RHONDDA CYNON TAF COUNTY BOROUGH COUNCIL

Flood and Water Management Act 2010

Section 19 Flood Investigation Report

Storm Dennis –

Flood Investigation Area RCT19 (Porth)

June 2022

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This report should be read in its entirety

This report has been prepared in accordance with the requirements of section 19 Flood and Water Management Act 2010. The Council assumes no responsibility or liability from any person in connection with its contents or findings.

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EXECUTIVE SUMMARY

This report has been produced through the duties placed upon Rhondda Cynon Taf County Borough Council (RCT) under Section 19 of the Flood and Water Management Act 2010. The Act states, “On becoming aware of a flood in its area, a lead local flood authority must, to the extent that it considers it necessary or appropriate, investigate:

a) which risk management authorities have relevant flood risk management functions and
b) Whether each of those risk management authorities has exercised, or is proposing to exercise those functions in response to the flood”.

This Section 19 investigation provides a factual report of the storm event that occurred on the 15 and 16th of February 2020 within the Rhondda Cynon Taf County Borough Council area, focusing investigation on the flooding that occurred within the impacted areas of Porth in the Rhondda valley (Flood Investigation Area RCT19, Figure 1).

This report was undertaken to identify the mechanism for flooding, establish which Risk Management Authorities have relevant flood risk management functions under the Flood and Water Management Act 2010 and ascertain if those Risk Management Authorities’ have undertaken or were planning to undertake actions related to those functions to manage the risk of flooding.

The flooding that affected RCT on the 15 and 16th of February 2020 was a result of an extreme rainfall event, designated by the Met Office as ‘Storm Dennis’. The impact of the event at investigation area RCT19 resulted in internal flooding to 60 properties: including 45 residential properties and 16 non-residential properties. Significant flooding to the highway also occurred throughout the investigation area. These impacts were identified through inspections made by RCT’s Flood Risk Management Team during the days following the storm event, as well as information collated by residents, RCT’s Public Health team, RCT’s Highway and Streetcare Depot, Natural Resources Wales and Dŵr Cymru Welsh Water.

The evidence gathered within this report identifies three primary sources of internal flooding within the investigation area: the overtopping of the two main rivers within the investigation area, the River Rhondda and the Rhondda Fach, the surcharging of two culvert inlets associated to the Nant Llwyncelyn ordinary watercourse, and the localised accumulation of surface water across RCT19.

The Rhondda Fach and Rhondda Rivers overtopped their eastern and western embankments at several locations following persistent and heavy rainfall. Obstructions

caused by floating debris at several bridges along the Rhondda Fach and Rhondda River channels are also considered to have contributed to the overtopping by causing water to rise behind the obstructions. River level gauge data from NRW's Trehafod monitoring station reveal that the River Rhondda was over three times it's typical level during Storm Dennis, reaching a peak level of 3.977 metres; the highest river level recorded at the station since it's opening in 2001.

On review of NRW's FRAW maps, the majority of the impacted properties within RCT19 are identified at high and medium risk of flooding from the main river and are currently 'Undefended'.

The surcharging of two culvert inlets associated to the Nant Llwyncelyn watercourse was caused by accumulation of debris on both culvert inlet's debris screens caused by the displacement of debris within the upper watercourse channels. An identified unconsented culvert structure downstream of 'Culvert Inlet 2' is also considered to have contributed to the flooding due to the reduction in hydraulic capacity within the network.

Surface water flooding was also noted as a primary and contributing source of flooding to several properties within RCT19 as a result of intense rainfall and overwhelmed highway and surface water drainage infrastructure.

NRW has been determined as the relevant Risk Management Authority responsible for managing the main river flooding that occurred during Storm Dennis. In response to the flooding at investigation area RCT19, NRW have;

- Carried out their own post event investigative analysis work to understand the mechanism of flooding from the Rhondda River and Rhondda Fach Rivers at RCT19;
- Undertaken debris clearance works to the main river channels within RCT19;
- Commissioned a Rhondda Flood Modelling Project, the outcomes of which will include an initial assessment of the viability of potential flood risk management options; and
- Developed a series of recommendations and a detailed action plan to address the areas of improvement for future storm events, including the performance of NRW's Flood Warning Service and incident management response.

RCT as the LLFA, LDA and Highway Authority has been determined as the relevant Risk Management Authority responsible for managing the ordinary watercourse and

surface water flooding that occurred during Storm Dennis. In response to the flooding at investigation area RCT19, the LLFA has;

- Carried out survey, jetting and cleansing operations to an estimated 445 metres of culvert network within the investigation area;
- Utilised its powers, under Section 24 of the Land Drainage Act 1991, to enforce the removal of an unconsented culvert structure;
- Led on the development of a central Control Room to compliment the Council's Contact Centre and CCTV Centre; and to provide a comprehensive and informed response to residents during storm events;
- Exercised its powers, under Section 13 of the Flood and Water Management Act 2010, to engage with NRW and DCWW in relation to their responsibilities as the Risk Management Authorities; and
- Working in partnership with NRW, the LLFA have expanded their interim Property Flood Resistance project offering expandable flood gates to those properties deemed at high risk of river flooding, as per NRW's determination.

The event that occurred on 15 and 16th February was extreme, and it is unlikely that flooding from a similar event could be prevented entirely. It is concluded that Risk Management Authorities satisfactorily carried out their flood risk management functions in response to the flood event at RCT19, however, further measures have been proposed by all RMAs to improve preparedness and response to future flood events.

ABBREVIATIONS

CaRR – Communities at Risk Register

DCWW – Welsh Water

FRMP – Flood Risk Management Plan

FWMA – Flood and Water Management Act 2010

LDA – Land Drainage Authority

LFRMS – Local Flood Risk Management Strategy

LLFA – Lead Local Flood Authority

NFD – Non-Flood Defence – A structure that provides a flood defence benefit, which is not designated or maintained as a Flood Defence Structure. Thereby the benefits derived from the structure cannot be depending upon to deliver a Flood Defence.

NRW – Natural Resources Wales

Q – Return Period (1 in X chance of an event occurring in any given year)

RCT - Rhondda Cynon Taff CBC

RCT19 – Flood Investigation Area RCT 19

RMA – Risk Management Authority

SAB – Sustainable Drainage Approval Body

SFRA – Strategic Flood Risk Assessment

SOC – Strategic Outline Business Case

SuDs – Sustainable Drainage Systems

TABLES AND FIGURES

1 INTRODUCTION

1.1. PURPOSE OF INVESTIGATION

On the 15th and 16th of February 2020, RCT was impacted by an extreme weather event which was designated by the Met Office as 'Storm Dennis'. Due to the extent of the event's impact, the LLFA opted to undertake a formal investigation.

The storm resulted in widespread residential and commercial flooding within the Rhondda Cynon Taf County Borough Council area. This report will focus on Flood Investigation Area RCT 19 (further referred to as RCT19) which encompasses the town of Porth within the Rhondda valley.

The reason behind RCT's investigation is in response to the duties of the local authority in regard to Section 19; of the Flood and Water Management Act 2010, which states:

1. on becoming Aware of a flood in its area, a lead local flood authority must, to the extent that it considers it necessary or appropriate, investigate:

    a) "Which risk management authorities have relevant flood risk management functions and,
    b) Whether each of those risk management authorities has exercised, or is proposing to exercise, those functions in the response to the flood."

2. "When an authority carries out an investigation under subsection (1) it must (a) publish the results of its investigation, and (b) notify any relevant risk management authority"[1]

The purpose of the investigation is to determine which RMAs have relevant flood risk management functions and which functions have been exercised in response to the flood event in question.

Specific details of Storm Dennis, such as rainfall analysis are covered within a separate overview report that covers the wider RCT area. The report is titled 'Storm Dennis February 2020 – Overview Report' and will be referred to as 'FRM – Storm Dennis – Overview Report'[2].

[1] Flood and Water Management Act 2010 – Section 19 - https://www.legislation.gov.uk/ukpga/2010/29/section/19
[2] Flood Investigation Reports | Rhondda Cynon Taf County Borough Council (rctcbc.gov.uk)

1.2. SITE LOCATION

The area investigated within this report covers the town of Porth, located within the Rhondda valley and the River Rhondda catchment in the central region of the county borough.

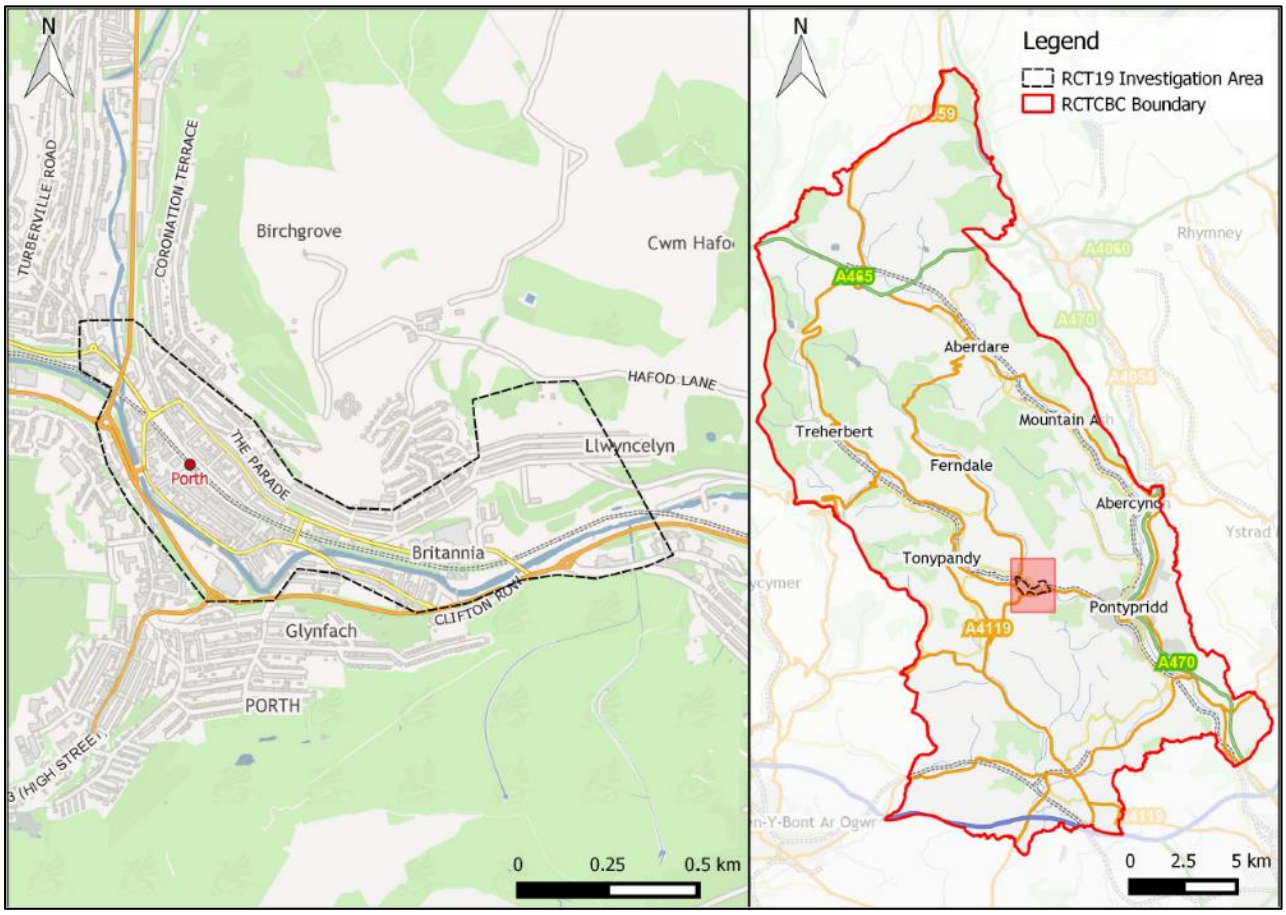

Figure 1: Flood Investigation Area RCT19 Location Plan

The confluence of the Rhondda Fach and Rhondda Fawr rivers is located in the northwest of the investigation area and the River Rhondda meanders along the southwestern boundary of RCT19 towards Trehafod, located to the east of Porth.

Steep valley hillsides to the east, west and south of the investigation area confine residential development to the base of the Rhondda valley. A number of unnamed ordinary watercourses drain the hillsides and discharge into the River Rhondda, many of which are partially culverted beneath Porth's residential and commercial areas.

According to the Welsh Government's CaRR, the community area of Porth is ranked 35th for surface water and ordinary watercourse flood risk and 89th for main river flood risk in Wales.

Flood risk is broadly associated with the River Rhondda and Rhondda Fach, particularly at the confluence. Natural Resources Wales' FRAW map (Figure 2) indicates a low to high fluvial flood risk present along the length of the River Rhondda. Figure 2 also depicts several localised areas of surface water and ordinary watercourse flood risk throughout RCT19, largely associated with the culvert inlets in the area. Flood risk throughout Porth is further described within RCT's Flood Risk Management Plan (FRMP)[3].

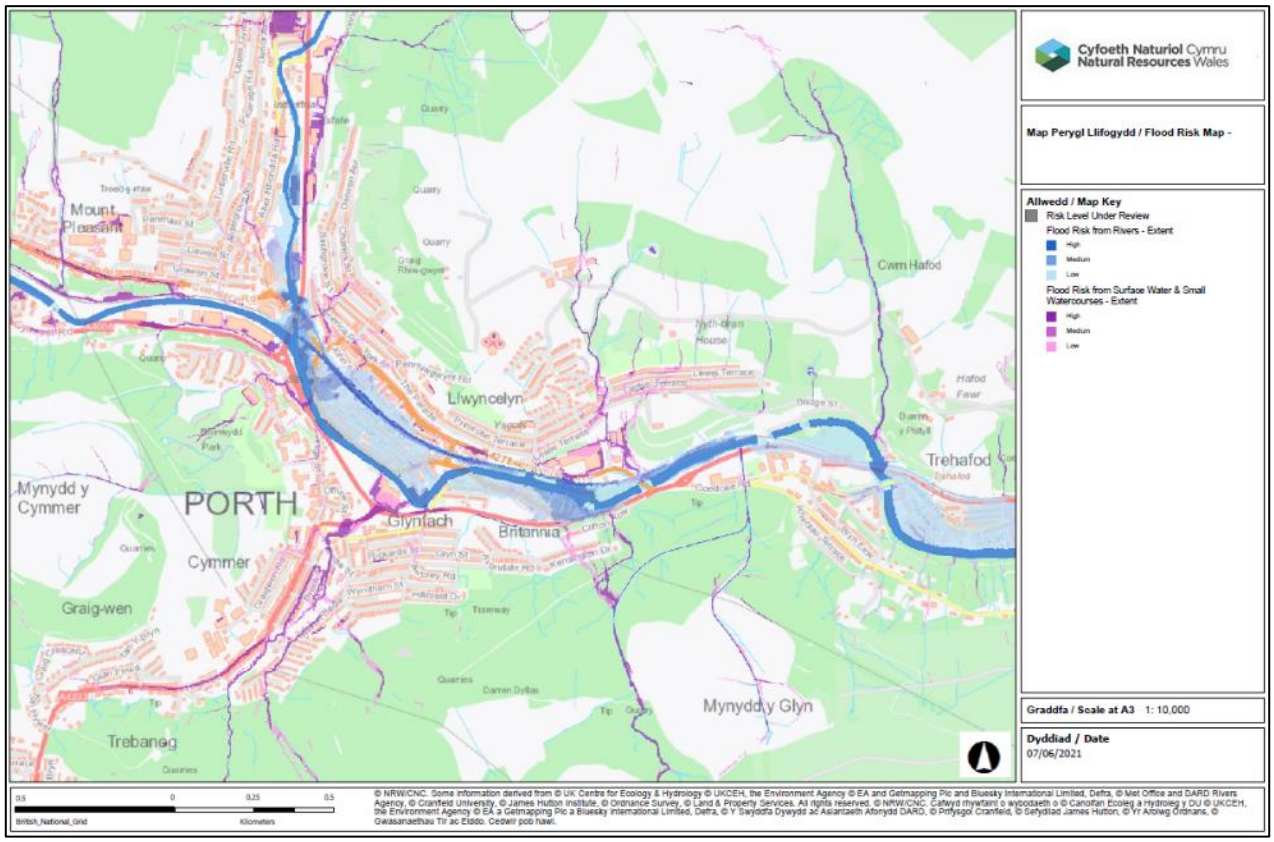

Figure 2: Natural Resources Wales' Flood Risk Assessment Wales (FRAW) map for rivers and ordinary watercourse and surface water flood risk at investigation area RCT19. Contains Natural Resources Wales information © Natural Resources Wales and database right. All rights reserved.

[3] RCT'S Flood Risk Management Plan (rctcbc.gov.uk)

1.3. Drainage System

The surface water drainage systems that serve RCT19 are that of the highway drainage network designed to manage the surface water within the highway and public surface water sewer and combined sewer network operated by Dŵr Cymru Welsh Water.

1.4. Investigation Evidence

To support the investigation, a range of qualitative and quantitative evidence has been gathered from numerous sources, the summary of which is listed within Table 1.

Table 1: Investigative evidence gathered in preparation of the Storm Dennis Section 19 report

Source	Data
Residents	Photos, videos, statements, email correspondence, public engagement survey responses
Responders' statements	Local responders' statements
CCTV Surveys	Internal surveys of the local drainage networks
Met Office Data	Weather Warning information (see FRM – Storm Dennis – Overview Report)
Rain Gauges	RCT and NRW operated gauge information (see FRM – Storm Dennis – Overview Report)
Natural Resources Wales	River Level and Flood Warning data
RCT Flood Risk Management Plan	Site specific information and data for each electoral ward in RCT
Communities at Risk Register	Flood risk ranking and scores for all flood types based on community data in Wales
Flood Investigation Report (Redstart's FIR)	A summary of the source-pathway-receptors, culvert capacity assessment and hydraulic modelling work undertaken by Redstart. The Flood Investigation Report was commissioned by RCT prior to writing the Section 19 report.

Evidence sourced from the 'Flood Investigation Report', commissioned by RCT, will be further referred to as 'Redstart's FIR' throughout this report.

1.5. PUBLIC ENGAGEMENT

Following the initial flooding event that occurred on the 15 and 16th of February during Storm Dennis, flood risk officers from the RCT Flood Risk Management department were deployed to areas across the borough to investigate reports of internal flooding by residents. Residents were engaged with by the Flood Risk Management team to help determine the initial impacts caused by the flooding event and to investigate the potential source(s) and pathway(s) of flood water during the event. Due to the volume of calls received by RCT's Out of Hours department, visits were prioritised to those areas experiencing significant internal flooding to residential properties.

To support the flood investigations, a public engagement exercise was undertaken between the 4th and 25th of January 2021 by Redstart, on behalf of RCT. The aim of this exercise was to engage with local residents who were affected by the flood event to capture details on how they were impacted, the source and movement of flood water within the area, how receptors were impacted as well as drawing on local knowledge to query how local conditions could have exacerbated the event. This data is useful to help the LLFA better understand and validate our assessment of the flood event to support the investigation under Section 19 of the FWMA.

2 FLOODING HISTORY

2.1. PREVIOUS FLOOD INCIDENTS

Historical flood records and resident accounts captured by RCT's Flood Risk Management officers following Storm Dennis indicate that, whilst there have been several isolated incidents of internal flooding across Porth, most properties within RCT19 impacted during Storm Dennis had not experienced flooding prior.

At least 10 instances of internal flooding have been recorded across the investigation area over the past 10 years, with causes of flooding including localised surface water and ordinary watercourse runoff and overwhelmed highway drainage infrastructure. Reports of flooding have also been recorded in relation to overland flows across the wider valley catchment at residential areas on the valley hillsides surrounding RCT19.

2.2. FLOOD INCIDENT

The flooding that occurred on the 15th and 16th February 2020 was a result of an extreme rainfall event, designated by the Met Office as 'Storm Dennis', which affected the majority of RCT and caused widespread flooding to communities.

Specific details of Storm Dennis, such as rainfall and river level analysis are covered within a separate overview report that covers the wider RCT area, referenced 'FRM – Storm Dennis – Overview Report'[2].

The post event inspections undertaken on the days following the storm event by RCT's Flood Risk Management Team and RCT's Public Health, Protection and Community team identified 45 residential properties and 16 non-residential properties as internally flooded within the investigation area.

A summary of the source(s) and pathway(s) of flooding within RCT19 during Storm Dennis have been outlined in the Table 2 and further described throughout this section.

Table 2: Summary of the source(s), pathway(s) and receptor(s) affected during Storm Dennis within investigation area RCT19

Source	Pathway	Receptor
The River Rhondda overtopping its banks at several locations throughout the investigation area.	Main river flood water conveyed into properties adjacent to the river channel on Pontypridd Road and Eirw Road. Fluvial flows also conveyed onto adjacent highway networks, resulting in flood water entering the front and/or the rear of properties on Britannia Street and Brook Street	The overtopping of the River Rhondda resulted in the internal flooding of 19 residential and 1 non-residential property on Britannia Street, 8 residential properties on Brook Street and 9 residential properties on Eirw Road. 2 non-residential properties on Pontypridd Road and were also internally flooded by fluvial flows.
The Rhondda Fach River overtopping its banks due to a blockage at a railway bridge adjacent to Rheola Road.	Main river flood water from the Rhondda Fach River conveyed eastwards along Rheola Road and the adjacent railway line, resulting in flood water entering the rear of property thresholds at Williams Place	The overtopping of the River Rhondda Fach near the confluence resulted in the internal flooding of at least 7 receptors: 1 residential property on Williams Place, 4 properties at Aber-Rhondda Road,1 non-residential

	and onwards towards Porth Police Station car park. The main river also overtopped its western bank at the rear of properties on Aber-Rhondda Road.	property on Rheola Road and 1 non-residential property at Porth Street.
Intense rainfall running off the steep hillsides to the north of RCT19 and draining to lower ground via the Nant Llwyncelyn ordinary watercourse. Two culvert inlets associated to the Nant Llwyncelyn ordinary watercourse surcharged during the event.	A culvert inlet adjacent to St Luke's Road caused water to flow towards Primrose and Leslie Terrace and onwards to the B4278 (Llwyncelyn Road). On its flow path, water also conveyed towards Llwyncelyn Industrial Estate via a path leading from Leslie Terrace and also by flowing down the area of hillside to the rear of commercial units. A second culvert inlet within Llwyncelyn Industrial Estate surcharged onto the adjacent highway and entered the surrounding commercial properties.	The culvert inlet adjacent to St Luke's Road caused internal flooding to 1 non-residential property at St Luke's Road and contributed to the internal flooding of 1 residential property at Leslie Terrace and 6 non-residential properties within Llwyncelyn Industrial Estate and along the B4278 (Llwyncelyn Road). The culvert inlet within Llwyncelyn Industrial Estate contributed to the internal flooding of 4 commercial properties within the industrial estate.
A surface water manhole at Leslie Terrace surcharged during the storm event.	Surcharging flows from the manhole flowed over the kerb line and down the area of hillside towards the rear of commercial units at Llwyncelyn Industrial Estate. Flows also conveyed down the path leading from Leslie Terrace.	Contributed to the internal flooding of 6 commercial properties within Llwyncelyn Industrial Estate and along the B4278 (Llwyncelyn Road).
Intense rainfall and surface water accumulation.	Intense rainfall across RCT19 and subsequent surface water runoff resulted in isolated flow pathways in accordance with the local topography throughout the investigation area.	Internal flooding to 3 residential properties (Birchgrove Street, High Street, North Road) and 4 commercial properties (Hannah Street, Station Street, Coedcae Road).

On review of Table 2, the primary source of the recorded flooding within RCT19 was the overtopping of the main rivers, the Rhondda Fach and the Rhondda River. To the

northeast of the investigation area, a surcharging ordinary watercourse culvert inlet associated to the Nant Llwyncelyn watercourse was also identified as a source of flooding. Across RCT19, the impacts of main river and ordinary watercourse flooded were exacerbated due to intense rainfall and subsequent surface water flows conveying via the highway network, which resulted in multiple incidences of isolated internal flooding.

During the early hours of Sunday 16th February 2020, RCT received several calls from residents at Porth reporting the overtopping of the River Rhondda and Rhondda Fach and the ingress of water into properties. Several flow paths were observed as properties adjacent to the main river channels on both the eastern and western embankments experienced internal flooding.

Upon an inspection of the Rhondda Fach River in the days following the storm event, a significant build-up of material was identified within the channel and across the railway bridge adjacent to the B4278 (Rheola Road). Figure 3 depicts the accumulation of material, inclusive of large woody debris, which is considered to have been mobilised by the fast-flowing water during the storm event, causing an impediment of flow at the railway bridge, resulting in water levels within the Rhondda Fach River to rise quickly behind the obstruction and overtopping onto the adjacent embankments.

Figure 3: Image of obstruction at Rhondda Fach railway bridge (captured by RCT's Flood Risk Management team on 17th February 2020)

Water reportedly overtopped its western embankment to the rear of properties at Aber-Rhondda Road, resulting in internal flooding to 4 properties. Fluvial flood water also conveyed onto the B4278 (Rheola Road), resulting in internal flooding to one commercial property on the eastern embankment. Water also conveyed onto the railway line in a south-easterly direction before entering the rear gardens of properties on Williams Place. One property on Williams Place was confirmed as internally flooded, with approximately 30 centimetres of water entering the property.

Beyond the confluence of the Rhondda Fawr and Fach Rivers, the River Rhondda reportedly overtopped the eastern retaining wall to the rear of Porth Police Station, resulting in significant deposition of mud and silt onto the highway network and causing internal flooding to one commercial property at Porth Street.

The River Rhondda was also identified to have overtopped at Eirw Uchaf bridge. Two non-residential properties on the northern embankment, adjacent to the main river, were flooded as a result of the overtopping. On the southern embankment, the River Rhondda overtopped the rear retaining walls of several properties at Eirw Road, resulting in internal flooding to 9 residential properties, with flood depths of up to 1.5 metres reported by residents. Figure 4 depicts the mud and silt deposited in the rear gardens of properties at Eirw Road as a result of the overtopping.

Figure 4: Image of debris material at a property on Eirw Road (image captured by a DCWW Officer on 16th February 2020)

Further downstream, in the southeast of the investigation area, the River Rhondda overtopped its southern embankment and conveyed onto Edmund Street, Britannia Street and Brook Street. It was reported by residents that water initially overtopped the retaining wall (classified as a Non-Flood Defence (NFD) Structure) at Brook Street,

resulting in its partial collapse (Figure 5), before conveying towards the front and rear of properties at Britannia Street. Sewer flooding was also reported within the impacted properties following the overtopping of the River Rhondda.

As a result of the overtopping, 8 residential properties at Brook Street and 19 residential and 1 non-residential property at Britannia Street were internally flooded. External flooding was also reported along Edmund Street, along with significant deposits of riverine silt and mud along the highway network which are assumed to have entered the highway drainage system, leading to a reduction in the capacity of the network to manage excess water.

Figure 5: 8-metre-long section of collapsed retaining wall (NFD Structure) adjacent to the River Rhondda at Brook Street (image captured by RCT officers on 17th February 2020)

Figure 6: Evidence of riverine mud and silt at Brook Street following the overtopping of the River Rhondda during Storm Dennis (image provided by resident and captured on 16th February 2020)

To the northwest of the investigation area, two culvert inlets associated to the Nant Llwyncelyn watercourse were identified as sources of flooding to 2 residential and 7 commercial properties during Storm Dennis. Both inlets are highlighted in Figure 7 which also illustrates the large catchment area associated to the Nant Llwyncelyn watercourse.

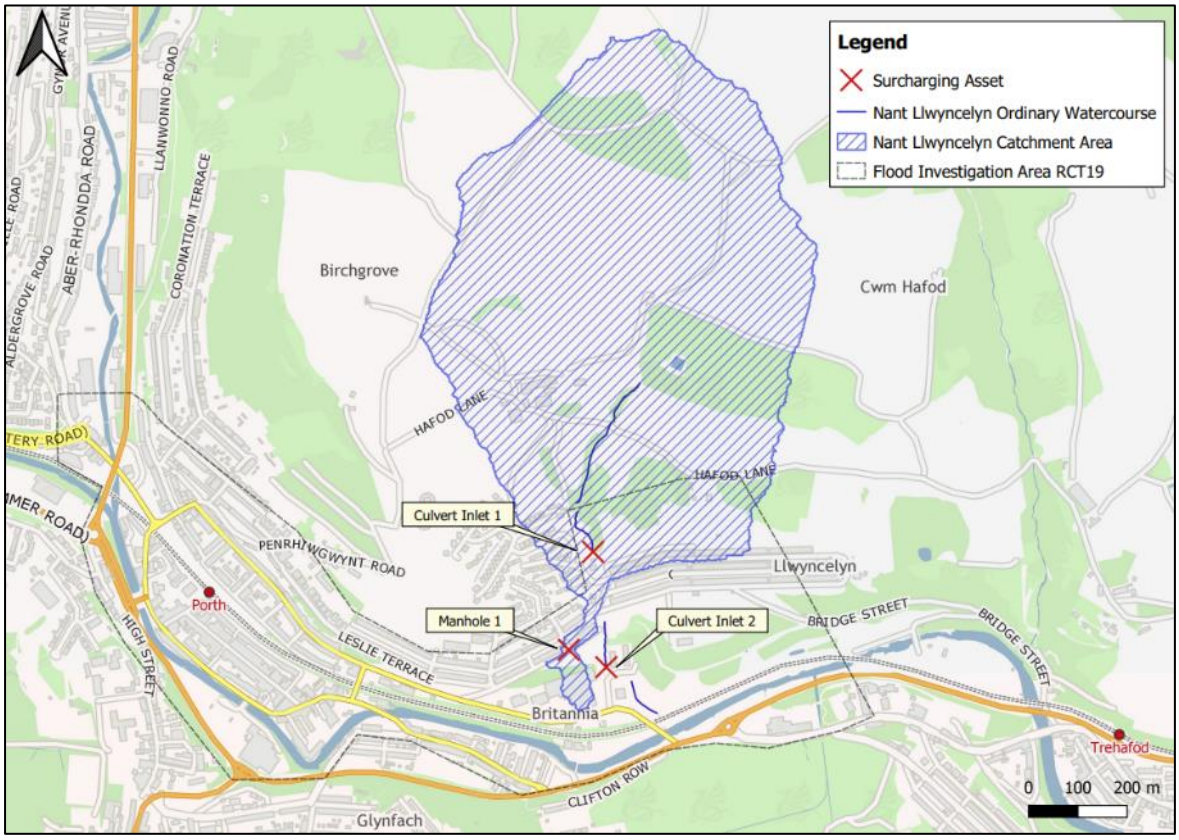

Figure 7: Nant Llwyncelyn ordinary watercourse catchment area and associated infrastructure identified as sources of flooding during Storm Dennis

The Nant Llwyncelyn ordinary watercourse drains the northern hillsides above Porth and is culverted beneath residential development at 'Culvert Inlet 1', adjacent to St Luke's Road. The ordinary watercourse continues to convey as an open channel toward Llwyncelyn Industrial Estate and is culverted again at 'Culvert Inlet 2' which conveys the industrial estate's access road. Beyond the access road, the culverted ordinary watercourse conveys south-easterly towards the River Rhondda.

Significant flows were reported along several streets, including Leslie Terrace and Llwyncelyn Road. Based on reports provided by RCT's Highway and Streetcare Depot, 'Culvert Inlet 1' was identified as surcharging during the storm event after becoming hydraulically overwhelmed by intense rainfall and ordinary watercourse flows travelling

down the hillside. Figure 8 depicts the condition of 'Culvert Inlet 1' during emergency clearance works on 16th February 2020. Significant accumulation of debris behind the debris screen and silt deposits within the surrounding area was evident during post event inspections.

Figure 8: Post event condition of 'Culvert Inlet 1' which surcharged during Storm Dennis (image captured by RCT's Highway and Streetcare Depot on 16th February 2020)

Exceedance flows from 'Culvert Inlet 1' travelled south along Primrose and Leslie Terrace towards the B4278 (Llwyncelyn Road), causing internal flooding to one non-residential property situated directly below the inlet, in additional to contributing to the flooding of one residential property at Leslie Terrace and a further two commercial properties at Llwyncelyn Road.

On its course of flow, water overtopped the kerb line at Leslie Terrace and travelled overland down the hillside towards the rear of Llwyncelyn Industrial Estate (Figure 9). Exceedance flows also conveyed along a path leading from Leslie Terrace which runs behind the commercial units at Llwyncelyn Industrial Estate (Figure 10). As a result of the flow paths, water conveyed towards the rear of 4 commercial units within the industrial estate and accumulated within the confined areas surrounding the property thresholds (Figure 11).

Figure 9: Overland flow travelling down the hillside from Leslie Terrace and conveying towards the rear of Llwyncelyn Industrial Estate during the storm event (image provided by business owner)

Figure 10: Flow path of water along path leading from Leslie Terrace towards the rear of Llwyncelyn Industrial Estate (image provided by business owner)

Figure 11: Ordinary watercourse and surface water flows causing external flooding to the rear of commercial units at Llwyncelyn Industrial Estate during Storm Dennis (image provided by business owner)

In addition to flows originating from ‘Culvert Inlet 1’, a surcharging surface water manhole at Leslie Terrace (labelled ‘Manhole 1’, Figure 7) was also reported by property owners. Video footage provided by residents show evidence of ‘Manhole 1’ surcharging during the storm event and contributing surface water flows towards the rear of Llwyncelyn Industrial Estate (Figure 12).

Figure 12: Evidence of 'Manhole 1' surcharging at Leslie Terrace during Storm Dennis (image provided by business owner)

Upon post event inspections, a second culvert inlet, labelled ‘Culvert Inlet 2’ (Figure 7) was also identified as showing evidence of surcharge. Figure 13 depicts the condition of ‘Culvert Inlet 2’ post Storm Dennis, with debris noted along the embankments, indicative of the exceedance flows.

Figure 13: Post event condition of 'Culvert Inlet 2' which was identified as a source of flooding during Storm Dennis (image provided by business owner)

Exceedance flows from ‘Culvert Inlet 2’ conveyed south towards the B4278 (Llwyncelyn Road), contributing to the flow path from ‘Culvert Inlet 1’ and ‘Manhole 1’. Flood water from the surcharging infrastructure conveyed towards the fronts of properties within the industrial estate and accumulated along the B4278 (Llwyncelyn Road). Internal flood depths of up to 30 centimeres were reported at the impacted commercial properties. Figure 14 depicts surface water accumulation along the B4278 (Llwyncelyn Road) as a result of the surcharging inlets. Internal flood depths of up to 30 centimeres were reported at the impacted commercial properties.

Figure 14: Image of ordinary watercourse and surface water flooding along the B4278 (Llwyncelyn Road) during Storm Dennis (image provided by a resident)

In addition to the main river and ordinary watercourse flooding at RCT19, surface water accumulation due to intense rainfall and overwhelmed highway drainage is also identified as a cause of flooding to several properties within the investigation area.

Three commercial properties in Porth town centre reported internal flooding following Storm Dennis. Internal flooding at each of these properties was a result of intense rainfall and overwhelmed highway drainage infrastructure resulting in surface water accumulation and ingress into properties.

Intense rainfall and associated surface water accumulation was also considered the cause of flooding to three residential properties within RCT19. Flood water reportedly entered the front and basements of properties on High Street and Birchgrove Street, and flooding from the rear as a result of surface water conveyance along York Street was reported at a property on North Road.

To the southeast of RCT19, a further non-residential property at Coedcae Road was confirmed as internally flooded as a result of localised surface water accumulation at low points across the property site. Whilst unconfirmed, overland flows in accordance with the dominant valley gradient at Coedcae Road may have also contributed to the flooding that occurred.

2.3. RAINFALL ANALYSIS

See RCT's 'Overview Report' of Storm Dennis, reference 'FRM – Storm Dennis – Overview Report'[2], for a detailed analysis of the rainfall and ordinary watercourse response.

3. POSSIBLE CAUSES

3.1. CULVERT CONDITIONS

There are several ordinary watercourses which drain the hillsides to the north, south and west of the investigation area. Many of these watercourses are partially culverted beneath investigation area RCT19 and discharge into the River Rhondda. The most notable culverted ordinary watercourse in relation to the flooding during Storm Dennis is the Nant Llwyncelyn.

The Nant Llwyncelyn is culverted beneath residential properties at 'Culvert Inlet 1' before out falling into an open channel above Llwyncelyn Industrial Estate. The watercourse is culverted again at 'Culvert Inlet 2' which conveys beneath the railway line and discharges into the River Rhondda. Both culvert inlets were inspected by RCT's Flood Risk Management team and the Council's Highways and Streetcare Depot following the flood event to assess their condition. A CCTV survey inspection of the Nant Llwyncelyn culvert network was also undertaken to ascertain both the operational condition of the network, and its structural integrity along sections of the network. The surveyed Nant Llwyncelyn culvert network is depicted in Figure 15.

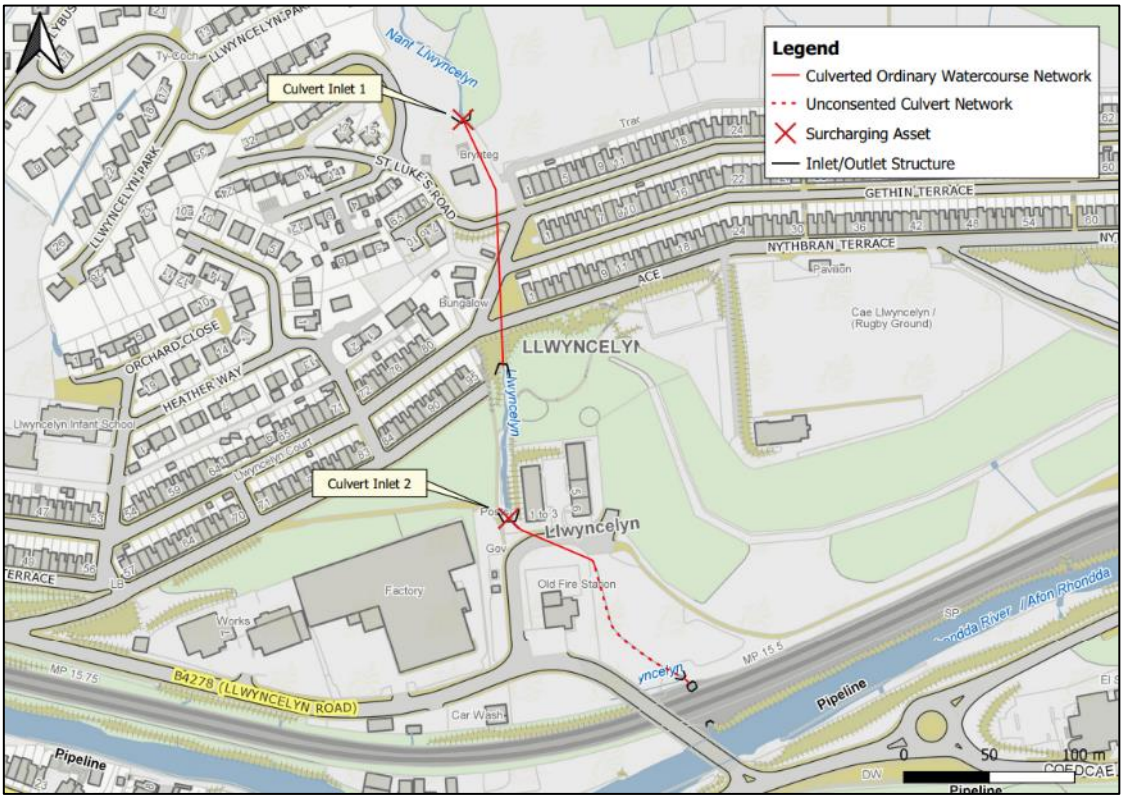

Figure 15: The Nant Llwyncelyn culverted ordinary watercourse network and culvert inlets identified as sources of flooding during Storm Dennis

'Culvert Inlet 1' consists of a 0.45 metre wide and 0.6 metre high concrete box culvert with two debris screens bolted to the structure (Figure 16). The inlet is identified as a privately owned asset.

Figure 16: Image of 'Culvert Inlet 1' captured by RCT's Flood Risk Management team post event

'Culvert Inlet 1' was identified by first responders as being partially blocked with debris mobilised from the hillside. This debris consisted primarily of natural scour material and small woody detritus which was identified to be obstructing the full width of the upstream debris screen (Figure 8). Both debris screens were identified to be in poor condition, indicating damages caused by mobilised debris occurred during the storm event.

In response to the identified debris, approximately 30 tonnes of material was removed by the Council's Highway and Streetcare Depot during cleansing operations post event.

The survey identified the culvert network downstream of 'Culvert Inlet 1' to be in acceptable condition, with minor scouring of the invert and settled debris identified along sections of the network. Based on the available evidence, the condition of the culvert network downstream of 'Culvert Inlet 1' is not considered to have significantly contributed to the recorded surcharging as the obstruction was associated with the inlet structure rather than the network itself.

'Culvert Inlet 2' consists of a 1.5 metre diameter concrete pipe and is identified as a privately owned asset. The inlet debris screen was identified to be in poor condition during post event inspections however, no significant obstructions were identified.

The CCTV survey identified several minor structural defects within the culvert network, in addition to significant obstructions and settled debris downstream of ‘Culvert Inlet 2’. Notably, a full-bore blockage was identified downstream of ‘Culvert Inlet 2’. Figure 17 depicts the material removed from the culvert network during post event clearance operations. The material consists of natural scour material, in addition to tyres and a children’s bicycle, indicative of fly tipping material. The evidence suggests that a majority of the identified material was present in the network prior to the storm event.

Figure 17: Material removed from the Nant Llwyncelyn culvert network downstream of ‘Culvert Inlet 2’ during cleansing operations

The survey also shows the culvert network downstream of ‘Culvert Inlet 2’ to change from a circular 1.5 metre diameter concrete section (Figure 18, left) to a circular polyvinyl chloride 600 mm diameter section near to the outfall (Figure 18, right). The significant reduction if culvert pipe diameter suggests that material entering the network at ‘Culvert Inlet 2’ would have become obstructed at the point of diameter change due to a reduction in capacity.

Figure 18: 'Culvert Inlet 2' consisting of a large 1.5 metre diameter concrete pipe (left) and the downstream outlet consisting of a 600mm diameter plastic pipe (captured by external surveying team post event)

In response to the identified reduction in culvert diameter, the Land Drainage Authority carried out further investigations of the culvert network. It was identified that the polyvinyl chloride culvert section had been installed without consent from the Land Drainage Authority under Section 23 of the Land Drainage Act 1991. The section of unconsented culvert network is illustrated by a dashed red line in Figure 15.

Figure 19 depicts the change in land use at Llwyncelyn Industrial Estate between 2014 and 2020. It can be observed that in 2014 the section of unconsented culvert network downstream of 'Culvert Inlet 2' was originally an open ordinary watercourse channel.

In response to the identified unconsented culvert section, the Land Drainage Authority regulated the unconsented culvert network, which led to the serving of a Notice under Section 24 of the Land Drainage Act 1991. Following which the landowner set out a proposal to rectify the unconsented works with an appropriately sized culvert barrel that was subject to approval under section 23 of the LDA 1991.

Figure 19: Aerial view of Llwyncelyn Industrial Estate in 2014 (top) and in 2020 (bottom)

Based on the available evidence, it is considered that the unconsented culverted network severely reduced the capacity of the network to manage the flow of water entering ‘Culvert Inlet 2’. The reduction in culvert pipe size is also considered to have allowed material and debris to settle within the network, leading to an impediment of the flow and contributing to the surcharge of ‘Culvert Inlet 2’ and the associated flooding of adjacent commercial properties.

3.2. ORDINARY WATERCOURSE CONDITIONS

Several named and unnamed ordinary watercourses drain the hillsides above Porth and convey towards the Rhondda River through the investigation area via open channels and culverted networks. The ordinary watercourses have been illustrated in Figure 20.

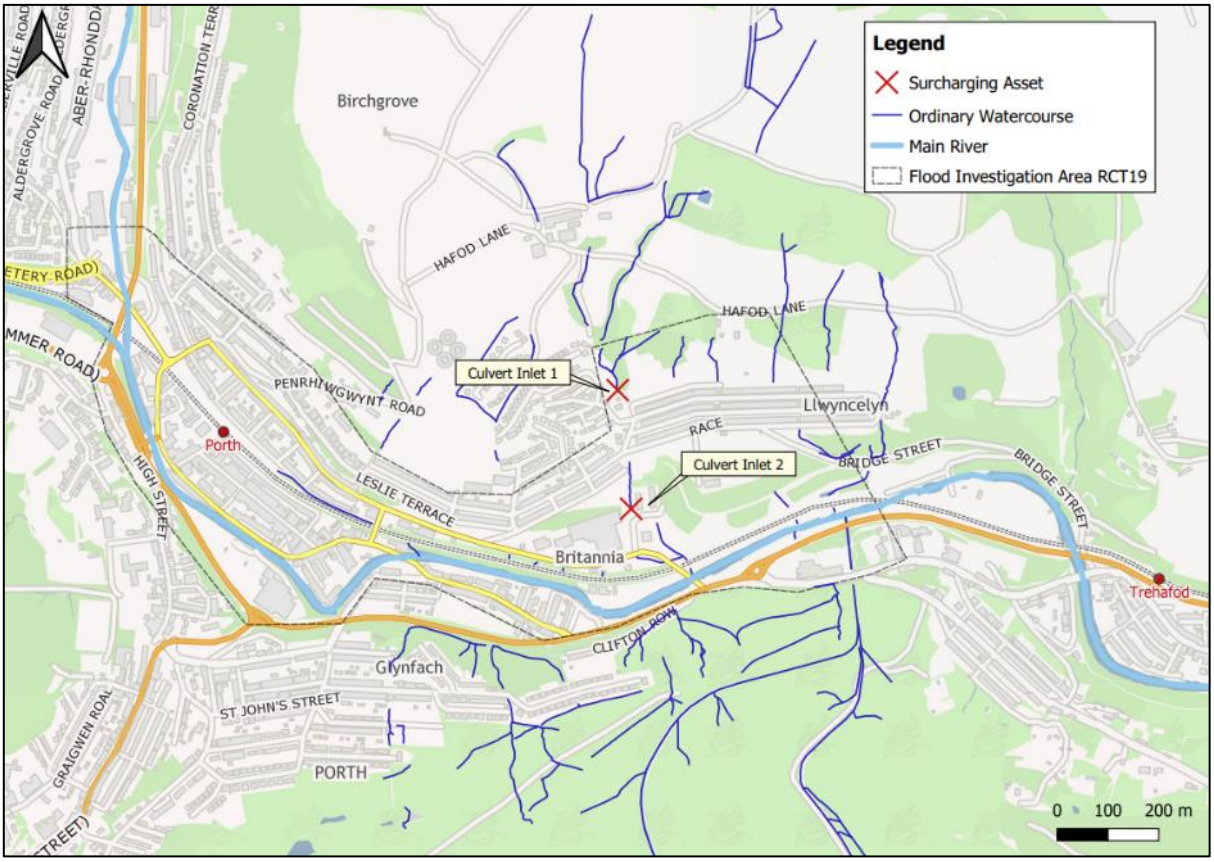

Figure 20: *Map of ordinary watercourses which feed into investigation area RCT19*

Following the storm event, RCT Flood Risk Management officers carried out a site walk-over assessment of the Nant Llwyncelyn upstream of the culvert inlets identified as sources of flooding to assess the condition of the watercourses for any signs of overtopping, evidence of scour and any land movement of the hillsides.

On review of the Nant Llwyncelyn upstream of 'Culvert Inlet 1', several indications of scour across the hillside were observed. The evidence suggests that intense rainfall and resultant surface water and ordinary watercourse flows caused severe erosion of the natural channels, leading to a significant displacement of debris, and sediment transportation within the watercourse itself, which conveyed towards 'Culvert Inlet 1' during the storm event.

Figure 8 provides evidence of significant deposition of material within the channel and behind the upper debris screen, indicative of the entrainment of debris within the Nant Llwyncelyn during the storm event, which contributed to the surcharging of 'Culvert Inlet 1'.

Figure 21 shows a significant volume of natural scour material consisting primarily of stone and silt within the ordinary watercourse channel and embankments, indicative of the fast flowing water travelling towards the inlet during Storm Dennis.

Figure 21: Upstream view of the Nant Llwyncelyn ordinary watercourse channel (captured by RCT's Flood Risk management team post Storm Dennis)

The material identified across the debris screen and cleared from the culvert inlet structure is considered to have severely restricted the conveyance of the ordinary watercourse into the culvert system and consequently contributed to the surcharging of 'Culvert Inlet 1' during the storm event.

The condition of the Nant Llwyncelyn channel upstream of 'Culvert Inlet 2' was also assessed post event. Figure 22, captured during CCTV surveying operations in March 2020, identifies the watercourse as heavily eroded with evidence of embankment scour exposing bare soil. Natural scour material is also identified along the channel length, indicative of the entrainment of material downstream during the storm event.

Figure 22: Nant Llwyncelyn ordinary watercourse upstream of 'Culvert Inlet 2' within Llwyncelyn Industrial Estate (captured during CCTV survey operations post Storm Dennis)

It is considered that the displacement of debris from the upstream open watercourse channel above 'Culvert Inlet 1' contributed to the material observed within the channel upstream of 'Culvert Inlet 2'. This material is considered to have entered the culvert network at 'Culvert Inlet 2', contributing to its surcharging during Storm Dennis.

With the exception of the Nant Llwyncelyn ordinary watercourse, there is no evidence to suggest that the network of ordinary watercourses illustrated in Figure 20 contributed to the flooding experienced during Storm Dennis.

3.3. Main River

There are two designated main rivers which flow through investigation area RCT19: the Rhondda Fach and the Rhondda River. The Rhondda Fach River flows from the northwest of the investigation area towards Porth town centre before merging with the Rhondda Fawr River to form the Rhondda River which continues to flow in a south westerly direction towards Trehafod (Figure 1).

Properties on both western and eastern embankments of the River Rhondda and Rhondda Fach were impacted by main river flooding during Storm Dennis.

3.3.1. Main River Levels and Flood Warnings

The hydrograph in Figure 23 illustrates the rapid rise in levels of the River Rhondda in response to rainfall between the 14 – 17th February 2020. River level data was captured at NRW's Trehafod station, located approximately 1.25 kilometres southeast of the investigation area's eastern boundary.

NRW issued a 'Flood Alert' (indicating possible flooding) for the entirety of the River Rhondda at 14:43 on 15th February; at which point the main river was almost 2 metres in depth and continuing to rise at Trehafod station. At approximately 23:00 on 15th February the River Rhondda began to rise again, reaching a peak river level of 3.977 metres at 04:00 on 16th February; the highest level recorded for the River Rhondda at Trehafod since 2001.

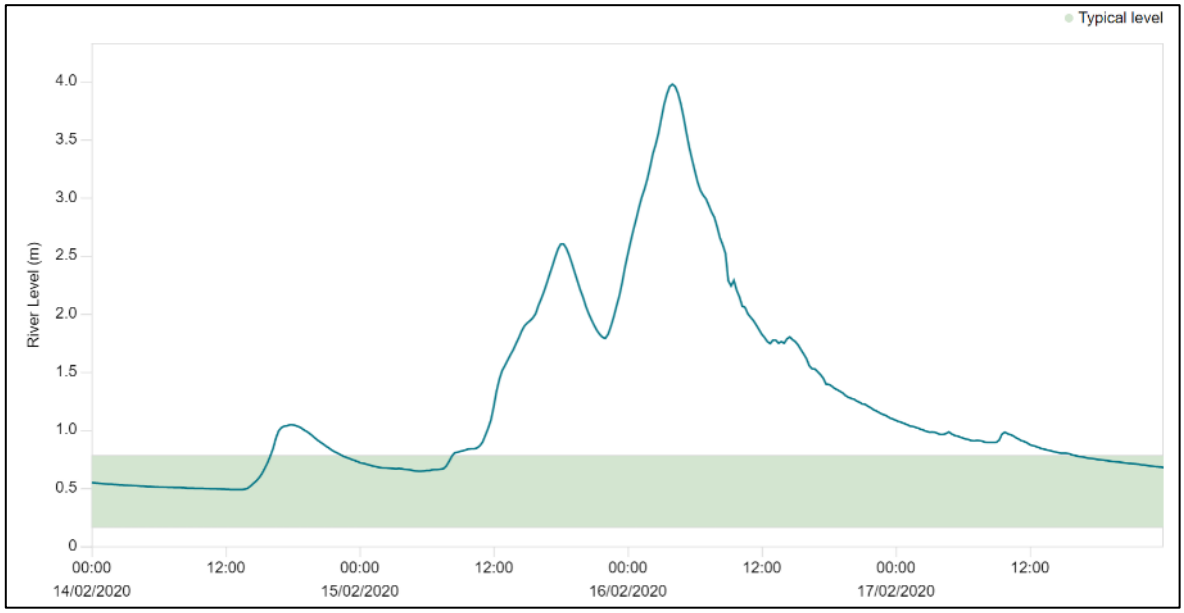

Figure 23: The River Rhondda levels at Trehafod station between the 14th and 17th February 2020 (Natural Resources Wales)

The green bar displayed on the hydrograph shows the typical level of the River Rhondda at Trehafod, ranging between approximately 0.2 and 0.8 metres. At its peak, the Rhondda River was over 3 metres higher than its average level, stressing the extreme and unprecedented levels that RCT's rivers rose to during the storm's peak intensity.

The Rhondda Fach and Fawr Rivers also reached unprecedently high levels at both the Maerdy and Gelli monitoring stations (both operated by NRW), highlighting that both the Rhondda Fach and Fawr catchment experienced significant rainfall and subsequent record-breaking river levels during Storm Dennis (Table 3). The location of NRW's monitoring stations in relation to the investigation area are illustrated in Figure 24.

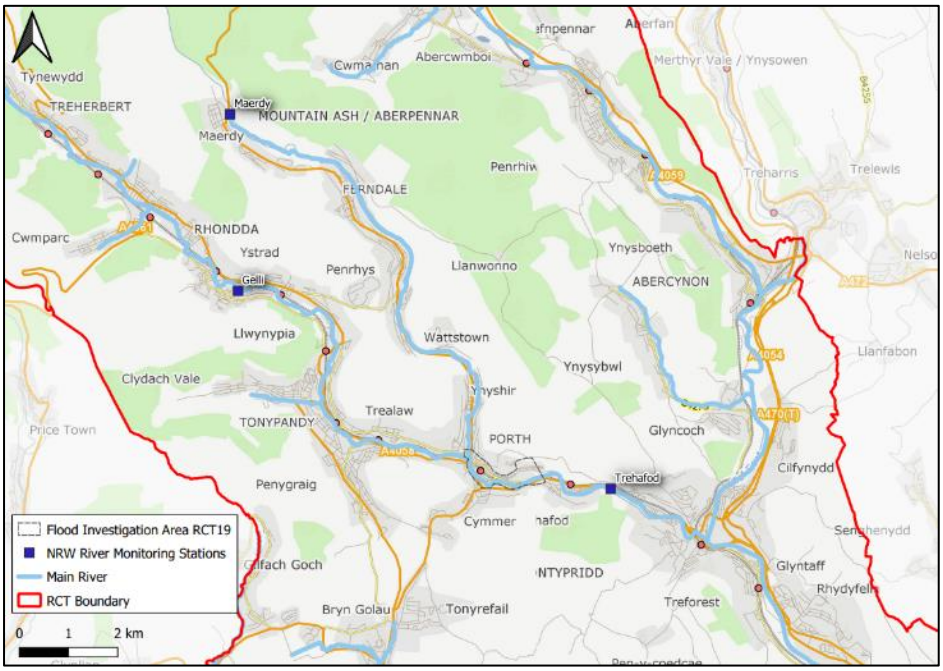

Figure 24: NRW River Level Monitoring Stations along the Rhondda Fawr and Fach Rivers

Table 3: Peak river levels at NRW's monitoring stations along the Rhondda Fawr and Fach Rivers during Storm Dennis

NRW Monitoring Station	Location	Peak River Level (m)	Date & Time of Peak Level
Maerdy	River Rhondda Fach	1.371	02:30 16/02/2020
Gelli	River Rhondda Fawr	1.998	03:15 16/02/2020
Trehafod	River Rhondda	3.977	04:00 16/02/2020

RCT19 falls within NRW's Porth Flood Warning Area. The Flood Warnings issued by NRW for Porth, and the associated river levels for the River Rhondda captured at NRW's Trehafod station during Storm Dennis are shown in Table 4.

Table 4: Flood Warnings issued by NRW for the River Rhondda at RCT19 during Storm Dennis

Flood Warning Type	Location	Start Time	River Level (m) at Trehafod
Flood Alert	River Rhondda	14:43 15/02/2020	1.89
Flood Warning	River Rhondda at Porth	02:49 16/02/2020	3.59

NRW issued a 'Flood Warning' alert (indicating flooding is expected) for the River Rhondda at Porth at 02:49 on the 16th of February; at which point the main river was over 3.5 metres in depth. Responses provided by residents as part of the public engagement exercise indicate that main river flooding at RCT19 had already commenced prior to the 'Flood Warning' alert being issued, with residents expressing that the "flood warning was issued too late".

NRW have acknowledged within their 'Flood Incidence Response Review'[4] that "the operation of the Flood Warning Service "came under significant pressure during February and at times became overwhelmed", resulting in flood warnings being issued late (after the onset of flooding) or not issued at all. At this location (RCT19), this is in reference to the 'Flood Warning' alert at Porth.

Improvements to their flood forecasting and warning services are being internally investigated by NRW and where feasible implemented to deliver the recommendations outlined within their Flood Incident Response Review[4].

[4] February 2020 Floods in Wales: Flood Incident Management Review (cyfoethnaturiol.cymru)

3.3.2. Main River Flood Risk

As outlined in Section 2, the overtopping of the Rhondda Fach and Rhondda River that occurred at RCT19 during Storm Dennis has been identified as the primary cause of flooding to 41 residential and 5 commercial properties within the investigation area.

Figure 25 is an excerpt from NRW's Flood Risk Assessment Wales (FRAW) mapping exercise which depicts the main river flood risk extents for the 'Defended' scenario, i.e., with the presence of flood defence infrastructure. The darker shading identifies areas at higher risk of flooding (more frequent/less extreme rainfall events) and lighter shading showing the lower risk areas (less frequent/more extreme rainfall events).

The flooding that occurred within RCT19 during Storm Dennis is largely consistent with the modelled outputs of NRW's FRAW map (Figure 25), with the majority of the impacted properties falling within an area of high and medium risk of fluvial flooding. A high risk of flooding means that an area has a chance of flooding of greater than 1 in 30 (3.3%) each year; a medium risk of flooding signifies a yearly chance of flooding between 1 in 100 (1%) and 1 in 30 (3.3%); meanwhile a low risk of flooding means that an area has a chance of flooding between 1 in 1000 (0.1%) and 1 in 100 (1%) each year.

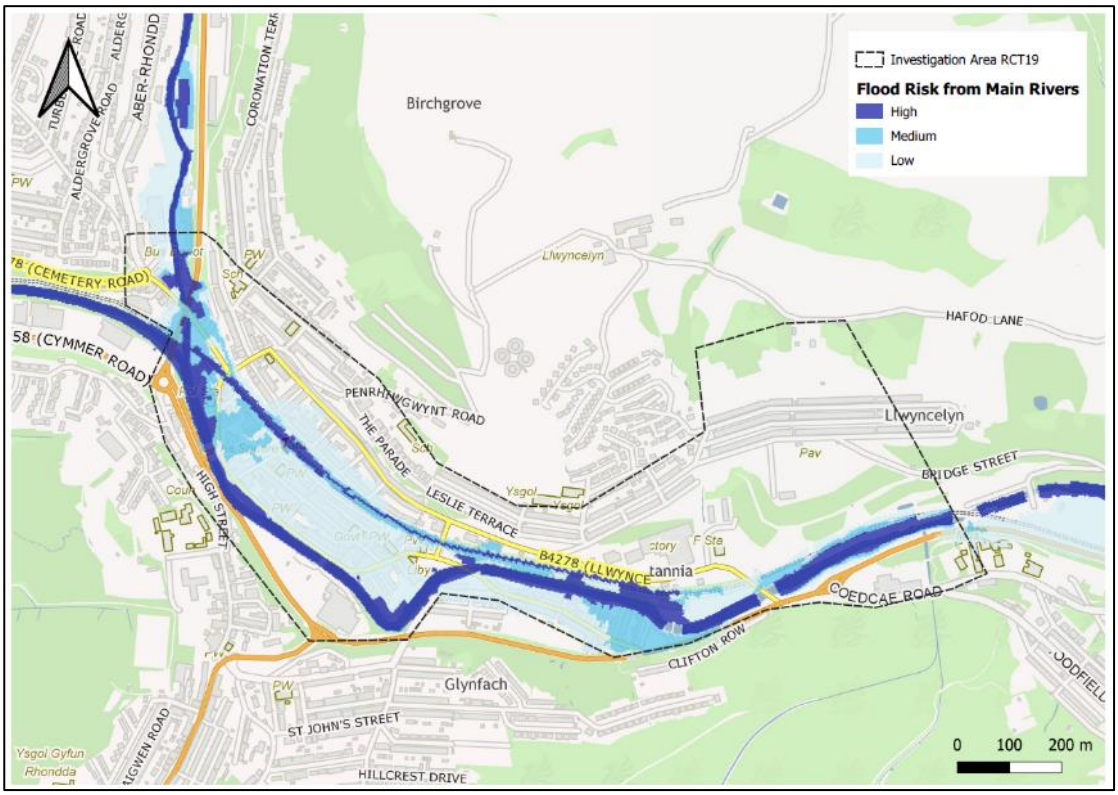

Figure 25*:* NRW's FRAW map for River sources at RCT19. Contains Natural Resources Wales information © Natural Resources Wales and database right. All rights reserved.

The worst affected areas of Porth, including Eirw Road, Brook Street and Britannia Street reported flood depths of up to 1.5 metres, which is also consistent with NRW' Flood Hazard maps which illustrate the modelled flood depth predictions for a medium risk flood event (Figure 26).

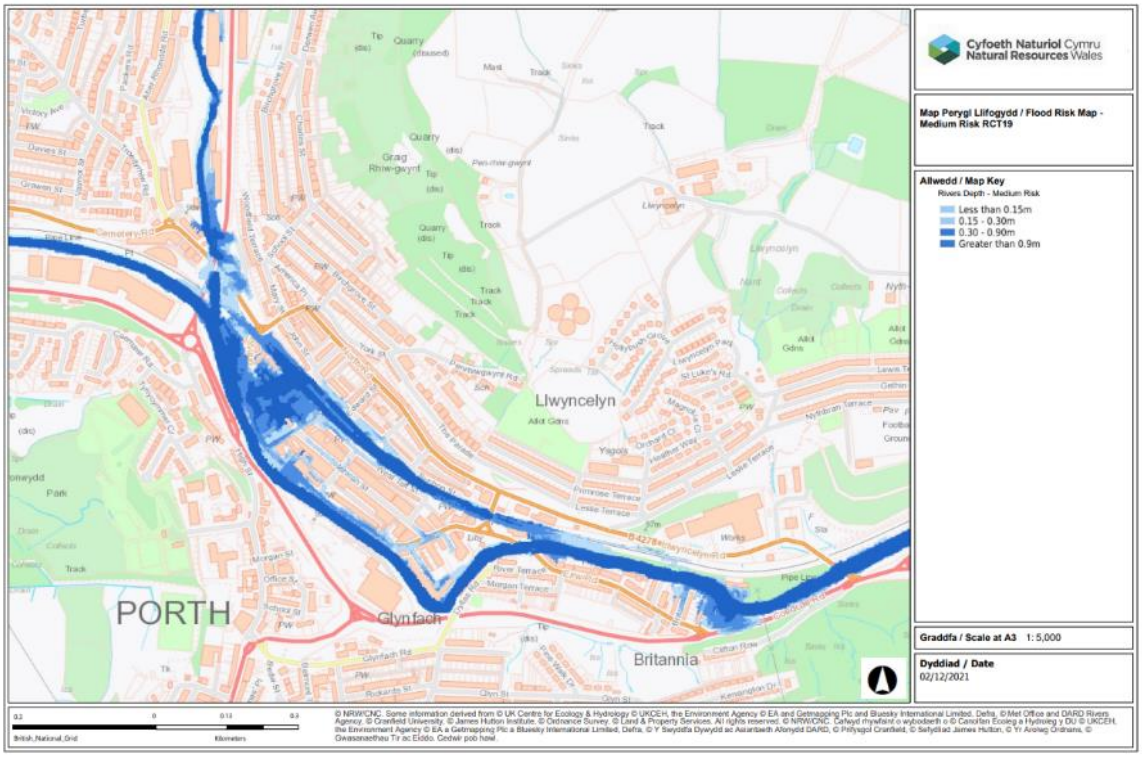

Figure 26: NRW's National Hazard map for Medium Risk River Flood Depth in RCT19. Contains Natural Resources Wales information © Natural Resources Wales and database right. All rights reserved.

It should be noted that a significant volume of accumulated debris at several bridge structures within RCT19, including at the railway bridge adjacent to the B4278 (Rheola Road) (Figure 27) and at Brook Street bridge, was identified post storm event. The obstruction caused by the accumulated debris is considered to have created a damming effect which contributed to the overtopping of both main rivers upstream of the bridge structures.

Deposited debris was also identified within the channel bed of the Rhondda Fach and Rhondda Rivers following the fall in water levels post Storm Dennis. The entrainment and deposition of debris downstream is indicative of the powerful flows within the main rivers during Storm Dennis and is considered to have influenced the water level within the channel however there is limited evidence to outline this interaction.

Figure 27: Accumulated debris within the Rhondda Fach River channel and at Rheola Bridge structure which caused a damming effect to the flow during Storm Dennis (captured by RCT officer on 17th February 2020)

3.3.3. Main River Flood Defences

The properties impacted by the River Rhondda and Rhondda Fach at RCT19 are currently 'Undefended', i.e., there are no formally designated flood defence infrastructure under the operation and maintenance of NRW in place along the Rhondda Fach and Rhondda Rivers at Porth.

During the storm event a section of retaining wall at Brook Street was identified as partially collapsed as a result of the River Rhondda overtopping its banks. The retaining wall is identified as a NFD Structure and is therefore not a designated flood defence structure.

3.4. HIGHWAY DRAINAGE CONDITIONS

Several streets including Rheola Road, Britannia Street and Brook Street, were observed as flooded during the storm event as a result of the overtopping of the River Rhondda and Rhondda Fach during Storm Dennis. As illustrated in Figure 28, these fluvial flows deposited mud, silt and debris across the investigation area which are assumed to have entered the highway drainage system, leading to blockages and a reduction in the hydraulic capacity of the surface water network.

Figure 28: Image of mud, silt and debris deposited onto the highway at Britannia Street as a result of the overtopping of the Rhondda River during Storm Dennis (captured by RCT's Flood Risk Management team on 17th February 2020)

Furthermore, ordinary watercourse and surface water runoff originating from 'Culvert Inlet 1 and 2' conveyed onto Primrose Terrace, Leslie Terrace and the B4278 (Llwyncelyn Road) and overwhelmed the highway drainage infrastructure. Detritus being transported by the overland flows also reduced the capacity of the drainage infrastructure to intercept the flows within the investigation area, exacerbating the surface water flows conveying towards the lower reaches of RCT19.

Highway drainage is not designed to manage overland flows from private areas, parks or open space, nor is it designed to accommodate fluvial flows that may arise during storm events. In this instance, the capacity of the highway drainage in RCT19 was exceeded as a result of a both main river and surface water flows entering the network.

The maintenance condition of the highway drainage infrastructure is not considered to have significantly impacted the flooding experienced during Storm Dennis.

3.5. DCWW Apparatus Conditions

During post storm inspections undertaken by RCT's Flood Risk Management department, residents of Aber-Rhondda Road which were impacted by flooding described the flows entering their properties as "foul sewage". Furthermore, a DCWW pumping station is located immediately to the rear of the impacted properties.

DCWW undertook an inspection of the area on 16th February 2020 and identified riverine debris in the lane to the rear of the impacted properties. DCWW also checked their network which was clear and operating with no restrictions. DCWW thereby concluded that the cause of internal flooding at Aber-Rhondda Road was the overtopping of the River Rhondda Fach.

Reports of flooding at Eirw Road, Brook Street and Britannia Street were also received by DCWW during Storm Dennis. Upon an investigation into DCWW's network and pumping station located at Brook Street, it was found that both were coping with the high flows and the pumping station was operating with no failures. Minor debris deposited by the overtopping of the River Rhondda was identified within DCWW's network at Eirw Road however this was cleared by DCWW operatives during on-site inspections.

Elsewhere across the investigation area, there is no evidence to suggest that DCWW apparatus caused the flooding that occurred during Storm Dennis. Furthermore, DCWW did not report that any of their infrastructure was damaged during the storm event.

Whilst DCWW have concluded that their assets performed well during Storm Dennis, the majority of drainage infrastructure within the investigation area is comprised of combined sewer networks which are likely to have become overwhelmed during the storm event for the reasons outline in Section 3.4.

3.6. SURFACE WATER

Surface water flows generated by intense rainfall and overwhelmed surface water drainage infrastructure conveying via local topography and the highway network is considered the primary source of flooding to 7 properties across RCT19, including 3 residential and 4 commercial properties.

The pathways for surface water flooding during the storm event was observed primarily along the highway network. It should be noted that the exact flow routes have not been confirmed due to limited anecdotal evidence regarding the isolated incidences which occurred during the storm event however, NRW's national surface water and ordinary watercourse flood map (Figure 29) provides a reasonable indication of the pathways and areas of surface water flooding that would have occurred during Storm Dennis.

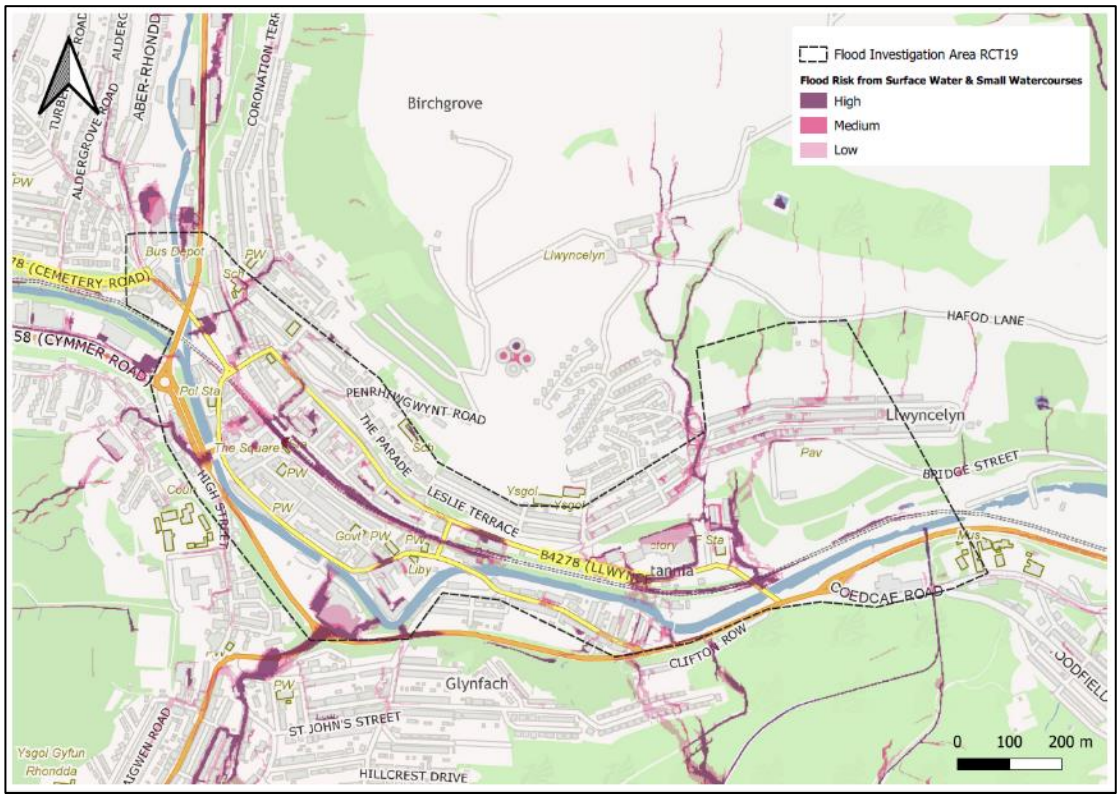

Figure 29: NRW's FRAW map for surface water and ordinary watercourse sources in RCT19. Contains Natural Resources Wales information © Natural Resources Wales and database right. All rights reserved.

Figure 29 identifies the impacted properties on Birchgrove Street, High Street, North Road and Coedcae Road to fall within areas of high to low surface water flood risk. In most cases, the surface water flooding at RCT19 was primarily caused by intense

rainfall falling on already saturated catchments following Storm Ciara on 7-8th February 2020, leading to accumulation of standing water at localised low points across Porth.

Surface water is also considered to have contributed to the ordinary watercourse and main river flooding experienced within the lower reaches of Porth, particurarly along Rheola Road, the B4278 (Llwncelyn Road) and Llwyncelyn Industrial Estate, where water naturally accumulates, as depicted in Figure 29.

A surface water manhole (‘Manhole 1’, Figure 7) was also observed as surcharging during the storm event and contributing to the surface water and ordinary watercourse flooding within Llwyncelyn Industrial Estate. Upon an inspection of ‘Manhole 1’ during post event surveying operations, the surface water manhole was observed as free flowing with no blockages identified within the network. It is likely that some debris carried by the ordinary watercourse flows from ‘Culvert Inlet 1’ entered the surface water network during the storm event, impacting its capacity, however, the primary cause of surcharge at ‘Manhole 1’ has been attributed to hydraulic overload due to intense rainfall and exceedance flows from ‘Culvert Inlet 1’.

3.7. ACCESS STRUCTURES

No access structures were identified during the asset investigations within the area, as such ‘access structures’ have not been considered within this report.

3.8. SYSTEM AT CAPACITY

The Nant Llwyncelyn culvert networks associated to 'Culvert Inlet 1 and 2' (Figure 15) were surveyed post event to ascertain the internal condition of the networks, the results of which fed into a review of the hydraulic performance of the network to ascertain its current standard of protection. Causeway Flow modelling was used to assess the standard of protection of 'Culvert Inlet 2', while the online calculation tool from HR Wallingford, 'Greenfield runoff rate estimation tool'[5], was used to generate the runoff flow calculation for 'Culvert Inlet 1'. The results of both culvert inlet capacity assessments are summarised in Table 5 and 6 below (refer to Figure 15 for culvert labels).

It should be noted that the capacity of 'Culvert Inlet 2' was assessed for the 1500mm diameter concrete section. The standard of protection of the unconsented section of culvert infrastructure was unable to be assessed.

Table 5: Summary of the culvert capacity assessment results which indicate the current standard of protection of culverts identified as sources of flooding in free flowing and blockage conditions

Culvert Network	Standard of Protection (SOP) – Free Flowing	Standard of Protection (SOP) – Blockage Condition
Nant Llwyncelyn – Culvert Inlet 2 (1500mm diameter concrete section)	>Q1000 (<0.1% AEP)	Q50 (2% AEP)

The assessment infers that 'Culvert Inlet 2' has an acceptable standard of protection in accordance with current design standards, as defined by CIRIA C789, assuming free-flowing conditions.

On review of the condition of 'Culvert Inlet 2' post Storm Dennis, a sensitivity analysis was undertaken to review the impact of flooding during both free-flowing and 'medium' (67%) blockage conditions[6]. In 'medium' blockage conditions the hydraulic capacity of 'Culvert Inlet 2' is reduced significantly to below design standards. It can be concluded the blockages to the inlets' debris screen, which reduced the networks capacity to manage the flow of water conveying down the Nant Llwyncelyn, was a contributing cause of surcharge.

[5] Greenfield runoff rate estimation | UK SuDS
[6] Natural Resources Wales Guidance Note (Ref No GN43)

Whilst it is not possible to confirm the capacity of the downstream section of the culvert network below 'Culvert Inlet 2', it is considered that the significant reduction in culvert pipe size reduced the hydraulic capacity of the network and exacerbated the risk of debris blockages within the network, further reducing its standard of protection, and contributing to the inlets' surcharge.

The online calculation tool from HR Wallingford, 'Greenfield runoff rate estimation tool'[5], was used to generate the runoff flow calculation for the hillside above Llwyncelyn. The watershed area considered to have discharged into 'Culvert Inlet 1' was measured using GIS software, utilising contour and topographical features. The watershed area for 'Culvert Inlet 1' during the storm event was approximated as 35 Ha.

The results from the greenfield estimation tool for 'Culvert Inlet 1', which was identified as a source of flooding during Storm Dennis, are presented in Table 6, along with the culvert capacity determination based upon the diameter, type and gradient of the culvert structure.

Table 6: Runoff flow calculation for Culvert Inlet 1 for Q100 return period using the Greenfield runoff rate estimation tool and the IH124 approach

Culvert Name	Watershed Area (Ha)	Culvert Capacity (l/s)	Q100 + 40% (l/s)
Nant Llwyncelyn - Culvert Inlet 1	35	901	885.71

The estimated greenfield runoff rate for the 1 in 100-year annual probability event (Q100), plus 40% climate change allowance, generates a runoff flow of 885.71 l/s. The culvert capacity of 'Culvert Inlet 1' is greater than the generated runoff flow.

Based on the results presented in Table 6, it is considered that the existing structure has sufficient capacity to accommodate the expected flows from the hillside during a Q100 + 40% climate change allowance storm event. This provides further evidence that the observed surcharging of 'Culvert Inlet 1' during Storm Dennis was primarily caused by blockages to the debris screen as a result of mobilised debris carried by the Nant Llwyncelyn watercourse.

3.9. SUMMARY OF POSSIBLE CAUSES

The above sections have identified and described the possible causes of flooding within the town of Porth during Storm Dennis, which occurred on the 15 and 16th February 2020. A summary of the identified source(s) and possible cause(s) of flooding (issue) has been outlined below in Table 7.

Table 7: Summary of source(s) and possible cause(s) of flooding in investigation area RCT19 during Storm Dennis

Ref No	Asset (Source)	Issue	Asset Owner	Type of Flooding
1	Rhondda Fach River	Unprecedentedly high river levels within the Rhondda Fach River resulted in the main river overtopping its banks at several locations, resulting in flood water conveying into 5 residential and 2 commercial properties at Aber-Rhondda Road, Rheola Road, Porth Road and Williams Place.	Mixed Ownership	Main River
2	Rhondda River	Unprecedentedly high river levels within the Rhondda River resulted in the main river overtopping its banks at several locations, resulting in flood water conveying into several properties at Eirw Road, Brook Street and Britannia Street.	Mixed Ownership	Main River
3	Nant Llwyncelyn Culvert Inlet 1	The culvert inlet surcharged during the storm event after becoming blocked with debris mobilised from the ordinary watercourse upstream, causing water to overtop at the inlet and flow towards the lower reaches of Porth.	Private Landowner	Ordinary Watercourse
4	Nant Llwyncelyn Culvert Inlet 2	The culvert inlet surcharged during the storm event after becoming blocked with debris mobilised from the ordinary	Private Landowner	Ordinary Watercourse

		watercourse upstream, causing water to overtop at the inlet and flow towards the lower reaches of Porth. An unconsented section of culvert network was also identified to have restricted the capacity of the network and resulting in the accumulation of debris within the culvert barrel and contributing to the surcharge at the inlet.		
5	Manhole 1 (Leslie Terrace)	A surface water manhole at Leslie Terrace surcharged during the storm event due to becoming hydraulically overloaded, contributing surface water flows towards the rear of commercial properties at Llwyncelyn Industrial Estate.	RCT Highway Authority	Surface Water
6	Surface water drainage network across RCT19	Intense rainfall across RCT, combined with the overtopping of the main rivers and exceedance flows from surcharging ordinary watercourse infrastructure, River Rhondda in certain locations, severely overwhelmed highway drainage infrastructure and resulted in the accumulation of surface water on several streets throughout the investigation area.	RCT Highway Authority	Surface Water

4. Risk Management Authority Actions

A Welsh Risk Management Authority is defined in Section 6 of the Flood and Water Management Act 2010 as NRW; a LLFA, a district council for an area where there is no unitary authority, or a highway authority wholly in Wales; an internal drainage board for an internal drainage district that is wholly or mainly in Wales; a water company that exercises functions in relation to an area in Wales. As the LLFA, RCT has the responsibility to coordinate the management of flood risk and the interaction of Risk Management Authorities across Rhondda Cynon Taf.

An overview of the relevant Risk Management Authority in relation to flood type is provided in Table 8. For further details of the roles and responsibilities of individual Risk Management Authorities in managing flooding, refer to the Welsh Government's National Strategy for Flood and Coastal Erosion Risk Management, Section 4 'Roles & Responsibilities'**Error! Bookmark not defined.**, and RCT's 'FRM – Storm Dennis - Overview Report'**Error! Bookmark not defined.**.

Table 8: Risk Management Authority with relevant functions to manage the risk for different flood types

Type of Flooding	Relevant Risk Management Authority
Flooding from Main River, reservoirs and the sea (including coastal erosion).	Natural Resources Wales
Flooding from ordinary watercourses, surface water and groundwater	Lead Local Flood Authority
Flooding from water and sewage systems	Water Companies (Dŵr Cymru Welsh Water)
Flooding from the highway	Highway Authority
Flooding from the highway (motorways and major trunk roads)	Welsh Government Trunk Road Agency

Risk Management Authorities have direct flood risk management functions under the Flood and Water Management Act 2010, as well as the Water Resources Act 1991, Land Drainage Act 1991, the Water Resources Act 1991 and the Highways Act 1980. Through analysis of the flooding that impacted investigation area RCT19, the flood risk management functions exercised or proposed to be exercised by relevant RMAs were recorded pursuant to Section 19 of the Flood and Water Management Act 2010, which states:

"On becoming aware of a flood in its area, a lead local flood authority must, to the extent that it considers it necessary or appropriate, investigate:

a) Which risk management authorities have relevant flood risk management functions and,

b) Whether each of those risk management authorities has exercised, or is proposing to exercise, those functions in the response to the flood."

Through the investigation process, the source(s) and possible cause(s) of flooding in RCT19 during Storm Dennis have previously been identified and summarised within Table 7. The Risk Management Authorities responsible for managing that flooding have been listed in Table 9 below, along with a series of recommendations put forward by the LLFA.

Table 9: Recommendations provided by the LLFA to be considered by the relevant Risk Management Authority identified in response to the source(s) of flooding in RCT19 (as per Table 7)

Ref No	Asset (Source)	Asset Owner	Type of Flooding	Relevant Risk Management Authority	Recommendations	
1	Rhondda Fach River	Mixed Ownership	Main River	Natural Resources Wales	R1A	NRW to "complete detailed investigative analysis work to understand the mechanisms of flooding in areas known to have flooded from main rivers", including the River Rhondda at Porth. Aligns with recommendation 'Action FD2' within NRW's Flood Incident Management Review.
					R1B	NRW to work with asset owners to assess and review

						the risk of flooding from the Rhondda River at RCT19 to identify the viability of risk management options.
					R1C	NRW to review its flood warning service provision, especially for extreme events. This will form part of NRW's Flood Warning Service Review Implementation Programme and aligns with the recommendations set out in their 'Flood Incidence Management Review'.
2	Rhondda River	Mixed Ownership	Main River	Natural Resources Wales	R2A	NRW to "complete detailed investigative analysis work to understand the mechanisms of flooding in areas known to have flooded from main rivers", including the Rhondda Fach River at Porth. Aligns with recommendation 'Action FD2' within NRW's Flood Incident Management Review.
					R2B	NRW to work with asset owners to

						assess and review the risk of flooding from the Rhondda Fach River at RCT19 to identify the viability of risk management options.
					R2C	NRW to review its flood warning service provision, especially for extreme events. This will form part of NRW's Flood Warning Service Review Implementation Programme and aligns with the recommendations set out in their 'Flood Incidence Management Review'.
3	Nant Llwyncelyn Culvert Inlet 1	Private Landowner	Ordinary Watercourse	Lead Local Flood Authority	R3A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R3B	The LLFA and LDA to investigate the standard of protection and the condition of authorised culvert structures and network as a whole.
					R3C	The LLFA to jet and cleanse the ordinary watercourse culvert network.

					R3D	The LLFA and LDA to review the risk of scour potential within the upstream ordinary watercourse channel.
					R3E	The LLFA and LDA to work with riparian landowners to identify suitable management methods to reduce the risk of scour within the ordinary watercourse.
					R3F	The LLFA to install remote telemetry monitoring at Culvert Inlet 1 to monitor the risk of blockage.
					R3G	The LLFA to develop a SOC to identify suitable management methods to reduce the risk of ordinary watercourse and surface water flooding in Porth.
4	Nant Llwyncelyn Culvert Inlet 2	Private Landowner	Ordinary Watercourse	Lead Local Flood Authority	R4A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R4B	The LLFA and LDA to investigate the standard of protection and the condition of authorised culvert

						structures and network as a whole.
					R4C	The LLFA to jet and cleanse the ordinary watercourse culvert network.
					R4D	The LLFA and LDA to review the risk of scour within the upstream ordinary watercourse channel.
					R4E	The LLFA and LDA to work with riparian landowners to identify suitable management methods to reduce the risk of scour within the ordinary watercourse.
					R4F	The LLFA and LDA to exercise their permissive powers under Section 24 of the Land Drainage Act to ensure that the unconsented structure is removed from the watercourse channel.
					R4G	The LLFA to develop a SOC to identify suitable management methods to reduce the risk of ordinary watercourse and

						surface water flooding in Porth.
5	Manhole 1 (Leslie Terrace)	RCT Highway Authority	Surface Water	Highway Authority and Lead Local Flood Authority	R5A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R5B	The LLFA and LDA to investigate the condition and capacity of surface water network.
					R5C	The Highway Authority to jet and cleanse the surface water drainage network and action repairs accordingly.
					R5D	The LLFA to develop a SOC to identify suitable management methods to reduce the risk of ordinary watercourse and surface water flooding in Porth.
6	Surface water drainage network across RCT19	RCT Highway Authority	Surface Water	Highway Authority and Lead Local Flood Authority	R6A	The Highways Authority to jet and cleanse the highway drainage network and action repairs accordingly.
					R6B	The LLFA, Highway Authority and DCWW to evaluate surface water management options to alleviate pluvial flooding at

						locations across the investigation area.

4.1. LEAD LOCAL FLOOD AUTHORITY

In review of Ref 3 - 6 of Table 9, the LLFA has been determined as the relevant Risk Management Authority in relation to the ordinary watercourse and surface water flooding which occurred at RCT19 during Storm Dennis.

The LLFA exercised the following functions in response to the flooding at investigation area RCT19:

- Officers investigated the initial flooding and have produced this report in line with Section 19 of the Flood and Water Management Act 2010.
- Officers contacted residents affected by flooding to offer support and advice to assist in the recovery following the event.
- A public engagement exercise carried out by Redstart, on behalf of RCT as the LLFA, was undertaken in order to gain further local insight and anecdotal evidence to support the flood investigation.
- The LLFA and LDA have exercised their permissive powers under Section 64 of the Land Drainage Act 1991 to investigate the culvert structures and network conditions and its impact on the flooding within the investigation area. **(R3B, R4B, R5B)**
- An estimated 445.5 metres of ordinary watercourse culvert network length within RCT19 has been surveyed following the storm event to ascertain both the operational condition and structural integrity along sections of the network. **(R3B)**
- An estimated 33 tonnes of debris were removed from the ordinary watercourse channel and culverted watercourse network within investigation area RCT19 during cleansing operations. **(R3C, R4C)**
- RCT commissioned Edwards Diving Services to carry out a confined space Principal Inspection of the Nant Llwyncelyn ‘Culvert Inlet 1’ culvert network, in accordance with CS 450 Inspection of Highway Structures and the Inspection Manual for Highway Structures, to identify any defects or obstructions. **(R3B)**
- The LLFA and LDA have undertaken clearance works to the culvert network systems which fall under private land ownership utilising powers under Section 14A of the Land Drainage Act. **(R3C, R4C)**
- The LLFA and LDA have undertaken clearance works and replaced the defected debris screen structures at ‘Culvert Inlet 2’.

- The LLFA commissioned Redstart to investigate the standard of protection of culvert networks in RCT19 to determine their hydraulic capacity following the identification of structural and operational defects within sections of the networks. **(R3B, R4B)**
- The LLFA has exercised its powers, under Section 13 of the FWMA, to request information and co-operation from the relevant risk management authorities (NRW and DCWW) in relation to their responsibilities as RMAs in response to Storm Dennis.
- The LLFA has set up a central Control Room, to compliment the Council's Contact Centre and CCTV centre which is based at the Council's offices, to provide a comprehensive and informed response to the residents of RCT as appropriate during storm events.
- The LLFA have initiated an interim Property Flood Resistance project offering expandable flood gates to those properties deemed at high risk of flooding from local sources.
- The LLFA, working in partnership with NRW, have expanded their interim Property Flood Resistance project offering expandable flood gates to those properties deemed at high risk of flooding from the main river, as per NRW's determination.
- In response to the identified unconsented culvert structure downstream of 'Culvert Inlet 2', the LLFA and LDA initiated engagement with the riparian landowner and issued an enforcement notice under Section 24 of the Land Drainage Act 1991 to remove the unconsented section. In response to the enforcement notice, the riparian landowner has replaced the undersized culvert section with a larger diameter pipe to provide adequate standard of protection in accordance with current design standards for new culverts. **(R4F)**

The LLFA propose to exercise the following functions in response to the flooding at RCT19;

- Following the surveying of culvert networks in RCT19, the LLFA propose to input and update all relevant asset data. **(R3A, R4A, R5A)**
- The LLFA and LDA intend to clarify drainage asset owners and management responsibilities to make them aware of their personal risk. To ensure landowners manage the risk in compliance with the relevant legislation, a team of Flood Enforcement Officers including legal support is to be appointed. **(R3A, R4A)**

- The LLFA and LDA will work with landowners and property owners to manage their personal flood risk through local measures, such as property resilience and resistance measures.
- The LLFA propose to develop a SOC to better understand the risk of flooding within RCT19, using a whole catchment approach to provide recommendations for suitable management mechanisms and thus reduce the wider risk of flooding to people and properties from local sources (Ordinary Watercourse, Surface Water and Groundwater). **(R3G, R4G, R5D)**
- As part of RCT's comprehensive review of the County Borough's most at risk communities, the LLFA are proposing to undertake a formal SFRA of the Rhondda catchment area to better understand the overall risk from ordinary watercourse and surface water flooding in order to target investment to areas of highest risk. The SFRA also aims to encourage whole catchment measures, including working with natural processes, to alleviate flood risk in those areas of highest risk. **(R3D, R4D, R6B)**
- The LLFA and LDA propose to undertake Geomorphological assessments of the upper catchments above RCT19 to determine the risk of culvert blockages as a result of scour and debris potential. In addition to this the LLFA and LDA will engage with Riparian landowners to identify suitable management methods to reduce the risk of scour within the ordinary watercourse. **(R3D, R3E, R4D, R4E)**
- The LLFA will cooperate and collaborate with NRW to ensure a detailed study of the investigation area is completed and that appropriate actions to mitigate the impacts of river flooding are undertaken in accordance with NRW's Flood Incident Management Review.
- The LLFA propose to install remote telemetry monitoring devices at 'Culvert Inlet 1' to enable operators to ensure the drainage systems in Porth are operating effectively. **(R3F)**

4.2. NATURAL RESOURCES WALES

In review of Ref 1 and 2 in Table 9, NRW has been identified as the relevant Risk Management Authority in relation to the main river flooding from the River Rhondda and the River Rhondda Fach during Storm Dennis.

NRW has exercised the following functions in response to the flooding at RCT19:

- NRW have carried out post event data collection including an assessment of the properties impacted by main river flooding and a survey of wrack marks, i.e., the marked high-water level.
- Following Storm Dennis, NRW undertook an inspection of the River Rhondda and the River Rhondda Fach at Porth, and undertook clearance works to remove debris and vegetation from the river channel. In conjunction with DCWW and Transport for Wales, NRW also removed the accumulation of debris at Rheola Bridge.
- Utilising post event data and information, NRW have reviewed the Resultant Thresholds for the River Rhondda at Porth Flood Warning Area (FWA). This is critical for assessing the performance, timeliness and accuracy of the warning service after a flood. **(R1C, R2C)**.
- NRW has introduced improved digital services to provide comprehensive flood risk, river level and rainfall information to households, businesses and communities across Wales. The improved service was launched in September 2020 on the NRW website and will, according to NRW, improve how live flood warning and water level data is shared before and during flood events. **(R1C, R2C)**
- Following the flooding events of February 2020, NRW published a review of its incident response to Storm Ciara and Dennis in October 2020[7]. This review contains several recommendations for improvements to their ways of working and services which NRW are in the process of implementing through an internal delivery programme.
- NRW have developed a detailed Implementation Programme to address the areas of improvement work required to deliver the recommendations of the Flood Warning Service Review carried out by NRW in 2018. Several of the recommendations directly link to the recommendations set out by NRW within their Flood Incident Management Review **(R1C, R2C)**.

[7] Natural Resources Wales / Our response to Storm Ciara and Storm Dennis

- NRW have commissioned a Rhondda River flood modelling project for completion in Spring 2022. **(R1A, R2A)**

NRW propose to exercise the following functions in response to the flooding at RCT19:

- Following the completion of NRW's Rhondda flood modelling project, NRW propose to undertake an initial assessment of the viability of potential flood risk management options. Consideration should be given to areas at high risk of flooding from rivers on a prioritised basis. **(R1A, R1B)**
- Following the completion of NRW's Rhondda flood modelling project, NRW propose to undertake further threshold work and flood warning area amendments. **(R1A, R1C)**
- NRW to undertake scheduled T89 inspections at different locations across the main river channel within Porth on a 6-monthly basis.

4.3. WATER COMPANY

Following the investigation into the flooding at Porth, DCWW were not identified as a relevant Risk Management Authority in relation to the flooding at RCT19 during Storm Dennis, however, DCWW undertook the following functions in response to the flooding within the investigation area:

- DCWW carried out their own investigations in response to incidences of flooding that were reported by residents directly to DCWW.
- DCWW contacted residents affected by flooding to offer support and advice to assist in the recovery following the flood event.
- Upon the identification of blockages within the DCWW network at Eirw Road, clearance works were undertaken to remove the deposited riverine debris.
- DCWW investigated the performance of their network and pumping stations within RCT19 to ensure their assets were operating with no issues.

DCWW propose to exercise the following function in relation to the flood event at investigation area RCT19;

- DCWW will work with the LLFA and Highway Authority to evaluate surface water management options to alleviate pluvial flooding at locations across the investigation area. **(R6B)**

4.4. HIGHWAY AUTHORITY

During the investigation into the flooding at RCT19 during Storm Dennis, the Highway was identified as flooding from a combination of sources at different locations, most notably as a result of surface water runoff and main river flooding from the Rhondda Fach and Rhondda rivers.

Ref 6 of Table 9 identifies the Highway Authority as a relevant Risk Management Authority in relation to the surface water flooding that occurred along the highway across RCT19.

RCT as the Highway Authority have exercised the following functions in response to the flooding within RCT19:

- The Highway Authority assisted with the emergency response during the event by supplying equipment and sandbags, some to individual properties and using sandbags to redirect flood water away from properties.
- The Highway Authority exercised their functions under Section 100 of the Highways Act 1980, to arrange for all gullies and open drains in the highway to be inspected and cleansed following the influx of fluvial flood water to ensure the safety of the highway post event. **(R6A)**
- The Highway Authority has undertaken emergency clearance works to the culvert inlets identified as sources of flooding. **(R3C, R4C)**
- The Highway Authority have increased their resource capacity by establishing a dedicated 'Pluvial Drainage Team' to focus entirely on the refurbishment and maintenance of RCT's existing and enhanced highway drainage infrastructure.
- In response to the damages caused by the River Rhondda to the highway retaining wall (NFD Structure) at Brook Street during Storm Dennis, the Highway Authority have undertaken repair works to upgrade its structural integrity.

RCT as the Highway Authority propose to undertake the following function in relation to the storm event at RCT19:

- The Highway Authority to work with the LLFA and DCWW to evaluate surface water management option to alleviate pluvial flooding at locations across the investigation area. **(R6B)**

USEFUL LINKS/CONTACTS

Blue Pages – property Resilience - http://bluepages.org.uk/

Flood Re – Flooded Property Insurance Scheme - https://www.floodre.co.uk/

Natural Resources Wales – Check Flood Warnings - https://naturalresources.wales/flooding/check-flood-warnings/?lang=en

Natural Resources Wales - Long Term Flood Risk - https://naturalresources.wales/evidence-and-data/maps/long-term-flood-risk/?lang=en

Rhondda Cynon Taf CBC - Local Flood Risk Management Plan - https://www.rctcbc.gov.uk/EN/Resident/ParkingRoadsandTravel/Roadspavementsandpaths/FloodAlleviation/Floodriskregulations2009.aspx

Rhondda Cynon Taf CBC - Local Flood Risk Management Strategy - https://www.rctcbc.gov.uk/EN/Resident/ParkingRoadsandTravel/Roadspavementsandpaths/FloodAlleviation/LocalFloodRiskManagementStrategy.aspx

Rhondda Cynon Taf CBC – Sustainable Drainage – https://www.rctcbc.gov.uk/EN/Resident/ParkingRoadsandTravel/Roadspavementsandpaths/SustainableDrainage/SustainableDrainage.aspx

Welsh Government - National Strategy for Flood and Coastal Erosion Risk Management - https://gov.wales/sites/default/files/publications/2019-03/national-strategy-for-flood-and-coastal-erosion-risk-management-in-wales.pdf

Welsh Water – How to Contact Us – https://www.welshwater.com/en/Contact-Us.aspx