Glais (see Figure 6.3). Catchment C1 (south) will remain unaffected (also as catchment “OR1”) and will follow the same drainage pathways as under current and greenfield conditions.

Catchments C2, C3 and C4 will eventually be combined into a central catchment, OR2, with all surface runoff draining south towards a single attenuation (infiltration) pond. The pond will be in place in its final form from Year 15 of the development (runoff prior to that point being dealt with through infiltration in the existing infiltration areas). The pond level will gradually increase as the quarry development intercepts more groundwater. Also, the maximum lake level after large rainfall events will increase as the catchment area draining to the pond increases.

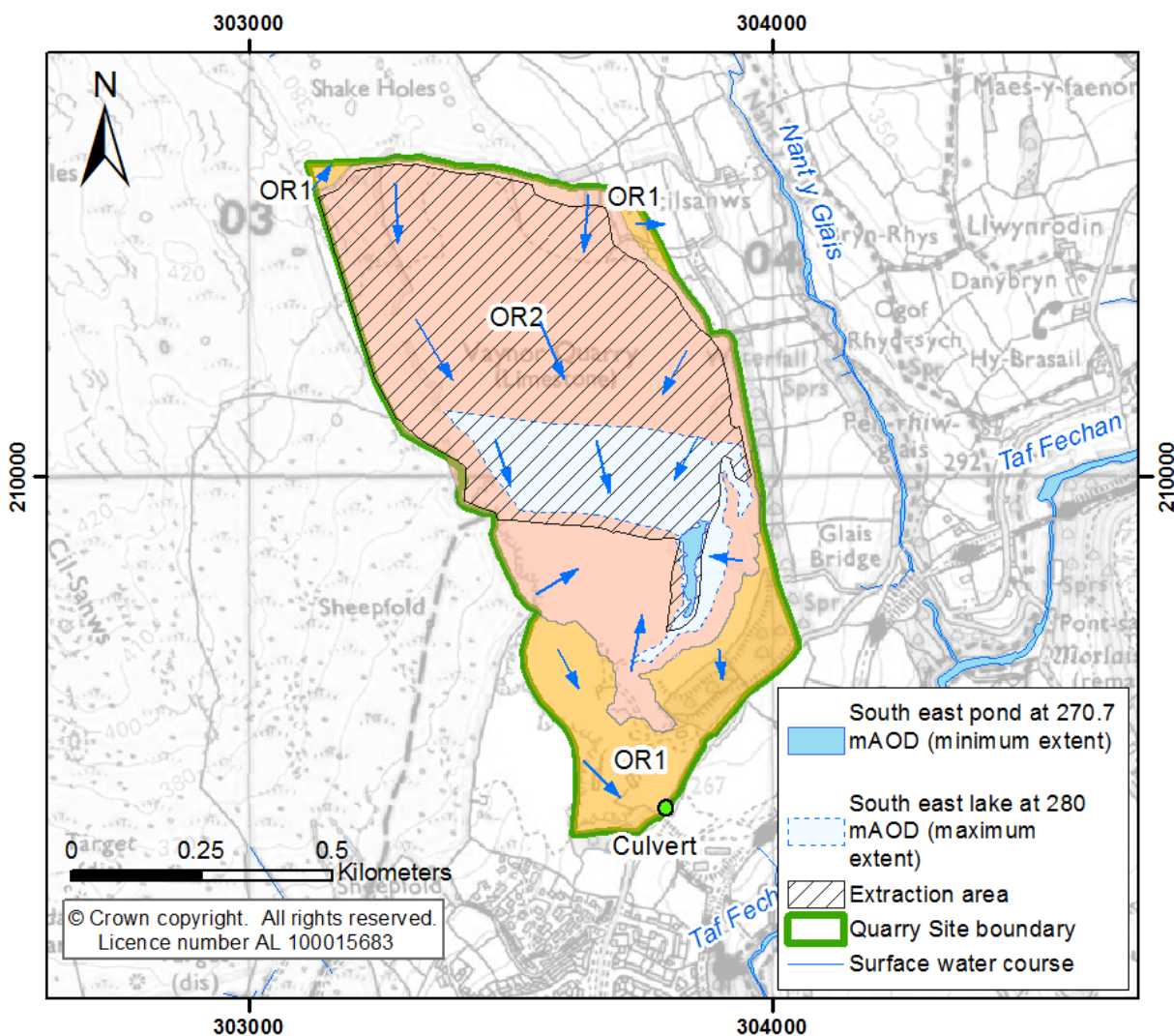


Figure 6.3 Runoff catchments – operational and post-restoration

Post-restoration

The Site will be restored to nature with no significant in-filling apart from the re-spreading of quarry waste, soils and overburden, thus the post-restoration stage catchment will remain the same as during the final operational phase (see Figure 6.3).

Summary

A summary has been provided below of the catchment areas over the lifetime of the development and post restoration. A prefix of “G” and “C” has been used to denote catchment areas within the greenfield and current phases of the development. Operational and restored phase catchment areas will remain of equal dimensions and are jointly denoted with a prefix “OR”. The areas which contribute runoff to the Taf Fechan catchment are expected to decrease over time as the extraction area expands (65.40, 21.41 and 12.43 ha in greenfield, current and final operational/restored phases respectively), with a corresponding increase in the closed quarry void sub-catchment area draining towards the attenuation pond (up to 52.97 ha at the final operational/restored phase).

Table 6.1 Site catchment areas over time

Phase	Catchment	Area (ha)	Notes
Greenfield	G1	65.40	Land draining into the Taf Fechan catchment
Current	C1	21.41	Land draining eastwards and southwards into the Taf Fechan catchment
	C2	14.65	Western sub-catchment draining into an infiltration pond
	C3	10.12	Central sub-catchment draining into an infiltration pond
	C4	19.22	Eastern sub-catchment draining into an infiltration pond
Operational and Restored	OR1	12.43	Land draining eastwards and southwards into the Taf Fechan catchment
	OR2	52.97	Vaynor Quarry void catchment

6.3.2 Runoff calculations – greenfield

The proportion of rainfall diverted to overland flow is a function of several key factors, including: slope gradient, soil type, and land cover type. There are numerous methodologies for calculating runoff rates and volumes for a given catchment and the suitability depends upon the catchment characteristics. The Revitalised Flood Hydrograph (ReFH2) method is considered appropriate for establishing runoff rates and volumes for both greenfield and developed sites (CIRIA, 2015).

The ReFH2 program generates a total runoff hydrograph (summation of surface runoff and baseflow) for a given storm event based upon the catchment descriptors. This allows for total runoff volumes and peak runoff rates to be calculated.

The values of SAAR and BFI used in the runoff calculations have been taken from the hydrological catchment descriptors for the Nant y Glais catchment in the vicinity of, and

including, the Site (Table 6.2). The soil in the area is generally mapped as freely draining, slightly acid but base-rich soils (Cranfield University, 2019).

Table 6.2 Hydrological catchment descriptors (CEH, 2019)

Descriptor	Abbreviation
NGR	SO 04300 09700
BFIHOST	0.389
SPRHOST	46.33%
PROPWET	0.54
SAAR	1,659 mm

Table 6.3 summarises the runoff for the pre-development greenfield catchment G1 under a six-hour duration storm event for a range of return periods. ReFH2 output reports for this baseline scenario are included in Appendix F.

Table 6.3 Greenfield runoff

Return period	6 hour rainfall (mm)	Site peak runoff rate (m ³ /s)	Total runoff volume (m ³)
1 in 1 year	30.10	0.98	9,790
1 in 30 year	59.63	2.11	21,690
1 in 100 year	71.30	2.62	27,010

6.3.3 Runoff calculations – operational & restored sites

Only runoff from catchment OR1 will contribute to off-site runoff from the Site.

Given that the sub-catchment OR2 will be largely bare rock during the operational phase, the runoff characteristics of soil HOST class 22 (Institute of Hydrology, 1995) – “Relatively free draining soils with a low storage capacity over hard impermeable rocks with no storage capacity” have been utilised to more accurately represent the operational site conditions. In this case this represents a small change in the BFIHOST value from 0.389 to 0.315. Following restoration of the quarry void to nature, the bare rock within the quarry void will be re-vegetated and the original greenfield BFIHOST value is applied. A waterbody area of 2.1 ha, approximately representing a peak pond extent after a 6-hour, 1 in 100 year event, was included as an impermeable area for OR2 (with a runoff coefficient of 1.00). This is conservative as the peak pond extent (i.e. peak water storage) typically occurs in the second half of the rainfall event (see Figure 8.1).

The attenuation storage volume is the required storage to deal with additional runoff caused by a development compared to the greenfield scenario.

Tables 6.4, 6.5 and 6.6 compare the predicted site runoff for the operational and restored phases with the greenfield runoff for the 1 in 1 year, 1 in 30 year and 1 in 100 year, 6 hour storm event plus 40% climate change allowances.

Table 6.4 Predicted runoff from the Site (1 in 1 year event)

Catchment	Scenario	Peak runoff rate (l/s)	Change in rate from greenfield (l/s)	Runoff volume (m ³)	Change in volume from greenfield (m ³)
G1	Greenfield Runoff	983	N/A	9,791	N/A
OR1	Operational and Restoration inc. CC (40%)	273	-710	2,755	-7,036
OR2	Operational inc. CC (40%)	1,300	N/A	13,297	N/A
	Restoration inc. CC (40%)	1,155	N/A	11,654	N/A

Table 6.5 Predicted runoff from the Site (1 in 30 year event)

Catchment	Scenario	Peak runoff rate (l/s)	Change in rate from greenfield (l/s)	Runoff volume (m ³)	Change in volume from greenfield (m ³)
G1	Greenfield Runoff	2,114	N/A	21,691	N/A
OR1	Operational and Restoration inc. CC (40%)	611	-1,504	6,324	-15,367
OR2	Operational inc. CC (40%)	2,893	N/A	30,263	N/A
	Restoration inc. CC (40%)	2,581	N/A	26,726	N/A

Table 6.6 Predicted runoff from the Site (1 in 100 year event)

Catchment	Scenario	Peak runoff rate (l/s)	Change in rate from greenfield (l/s)	Runoff volume (m ³)	Change in volume from greenfield (m ³)
G1	Greenfield Runoff	2,616	N/A	27,013	N/A
OR1	Operational and Restoration inc. CC (40%)	765	-1,852	7,966	-19,047
OR2	Operational inc. CC (40%)	3,616	N/A	37,996	N/A
	Restoration inc. CC (40%)	3,231	N/A	33,657	N/A

Off-site runoff to the Taf Fechan (via catchment OR1) is predicted to reduce by approximately 71% relative to the pre-development greenfield rates and volumes even including a 40% climate change allowance. This is owing to the reduction in the contributing area as the quarry void is excavated and expanded thus reducing the land area draining naturally off-site.

As the quarry void will be dewatered passively with no off-site water disposal, there will be no contribution to off-site runoff from the sub-catchment OR2.

Rainfall runoff volume and peak rate within the quarry void (catchment OR2) draining towards the attenuation pond (see Section 8.1) decreases by approximately 12% between the operational and restoration phases. This is caused by the quarry void being restored to natural vegetation cover in the restoration phase which acts to slow down the flow and increase the proportion of the runoff loss through evapotranspiration before it can reach the attenuation pond.

6.4 Flood Risk During the Operational Phase

Given that off-site runoff rates and volumes are predicted to decline during the operational phase, for the reasons stated above, there will be no increase in off-site flood risk over this time. The extension of the quarry void provides a significant reduction in storm flows in the downstream Taf Fechan catchment.

6.5 Flood Risk Post Restoration

Apart from the quarry void (catchment OR2) greenification, no major changes in the post-restoration catchment areas or surface topography relative to the final operational phase are expected. Similar to the final operational phase, off-site rainfall runoff rates are expected to be significantly below the natural greenfield runoff volumes and rates (see Section 6.3.3) thus providing a reduction in storm flows in the downstream Taf Fechan catchment.

6.6 Flood Risk Mitigation Measures

Given off-site runoff rates and volumes are calculated to be lower during the operational phase and post-restoration relative to greenfield runoff, no specific measures are recommended to control runoff directly apart from the surface water management strategy described in Section 8.

7 Flood Risk Considerations

7.1 Key Considerations

To meet (or exceed) the TAN15 requirements, 'Less Vulnerable' developments, including mineral extraction sites, are considered suitable for location within Flood Zone A. Good practice with regards to development design and flood risk requires new developments to:

- Remain safe in times of flooding whilst taking climate change into account;
- result in no net loss of floodplain storage;
- not impede flood water flows; and
- not increase the volume and rate of surface water runoff leaving the Site over its intended design lifetime (thereby increasing local flood risk).

Each of these requirements is discussed in relation to the proposed development in Sections 7.2 to 7.6 below.

7.2 Remain Safe in Times of Flooding

The DAM indicates that the Site is not at risk of flooding from rivers or the sea. The quarry void will be utilised as part of the surface water management strategy (see Section 8). Open water bodies present within the Site will be managed in accordance with industry best practice to ensure they do not present a hazard to site staff and visitors. The only flood risk is posed by pluvial flooding during rainfall events; however, this can be managed by the drainage strategy (see Section 8).

7.3 No Net Loss of Floodplain Storage

The proposed development would not result in a net loss of river floodplain storage given that no part of the Site is within the floodplain (Section 4.3).

7.4 No Impediment to Flood Water Flows

The proposed development should not impede surface water flows such that localised flood risk is increased. This is not a possibility in this instance given that the Site is sited on a plateau, outside of the floodplain and will capture (and subsequently infiltrate into the ground) any incident surface runoff.

7.5 Surface Water Runoff

The proposed development will extend the existing quarry void by excavating the adjacent greenfield area. The area draining to the Taf Fechan catchment will reduce and so too will surface runoff rates and volumes compared to the greenfield rates and volumes, thus effectively decreasing the local flood risk downstream of the Site.

7.6 Risks to People

No personnel are expected to be residing on-site. The Site is not at risk of flooding from rivers or the sea as designated in the DAM, and surface water runoff during heavy rainfall events will be managed by the drainage strategy. Open water bodies present within the Site will be managed in accordance with industry best practice to ensure they do not present a hazard to site staff and visitors.

8 Drainage Strategy

8.1 Operational Phase

8.1.1 Overview

There is no off-site discharge planned from the part of the catchment that is to be quarried, and between Year 5 and Year 10 of the development water will be able to discharge into an attenuation pond located in the southern part of the extraction area (south east pond). The attenuation pond will be designed to ensure it holds and infiltrates groundwater runoff from a 1 in 100-year storm event with 40% climate change allowance during the operational and post-restoration phases (see Section 8.1.4). Prior to Year 10, quarrying will occur predominantly in the western arm and runoff and groundwater inflows will flow to the western infiltration pond to the south west of the extraction area (see Figure 2.3).

Off-site drainage from the southern part of catchment OR1 will continue to discharge to the Taf Fechan via the culvert and settlement pond during the operational phase. The total outflow from runoff will reduce over time as the quarry void area is increased and the OR1 runoff catchment size reduces.

8.1.2 Performance requirements

As discussed and quantified above, off-site runoff will reduce during the operational and restoration stages (relative to greenfield runoff) as the closed quarry void sub-catchments within the Site boundary are enlarged. Given the above, there are no specific requirements to provide additional attenuation capacity on-site. The quarry void itself provides a great deal of storm water attenuation capacity.

The infiltration ponds should drain sufficiently fast such that it does not cause an on-site flood hazard in the event of a very wet meteorological period – such as the occurrence of multiple storms in succession.

8.1.3 Water quality

SuDS techniques can be used by way of a treatment train process to effectively manage the quality of surface water flowing across a site. Different methods can be used to intercept pollutants and allow them to degrade or be stored in-situ without impacting the water quality further downstream. The inclusion of SuDS in development designs became mandatory in 2019 for all significant developments (greater than a single dwelling or >100 m²) under Schedule 3 to the Flood and Water Management Act 2010.

In this instance, the quarry void will act as a large SuDS features allowing for stormwater attenuation. The majority of the runoff at the Site will accumulate in the infiltration ponds and infiltrate to ground. The north-western and north-eastern corners of the future extraction area will continue to generate rainfall surface runoff which will flow towards the Taf Fechan and Nant y Glais, or be captured by a sinkhole in the limestone, as per current conditions.

Runoff from the southern part of the Site will continue to be routed via the existing settlement lagoon (south of Vaynor Road) to reduce suspended solids loads prior to discharge to the Taf Fechan. It is recommended that this feature is surveyed by a drainage engineer and required remedial works are undertaken prior to the recommencement of quarrying activities.

The proposed development will see some heavy plant (tipper trucks etc.) moving around the Site on haul roads and some stockpiles of overburden and stone at the eastern part of the quarry void. These areas, especially during high-magnitude rainfall events, may increase the suspended solid particle loads in the runoff water. This will be managed by allowing the runoff within the quarry void to collect in the south-east pond and infiltrate to ground. This will provide a suitably long residence time for settlement to occur and the water to clarify.

As mentioned in Section 6.3.1, some of the areas currently contributing to off-site runoff will be excavated during the operational phase, adding them to the quarry void sub-catchment. Land to the south of the future extraction area generating off-site runoff will be utilised for mineral stockpiling and loading. Runoff from this area will be discharged via the culvert beneath Vaynor Road in the south of the Site. This will pass to the Taf Fechan via settlement ponds south of Vaynor Road. These settlement ponds will be refurbished to ensure that the discharge is compliant with the conditions of the discharge permit. The remaining land generating off-site runoff will not be developed and therefore there is no source of contamination present in these areas. No specific SuDS features are proposed in these areas.

8.1.4 Proposed drainage strategy – operation phase from Year 0 to Year 10

During the first ten years of development, excavation will be constrained to the western arm of the quarry. There will be minimal additional interception of groundwater during these ten years and therefore groundwater inflows are not expected to increase. It is therefore only the accommodation of increased surface water flows up to Year 10 in the western arm that requires consideration.

At Year 10, the catchment area for the western arm will be approximately 2.3 ha larger than the current catchment (14.65 ha), as the excavation has expanded to the north and northeast. This is an increase of 16% by area over the current catchment area.

Taking the 24-hour, 1 in 100 year event, if the volume of 59,968 m³ for a 52.97 ha catchment was pro-rated for the western arm catchment area of 16.95 ha and a 10% climate change allowance (CCA) was applied this would give a volume of 15,077 m³. The western pond would overflow at 301.4 mAOD when the volume of the western pond reached approximately 14,600 m³. However, infiltration would occur during this period, effectively reducing the storage requirement.

No data exists for the infiltration rates in the western pond; however, it is considered likely that infiltration rates will be similar to the southeastern pond. The unsaturated zone beneath the largest and southernmost infiltration pond of the western arm is 3 m in the north and 8 m in the south. This is a good thickness to permit infiltration. Based on an infiltration area of 1.04 ha which would be available at an elevation of 301.4 mAOD and an average depth of 1.7 m, using the observed infiltration response at the southeastern pond of 0.48 m/day, this would equate to an infiltration rate of approximately 5,011 m³/d over the entire western pond area. The sum of available storage and infiltration volume is 19,611 m³/d. This is well in excess of the predicted runoff volume and demonstrates the adequacy of surface water management measures during this period of quarry development. In reality this runoff would be shared amongst the multiple pond features in the western arm. It should also be noted that the increase in surface water flows over those currently being accommodated are relatively modest.

8.1.5 Proposed drainage strategy – operational phase from Year 10 to final development

From Year 10 of the operational phases and post-restoration phase, surface runoff from within the quarry void will discharge into an infiltration pond located at the southern (i.e. lowest) part of the quarry void (see Figure 6.3). The pond area will be dependent on the water level, which in turn will depend on the rate of runoff and groundwater flowing into it. At a minimum it is estimated to be 0.4 ha (when water levels are 270.7 mAOD) and could theoretically reach a maximum of 10 ha (when water level are at the maximum of 280 mAOD). However realistically it is unlikely ever to reach its maximum extent.

To confirm the suitability of the future pond design, a simple water balance spreadsheet model has been set up to simulate inflows (from runoff) and outflows (from infiltration to the underlying aquifer). Changes in storage and stage of the attenuation pond were then computed based on a stage vs volume relationship for the attenuation pond, calculated using Surfer 22 (Golden Software, 2021).

Outflows were computed by multiplying an assumed infiltration rate of 0.48 m/day (as calculated in Section 2.3.4) by the “wetted” surface area of the infiltration pond (i.e. the area below the water surface for a given water level). As the infiltration pond is expected to be connected to the groundwater table, only the “wetted” area above the observed rest water level of 270.7 m AOD is assumed to be available for infiltration. This area was calculated for each theoretical water level (at 0.05 m increments) from a stage vs surface area relationship for the pond, again calculated using Surfer 22 (Golden Software, 2021). Though this methodology simplifies the real system and does not account for seasonal or long-term variation in the hydraulic heads of the pond and local groundwater table, it is deemed to provide a reasonable approximation.

Assuming the maximum acceptable level that water in the infiltration pond could rise to is the spillover point on the southern edge of the quarry void at 280 m AOD (thus precluding overspill outside the quarry void), under normal or average conditions there would be 9.3 m of available freeboard and approximately 451,036 m³ of available water storage. ReFH2 was used to establish runoff rates and volumes for 1-in-100-year rainfall event (with 40% CCA) with a range of storm durations to evaluate the attenuation pond’s suitability during the operational phase.

The results are summarised in Table 8.1. The results indicate that a 48-hour storm would produce a peak water stage of 273.75 m AOD leaving 6.20 m of freeboard, and the pond area would be approximately 3.2 ha. It could take up to 8.5 days for all runoff from the 1-in-100-year 24-hour storm event to infiltrate after the start of the storm event, and it will take approximately 79 hours for 50% of peak total volume to infiltrate into the ground (see Figure 8.1).

Using the estimated infiltration rate of 0.48 m/day, the water balance calculations indicate that the infiltration volume per 15-minute interval would be 527 m³ when the south-east pond is at its greatest areal extent (i.e. at 280 mAOD). The peak runoff rates for storm events reduce as the duration of storm events increases, although the total volume of runoff is higher. The average inflow of runoff per 15-minute interval to the south-east pond from a 36-hour and 48-hour 1 in 100 year storm event (plus 40% CCA) is 432 and 364 m³ respectively. This is less than the 15-minute infiltration volume for the maximum pond extent and so an infinite number of these events could occur consecutively without leading to an ongoing rise in pond levels. As the peak runoff for longer duration events will be less than for the 36-hour and 48-hour 1 in 100 year events we can conclude that these could also be accommodated by the south-east pond.

For shorter events (3-hour, 6-hour, 12-hour and 24-hour events), the average inflows are higher than the 15-minute infiltration volume for the maximum pond area; however, there is ample storage in the south-east pond to accommodate at least 17 consecutive 3-hour, 6-hour, 12-hour or 24-hour storm events. This would be equivalent to a rainfall depth of up to 1924 mm (i.e. approximately total annual rainfall) occurring over a period of 17 days and is therefore considered to be an extremely unlikely occurrence. Taking account of both infiltration and storage capacity, this is more than sufficient to manage storm events of all durations.

Table 8.1 Summary of calculation results

1-in-100-year (with 40% climate change allowance) Storm Duration (Hours)	Modelled Rainfall Depth (mm)	Total Storage Capacity Used (m³)	Maximum Stage (m AOD)	Available Freeboard (m)	Remaining available Storage (m³)	Time to infiltrate storm (days)
3	54.3	28,148	272.75	7.25	422,888	4.57
6	73.7	37,448	273.10	6.90	413,588	5.46
12	93.9	45,942	273.45	6.55	405,094	6.32
24	113.2	51,576	273.60	6.40	399,460	7.19
36	129.52	55,440	273.75	6.25	395,597	7.91
48	142.27	57,780	273.80	6.20	393,256	8.50

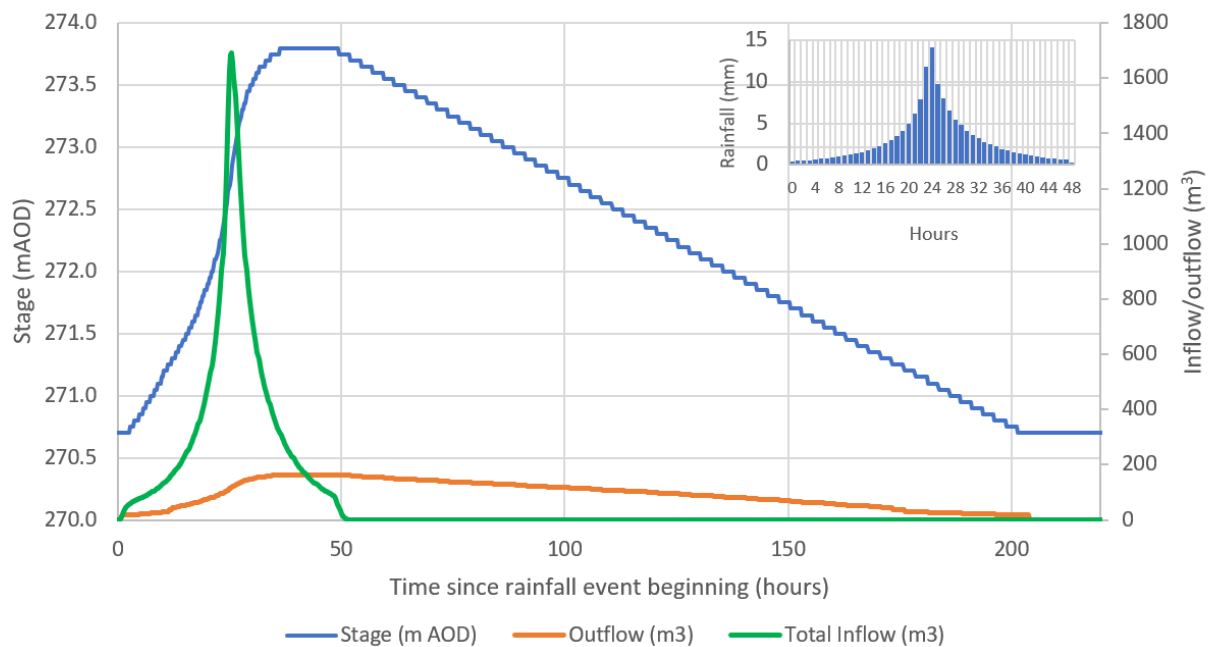


Figure 8.1 Results for 48-hour 1-in-100-year storm event plus climate change

8.2 Restoration Phase

The Site will be restored to nature with a natural vegetation cover which will effectively slow down rainfall runoff (relative to the bare rock present during the operational phase). Furthermore, the vegetation cover will increase the proportion of each rainfall event runoff loss through evapotranspiration before it reaches the attenuation pond thus resulting in smaller total attenuation pond storage peak volumes relative to the operational phase. Therefore, as the attenuation pond calculations (Table 8.1) suggest it will be suitable during the operational phase, it will also be appropriate for the restoration phase.

Following cessation of quarrying operations and re-vegetation of the quarry, water runoff leaving the southern section of catchment OR1 via the culvert will be clean and no longer need to be filtered in the settlement pond before it is discharged to the Taf Fechan.

8.3 Maintenance

Inspection and long-term maintenance of SuDS components ensures efficient operation and prevents failure. Surface SuDS components can be managed using landscape maintenance techniques. Table 8.2 describes the management and maintenance requirements for infiltration basins. These requirements will be implemented throughout the operational phase of the development and will be undertaken either by a private management company or by Hanson staff directly.

Table 8.2 General management and maintenance requirements for infiltration basins

SuDS Device	Maintenance requirements	Maintenance frequency
Infiltration basin	• Litter removal • Inlet/outlet cleaning • Vegetation management • Sediment monitoring and silt removal	• Monthly • Quarterly • Quarterly • Annually or every 3 years

Following greenification and natural re-wilding of the Site in the restoration phase, the maintenance requirements are expected to be reduced. As the surface runoff will be slowed and filtered by the vegetation before reaching the attenuation pond, the water will no longer carry silt thus silt removal will no longer be necessary.

8.4 Biodiversity and Amenity

SuDS schemes present opportunities to enhance habitat for wildlife onsite and this often improves the biodiversity of the vicinity. Ponds, constructed wetlands and other surface water features are landscape assets that have amenity value and improve the aesthetics of a site more than conventional drainage systems.

9 Conclusions

Hanson is submitting ROMP applications for the review and updating of planning conditions at Vaynor Quarry. The combined extent of the Quarry Site is approximately 65.4 ha within which the maximum proposed extent of future mineral extraction is 38.3 ha. The western and eastern limbs of the currently extracted area are proposed to be extended northwards, deepened, and eventually combined as the central ridge separating them is removed. The quarrying is expected to take at least 100 years over six phases, and, once the limestone extraction is complete, the quarry void will be restored to nature.

Stantec has reviewed the potential flood risk which shows that the Site lies entirely within DAM Zone A i.e. is considered to be at little or no risk of flooding from fluvial or coastal flooding. Pluvial flood risk at the Site is generally low, although some surface water flow paths and attenuation points are noted in the mapping data which correlates well with site observations. The pluvial flood risk at the Site is predominantly limited to local depressions (e.g. quarry voids and limestone sinkholes) and several overland flow channels which are observed to preferentially follow roads and artificially flat surfaces.

The future extraction area will be passively dewatered with no off-site water discharge from the extraction area itself. In the operational and post-restoration phases, runoff from the former mineral processing area, which is in future to be used for aggregates stockpiling and loading, to the south will discharge via settlement lagoons to the Taf Fechan under the conditions of a discharge permit. The undeveloped parts of the Site will continue as per the greenfield/current condition either towards the Taf Fechan to the south or its tributary Nant y Glais to the east of the Site.

The existing quarry void will be progressively extended during the operational phase by excavating into the adjacent greenfield area. Consequently, the off-site runoff rate and volume to the Taf Fechan during the final operational and post-restoration phases is predicted to reduce by approximately 71% relative to the pre-development greenfield rates thus providing a reduction in storm flows in the downstream Taf Fechan catchment. This water will continue to reach the watercourse in a highly attenuated form via groundwater.

Rainfall runoff from the quarry void will drain downgradient towards an attenuation (infiltration) pond at the extraction area's southern boundary where it will infiltrate to ground. Calculations demonstrate that the attenuation pond during the operational and post-restoration phases would be able to attenuate and infiltrate 1-in-100-year critical storm duration rainfall events whilst maintaining a very significant freeboard. For storms of 36 hours or longer there is a high enough infiltration rate to manage runoff from an infinite number of these storms in succession. For events of 24 hours and shorter, there is ample storage to hold at least 17 consecutive events, which is equivalent to up to a year's rainfall in 17 days. Therefore the attenuation pond (south east pond) is considered to be sufficient to accommodate and infiltrate rainfall from all storm scenarios.

Rainfall runoff from the southern part of the Site will be clean following the post-restoration phase, thus the settlement pond will no longer be necessary to treat runoff before its discharge into the Taf Fechan.

References

- BGS. (1979). Geological Survey of England and Wales 1:50,000 geological map series. Merthyr Tydfil. Sheet number 231.
- CEH. (2019). National River Flow Archive. Retrieved from <https://nrfa.ceh.ac.uk/data/search>
- CEH. (2020). Flood Estimation Handbook online web service.
- CIRIA. (2015). The SuDS manual, 2015.
- Cranfield University. (2019). Soilscales online soil mapping data. Retrieved from <http://www.landis.org.uk/soilscales/>
- ESI. (2007). 6227 WMP Cornelly Quarry, August 2007.
- Ford, T. D. (1989). Limestones and Caves of Wales. Cambridge University Press.
- Garvin, S. (2016). BRE Digest 365 Soakaway guidance.
- Golden Software. (2021, February). Surfer. Retrieved from Golden Software: <https://www.goldensoftware.com/products/surfer>
- MTCBC. (2011). Local Development Plan 2006-2021.
- MTCBC. (2018). Merthyr Tydfil Strategic Flood Consequence Assessment.
- NRW. (2015). Producing flood risk hydraulic models and flood consequence assessments for development planning purposes.
- NRW. (2017). Flood estimation: technical guidance GN008.
- SLR Consulting. (2022). Vaynor Quarry: Environmental Statement Volume 1, SLR Consulting, July 2022
- Stantec. (2022). Vaynor Quarry Tracer and Water Quality Testing.
- Streetly, M. J. (2008). Transient water balances to support the conceptual understanding of flows in limestone aquifers. Quarterly Journal of Engineering Geology and Hydrogeology.
- Welsh Assembly Government. (2004). Technical Advice Note (TAN) 15 : Development and Flood Risk.
- Welsh Government. (2016). Flood Consequence Assessments: Climate change allowances.
- Welsh Government. (2017). Recommended non-statutory standards for sustainable drainage (SUDs) in Wales.

APPENDICES

Appendix A

Development plans

Please refer to the following drawings provided with the applications:

Merthyr Tydfil: V6/PR/MT/7, V6/PR/MT/8,
V6/PR/MT/9,V6/PR/MT/10,V6/PR/MT/11,
V6/PR/MT/12

Brecon Beacons National Park: V6/PR/BBNP/7,
V6/PR/BBNP/8, V6/PR/BBNP/9,V6/PR/BBNP/10,
V6/PR/BBNP/11, V6/PR/BBNP/12

Appendix B

Restoration plans

Please refer to the following drawings provided with the applications:

Merthyr Tydfil: V6/PR/MT/16

Brecon Beacons National Park: V6/PR/BBNP/16

Appendix C

Greenfield runoff calculation output reports

UK Design Flood Estimation

Generated on Thursday, March 19, 2020 7:30:28 AM by hekelly
Printed from the ReFH2 Flood Modelling software package, version 3.0.7257.30020

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details

Checksum: C2E7-D057

Site name: FEH_Descriptors_Vaynor-quarry

Easting: 304300

Northing: 209700

Country: England, Wales or Northern Ireland

Catchment Area (km²): 0.65 [5.4]*

Using plot scale calculations: Yes

Model: ReFH2.3

Site description: None

Model run: 1 year

Summary of results

Rainfall - FEH 2013 model (mm):	32.66	Total runoff (ML):	9.79
Total Rainfall (mm):	30.10	Total flow (ML):	19.67
Peak Rainfall (mm):	2.07	Peak flow (m ³ /s):	0.98

Parameters

Where the user has overridden a system-generated value, this original value is shown in square brackets after the value used.

** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	06:05:00 [02:42:00]	Yes
Timestep (hh:mm:ss)	00:05:00 [00:06:00]	Yes
SCF (Seasonal correction factor)	0.94	No
ARF (Areal reduction factor)	0.98	No
Seasonality	Summer [Winter]	Yes

Loss model parameters

Name	Value	User-defined?
Cini (mm)	109.35	No
Cmax (mm)	248.36	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	1	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m ³ /s)	0.04	No
BL (hr)	26.24	No
BR	1	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km ²)	0	No
Urbext 2000	0	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No
Exporting drained area (km ²)	0.00	Yes
Sewer capacity (m ³ /s)	0.00	Yes

Time series data

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m³/s)	Baseflow (m³/s)	Total Flow (m³/s)
00:00:00	0.0884	0.0000	0.0390	0.0000	0.0394	0.0394
00:05:00	0.0937	0.0000	0.0413	0.0002	0.0393	0.0394
00:10:00	0.0993	0.0000	0.0438	0.0008	0.0391	0.0399
00:15:00	0.1052	0.0000	0.0464	0.0018	0.039	0.0408
00:20:00	0.1115	0.0000	0.0493	0.0032	0.0389	0.0421
00:25:00	0.1182	0.0000	0.0523	0.0052	0.0388	0.0439
00:30:00	0.1254	0.0000	0.0556	0.0076	0.0387	0.0463
00:35:00	0.1332	0.0000	0.0591	0.0105	0.0386	0.0491
00:40:00	0.1414	0.0000	0.0628	0.0140	0.0385	0.0526
00:45:00	0.1503	0.0000	0.0668	0.0182	0.0385	0.0566
00:50:00	0.1599	0.0000	0.0712	0.0229	0.0384	0.0613
00:55:00	0.1701	0.0000	0.0759	0.0283	0.0384	0.0667
01:00:00	0.1811	0.0000	0.0809	0.0345	0.0384	0.0729
01:05:00	0.1931	0.0000	0.0864	0.0411	0.0384	0.0795
01:10:00	0.2059	0.0000	0.0923	0.0479	0.0385	0.0864
01:15:00	0.2198	0.0000	0.0987	0.0550	0.0385	0.0935
01:20:00	0.2349	0.0000	0.1057	0.0622	0.0386	0.101
01:25:00	0.2513	0.0000	0.1133	0.0698	0.0388	0.109
01:30:00	0.2690	0.0000	0.1216	0.0776	0.0389	0.116
01:35:00	0.2884	0.0000	0.1307	0.0857	0.0391	0.125
01:40:00	0.3096	0.0000	0.1407	0.0942	0.0393	0.134
01:45:00	0.3327	0.0000	0.1516	0.1031	0.0396	0.143
01:50:00	0.3583	0.0000	0.1638	0.1123	0.0398	0.152
01:55:00	0.3864	0.0000	0.1772	0.1221	0.0401	0.162
02:00:00	0.4174	0.0000	0.1921	0.1324	0.0405	0.173
02:05:00	0.4524	0.0000	0.2090	0.1434	0.0409	0.184
02:10:00	0.4913	0.0000	0.2279	0.1551	0.0413	0.196
02:15:00	0.5348	0.0000	0.2491	0.1677	0.0418	0.21
02:20:00	0.5854	0.0000	0.2741	0.1814	0.0423	0.224
02:25:00	0.6432	0.0000	0.3027	0.1962	0.0429	0.239
02:30:00	0.7095	0.0000	0.3358	0.2122	0.0435	0.256
02:35:00	0.7918	0.0000	0.3738	0.2298	0.0442	0.274
02:40:00	0.8923	0.0000	0.4242	0.2490	0.045	0.294
02:45:00	1.0161	0.0000	0.4870	0.2703	0.0458	0.316
02:50:00	1.2148	0.0000	0.5877	0.2940	0.0467	0.341

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
02:55:00	1.5390	0.0000	0.7531	0.3207	0.0477	0.368
03:00:00	2.0672	0.0000	1.0265	0.3516	0.0488	0.4
03:05:00	1.5390	0.0000	0.7754	0.3886	0.05	0.439
03:10:00	1.2148	0.0000	0.6188	0.4316	0.0513	0.483
03:15:00	1.0161	0.0000	0.5221	0.4784	0.0527	0.531
03:20:00	0.8923	0.0000	0.4620	0.5273	0.0543	0.582
03:25:00	0.7918	0.0000	0.4126	0.5774	0.056	0.633
03:30:00	0.7095	0.0000	0.3719	0.6276	0.0579	0.685
03:35:00	0.6432	0.0000	0.3389	0.6771	0.0599	0.737
03:40:00	0.5854	0.0000	0.3099	0.7249	0.062	0.787
03:45:00	0.5348	0.0000	0.2843	0.7703	0.0642	0.835
03:50:00	0.4913	0.0000	0.2622	0.8121	0.0666	0.879
03:55:00	0.4524	0.0000	0.2423	0.8487	0.0691	0.918
04:00:00	0.4174	0.0000	0.2243	0.8781	0.0716	0.95
04:05:00	0.3864	0.0000	0.2082	0.8966	0.0742	0.971
04:10:00	0.3583	0.0000	0.1936	0.9040	0.0768	0.981
04:15:00	0.3327	0.0000	0.1802	0.9033	0.0794	0.983
04:20:00	0.3096	0.0000	0.1681	0.8965	0.082	0.978
04:25:00	0.2884	0.0000	0.1570	0.8847	0.0845	0.969
04:30:00	0.2690	0.0000	0.1467	0.8688	0.087	0.956
04:35:00	0.2513	0.0000	0.1373	0.8495	0.0894	0.939
04:40:00	0.2349	0.0000	0.1286	0.8273	0.0917	0.919
04:45:00	0.2198	0.0000	0.1205	0.8029	0.094	0.897
04:50:00	0.2059	0.0000	0.1131	0.7768	0.0961	0.873
04:55:00	0.1931	0.0000	0.1062	0.7495	0.0982	0.848
05:00:00	0.1811	0.0000	0.0998	0.7218	0.1	0.822
05:05:00	0.1701	0.0000	0.0938	0.6946	0.102	0.797
05:10:00	0.1599	0.0000	0.0869	0.6681	0.104	0.772
05:15:00	0.1503	0.0000	0.0818	0.6420	0.105	0.747
05:20:00	0.1414	0.0000	0.0770	0.6159	0.107	0.723
05:25:00	0.1332	0.0000	0.0726	0.5898	0.109	0.698
05:30:00	0.1254	0.0000	0.0684	0.5637	0.11	0.674
05:35:00	0.1182	0.0000	0.0646	0.5377	0.111	0.649
05:40:00	0.1115	0.0000	0.0609	0.5117	0.113	0.624
05:45:00	0.1052	0.0000	0.0575	0.4857	0.114	0.6
05:50:00	0.0993	0.0000	0.0543	0.4600	0.115	0.575

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
05:55:00	0.0937	0.0000	0.0514	0.4344	0.116	0.55
06:00:00	0.0884	0.0000	0.0485	0.4091	0.117	0.526
06:05:00	0.0000	0.0000	0.0000	0.3841	0.118	0.502
06:10:00	0.0000	0.0000	0.0000	0.3594	0.118	0.478
06:15:00	0.0000	0.0000	0.0000	0.3348	0.119	0.454
06:20:00	0.0000	0.0000	0.0000	0.3105	0.12	0.43
06:25:00	0.0000	0.0000	0.0000	0.2866	0.12	0.407
06:30:00	0.0000	0.0000	0.0000	0.2635	0.12	0.384
06:35:00	0.0000	0.0000	0.0000	0.2414	0.121	0.362
06:40:00	0.0000	0.0000	0.0000	0.2208	0.121	0.342
06:45:00	0.0000	0.0000	0.0000	0.2021	0.121	0.323
06:50:00	0.0000	0.0000	0.0000	0.1847	0.121	0.306
06:55:00	0.0000	0.0000	0.0000	0.1684	0.122	0.29
07:00:00	0.0000	0.0000	0.0000	0.1528	0.122	0.274
07:05:00	0.0000	0.0000	0.0000	0.1379	0.122	0.26
07:10:00	0.0000	0.0000	0.0000	0.1240	0.122	0.246
07:15:00	0.0000	0.0000	0.0000	0.1112	0.122	0.233
07:20:00	0.0000	0.0000	0.0000	0.0996	0.122	0.221
07:25:00	0.0000	0.0000	0.0000	0.0891	0.121	0.211
07:30:00	0.0000	0.0000	0.0000	0.0794	0.121	0.201
07:35:00	0.0000	0.0000	0.0000	0.0707	0.121	0.192
07:40:00	0.0000	0.0000	0.0000	0.0627	0.121	0.184
07:45:00	0.0000	0.0000	0.0000	0.0555	0.121	0.176
07:50:00	0.0000	0.0000	0.0000	0.0491	0.12	0.17
07:55:00	0.0000	0.0000	0.0000	0.0433	0.12	0.163
08:00:00	0.0000	0.0000	0.0000	0.0381	0.12	0.158
08:05:00	0.0000	0.0000	0.0000	0.0335	0.12	0.153
08:10:00	0.0000	0.0000	0.0000	0.0293	0.119	0.149
08:15:00	0.0000	0.0000	0.0000	0.0255	0.119	0.145
08:20:00	0.0000	0.0000	0.0000	0.0221	0.119	0.141
08:25:00	0.0000	0.0000	0.0000	0.0190	0.118	0.137
08:30:00	0.0000	0.0000	0.0000	0.0162	0.118	0.134
08:35:00	0.0000	0.0000	0.0000	0.0137	0.118	0.131
08:40:00	0.0000	0.0000	0.0000	0.0114	0.117	0.129
08:45:00	0.0000	0.0000	0.0000	0.0094	0.117	0.126
08:50:00	0.0000	0.0000	0.0000	0.0076	0.117	0.124

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
08:55:00	0.0000	0.0000	0.0000	0.0061	0.116	0.122
09:00:00	0.0000	0.0000	0.0000	0.0047	0.116	0.121
09:05:00	0.0000	0.0000	0.0000	0.0036	0.116	0.119
09:10:00	0.0000	0.0000	0.0000	0.0026	0.115	0.118
09:15:00	0.0000	0.0000	0.0000	0.0018	0.115	0.117
09:20:00	0.0000	0.0000	0.0000	0.0011	0.115	0.116
09:25:00	0.0000	0.0000	0.0000	0.0006	0.114	0.115
09:30:00	0.0000	0.0000	0.0000	0.0003	0.114	0.114
09:35:00	0.0000	0.0000	0.0000	0.0001	0.114	0.114
09:40:00	0.0000	0.0000	0.0000	0.0000	0.113	0.113
09:45:00	0.0000	0.0000	0.0000	0.0000	0.113	0.113
09:50:00	0.0000	0.0000	0.0000	0.0000	0.112	0.112
09:55:00	0.0000	0.0000	0.0000	0.0000	0.112	0.112
10:00:00	0.0000	0.0000	0.0000	0.0000	0.112	0.112
10:05:00	0.0000	0.0000	0.0000	0.0000	0.111	0.111
10:10:00	0.0000	0.0000	0.0000	0.0000	0.111	0.111
10:15:00	0.0000	0.0000	0.0000	0.0000	0.111	0.111
10:20:00	0.0000	0.0000	0.0000	0.0000	0.11	0.11
10:25:00	0.0000	0.0000	0.0000	0.0000	0.11	0.11
10:30:00	0.0000	0.0000	0.0000	0.0000	0.11	0.11
10:35:00	0.0000	0.0000	0.0000	0.0000	0.109	0.109
10:40:00	0.0000	0.0000	0.0000	0.0000	0.109	0.109
10:45:00	0.0000	0.0000	0.0000	0.0000	0.109	0.109
10:50:00	0.0000	0.0000	0.0000	0.0000	0.108	0.108
10:55:00	0.0000	0.0000	0.0000	0.0000	0.108	0.108
11:00:00	0.0000	0.0000	0.0000	0.0000	0.108	0.108
11:05:00	0.0000	0.0000	0.0000	0.0000	0.107	0.107
11:10:00	0.0000	0.0000	0.0000	0.0000	0.107	0.107
11:15:00	0.0000	0.0000	0.0000	0.0000	0.107	0.107
11:20:00	0.0000	0.0000	0.0000	0.0000	0.106	0.106
11:25:00	0.0000	0.0000	0.0000	0.0000	0.106	0.106
11:30:00	0.0000	0.0000	0.0000	0.0000	0.106	0.106
11:35:00	0.0000	0.0000	0.0000	0.0000	0.105	0.105
11:40:00	0.0000	0.0000	0.0000	0.0000	0.105	0.105
11:45:00	0.0000	0.0000	0.0000	0.0000	0.105	0.105
11:50:00	0.0000	0.0000	0.0000	0.0000	0.104	0.104

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
11:55:00	0.0000	0.0000	0.0000	0.0000	0.104	0.104
12:00:00	0.0000	0.0000	0.0000	0.0000	0.104	0.104
12:05:00	0.0000	0.0000	0.0000	0.0000	0.103	0.103
12:10:00	0.0000	0.0000	0.0000	0.0000	0.103	0.103
12:15:00	0.0000	0.0000	0.0000	0.0000	0.103	0.103
12:20:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102
12:25:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102
12:30:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102
12:35:00	0.0000	0.0000	0.0000	0.0000	0.101	0.101
12:40:00	0.0000	0.0000	0.0000	0.0000	0.101	0.101
12:45:00	0.0000	0.0000	0.0000	0.0000	0.101	0.101
12:50:00	0.0000	0.0000	0.0000	0.0000	0.1	0.1
12:55:00	0.0000	0.0000	0.0000	0.0000	0.1	0.1
13:00:00	0.0000	0.0000	0.0000	0.0000	0.0997	0.0997
13:05:00	0.0000	0.0000	0.0000	0.0000	0.0993	0.0993
13:10:00	0.0000	0.0000	0.0000	0.0000	0.099	0.099
13:15:00	0.0000	0.0000	0.0000	0.0000	0.0987	0.0987
13:20:00	0.0000	0.0000	0.0000	0.0000	0.0984	0.0984
13:25:00	0.0000	0.0000	0.0000	0.0000	0.0981	0.0981
13:30:00	0.0000	0.0000	0.0000	0.0000	0.0978	0.0978
13:35:00	0.0000	0.0000	0.0000	0.0000	0.0975	0.0975
13:40:00	0.0000	0.0000	0.0000	0.0000	0.0972	0.0972
13:45:00	0.0000	0.0000	0.0000	0.0000	0.0969	0.0969
13:50:00	0.0000	0.0000	0.0000	0.0000	0.0965	0.0965
13:55:00	0.0000	0.0000	0.0000	0.0000	0.0962	0.0962
14:00:00	0.0000	0.0000	0.0000	0.0000	0.0959	0.0959
14:05:00	0.0000	0.0000	0.0000	0.0000	0.0956	0.0956
14:10:00	0.0000	0.0000	0.0000	0.0000	0.0953	0.0953
14:15:00	0.0000	0.0000	0.0000	0.0000	0.095	0.095
14:20:00	0.0000	0.0000	0.0000	0.0000	0.0947	0.0947
14:25:00	0.0000	0.0000	0.0000	0.0000	0.0944	0.0944
14:30:00	0.0000	0.0000	0.0000	0.0000	0.0941	0.0941
14:35:00	0.0000	0.0000	0.0000	0.0000	0.0938	0.0938
14:40:00	0.0000	0.0000	0.0000	0.0000	0.0935	0.0935
14:45:00	0.0000	0.0000	0.0000	0.0000	0.0932	0.0932
14:50:00	0.0000	0.0000	0.0000	0.0000	0.0929	0.0929

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
14:55:00	0.0000	0.0000	0.0000	0.0000	0.0926	0.0926
15:00:00	0.0000	0.0000	0.0000	0.0000	0.0923	0.0923
15:05:00	0.0000	0.0000	0.0000	0.0000	0.0921	0.0921
15:10:00	0.0000	0.0000	0.0000	0.0000	0.0918	0.0918
15:15:00	0.0000	0.0000	0.0000	0.0000	0.0915	0.0915
15:20:00	0.0000	0.0000	0.0000	0.0000	0.0912	0.0912
15:25:00	0.0000	0.0000	0.0000	0.0000	0.0909	0.0909
15:30:00	0.0000	0.0000	0.0000	0.0000	0.0906	0.0906
15:35:00	0.0000	0.0000	0.0000	0.0000	0.0903	0.0903
15:40:00	0.0000	0.0000	0.0000	0.0000	0.09	0.09
15:45:00	0.0000	0.0000	0.0000	0.0000	0.0897	0.0897
15:50:00	0.0000	0.0000	0.0000	0.0000	0.0895	0.0895
15:55:00	0.0000	0.0000	0.0000	0.0000	0.0892	0.0892
16:00:00	0.0000	0.0000	0.0000	0.0000	0.0889	0.0889
16:05:00	0.0000	0.0000	0.0000	0.0000	0.0886	0.0886
16:10:00	0.0000	0.0000	0.0000	0.0000	0.0883	0.0883
16:15:00	0.0000	0.0000	0.0000	0.0000	0.0881	0.0881
16:20:00	0.0000	0.0000	0.0000	0.0000	0.0878	0.0878
16:25:00	0.0000	0.0000	0.0000	0.0000	0.0875	0.0875
16:30:00	0.0000	0.0000	0.0000	0.0000	0.0872	0.0872
16:35:00	0.0000	0.0000	0.0000	0.0000	0.0869	0.0869
16:40:00	0.0000	0.0000	0.0000	0.0000	0.0867	0.0867
16:45:00	0.0000	0.0000	0.0000	0.0000	0.0864	0.0864
16:50:00	0.0000	0.0000	0.0000	0.0000	0.0861	0.0861
16:55:00	0.0000	0.0000	0.0000	0.0000	0.0858	0.0858
17:00:00	0.0000	0.0000	0.0000	0.0000	0.0856	0.0856
17:05:00	0.0000	0.0000	0.0000	0.0000	0.0853	0.0853
17:10:00	0.0000	0.0000	0.0000	0.0000	0.085	0.085
17:15:00	0.0000	0.0000	0.0000	0.0000	0.0848	0.0848
17:20:00	0.0000	0.0000	0.0000	0.0000	0.0845	0.0845
17:25:00	0.0000	0.0000	0.0000	0.0000	0.0842	0.0842
17:30:00	0.0000	0.0000	0.0000	0.0000	0.084	0.084
17:35:00	0.0000	0.0000	0.0000	0.0000	0.0837	0.0837
17:40:00	0.0000	0.0000	0.0000	0.0000	0.0834	0.0834
17:45:00	0.0000	0.0000	0.0000	0.0000	0.0832	0.0832
17:50:00	0.0000	0.0000	0.0000	0.0000	0.0829	0.0829

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
17:55:00	0.0000	0.0000	0.0000	0.0000	0.0826	0.0826
18:00:00	0.0000	0.0000	0.0000	0.0000	0.0824	0.0824
18:05:00	0.0000	0.0000	0.0000	0.0000	0.0821	0.0821
18:10:00	0.0000	0.0000	0.0000	0.0000	0.0818	0.0818
18:15:00	0.0000	0.0000	0.0000	0.0000	0.0816	0.0816
18:20:00	0.0000	0.0000	0.0000	0.0000	0.0813	0.0813
18:25:00	0.0000	0.0000	0.0000	0.0000	0.0811	0.0811
18:30:00	0.0000	0.0000	0.0000	0.0000	0.0808	0.0808
18:35:00	0.0000	0.0000	0.0000	0.0000	0.0806	0.0806
18:40:00	0.0000	0.0000	0.0000	0.0000	0.0803	0.0803
18:45:00	0.0000	0.0000	0.0000	0.0000	0.08	0.08
18:50:00	0.0000	0.0000	0.0000	0.0000	0.0798	0.0798
18:55:00	0.0000	0.0000	0.0000	0.0000	0.0795	0.0795
19:00:00	0.0000	0.0000	0.0000	0.0000	0.0793	0.0793
19:05:00	0.0000	0.0000	0.0000	0.0000	0.079	0.079
19:10:00	0.0000	0.0000	0.0000	0.0000	0.0788	0.0788
19:15:00	0.0000	0.0000	0.0000	0.0000	0.0785	0.0785
19:20:00	0.0000	0.0000	0.0000	0.0000	0.0783	0.0783
19:25:00	0.0000	0.0000	0.0000	0.0000	0.078	0.078
19:30:00	0.0000	0.0000	0.0000	0.0000	0.0778	0.0778
19:35:00	0.0000	0.0000	0.0000	0.0000	0.0775	0.0775
19:40:00	0.0000	0.0000	0.0000	0.0000	0.0773	0.0773
19:45:00	0.0000	0.0000	0.0000	0.0000	0.0771	0.0771
19:50:00	0.0000	0.0000	0.0000	0.0000	0.0768	0.0768
19:55:00	0.0000	0.0000	0.0000	0.0000	0.0766	0.0766
20:00:00	0.0000	0.0000	0.0000	0.0000	0.0763	0.0763
20:05:00	0.0000	0.0000	0.0000	0.0000	0.0761	0.0761
20:10:00	0.0000	0.0000	0.0000	0.0000	0.0758	0.0758
20:15:00	0.0000	0.0000	0.0000	0.0000	0.0756	0.0756
20:20:00	0.0000	0.0000	0.0000	0.0000	0.0754	0.0754
20:25:00	0.0000	0.0000	0.0000	0.0000	0.0751	0.0751
20:30:00	0.0000	0.0000	0.0000	0.0000	0.0749	0.0749
20:35:00	0.0000	0.0000	0.0000	0.0000	0.0746	0.0746
20:40:00	0.0000	0.0000	0.0000	0.0000	0.0744	0.0744
20:45:00	0.0000	0.0000	0.0000	0.0000	0.0742	0.0742
20:50:00	0.0000	0.0000	0.0000	0.0000	0.0739	0.0739

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
20:55:00	0.0000	0.0000	0.0000	0.0000	0.0737	0.0737
21:00:00	0.0000	0.0000	0.0000	0.0000	0.0735	0.0735
21:05:00	0.0000	0.0000	0.0000	0.0000	0.0732	0.0732
21:10:00	0.0000	0.0000	0.0000	0.0000	0.073	0.073
21:15:00	0.0000	0.0000	0.0000	0.0000	0.0728	0.0728
21:20:00	0.0000	0.0000	0.0000	0.0000	0.0725	0.0725
21:25:00	0.0000	0.0000	0.0000	0.0000	0.0723	0.0723
21:30:00	0.0000	0.0000	0.0000	0.0000	0.0721	0.0721
21:35:00	0.0000	0.0000	0.0000	0.0000	0.0719	0.0719
21:40:00	0.0000	0.0000	0.0000	0.0000	0.0716	0.0716
21:45:00	0.0000	0.0000	0.0000	0.0000	0.0714	0.0714
21:50:00	0.0000	0.0000	0.0000	0.0000	0.0712	0.0712
21:55:00	0.0000	0.0000	0.0000	0.0000	0.0709	0.0709
22:00:00	0.0000	0.0000	0.0000	0.0000	0.0707	0.0707
22:05:00	0.0000	0.0000	0.0000	0.0000	0.0705	0.0705
22:10:00	0.0000	0.0000	0.0000	0.0000	0.0703	0.0703
22:15:00	0.0000	0.0000	0.0000	0.0000	0.0701	0.0701
22:20:00	0.0000	0.0000	0.0000	0.0000	0.0698	0.0698
22:25:00	0.0000	0.0000	0.0000	0.0000	0.0696	0.0696
22:30:00	0.0000	0.0000	0.0000	0.0000	0.0694	0.0694
22:35:00	0.0000	0.0000	0.0000	0.0000	0.0692	0.0692
22:40:00	0.0000	0.0000	0.0000	0.0000	0.0689	0.0689
22:45:00	0.0000	0.0000	0.0000	0.0000	0.0687	0.0687
22:50:00	0.0000	0.0000	0.0000	0.0000	0.0685	0.0685
22:55:00	0.0000	0.0000	0.0000	0.0000	0.0683	0.0683
23:00:00	0.0000	0.0000	0.0000	0.0000	0.0681	0.0681
23:05:00	0.0000	0.0000	0.0000	0.0000	0.0679	0.0679
23:10:00	0.0000	0.0000	0.0000	0.0000	0.0676	0.0676
23:15:00	0.0000	0.0000	0.0000	0.0000	0.0674	0.0674
23:20:00	0.0000	0.0000	0.0000	0.0000	0.0672	0.0672
23:25:00	0.0000	0.0000	0.0000	0.0000	0.067	0.067
23:30:00	0.0000	0.0000	0.0000	0.0000	0.0668	0.0668
23:35:00	0.0000	0.0000	0.0000	0.0000	0.0666	0.0666
23:40:00	0.0000	0.0000	0.0000	0.0000	0.0664	0.0664
23:45:00	0.0000	0.0000	0.0000	0.0000	0.0662	0.0662
23:50:00	0.0000	0.0000	0.0000	0.0000	0.0659	0.0659

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
23:55:00	0.0000	0.0000	0.0000	0.0000	0.0657	0.0657
24:00:00	0.0000	0.0000	0.0000	0.0000	0.0655	0.0655
24:05:00	0.0000	0.0000	0.0000	0.0000	0.0653	0.0653
24:10:00	0.0000	0.0000	0.0000	0.0000	0.0651	0.0651
24:15:00	0.0000	0.0000	0.0000	0.0000	0.0649	0.0649
24:20:00	0.0000	0.0000	0.0000	0.0000	0.0647	0.0647
24:25:00	0.0000	0.0000	0.0000	0.0000	0.0645	0.0645
24:30:00	0.0000	0.0000	0.0000	0.0000	0.0643	0.0643
24:35:00	0.0000	0.0000	0.0000	0.0000	0.0641	0.0641
24:40:00	0.0000	0.0000	0.0000	0.0000	0.0639	0.0639
24:45:00	0.0000	0.0000	0.0000	0.0000	0.0637	0.0637
24:50:00	0.0000	0.0000	0.0000	0.0000	0.0635	0.0635
24:55:00	0.0000	0.0000	0.0000	0.0000	0.0633	0.0633
25:00:00	0.0000	0.0000	0.0000	0.0000	0.0631	0.0631
25:05:00	0.0000	0.0000	0.0000	0.0000	0.0629	0.0629
25:10:00	0.0000	0.0000	0.0000	0.0000	0.0627	0.0627
25:15:00	0.0000	0.0000	0.0000	0.0000	0.0625	0.0625
25:20:00	0.0000	0.0000	0.0000	0.0000	0.0623	0.0623
25:25:00	0.0000	0.0000	0.0000	0.0000	0.0621	0.0621
25:30:00	0.0000	0.0000	0.0000	0.0000	0.0619	0.0619
25:35:00	0.0000	0.0000	0.0000	0.0000	0.0617	0.0617
25:40:00	0.0000	0.0000	0.0000	0.0000	0.0615	0.0615
25:45:00	0.0000	0.0000	0.0000	0.0000	0.0613	0.0613
25:50:00	0.0000	0.0000	0.0000	0.0000	0.0611	0.0611
25:55:00	0.0000	0.0000	0.0000	0.0000	0.0609	0.0609
26:00:00	0.0000	0.0000	0.0000	0.0000	0.0607	0.0607
26:05:00	0.0000	0.0000	0.0000	0.0000	0.0605	0.0605
26:10:00	0.0000	0.0000	0.0000	0.0000	0.0603	0.0603
26:15:00	0.0000	0.0000	0.0000	0.0000	0.0601	0.0601
26:20:00	0.0000	0.0000	0.0000	0.0000	0.06	0.06
26:25:00	0.0000	0.0000	0.0000	0.0000	0.0598	0.0598
26:30:00	0.0000	0.0000	0.0000	0.0000	0.0596	0.0596
26:35:00	0.0000	0.0000	0.0000	0.0000	0.0594	0.0594
26:40:00	0.0000	0.0000	0.0000	0.0000	0.0592	0.0592
26:45:00	0.0000	0.0000	0.0000	0.0000	0.059	0.059
26:50:00	0.0000	0.0000	0.0000	0.0000	0.0588	0.0588

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
26:55:00	0.0000	0.0000	0.0000	0.0000	0.0586	0.0586
27:00:00	0.0000	0.0000	0.0000	0.0000	0.0585	0.0585
27:05:00	0.0000	0.0000	0.0000	0.0000	0.0583	0.0583
27:10:00	0.0000	0.0000	0.0000	0.0000	0.0581	0.0581
27:15:00	0.0000	0.0000	0.0000	0.0000	0.0579	0.0579
27:20:00	0.0000	0.0000	0.0000	0.0000	0.0577	0.0577
27:25:00	0.0000	0.0000	0.0000	0.0000	0.0575	0.0575
27:30:00	0.0000	0.0000	0.0000	0.0000	0.0573	0.0573
27:35:00	0.0000	0.0000	0.0000	0.0000	0.0572	0.0572
27:40:00	0.0000	0.0000	0.0000	0.0000	0.057	0.057
27:45:00	0.0000	0.0000	0.0000	0.0000	0.0568	0.0568
27:50:00	0.0000	0.0000	0.0000	0.0000	0.0566	0.0566
27:55:00	0.0000	0.0000	0.0000	0.0000	0.0564	0.0564
28:00:00	0.0000	0.0000	0.0000	0.0000	0.0563	0.0563
28:05:00	0.0000	0.0000	0.0000	0.0000	0.0561	0.0561
28:10:00	0.0000	0.0000	0.0000	0.0000	0.0559	0.0559
28:15:00	0.0000	0.0000	0.0000	0.0000	0.0557	0.0557
28:20:00	0.0000	0.0000	0.0000	0.0000	0.0556	0.0556
28:25:00	0.0000	0.0000	0.0000	0.0000	0.0554	0.0554
28:30:00	0.0000	0.0000	0.0000	0.0000	0.0552	0.0552
28:35:00	0.0000	0.0000	0.0000	0.0000	0.055	0.055
28:40:00	0.0000	0.0000	0.0000	0.0000	0.0549	0.0549
28:45:00	0.0000	0.0000	0.0000	0.0000	0.0547	0.0547
28:50:00	0.0000	0.0000	0.0000	0.0000	0.0545	0.0545
28:55:00	0.0000	0.0000	0.0000	0.0000	0.0543	0.0543
29:00:00	0.0000	0.0000	0.0000	0.0000	0.0542	0.0542
29:05:00	0.0000	0.0000	0.0000	0.0000	0.054	0.054
29:10:00	0.0000	0.0000	0.0000	0.0000	0.0538	0.0538
29:15:00	0.0000	0.0000	0.0000	0.0000	0.0536	0.0536
29:20:00	0.0000	0.0000	0.0000	0.0000	0.0535	0.0535
29:25:00	0.0000	0.0000	0.0000	0.0000	0.0533	0.0533
29:30:00	0.0000	0.0000	0.0000	0.0000	0.0531	0.0531
29:35:00	0.0000	0.0000	0.0000	0.0000	0.053	0.053
29:40:00	0.0000	0.0000	0.0000	0.0000	0.0528	0.0528
29:45:00	0.0000	0.0000	0.0000	0.0000	0.0526	0.0526
29:50:00	0.0000	0.0000	0.0000	0.0000	0.0525	0.0525

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
29:55:00	0.0000	0.0000	0.0000	0.0000	0.0523	0.0523
30:00:00	0.0000	0.0000	0.0000	0.0000	0.0521	0.0521
30:05:00	0.0000	0.0000	0.0000	0.0000	0.052	0.052
30:10:00	0.0000	0.0000	0.0000	0.0000	0.0518	0.0518
30:15:00	0.0000	0.0000	0.0000	0.0000	0.0516	0.0516
30:20:00	0.0000	0.0000	0.0000	0.0000	0.0515	0.0515
30:25:00	0.0000	0.0000	0.0000	0.0000	0.0513	0.0513
30:30:00	0.0000	0.0000	0.0000	0.0000	0.0512	0.0512
30:35:00	0.0000	0.0000	0.0000	0.0000	0.051	0.051
30:40:00	0.0000	0.0000	0.0000	0.0000	0.0508	0.0508
30:45:00	0.0000	0.0000	0.0000	0.0000	0.0507	0.0507
30:50:00	0.0000	0.0000	0.0000	0.0000	0.0505	0.0505
30:55:00	0.0000	0.0000	0.0000	0.0000	0.0503	0.0503
31:00:00	0.0000	0.0000	0.0000	0.0000	0.0502	0.0502
31:05:00	0.0000	0.0000	0.0000	0.0000	0.05	0.05
31:10:00	0.0000	0.0000	0.0000	0.0000	0.0499	0.0499
31:15:00	0.0000	0.0000	0.0000	0.0000	0.0497	0.0497
31:20:00	0.0000	0.0000	0.0000	0.0000	0.0496	0.0496
31:25:00	0.0000	0.0000	0.0000	0.0000	0.0494	0.0494
31:30:00	0.0000	0.0000	0.0000	0.0000	0.0492	0.0492
31:35:00	0.0000	0.0000	0.0000	0.0000	0.0491	0.0491
31:40:00	0.0000	0.0000	0.0000	0.0000	0.0489	0.0489
31:45:00	0.0000	0.0000	0.0000	0.0000	0.0488	0.0488
31:50:00	0.0000	0.0000	0.0000	0.0000	0.0486	0.0486
31:55:00	0.0000	0.0000	0.0000	0.0000	0.0485	0.0485
32:00:00	0.0000	0.0000	0.0000	0.0000	0.0483	0.0483
32:05:00	0.0000	0.0000	0.0000	0.0000	0.0482	0.0482
32:10:00	0.0000	0.0000	0.0000	0.0000	0.048	0.048
32:15:00	0.0000	0.0000	0.0000	0.0000	0.0479	0.0479
32:20:00	0.0000	0.0000	0.0000	0.0000	0.0477	0.0477
32:25:00	0.0000	0.0000	0.0000	0.0000	0.0475	0.0475
32:30:00	0.0000	0.0000	0.0000	0.0000	0.0474	0.0474
32:35:00	0.0000	0.0000	0.0000	0.0000	0.0472	0.0472
32:40:00	0.0000	0.0000	0.0000	0.0000	0.0471	0.0471
32:45:00	0.0000	0.0000	0.0000	0.0000	0.0469	0.0469
32:50:00	0.0000	0.0000	0.0000	0.0000	0.0468	0.0468

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
32:55:00	0.0000	0.0000	0.0000	0.0000	0.0467	0.0467
33:00:00	0.0000	0.0000	0.0000	0.0000	0.0465	0.0465
33:05:00	0.0000	0.0000	0.0000	0.0000	0.0464	0.0464
33:10:00	0.0000	0.0000	0.0000	0.0000	0.0462	0.0462
33:15:00	0.0000	0.0000	0.0000	0.0000	0.0461	0.0461
33:20:00	0.0000	0.0000	0.0000	0.0000	0.0459	0.0459
33:25:00	0.0000	0.0000	0.0000	0.0000	0.0458	0.0458
33:30:00	0.0000	0.0000	0.0000	0.0000	0.0456	0.0456
33:35:00	0.0000	0.0000	0.0000	0.0000	0.0455	0.0455
33:40:00	0.0000	0.0000	0.0000	0.0000	0.0453	0.0453
33:45:00	0.0000	0.0000	0.0000	0.0000	0.0452	0.0452
33:50:00	0.0000	0.0000	0.0000	0.0000	0.045	0.045
33:55:00	0.0000	0.0000	0.0000	0.0000	0.0449	0.0449
34:00:00	0.0000	0.0000	0.0000	0.0000	0.0448	0.0448
34:05:00	0.0000	0.0000	0.0000	0.0000	0.0446	0.0446
34:10:00	0.0000	0.0000	0.0000	0.0000	0.0445	0.0445
34:15:00	0.0000	0.0000	0.0000	0.0000	0.0443	0.0443
34:20:00	0.0000	0.0000	0.0000	0.0000	0.0442	0.0442
34:25:00	0.0000	0.0000	0.0000	0.0000	0.0441	0.0441
34:30:00	0.0000	0.0000	0.0000	0.0000	0.0439	0.0439
34:35:00	0.0000	0.0000	0.0000	0.0000	0.0438	0.0438
34:40:00	0.0000	0.0000	0.0000	0.0000	0.0436	0.0436
34:45:00	0.0000	0.0000	0.0000	0.0000	0.0435	0.0435
34:50:00	0.0000	0.0000	0.0000	0.0000	0.0434	0.0434
34:55:00	0.0000	0.0000	0.0000	0.0000	0.0432	0.0432
35:00:00	0.0000	0.0000	0.0000	0.0000	0.0431	0.0431
35:05:00	0.0000	0.0000	0.0000	0.0000	0.043	0.043
35:10:00	0.0000	0.0000	0.0000	0.0000	0.0428	0.0428
35:15:00	0.0000	0.0000	0.0000	0.0000	0.0427	0.0427
35:20:00	0.0000	0.0000	0.0000	0.0000	0.0425	0.0425
35:25:00	0.0000	0.0000	0.0000	0.0000	0.0424	0.0424
35:30:00	0.0000	0.0000	0.0000	0.0000	0.0423	0.0423
35:35:00	0.0000	0.0000	0.0000	0.0000	0.0421	0.0421
35:40:00	0.0000	0.0000	0.0000	0.0000	0.042	0.042
35:45:00	0.0000	0.0000	0.0000	0.0000	0.0419	0.0419
35:50:00	0.0000	0.0000	0.0000	0.0000	0.0417	0.0417

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
35:55:00	0.0000	0.0000	0.0000	0.0000	0.0416	0.0416
36:00:00	0.0000	0.0000	0.0000	0.0000	0.0415	0.0415
36:05:00	0.0000	0.0000	0.0000	0.0000	0.0413	0.0413
36:10:00	0.0000	0.0000	0.0000	0.0000	0.0412	0.0412
36:15:00	0.0000	0.0000	0.0000	0.0000	0.0411	0.0411
36:20:00	0.0000	0.0000	0.0000	0.0000	0.041	0.041
36:25:00	0.0000	0.0000	0.0000	0.0000	0.0408	0.0408
36:30:00	0.0000	0.0000	0.0000	0.0000	0.0407	0.0407
36:35:00	0.0000	0.0000	0.0000	0.0000	0.0406	0.0406
36:40:00	0.0000	0.0000	0.0000	0.0000	0.0404	0.0404
36:45:00	0.0000	0.0000	0.0000	0.0000	0.0403	0.0403
36:50:00	0.0000	0.0000	0.0000	0.0000	0.0402	0.0402
36:55:00	0.0000	0.0000	0.0000	0.0000	0.0401	0.0401
37:00:00	0.0000	0.0000	0.0000	0.0000	0.0399	0.0399
37:05:00	0.0000	0.0000	0.0000	0.0000	0.0398	0.0398
37:10:00	0.0000	0.0000	0.0000	0.0000	0.0397	0.0397

Appendix

Catchment descriptors *

Name	Value	User-defined value used?
Area (km ²)	0.65 [5.4]	Yes
ALTBAR	376	No
ASPBAR	143	No
ASPVAR	0.42	No
BFIHOST	0.39	No
BFIHOST19	0.35	No
DPLBAR (km)	2.43	No
DPSBAR (mkm ⁻¹)	99.4	No
FARL	1	No
LDP	3.83	No
PROPWET (mm)	0.54	No
RMED1H	11.8	No
RMED1D	56.7	No
RMED2D	77.9	No
SAAR (mm)	1659	No
SAAR4170 (mm)	1738	No
SPRHOST	46.33	No
Urbext2000	0	No
Urbext1990	0	No
URBCONC	0	No
URBLOC	0	No
DDF parameter C	-0.03	No
DDF parameter D1	0.48	No
DDF parameter D2	0.47	No
DDF parameter D3	0.33	No
DDF parameter E	0.29	No
DDF parameter F	2.54	No
DDF parameter C (1km grid value)	-0.03	No
DDF parameter D1 (1km grid value)	0.49	No
DDF parameter D2 (1km grid value)	0.47	No
DDF parameter D3 (1km grid value)	0.32	No
DDF parameter E (1km grid value)	0.29	No
DDF parameter F (1km grid value)	2.52	No

Values in square brackets are the original values loaded from the FEH Web Service or FEH CD-ROM

UK Design Flood Estimation

Generated on Thursday, March 19, 2020 7:31:23 AM by hekelly
Printed from the ReFH2 Flood Modelling software package, version 3.0.7257.30020

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details

Checksum: C2E7-D057

Site name: FEH_Descriptors_Vaynor-quarry

Easting: 304300

Northing: 209700

Country: England, Wales or Northern Ireland

Catchment Area (km²): 0.65 [5.4]*

Using plot scale calculations: Yes

Model: ReFH2.3

Site description: None

Model run: 30 year

Summary of results

Rainfall - FEH 2013 model (mm):	64.71	Total runoff (ML):	21.69
Total Rainfall (mm):	59.63	Total flow (ML):	38.99
Peak Rainfall (mm):	4.10	Peak flow (m ³ /s):	2.11

Parameters

Where the user has overridden a system-generated value, this original value is shown in square brackets after the value used.

** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	06:05:00 [02:42:00]	Yes
Timestep (hh:mm:ss)	00:05:00 [00:06:00]	Yes
SCF (Seasonal correction factor)	0.94	No
ARF (Areal reduction factor)	0.98	No
Seasonality	Summer [Winter]	Yes

Loss model parameters

Name	Value	User-defined?
Cini (mm)	109.35	No
Cmax (mm)	248.36	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	1	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m ³ /s)	0.04	No
BL (hr)	26.24	No
BR	0.78	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km ²)	0	No
Urbext 2000	0	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No
Exporting drained area (km ²)	0.00	Yes
Sewer capacity (m ³ /s)	0.00	Yes

Time series data

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m³/s)	Baseflow (m³/s)	Total Flow (m³/s)
00:00:00	0.1752	0.0000	0.0772	0.0000	0.0394	0.0394
00:05:00	0.1857	0.0000	0.0820	0.0004	0.0393	0.0396
00:10:00	0.1967	0.0000	0.0869	0.0015	0.0391	0.0407
00:15:00	0.2084	0.0000	0.0923	0.0035	0.039	0.0426
00:20:00	0.2209	0.0000	0.0980	0.0064	0.0389	0.0453
00:25:00	0.2342	0.0000	0.1042	0.0102	0.0388	0.049
00:30:00	0.2485	0.0000	0.1107	0.0150	0.0387	0.0538
00:35:00	0.2638	0.0000	0.1179	0.0209	0.0387	0.0596
00:40:00	0.2802	0.0000	0.1255	0.0279	0.0386	0.0665
00:45:00	0.2978	0.0000	0.1337	0.0361	0.0386	0.0747
00:50:00	0.3168	0.0000	0.1426	0.0455	0.0387	0.0842
00:55:00	0.3371	0.0000	0.1522	0.0564	0.0387	0.0951
01:00:00	0.3589	0.0000	0.1626	0.0686	0.0388	0.107
01:05:00	0.3826	0.0000	0.1739	0.0818	0.0389	0.121
01:10:00	0.4080	0.0000	0.1861	0.0955	0.0391	0.135
01:15:00	0.4355	0.0000	0.1993	0.1096	0.0394	0.149
01:20:00	0.4655	0.0000	0.2139	0.1241	0.0397	0.164
01:25:00	0.4978	0.0000	0.2297	0.1393	0.04	0.179
01:30:00	0.5329	0.0000	0.2470	0.1550	0.0404	0.195
01:35:00	0.5715	0.0000	0.2662	0.1714	0.0408	0.212
01:40:00	0.6134	0.0000	0.2872	0.1886	0.0413	0.23
01:45:00	0.6591	0.0000	0.3102	0.2066	0.0419	0.248
01:50:00	0.7099	0.0000	0.3361	0.2254	0.0425	0.268
01:55:00	0.7656	0.0000	0.3648	0.2454	0.0432	0.289
02:00:00	0.8270	0.0000	0.3967	0.2664	0.044	0.31
02:05:00	0.8963	0.0000	0.4330	0.2889	0.0448	0.334
02:10:00	0.9734	0.0000	0.4740	0.3131	0.0457	0.359
02:15:00	1.0596	0.0000	0.5202	0.3392	0.0467	0.386
02:20:00	1.1599	0.0000	0.5747	0.3675	0.0478	0.415
02:25:00	1.2743	0.0000	0.6376	0.3983	0.049	0.447
02:30:00	1.4057	0.0000	0.7109	0.4319	0.0503	0.482
02:35:00	1.5688	0.0000	0.7953	0.4687	0.0517	0.52
02:40:00	1.7679	0.0000	0.9081	0.5094	0.0533	0.563
02:45:00	2.0132	0.0000	1.0494	0.5544	0.055	0.609
02:50:00	2.4070	0.0000	1.2761	0.6049	0.0568	0.662

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
02:55:00	3.0493	0.0000	1.6501	0.6622	0.0588	0.721
03:00:00	4.0957	0.0000	2.2753	0.7289	0.0609	0.79
03:05:00	3.0493	0.0000	1.7378	0.8095	0.0632	0.873
03:10:00	2.4070	0.0000	1.3982	0.9039	0.0658	0.97
03:15:00	2.0132	0.0000	1.1874	1.0073	0.0685	1.08
03:20:00	1.7679	0.0000	1.0562	1.1162	0.0715	1.19
03:25:00	1.5688	0.0000	0.9478	1.2283	0.0747	1.3
03:30:00	1.4057	0.0000	0.8577	1.3414	0.0781	1.42
03:35:00	1.2743	0.0000	0.7844	1.4538	0.0817	1.54
03:40:00	1.1599	0.0000	0.7196	1.5633	0.0855	1.65
03:45:00	1.0596	0.0000	0.6621	1.6681	0.0895	1.76
03:50:00	0.9734	0.0000	0.6123	1.7655	0.0937	1.86
03:55:00	0.8963	0.0000	0.5672	1.8524	0.098	1.95
04:00:00	0.8270	0.0000	0.5261	1.9235	0.102	2.03
04:05:00	0.7656	0.0000	0.4896	1.9710	0.107	2.08
04:10:00	0.7099	0.0000	0.4561	1.9937	0.112	2.11
04:15:00	0.6591	0.0000	0.4252	1.9983	0.116	2.11
04:20:00	0.6134	0.0000	0.3973	1.9891	0.121	2.11
04:25:00	0.5715	0.0000	0.3715	1.9684	0.125	2.09
04:30:00	0.5329	0.0000	0.3476	1.9382	0.129	2.07
04:35:00	0.4978	0.0000	0.3258	1.9000	0.133	2.03
04:40:00	0.4655	0.0000	0.3055	1.8551	0.138	1.99
04:45:00	0.4355	0.0000	0.2866	1.8047	0.141	1.95
04:50:00	0.4080	0.0000	0.2692	1.7501	0.145	1.9
04:55:00	0.3826	0.0000	0.2531	1.6925	0.149	1.84
05:00:00	0.3589	0.0000	0.2379	1.6334	0.152	1.79
05:05:00	0.3371	0.0000	0.2239	1.5751	0.156	1.73
05:10:00	0.3168	0.0000	0.2057	1.5181	0.159	1.68
05:15:00	0.2978	0.0000	0.1937	1.4616	0.162	1.62
05:20:00	0.2802	0.0000	0.1826	1.4049	0.164	1.57
05:25:00	0.2638	0.0000	0.1722	1.3481	0.167	1.52
05:30:00	0.2485	0.0000	0.1625	1.2910	0.17	1.46
05:35:00	0.2342	0.0000	0.1534	1.2338	0.172	1.41
05:40:00	0.2209	0.0000	0.1448	1.1764	0.174	1.35
05:45:00	0.2084	0.0000	0.1368	1.1191	0.176	1.3
05:50:00	0.1967	0.0000	0.1293	1.0618	0.178	1.24

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
05:55:00	0.1857	0.0000	0.1222	1.0049	0.18	1.18
06:00:00	0.1752	0.0000	0.1155	0.9483	0.181	1.13
06:05:00	0.0000	0.0000	0.0000	0.8924	0.183	1.08
06:10:00	0.0000	0.0000	0.0000	0.8368	0.184	1.02
06:15:00	0.0000	0.0000	0.0000	0.7812	0.185	0.967
06:20:00	0.0000	0.0000	0.0000	0.7260	0.186	0.912
06:25:00	0.0000	0.0000	0.0000	0.6717	0.187	0.859
06:30:00	0.0000	0.0000	0.0000	0.6187	0.188	0.807
06:35:00	0.0000	0.0000	0.0000	0.5679	0.189	0.757
06:40:00	0.0000	0.0000	0.0000	0.5205	0.189	0.71
06:45:00	0.0000	0.0000	0.0000	0.4770	0.19	0.667
06:50:00	0.0000	0.0000	0.0000	0.4365	0.19	0.627
06:55:00	0.0000	0.0000	0.0000	0.3982	0.19	0.588
07:00:00	0.0000	0.0000	0.0000	0.3616	0.19	0.552
07:05:00	0.0000	0.0000	0.0000	0.3266	0.191	0.517
07:10:00	0.0000	0.0000	0.0000	0.2938	0.191	0.484
07:15:00	0.0000	0.0000	0.0000	0.2638	0.19	0.454
07:20:00	0.0000	0.0000	0.0000	0.2364	0.19	0.427
07:25:00	0.0000	0.0000	0.0000	0.2114	0.19	0.402
07:30:00	0.0000	0.0000	0.0000	0.1885	0.19	0.379
07:35:00	0.0000	0.0000	0.0000	0.1678	0.19	0.358
07:40:00	0.0000	0.0000	0.0000	0.1490	0.189	0.338
07:45:00	0.0000	0.0000	0.0000	0.1319	0.189	0.321
07:50:00	0.0000	0.0000	0.0000	0.1166	0.189	0.305
07:55:00	0.0000	0.0000	0.0000	0.1028	0.188	0.291
08:00:00	0.0000	0.0000	0.0000	0.0905	0.188	0.278
08:05:00	0.0000	0.0000	0.0000	0.0795	0.188	0.267
08:10:00	0.0000	0.0000	0.0000	0.0697	0.187	0.257
08:15:00	0.0000	0.0000	0.0000	0.0607	0.187	0.247
08:20:00	0.0000	0.0000	0.0000	0.0525	0.186	0.239
08:25:00	0.0000	0.0000	0.0000	0.0451	0.186	0.231
08:30:00	0.0000	0.0000	0.0000	0.0385	0.185	0.224
08:35:00	0.0000	0.0000	0.0000	0.0325	0.185	0.217
08:40:00	0.0000	0.0000	0.0000	0.0271	0.184	0.211
08:45:00	0.0000	0.0000	0.0000	0.0223	0.183	0.206
08:50:00	0.0000	0.0000	0.0000	0.0181	0.183	0.201

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
08:55:00	0.0000	0.0000	0.0000	0.0144	0.182	0.197
09:00:00	0.0000	0.0000	0.0000	0.0112	0.182	0.193
09:05:00	0.0000	0.0000	0.0000	0.0085	0.181	0.19
09:10:00	0.0000	0.0000	0.0000	0.0061	0.181	0.187
09:15:00	0.0000	0.0000	0.0000	0.0042	0.18	0.184
09:20:00	0.0000	0.0000	0.0000	0.0027	0.18	0.182
09:25:00	0.0000	0.0000	0.0000	0.0015	0.179	0.181
09:30:00	0.0000	0.0000	0.0000	0.0007	0.178	0.179
09:35:00	0.0000	0.0000	0.0000	0.0002	0.178	0.178
09:40:00	0.0000	0.0000	0.0000	0.0000	0.177	0.177
09:45:00	0.0000	0.0000	0.0000	0.0000	0.177	0.177
09:50:00	0.0000	0.0000	0.0000	0.0000	0.176	0.176
09:55:00	0.0000	0.0000	0.0000	0.0000	0.176	0.176
10:00:00	0.0000	0.0000	0.0000	0.0000	0.175	0.175
10:05:00	0.0000	0.0000	0.0000	0.0000	0.175	0.175
10:10:00	0.0000	0.0000	0.0000	0.0000	0.174	0.174
10:15:00	0.0000	0.0000	0.0000	0.0000	0.173	0.173
10:20:00	0.0000	0.0000	0.0000	0.0000	0.173	0.173
10:25:00	0.0000	0.0000	0.0000	0.0000	0.172	0.172
10:30:00	0.0000	0.0000	0.0000	0.0000	0.172	0.172
10:35:00	0.0000	0.0000	0.0000	0.0000	0.171	0.171
10:40:00	0.0000	0.0000	0.0000	0.0000	0.171	0.171
10:45:00	0.0000	0.0000	0.0000	0.0000	0.17	0.17
10:50:00	0.0000	0.0000	0.0000	0.0000	0.17	0.17
10:55:00	0.0000	0.0000	0.0000	0.0000	0.169	0.169
11:00:00	0.0000	0.0000	0.0000	0.0000	0.169	0.169
11:05:00	0.0000	0.0000	0.0000	0.0000	0.168	0.168
11:10:00	0.0000	0.0000	0.0000	0.0000	0.167	0.167
11:15:00	0.0000	0.0000	0.0000	0.0000	0.167	0.167
11:20:00	0.0000	0.0000	0.0000	0.0000	0.166	0.166
11:25:00	0.0000	0.0000	0.0000	0.0000	0.166	0.166
11:30:00	0.0000	0.0000	0.0000	0.0000	0.165	0.165
11:35:00	0.0000	0.0000	0.0000	0.0000	0.165	0.165
11:40:00	0.0000	0.0000	0.0000	0.0000	0.164	0.164
11:45:00	0.0000	0.0000	0.0000	0.0000	0.164	0.164
11:50:00	0.0000	0.0000	0.0000	0.0000	0.163	0.163

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
11:55:00	0.0000	0.0000	0.0000	0.0000	0.163	0.163
12:00:00	0.0000	0.0000	0.0000	0.0000	0.162	0.162
12:05:00	0.0000	0.0000	0.0000	0.0000	0.162	0.162
12:10:00	0.0000	0.0000	0.0000	0.0000	0.161	0.161
12:15:00	0.0000	0.0000	0.0000	0.0000	0.161	0.161
12:20:00	0.0000	0.0000	0.0000	0.0000	0.16	0.16
12:25:00	0.0000	0.0000	0.0000	0.0000	0.16	0.16
12:30:00	0.0000	0.0000	0.0000	0.0000	0.159	0.159
12:35:00	0.0000	0.0000	0.0000	0.0000	0.159	0.159
12:40:00	0.0000	0.0000	0.0000	0.0000	0.158	0.158
12:45:00	0.0000	0.0000	0.0000	0.0000	0.158	0.158
12:50:00	0.0000	0.0000	0.0000	0.0000	0.157	0.157
12:55:00	0.0000	0.0000	0.0000	0.0000	0.157	0.157
13:00:00	0.0000	0.0000	0.0000	0.0000	0.156	0.156
13:05:00	0.0000	0.0000	0.0000	0.0000	0.156	0.156
13:10:00	0.0000	0.0000	0.0000	0.0000	0.155	0.155
13:15:00	0.0000	0.0000	0.0000	0.0000	0.155	0.155
13:20:00	0.0000	0.0000	0.0000	0.0000	0.154	0.154
13:25:00	0.0000	0.0000	0.0000	0.0000	0.154	0.154
13:30:00	0.0000	0.0000	0.0000	0.0000	0.153	0.153
13:35:00	0.0000	0.0000	0.0000	0.0000	0.153	0.153
13:40:00	0.0000	0.0000	0.0000	0.0000	0.152	0.152
13:45:00	0.0000	0.0000	0.0000	0.0000	0.152	0.152
13:50:00	0.0000	0.0000	0.0000	0.0000	0.151	0.151
13:55:00	0.0000	0.0000	0.0000	0.0000	0.151	0.151
14:00:00	0.0000	0.0000	0.0000	0.0000	0.15	0.15
14:05:00	0.0000	0.0000	0.0000	0.0000	0.15	0.15
14:10:00	0.0000	0.0000	0.0000	0.0000	0.149	0.149
14:15:00	0.0000	0.0000	0.0000	0.0000	0.149	0.149
14:20:00	0.0000	0.0000	0.0000	0.0000	0.148	0.148
14:25:00	0.0000	0.0000	0.0000	0.0000	0.148	0.148
14:30:00	0.0000	0.0000	0.0000	0.0000	0.147	0.147
14:35:00	0.0000	0.0000	0.0000	0.0000	0.147	0.147
14:40:00	0.0000	0.0000	0.0000	0.0000	0.147	0.147
14:45:00	0.0000	0.0000	0.0000	0.0000	0.146	0.146
14:50:00	0.0000	0.0000	0.0000	0.0000	0.146	0.146

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
14:55:00	0.0000	0.0000	0.0000	0.0000	0.145	0.145
15:00:00	0.0000	0.0000	0.0000	0.0000	0.145	0.145
15:05:00	0.0000	0.0000	0.0000	0.0000	0.144	0.144
15:10:00	0.0000	0.0000	0.0000	0.0000	0.144	0.144
15:15:00	0.0000	0.0000	0.0000	0.0000	0.143	0.143
15:20:00	0.0000	0.0000	0.0000	0.0000	0.143	0.143
15:25:00	0.0000	0.0000	0.0000	0.0000	0.142	0.142
15:30:00	0.0000	0.0000	0.0000	0.0000	0.142	0.142
15:35:00	0.0000	0.0000	0.0000	0.0000	0.142	0.142
15:40:00	0.0000	0.0000	0.0000	0.0000	0.141	0.141
15:45:00	0.0000	0.0000	0.0000	0.0000	0.141	0.141
15:50:00	0.0000	0.0000	0.0000	0.0000	0.14	0.14
15:55:00	0.0000	0.0000	0.0000	0.0000	0.14	0.14
16:00:00	0.0000	0.0000	0.0000	0.0000	0.139	0.139
16:05:00	0.0000	0.0000	0.0000	0.0000	0.139	0.139
16:10:00	0.0000	0.0000	0.0000	0.0000	0.138	0.138
16:15:00	0.0000	0.0000	0.0000	0.0000	0.138	0.138
16:20:00	0.0000	0.0000	0.0000	0.0000	0.138	0.138
16:25:00	0.0000	0.0000	0.0000	0.0000	0.137	0.137
16:30:00	0.0000	0.0000	0.0000	0.0000	0.137	0.137
16:35:00	0.0000	0.0000	0.0000	0.0000	0.136	0.136
16:40:00	0.0000	0.0000	0.0000	0.0000	0.136	0.136
16:45:00	0.0000	0.0000	0.0000	0.0000	0.135	0.135
16:50:00	0.0000	0.0000	0.0000	0.0000	0.135	0.135
16:55:00	0.0000	0.0000	0.0000	0.0000	0.134	0.134
17:00:00	0.0000	0.0000	0.0000	0.0000	0.134	0.134
17:05:00	0.0000	0.0000	0.0000	0.0000	0.134	0.134
17:10:00	0.0000	0.0000	0.0000	0.0000	0.133	0.133
17:15:00	0.0000	0.0000	0.0000	0.0000	0.133	0.133
17:20:00	0.0000	0.0000	0.0000	0.0000	0.132	0.132
17:25:00	0.0000	0.0000	0.0000	0.0000	0.132	0.132
17:30:00	0.0000	0.0000	0.0000	0.0000	0.132	0.132
17:35:00	0.0000	0.0000	0.0000	0.0000	0.131	0.131
17:40:00	0.0000	0.0000	0.0000	0.0000	0.131	0.131
17:45:00	0.0000	0.0000	0.0000	0.0000	0.13	0.13
17:50:00	0.0000	0.0000	0.0000	0.0000	0.13	0.13

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
17:55:00	0.0000	0.0000	0.0000	0.0000	0.129	0.129
18:00:00	0.0000	0.0000	0.0000	0.0000	0.129	0.129
18:05:00	0.0000	0.0000	0.0000	0.0000	0.129	0.129
18:10:00	0.0000	0.0000	0.0000	0.0000	0.128	0.128
18:15:00	0.0000	0.0000	0.0000	0.0000	0.128	0.128
18:20:00	0.0000	0.0000	0.0000	0.0000	0.127	0.127
18:25:00	0.0000	0.0000	0.0000	0.0000	0.127	0.127
18:30:00	0.0000	0.0000	0.0000	0.0000	0.127	0.127
18:35:00	0.0000	0.0000	0.0000	0.0000	0.126	0.126
18:40:00	0.0000	0.0000	0.0000	0.0000	0.126	0.126
18:45:00	0.0000	0.0000	0.0000	0.0000	0.125	0.125
18:50:00	0.0000	0.0000	0.0000	0.0000	0.125	0.125
18:55:00	0.0000	0.0000	0.0000	0.0000	0.125	0.125
19:00:00	0.0000	0.0000	0.0000	0.0000	0.124	0.124
19:05:00	0.0000	0.0000	0.0000	0.0000	0.124	0.124
19:10:00	0.0000	0.0000	0.0000	0.0000	0.123	0.123
19:15:00	0.0000	0.0000	0.0000	0.0000	0.123	0.123
19:20:00	0.0000	0.0000	0.0000	0.0000	0.123	0.123
19:25:00	0.0000	0.0000	0.0000	0.0000	0.122	0.122
19:30:00	0.0000	0.0000	0.0000	0.0000	0.122	0.122
19:35:00	0.0000	0.0000	0.0000	0.0000	0.121	0.121
19:40:00	0.0000	0.0000	0.0000	0.0000	0.121	0.121
19:45:00	0.0000	0.0000	0.0000	0.0000	0.121	0.121
19:50:00	0.0000	0.0000	0.0000	0.0000	0.12	0.12
19:55:00	0.0000	0.0000	0.0000	0.0000	0.12	0.12
20:00:00	0.0000	0.0000	0.0000	0.0000	0.12	0.12
20:05:00	0.0000	0.0000	0.0000	0.0000	0.119	0.119
20:10:00	0.0000	0.0000	0.0000	0.0000	0.119	0.119
20:15:00	0.0000	0.0000	0.0000	0.0000	0.118	0.118
20:20:00	0.0000	0.0000	0.0000	0.0000	0.118	0.118
20:25:00	0.0000	0.0000	0.0000	0.0000	0.118	0.118
20:30:00	0.0000	0.0000	0.0000	0.0000	0.117	0.117
20:35:00	0.0000	0.0000	0.0000	0.0000	0.117	0.117
20:40:00	0.0000	0.0000	0.0000	0.0000	0.117	0.117
20:45:00	0.0000	0.0000	0.0000	0.0000	0.116	0.116
20:50:00	0.0000	0.0000	0.0000	0.0000	0.116	0.116

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
20:55:00	0.0000	0.0000	0.0000	0.0000	0.115	0.115
21:00:00	0.0000	0.0000	0.0000	0.0000	0.115	0.115
21:05:00	0.0000	0.0000	0.0000	0.0000	0.115	0.115
21:10:00	0.0000	0.0000	0.0000	0.0000	0.114	0.114
21:15:00	0.0000	0.0000	0.0000	0.0000	0.114	0.114
21:20:00	0.0000	0.0000	0.0000	0.0000	0.114	0.114
21:25:00	0.0000	0.0000	0.0000	0.0000	0.113	0.113
21:30:00	0.0000	0.0000	0.0000	0.0000	0.113	0.113
21:35:00	0.0000	0.0000	0.0000	0.0000	0.113	0.113
21:40:00	0.0000	0.0000	0.0000	0.0000	0.112	0.112
21:45:00	0.0000	0.0000	0.0000	0.0000	0.112	0.112
21:50:00	0.0000	0.0000	0.0000	0.0000	0.112	0.112
21:55:00	0.0000	0.0000	0.0000	0.0000	0.111	0.111
22:00:00	0.0000	0.0000	0.0000	0.0000	0.111	0.111
22:05:00	0.0000	0.0000	0.0000	0.0000	0.11	0.11
22:10:00	0.0000	0.0000	0.0000	0.0000	0.11	0.11
22:15:00	0.0000	0.0000	0.0000	0.0000	0.11	0.11
22:20:00	0.0000	0.0000	0.0000	0.0000	0.109	0.109
22:25:00	0.0000	0.0000	0.0000	0.0000	0.109	0.109
22:30:00	0.0000	0.0000	0.0000	0.0000	0.109	0.109
22:35:00	0.0000	0.0000	0.0000	0.0000	0.108	0.108
22:40:00	0.0000	0.0000	0.0000	0.0000	0.108	0.108
22:45:00	0.0000	0.0000	0.0000	0.0000	0.108	0.108
22:50:00	0.0000	0.0000	0.0000	0.0000	0.107	0.107
22:55:00	0.0000	0.0000	0.0000	0.0000	0.107	0.107
23:00:00	0.0000	0.0000	0.0000	0.0000	0.107	0.107
23:05:00	0.0000	0.0000	0.0000	0.0000	0.106	0.106
23:10:00	0.0000	0.0000	0.0000	0.0000	0.106	0.106
23:15:00	0.0000	0.0000	0.0000	0.0000	0.106	0.106
23:20:00	0.0000	0.0000	0.0000	0.0000	0.105	0.105
23:25:00	0.0000	0.0000	0.0000	0.0000	0.105	0.105
23:30:00	0.0000	0.0000	0.0000	0.0000	0.105	0.105
23:35:00	0.0000	0.0000	0.0000	0.0000	0.104	0.104
23:40:00	0.0000	0.0000	0.0000	0.0000	0.104	0.104
23:45:00	0.0000	0.0000	0.0000	0.0000	0.104	0.104
23:50:00	0.0000	0.0000	0.0000	0.0000	0.103	0.103

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
23:55:00	0.0000	0.0000	0.0000	0.0000	0.103	0.103
24:00:00	0.0000	0.0000	0.0000	0.0000	0.103	0.103
24:05:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102
24:10:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102
24:15:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102
24:20:00	0.0000	0.0000	0.0000	0.0000	0.101	0.101
24:25:00	0.0000	0.0000	0.0000	0.0000	0.101	0.101
24:30:00	0.0000	0.0000	0.0000	0.0000	0.101	0.101
24:35:00	0.0000	0.0000	0.0000	0.0000	0.1	0.1
24:40:00	0.0000	0.0000	0.0000	0.0000	0.1	0.1
24:45:00	0.0000	0.0000	0.0000	0.0000	0.0998	0.0998
24:50:00	0.0000	0.0000	0.0000	0.0000	0.0995	0.0995
24:55:00	0.0000	0.0000	0.0000	0.0000	0.0992	0.0992
25:00:00	0.0000	0.0000	0.0000	0.0000	0.0988	0.0988
25:05:00	0.0000	0.0000	0.0000	0.0000	0.0985	0.0985
25:10:00	0.0000	0.0000	0.0000	0.0000	0.0982	0.0982
25:15:00	0.0000	0.0000	0.0000	0.0000	0.0979	0.0979
25:20:00	0.0000	0.0000	0.0000	0.0000	0.0976	0.0976
25:25:00	0.0000	0.0000	0.0000	0.0000	0.0973	0.0973
25:30:00	0.0000	0.0000	0.0000	0.0000	0.097	0.097
25:35:00	0.0000	0.0000	0.0000	0.0000	0.0967	0.0967
25:40:00	0.0000	0.0000	0.0000	0.0000	0.0964	0.0964
25:45:00	0.0000	0.0000	0.0000	0.0000	0.0961	0.0961
25:50:00	0.0000	0.0000	0.0000	0.0000	0.0957	0.0957
25:55:00	0.0000	0.0000	0.0000	0.0000	0.0954	0.0954
26:00:00	0.0000	0.0000	0.0000	0.0000	0.0951	0.0951
26:05:00	0.0000	0.0000	0.0000	0.0000	0.0948	0.0948
26:10:00	0.0000	0.0000	0.0000	0.0000	0.0945	0.0945
26:15:00	0.0000	0.0000	0.0000	0.0000	0.0942	0.0942
26:20:00	0.0000	0.0000	0.0000	0.0000	0.0939	0.0939
26:25:00	0.0000	0.0000	0.0000	0.0000	0.0936	0.0936
26:30:00	0.0000	0.0000	0.0000	0.0000	0.0933	0.0933
26:35:00	0.0000	0.0000	0.0000	0.0000	0.093	0.093
26:40:00	0.0000	0.0000	0.0000	0.0000	0.0928	0.0928
26:45:00	0.0000	0.0000	0.0000	0.0000	0.0925	0.0925
26:50:00	0.0000	0.0000	0.0000	0.0000	0.0922	0.0922

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
26:55:00	0.0000	0.0000	0.0000	0.0000	0.0919	0.0919
27:00:00	0.0000	0.0000	0.0000	0.0000	0.0916	0.0916
27:05:00	0.0000	0.0000	0.0000	0.0000	0.0913	0.0913
27:10:00	0.0000	0.0000	0.0000	0.0000	0.091	0.091
27:15:00	0.0000	0.0000	0.0000	0.0000	0.0907	0.0907
27:20:00	0.0000	0.0000	0.0000	0.0000	0.0904	0.0904
27:25:00	0.0000	0.0000	0.0000	0.0000	0.0901	0.0901
27:30:00	0.0000	0.0000	0.0000	0.0000	0.0899	0.0899
27:35:00	0.0000	0.0000	0.0000	0.0000	0.0896	0.0896
27:40:00	0.0000	0.0000	0.0000	0.0000	0.0893	0.0893
27:45:00	0.0000	0.0000	0.0000	0.0000	0.089	0.089
27:50:00	0.0000	0.0000	0.0000	0.0000	0.0887	0.0887
27:55:00	0.0000	0.0000	0.0000	0.0000	0.0884	0.0884
28:00:00	0.0000	0.0000	0.0000	0.0000	0.0882	0.0882
28:05:00	0.0000	0.0000	0.0000	0.0000	0.0879	0.0879
28:10:00	0.0000	0.0000	0.0000	0.0000	0.0876	0.0876
28:15:00	0.0000	0.0000	0.0000	0.0000	0.0873	0.0873
28:20:00	0.0000	0.0000	0.0000	0.0000	0.087	0.087
28:25:00	0.0000	0.0000	0.0000	0.0000	0.0868	0.0868
28:30:00	0.0000	0.0000	0.0000	0.0000	0.0865	0.0865
28:35:00	0.0000	0.0000	0.0000	0.0000	0.0862	0.0862
28:40:00	0.0000	0.0000	0.0000	0.0000	0.0859	0.0859
28:45:00	0.0000	0.0000	0.0000	0.0000	0.0857	0.0857
28:50:00	0.0000	0.0000	0.0000	0.0000	0.0854	0.0854
28:55:00	0.0000	0.0000	0.0000	0.0000	0.0851	0.0851
29:00:00	0.0000	0.0000	0.0000	0.0000	0.0849	0.0849
29:05:00	0.0000	0.0000	0.0000	0.0000	0.0846	0.0846
29:10:00	0.0000	0.0000	0.0000	0.0000	0.0843	0.0843
29:15:00	0.0000	0.0000	0.0000	0.0000	0.0841	0.0841
29:20:00	0.0000	0.0000	0.0000	0.0000	0.0838	0.0838
29:25:00	0.0000	0.0000	0.0000	0.0000	0.0835	0.0835
29:30:00	0.0000	0.0000	0.0000	0.0000	0.0833	0.0833
29:35:00	0.0000	0.0000	0.0000	0.0000	0.083	0.083
29:40:00	0.0000	0.0000	0.0000	0.0000	0.0827	0.0827
29:45:00	0.0000	0.0000	0.0000	0.0000	0.0825	0.0825
29:50:00	0.0000	0.0000	0.0000	0.0000	0.0822	0.0822

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
29:55:00	0.0000	0.0000	0.0000	0.0000	0.0819	0.0819
30:00:00	0.0000	0.0000	0.0000	0.0000	0.0817	0.0817
30:05:00	0.0000	0.0000	0.0000	0.0000	0.0814	0.0814
30:10:00	0.0000	0.0000	0.0000	0.0000	0.0812	0.0812
30:15:00	0.0000	0.0000	0.0000	0.0000	0.0809	0.0809
30:20:00	0.0000	0.0000	0.0000	0.0000	0.0807	0.0807
30:25:00	0.0000	0.0000	0.0000	0.0000	0.0804	0.0804
30:30:00	0.0000	0.0000	0.0000	0.0000	0.0801	0.0801
30:35:00	0.0000	0.0000	0.0000	0.0000	0.0799	0.0799
30:40:00	0.0000	0.0000	0.0000	0.0000	0.0796	0.0796
30:45:00	0.0000	0.0000	0.0000	0.0000	0.0794	0.0794
30:50:00	0.0000	0.0000	0.0000	0.0000	0.0791	0.0791
30:55:00	0.0000	0.0000	0.0000	0.0000	0.0789	0.0789
31:00:00	0.0000	0.0000	0.0000	0.0000	0.0786	0.0786
31:05:00	0.0000	0.0000	0.0000	0.0000	0.0784	0.0784
31:10:00	0.0000	0.0000	0.0000	0.0000	0.0781	0.0781
31:15:00	0.0000	0.0000	0.0000	0.0000	0.0779	0.0779
31:20:00	0.0000	0.0000	0.0000	0.0000	0.0776	0.0776
31:25:00	0.0000	0.0000	0.0000	0.0000	0.0774	0.0774
31:30:00	0.0000	0.0000	0.0000	0.0000	0.0771	0.0771
31:35:00	0.0000	0.0000	0.0000	0.0000	0.0769	0.0769
31:40:00	0.0000	0.0000	0.0000	0.0000	0.0767	0.0767
31:45:00	0.0000	0.0000	0.0000	0.0000	0.0764	0.0764
31:50:00	0.0000	0.0000	0.0000	0.0000	0.0762	0.0762
31:55:00	0.0000	0.0000	0.0000	0.0000	0.0759	0.0759
32:00:00	0.0000	0.0000	0.0000	0.0000	0.0757	0.0757
32:05:00	0.0000	0.0000	0.0000	0.0000	0.0755	0.0755
32:10:00	0.0000	0.0000	0.0000	0.0000	0.0752	0.0752
32:15:00	0.0000	0.0000	0.0000	0.0000	0.075	0.075
32:20:00	0.0000	0.0000	0.0000	0.0000	0.0747	0.0747
32:25:00	0.0000	0.0000	0.0000	0.0000	0.0745	0.0745
32:30:00	0.0000	0.0000	0.0000	0.0000	0.0743	0.0743
32:35:00	0.0000	0.0000	0.0000	0.0000	0.074	0.074
32:40:00	0.0000	0.0000	0.0000	0.0000	0.0738	0.0738
32:45:00	0.0000	0.0000	0.0000	0.0000	0.0736	0.0736
32:50:00	0.0000	0.0000	0.0000	0.0000	0.0733	0.0733

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
32:55:00	0.0000	0.0000	0.0000	0.0000	0.0731	0.0731
33:00:00	0.0000	0.0000	0.0000	0.0000	0.0729	0.0729
33:05:00	0.0000	0.0000	0.0000	0.0000	0.0726	0.0726
33:10:00	0.0000	0.0000	0.0000	0.0000	0.0724	0.0724
33:15:00	0.0000	0.0000	0.0000	0.0000	0.0722	0.0722
33:20:00	0.0000	0.0000	0.0000	0.0000	0.0719	0.0719
33:25:00	0.0000	0.0000	0.0000	0.0000	0.0717	0.0717
33:30:00	0.0000	0.0000	0.0000	0.0000	0.0715	0.0715
33:35:00	0.0000	0.0000	0.0000	0.0000	0.0713	0.0713
33:40:00	0.0000	0.0000	0.0000	0.0000	0.071	0.071
33:45:00	0.0000	0.0000	0.0000	0.0000	0.0708	0.0708
33:50:00	0.0000	0.0000	0.0000	0.0000	0.0706	0.0706
33:55:00	0.0000	0.0000	0.0000	0.0000	0.0704	0.0704
34:00:00	0.0000	0.0000	0.0000	0.0000	0.0701	0.0701
34:05:00	0.0000	0.0000	0.0000	0.0000	0.0699	0.0699
34:10:00	0.0000	0.0000	0.0000	0.0000	0.0697	0.0697
34:15:00	0.0000	0.0000	0.0000	0.0000	0.0695	0.0695
34:20:00	0.0000	0.0000	0.0000	0.0000	0.0693	0.0693
34:25:00	0.0000	0.0000	0.0000	0.0000	0.069	0.069
34:30:00	0.0000	0.0000	0.0000	0.0000	0.0688	0.0688
34:35:00	0.0000	0.0000	0.0000	0.0000	0.0686	0.0686
34:40:00	0.0000	0.0000	0.0000	0.0000	0.0684	0.0684
34:45:00	0.0000	0.0000	0.0000	0.0000	0.0682	0.0682
34:50:00	0.0000	0.0000	0.0000	0.0000	0.0679	0.0679
34:55:00	0.0000	0.0000	0.0000	0.0000	0.0677	0.0677
35:00:00	0.0000	0.0000	0.0000	0.0000	0.0675	0.0675
35:05:00	0.0000	0.0000	0.0000	0.0000	0.0673	0.0673
35:10:00	0.0000	0.0000	0.0000	0.0000	0.0671	0.0671
35:15:00	0.0000	0.0000	0.0000	0.0000	0.0669	0.0669
35:20:00	0.0000	0.0000	0.0000	0.0000	0.0667	0.0667
35:25:00	0.0000	0.0000	0.0000	0.0000	0.0665	0.0665
35:30:00	0.0000	0.0000	0.0000	0.0000	0.0662	0.0662
35:35:00	0.0000	0.0000	0.0000	0.0000	0.066	0.066
35:40:00	0.0000	0.0000	0.0000	0.0000	0.0658	0.0658
35:45:00	0.0000	0.0000	0.0000	0.0000	0.0656	0.0656
35:50:00	0.0000	0.0000	0.0000	0.0000	0.0654	0.0654

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
35:55:00	0.0000	0.0000	0.0000	0.0000	0.0652	0.0652
36:00:00	0.0000	0.0000	0.0000	0.0000	0.065	0.065
36:05:00	0.0000	0.0000	0.0000	0.0000	0.0648	0.0648
36:10:00	0.0000	0.0000	0.0000	0.0000	0.0646	0.0646
36:15:00	0.0000	0.0000	0.0000	0.0000	0.0644	0.0644
36:20:00	0.0000	0.0000	0.0000	0.0000	0.0642	0.0642
36:25:00	0.0000	0.0000	0.0000	0.0000	0.064	0.064
36:30:00	0.0000	0.0000	0.0000	0.0000	0.0638	0.0638
36:35:00	0.0000	0.0000	0.0000	0.0000	0.0636	0.0636
36:40:00	0.0000	0.0000	0.0000	0.0000	0.0634	0.0634
36:45:00	0.0000	0.0000	0.0000	0.0000	0.0632	0.0632
36:50:00	0.0000	0.0000	0.0000	0.0000	0.063	0.063
36:55:00	0.0000	0.0000	0.0000	0.0000	0.0628	0.0628
37:00:00	0.0000	0.0000	0.0000	0.0000	0.0626	0.0626
37:05:00	0.0000	0.0000	0.0000	0.0000	0.0624	0.0624
37:10:00	0.0000	0.0000	0.0000	0.0000	0.0622	0.0622
37:15:00	0.0000	0.0000	0.0000	0.0000	0.062	0.062
37:20:00	0.0000	0.0000	0.0000	0.0000	0.0618	0.0618
37:25:00	0.0000	0.0000	0.0000	0.0000	0.0616	0.0616
37:30:00	0.0000	0.0000	0.0000	0.0000	0.0614	0.0614
37:35:00	0.0000	0.0000	0.0000	0.0000	0.0612	0.0612
37:40:00	0.0000	0.0000	0.0000	0.0000	0.061	0.061
37:45:00	0.0000	0.0000	0.0000	0.0000	0.0608	0.0608
37:50:00	0.0000	0.0000	0.0000	0.0000	0.0606	0.0606
37:55:00	0.0000	0.0000	0.0000	0.0000	0.0604	0.0604
38:00:00	0.0000	0.0000	0.0000	0.0000	0.0602	0.0602
38:05:00	0.0000	0.0000	0.0000	0.0000	0.06	0.06
38:10:00	0.0000	0.0000	0.0000	0.0000	0.0598	0.0598
38:15:00	0.0000	0.0000	0.0000	0.0000	0.0596	0.0596
38:20:00	0.0000	0.0000	0.0000	0.0000	0.0595	0.0595
38:25:00	0.0000	0.0000	0.0000	0.0000	0.0593	0.0593
38:30:00	0.0000	0.0000	0.0000	0.0000	0.0591	0.0591
38:35:00	0.0000	0.0000	0.0000	0.0000	0.0589	0.0589
38:40:00	0.0000	0.0000	0.0000	0.0000	0.0587	0.0587
38:45:00	0.0000	0.0000	0.0000	0.0000	0.0585	0.0585
38:50:00	0.0000	0.0000	0.0000	0.0000	0.0583	0.0583

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
38:55:00	0.0000	0.0000	0.0000	0.0000	0.0582	0.0582
39:00:00	0.0000	0.0000	0.0000	0.0000	0.058	0.058
39:05:00	0.0000	0.0000	0.0000	0.0000	0.0578	0.0578
39:10:00	0.0000	0.0000	0.0000	0.0000	0.0576	0.0576
39:15:00	0.0000	0.0000	0.0000	0.0000	0.0574	0.0574
39:20:00	0.0000	0.0000	0.0000	0.0000	0.0572	0.0572
39:25:00	0.0000	0.0000	0.0000	0.0000	0.0571	0.0571
39:30:00	0.0000	0.0000	0.0000	0.0000	0.0569	0.0569
39:35:00	0.0000	0.0000	0.0000	0.0000	0.0567	0.0567
39:40:00	0.0000	0.0000	0.0000	0.0000	0.0565	0.0565
39:45:00	0.0000	0.0000	0.0000	0.0000	0.0563	0.0563
39:50:00	0.0000	0.0000	0.0000	0.0000	0.0562	0.0562
39:55:00	0.0000	0.0000	0.0000	0.0000	0.056	0.056
40:00:00	0.0000	0.0000	0.0000	0.0000	0.0558	0.0558
40:05:00	0.0000	0.0000	0.0000	0.0000	0.0556	0.0556
40:10:00	0.0000	0.0000	0.0000	0.0000	0.0554	0.0554
40:15:00	0.0000	0.0000	0.0000	0.0000	0.0553	0.0553
40:20:00	0.0000	0.0000	0.0000	0.0000	0.0551	0.0551
40:25:00	0.0000	0.0000	0.0000	0.0000	0.0549	0.0549
40:30:00	0.0000	0.0000	0.0000	0.0000	0.0547	0.0547
40:35:00	0.0000	0.0000	0.0000	0.0000	0.0546	0.0546
40:40:00	0.0000	0.0000	0.0000	0.0000	0.0544	0.0544
40:45:00	0.0000	0.0000	0.0000	0.0000	0.0542	0.0542
40:50:00	0.0000	0.0000	0.0000	0.0000	0.0541	0.0541
40:55:00	0.0000	0.0000	0.0000	0.0000	0.0539	0.0539
41:00:00	0.0000	0.0000	0.0000	0.0000	0.0537	0.0537
41:05:00	0.0000	0.0000	0.0000	0.0000	0.0535	0.0535
41:10:00	0.0000	0.0000	0.0000	0.0000	0.0534	0.0534
41:15:00	0.0000	0.0000	0.0000	0.0000	0.0532	0.0532
41:20:00	0.0000	0.0000	0.0000	0.0000	0.053	0.053
41:25:00	0.0000	0.0000	0.0000	0.0000	0.0529	0.0529
41:30:00	0.0000	0.0000	0.0000	0.0000	0.0527	0.0527
41:35:00	0.0000	0.0000	0.0000	0.0000	0.0525	0.0525
41:40:00	0.0000	0.0000	0.0000	0.0000	0.0524	0.0524
41:45:00	0.0000	0.0000	0.0000	0.0000	0.0522	0.0522
41:50:00	0.0000	0.0000	0.0000	0.0000	0.052	0.052

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
41:55:00	0.0000	0.0000	0.0000	0.0000	0.0519	0.0519
42:00:00	0.0000	0.0000	0.0000	0.0000	0.0517	0.0517
42:05:00	0.0000	0.0000	0.0000	0.0000	0.0515	0.0515
42:10:00	0.0000	0.0000	0.0000	0.0000	0.0514	0.0514
42:15:00	0.0000	0.0000	0.0000	0.0000	0.0512	0.0512
42:20:00	0.0000	0.0000	0.0000	0.0000	0.0511	0.0511
42:25:00	0.0000	0.0000	0.0000	0.0000	0.0509	0.0509
42:30:00	0.0000	0.0000	0.0000	0.0000	0.0507	0.0507
42:35:00	0.0000	0.0000	0.0000	0.0000	0.0506	0.0506
42:40:00	0.0000	0.0000	0.0000	0.0000	0.0504	0.0504
42:45:00	0.0000	0.0000	0.0000	0.0000	0.0502	0.0502
42:50:00	0.0000	0.0000	0.0000	0.0000	0.0501	0.0501
42:55:00	0.0000	0.0000	0.0000	0.0000	0.0499	0.0499
43:00:00	0.0000	0.0000	0.0000	0.0000	0.0498	0.0498
43:05:00	0.0000	0.0000	0.0000	0.0000	0.0496	0.0496
43:10:00	0.0000	0.0000	0.0000	0.0000	0.0495	0.0495
43:15:00	0.0000	0.0000	0.0000	0.0000	0.0493	0.0493
43:20:00	0.0000	0.0000	0.0000	0.0000	0.0491	0.0491
43:25:00	0.0000	0.0000	0.0000	0.0000	0.049	0.049
43:30:00	0.0000	0.0000	0.0000	0.0000	0.0488	0.0488
43:35:00	0.0000	0.0000	0.0000	0.0000	0.0487	0.0487
43:40:00	0.0000	0.0000	0.0000	0.0000	0.0485	0.0485
43:45:00	0.0000	0.0000	0.0000	0.0000	0.0484	0.0484
43:50:00	0.0000	0.0000	0.0000	0.0000	0.0482	0.0482
43:55:00	0.0000	0.0000	0.0000	0.0000	0.0481	0.0481
44:00:00	0.0000	0.0000	0.0000	0.0000	0.0479	0.0479
44:05:00	0.0000	0.0000	0.0000	0.0000	0.0478	0.0478
44:10:00	0.0000	0.0000	0.0000	0.0000	0.0476	0.0476
44:15:00	0.0000	0.0000	0.0000	0.0000	0.0475	0.0475
44:20:00	0.0000	0.0000	0.0000	0.0000	0.0473	0.0473
44:25:00	0.0000	0.0000	0.0000	0.0000	0.0472	0.0472
44:30:00	0.0000	0.0000	0.0000	0.0000	0.047	0.047
44:35:00	0.0000	0.0000	0.0000	0.0000	0.0469	0.0469
44:40:00	0.0000	0.0000	0.0000	0.0000	0.0467	0.0467
44:45:00	0.0000	0.0000	0.0000	0.0000	0.0466	0.0466
44:50:00	0.0000	0.0000	0.0000	0.0000	0.0464	0.0464

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
44:55:00	0.0000	0.0000	0.0000	0.0000	0.0463	0.0463
45:00:00	0.0000	0.0000	0.0000	0.0000	0.0461	0.0461
45:05:00	0.0000	0.0000	0.0000	0.0000	0.046	0.046
45:10:00	0.0000	0.0000	0.0000	0.0000	0.0458	0.0458
45:15:00	0.0000	0.0000	0.0000	0.0000	0.0457	0.0457
45:20:00	0.0000	0.0000	0.0000	0.0000	0.0455	0.0455
45:25:00	0.0000	0.0000	0.0000	0.0000	0.0454	0.0454
45:30:00	0.0000	0.0000	0.0000	0.0000	0.0452	0.0452
45:35:00	0.0000	0.0000	0.0000	0.0000	0.0451	0.0451
45:40:00	0.0000	0.0000	0.0000	0.0000	0.045	0.045
45:45:00	0.0000	0.0000	0.0000	0.0000	0.0448	0.0448
45:50:00	0.0000	0.0000	0.0000	0.0000	0.0447	0.0447
45:55:00	0.0000	0.0000	0.0000	0.0000	0.0445	0.0445
46:00:00	0.0000	0.0000	0.0000	0.0000	0.0444	0.0444
46:05:00	0.0000	0.0000	0.0000	0.0000	0.0443	0.0443
46:10:00	0.0000	0.0000	0.0000	0.0000	0.0441	0.0441
46:15:00	0.0000	0.0000	0.0000	0.0000	0.044	0.044
46:20:00	0.0000	0.0000	0.0000	0.0000	0.0438	0.0438
46:25:00	0.0000	0.0000	0.0000	0.0000	0.0437	0.0437
46:30:00	0.0000	0.0000	0.0000	0.0000	0.0436	0.0436
46:35:00	0.0000	0.0000	0.0000	0.0000	0.0434	0.0434
46:40:00	0.0000	0.0000	0.0000	0.0000	0.0433	0.0433
46:45:00	0.0000	0.0000	0.0000	0.0000	0.0431	0.0431
46:50:00	0.0000	0.0000	0.0000	0.0000	0.043	0.043
46:55:00	0.0000	0.0000	0.0000	0.0000	0.0429	0.0429
47:00:00	0.0000	0.0000	0.0000	0.0000	0.0427	0.0427
47:05:00	0.0000	0.0000	0.0000	0.0000	0.0426	0.0426
47:10:00	0.0000	0.0000	0.0000	0.0000	0.0425	0.0425
47:15:00	0.0000	0.0000	0.0000	0.0000	0.0423	0.0423
47:20:00	0.0000	0.0000	0.0000	0.0000	0.0422	0.0422
47:25:00	0.0000	0.0000	0.0000	0.0000	0.0421	0.0421
47:30:00	0.0000	0.0000	0.0000	0.0000	0.0419	0.0419
47:35:00	0.0000	0.0000	0.0000	0.0000	0.0418	0.0418
47:40:00	0.0000	0.0000	0.0000	0.0000	0.0417	0.0417
47:45:00	0.0000	0.0000	0.0000	0.0000	0.0415	0.0415
47:50:00	0.0000	0.0000	0.0000	0.0000	0.0414	0.0414

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
47:55:00	0.0000	0.0000	0.0000	0.0000	0.0413	0.0413
48:00:00	0.0000	0.0000	0.0000	0.0000	0.0411	0.0411
48:05:00	0.0000	0.0000	0.0000	0.0000	0.041	0.041
48:10:00	0.0000	0.0000	0.0000	0.0000	0.0409	0.0409
48:15:00	0.0000	0.0000	0.0000	0.0000	0.0407	0.0407
48:20:00	0.0000	0.0000	0.0000	0.0000	0.0406	0.0406
48:25:00	0.0000	0.0000	0.0000	0.0000	0.0405	0.0405
48:30:00	0.0000	0.0000	0.0000	0.0000	0.0404	0.0404
48:35:00	0.0000	0.0000	0.0000	0.0000	0.0402	0.0402
48:40:00	0.0000	0.0000	0.0000	0.0000	0.0401	0.0401
48:45:00	0.0000	0.0000	0.0000	0.0000	0.04	0.04
48:50:00	0.0000	0.0000	0.0000	0.0000	0.0398	0.0398
48:55:00	0.0000	0.0000	0.0000	0.0000	0.0397	0.0397
49:00:00	0.0000	0.0000	0.0000	0.0000	0.0396	0.0396

Appendix

Catchment descriptors *

Name	Value	User-defined value used?
Area (km ²)	0.65 [5.4]	Yes
ALTBAR	376	No
ASPBAR	143	No
ASPVAR	0.42	No
BFIHOST	0.39	No
BFIHOST19	0.35	No
DPLBAR (km)	2.43	No
DPSBAR (mkm ⁻¹)	99.4	No
FARL	1	No
LDP	3.83	No
PROPWET (mm)	0.54	No
RMED1H	11.8	No
RMED1D	56.7	No
RMED2D	77.9	No
SAAR (mm)	1659	No
SAAR4170 (mm)	1738	No
SPRHOST	46.33	No
Urbext2000	0	No
Urbext1990	0	No
URBCONC	0	No
URBLOC	0	No
DDF parameter C	-0.03	No
DDF parameter D1	0.48	No
DDF parameter D2	0.47	No
DDF parameter D3	0.33	No
DDF parameter E	0.29	No
DDF parameter F	2.54	No
DDF parameter C (1km grid value)	-0.03	No
DDF parameter D1 (1km grid value)	0.49	No
DDF parameter D2 (1km grid value)	0.47	No
DDF parameter D3 (1km grid value)	0.32	No
DDF parameter E (1km grid value)	0.29	No
DDF parameter F (1km grid value)	2.52	No

Values in square brackets are the original values loaded from the FEH Web Service or FEH CD-ROM

UK Design Flood Estimation

Generated on Thursday, March 19, 2020 7:31:55 AM by hekelly
Printed from the ReFH2 Flood Modelling software package, version 3.0.7257.30020

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details

Checksum: C2E7-D057

Site name: FEH_Descriptors_Vaynor-quarry

Easting: 304300

Northing: 209700

Country: England, Wales or Northern Ireland

Catchment Area (km²): 0.65 [5.4]*

Using plot scale calculations: Yes

Model: ReFH2.3

Site description: None

Model run: 100 year

Summary of results

Rainfall - FEH 2013 model (mm):	77.37	Total runoff (ML):	27.01
Total Rainfall (mm):	71.30	Total flow (ML):	46.61
Peak Rainfall (mm):	4.90	Peak flow (m ³ /s):	2.62

Parameters

Where the user has overridden a system-generated value, this original value is shown in square brackets after the value used.

* Indicates that the user locked the duration/timestep

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	06:05:00 [02:42:00]	Yes
Timestep (hh:mm:ss)	00:05:00 [00:06:00]	Yes
SCF (Seasonal correction factor)	0.94	No
ARF (Areal reduction factor)	0.98	No
Seasonality	Summer [Winter]	Yes

Loss model parameters

Name	Value	User-defined?
Cini (mm)	109.35	No
Cmax (mm)	248.36	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	1	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m ³ /s)	0.04	No
BL (hr)	26.24	No
BR	0.71	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km ²)	0	No
Urbext 2000	0	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No
Exporting drained area (km ²)	0.00	Yes
Sewer capacity (m ³ /s)	0.00	Yes

Time series data

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
00:00:00	0.2095	0.0000	0.0923	0.0000	0.0394	0.0394
00:05:00	0.2221	0.0000	0.0981	0.0005	0.0393	0.0397
00:10:00	0.2351	0.0000	0.1040	0.0018	0.0391	0.041
00:15:00	0.2491	0.0000	0.1105	0.0042	0.039	0.0433
00:20:00	0.2641	0.0000	0.1174	0.0077	0.0389	0.0466
00:25:00	0.2800	0.0000	0.1248	0.0122	0.0388	0.0511
00:30:00	0.2971	0.0000	0.1327	0.0180	0.0388	0.0567
00:35:00	0.3154	0.0000	0.1413	0.0250	0.0387	0.0637
00:40:00	0.3350	0.0000	0.1505	0.0334	0.0387	0.0721
00:45:00	0.3560	0.0000	0.1605	0.0432	0.0387	0.0819
00:50:00	0.3787	0.0000	0.1712	0.0545	0.0387	0.0933
00:55:00	0.4030	0.0000	0.1828	0.0675	0.0388	0.106
01:00:00	0.4291	0.0000	0.1954	0.0822	0.039	0.121
01:05:00	0.4574	0.0000	0.2091	0.0980	0.0391	0.137
01:10:00	0.4878	0.0000	0.2240	0.1144	0.0394	0.154
01:15:00	0.5207	0.0000	0.2401	0.1313	0.0397	0.171
01:20:00	0.5565	0.0000	0.2578	0.1488	0.04	0.189
01:25:00	0.5952	0.0000	0.2771	0.1670	0.0404	0.207
01:30:00	0.6371	0.0000	0.2982	0.1860	0.0409	0.227
01:35:00	0.6833	0.0000	0.3217	0.2057	0.0415	0.247
01:40:00	0.7333	0.0000	0.3473	0.2264	0.0421	0.268
01:45:00	0.7880	0.0000	0.3756	0.2481	0.0427	0.291
01:50:00	0.8488	0.0000	0.4074	0.2709	0.0435	0.314
01:55:00	0.9154	0.0000	0.4426	0.2950	0.0443	0.339
02:00:00	0.9887	0.0000	0.4819	0.3205	0.0452	0.366
02:05:00	1.0717	0.0000	0.5267	0.3477	0.0462	0.394
02:10:00	1.1638	0.0000	0.5773	0.3771	0.0473	0.424
02:15:00	1.2668	0.0000	0.6346	0.4088	0.0485	0.457
02:20:00	1.3868	0.0000	0.7020	0.4433	0.0498	0.493
02:25:00	1.5236	0.0000	0.7802	0.4807	0.0512	0.532
02:30:00	1.6807	0.0000	0.8715	0.5217	0.0528	0.575
02:35:00	1.8756	0.0000	0.9767	0.5668	0.0545	0.621
02:40:00	2.1137	0.0000	1.1176	0.6165	0.0563	0.673
02:45:00	2.4070	0.0000	1.2946	0.6718	0.0583	0.73
02:50:00	2.8777	0.0000	1.5784	0.7338	0.0605	0.794

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
02:55:00	3.6457	0.0000	2.0475	0.8044	0.0629	0.867
03:00:00	4.8968	0.0000	2.8343	0.8868	0.0654	0.952
03:05:00	3.6457	0.0000	2.1729	0.9865	0.0681	1.05
03:10:00	2.8777	0.0000	1.7530	1.1037	0.0711	1.17
03:15:00	2.4070	0.0000	1.4918	1.2323	0.0743	1.31
03:20:00	2.1137	0.0000	1.3293	1.3682	0.0777	1.45
03:25:00	1.8756	0.0000	1.1946	1.5083	0.0814	1.59
03:30:00	1.6807	0.0000	1.0825	1.6501	0.0854	1.74
03:35:00	1.5236	0.0000	0.9911	1.7911	0.0895	1.88
03:40:00	1.3868	0.0000	0.9103	1.9290	0.0939	2.02
03:45:00	1.2668	0.0000	0.8383	2.0613	0.0984	2.16
03:50:00	1.1638	0.0000	0.7758	2.1847	0.103	2.29
03:55:00	1.0717	0.0000	0.7192	2.2952	0.108	2.4
04:00:00	0.9887	0.0000	0.6677	2.3865	0.113	2.5
04:05:00	0.9154	0.0000	0.6216	2.4482	0.118	2.57
04:10:00	0.8488	0.0000	0.5794	2.4792	0.123	2.6
04:15:00	0.7880	0.0000	0.5405	2.4877	0.128	2.62
04:20:00	0.7333	0.0000	0.5053	2.4786	0.134	2.61
04:25:00	0.6833	0.0000	0.4727	2.4552	0.138	2.59
04:30:00	0.6371	0.0000	0.4425	2.4197	0.143	2.56
04:35:00	0.5952	0.0000	0.4148	2.3740	0.148	2.52
04:40:00	0.5565	0.0000	0.3892	2.3199	0.153	2.47
04:45:00	0.5207	0.0000	0.3653	2.2587	0.157	2.42
04:50:00	0.4878	0.0000	0.3432	2.1920	0.161	2.35
04:55:00	0.4574	0.0000	0.3227	2.1214	0.165	2.29
05:00:00	0.4291	0.0000	0.3035	2.0488	0.169	2.22
05:05:00	0.4030	0.0000	0.2857	1.9770	0.173	2.15
05:10:00	0.3787	0.0000	0.2613	1.9068	0.176	2.08
05:15:00	0.3560	0.0000	0.2462	1.8369	0.18	2.02
05:20:00	0.3350	0.0000	0.2321	1.7669	0.183	1.95
05:25:00	0.3154	0.0000	0.2190	1.6965	0.186	1.88
05:30:00	0.2971	0.0000	0.2066	1.6257	0.189	1.81
05:35:00	0.2800	0.0000	0.1950	1.5546	0.191	1.75
05:40:00	0.2641	0.0000	0.1842	1.4832	0.194	1.68
05:45:00	0.2491	0.0000	0.1740	1.4118	0.196	1.61
05:50:00	0.2351	0.0000	0.1645	1.3405	0.198	1.54

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
05:55:00	0.2221	0.0000	0.1556	1.2693	0.2	1.47
06:00:00	0.2095	0.0000	0.1470	1.1987	0.202	1.4
06:05:00	0.0000	0.0000	0.0000	1.1287	0.204	1.33
06:10:00	0.0000	0.0000	0.0000	1.0590	0.205	1.26
06:15:00	0.0000	0.0000	0.0000	0.9893	0.206	1.2
06:20:00	0.0000	0.0000	0.0000	0.9200	0.207	1.13
06:25:00	0.0000	0.0000	0.0000	0.8517	0.208	1.06
06:30:00	0.0000	0.0000	0.0000	0.7851	0.209	0.994
06:35:00	0.0000	0.0000	0.0000	0.7210	0.21	0.931
06:40:00	0.0000	0.0000	0.0000	0.6611	0.211	0.872
06:45:00	0.0000	0.0000	0.0000	0.6061	0.211	0.817
06:50:00	0.0000	0.0000	0.0000	0.5548	0.211	0.766
06:55:00	0.0000	0.0000	0.0000	0.5062	0.212	0.718
07:00:00	0.0000	0.0000	0.0000	0.4598	0.212	0.672
07:05:00	0.0000	0.0000	0.0000	0.4154	0.212	0.627
07:10:00	0.0000	0.0000	0.0000	0.3737	0.212	0.586
07:15:00	0.0000	0.0000	0.0000	0.3356	0.212	0.548
07:20:00	0.0000	0.0000	0.0000	0.3007	0.212	0.513
07:25:00	0.0000	0.0000	0.0000	0.2689	0.212	0.481
07:30:00	0.0000	0.0000	0.0000	0.2399	0.211	0.451
07:35:00	0.0000	0.0000	0.0000	0.2136	0.211	0.425
07:40:00	0.0000	0.0000	0.0000	0.1896	0.211	0.4
07:45:00	0.0000	0.0000	0.0000	0.1679	0.21	0.378
07:50:00	0.0000	0.0000	0.0000	0.1484	0.21	0.358
07:55:00	0.0000	0.0000	0.0000	0.1308	0.21	0.34
08:00:00	0.0000	0.0000	0.0000	0.1151	0.209	0.324
08:05:00	0.0000	0.0000	0.0000	0.1012	0.209	0.31
08:10:00	0.0000	0.0000	0.0000	0.0887	0.208	0.297
08:15:00	0.0000	0.0000	0.0000	0.0772	0.207	0.285
08:20:00	0.0000	0.0000	0.0000	0.0668	0.207	0.274
08:25:00	0.0000	0.0000	0.0000	0.0574	0.206	0.264
08:30:00	0.0000	0.0000	0.0000	0.0489	0.206	0.255
08:35:00	0.0000	0.0000	0.0000	0.0413	0.205	0.247
08:40:00	0.0000	0.0000	0.0000	0.0345	0.205	0.239
08:45:00	0.0000	0.0000	0.0000	0.0284	0.204	0.232
08:50:00	0.0000	0.0000	0.0000	0.0231	0.203	0.226

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
08:55:00	0.0000	0.0000	0.0000	0.0184	0.203	0.221
09:00:00	0.0000	0.0000	0.0000	0.0143	0.202	0.216
09:05:00	0.0000	0.0000	0.0000	0.0108	0.202	0.212
09:10:00	0.0000	0.0000	0.0000	0.0078	0.201	0.209
09:15:00	0.0000	0.0000	0.0000	0.0054	0.2	0.206
09:20:00	0.0000	0.0000	0.0000	0.0034	0.2	0.203
09:25:00	0.0000	0.0000	0.0000	0.0019	0.199	0.201
09:30:00	0.0000	0.0000	0.0000	0.0009	0.198	0.199
09:35:00	0.0000	0.0000	0.0000	0.0003	0.198	0.198
09:40:00	0.0000	0.0000	0.0000	0.0000	0.197	0.197
09:45:00	0.0000	0.0000	0.0000	0.0000	0.197	0.197
09:50:00	0.0000	0.0000	0.0000	0.0000	0.196	0.196
09:55:00	0.0000	0.0000	0.0000	0.0000	0.195	0.195
10:00:00	0.0000	0.0000	0.0000	0.0000	0.195	0.195
10:05:00	0.0000	0.0000	0.0000	0.0000	0.194	0.194
10:10:00	0.0000	0.0000	0.0000	0.0000	0.193	0.193
10:15:00	0.0000	0.0000	0.0000	0.0000	0.193	0.193
10:20:00	0.0000	0.0000	0.0000	0.0000	0.192	0.192
10:25:00	0.0000	0.0000	0.0000	0.0000	0.192	0.192
10:30:00	0.0000	0.0000	0.0000	0.0000	0.191	0.191
10:35:00	0.0000	0.0000	0.0000	0.0000	0.19	0.19
10:40:00	0.0000	0.0000	0.0000	0.0000	0.19	0.19
10:45:00	0.0000	0.0000	0.0000	0.0000	0.189	0.189
10:50:00	0.0000	0.0000	0.0000	0.0000	0.189	0.189
10:55:00	0.0000	0.0000	0.0000	0.0000	0.188	0.188
11:00:00	0.0000	0.0000	0.0000	0.0000	0.187	0.187
11:05:00	0.0000	0.0000	0.0000	0.0000	0.187	0.187
11:10:00	0.0000	0.0000	0.0000	0.0000	0.186	0.186
11:15:00	0.0000	0.0000	0.0000	0.0000	0.186	0.186
11:20:00	0.0000	0.0000	0.0000	0.0000	0.185	0.185
11:25:00	0.0000	0.0000	0.0000	0.0000	0.184	0.184
11:30:00	0.0000	0.0000	0.0000	0.0000	0.184	0.184
11:35:00	0.0000	0.0000	0.0000	0.0000	0.183	0.183
11:40:00	0.0000	0.0000	0.0000	0.0000	0.183	0.183
11:45:00	0.0000	0.0000	0.0000	0.0000	0.182	0.182
11:50:00	0.0000	0.0000	0.0000	0.0000	0.182	0.182

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
11:55:00	0.0000	0.0000	0.0000	0.0000	0.181	0.181
12:00:00	0.0000	0.0000	0.0000	0.0000	0.18	0.18
12:05:00	0.0000	0.0000	0.0000	0.0000	0.18	0.18
12:10:00	0.0000	0.0000	0.0000	0.0000	0.179	0.179
12:15:00	0.0000	0.0000	0.0000	0.0000	0.179	0.179
12:20:00	0.0000	0.0000	0.0000	0.0000	0.178	0.178
12:25:00	0.0000	0.0000	0.0000	0.0000	0.178	0.178
12:30:00	0.0000	0.0000	0.0000	0.0000	0.177	0.177
12:35:00	0.0000	0.0000	0.0000	0.0000	0.176	0.176
12:40:00	0.0000	0.0000	0.0000	0.0000	0.176	0.176
12:45:00	0.0000	0.0000	0.0000	0.0000	0.175	0.175
12:50:00	0.0000	0.0000	0.0000	0.0000	0.175	0.175
12:55:00	0.0000	0.0000	0.0000	0.0000	0.174	0.174
13:00:00	0.0000	0.0000	0.0000	0.0000	0.174	0.174
13:05:00	0.0000	0.0000	0.0000	0.0000	0.173	0.173
13:10:00	0.0000	0.0000	0.0000	0.0000	0.173	0.173
13:15:00	0.0000	0.0000	0.0000	0.0000	0.172	0.172
13:20:00	0.0000	0.0000	0.0000	0.0000	0.171	0.171
13:25:00	0.0000	0.0000	0.0000	0.0000	0.171	0.171
13:30:00	0.0000	0.0000	0.0000	0.0000	0.17	0.17
13:35:00	0.0000	0.0000	0.0000	0.0000	0.17	0.17
13:40:00	0.0000	0.0000	0.0000	0.0000	0.169	0.169
13:45:00	0.0000	0.0000	0.0000	0.0000	0.169	0.169
13:50:00	0.0000	0.0000	0.0000	0.0000	0.168	0.168
13:55:00	0.0000	0.0000	0.0000	0.0000	0.168	0.168
14:00:00	0.0000	0.0000	0.0000	0.0000	0.167	0.167
14:05:00	0.0000	0.0000	0.0000	0.0000	0.167	0.167
14:10:00	0.0000	0.0000	0.0000	0.0000	0.166	0.166
14:15:00	0.0000	0.0000	0.0000	0.0000	0.166	0.166
14:20:00	0.0000	0.0000	0.0000	0.0000	0.165	0.165
14:25:00	0.0000	0.0000	0.0000	0.0000	0.164	0.164
14:30:00	0.0000	0.0000	0.0000	0.0000	0.164	0.164
14:35:00	0.0000	0.0000	0.0000	0.0000	0.163	0.163
14:40:00	0.0000	0.0000	0.0000	0.0000	0.163	0.163
14:45:00	0.0000	0.0000	0.0000	0.0000	0.162	0.162
14:50:00	0.0000	0.0000	0.0000	0.0000	0.162	0.162

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
14:55:00	0.0000	0.0000	0.0000	0.0000	0.161	0.161
15:00:00	0.0000	0.0000	0.0000	0.0000	0.161	0.161
15:05:00	0.0000	0.0000	0.0000	0.0000	0.16	0.16
15:10:00	0.0000	0.0000	0.0000	0.0000	0.16	0.16
15:15:00	0.0000	0.0000	0.0000	0.0000	0.159	0.159
15:20:00	0.0000	0.0000	0.0000	0.0000	0.159	0.159
15:25:00	0.0000	0.0000	0.0000	0.0000	0.158	0.158
15:30:00	0.0000	0.0000	0.0000	0.0000	0.158	0.158
15:35:00	0.0000	0.0000	0.0000	0.0000	0.157	0.157
15:40:00	0.0000	0.0000	0.0000	0.0000	0.157	0.157
15:45:00	0.0000	0.0000	0.0000	0.0000	0.156	0.156
15:50:00	0.0000	0.0000	0.0000	0.0000	0.156	0.156
15:55:00	0.0000	0.0000	0.0000	0.0000	0.155	0.155
16:00:00	0.0000	0.0000	0.0000	0.0000	0.155	0.155
16:05:00	0.0000	0.0000	0.0000	0.0000	0.154	0.154
16:10:00	0.0000	0.0000	0.0000	0.0000	0.154	0.154
16:15:00	0.0000	0.0000	0.0000	0.0000	0.153	0.153
16:20:00	0.0000	0.0000	0.0000	0.0000	0.153	0.153
16:25:00	0.0000	0.0000	0.0000	0.0000	0.152	0.152
16:30:00	0.0000	0.0000	0.0000	0.0000	0.152	0.152
16:35:00	0.0000	0.0000	0.0000	0.0000	0.151	0.151
16:40:00	0.0000	0.0000	0.0000	0.0000	0.151	0.151
16:45:00	0.0000	0.0000	0.0000	0.0000	0.151	0.151
16:50:00	0.0000	0.0000	0.0000	0.0000	0.15	0.15
16:55:00	0.0000	0.0000	0.0000	0.0000	0.15	0.15
17:00:00	0.0000	0.0000	0.0000	0.0000	0.149	0.149
17:05:00	0.0000	0.0000	0.0000	0.0000	0.149	0.149
17:10:00	0.0000	0.0000	0.0000	0.0000	0.148	0.148
17:15:00	0.0000	0.0000	0.0000	0.0000	0.148	0.148
17:20:00	0.0000	0.0000	0.0000	0.0000	0.147	0.147
17:25:00	0.0000	0.0000	0.0000	0.0000	0.147	0.147
17:30:00	0.0000	0.0000	0.0000	0.0000	0.146	0.146
17:35:00	0.0000	0.0000	0.0000	0.0000	0.146	0.146
17:40:00	0.0000	0.0000	0.0000	0.0000	0.145	0.145
17:45:00	0.0000	0.0000	0.0000	0.0000	0.145	0.145
17:50:00	0.0000	0.0000	0.0000	0.0000	0.144	0.144

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
17:55:00	0.0000	0.0000	0.0000	0.0000	0.144	0.144
18:00:00	0.0000	0.0000	0.0000	0.0000	0.143	0.143
18:05:00	0.0000	0.0000	0.0000	0.0000	0.143	0.143
18:10:00	0.0000	0.0000	0.0000	0.0000	0.143	0.143
18:15:00	0.0000	0.0000	0.0000	0.0000	0.142	0.142
18:20:00	0.0000	0.0000	0.0000	0.0000	0.142	0.142
18:25:00	0.0000	0.0000	0.0000	0.0000	0.141	0.141
18:30:00	0.0000	0.0000	0.0000	0.0000	0.141	0.141
18:35:00	0.0000	0.0000	0.0000	0.0000	0.14	0.14
18:40:00	0.0000	0.0000	0.0000	0.0000	0.14	0.14
18:45:00	0.0000	0.0000	0.0000	0.0000	0.139	0.139
18:50:00	0.0000	0.0000	0.0000	0.0000	0.139	0.139
18:55:00	0.0000	0.0000	0.0000	0.0000	0.139	0.139
19:00:00	0.0000	0.0000	0.0000	0.0000	0.138	0.138
19:05:00	0.0000	0.0000	0.0000	0.0000	0.138	0.138
19:10:00	0.0000	0.0000	0.0000	0.0000	0.137	0.137
19:15:00	0.0000	0.0000	0.0000	0.0000	0.137	0.137
19:20:00	0.0000	0.0000	0.0000	0.0000	0.136	0.136
19:25:00	0.0000	0.0000	0.0000	0.0000	0.136	0.136
19:30:00	0.0000	0.0000	0.0000	0.0000	0.136	0.136
19:35:00	0.0000	0.0000	0.0000	0.0000	0.135	0.135
19:40:00	0.0000	0.0000	0.0000	0.0000	0.135	0.135
19:45:00	0.0000	0.0000	0.0000	0.0000	0.134	0.134
19:50:00	0.0000	0.0000	0.0000	0.0000	0.134	0.134
19:55:00	0.0000	0.0000	0.0000	0.0000	0.133	0.133
20:00:00	0.0000	0.0000	0.0000	0.0000	0.133	0.133
20:05:00	0.0000	0.0000	0.0000	0.0000	0.133	0.133
20:10:00	0.0000	0.0000	0.0000	0.0000	0.132	0.132
20:15:00	0.0000	0.0000	0.0000	0.0000	0.132	0.132
20:20:00	0.0000	0.0000	0.0000	0.0000	0.131	0.131
20:25:00	0.0000	0.0000	0.0000	0.0000	0.131	0.131
20:30:00	0.0000	0.0000	0.0000	0.0000	0.13	0.13
20:35:00	0.0000	0.0000	0.0000	0.0000	0.13	0.13
20:40:00	0.0000	0.0000	0.0000	0.0000	0.13	0.13
20:45:00	0.0000	0.0000	0.0000	0.0000	0.129	0.129
20:50:00	0.0000	0.0000	0.0000	0.0000	0.129	0.129

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
20:55:00	0.0000	0.0000	0.0000	0.0000	0.128	0.128
21:00:00	0.0000	0.0000	0.0000	0.0000	0.128	0.128
21:05:00	0.0000	0.0000	0.0000	0.0000	0.128	0.128
21:10:00	0.0000	0.0000	0.0000	0.0000	0.127	0.127
21:15:00	0.0000	0.0000	0.0000	0.0000	0.127	0.127
21:20:00	0.0000	0.0000	0.0000	0.0000	0.126	0.126
21:25:00	0.0000	0.0000	0.0000	0.0000	0.126	0.126
21:30:00	0.0000	0.0000	0.0000	0.0000	0.126	0.126
21:35:00	0.0000	0.0000	0.0000	0.0000	0.125	0.125
21:40:00	0.0000	0.0000	0.0000	0.0000	0.125	0.125
21:45:00	0.0000	0.0000	0.0000	0.0000	0.124	0.124
21:50:00	0.0000	0.0000	0.0000	0.0000	0.124	0.124
21:55:00	0.0000	0.0000	0.0000	0.0000	0.124	0.124
22:00:00	0.0000	0.0000	0.0000	0.0000	0.123	0.123
22:05:00	0.0000	0.0000	0.0000	0.0000	0.123	0.123
22:10:00	0.0000	0.0000	0.0000	0.0000	0.122	0.122
22:15:00	0.0000	0.0000	0.0000	0.0000	0.122	0.122
22:20:00	0.0000	0.0000	0.0000	0.0000	0.122	0.122
22:25:00	0.0000	0.0000	0.0000	0.0000	0.121	0.121
22:30:00	0.0000	0.0000	0.0000	0.0000	0.121	0.121
22:35:00	0.0000	0.0000	0.0000	0.0000	0.12	0.12
22:40:00	0.0000	0.0000	0.0000	0.0000	0.12	0.12
22:45:00	0.0000	0.0000	0.0000	0.0000	0.12	0.12
22:50:00	0.0000	0.0000	0.0000	0.0000	0.119	0.119
22:55:00	0.0000	0.0000	0.0000	0.0000	0.119	0.119
23:00:00	0.0000	0.0000	0.0000	0.0000	0.119	0.119
23:05:00	0.0000	0.0000	0.0000	0.0000	0.118	0.118
23:10:00	0.0000	0.0000	0.0000	0.0000	0.118	0.118
23:15:00	0.0000	0.0000	0.0000	0.0000	0.117	0.117
23:20:00	0.0000	0.0000	0.0000	0.0000	0.117	0.117
23:25:00	0.0000	0.0000	0.0000	0.0000	0.117	0.117
23:30:00	0.0000	0.0000	0.0000	0.0000	0.116	0.116
23:35:00	0.0000	0.0000	0.0000	0.0000	0.116	0.116
23:40:00	0.0000	0.0000	0.0000	0.0000	0.116	0.116
23:45:00	0.0000	0.0000	0.0000	0.0000	0.115	0.115
23:50:00	0.0000	0.0000	0.0000	0.0000	0.115	0.115

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
23:55:00	0.0000	0.0000	0.0000	0.0000	0.115	0.115
24:00:00	0.0000	0.0000	0.0000	0.0000	0.114	0.114
24:05:00	0.0000	0.0000	0.0000	0.0000	0.114	0.114
24:10:00	0.0000	0.0000	0.0000	0.0000	0.113	0.113
24:15:00	0.0000	0.0000	0.0000	0.0000	0.113	0.113
24:20:00	0.0000	0.0000	0.0000	0.0000	0.113	0.113
24:25:00	0.0000	0.0000	0.0000	0.0000	0.112	0.112
24:30:00	0.0000	0.0000	0.0000	0.0000	0.112	0.112
24:35:00	0.0000	0.0000	0.0000	0.0000	0.112	0.112
24:40:00	0.0000	0.0000	0.0000	0.0000	0.111	0.111
24:45:00	0.0000	0.0000	0.0000	0.0000	0.111	0.111
24:50:00	0.0000	0.0000	0.0000	0.0000	0.111	0.111
24:55:00	0.0000	0.0000	0.0000	0.0000	0.11	0.11
25:00:00	0.0000	0.0000	0.0000	0.0000	0.11	0.11
25:05:00	0.0000	0.0000	0.0000	0.0000	0.11	0.11
25:10:00	0.0000	0.0000	0.0000	0.0000	0.109	0.109
25:15:00	0.0000	0.0000	0.0000	0.0000	0.109	0.109
25:20:00	0.0000	0.0000	0.0000	0.0000	0.109	0.109
25:25:00	0.0000	0.0000	0.0000	0.0000	0.108	0.108
25:30:00	0.0000	0.0000	0.0000	0.0000	0.108	0.108
25:35:00	0.0000	0.0000	0.0000	0.0000	0.107	0.107
25:40:00	0.0000	0.0000	0.0000	0.0000	0.107	0.107
25:45:00	0.0000	0.0000	0.0000	0.0000	0.107	0.107
25:50:00	0.0000	0.0000	0.0000	0.0000	0.106	0.106
25:55:00	0.0000	0.0000	0.0000	0.0000	0.106	0.106
26:00:00	0.0000	0.0000	0.0000	0.0000	0.106	0.106
26:05:00	0.0000	0.0000	0.0000	0.0000	0.105	0.105
26:10:00	0.0000	0.0000	0.0000	0.0000	0.105	0.105
26:15:00	0.0000	0.0000	0.0000	0.0000	0.105	0.105
26:20:00	0.0000	0.0000	0.0000	0.0000	0.104	0.104
26:25:00	0.0000	0.0000	0.0000	0.0000	0.104	0.104
26:30:00	0.0000	0.0000	0.0000	0.0000	0.104	0.104
26:35:00	0.0000	0.0000	0.0000	0.0000	0.103	0.103
26:40:00	0.0000	0.0000	0.0000	0.0000	0.103	0.103
26:45:00	0.0000	0.0000	0.0000	0.0000	0.103	0.103
26:50:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
26:55:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102
27:00:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102
27:05:00	0.0000	0.0000	0.0000	0.0000	0.102	0.102
27:10:00	0.0000	0.0000	0.0000	0.0000	0.101	0.101
27:15:00	0.0000	0.0000	0.0000	0.0000	0.101	0.101
27:20:00	0.0000	0.0000	0.0000	0.0000	0.101	0.101
27:25:00	0.0000	0.0000	0.0000	0.0000	0.1	0.1
27:30:00	0.0000	0.0000	0.0000	0.0000	0.0999	0.0999
27:35:00	0.0000	0.0000	0.0000	0.0000	0.0996	0.0996
27:40:00	0.0000	0.0000	0.0000	0.0000	0.0993	0.0993
27:45:00	0.0000	0.0000	0.0000	0.0000	0.099	0.099
27:50:00	0.0000	0.0000	0.0000	0.0000	0.0986	0.0986
27:55:00	0.0000	0.0000	0.0000	0.0000	0.0983	0.0983
28:00:00	0.0000	0.0000	0.0000	0.0000	0.098	0.098
28:05:00	0.0000	0.0000	0.0000	0.0000	0.0977	0.0977
28:10:00	0.0000	0.0000	0.0000	0.0000	0.0974	0.0974
28:15:00	0.0000	0.0000	0.0000	0.0000	0.0971	0.0971
28:20:00	0.0000	0.0000	0.0000	0.0000	0.0968	0.0968
28:25:00	0.0000	0.0000	0.0000	0.0000	0.0965	0.0965
28:30:00	0.0000	0.0000	0.0000	0.0000	0.0962	0.0962
28:35:00	0.0000	0.0000	0.0000	0.0000	0.0959	0.0959
28:40:00	0.0000	0.0000	0.0000	0.0000	0.0956	0.0956
28:45:00	0.0000	0.0000	0.0000	0.0000	0.0953	0.0953
28:50:00	0.0000	0.0000	0.0000	0.0000	0.095	0.095
28:55:00	0.0000	0.0000	0.0000	0.0000	0.0947	0.0947
29:00:00	0.0000	0.0000	0.0000	0.0000	0.0944	0.0944
29:05:00	0.0000	0.0000	0.0000	0.0000	0.0941	0.0941
29:10:00	0.0000	0.0000	0.0000	0.0000	0.0938	0.0938
29:15:00	0.0000	0.0000	0.0000	0.0000	0.0935	0.0935
29:20:00	0.0000	0.0000	0.0000	0.0000	0.0932	0.0932
29:25:00	0.0000	0.0000	0.0000	0.0000	0.0929	0.0929
29:30:00	0.0000	0.0000	0.0000	0.0000	0.0926	0.0926
29:35:00	0.0000	0.0000	0.0000	0.0000	0.0923	0.0923
29:40:00	0.0000	0.0000	0.0000	0.0000	0.092	0.092
29:45:00	0.0000	0.0000	0.0000	0.0000	0.0917	0.0917
29:50:00	0.0000	0.0000	0.0000	0.0000	0.0914	0.0914

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
29:55:00	0.0000	0.0000	0.0000	0.0000	0.0911	0.0911
30:00:00	0.0000	0.0000	0.0000	0.0000	0.0908	0.0908
30:05:00	0.0000	0.0000	0.0000	0.0000	0.0905	0.0905
30:10:00	0.0000	0.0000	0.0000	0.0000	0.0903	0.0903
30:15:00	0.0000	0.0000	0.0000	0.0000	0.09	0.09
30:20:00	0.0000	0.0000	0.0000	0.0000	0.0897	0.0897
30:25:00	0.0000	0.0000	0.0000	0.0000	0.0894	0.0894
30:30:00	0.0000	0.0000	0.0000	0.0000	0.0891	0.0891
30:35:00	0.0000	0.0000	0.0000	0.0000	0.0888	0.0888
30:40:00	0.0000	0.0000	0.0000	0.0000	0.0885	0.0885
30:45:00	0.0000	0.0000	0.0000	0.0000	0.0883	0.0883
30:50:00	0.0000	0.0000	0.0000	0.0000	0.088	0.088
30:55:00	0.0000	0.0000	0.0000	0.0000	0.0877	0.0877
31:00:00	0.0000	0.0000	0.0000	0.0000	0.0874	0.0874
31:05:00	0.0000	0.0000	0.0000	0.0000	0.0872	0.0872
31:10:00	0.0000	0.0000	0.0000	0.0000	0.0869	0.0869
31:15:00	0.0000	0.0000	0.0000	0.0000	0.0866	0.0866
31:20:00	0.0000	0.0000	0.0000	0.0000	0.0863	0.0863
31:25:00	0.0000	0.0000	0.0000	0.0000	0.0861	0.0861
31:30:00	0.0000	0.0000	0.0000	0.0000	0.0858	0.0858
31:35:00	0.0000	0.0000	0.0000	0.0000	0.0855	0.0855
31:40:00	0.0000	0.0000	0.0000	0.0000	0.0852	0.0852
31:45:00	0.0000	0.0000	0.0000	0.0000	0.085	0.085
31:50:00	0.0000	0.0000	0.0000	0.0000	0.0847	0.0847
31:55:00	0.0000	0.0000	0.0000	0.0000	0.0844	0.0844
32:00:00	0.0000	0.0000	0.0000	0.0000	0.0842	0.0842
32:05:00	0.0000	0.0000	0.0000	0.0000	0.0839	0.0839
32:10:00	0.0000	0.0000	0.0000	0.0000	0.0836	0.0836
32:15:00	0.0000	0.0000	0.0000	0.0000	0.0834	0.0834
32:20:00	0.0000	0.0000	0.0000	0.0000	0.0831	0.0831
32:25:00	0.0000	0.0000	0.0000	0.0000	0.0828	0.0828
32:30:00	0.0000	0.0000	0.0000	0.0000	0.0826	0.0826
32:35:00	0.0000	0.0000	0.0000	0.0000	0.0823	0.0823
32:40:00	0.0000	0.0000	0.0000	0.0000	0.0821	0.0821
32:45:00	0.0000	0.0000	0.0000	0.0000	0.0818	0.0818
32:50:00	0.0000	0.0000	0.0000	0.0000	0.0815	0.0815

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
32:55:00	0.0000	0.0000	0.0000	0.0000	0.0813	0.0813
33:00:00	0.0000	0.0000	0.0000	0.0000	0.081	0.081
33:05:00	0.0000	0.0000	0.0000	0.0000	0.0808	0.0808
33:10:00	0.0000	0.0000	0.0000	0.0000	0.0805	0.0805
33:15:00	0.0000	0.0000	0.0000	0.0000	0.0802	0.0802
33:20:00	0.0000	0.0000	0.0000	0.0000	0.08	0.08
33:25:00	0.0000	0.0000	0.0000	0.0000	0.0797	0.0797
33:30:00	0.0000	0.0000	0.0000	0.0000	0.0795	0.0795
33:35:00	0.0000	0.0000	0.0000	0.0000	0.0792	0.0792
33:40:00	0.0000	0.0000	0.0000	0.0000	0.079	0.079
33:45:00	0.0000	0.0000	0.0000	0.0000	0.0787	0.0787
33:50:00	0.0000	0.0000	0.0000	0.0000	0.0785	0.0785
33:55:00	0.0000	0.0000	0.0000	0.0000	0.0782	0.0782
34:00:00	0.0000	0.0000	0.0000	0.0000	0.078	0.078
34:05:00	0.0000	0.0000	0.0000	0.0000	0.0777	0.0777
34:10:00	0.0000	0.0000	0.0000	0.0000	0.0775	0.0775
34:15:00	0.0000	0.0000	0.0000	0.0000	0.0772	0.0772
34:20:00	0.0000	0.0000	0.0000	0.0000	0.077	0.077
34:25:00	0.0000	0.0000	0.0000	0.0000	0.0768	0.0768
34:30:00	0.0000	0.0000	0.0000	0.0000	0.0765	0.0765
34:35:00	0.0000	0.0000	0.0000	0.0000	0.0763	0.0763
34:40:00	0.0000	0.0000	0.0000	0.0000	0.076	0.076
34:45:00	0.0000	0.0000	0.0000	0.0000	0.0758	0.0758
34:50:00	0.0000	0.0000	0.0000	0.0000	0.0755	0.0755
34:55:00	0.0000	0.0000	0.0000	0.0000	0.0753	0.0753
35:00:00	0.0000	0.0000	0.0000	0.0000	0.0751	0.0751
35:05:00	0.0000	0.0000	0.0000	0.0000	0.0748	0.0748
35:10:00	0.0000	0.0000	0.0000	0.0000	0.0746	0.0746
35:15:00	0.0000	0.0000	0.0000	0.0000	0.0744	0.0744
35:20:00	0.0000	0.0000	0.0000	0.0000	0.0741	0.0741
35:25:00	0.0000	0.0000	0.0000	0.0000	0.0739	0.0739
35:30:00	0.0000	0.0000	0.0000	0.0000	0.0737	0.0737
35:35:00	0.0000	0.0000	0.0000	0.0000	0.0734	0.0734
35:40:00	0.0000	0.0000	0.0000	0.0000	0.0732	0.0732
35:45:00	0.0000	0.0000	0.0000	0.0000	0.073	0.073
35:50:00	0.0000	0.0000	0.0000	0.0000	0.0727	0.0727

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
35:55:00	0.0000	0.0000	0.0000	0.0000	0.0725	0.0725
36:00:00	0.0000	0.0000	0.0000	0.0000	0.0723	0.0723
36:05:00	0.0000	0.0000	0.0000	0.0000	0.072	0.072
36:10:00	0.0000	0.0000	0.0000	0.0000	0.0718	0.0718
36:15:00	0.0000	0.0000	0.0000	0.0000	0.0716	0.0716
36:20:00	0.0000	0.0000	0.0000	0.0000	0.0713	0.0713
36:25:00	0.0000	0.0000	0.0000	0.0000	0.0711	0.0711
36:30:00	0.0000	0.0000	0.0000	0.0000	0.0709	0.0709
36:35:00	0.0000	0.0000	0.0000	0.0000	0.0707	0.0707
36:40:00	0.0000	0.0000	0.0000	0.0000	0.0704	0.0704
36:45:00	0.0000	0.0000	0.0000	0.0000	0.0702	0.0702
36:50:00	0.0000	0.0000	0.0000	0.0000	0.07	0.07
36:55:00	0.0000	0.0000	0.0000	0.0000	0.0698	0.0698
37:00:00	0.0000	0.0000	0.0000	0.0000	0.0696	0.0696
37:05:00	0.0000	0.0000	0.0000	0.0000	0.0693	0.0693
37:10:00	0.0000	0.0000	0.0000	0.0000	0.0691	0.0691
37:15:00	0.0000	0.0000	0.0000	0.0000	0.0689	0.0689
37:20:00	0.0000	0.0000	0.0000	0.0000	0.0687	0.0687
37:25:00	0.0000	0.0000	0.0000	0.0000	0.0685	0.0685
37:30:00	0.0000	0.0000	0.0000	0.0000	0.0682	0.0682
37:35:00	0.0000	0.0000	0.0000	0.0000	0.068	0.068
37:40:00	0.0000	0.0000	0.0000	0.0000	0.0678	0.0678
37:45:00	0.0000	0.0000	0.0000	0.0000	0.0676	0.0676
37:50:00	0.0000	0.0000	0.0000	0.0000	0.0674	0.0674
37:55:00	0.0000	0.0000	0.0000	0.0000	0.0672	0.0672
38:00:00	0.0000	0.0000	0.0000	0.0000	0.067	0.067
38:05:00	0.0000	0.0000	0.0000	0.0000	0.0667	0.0667
38:10:00	0.0000	0.0000	0.0000	0.0000	0.0665	0.0665
38:15:00	0.0000	0.0000	0.0000	0.0000	0.0663	0.0663
38:20:00	0.0000	0.0000	0.0000	0.0000	0.0661	0.0661
38:25:00	0.0000	0.0000	0.0000	0.0000	0.0659	0.0659
38:30:00	0.0000	0.0000	0.0000	0.0000	0.0657	0.0657
38:35:00	0.0000	0.0000	0.0000	0.0000	0.0655	0.0655
38:40:00	0.0000	0.0000	0.0000	0.0000	0.0653	0.0653
38:45:00	0.0000	0.0000	0.0000	0.0000	0.0651	0.0651
38:50:00	0.0000	0.0000	0.0000	0.0000	0.0649	0.0649

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
38:55:00	0.0000	0.0000	0.0000	0.0000	0.0647	0.0647
39:00:00	0.0000	0.0000	0.0000	0.0000	0.0645	0.0645
39:05:00	0.0000	0.0000	0.0000	0.0000	0.0642	0.0642
39:10:00	0.0000	0.0000	0.0000	0.0000	0.064	0.064
39:15:00	0.0000	0.0000	0.0000	0.0000	0.0638	0.0638
39:20:00	0.0000	0.0000	0.0000	0.0000	0.0636	0.0636
39:25:00	0.0000	0.0000	0.0000	0.0000	0.0634	0.0634
39:30:00	0.0000	0.0000	0.0000	0.0000	0.0632	0.0632
39:35:00	0.0000	0.0000	0.0000	0.0000	0.063	0.063
39:40:00	0.0000	0.0000	0.0000	0.0000	0.0628	0.0628
39:45:00	0.0000	0.0000	0.0000	0.0000	0.0626	0.0626
39:50:00	0.0000	0.0000	0.0000	0.0000	0.0624	0.0624
39:55:00	0.0000	0.0000	0.0000	0.0000	0.0622	0.0622
40:00:00	0.0000	0.0000	0.0000	0.0000	0.062	0.062
40:05:00	0.0000	0.0000	0.0000	0.0000	0.0618	0.0618
40:10:00	0.0000	0.0000	0.0000	0.0000	0.0617	0.0617
40:15:00	0.0000	0.0000	0.0000	0.0000	0.0615	0.0615
40:20:00	0.0000	0.0000	0.0000	0.0000	0.0613	0.0613
40:25:00	0.0000	0.0000	0.0000	0.0000	0.0611	0.0611
40:30:00	0.0000	0.0000	0.0000	0.0000	0.0609	0.0609
40:35:00	0.0000	0.0000	0.0000	0.0000	0.0607	0.0607
40:40:00	0.0000	0.0000	0.0000	0.0000	0.0605	0.0605
40:45:00	0.0000	0.0000	0.0000	0.0000	0.0603	0.0603
40:50:00	0.0000	0.0000	0.0000	0.0000	0.0601	0.0601
40:55:00	0.0000	0.0000	0.0000	0.0000	0.0599	0.0599
41:00:00	0.0000	0.0000	0.0000	0.0000	0.0597	0.0597
41:05:00	0.0000	0.0000	0.0000	0.0000	0.0595	0.0595
41:10:00	0.0000	0.0000	0.0000	0.0000	0.0593	0.0593
41:15:00	0.0000	0.0000	0.0000	0.0000	0.0592	0.0592
41:20:00	0.0000	0.0000	0.0000	0.0000	0.059	0.059
41:25:00	0.0000	0.0000	0.0000	0.0000	0.0588	0.0588
41:30:00	0.0000	0.0000	0.0000	0.0000	0.0586	0.0586
41:35:00	0.0000	0.0000	0.0000	0.0000	0.0584	0.0584
41:40:00	0.0000	0.0000	0.0000	0.0000	0.0582	0.0582
41:45:00	0.0000	0.0000	0.0000	0.0000	0.058	0.058
41:50:00	0.0000	0.0000	0.0000	0.0000	0.0579	0.0579

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
41:55:00	0.0000	0.0000	0.0000	0.0000	0.0577	0.0577
42:00:00	0.0000	0.0000	0.0000	0.0000	0.0575	0.0575
42:05:00	0.0000	0.0000	0.0000	0.0000	0.0573	0.0573
42:10:00	0.0000	0.0000	0.0000	0.0000	0.0571	0.0571
42:15:00	0.0000	0.0000	0.0000	0.0000	0.0569	0.0569
42:20:00	0.0000	0.0000	0.0000	0.0000	0.0568	0.0568
42:25:00	0.0000	0.0000	0.0000	0.0000	0.0566	0.0566
42:30:00	0.0000	0.0000	0.0000	0.0000	0.0564	0.0564
42:35:00	0.0000	0.0000	0.0000	0.0000	0.0562	0.0562
42:40:00	0.0000	0.0000	0.0000	0.0000	0.056	0.056
42:45:00	0.0000	0.0000	0.0000	0.0000	0.0559	0.0559
42:50:00	0.0000	0.0000	0.0000	0.0000	0.0557	0.0557
42:55:00	0.0000	0.0000	0.0000	0.0000	0.0555	0.0555
43:00:00	0.0000	0.0000	0.0000	0.0000	0.0553	0.0553
43:05:00	0.0000	0.0000	0.0000	0.0000	0.0552	0.0552
43:10:00	0.0000	0.0000	0.0000	0.0000	0.055	0.055
43:15:00	0.0000	0.0000	0.0000	0.0000	0.0548	0.0548
43:20:00	0.0000	0.0000	0.0000	0.0000	0.0546	0.0546
43:25:00	0.0000	0.0000	0.0000	0.0000	0.0545	0.0545
43:30:00	0.0000	0.0000	0.0000	0.0000	0.0543	0.0543
43:35:00	0.0000	0.0000	0.0000	0.0000	0.0541	0.0541
43:40:00	0.0000	0.0000	0.0000	0.0000	0.054	0.054
43:45:00	0.0000	0.0000	0.0000	0.0000	0.0538	0.0538
43:50:00	0.0000	0.0000	0.0000	0.0000	0.0536	0.0536
43:55:00	0.0000	0.0000	0.0000	0.0000	0.0534	0.0534
44:00:00	0.0000	0.0000	0.0000	0.0000	0.0533	0.0533
44:05:00	0.0000	0.0000	0.0000	0.0000	0.0531	0.0531
44:10:00	0.0000	0.0000	0.0000	0.0000	0.0529	0.0529
44:15:00	0.0000	0.0000	0.0000	0.0000	0.0528	0.0528
44:20:00	0.0000	0.0000	0.0000	0.0000	0.0526	0.0526
44:25:00	0.0000	0.0000	0.0000	0.0000	0.0524	0.0524
44:30:00	0.0000	0.0000	0.0000	0.0000	0.0523	0.0523
44:35:00	0.0000	0.0000	0.0000	0.0000	0.0521	0.0521
44:40:00	0.0000	0.0000	0.0000	0.0000	0.0519	0.0519
44:45:00	0.0000	0.0000	0.0000	0.0000	0.0518	0.0518
44:50:00	0.0000	0.0000	0.0000	0.0000	0.0516	0.0516

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
44:55:00	0.0000	0.0000	0.0000	0.0000	0.0514	0.0514
45:00:00	0.0000	0.0000	0.0000	0.0000	0.0513	0.0513
45:05:00	0.0000	0.0000	0.0000	0.0000	0.0511	0.0511
45:10:00	0.0000	0.0000	0.0000	0.0000	0.051	0.051
45:15:00	0.0000	0.0000	0.0000	0.0000	0.0508	0.0508
45:20:00	0.0000	0.0000	0.0000	0.0000	0.0506	0.0506
45:25:00	0.0000	0.0000	0.0000	0.0000	0.0505	0.0505
45:30:00	0.0000	0.0000	0.0000	0.0000	0.0503	0.0503
45:35:00	0.0000	0.0000	0.0000	0.0000	0.0502	0.0502
45:40:00	0.0000	0.0000	0.0000	0.0000	0.05	0.05
45:45:00	0.0000	0.0000	0.0000	0.0000	0.0498	0.0498
45:50:00	0.0000	0.0000	0.0000	0.0000	0.0497	0.0497
45:55:00	0.0000	0.0000	0.0000	0.0000	0.0495	0.0495
46:00:00	0.0000	0.0000	0.0000	0.0000	0.0494	0.0494
46:05:00	0.0000	0.0000	0.0000	0.0000	0.0492	0.0492
46:10:00	0.0000	0.0000	0.0000	0.0000	0.049	0.049
46:15:00	0.0000	0.0000	0.0000	0.0000	0.0489	0.0489
46:20:00	0.0000	0.0000	0.0000	0.0000	0.0487	0.0487
46:25:00	0.0000	0.0000	0.0000	0.0000	0.0486	0.0486
46:30:00	0.0000	0.0000	0.0000	0.0000	0.0484	0.0484
46:35:00	0.0000	0.0000	0.0000	0.0000	0.0483	0.0483
46:40:00	0.0000	0.0000	0.0000	0.0000	0.0481	0.0481
46:45:00	0.0000	0.0000	0.0000	0.0000	0.048	0.048
46:50:00	0.0000	0.0000	0.0000	0.0000	0.0478	0.0478
46:55:00	0.0000	0.0000	0.0000	0.0000	0.0477	0.0477
47:00:00	0.0000	0.0000	0.0000	0.0000	0.0475	0.0475
47:05:00	0.0000	0.0000	0.0000	0.0000	0.0474	0.0474
47:10:00	0.0000	0.0000	0.0000	0.0000	0.0472	0.0472
47:15:00	0.0000	0.0000	0.0000	0.0000	0.0471	0.0471
47:20:00	0.0000	0.0000	0.0000	0.0000	0.0469	0.0469
47:25:00	0.0000	0.0000	0.0000	0.0000	0.0468	0.0468
47:30:00	0.0000	0.0000	0.0000	0.0000	0.0466	0.0466
47:35:00	0.0000	0.0000	0.0000	0.0000	0.0465	0.0465
47:40:00	0.0000	0.0000	0.0000	0.0000	0.0463	0.0463
47:45:00	0.0000	0.0000	0.0000	0.0000	0.0462	0.0462
47:50:00	0.0000	0.0000	0.0000	0.0000	0.046	0.046

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
47:55:00	0.0000	0.0000	0.0000	0.0000	0.0459	0.0459
48:00:00	0.0000	0.0000	0.0000	0.0000	0.0457	0.0457
48:05:00	0.0000	0.0000	0.0000	0.0000	0.0456	0.0456
48:10:00	0.0000	0.0000	0.0000	0.0000	0.0454	0.0454
48:15:00	0.0000	0.0000	0.0000	0.0000	0.0453	0.0453
48:20:00	0.0000	0.0000	0.0000	0.0000	0.0452	0.0452
48:25:00	0.0000	0.0000	0.0000	0.0000	0.045	0.045
48:30:00	0.0000	0.0000	0.0000	0.0000	0.0449	0.0449
48:35:00	0.0000	0.0000	0.0000	0.0000	0.0447	0.0447
48:40:00	0.0000	0.0000	0.0000	0.0000	0.0446	0.0446
48:45:00	0.0000	0.0000	0.0000	0.0000	0.0444	0.0444
48:50:00	0.0000	0.0000	0.0000	0.0000	0.0443	0.0443
48:55:00	0.0000	0.0000	0.0000	0.0000	0.0442	0.0442
49:00:00	0.0000	0.0000	0.0000	0.0000	0.044	0.044
49:05:00	0.0000	0.0000	0.0000	0.0000	0.0439	0.0439
49:10:00	0.0000	0.0000	0.0000	0.0000	0.0437	0.0437
49:15:00	0.0000	0.0000	0.0000	0.0000	0.0436	0.0436
49:20:00	0.0000	0.0000	0.0000	0.0000	0.0435	0.0435
49:25:00	0.0000	0.0000	0.0000	0.0000	0.0433	0.0433
49:30:00	0.0000	0.0000	0.0000	0.0000	0.0432	0.0432
49:35:00	0.0000	0.0000	0.0000	0.0000	0.0431	0.0431
49:40:00	0.0000	0.0000	0.0000	0.0000	0.0429	0.0429
49:45:00	0.0000	0.0000	0.0000	0.0000	0.0428	0.0428
49:50:00	0.0000	0.0000	0.0000	0.0000	0.0427	0.0427
49:55:00	0.0000	0.0000	0.0000	0.0000	0.0425	0.0425
50:00:00	0.0000	0.0000	0.0000	0.0000	0.0424	0.0424
50:05:00	0.0000	0.0000	0.0000	0.0000	0.0422	0.0422
50:10:00	0.0000	0.0000	0.0000	0.0000	0.0421	0.0421
50:15:00	0.0000	0.0000	0.0000	0.0000	0.042	0.042
50:20:00	0.0000	0.0000	0.0000	0.0000	0.0418	0.0418
50:25:00	0.0000	0.0000	0.0000	0.0000	0.0417	0.0417
50:30:00	0.0000	0.0000	0.0000	0.0000	0.0416	0.0416
50:35:00	0.0000	0.0000	0.0000	0.0000	0.0414	0.0414
50:40:00	0.0000	0.0000	0.0000	0.0000	0.0413	0.0413
50:45:00	0.0000	0.0000	0.0000	0.0000	0.0412	0.0412
50:50:00	0.0000	0.0000	0.0000	0.0000	0.0411	0.0411

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m ³ /s)	Baseflow (m ³ /s)	Total Flow (m ³ /s)
50:55:00	0.0000	0.0000	0.0000	0.0000	0.0409	0.0409
51:00:00	0.0000	0.0000	0.0000	0.0000	0.0408	0.0408
51:05:00	0.0000	0.0000	0.0000	0.0000	0.0407	0.0407
51:10:00	0.0000	0.0000	0.0000	0.0000	0.0405	0.0405
51:15:00	0.0000	0.0000	0.0000	0.0000	0.0404	0.0404
51:20:00	0.0000	0.0000	0.0000	0.0000	0.0403	0.0403
51:25:00	0.0000	0.0000	0.0000	0.0000	0.0402	0.0402
51:30:00	0.0000	0.0000	0.0000	0.0000	0.04	0.04
51:35:00	0.0000	0.0000	0.0000	0.0000	0.0399	0.0399
51:40:00	0.0000	0.0000	0.0000	0.0000	0.0398	0.0398
51:45:00	0.0000	0.0000	0.0000	0.0000	0.0396	0.0396

Appendix

Catchment descriptors *

Name	Value	User-defined value used?
Area (km ²)	0.65 [5.4]	Yes
ALTBAR	376	No
ASPBAR	143	No
ASPVAR	0.42	No
BFIHOST	0.39	No
BFIHOST19	0.35	No
DPLBAR (km)	2.43	No
DPSBAR (mkm ⁻¹)	99.4	No
FARL	1	No
LDP	3.83	No
PROPWET (mm)	0.54	No
RMED1H	11.8	No
RMED1D	56.7	No
RMED2D	77.9	No
SAAR (mm)	1659	No
SAAR4170 (mm)	1738	No
SPRHOST	46.33	No
Urbext2000	0	No
Urbext1990	0	No
URBCONC	0	No
URBLOC	0	No
DDF parameter C	-0.03	No
DDF parameter D1	0.48	No
DDF parameter D2	0.47	No
DDF parameter D3	0.33	No
DDF parameter E	0.29	No
DDF parameter F	2.54	No
DDF parameter C (1km grid value)	-0.03	No
DDF parameter D1 (1km grid value)	0.49	No
DDF parameter D2 (1km grid value)	0.47	No
DDF parameter D3 (1km grid value)	0.32	No
DDF parameter E (1km grid value)	0.29	No
DDF parameter F (1km grid value)	2.52	No

Values in square brackets are the original values loaded from the FEH Web Service or FEH CD-ROM

Appendix D

Technical Note on Calculation of CBAC

Appendix D - Technical Note on Calculation of Climate Based Assessment Criteria and Associated Statistical Tools

Report reference: 6227 WMP Cornelly Quarry, August 2007

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CONTENTS

1	INTRODUCTION.....	1
1.1	Background	1
1.2	Objectives of this Technical Note.....	1
1.3	Approach.....	1
2	CALCULATION OF CLIMATE BASED ASSESSMENT CRITERIA.....	3
2.1	Introduction	3
2.2	Data	3
2.2.1	Rainfall data	3
2.2.2	Potential Evapotranspiration data (PE).....	4
2.3	Soil Moisture Balance Calculations.....	4
2.4	Comparison with Data.....	5
2.4.1	Kenfig Dunes	5
2.4.2	Carboniferous Limestone	6
2.4.3	New Mill Farm Catchment.....	6
2.5	Summary.....	6
3	STATISTICAL TOOLS	7
3.1	Approach.....	7
3.1.1	Shewart Charts	7
3.1.2	Cu-Sum Charts	7
3.1.3	The Wilcoxon Rank-Sum test for Two Groups.....	8
3.1.4	The two sample t-test.....	9
3.2	Application	10
3.2.1	Existing data sets.....	10
3.2.2	Application to 'future' scenario with applied drawdown.....	10
3.2.3	Statistical Confirmation	11
3.3	Summary.....	11
4	REFERENCES.....	12

FIGURES

- 2.1a Penman two store moisture balance model
- 2.1b Linear catchment store model for unsaturated zone
- 2.2 Modelled and actual groundwater levels – Kenfig Dunes
- 2.3 Simulated and actual groundwater levels in the Carboniferous Limestone
- 2.4 Simulated and actual groundwater levels in the Triassic
- 3.1 Measured and simulated time series data and resultant Shewart and Cusum charts – historical data only $K=0.05$
- 3.2 Measured and simulated time series data and resultant Shewart and Cusum charts – includes 3 year repeated cycle beyond May 2006 $K=0.05$ Drawdown = 0.1m
- 3.3 Measured and simulated time series data and resultant Shewart and Cusum charts – includes 3 year repeated cycle beyond May 2006 $K=0.05$ Drawdown = 0.2m
- 3.4 Measured and simulated time series data and resultant Shewart and Cusum charts – includes 3 year repeated cycle beyond May 2006 $K=0.05$ Drawdown = 0.3m
- 3.5 Sensitivity of Cusum results to value of K

APPENDICES

- D.1 Parameters for Climate Based Assessment Criteria at each Site

1 INTRODUCTION

1.1 Background

Cornelly Quarry (the “Quarry”) is the largest quarry in Wales providing over 1 million tonnes of limestone per year, principally for the steel mill at Port Talbot. It is also an important supplier of aggregates into the local construction industry.

In 1997, applications were made to Bridgend County Borough Council under the Environment Act, 1995 (Review of old mineral permissions – ROMP), for determination of a scheme of conditions in respect of the area of the Quarry covered by those planning permissions (the “ROMP application”). Separate applications were made in respect of the nearby Grove and Gaens’ Quarries. The applications were referred to the Secretary of State for Wales in May 1998 (Gaens’) and July 1998 (Cornelly and Grove). Due to the commonality of issues at these sites, it was decided that they should be determined as a group. The National Assembly for Wales (now the Welsh Assembly Government) subsequently took on the role of determining authority for the applications.

An Environmental Impact Assessment (EIA) in connection with the ROMP applications for the Quarry was submitted voluntarily in 2004 (WynThomasGordonLewis, 2004). The EIA was based on the continuation and extension of current water management practices at the Quarry. The EIA included a set of proposed planning conditions.

One of the proposed new planning conditions submitted in the EIA was the requirement to develop a Water Management Plan (WMP) for the Quarry (WynThomasGordonLewis, 2004 Appendix 8, C No. 9). The objective of the WMP is to guide the Quarry Operator in its management of water at the Quarry such that any adverse environmental impacts resulting from these activities can be minimised. In order to achieve this, the WMP will:

- Specify the monitoring activities required;
- Outline how the resultant data should be reviewed in order to determine whether the operation of the Quarry has affected any of the monitoring sites;
- Outline the options for management of water at the Quarry and how these could be adjusted in light of any effects detected at any of the monitoring sites.

1.2 Objectives of this Technical Note

For the purposes of the WMP, the Quarry Operator and Regulator need to be able to determine whether any future variations in monitoring data at any of the monitoring sites are due to the effects of climate or are due to other causes (such as land use change, private abstraction and quarry dewatering). There are two components to this technical issue:

1. A mechanism is required that can allow the behaviour of water levels at a monitoring site to be predicted under future climatic conditions (a Climate Based Assessment Criterion);
2. Statistical tools are required that will allow an assessment to be made as to the timing and scale of any Deviation¹ between the water levels predicted by the Climate Based Assessment Criterion and those measured in the future.

1.3 Approach

This technical note presents details of the two tools described above. Section 2 presents a generic description of calculations to be used for generating Climate Based Assessment Criteria. These calculations were originally presented as part of the conceptual model report that underpinned the EIA and were reviewed in detail by the Environment Agency at that time. The calculations have been updated with more recent climate data using several demonstration datasets from the monitoring sites in the area.

¹ In this context, Deviation is defined as the occurrence of a statistically significant difference between the behaviour measured at a site and the behaviour that would be anticipated under ‘natural’ conditions.

Section 3.1 presents details of statistical techniques that it is proposed should be used to determine whether a Deviation has occurred. This is a two stage process:

1. Firstly standard control chart techniques are applied to identify periods during which there is a sudden or sustained change in the relationship between the observed data and the Climate Based Assessment Criterion.
2. Then statistical tests are applied to confirm whether there has been a statistically significant change in the relationship between the observed data and the Climate Based Assessment Criterion during this period. If a statistically significant change is confirmed, this is considered to be a Deviation.

The use of these techniques is demonstrated in Section 3.2 by artificially adjusting a segment of time series data of a sample data set by a fixed amount to illustrate the sensitivity of the techniques to small changes in water level.

Note that, in this technical note, the techniques are only discussed in terms of water levels. However, they could be equally applicable to flow data.

2 CALCULATION OF CLIMATE BASED ASSESSMENT CRITERIA

2.1 Introduction

This section provides a generic discussion of the calculations that will be used to derive Climate Based Assessment Criterion and the data that they require as inputs. It then illustrates how these calculations can be used to generate a time series of predicted water levels at a site for given antecedent climatic conditions.

The calculations to derive Climate Based Assessment Criteria are based on daily soil moisture balance calculations which use rainfall and potential evapotranspiration data as inputs. The calculations have a number of parameters that affect the way in which the soil moisture balance operates and which control the division of outputs between actual evapotranspiration, runoff and infiltration to groundwater.

The infiltration to groundwater is passed into a '1D store'. This is a simple algebraic device that is used as a 'groundwater model': the rate of outflow in the store is proportional to the level of water in the store. The constant of proportionality of the 1D store is one of the parameters that can be used to adjust the temporal behaviour of both the water levels in the store and the resultant outflows. The water level in the store can be converted to an equivalent measured groundwater level by means of a 'specific yield'.

The values of the parameters used in the calculations presented here were selected partially on the basis of values commonly used for these parameters in regional water resource assessments and partly by 'calibration' against local flow data (e.g. quarry abstraction rates, some stream flow data). These values have not been adjusted since the calculations were originally developed to support the conceptual model in 2003. The match between the simulated and measured water levels at these sites since that time provides a measure of confidence in the calculations and their parameterisation for those sites.

2.2 Data

2.2.1 Rainfall data

The following rainfall data sets are available from the Environment Agency:

Cefn Cribwr (1) – Daily rainfall data for the period Jan 1981 to Jan 02 (with some gaps)

Cefn Cribwr (2) – Daily rainfall data for the period Jan 02 to Dec 05 (with some gaps)

Schwyll - Daily rainfall data for the period Dec 91 to Sept 06 (with some gaps)

Margam - Daily rainfall data for the period Feb 93 to July 06 (with some gaps)

In addition, staff at Kenfig National Nature Reserve monitor rainfall at Kenfig at intermittent (daily/weekly intervals). Data are available for the period Jan 2000 to May 06.

The calculations presented in the conceptual model report (ESI, 2003) were based on the Cefn Cribwr (1) data series. This is an appropriate site for the calculation of the limestone block around the quarry as it is at a similar elevation. As monitoring at this site has been discontinued and there is relatively little overlap with the new monitoring site here, gaps in the data series have primarily been filled by reference to the Schwyll rainfall series. Conversion was by means of the equation $\text{Cefn Cribwr (1)} = 1.27 \times \text{Schwyll}$ (based on the ratio of long term average rainfall at the two sites for periods during which reliable data are available at both sites). Ultimately, it is anticipated that this will be replaced by reference to data from a new rain gauge to be installed at Cornelly Quarry itself.

It is clear from the available data from Kenfig Nature Reserve that rainfall here is lower than at Cefn Cribwr (1) due to the lower elevation of the former. In order to convert the continuous daily time series from Cefn Cribwr (1) to an appropriate series for calculations for the sand dunes, the Cefn Cribwr (1) data have been converted by means of the equation

Kenfig = 0.885 x Cefn Cribwr (1) (based on the ratio of long term average rainfall at the two sites for periods during which reliable data are available at both sites) for the period when there is no data at Kenfig. For the period for which there are rainfall data at Kenfig, the daily rainfall at Schwyll has been factored so that the monthly totals are the same as those measured at Kenfig.

2.2.2 Potential Evapotranspiration data (PE)

Weekly PE data for MORECS square 155 were converted to daily values by distributing the weekly total evenly across each day of the week. There is less spatial variation in PE data and the outputs from the calculations are less sensitive to this parameter and so this has not been varied spatially.

2.3 Soil Moisture Balance Calculations

Recharge to the groundwater system has been calculated using a Penman two store soil moisture balance model implemented in an Excel spreadsheet.

Prior to passing rainfall to the soil moisture store, any runoff is removed. In areas in which the ground surface is relatively impermeable this may be a relatively significant amount (say 10-20%). On areas of permeable aquifer (e.g. limestone or dune sands) runoff is likely to be relatively low although water may effectively bypass the soil zone (see below).

The Penman store model consists of an upper and a lower soil store. The depth of the upper store is the depth up to which roots are able to draw as much water as required. At greater depths of store, water is only available to plants at a reduced rate. A bypass mechanism allowing direct percolation to the unsaturated zone via e.g. macropores or root channels may also be included. Referring to the schematic diagram in Figure 2.1 (a), the Penman store model works in the following manner.

The status of the model is wetting if precipitation is greater than potential evapotranspiration (i.e. $P-PE>0$), otherwise it is drying ($P-PE<0$).

In wetting mode, the direct percolation (i.e. bypass of the soil zone) is a constant percentage of the effective precipitation, i.e. $f(P-PE)$, where f is the proportional factor (1). The remaining water $(1-f)(P-PE)$ infiltrates the upper soil store (2). When the upper store is full, the excess begins to saturate the lower soil store (3). When the lower soil store is full the excess leaves the lower soil store as percolation to the unsaturated zone (4).

In drying mode, whilst the upper soil store is not dry (5), the soil moisture deficit of the store increases by the shortfall in potential evapotranspiration once precipitation has been taken into account, i.e.

$$\Delta SMD_1 = (PE - P) \quad \text{if } SMD_1 < D_c$$

where

SMD_1 is the soil moisture deficit of the upper store

ΔSMD_1 is the change in the soil moisture deficit of the upper store

D_c is the drying constant.

When the upper soil store is dry, drying of the lower store takes place at a lower rate:

$$\Delta SMD_2 = \gamma(PE - P) \quad \text{if } SMD_1 = D_c$$

where the factor γ represents the drying curve slope

Typical parameter values are as follows $f=15\%$, $D_c=75$ mm, $\gamma=0.3$. For the karstic Carboniferous Limestone areas it is likely that the bypass percentage will be higher and a value of 25% has been used.

The output from the soil moisture deficit model (infiltration to groundwater) has then been processed by passing through a two stage store as illustrated on Figure 2.1 (b). The store is characterised by three parameters:

Time constant for lower release

Time constant for upper release

Level for upper release to be activated

The methodology effectively uses catchment averaged rainfall and PE data series to calculate total catchment flow (e.g. in a river). This approach has proved to be very successful in simulating saturated flow in small to medium sized aquifer systems and is used extensively by the Environment Agency in Thames Region (Catchmod).

2.4 Comparison with Data

Whilst the approach described above has been proven to be widely applicable in a variety of settings (including Carboniferous Limestone areas), the effectiveness of the calculations needs to be demonstrated by comparison with field data for the current study area. Comparison of outputs with observed river flows is presented in Appendix D of ESI, 2003. The text below focuses on comparison with observed groundwater levels as this is the primary interest of this technical note.

The status of the 'groundwater store' provides a prediction of groundwater levels in the aquifer. A good match between store volume and groundwater levels indicates that the calculations are effectively simulating the temporal variation in groundwater recharge and discharge from the aquifer system.

2.4.1 Kenfig Dunes

Calculations were developed for the sand dune system at Kenfig using the synthesised daily Kenfig time series (see Section 2.2.1). Key parameters used are:

$S_y=0.2$ (dune sands)

Store time constant = 180 days

Runoff= 8% (average)

Drying constant (D_o)= 75 mm

Drying curve (γ) = 0.3

Direct percolation (f) = 25%

The results of this calculation are shown in Figure 2.2. Clearly there are a number of simplifications in trying to simulate a complex structure such as the dunes in such a simple manner. However, overall the qualitative fit to the data is reasonable. The summary statistics for the calculations include:

LTA (Feb 93- Jul 06) effective precipitation = 632 mm/a

Percentage of recharge 'overtopping' = 2% (not much 'overtopping' effect in this hydrograph)

The overall range of the simulated and observed groundwater levels during the period of overlap is very close (8.94 to 10.51 mAOD and 8.91 to 10.50 mAOD respectively). There is a slight bias of the calculations to simulate levels lower than those observed (0.1 m on average). However, the current simulation was retained as, on average it was considered to simulate levels better during the critical summer periods. This difference is relatively small compared to the range of levels simulated (7% of range).

2.4.2 Carboniferous Limestone

A similar calculation was set up to simulate recharge processes in the Carboniferous Limestone around Cornelly Quarry. The following parameters were used in the calculations:

$S_y=0.005$
 $\text{Runoff}=0\%$,
 $f=25\%$,
 $D_c=75 \text{ mm}$,
 $\gamma=0.3$

Figure 2.3 shows the comparison between the simulated groundwater levels and actual data for borehole 96/11 (just to the east of Cornelly Quarry). There is a good qualitative fit between simulated and observed data. The parameterisation of the calculations has not been modified for the presence of the quarry as it is not clear whether the nature of the workings will increase or decrease the total recharge available (reduced evaporation due to the absence of plants but increased evaporation in areas of open water). The surface of the quarry floors is generally permeable due to the effects of blasting and there does not appear to be significant amounts of runoff.

There is some indication that there has been some drawdown at this site over the period simulated and this is consistent with its position in the immediate vicinity of the quarry.

2.4.3 New Mill Farm Catchment

In this case the groundwater levels in the Triassic marginal facies at the South Cornelly Borehole were simulated. The following parameters were used in the calculations:

$S_y=0.015$
 $\text{Runoff}=0\%$,
 $f=25\%$,
 $D_c=75 \text{ mm}$,
 $\gamma=0.3$

The observed and simulated groundwater levels are shown on Figure 2.4. Again, there is a reasonable degree of correlation between the

2.5 Summary

The proposed approach for assessing the effect of climatic variations (principally rainfall rates) on groundwater levels has been shown to be generally successful for the main types of hydrogeological conditions of relevance to the WMP. It is therefore concluded that this approach is appropriate for the purposes required by the WMP.

3 STATISTICAL TOOLS

Control charts are a method commonly used in to monitor processes and produce an early warning whenever a situation deviates from 'normal'. The two main types of control charts used in groundwater monitoring are the Shewart and the Cu-Sum charts. These techniques are used to identify periods during which there is a sudden or sustained change in the relationship between the observed data and the Climate Based Assessment Criteria.

Once such a period has been identified, supplementary statistical tests can be applied to confirm whether there is a statistically significant change in the relationship between the observed data and the Climate Based Assessment Criteria during this period compared to the relationship beforehand (baseline). The choice of tests depends on whether the differences between the observed data and the Climate Based Assessment Criteria are normally distributed or not. The two sample t-test is a well known test that is appropriate for use with populations that are normally distributed with the same variance around their respective means. The Wilcoxon Rank-Sum Test for Two Groups is a non-parametric test that can be used with non-normally distributed datasets.

Section 3.1 presents a brief technical description of the implementation of these methods. This is followed in Section 3.2 by an illustration of the application of these techniques to determine whether there is any deviation between observed water level data and outputs from the calculations presented in Section 2.

3.1 Approach

3.1.1 Shewart Charts

The Shewart control chart is used to detect relatively sudden changes in a process under investigation (e.g. rapid increase/decrease of groundwater level).

Assuming that $x_1, x_2, \dots, x_n$ are n differences between the simulated and measured groundwater levels at the times $t_1, t_2, \dots, t_n$, a Shewart control chart of these differences is obtained by standardising the values of x_i as follows:

$$z_i = \frac{x_i - m}{s}; \quad i = 1, 2, \dots, n$$

where: m and s are the average and the unbiased standard deviation of the $x_i, i = 1, 2, \dots, n$,

and then plotting them versus the times $t_1, t_2, \dots, t_n$.

In order to identify when the process has deviated from 'normal' the standardised data z_i are compared to a threshold Z (control limit). When the z_i exceed the control limit the process is declared to be 'beyond normal range'. Gibbons suggests that a value of Z of 4.5 should be taken as a level at which a statistically significant change is considered to have occurred.

3.1.2 Cu-Sum Charts

The Cumulative Summation (Cu-Sum) approach not only focuses on the current monitoring value, but also incorporates information from the previous observations. The main advantage of a Cu-Sum over a Shewart chart, is that the Cu-Sum chart is suitable to detect slower, but systematic processes or trends which would not appear as evident by analysing the time series of the raw data or the Shewart chart. This is perhaps more common in the diffuse systems common in hydrogeology.

Assuming that $x_1, x_2, \dots, x_n$ are n differences between the simulated and measured groundwater levels at the times $t_1, t_2, \dots, t_n$.

The Cu-Sum control chart of these differences is obtained by calculating the quantity:

$$S_i = \max(0, z_i - k + S_{i-1})$$

Where:

- z_i are the standardised differences described in Section 3.1.1;
- k is a parameter representing $\frac{1}{2}$ the change that it is appropriate to try and detect (see more discussion on selection of this parameter in Section 3.2);
- S_{i-1} is the value of S_i at the previous observation event.

In order to detect a when the process has fallen out of normal range, the values of S_i are compared to a threshold (or control limit) h . The selection of the value of h should be based on an assessment of the maximum value of S_i that is appropriate – this could be determined by consideration of the typical range of values of S_i during a period in which no Deviation is considered to occur. Note that, the value selected may in part be determined by the frequency of the data (i.e. a larger Cu-Sum will accumulate with daily data if the observed and simulated deviate over a 6 month period than if monthly data is used). If the frequency of monitoring changes then some allowance for this will need to be made (either by sampling the higher frequency data set to a lower frequency or by interpolating between the values in the less frequent data set).

For technical, statistical reasons the value of S_i should not fall below zero. In order to detect trends in the opposite direction, a 'negative' Cu-Sum is calculated. (i.e. the positive Cu-Sum could be used to detect when the observed data falls below the simulated level whilst the 'negative' Cu-Sum could be considered to detect when the observed data rises above that simulated).

The use of the combined Shewart-Cu-Sum control chart gives the advantages of being able to detect sudden changes in the system as well as gradual and consistent shifts, which would not be easily detected by a simple time series plot.

3.1.3 The Wilcoxon Rank-Sum test for Two Groups

The Wilcoxon Rank-Sum Test for Two Groups (Lehmann, 1975) is used to compare a two datasets to check for an increasing/decreasing average value. This is a non-parametric test and, as such, it is robust to outliers and non-detects.

In groundwater monitoring this test is often used to compare a historic dataset with a recent one in order to detect a statistical difference between the two.

To run the Wilcoxon Rank-Sum test the compliance and background data are combined and ranked from 1 to N. The Wilcoxon statistic W is then calculated as:

$$W = \sum_{i=1}^n C_i - \frac{1}{2}n(n+1)$$

where:

- C_i denotes the ranks of the compliance samples, and
- n denotes the number of compliance samples.

In order to determine whether the null hypothesis of no decreased average can be accepted an approximate Z-score for the Wilcoxon Rank-Sum test has to be compared to a critical value of W . The approximate Z-score for the Wilcoxon test is:

$$Z \approx \frac{W - E(W) - 1/2}{SD(W)} ;$$

where:

- W is the Wilcoxon statistic as above defined;

- $E(W) = \frac{1}{2}mn$ represents the expected value of W ;
- m is the number of values in the background sample;
- $SD(W) = \sqrt{\frac{1}{12}mn(N+1)\left(1 - \sum_{i=1}^g \frac{t_i^3 - t_i}{N^3 - N}\right)}$ is the standard deviation of the W statistic adjusted for tied values;
- t_i represents the number of ties in the i^{th} group;
- g represents the number of groups of distinct tied observations.

The critical value of W is the upper 0.01 percentile of the standard Normal distribution $z_{0.01}=2.326$.

If the Z-score is greater than 2.326, the null hypothesis of no significant difference may be rejected.

An appropriate choice of the background and compliance datasets allows us to use the Wilcoxon Rank-Sum Test for Two Groups as a means to identify a statistical evidence of decreasing average.

3.1.4 The two sample t-test

The t-test is the most widely used method for comparing two independent groups of data, however it presents some problems when applied to non normal datasets.

The null hypothesis of the test is that the difference between the averages of the two datasets equals a number δ_0 . The test statistics is:

$$t_0 = \frac{(\bar{X} - \bar{Y}) * \delta_0}{s_p \sqrt{\frac{1}{m} + \frac{1}{n}}} \quad (1)$$

where:

$\bar{X}$ is the average of the data over the period during which a change appears to have occurred;

$\bar{Y}$ is the average of all the rest of the data;

$s_p = \sqrt{\frac{(m-1)*s_x^2 + (n-1)*s_y^2}{m+n-2}}$ is the pooled standard deviation estimate;

s_x and s_y the sample variances of the two populations;

m and n the sample sizes of the x and y datasets respectively

In the case that the test statistics is greater than the critical value $t_{m+n-2, 1-\alpha}$ (which should be looked up in the test statistical tables), the null hypothesis should be rejected.

3.2 Application

3.2.1 Existing data sets

The application of these techniques is illustrated by reference to the observed and simulated data for the Kenfig Dunes sites as discussed in Section 2.4.1.

First the existing sequence of observed and simulated data were taken to form a 'baseline' for the statistical techniques. This created a series of pairs of observed:simulated data values at approximately monthly intervals for the period Jan 1997 to May 2006. Figure 3.1 shows the combined Cu-Sum and Shewart chart for the differences between the observed and simulated data (lower plot). The actual observed and simulated data are shown in the upper plot for comparison.

The Shewart chart shows that the control limit is not exceeded at any point in the historical time sequence.

The 'positive' Cu-Sum chart, conversely, shows that in the early part of the time series (1997 drought) there are some small but consistently positive differences between the simulated and observed data, whereas the 'negative' Cu-Sum chart shows a similar consistency in negative differences in the following part of the time series (through to the heavy rainfall in 2000). Following this there is relatively little consistent difference between simulated and observed data for the remaining time period. These differences can be seen in the observed and simulated data can be seen in the upper plot. It is not clear whether these differences are due to limitations of the calculations or inaccuracies in the input rainfall time series during this period.

The maximum (minimum) value represented in the positive (negative) Cu-Sum chart is less than +20 (greater than -26 respectively). If the calculations can be qualitatively accepted as an appropriate simulation of the groundwater conditions at this site (see discussion in Section 2.4.1) and it is considered that there is no general background trend in the differences during this period then, given that the period includes some fairly extreme climatic conditions (drought and flood), this range of Cu-Sum values can be considered to be appropriate levels at which to detect that a significant change has occurred. If the calculations could be improved to provide a more consistently good fit between observed and simulated levels, then the critical values of Cu-Sum can also be reduced.

3.2.2 Application to 'future' scenario with applied drawdown

In order to assess how effective the technique is at detecting the presence of a small but consistent drawdown in groundwater levels, a sequence of three years was added to the end of the time series and then manipulated to introduce a consistent difference between observed and simulated levels.

The data pairs for 2002 (which was considered to be a 'typical year') were repeated three times to create the 'future' sequence. This 'future' sequence was then modified by reducing the observed groundwater levels by a constant value (i.e. equivalent to a non-climate related drawdown occurring in the data). The Cu-Sum and Shewart charts were then calculated to see what size of deviation between the measured data and the simulated groundwater levels could be detected.

The results of this exercise are shown in Figures 3.2, 3.3 and 3.4 for drawdowns of 0.1, 0.2 and 0.3 m respectively. K was set at 0.05 m for this exercise, but in general will be set to half the difference that needs to be detected – for instance the Significance Criteria. The sensitivity of these results to K is shown in Figure 3.5.

From inspection of these figures, it can be seen that the Shewart approach does not detect these small but consistent changes (a change of around 0.6 m would be required to breach the Shewart control limit). The change of 0.1m would be confirmed in around 28 months (although the upward trend would have been apparent for the whole of this period), the change of 0.2 m would be confirmed in 9 months).

Comparison of the observed and simulated hydrographs in the upper plots shows that it is unlikely that a change of 0.1 m would be detected by visual comparison alone and that even a change of 0.2 m would be hard to be confident about.

A number of points are apparent from this exercise:

- The Cu-Sum approach is more sensitive and objective than visual inspection of the hydrographs.
- The length of time that the Cu-Sum takes to detect a change is inversely related to the size of the change (i.e. bigger changes are detected more quickly).
- The length of time that the Cu-Sum takes to detect a change is also related to the quality of the calculations (changes will be detected more quickly with a better match between observed and simulated data).
- The Shewart Chart is less sensitive than the Cu-Sum approach in detecting small but consistent changes. However, it would be effective at detecting a larger but more abrupt change.

3.2.3 Statistical Confirmation

The Cu-Sum chart method is dependent on time correlation effects and so, where water level changes are very gradual in comparison to the frequency of monitoring, this methodology may falsely indicate a systematic change in water levels. Once the Cu-Sum chart detects an apparent systematic change, it is therefore important to double check that a statistically significant difference is present in the data.

To achieve this, the two sample t-test or the Wilcoxon test can be used to compare the model residuals during the 'baseline' and apparently affected periods. In this case, the Wilcoxon test was used to confirm that there was a statistically significant change between the last three years of data (i.e. the period over which a change in the data was artificially applied) and the rest of the dataset. The Wilcoxon test was used as the model residuals were not normally distributed.

3.3 Summary

The example presented above suggests that the combined Shewart-Cu-Sum approach should be effective at detecting both abrupt changes in observed and simulated water levels and small but consistent changes. The sensitivity of these techniques in detecting changes in water level is primarily controlled by the quality of the fit between the observed and simulated data over a representative 'baseline' period. Where a good fit cannot be achieved, simpler approaches may be appropriate.

Once a period of apparent variation between the Climate Based Assessment Criterion and the observed data has been identified, it is important to carry out supplementary statistical tests to confirm this conclusion. To achieve this, the two sample t-test or the Wilcoxon test can be used.

In all cases, conditions at adjacent sites should be considered wherever possible in order to confirm the conclusions of techniques such as these.

4 REFERENCES

- ESI, 2003. Cornelly Group of Quarries: Conceptual model of the local hydrogeology
- R. Gibbons "Statistical Methods for Groundwater Monitoring" John Wiley & Sons, Inc
- Lehmann, E.L. (1975) Nonparametrics: Statistical Methods Based on Ranks. San Francisco: Holden-Day, Inc.
- WynThomasGordonLewis, 2004. Environment Act 1995: Review of Mineral Planning Permissions Cornelly Quarry Environmental Impact Assessment

Appendix D.1 Parameters for Climate Based Assessment Criteria at Each Site

To be completed after first annual review after formal adoption of WMP.

Appendix E

Discharge permit

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



**ENVIRONMENT
AGENCY**

Part A

To: JOINT HOLDER
SEE ATTACHED SCHEDULE

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 AF4026001 Consent Issued: 23/05/1978

Nature of Discharge(s); TMWR Trade - Minewater - Rainfall
at SO0396009310 VAYNOR QUARRY CEFN COED MERTHYR TY

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: AF4026001
Consent Issued: 23/05/1978
Name:
Address:

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:**



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



ASiantaeth yr
AMGYLCHEDD

Rhan A

At:

Cyd Ddaliwr

Gweler yr Atodlen yng Nglwm

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 AF4026001 Cyhoeddwyd Caniatâd: 23/05/1978

Natur y gollwng: TMWR Trade - Minewater - Rainfall
yn SO0396009310 VAYNOR QUARRY CEFN COED MERTHYR TY

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 olynnydd.** 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 fâth 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: AF4026001

Enw:

Cyfeiriad:

Cyhoeddwyd Caniatâd: 23/05/1978

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:**



Joint Holder Listing

21 August 2001

Consent

AF4026001

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

Consent

AF4026001

TARMAC HEAVY BUILDING MATERIALS UK LTD
PO BOX 8
MILLFIELDS ROAD
ETTINGSHALL
WOLVERHAMPTON
WV4 6JP

Caniatad
AF4026001

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

Caniatad
AF4026001

TARMAC HEAVY BUILDING MATERIALS UK LTD
PO BOX 8
MILLFIELDS ROAD
ETTINGSHALL
WOLVERHAMPTON
WV4 6JP

REGISTER OF CONDITIONS

AND OTHER TERMS

IMPOSED UNDER SECTION 7 OF THE RIVERS (PREVENTION OF POLLUTION) ACT, 1951

(AS APPLIED BY THE CLEAN RIVERS (ESTUARIES AND TIDAL WATERS) ACT, 1960)

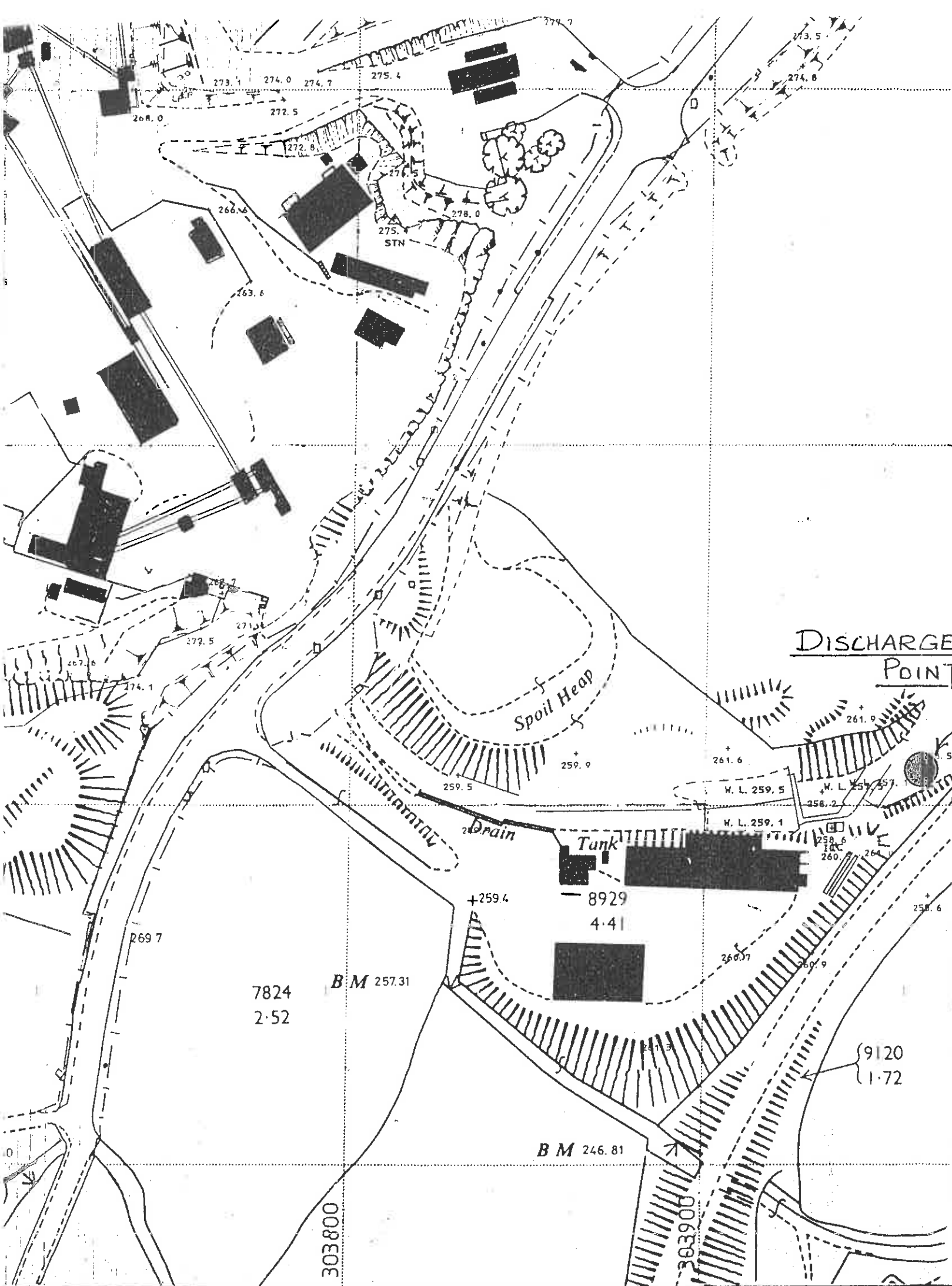
AND THE RIVERS (PREVENTION OF POLLUTION) ACT, 1961.

CAT. No. R.B.12 SHAW & SONS LTD., FETTER LANE, E.C.4.

AF4026001
No. 4/260

DATE ON WHICH CONDITION CAME INTO FORCE AND PERIOD OF EFFECT		FULL ADDRESS OR OTHER SUFFICIENT DESCRIPTION OF LAND OR PREMISES TO WHICH THE TERM OR CONDITION RELATES	
23.5.1978		Powell Duffryn Quarries Limited Vaynor Quarry, Cefn Coed, Merthyr Tydfil.	
File 3480			
USE OF NEW OR ALTERED OUTLET		DISCHARGE OF TRADE OR SEWAGE EFFLUENT	
CONDITIONS IMPOSED WITH RESPECT TO:- (I) PRECISE LOCATION OF OUTLET Pt. "A" discharging to Taf Fechan <u>Vaynor Quarry, as above.</u> S.O.Map 04 Grid ref. 0396W 0931N (II) CONSTRUCTION OF OUTLET (OTHER THAN CONDITIONS TO BE SATISFIED BEFORE OUTLET IS BROUGHT INTO USE) Overflow from final settlement tanks (III) USE OF OUTLET discharge of treated quarry drainage (IV) USE OF ANY OTHER OUTLET FOR TRADE OR SEWAGE EFFLUENT FROM THE SAME LAND OR PREMISES natural mountain stream + quarry plant operational drainage		CONDITIONS IMPOSED WITH RESPECT TO:- Cement, limestone dust, & oil traces. (I) NATURE AND COMPOSITION OF DISCHARGE 1. Total Suspended Solids - Must not exceed 60 mg/l 2. Oil, soluble in "Freon"} " " 10 mg/l and grease 3. pH range = 5-9 (II) TEMPERATURE OF DISCHARGE ambient (III) VOLUME OR RATE OF DISCHARGE OF EFFLUENT FROM LAND OR PREMISES dependent upon rainfall * (IV) PROVISION OF FACILITIES FOR TAKING SAMPLES at outlet * (V) DATE OF EXPIRATION OF PERIOD SPECIFIED UNDER S-5(2) OF 1961 ACT 25.5.1980	
REMARKS-		REMARKS-	

* IF DISCHARGE NOT CONTROLLED UNDER S.7 OF 1951 ACT



Based upon the Ordnance Survey 1:2500 map with permission of the Controller of Her Majesty's Stationery Office - Crown Copyright Reserved - Licence No. AL 544256

Site		VAYNOR QUARRY	
ARC South Wales Ltd.			
ALL LEVELS IN METRES ABOVE ORDNANCE DATUM			
Scale 1 / 1250	Drawn	Revisions March 1995	Drawing (No.) V6 d/2
Date 4.10.84	Checked <i>Stu. Roberts</i>		
LASER REFERENCE STATION ----- ⊕LS1			
ARC FREEHOLD -----			
CONSENTED PLANNING LINE -----			

Notice of transfer with introductory note

The Environmental Permitting (England & Wales) Regulations 2016

Hanson Quarry Products Europe Limited

Vaynor Quarry
Cefn Coed
Merthyr Tydfil
CF48 2LA

Transfer notification number
AF4026001/T002

Permit number
AF4026001

Trade Effluent discharge from Vaynor Quarry

Permit number AF4026001

Introductory note

This introductory note does not form a part of the notice

The following notice gives notice of the transfer of an environmental permit from the existing operator (the transferor) to the new operator (the transferee), following notification from both.

This is a full transfer of an environment discharge permit for a trade effluent plant serving Vaynor Quarry from Tarmac Trading Limited to Hanson Quarry Products Europe Limited.

The status log of a permit sets out the permitting history, including any changes to the permit reference number. It is not backdated before 6 April 2010.

Status log of the permit		
Description	Date	Comments
Application to vary environmental permit	11/08/2016	Administrative variation to change company name to Tarmac Trading Limited
Variation issued AF4026001/V001	17/08/2016	Varied permit issued to Tarmac Trading Limited
Transfer notification AF4026001/T002	Duly made 21/06/2017	Application to transfer the permit in full to Hanson Quarry Products Europe Limited.
Transfer determined AF4026001	07/07/2017	Full transfer of permit complete.

End of Introductory Note

Notice of transfer

The Environmental Permitting (England and Wales) Regulations 2016

The Natural Resources Body for Wales (“Natural Resources Wales”) in exercise of its powers under regulation 21(4) of the Environmental Permitting (England and Wales) Regulations 2016 following joint notification transfers

permit number
AF4026001

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

Vaynor Quarry
Cefn Coed
Merthyr Tydfil
CF48 2LA

from: Tarmac Trading Limited

This notice shall take effect from 19/07/2017.

Name

Date

Stephen Attwood

07/07/2017

Authorised on behalf of the Natural Resources Wales