Hydroelectric Power

Resource Assessment Exercise

2023-24

Dr Julian Feuchtwang

julian.feuchtwang@strath.ac.uk

Task: carry out an outline (desktop) hydro power resource assessment

Steps:

1. Estimate the gross annual mean flow in Caaf Water 14%
2. Estimate the nett annual mean flow in Caaf Water by correlation with another catchment 19%
3. Set the design flow for the scheme 11%
4. Estimate the gross head and identify the key components of the scheme's layout 13%
5. Estimate head losses 17%
6. Turbine rating and selection 13%
7. Conclusion 6%

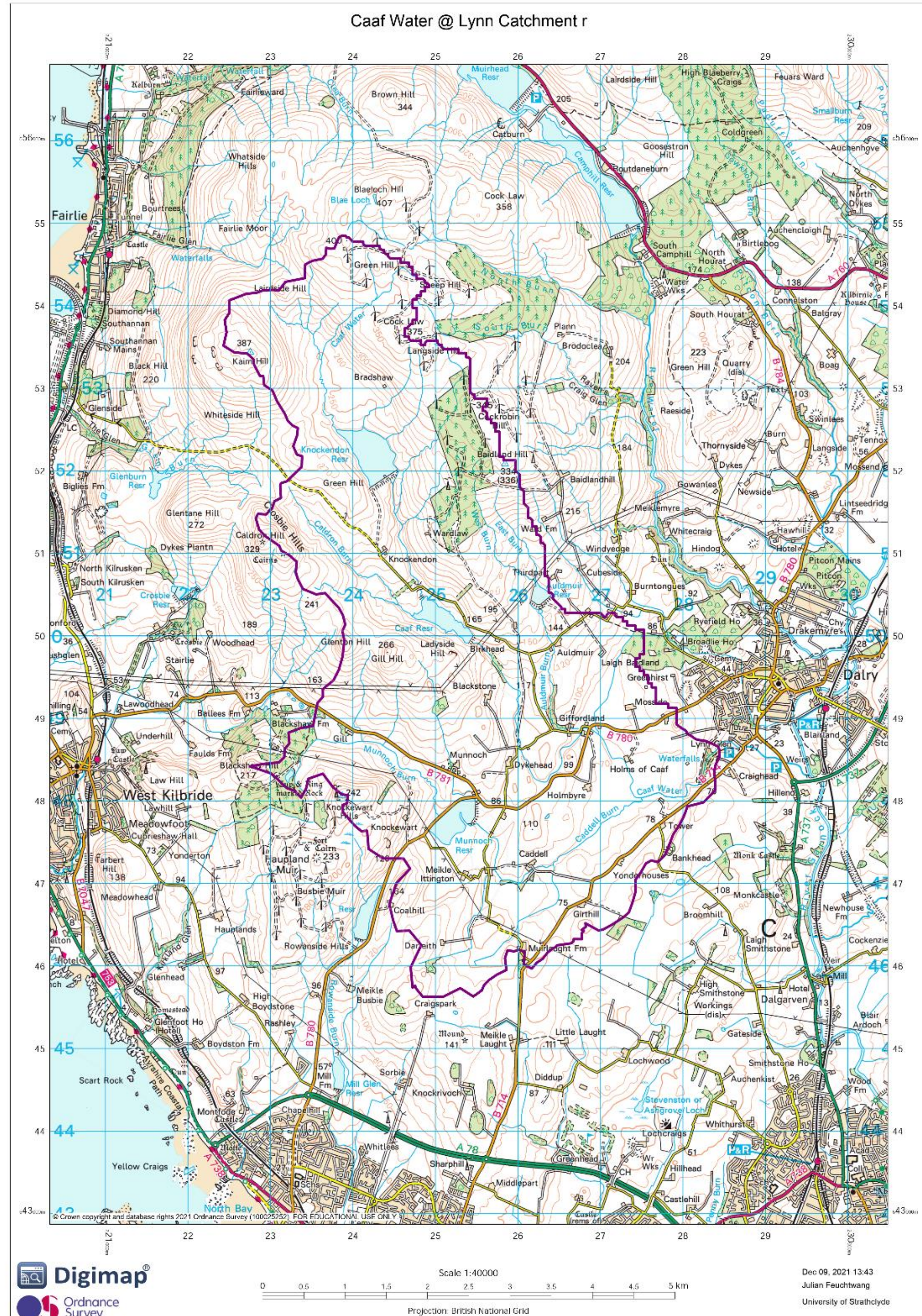
– Quality of Discussion, Reasoning, Explanation, Conclusions matters.

– Evidence of working (spreadsheet or scanned notes 7%

Total 100%

Background

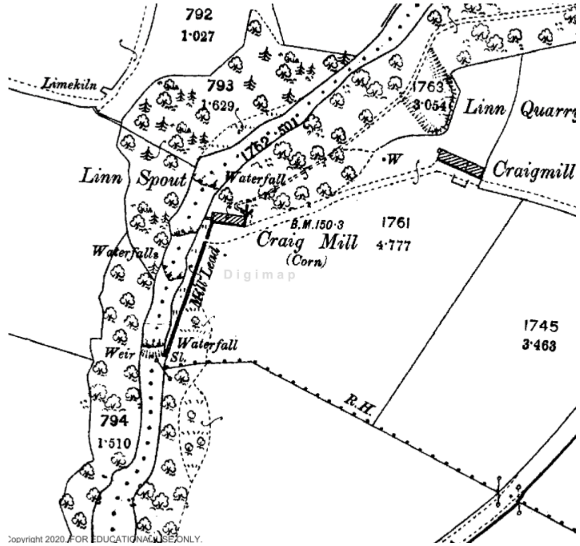
- 4th year individual project
- Broad filtering from a long list of potential schemes
- Visited a number of sites within easy access of Strathclyde
- Selected 1 site to carry out feasibility:
  Caaf Water at Lynn Spout near Dalry in North Ayrshire
- Project made good progress but was cut short by COVID-19

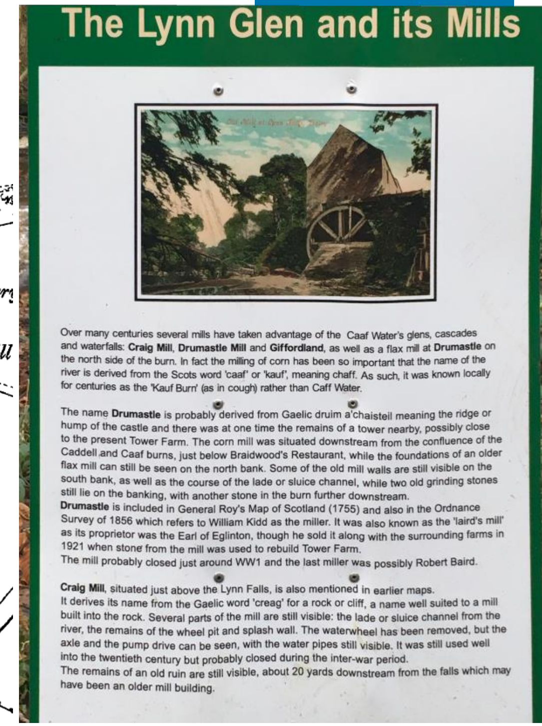


Context

- History:
- Site once had a watermill, Craig Mill

- Geography:
- Site includes a moderate size waterfall and potentially several smaller waterfalls.



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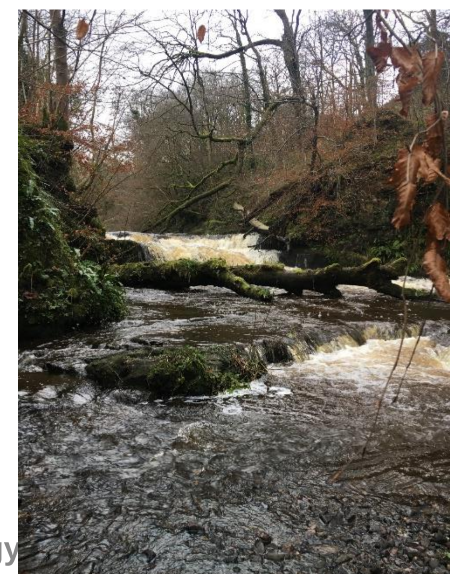
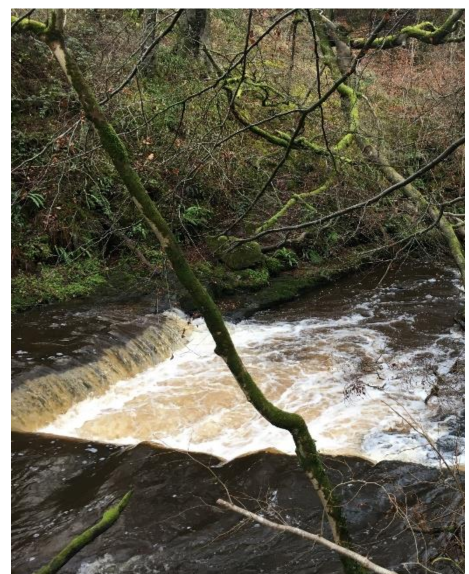




Context

- The Lynn Spout site is NOT gauged so direct data are not available
- However, it is a distinct part of one gauged catchment and is adjacent to another
- Site is easily accessible, and is close to the local distribution network and possible end-users.
- BUT Site is a SSSI (Site of Special Scientific Interest) due to its geology, placing restrictions on development.

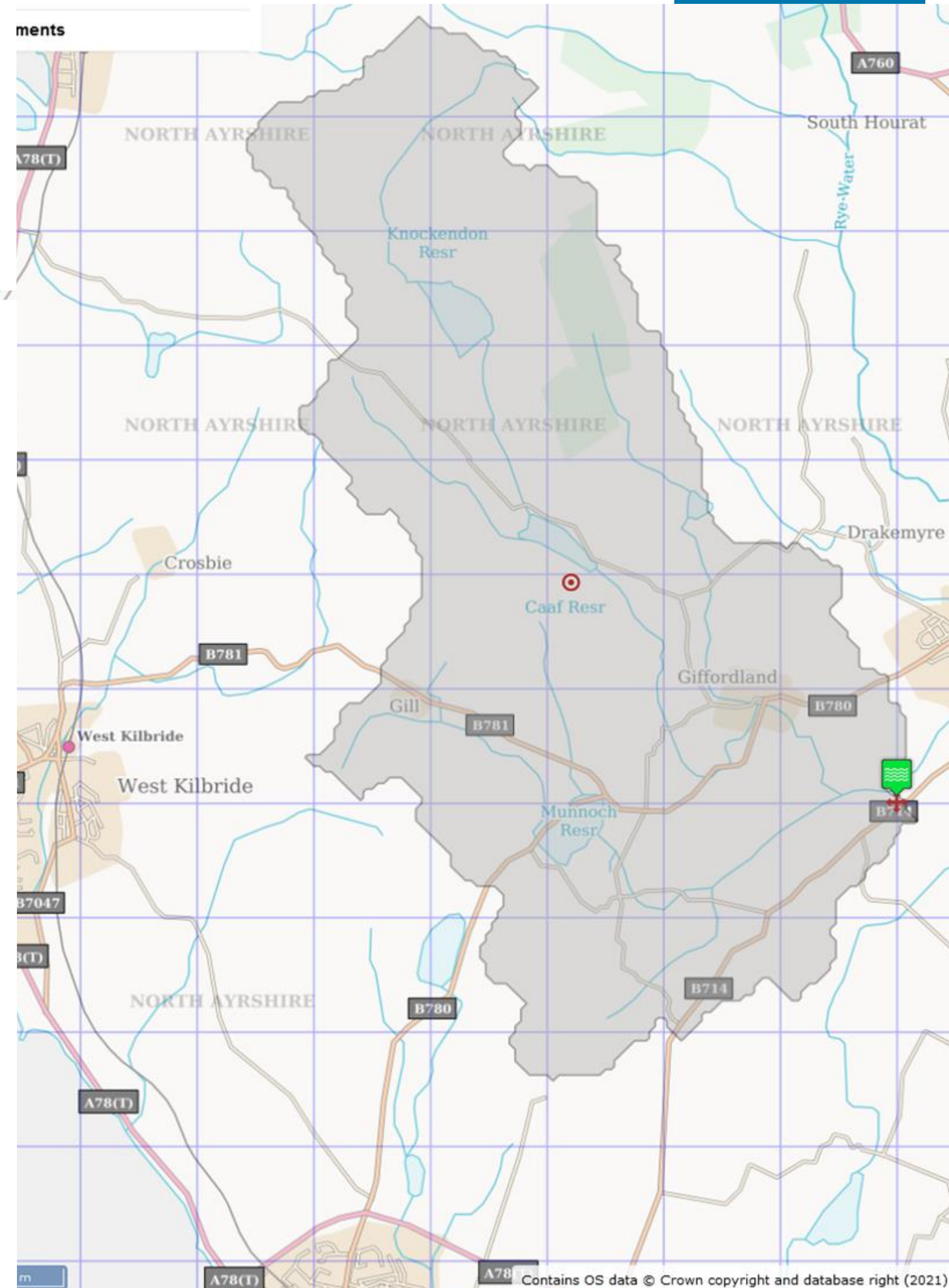
1) Estimate the gross annual mean flow in Caaf Water

a) Estimate the catchment area from the map

- There are 2 versions of the catchment map. The coarse grid squares are 1 km × 1 km on **both** maps.
- On the coarsely gridded map, you can make a perfectly adequate estimate of the catchment area. Estimate by eye, to the nearest ⅛, how much of each grid square is within the catchment and add them up.

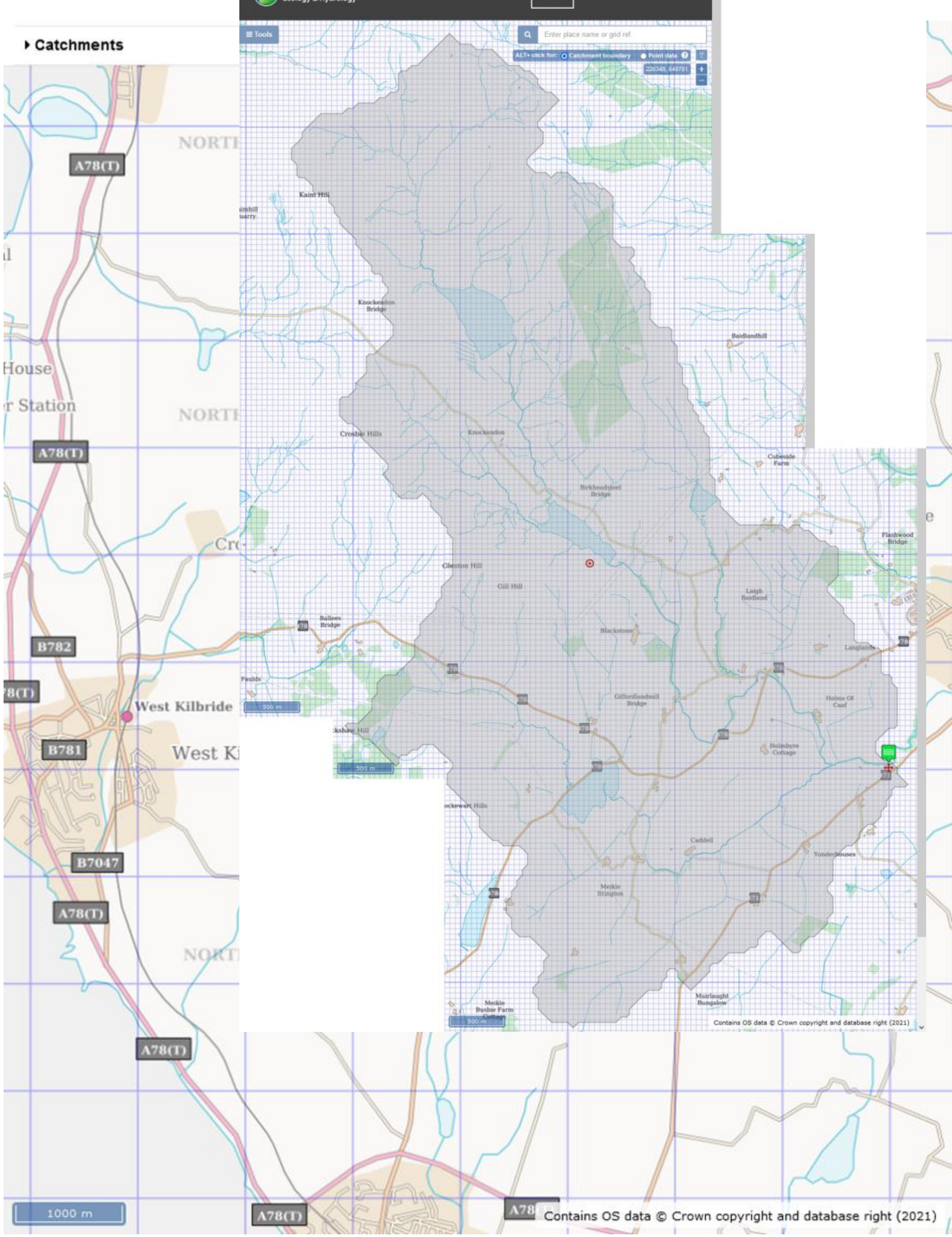
- *A*=

5.5 marks



1) a)

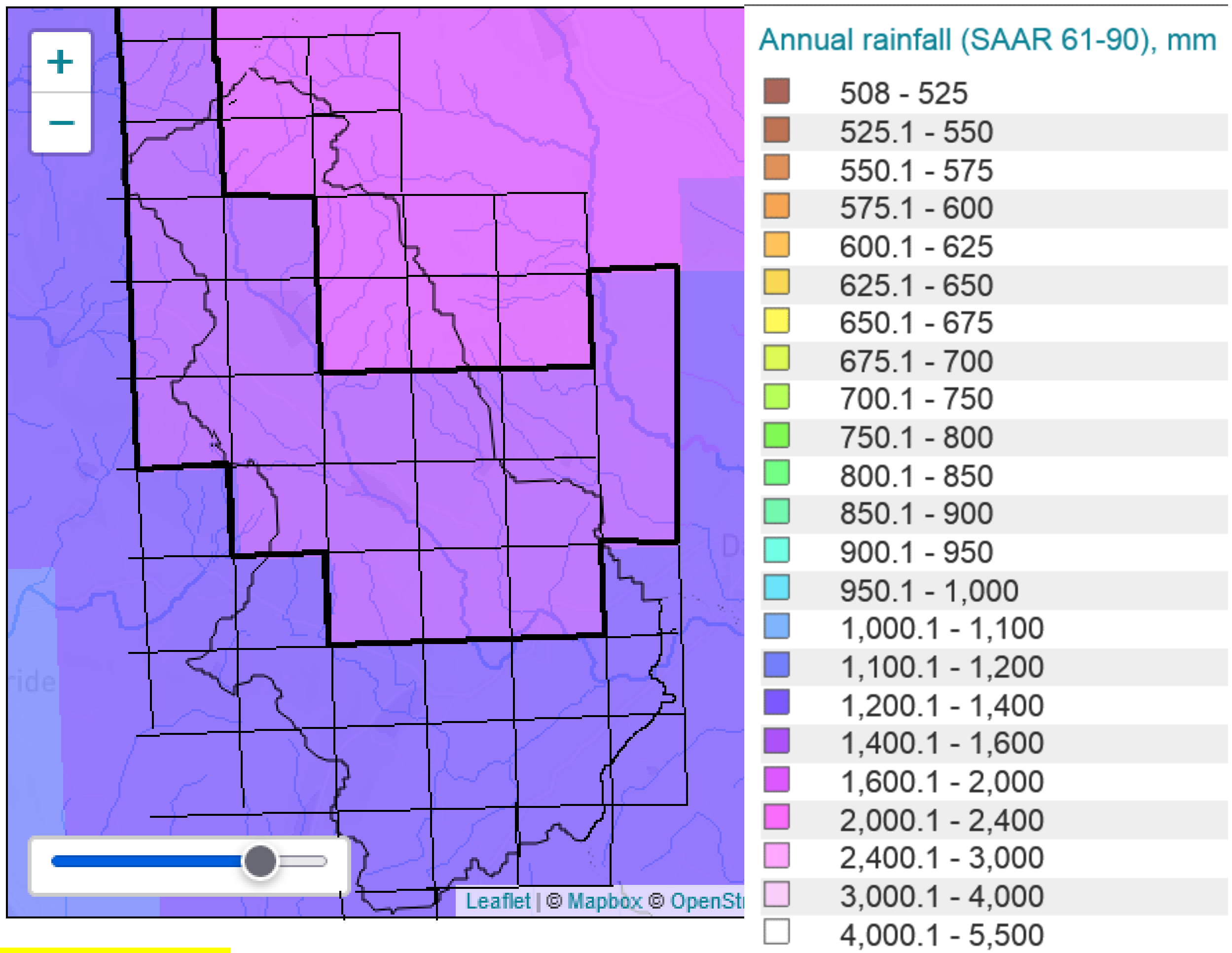
- Estimate the catchment area
- Alternatively, on the finely gridded map, each small grid square is 50 m × 50 m. (ie 400 in each coarse square!) You would then need to count how many are within the catchment in a coarse square that is not wholly within the catchment. This is probably more accurate and more time consuming than you are likely to need but it is your choice.



1) Estimate the gross annual mean flow in Caaf Water

- b) Estimate the annual rainfall intensity from the rainfall map

- You can estimate the mean rainfall in the catchment in a similar way to the catchment area, by counting squares. **These are not the same grid squares as in the previous map.**
- Count the number of squares covered by each colour of the rainfall map and use the square counts to weight your calculation of the mean rainfall, given the stated rainfall for each square-colour.



Square count	Annual rainfall
	1300
	1500
	1700

5.5 marks

1) Estimate the gross annual mean flow in Caaf Water

- c) Estimate Caaf Water's gross annual flow from rainfall and area

  Use the formula in the lecture slides and remember to correct for the non-standard units that rainfall intensity and catchment area are expressed in.

- $Q_{LSgr} =$

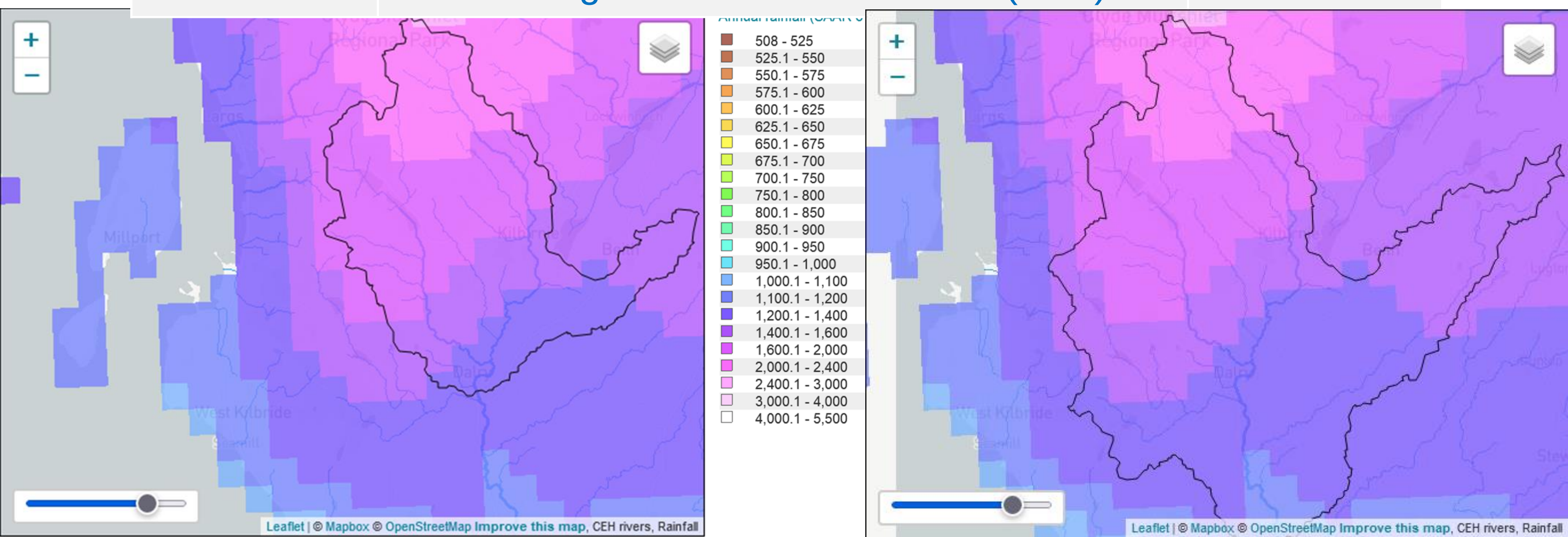
3 marks

2) Correlate the flow in Caaf Water with another catchment

- Caaf Water is a tributary of River Garnock,
- (which means its catchment is a 'subset' of Garnock's)
- River Garnock is gauged at Dalry, just <u>upstream</u> of Caaf Water's confluence
- It is also gauged at Kilwinning, somewhat <u>downstream</u> of Caaf Water's confluence but also downstream of the confluence of another river (Dusk Water)

2) a) Correlate the flow in Caaf Water with another catchment

Dalry	Station Data	Kilwinning
NS293487	Grid Reference	NS306424
19.1	Station Level (m AOD)	4.4
1963 - 1977	Operating Period	1976 - N/A
88.8	Catchment Area (km^2)	183.8
1715	Rainfall SAAR (1961-1990) (mm/yr) (Standard-period Average Annual Rainfall)	1553
	Estimated gross mean annual flow (m^3/s)	



2) Correlate the flow in Caaf Water with another catchment

- a) Use the catchment maps and catchment areas of River Garnock at the Dalry and Kilwinning gauging stations
- Use the published annual rainfall data
- and the published catchment areas
- to estimate the Gross mean annual flow at the 2 stations
- Estimated gross mean annual flow
  - for G @ D: Q_{Dgr} =
  - for G @ K: Q_{Kgr} =

2) Correlate the flow in Caaf Water with another catchment

- a)(cont) Use the published flow data for the 2 stations to estimate the proportion not 'lost' in each catchment ie the proportion of the gross flow estimate that actually runs off in the river as river flow.
- Runoff proportion (nett flow/gross flow):
  - for G @ D: c_D =
  - for G @ K: c_K =

4 marks

2) b) Correlate the flow in Caaf Water with another catchment

- Examine the topographic (land height), land use, and geology maps of the 2 catchments to guess which better represents the Caaf Water catchment
  - The hydrological cycle shows that there is always a difference between the gross mean annual flow, as estimated from rainfall intensity and catchment area, and the nett mean annual flow that actually flows in the river and can be measured.
  - Caaf water is not gauged but you can expect it to behave in a similar manner to other rivers nearby if they have similar terrain, soil, underlying rock and land cover. If there is a similar catchment nearby, it is a reasonable assumption that they will each 'lose' a similar proportion of flow to evapotranspiration and other losses and have a similar proportion 'left' to flow in the river. This should apply quite well to a mean annual flow and still apply to a lesser extent to the various values of exceedance flow.

2) b) Correlate the flow in Caaf Water with another catchment

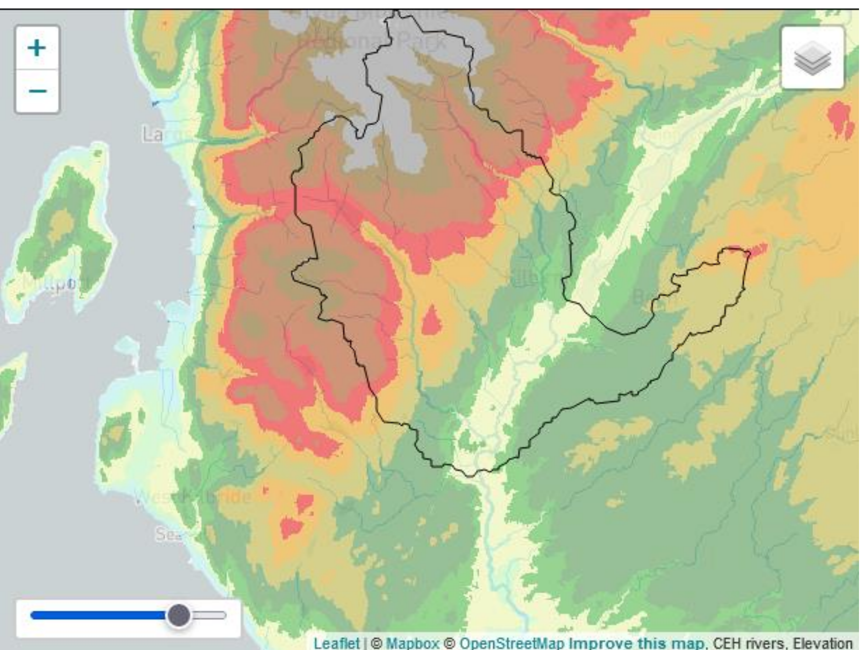
Elevation (IHDTM), mAS

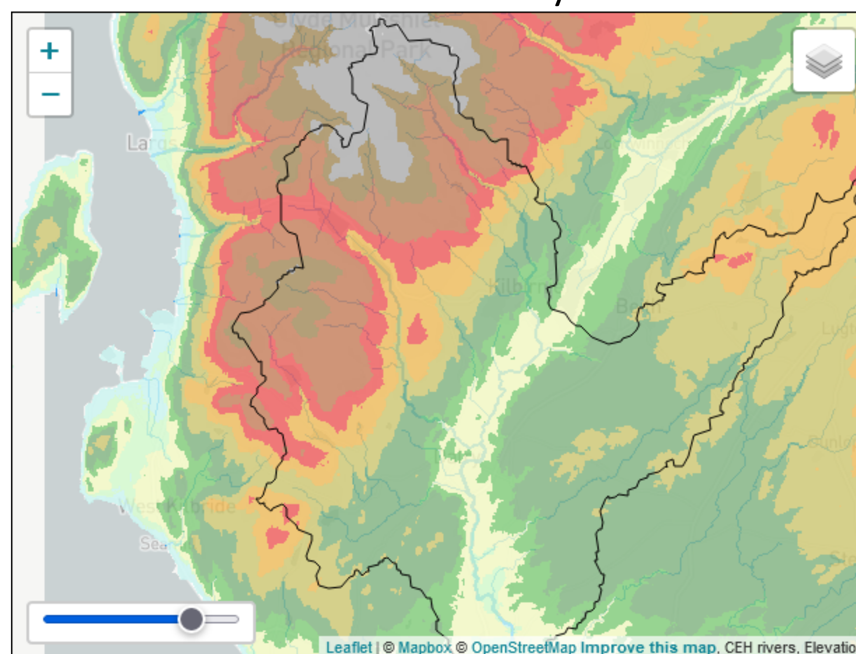
- -4.9 - 10
- 10.1 - 20
- 20.1 - 40
- 40.1 - 60
- 60.1 - 100
- 100.1 - 150
- 150.1 - 200
- 200.1 - 250
- 250.1 - 350
- 350.1 - 400
- 400.1 - 500
- 500.1 - 600
- 600.1 - 900
- 900.1 - 1,342.6

Dalry	Elevation (m AOD)	Kilwinning
21.4	Minimum altitude	4.4
520.4	Maximum altitude	520.4
45.1	10 percentile	39.0
183.4	50 percentile	111.3
393.3	90 percentile	352.9
94.9	Terrain Steepness: DPSBAR (m / km)	79.5

Terrain Steepness: DPSBAR: This landform descriptor (mean Drainage Path Slope) provides an index of overall catchment steepness.

values range from >300 in mountainous terrain to <25 in flat country





2) b) Correlate the flow in Caaf Water with another catchment

Dalry	Land Cover	Kilwinning
7.67%	Woodland	8.18%
0.29%	Arable / horticultural	0.69%
65.06%	Grassland	71.86%
21.24%	Mountain / Heath / Bog	13.62%
4.61%	Urban extent	4.55%
0.61	PROPWET:	0.61

Land Cover (LCM2000, aggregated

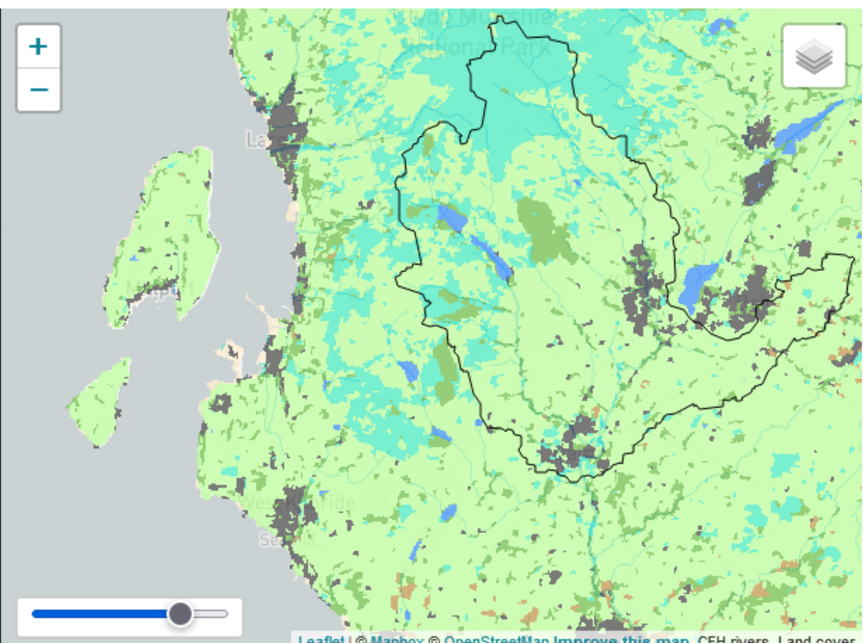
- Woodland
- Arable and Horticulture
- Grassland
- Mountain, Heath, Bog
- Water (inland, sea, estuary)
- Built-up areas
- Coastal

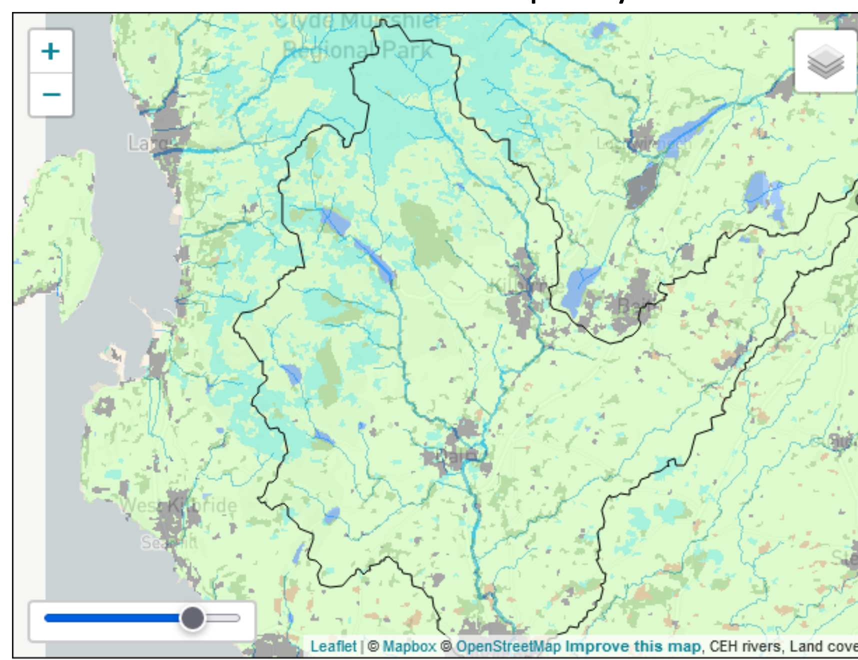
Soil Hydrology

PROPWET: a measure of the proportion of time that catchment soils are defined as wet

ranges from wettest at >80% to driest at ≤20%

Dry soils tend to absorb rainfall and delay runoff, wet soils have no capacity left





2) b) Correlate the flow in Caaf Water with another catchment

BGS Superficial geology (summary)

- Blown sand
- River terrace deposits (mainly sand and gravel)
- Raised beach and marine deposits
- Glacial sand and gravel
- Sand and gravel of uncertain age or origin
- Peat
- Lacustrine clays, silts, and sands
- Clay with flints
- Landslip
- Alluvium
- Till
- Brickearth

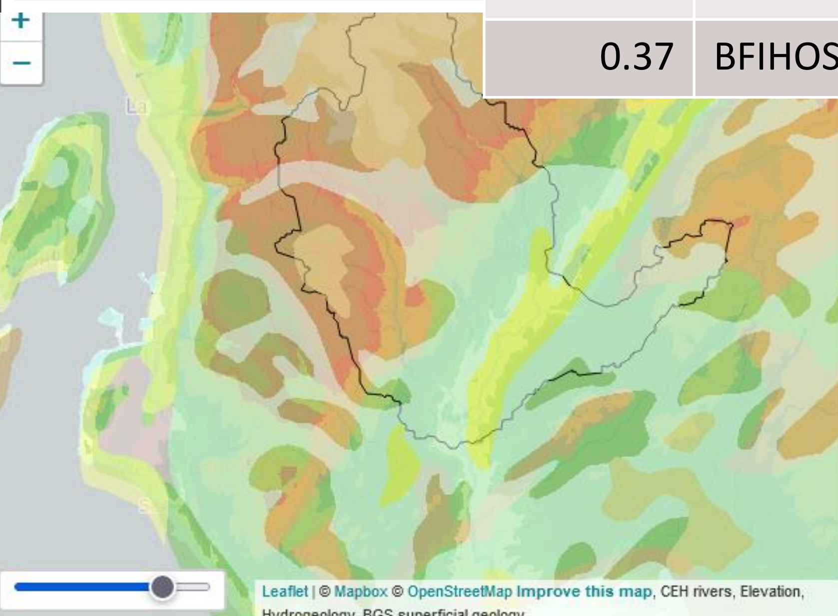
BGS Bedrock Hydrogeology (summary)

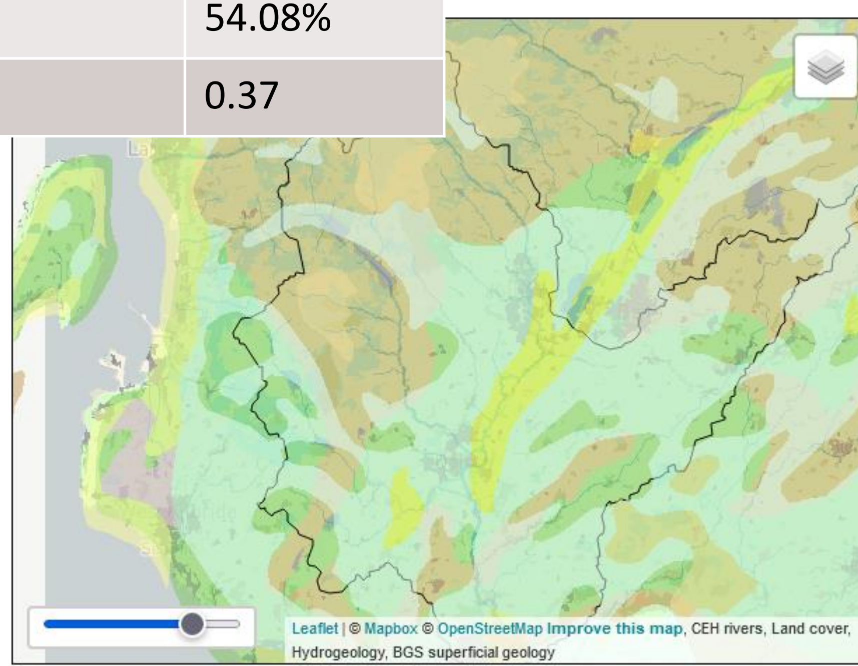
- High permeability (fissured)
- Moderate permeability (fissured)
- High permeability (intergranular)
- Moderate permeability (intergranular)
- Very low permeability
- Mixed permeability

Dalry	Geology: Bedrock Permeability	Kilwinning
41.17%	High	52.58%
0%	Moderate	0.91%
58.83%	Very Low	46.51%
0%	Mixed	0%
Dalry	**Superficial Permeability**	**Kilwinning**
0%	High	1.53%
16.56%	Low	8.84%
52.05%	Mixed	54.08%
0.37	BFIHOST:	0.37

Bedrock Hydrology

BFIHOST: a measure of the proportion of the river runoff that derives from stored sources





2) Correlate the flow in Caaf Water with another catchment

- b) Examine the topographic (land height), land use, and geology maps of the 2 catchments to guess which better represents the Caaf Water catchment.
  Give a brief explanation of your choice.

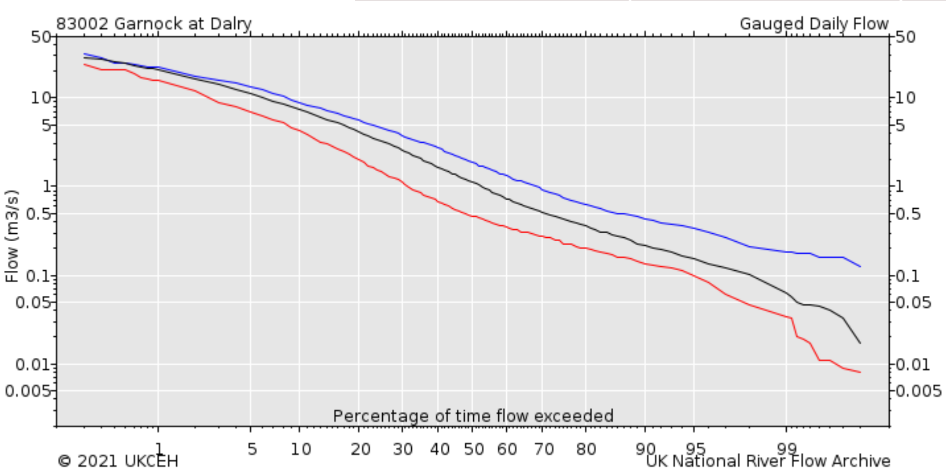
6 marks

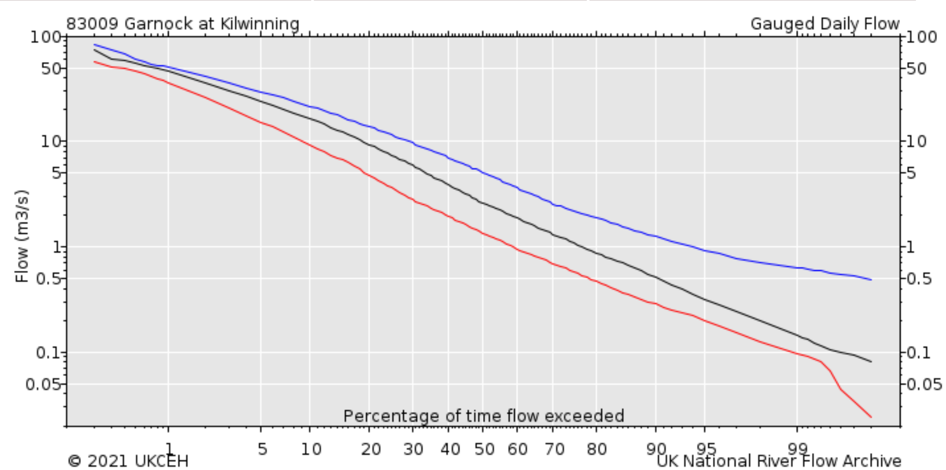
- Use the chosen data to adjust the Caaf Water gross estimate to give an estimate of its nett mean annual flow
- Also estimate Caaf Water's Q5, Q10, Q50, Q70 and Q95

2) b) Correlate the flow in Caaf Water with another catchment

	Dalry		Kilwinning	
Caaf Water Estimated Flow (m^3/s)	Gauged Flow (m^3/s)		Gauged Flow (m^3/s)	Caaf Water Estimated Flow (m^3/s)
	2.767	Mean	6.285	
	0.153	95% (Q95)	0.318	
	0.507	70% (Q70)	1.315	
	1.118	50% (Q50)	2.604	
	7.419	10% (Q10)	16.29	
	11.21	5% (Q5)	24.06	
	1963 - 1977	Period of Record	1978 - 2019	
	100%	Percent Complete	>99 %	

9 marks





3) Estimate the design flow for your hydro scheme

University of Strathclyde Engineering

a) The Water authority requires compensation flow equal to Q.95.

Estimate how much compensation flow is needed based on your estimated values for flow exceedance.

1 mark

Compensation flow = Q95 =

b) Decide what % of the time the scheme should be operated at full rated power and select your design flow accordingly.

Q?

What is the flow in the river at the chosen level of exceedance?

Calculate the Design (captured) flow based on your chosen level of exceedence

3 marks

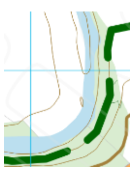
Design flow Qdes =

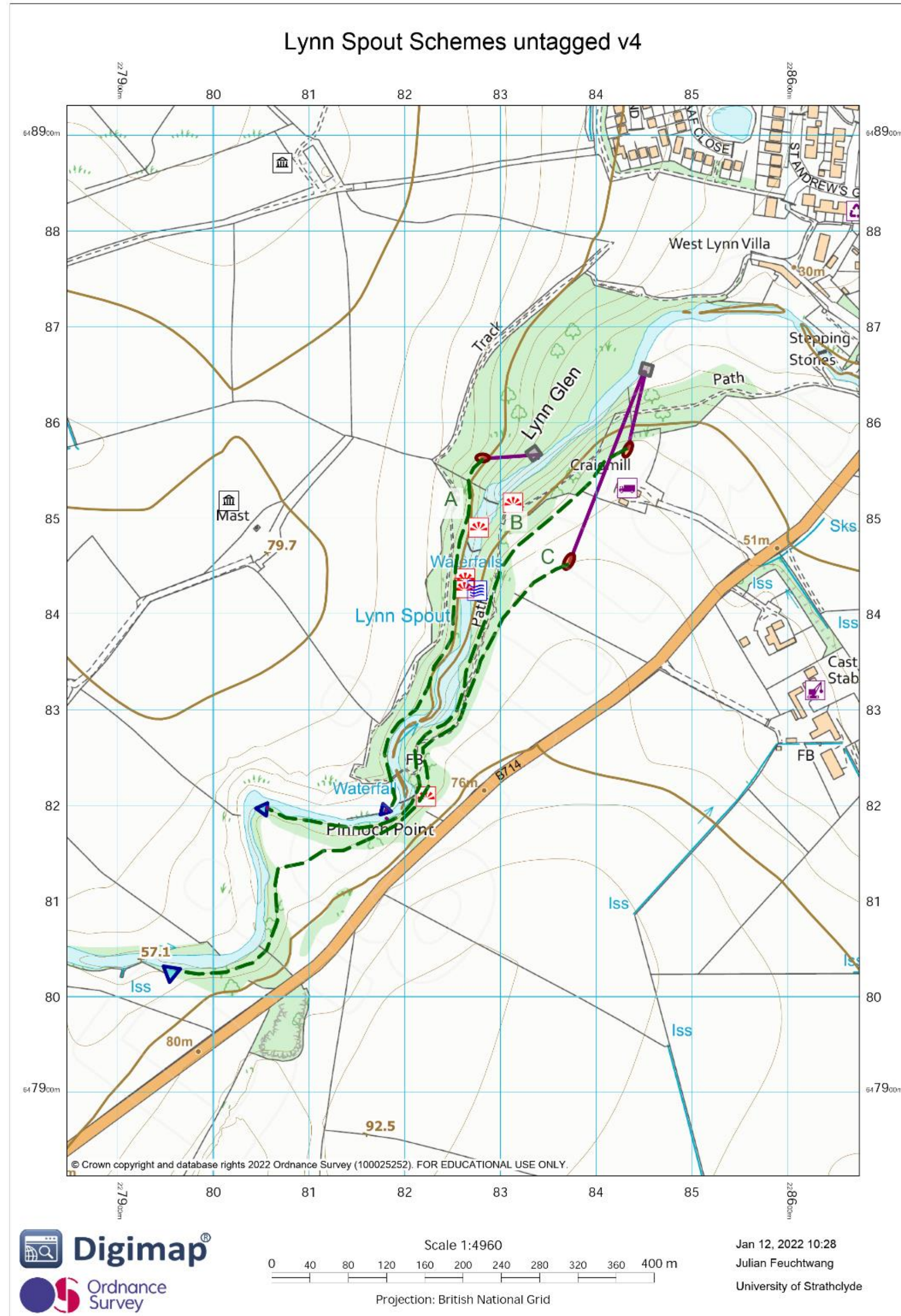
c) Justify your choice.

6 marks

4) Identify the key components of the scheme

a) Identify the key components of the schemes on the map





2.5 marks

4) Using the contour map, Estimate the gross head for the 3 proposed site layouts

b) Estimate dimensions:

Gross Head

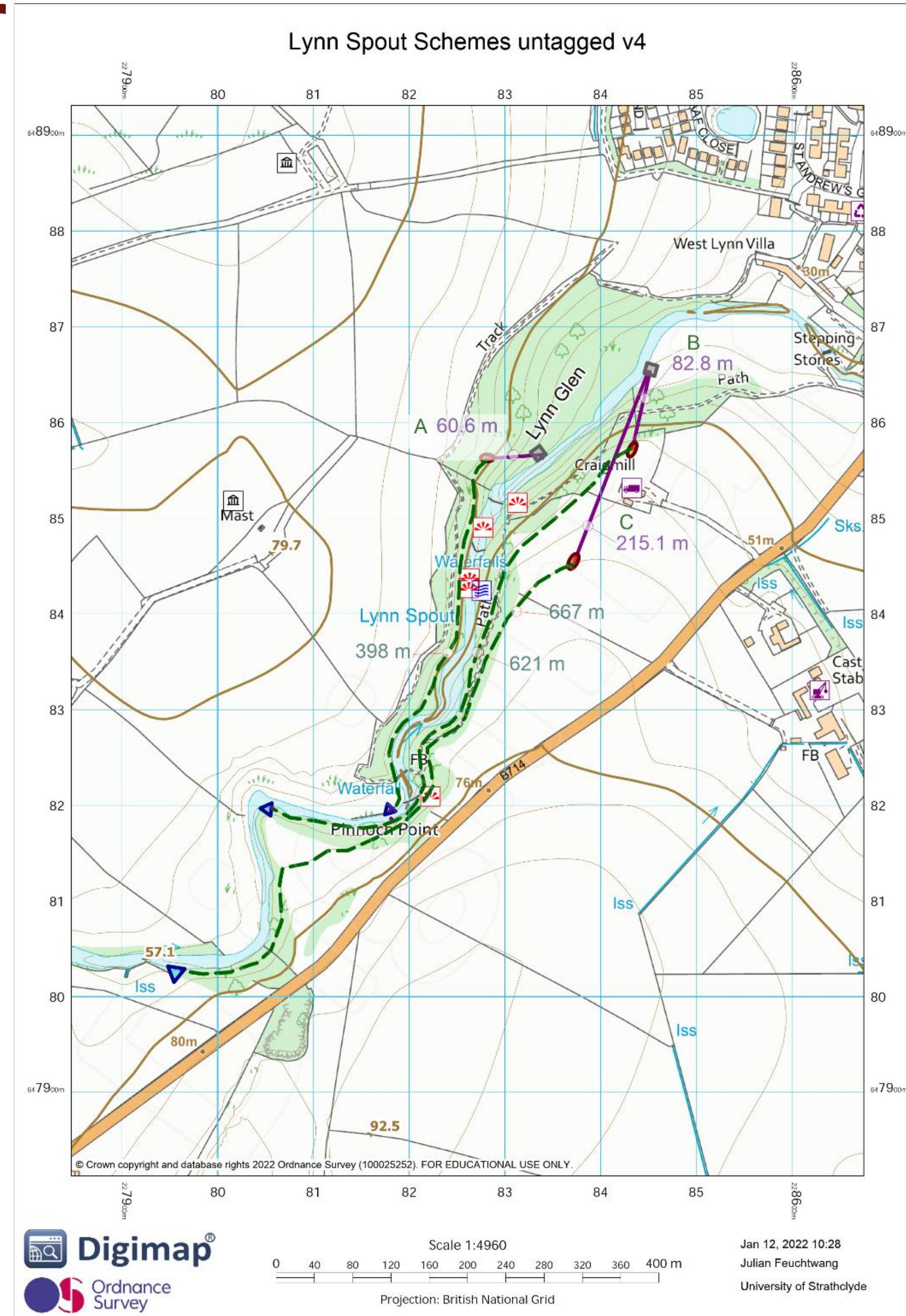
(5m contours):

A:

B:

C:

4.5 marks



- The relevant distances on the map have been estimated for you as well as the number and angle of bends

4) Estimate the head losses

c) Pick 1 of the 3 schemes (A, B or C).

d) Give its advantages and disadvantages compared to the other 2 schemes

e) Calculate the gross hydraulic power available

f) Calculate the pipe length needed

6 marks

5) Select a pipe diameter, Estimate head losses and available power and Select a Turbine Type

a) Select pipe diameter

b) & c) Flow Speed & Dynamic Head *3 marks*

d) Total head losses:

Nett head: *7 marks*

e) Calculate nett hydraulic power *2 marks*

f) Explain *3 marks*

6) Choose Gear/Speed Changer Ratio and Number of Pole-Pairs to set the turbine speed Select a Turbine Type

a) Choose Gear ratio

b) Choose Generator no. of pole pairs

c) Calculate Turbine speed
and thus Specific Speed

d) Select Turbine Type

Turbine speed is a **Design Choice** by choice of generator type and whether a mechanical speed changer is used and what ratio it provides. Of course every choice comes with cost and engineering implications.

e) Explain your choices

6 marks

7) Conclusions

- Comment on the viability of the scheme and any problems you foresee.

6 marks

MyPlace submission:

- Use the Excel spreadsheet provided or other methods for your calculations

- **You MUST UPLOAD either your spreadsheet or other evidence of working (eg Matlab code, scanned notebook)**
- **This represents ~ 7% of the overall marks**

- Enter calculated/estimated results into the pdf form
- Write short explanations where required

- **UPLOAD your answers in the pdf form**