



The Coal  
Authority

# Flintshire County Council: Mine Water Heat Opportunities

July 2024



Making a **better future** for people  
and the environment **in mining areas**

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# Executive summary

Coal mining has taken place in the Flintshire County Council area since at least the 16th Century with the last mine to close being Point of Ayr in 1996. Much of the county is underlain by coal mine workings, with multiple seams being worked in many localities. The presence of mine workings, combined with knowledge, where available, of recovered mine water levels are used to provide a very high level assessment of the potential for exploring the development of open loop mine water heat projects in the county. In addition to borehole opportunities, gravity-fed discharges have also been assessed for heat potential. Some discharges do not have sufficient data for assessment, hence are not included in this report.

The workings are relatively shallow across the county and occur in small localised areas. The strata and associated coal seams and generally workings dip to the east but are heavily affected by faulting. The presence of numerous 'gravity discharges' in the Flintshire administrative area together with the long period since the mines closed suggests that mine water has recovered.

The methodology for identifying the mine water heat opportunity areas is described in the overarching report. Mine water heat opportunities are based on mine workings information, with several 'good' and 'possible' opportunities in the Flintshire area. This reports also includes surface details to provide opportunities to be progressed, these are also shown in the table below.

While there are no Coal Authority mine water treatment schemes in Flintshire, there are some gravity-fed discharges, where mine water is emitting at surface. This mine water may offer potential for mine water heat without the cost and risk of drilling and pumping. Only one discharge was identified having a heat potential of over  $0.5\text{MW}_{\text{th}}$  and is listed in table below.

It is recommended that the opportunities listed are considered against surface heat demands to highlight those which may be served by mine water heat technologies. A subsequent, more detailed study of the mining and hydrogeology would add further information to firm up the case to take a number of mine water heat projects forward.

## Summary of selected mine heat opportunity locations

No./ Area	Opportunity name	Opportunity type	Opportunity Category	Estimated Heat Potential MW <sub>th</sub>
1	Hawarden	Discharge	Good	0.71
2	Buntwood Pentre	Borehole	Good	Subject to further testing
3	Buckley	Borehole	Good	Subject to further testing
4	Ewole Green/Ewole	Borehole	Good	Subject to further testing
5	Mostyn	Borehole	Good	Subject to further testing

# 1 Introduction

The area covered in this section is the whole of the Flintshire County Council (CC) administrative boundary. Assessment of mine workings and mine water status along with knowledge of the area are used to provide a very high level assessment of the potential for exploring the development of open loop mine water heat projects in the county.

## 1.1 Geographic area

Flintshire covers an area of approximately 490km<sup>2</sup>, and runs roughly 35km northwest-southeast between the coast and north of Wrexham; and approximately 15km southwest-northeast. Major urban areas include: Flint, Mold, Connah's Quay, and Buckley. Coal Measures strata and coal mine workings include along the Dee Estuary and in the eastern-central part of Flintshire. Elevation in Flintshire ranges from sea level along the Dee Estuary to >550m at Moel Famau. The Afon Lwyd southwest of Mold runs northerly before turning south-easterly around Mold and through Wrexham to the River Dee.

## 2 Geological summary

The solid and superficial geology, along with seam information has been ascertained by consultation of the available British Geological Survey records including:

- Online GeoIndex viewer;
- Online geological memoirs;
- Online geology maps (Sheet 108 and Sheet 96 for Flintshire area); and
- Borehole and mine shaft scans across the area of interest.

### 2.1 Bedrock geology

Flintshire contains bedrock geology (at surface) from the Permo-Triassic, Carboniferous, Devonian, and Silurian periods (**Table 2.1**).

The Carboniferous includes the Red Measures, Coal Measures (coal mine workings), Millstone Grit groups, which cover the central and northern parts of Flintshire. The Permo-Triassic cover parts of easternmost Flintshire, whilst the Silurian are present in part of west Flintshire (**Figure 2-1** and **Figure 2-2**). There is an overall dip in the Carboniferous rocks in Flintshire from west to east, with parts dipping east to west due folding and faulting present.

The coal mine workings are present within the Coal Measures group (Middle and Lower) and outcrop within parts of Flintshire. The Coal Measures in Flintshire comprises interbedded sequences of mudstone, siltstone, sandstone, seat earth, and coal seams. Nearly all of the Coal Measures and mine workings in Flintshire are the Flintshire Coalfield, the northernmost

part of Denbighshire Coalfield are present in the southernmost part of Flintshire. The Bwlchgwyn-Bala Fault effectively separates the two coalfields.

Up to 21 individual coal seams have been worked to varying extents in the area. Mine workings can have direct and indirect connections to each other. Hydraulically connected mine workings and mine form mine water blocks – where mine water behaves as a single unit.

Regional solid geology and selected structural geology is shown in **Figure 2-2**.

The stratigraphic sequence, approximate depths and thicknesses are shown in **Figure 2-3** and **Figure 2-3**.

**Table 2.1: Stratigraphy of Flintshire area between the Permo-Triassic and Upper Silurian (based on Davies et al 2004)**

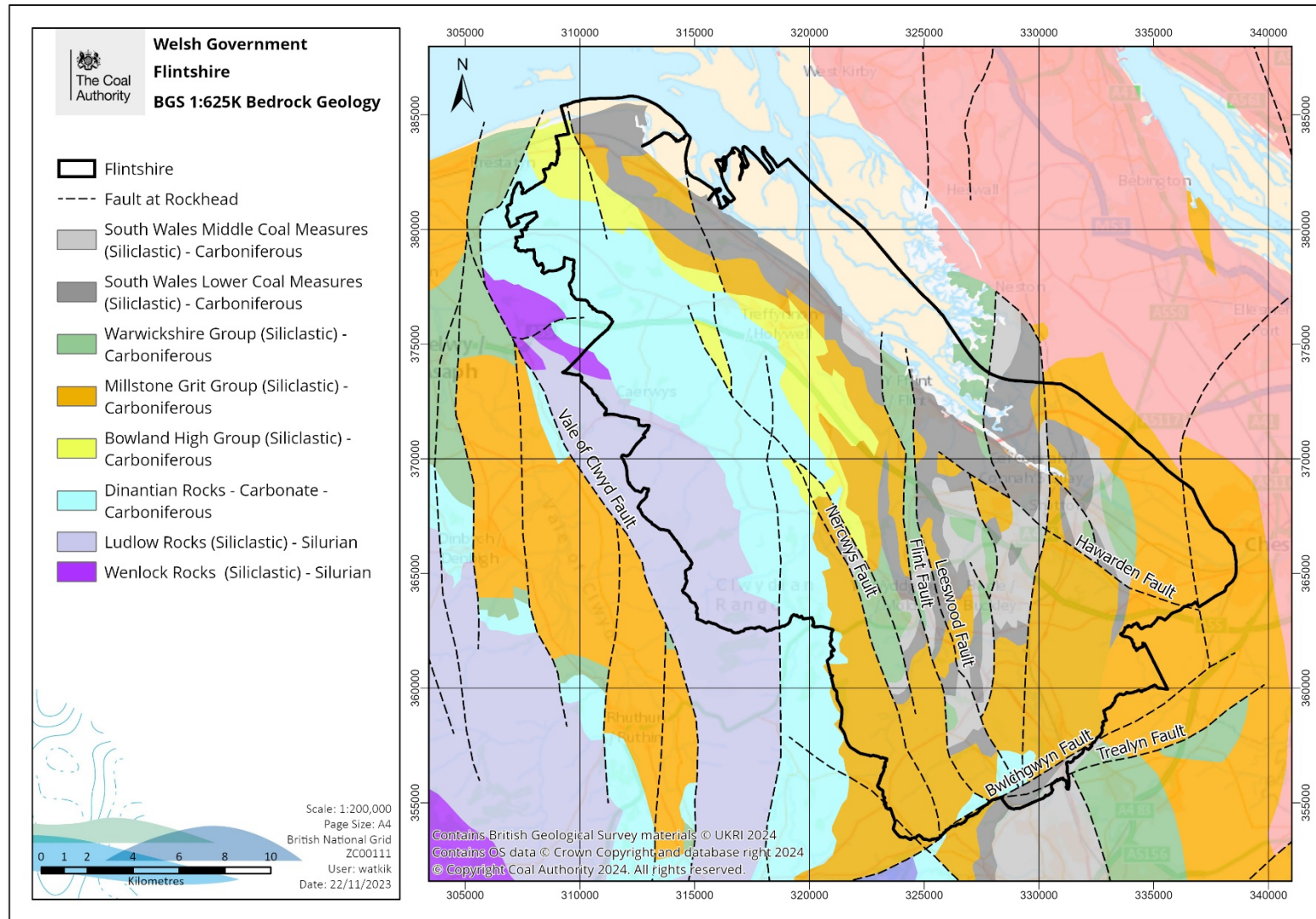
Period	Stages	Stage	Formations	Typical thickness (m)
Permo-Triassic	-	Sherwood Sandstone Group	Chester Peb Beds	>200
			Kinnerton Sandstone	>600
Unconformity				
Upper Carboniferous (Silesian)	Westphalian	Red Measures Group	Erbistock	>200
			Coed-yr-Allt	140
			Ruabon Marl	up to 300
		Coal Measures Group	Middle Coal Measures	up to 340
			Lower Coal Measures	up to 180
	Namurian	Millstone Grit Group	Gwespyr Sandstone	up to 260
			Holywell Shales	up to 120
			Cefn-y-few Sandstone	up to 600
Pentre Chert			up to 180	
Lower Carboniferous (Dinantian)	Visean	Carboniferous Limestone	Minera	up to 180
			Cefn Mawr	40 to 275
			Loggerheads Limestone	up to 175
			Llanarmon Limestone	75 to 280
			Leete Limestone	up to 140
			Foel	up to 88
Unconformity and part of Dinantion and Silurian missing from the sequence				
Upper Silurian	Ludlow	-	Elwy	up to 600
			Nantglyn Flags	up to 400

### 2.1.1 Structural geology

Major faults are shown in **Figure 2-1** and **Figure 2-2**. The main faults in the area typically trend approximately north-south, with some main faults such as the Blchgwyn-Bala fault that trends southwest-northeast.







**Figure 2-2: Bedrock geology in the Flintshire locality (Contains British Geological Survey materials © UKRI 2024)**

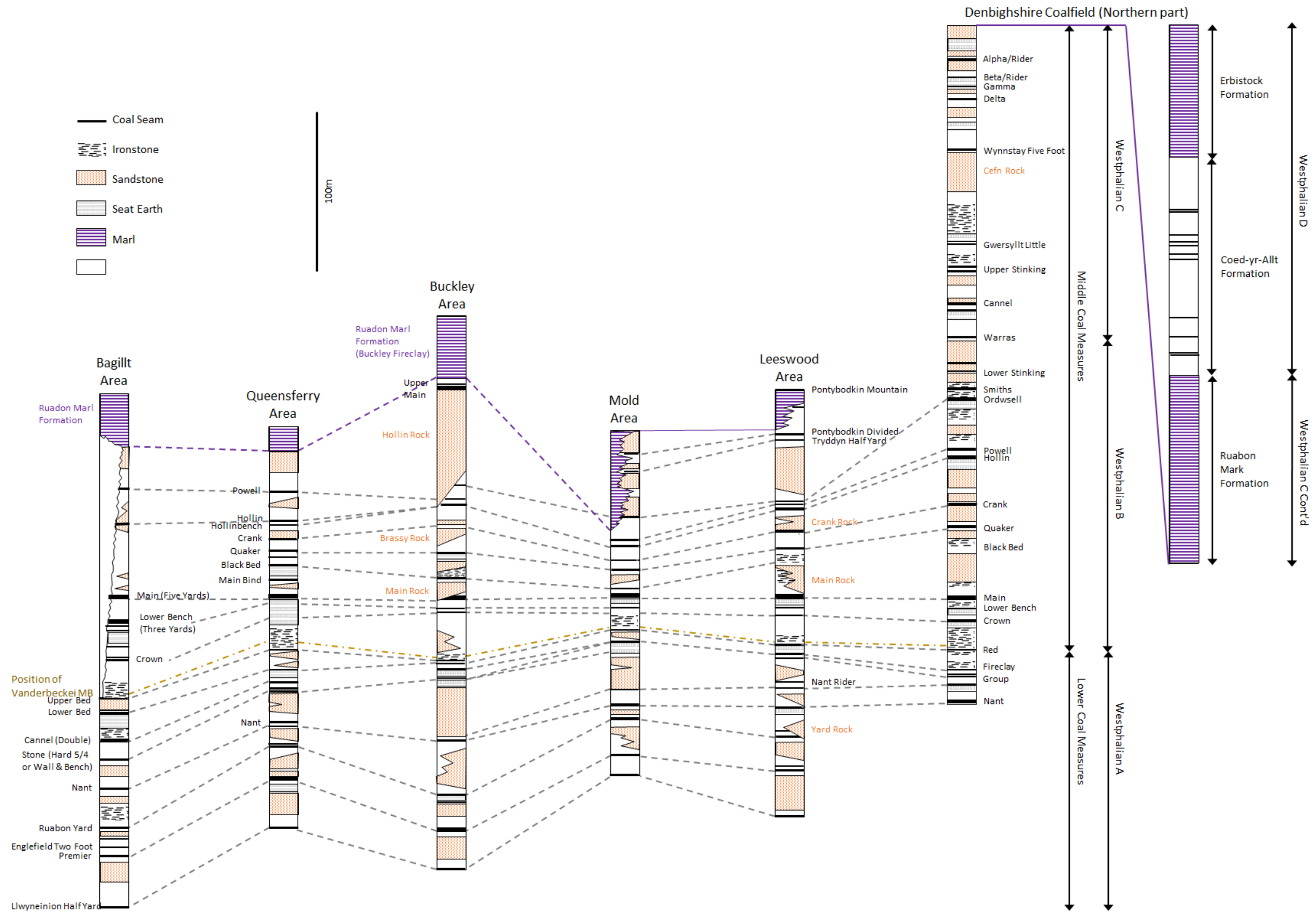


Figure 2-3: General sections of strata for the Coal Measures Group for Flintshire (based on Davies et al, 2004)



### 3 Mining situation

Coal mining has taken place in North Wales for several centuries with shallow seams being worked near to outcrop by means of roadways driven from the surface. These workings were often gravity drained by means of water levels or soughs. From the mid 1800's, the industrial revolution and concomitant increase in demand for coal led to the sinking of many collieries into the deeper seams.

Flintshire includes the mine workings in the Middle and Upper Coal Measures, with both onshore and offshore mine workings (at Point of Ayr Colliery). Parts of the coal mining areas also includes fireclay and ironstone mine workings. The shallow nature of the coal and ironstone results in early mining in the area, with a mixture of small scale and larger scale collieries. Some coal mines were connected during mining for aspects such as coal preparation, efficiency improvements, and water managements. These underground mining connections have a great bearing on the underground mine water regime by interconnecting considerable areas of mine workings. Due to volumes of pumping and associated financial costs, many collieries in the Mold / Buckley area closed around the 1920-1930s. The final collieries to close are shown in **Table 3.1**.

**Table 3.1: List of most recent colliery closures (surface location of mine in Flintshire)**

Colliery	Closure date	Connected underground to
Bettisfield	1934	Not confirmed
Buckley / Elm	1934	Not confirmed
Englefield	1928	Not confirmed
Leeswood Green	1932	Not confirmed
Mountain Buckley	1928	Not confirmed
Nerquis	1930	Not confirmed
Park Hill	1949	Not confirmed
Point of Ayr	1996	Not confirmed
Tan Llan	1943	Not confirmed

Following these closures, pumping ceased and the mines started to fill with mine water.

Up to 21 individual coal / ironstone / seatearth seams have been worked in the area with seams between the Pontybodkin Mountain (Cannel?) Seam and Llwyneinion Half Yard (Queen) being mined.

In general terms, coal mining in Flintshire is as follows:

- North Flintshire
  - Along the coast between Flint and Point of Ayr
  - Typically recorded mine workings are between 30 and 500m below surface
  - Potential for shallow and unrecorded mine workings
  - Includes offshore mine workings.
  - Potentially small isolated areas
  
- Central / south Central Flintshire
  - Coal mine workings are in areas between Mold and Garden City and extending down to south of Pontybodkin
  - Coal mine workings are present between <30m and 300m below surface
  - Potential for shallow and unrecorded mine workings
  - Potentially small to moderate areas, and may include area of isolated and connected mine workings
  
- Southern extremities of Flintshire
  - Coal mine workings from the Denbighshire Coalfield, around Cefn-y-bedd
  - Coal mine workings area present between <30m and 300m below surface
  - Includes areas where mine workings connected to a wider regional system and areas with potentially isolated mine workings

The same seam may have various names across the area, no seam nomenclature correlation has been undertaken for this report.

## 4 Mine water regime

### 4.1 Description of mine water blocks

Flintshire contains the Flintshire Coalfield and the part of the northernmost part of the Denbighshire Coalfield.

The Flintshire Coalfield contains several different areas of mine workings, some of which are likely to be isolated from other mine workings. Mine water levels in Flintshire Coalfield are considered to be recovered and potentially controlled by gravity-fed discharges to the surface. Point of Ayr Colliery workings were flooded by connecting the workings to the sea, the status of this connection is unknown.

The northern part of the Denbighshire Coalfield contains interconnected mine workings and form part of a wider mine system. Some of the mine workings in north Denbighshire Coalfield may be isolated. It is uncertain if all of the Denbighshire Coalfield is recovered, or which parts are undergoing mine water recovery.

### 4.2 Monitoring data

#### 4.2.1 Mine water levels

There are no Coal Authority mine water level monitoring points within Flintshire. Mine water level status can be estimated using existing gravity-fed discharges.

#### 4.2.2 Mine water discharges

The mine water discharge are places where mine water reaches the surface and can discharge. Mine water levels in mine workings connected to a discharge should be elevated above the surface elevation of a discharge.

There is one monitored mine water discharge (monitored by the Coal Authority) in Flintshire (**Table 4.1** and **Figure 4-2**), from Prescott Level in Hawarden. In addition to the monitored discharge at Hawarden, there are several known, unmonitored discharges (**Table 4.1** and **Figure 4-2**). It is unclear how representative the gravity discharges are of the mine water levels within the mine workings.

**Table 4.1:** Mine water discharges in Flintshire and adjacent areas

Monitoring point name	Mine water area	Comments
Hawarden Prescott Level	Hawarden	Remedial programme for coal mine discharges
Red Water Wood (Picton Brook)	Llanasa	Possible unrecorded mine workings and unrecorded mine entry. Other discharges may exist in area
Wepre Brook	Northop	Possibly from Dublin Main shaft(s) to north
River Alyn (Mold)	North Mold	Bankside staining
River Terrig	Nerquis (Nercwys)	Possibly from Nequis Colliery nearby
West Leeswood Adit	Leeswood	From Return Adit
River Alyn (Coppa Wood)	Coppa	Possible unrecorded workings or Coppa Colliery Shafts
Little Mountain (Pontybodkin) Adit	Leeswood	From Screen Adit
Black Diamond King Coal Adits	Cefn-y-coed	May also include former opencast water
River Cegidog	Coed-y-Felin	Adit to possible unrecorded mine workings
Bottom Lodge Adit (Fireclay)	South Flintshire	Connectivity to Denbighshire Coalfield mine system (confirmation required)
Cegidog Ffrwd (Ffwd Adit)	South Flintshire	From Ffwd Colliery Level Adit

### 4.2.3 Mine water temperature

A study into mine water temperatures at various depths around the Britain's coalfields was published in 2020 (Farr et al, 2020). This study used historic underground water and strata temperatures along with data from mine water pumping where available.

Temperature typically increases with depth and data published in the study suggests the following may be anticipated for the Flintshire area, there is no data in Farr et al, 2020 for the Flintshire Coalfield:

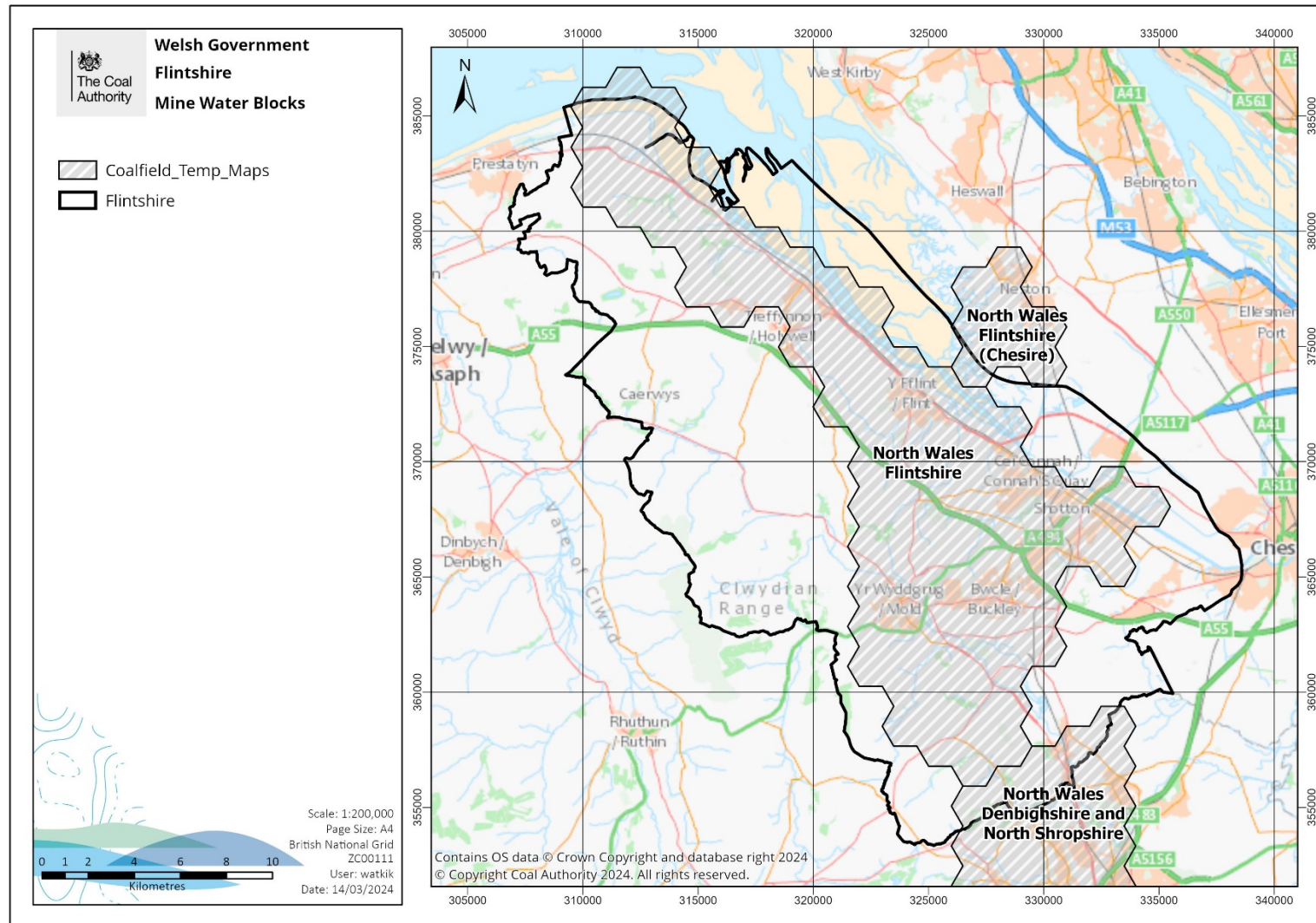
**Table 4.2: Anticipated underground mine water temperatures in Denbighshire Coalfield**

Depth (m BGL)	Mean Temperature (°C)
100	12.5
200	14.9
300	17.5
400	19.8
500	22.3

#### 4.2.4 Mine water chemistry

Mine water chemistry can be highly variable depending on specific location and would not normally form part of any initial high level opportunity scoping considerations guided by this study. The matter would be included in any more detailed, site specific, studies which may be commissioned in future.





**Figure 4-1: Mine water bocks in Flintshire**

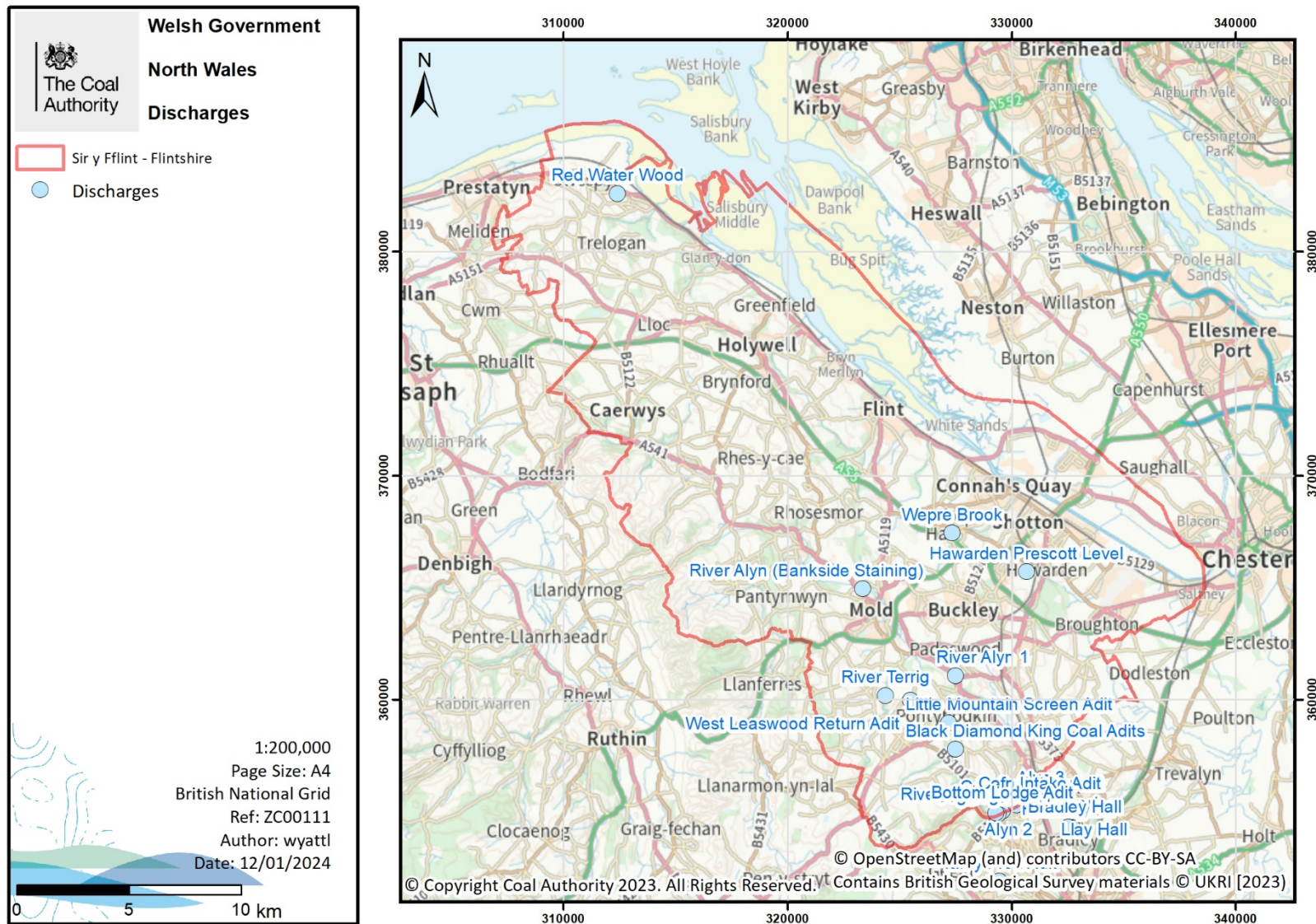


Figure 4-2: Gravity-fed coal water discharges in Flintshire



## 5 Mine water heat opportunities

Considerable areas of the Flintshire administrative area are underlain by abandoned coal mine workings. The earlier sections of this report consider the mining and mine water parameters across the whole borough to rank areas by reference to an opportunity classification system. This summary section overlays the opportunities on populated settlement areas to provide a steer on localities where mining aspects and surface development may present the most likely places to further investigate and potentially deploy mine water heat.

The opportunity areas are set out in **Table 5.1** and their locations illustrated in Figure 5-2

**Table 5.1: Mine water heat opportunities within Flintshire**

No./ Area	Opportunity name	Opportunity type	Category	Potential MW <sub>th</sub>
1	Hawarden	Discharge	Good	0.71
2	Buntwood Pentre	Borehole	Good	Subject to further testing
3	Buckley	Borehole	Good	Subject to further testing
4	Ewole Green/Ewole	Borehole	Good	Subject to further testing
5	Mostyn	Borehole	Good	Subject to further testing

### 5.1 Borehole schemes

The prospects for progressing a mine water heat scheme based on drilling boreholes to access and return the mine water are assessed on a ‘tier’ basis.

Three tiers have been adopted for the purposes of this study, the methodology and assessment criteria being set out in the over-arching report for Welsh Government. The tiers are:

**Good opportunities** – shown coloured dark orange

**Possible opportunities** – shown coloured medium orange

**Challenging opportunities** – shown coloured light orange

The tier areas within Flintshire CC boundary are outlined below and are illustrated on **Figure 5-1** and **Figure 5-2**.

Any areas where no opportunity exists, mainly due to absence of mine work are shown uncoloured/un-hatched. Other options such as discharges and using mine shafts can offer additional opportunities that are within tier zones, and that could also be outside of the tier zones.

### 5.1.1 Good Opportunities

Although areas of good opportunity have been identified across Flintshire, the age and nature of the workings will make integration into a potential heat network difficult due to the sporadic nature of the workings and where they sit regarding built up areas.

The built up areas around **Buckley, Little Mountain, Burntwood Pentre, Mold** and the area between **Ewloe Green**, and **Ewloe** represent good opportunities. There is also an area of good opportunity to the area to the west of **Flint** centred around the **Red Wood** area (**Figure 5.2**).

Other good areas exist in the borough but are either situated in rural areas or areas near the coast without any potential heat offtakers. These include rural areas to west of **Pontblyddyn** centred on **Leeswood Green Farm** and the rural area that sits between the A55 and A494 in a triangular area.

Good coastal opportunities include **Talacre, Mostyn and Baglit** but the residential areas are likely to be too small to generate the number of users required for a district scheme. There may be sufficient industrial demand in Mostyn to make a scheme viable.

The area to the north west of **Greenfield** represents an area of good to possible opportunities but is a combination of coastal and rural which will make and future development challenging.

### 5.1.2 Possible Opportunities

The possible opportunities in Flintshire are closely linked to the areas of good opportunities or are beneath highways. There are two areas of possible opportunities beneath the A55 highway to the south of Northop Hall and as a result are unlikely to ever be developed. Similarly there is an area beneath the A548 to the north east of Flint.

The possible areas closely associated with good opportunities include those around Buckley Mountain and Burntwood Pentre. Here any proposed development would benefit from early discussions with the Coal Authority to see if the surface layout could be altered in any way to take advantage of a 'good' opportunity.

There is an isolated area of possible opportunity in the area to the south east of Nercwys centred on The Poultry Court. This business may be able to use mine water to decarbonise and save energy costs.

### 5.1.3 Challenging Opportunities

An area of challenging opportunities exist around the Shotton area but these consist of small isolated areas that are unlikely to be viable options. Further challenging areas exist to the south of Mold and Padeswood, these opportunities are in areas where there is little or no development making the prospect of a heat network unlikely.

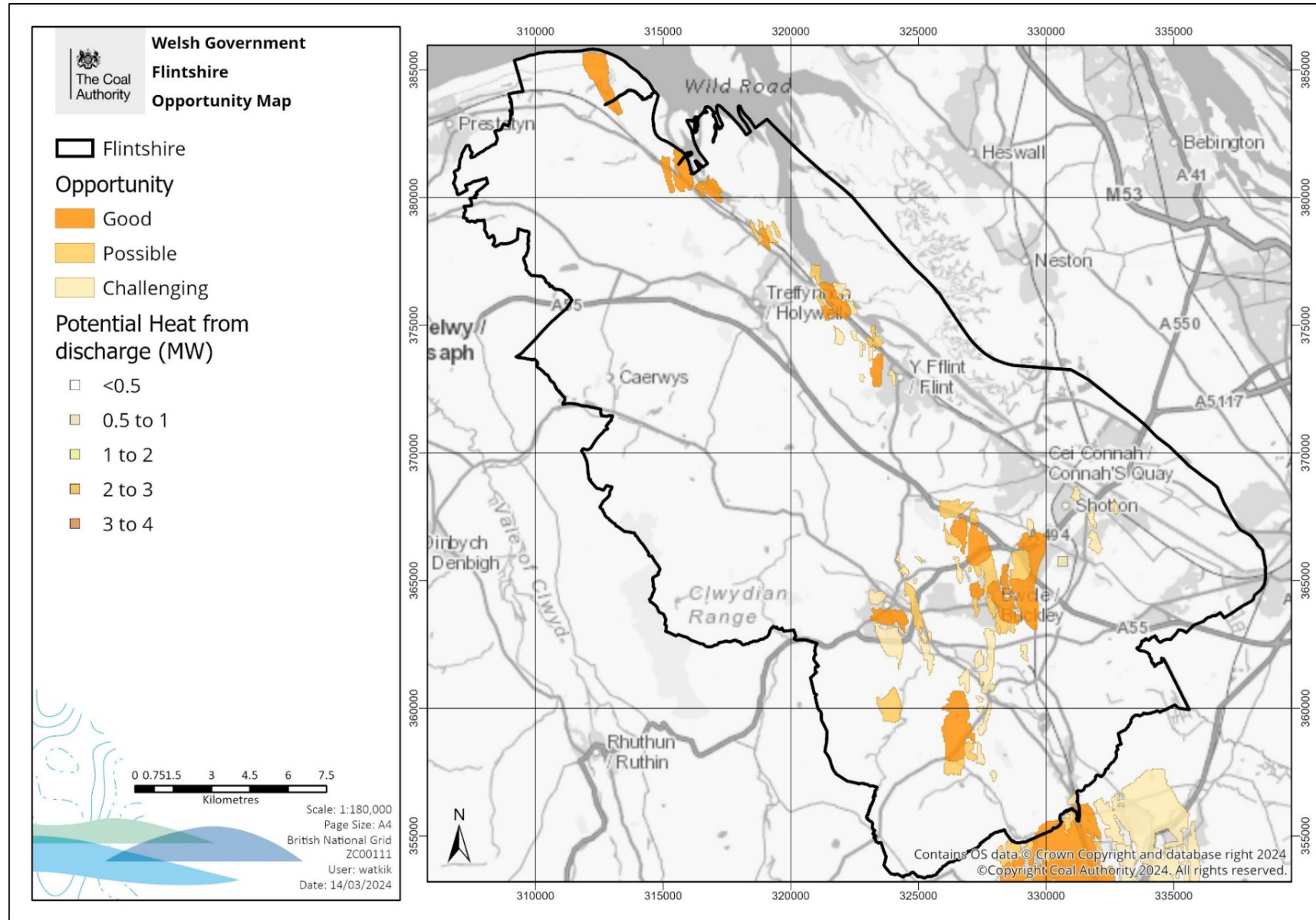
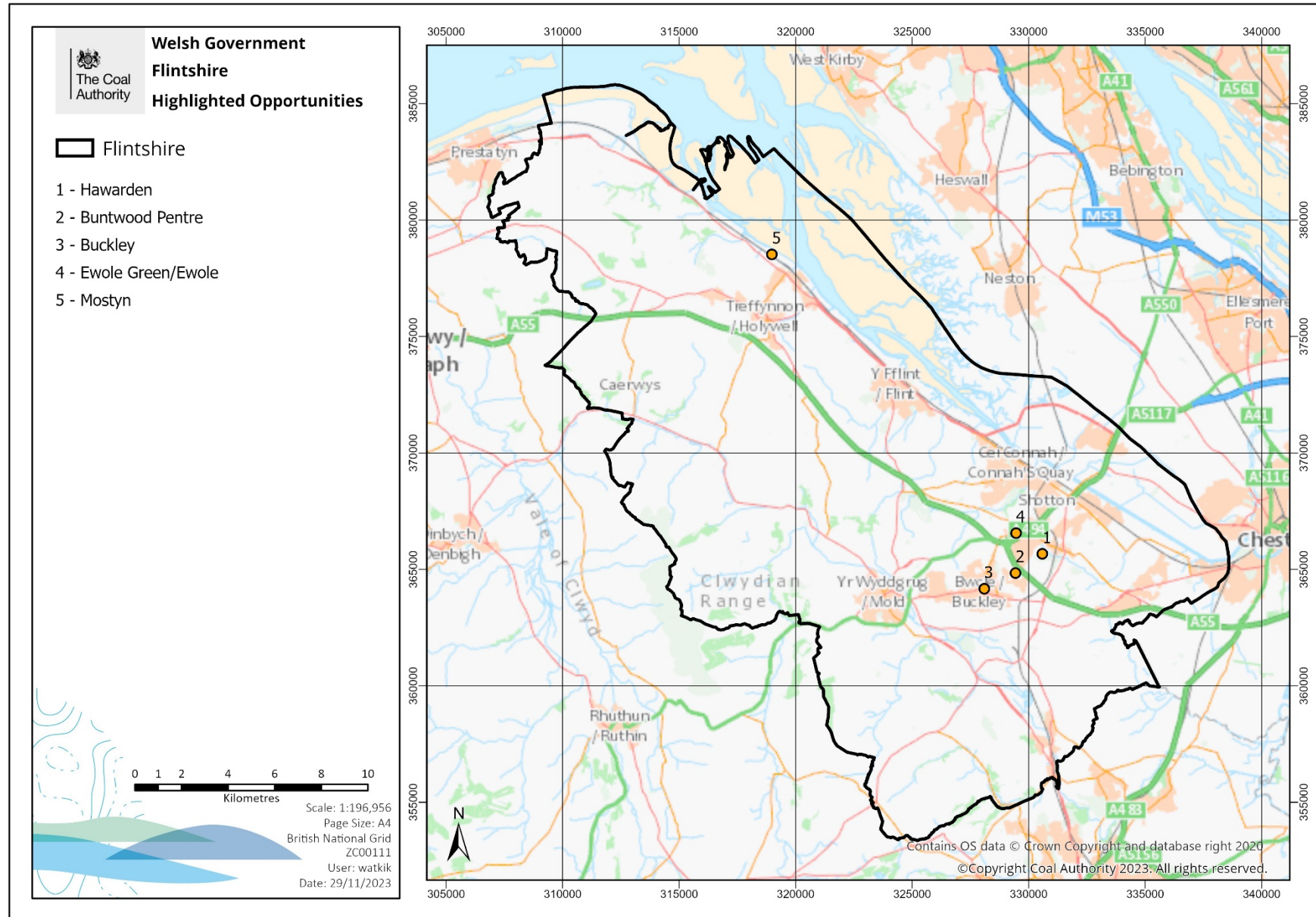


Figure 5-1: Borehole scheme opportunity tiers



**Figure 5-2 Highlighted good opportunities**



## 5.2 Mine water treatment schemes

Existing Coal Authority mine water treatment schemes where mine water is already either pumped or flowing may in some circumstances potentially offer a lower risk approach to developing mine water heat projects as new drilling and testing of boreholes would not be required. However there are currently no Coal Authority mine water treatment schemes IN Flintshire.

## 5.3 Gravity-fed discharge schemes

Numerous gravity mine water discharges exist in the Flintshire area. Many are not monitored for flow rate, water quality or temperature, some of these may offer heat potential not presented in this report. Gravity-fed discharges generally occur when mine workings connect with the surface, typically via mine entries and boreholes.

The nature of gravity-fed discharges (flow, temperature and quality) will be dependent upon a number of factors including mining type and geometry, the hydrogeological system of the mine workings and rainfall.

Some discharges are likely to be more variable in flow rate and temperature than others but as many of the discharges are not currently monitored for flow rate, water quality or temperature and it is difficult to evaluate with any degree of confidence.

Flow rate data is only available for one discharge in Flintshire; at Hawarden. The data for Hawarden shows an average flow rate of 30 L/s; and a temperature of 11.1°C; these suggest an average heat potential of 0.8MW. Assessment of heat potential for other known discharges will required further investigation, mainly to confirm flow rates.

Should a potential heat demand be identified, close to one of these discharges (shown in **Table 4.1**) or any other discharge in the area, then a more detailed study would be required. Additional investigation and data gathering will likely be required to establish its potential.

### 5.3.1 Prescott Level, Hawarden

The discharge is from an upwelling adjacent to the stream at Hawarden Golf Course. The upwelling is thought to be from a mine shaft sunk to the Prescott Level (drainage adit), the mouth of which is further downstream. The drainage adit runs from mine workings to the west of the discharge. There are mine shafts further upstream along the adit, which also access the drainage adit. Capturing the mine water discharge would need investigating. The discharge is on the priority list for remediation of existing discharges, however, it is uncertain if any scheme is likely to be implemented.

An initial broad estimate suggests an average potential of around  $0.71\text{MW}_{\text{th}}$  may be available, but a more detailed site specific study will be needed to assess flow rate and temperature with more certainty and confirm feasibility for a heat scheme(s). Further investigation will need to be undertaken to confirm potential heat users.



**Figure 5-3: Prescott Level, Hawarden discharge upwelling**



## 6 Summary & Recommendations – Flintshire

Flintshire CC was an active coal mining region between the mid1800s and 1996. Much of the borough is underlain by overlapping seams, with workings between 30 m and 500 m, and water levels <75 mBGL. There are some patches of open cast workings, and some shallow (<30 mBGL) and deep (>500 mBGL) workings also across the region. Mine water temperatures are expected to range between 12.5 and 22.3 °C between 100 mBGL and 500 mBGL.

A summary of opportunity areas are presented in **Table 5.2**.

**Table 5.2: Mine water heat opportunities in Flintshire**

No./ Area	Opportunity name	Opportunity type	Category	Potential MW <sub>th</sub>
1	Hawarden	Discharge	Good	0.71
2	Buntwood Pentre	Borehole	Good	Subject to further testing
3	Buckley	Borehole	Good	Subject to further testing
4	Ewloe Green/Ewloe	Borehole	Good	Subject to further testing
5	Mostyn	Borehole	Good	Subject to further testing

### 6.1 Borehole schemes

#### 6.1.1 Good Opportunities

There are a number of “Good” opportunity areas for borehole mine water heat schemes across much of Flintshire, with a number of the main settlements with existing end users underlain by mine workings which may be suitable. The built up areas around **Buckley, Little Mountain, Buntwood Pentre, Mold** and the area between **Ewloe Green**, and **Ewloe** may represent good opportunities.

#### 6.1.2 Possible Opportunities

“Possible” opportunities for boreholes schemes in Flintshire are located in mainly rural and coastal areas with little or no development. Depending on future development plans at these locations, they may warrant further investigation, but would be considered lower priority over those marked as “Good” opportunities

## 6.2 Mine water discharges

A number of gravity mine water discharges are known to exist in the Flintshire, but only one has any monitoring information. Ratings have been applied to discharges according to the following criteria:

- Good means heat potential over 0.5MW uncomplicated capture and uncomplicated heat transfer.
- Possible means heat potential over 0.5MW complicated capture or complicated heat transfer.
- Challenging heat potential over 0.5MW complicated capture and complicated heat transfer

The gravity discharges is:

- **Hawarden**, which sits to the west of Hawarden village, and is considered “Good” due to the distance to end users and lies in close proximity to a large secondary school.

## 7 References

Davies, J.R.; Wilson, D.; & Williamson, I.T. 2004. Geology of the country around Flint. Memoir for 1:50,000 geological sheet 108 (England and Wales). British Geological Survey (NERC), HMSO, London, 206pp. Available online:

<https://pubs.bgs.ac.uk/publications.html?pubID=B06065>

British Geological Survey, 2006. Solid geology of Sheet 96, Liverpool. Available online:

<https://largeimages.bgs.ac.uk/iip/mapsportal.html?id=1001585>

British Geological Survey, 1999. Solid geology of Sheet 108, Flint. Available online:

<https://largeimages.bgs.ac.uk/iip/mapsportal.html?id=1001596>

Howard, A.S.; Hough, E.; Crofts, R.G.; Reeves, H.J.; & Evans, D.J. 2007. Geology of the Liverpool District – a brief explanation of the geological map Sheet 96 Liverpool. British Geological Survey (NERC), Nottingham. 47pp. Available online:

<https://pubs.bgs.ac.uk/publications.html?pubID=B06820>