Hydro and Wind Consultancy, Design & Installation

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Eckington Weir

Hydroelectric Power Scheme Feasibility Study

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Summary

The report summarises the Renewables First feasibility assessment of a hydroelectric power (HEP) scheme situated in the River Avon in Eckington, Pershore. The scheme would utilise the head across the Eckington Weir.

An Archimedean screw is the most suitable turbine technology and would be installed around the existing lock. The electrical generation could be exported to the grid and the system would operate in parallel with the grid.

The financial success of the scheme is dependent on the existing HEP scheme at the Eckington Weir not becoming operational.

The HEP scheme has the potential to achieve a peak power output of 13.7 kW per Archimedean screw. A 3-screw system has been determined to offer the best return on investment and has the potential to generate 228,000 kWh of electricity per year. This equates to a CO_2 emission saving of almost 42 tonnes/year.

The capital cost for a 3-screw system has been estimated to be £847k, giving a levelised cost of energy of £188/MWh.

Once funding is secured, the next step to progress with the scheme would be to carry out an outline design and secure all the relevant consents.

Table of Contents

1 Site Details and Resource

1.1 Introduction

This feasibility study has been commissioned by Rob Jackson with the intention of assessing the suitability of a community hydroelectric power (HEP) scheme near Eckington, Pershore.

The proposed hydroelectric scheme location is in the vicinity of the Eckington Weir. The scheme will utilise the head available across this weir.

The existing site layout is shown in Figure 1.

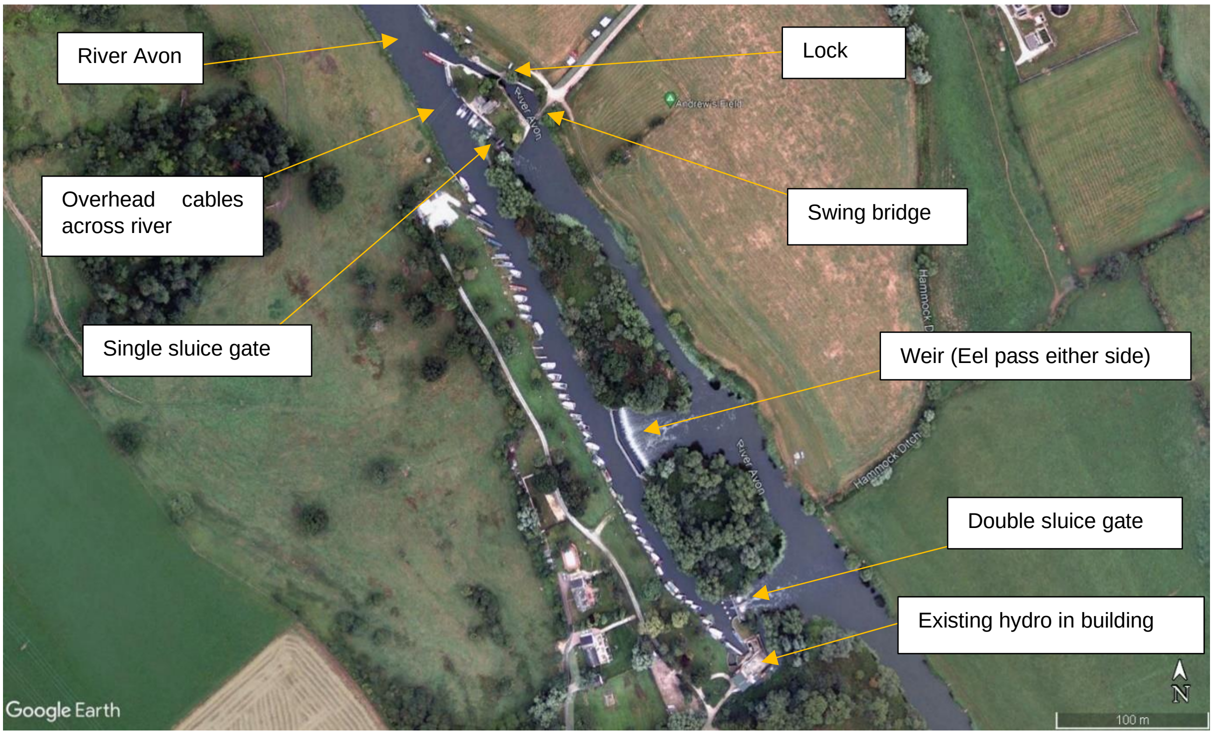


Figure 1. Site details.

1.2 Location

Site address	Mill Lane, Eckington, Pershore
Nearest postcode	WR10 3BQ
OS X (Eastings)	391532
OS Y (Northings)	240486
Lat (WGS84)	N52:03:46 (52.062684)
Long (WGS84)	W2:07:30 (-2.1249254)
Nat Grid	SO915404 / SO 91532 40486

1.3 Existing Infrastructure

The following pictures show the site as-is with relevant comments.

Figure 2. Swing bridge.

Figure 3. Single sluice.

Figure 4. Facing downstream from central land island.

Figure 5. Weir.

Figure 6. Eel pass on North side of weir.

Figure 7. Eel pass on South side of weir.

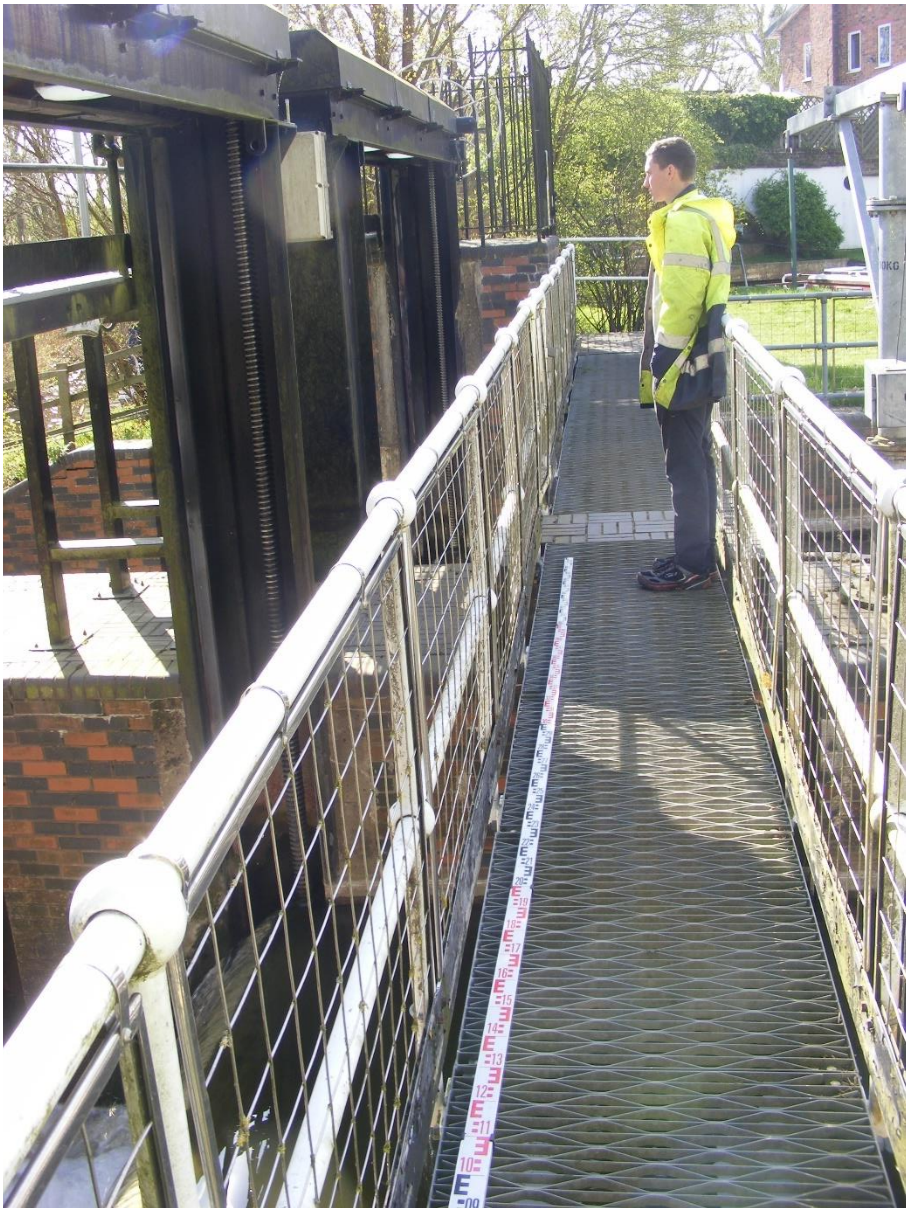


Figure 8. Double sluice gates (man facing downstream).

Figure 9. Double sluice gate (upstream side).

Figure 10. Existing hydroelectric scheme on downstream mill.

1.4 Gross Hydraulic Head

The gross hydraulic head, which is the difference in water levels across the two channels of the Avon River was measured across the lock on the 8th April 2021. The flow on the day was 10.15 m^3/s.

The net head (after hydraulic losses) is discussed below in the 'Proposed System Design' section.

Gross head (m)	Location
1.170	At the lock.

Table 1. Gross head data

1.5 Flow at the Site

The closest Environment Agency gauging station to the site is on the Avon at Bredon approximately 3 km downstream. However, the record set is very incomplete.

The next most applicable gauging station is on the Avon at Evesham, approximately 31 km upstream (see Table 2). The record set is much more complete. The gauging station at Evesham is much further away from the proposed site, so there is a greater possibility for abstraction and discharge between the locations. However, no obvious points of significant abstraction or discharge have been found. The Environment Agency notes the gauge matches spot readings accurately in medium to high flows but the error increases in low flows, due to difficulties in measuring low flow velocities.

For the energy modelling, the gauge data from Evesham has been extrapolated to find the flow at the proposed hydroelectric scheme site. The catchment area at the proposed hydroelectric scheme location is 2686 km^2, which is 121.5% of the catchment area at the Evesham gauging station. The daily average flow readings as measured at Evesham have been adjusted by 121.5% to allow for the larger catchment area at the HEP site. The daily flow readings from 2000 to 2019 have been used to generate the flow duration curve for the site (Figure 12).

The flowrates given in Table 3 represent the flowrates that are expected to be exceeded for a given percentage of time, based on past data. For example, the Q95 flowrate is the flowrate that is expected to be exceeded 95% of the time.

Figure 11. Satellite image showing location of gauging station in relation to proposed hydroelectric scheme location (Google Earth, 2022).

	Avon at Evesham
Station No.	54002
OS grid ref.	SP040437
Catchment Area	2210 km2
Base Flow Index	0.51
Mean flow rate	15.866 m3/s
Q95	2.97 m3/s
Station Type	Velocity-area
Sensitivity	15 %
Record Period	1936 - 2020

General Description
Velocity area station with gauge site can measure out-of-bank flows.

Hydrometric Description
Bed not stable with lots of silt that shifts; bed can move by up to 2m. Main control is Chadbury weir, sluices and lock approx. 4.5km downstream. Earlier in record gaugings were taken at Hampton Parks cableway 2.5km downstream, below confluence with River Isbourne. Gaugings taken at the same day at Hinton were subtracted from this to estimate flow at Evesham. There have been some errors found in these calculations for the earlier gaugings. Now majority of gaugings taken just downstream of the Evesham Workman Bridge above confluence with River Isbourne. Navigation control at lock downstream. Low flow velocities can make gauging difficult. Ratings fit spot gaugings very well including at medium to high flows above bankfull. Coarse early low flow record owing to crude rating. Gauging site/s can measure out-of-bank flows.

Flow Regime Description
Extensive modification to flow regime from abstractions and returns. At low flows influenced by navigation - reach is impounded with locking.

Table 2. Copy of Environmental Agency gauging station notes.

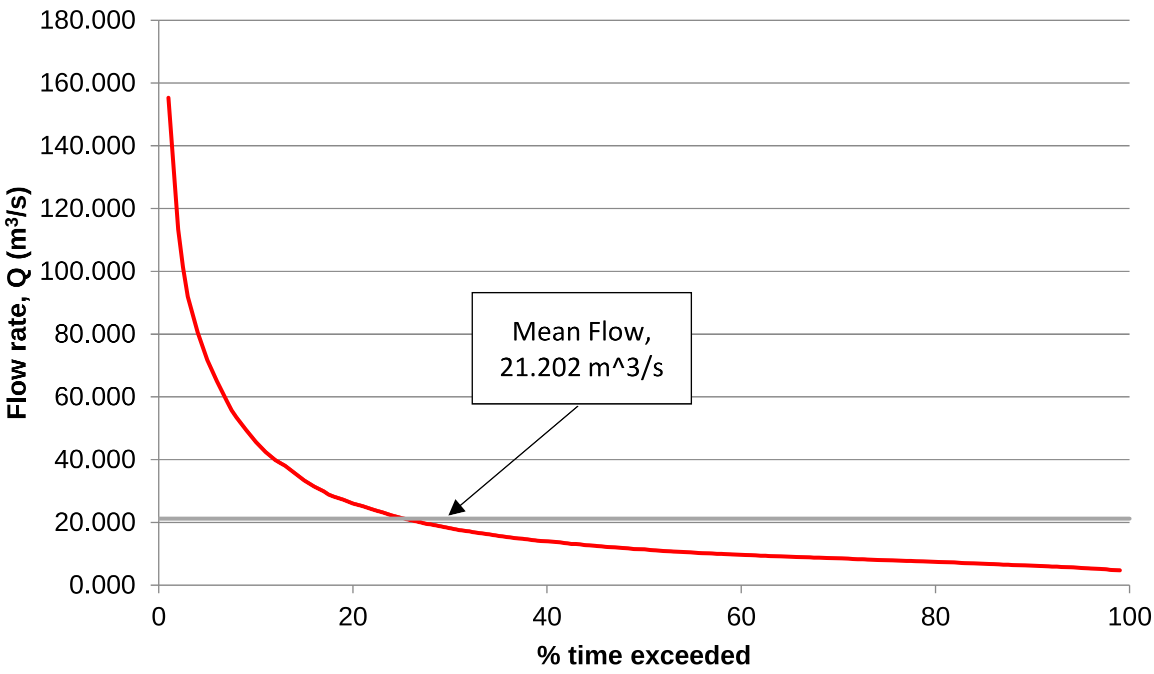


Figure 12. The flow duration curve at the proposed hydroelectric scheme location.

Flow Exceedance %	Gross Flowrate m^3/s
Q_{10}	45.628
Q_{20}	26.004
Q_{30}	18.179
Q_{40}	13.965
Q_{50}	11.389
Q_{60}	9.679
Q_{70}	8.536
Q_{80}	7.428
Q_{90}	6.200
Q_{95}	5.538
Qmean (Q28.2)	21.202

Table 3. Flow exceedance at the proposed hydroelectric scheme location.

1.6 Environmental Designations

The site has been checked for environmental designations that could affect the construction of a hydroelectric scheme, no relevant designations were found.

The Environment Agency (EA) has put the site in a nitrate vulnerable zone. In regards to the proposed hydroelectric scheme, nitrates could corrode the turbine, causing pitting or cracking to carbon steel and solder joints. At 50 mg/l corrosion is minimal, but as the nitrate concentration level approaches 100 mg/l, corrosion is more significant. Corrosion will just generally degrade turbine efficiency and reduce its service life. The turbine could be made from stainless steel to mitigate the risk, but this has a significant cost implication.

If the scheme goes forward, nitrate concentration levels should be requested from the EA or the river water should be tested and then the results passed to the turbine manufacturer for comment.

The proposed HEP scheme is within 3 km of various Sites of Special Scientific Interest (SSSI). The SSSI impact zone can be used by local planning authorities to consider whether a proposed development is likely to affect a SSSI and determine whether they will need to consult Natural England to seek advice on the nature of any potential SSSI impacts and how they might be avoided or mitigated. This means the planning process may involve submission of an ecology report, a risk and mitigation construction method statement and answering queries from Natural England.

The abstraction sensitivity band is 2 (Avon conf Workman Br, Evesham to conf R Severn, GB109054044403).

Statutory
Nitrate vulnerable zone (areas designated as being at risk from agricultural nitrate pollution). SSSI Impact Risk Zone (Rectory Farm Meadows, Upham Meadow and Summer Leasow).
Historic Statutory:
None

Table 4. Environmental Designations

1.7 Grid Infrastructure

The electricity network at the site is shown in 'Appendix A – Relevant DNO Network Maps'. The central land islands are connected to the grid at the most northern and southern points. There is a high voltage (HV) 11 kV overhead line that goes over the River Avon from the south west direction to supply the buildings near the lock. There is also an HV 11 kV cable approximately 360 m east of the site at what appears to be a treatment works.

Low voltage (LV) overhead lines run to the existing hydroelectric scheme at the southern end. There are no lines or cables within the two central islands.

1.8 Access

Both sides of the River Avon have good access. To access the site from the North side of the Avon (by Andrew's Field) requires an approximately 10.5 mile drive from Junction 1 of the M50. The route follows some A roads and B roads before reaching Mill Lane (slightly narrow), which leads to the site. There are no low underpasses or weak bridges along the route that would deny access.

The Southern side of the Avon at the location of the site (Strensham Mill Moorings) is approximately 3.6 miles from Junction 1 of the M50. The route along Brockeridge Road, Hill End Road, and Mill Lane does not include low underpasses or weak bridges.

If the proposed hydroelectric scheme is located on one of the islands, a large crane and ground reinforcement may be required to lift plant into position and a temporary floating pontoon may be required to get plant and materials onsite. Overhead cables and tress would have to be avoided or trimmed back to aid lifting operations.

2 Proposed Hydroelectric Scheme

2.1 Layout and General Specification

The proposed hydroelectric scheme should be located where it can make best use of the available head. This would be somewhere along the blue dotted line on Figure 12, parallel to the lock, weir, and sluice gates. Developing a scheme on the central islands introduces construction risk and uncertainty, and is more difficult to access, which results in a higher construction price. So, it would be more cost effective and less risky to develop on the bank side. A potential hydro scheme location on the bank has been identified. It has good access and can be connected to the grid. The land is also owned by Rob Jackson.

A new channel would need to be excavated into the river bank around the lock, to allow flow to pass through the hydro scheme, and back into the river. To minimise head losses as the water passes through the hydropower turbine, the water velocity in the intake and outfall is usually designed to be around 0.5 m/s. This would make it safe and easy for boats to pass the intake and outfall without been drawn into the intake or pushed off course from the outfall. The existing lock quay would be moved to the to the other side of the lock so boat owners can continue to access the lock mechanisms.

The proposed hydroelectric scheme location would have good access from Mill Lane to Andrew's Field, and would be able to connect to the grid either to the 11kV overhead on the lock island or from the structure in the top right corner of Figure 13 where there are HV cables.

The existing hydroelectric scheme, presently non-operational, was granted an Abstraction Licence from the Environment Agency. Therefore, this proposed scheme runs the risk of having its effective 'hands off' flow significantly increased if the existing scheme is redeveloped. This is discussed in section 2.2.2.

Figure 13. Map of site showing two proposed hydro scheme locations.

2.2 System Flow Rate Considerations

The maximum flow rate through a hydroelectric scheme is normally the maximum flow available that the Environment Agency would allow. The site will be categorised by the Environment Agency as an abstraction because the water is diverted just upstream of the lock through the scheme and then back to river just downstream of the lock. For this type of abstraction layout, the Environment Agency's normal guidance advices a maximum abstraction of 1.3 x Q_{mean}. For this site, the maximum abstraction would be 27.56 m^3/s.

However, since the head is so low, this limits the size of turbine that can be installed and the flow that can physically pass through each turbine. Therefore, it is difficult to design a scheme that will be able to utilise all the available flow.

2.2.1 'Hands off' Flow

The 'hands off' flow is the flow in any depleted river section. A depleted river section is any stretch of river which sees a smaller flow than the natural river flow because water has been diverted elsewhere, such as through a hydroelectric scheme.

Hydroelectric schemes that divert water away from the natural river course have a depleted section between the intake and the point where the water is returned to the river. Such sites usually require a flow down the depleted river section to maintain the fish passage, ecological connectivity and changing sediment transport.

The depleted reach at the site is across the weir. The Environment Agency guidance recommends a Q95 reserve flow (5.54 m^3/s) for this river. If it can be shown the weir pools are of little ecological importance it could be possible to reduce this further.

Another consideration is navigation. As the river is used to navigate boats along, a minimum water level is usually maintained and this will require a minimum flow over the weir.

2.2.2 Other Flow Considerations

Structural features where water can flow over the head differential of the river will affect the available flow at the hydro scheme. Some considerations are below.

Locking:

When a boat passes through the lock, the lock will need to fill up in order to help the boat across the difference in water level. This is known as a locking. To fill the locking chamber requires approximately 119 m^3 and probably takes somewhere between 0.2 m^3 to 0.4 m^3 of flow over a period of 5 to 10 minutes depending upon how much the boat owner opens the lock paddles. This will have negligible effect on the energy yield.

The lock gates and paddles do not have a watertight seal, so there will be some leakage. 0.1 m^3/s leakage allowance has therefore been included in our energy yield modelling.

Existing hydroelectric scheme:

The existing hydroelectric scheme isn’t operational at the moment, but if it were to be reinstated it would significantly affect the energy production of the proposed hydroelectric scheme. The existing hydroelectric scheme had a rated power of 50 kW. This gives us an indication of the scheme’s rated flow, which has been estimated to be 6.92 m^3/s based on a 70% turbine efficiency.

Sluice:

Ideally the sluice gates would be kept closed, to maximise the available flow for the hydro scheme. We have assumed the gates are closed and leakage is negligible in the energy yield modelling.

In practice the sluice gates would need to be opened to prevent flooding and so ideally would need to be integrated and controlled automatically by the proposed hydroelectric scheme. The single sluice gate (Eckington Sluice) and the double sluice gate (Strensham Sluice) are owned by the Environment Agency (EA) and look to be automated. We recommend that if the proposed hydroelectric scheme is progressed an agreement is made with the EA over the control of the gates. It is possible to link the proposed hydroelectric scheme’s control system up to the EA’s control system so that the gates allow optimal operation of the proposed hydroelectric scheme.

Figure 14 Sluice signing by EA

2.2.3 Fish and Eel Pass Flow Rates

The site is located over 30 km from the nearest estuary. As the river flows from the site to the estuary, it passes through a number of fish / eel obstructions (weirs, gates etc.). Migratory fish are unlikely to reach the site. Eels are sometimes able to overcome obstacles by crawling on land. Generally, eel numbers decrease exponentially with distance from the estuary. Eels also tend to be older and larger as the distance increases. When the Environment Agency is assessing the site, they will take these considerations into account and will also check if the proposed hydroelectric scheme impacts existing fish and eel passage. It would be helpful in the consenting process if a fish and eel pass was incorporated into the scheme or a provision made (e.g. a spare channel so that the EA could install one at a later date if they wish).

The fish and eel pass will allow some flow of water, so this must be taken into account when modelling the scheme's energy yield. 5% of the turbine rated flow has been assumed for the fish pass flow. Nominal flow in the eel pass is approximately 0.5 l/s, so is negligible.

System maximum flow rate	27.56 m^3/s
Turbine rated flow rate per screw	1.860 m^3/s

Table 5. System maximum flow rate.

Hands Off Flow Rate	5.54 m^3/s
Lock and Sluice Gate Leakage	0.10 m^3/s
Fish Pass	5% of total hydroelectric scheme flow rate
Eel Pass	0.0005 m^3/s
Existing hydroelectric scheme (if operating)	6.92 m^3/s

Table 6. Estimated reserve flow rate.

2.3 System Design Head Considerations

The gross head was measured and found to be 1.170 metres. The net head, which is the head the proposed hydroelectric scheme would 'see' to generate energy is less due to frictional and turbulent head losses as the water flows through the scheme. With good design the head loss on an Archimedean screw scheme would be less than 5%.

In the energy yield modelling, we have made assumptions on how the downstream water level would back up or increase as the flow increases. As it's a low head site, a small change in head represents a large variation in power output and so we recommend level loggers are installed to confirm exactly how the water level changes with flow.

The gross head was measured on the 8th April 2021 with a river rate of 10.15 m^3/s. When the river is at its mean flow of 21.20 m^3/s, the head at the scheme would be slightly lower. The gross head at mean flow has been estimated to be 1.106 metres. Assuming 5% head loss, the net head at the rated flow of the turbine has been assumed to be 1.051m.

Gross Head (m)	Net Head (m)
1.106	1.051

Table 7. Gross and net head assumptions.

2.4 Turbine and Related Hardware

A typical Archimedean screw scheme is shown in Figure 15. It is able to discharge a large proportion of flow whilst allowing safe fish passage and therefore avoiding large fine intake screens. The water enters the screw at the top and the weight of the water pushes on the helical flights, allowing the water to fall to the lower level and causing the screw to rotate. This rotational energy can then be extracted by an electrical generator connected to the main shaft of the screw.

The most appropriate size of turbine for a particular site depends on the flow and head characteristics of the site. A correctly sized turbine will produce the highest annual energy capture (measured in kWh) and is a compromise between making best use of higher winter flows while still having a system that can operate on lower flows during drier parts of the year.

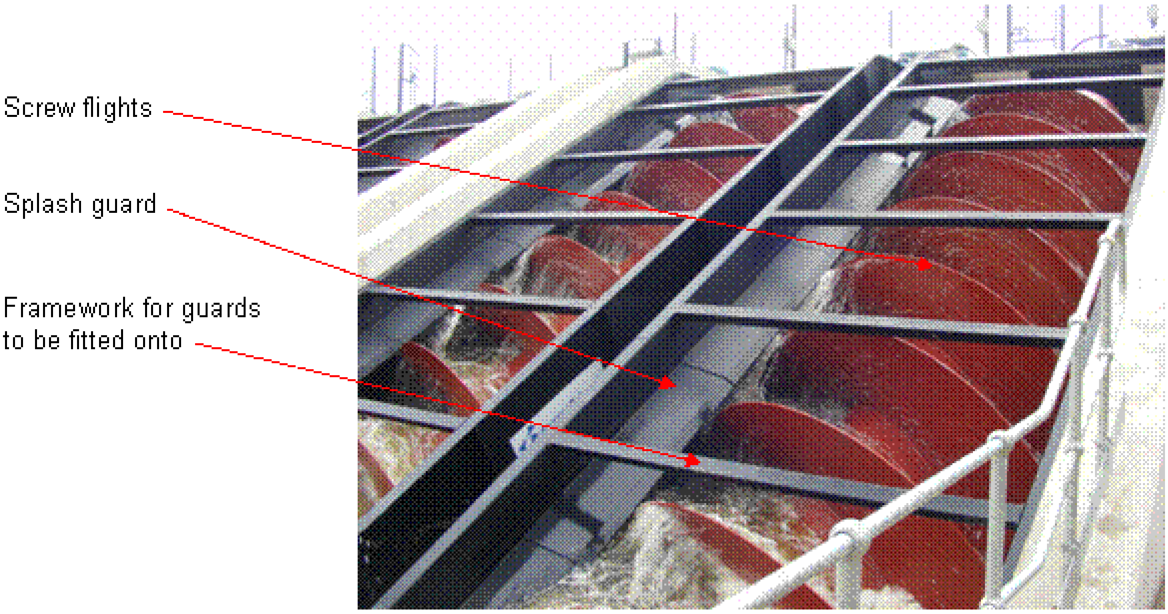


Figure 15. Archimedean Screw scheme.

2.5 Screening and Debris Handling

A significant advantage of an Archimedean Screw is their safe fish passage ability. Due to the relatively large dimensions of the screw's flights and slow rotational speed, fish and eels can pass safely through the screw, providing the blades are fitted with fish bumpers. This means that fine screens and specific approach velocities are not required and a smaller coarse screen can be used. This leads to relatively modest amounts of debris build-up on the course screen and removes the requirement for (expensive) automatic intake screen cleaners which are normally required on larger low-head hydroelectric schemes.

2.6 Power Output and Energy Capture

Assuming a water to wire efficiency of 74%, the hydro system could have a maximum power output of 13.7 kW per turbine. Using the site characteristics, the system has been modelled using an Archimedes screw VSD turbine. Table 8 summarises the performance of a 2, 3 and 4 screw system, assuming the existing hydro system is no longer operational.

If the existing HEP system is operating, it is assumed that the hands-off flow will be increased by the flow through the system. The system performance with the existing HEP operating is shown in Table 9. With the existing HEP system operating, the annual energy capture is reduced to less than half that without the existing HEP system.

Site Parameters - Fixed					
Mean Flow (Q_{mean})	21.202				*m^3s^{-1}*
Q_{95}/Q_{mean}	0.26				
Gross Head at System Rated Flow	1.106				*m*
Net Head at System Rated Flow	1.051				*m*
System Parameters - Variable					
Turbine Type	Archimedes Screw VSD				
Turbine Rated Flow	1.86	3.72	5.58	7.44	*m^3s^{-1}*
Water to Wire Efficiency	74%	74%	74%	74%	
Rated Electrical Power Output	13.7	27.4	41.1	54.9	*kW*
System Downtime	10	10	10	10	*days*
Maximum Hourly Abstraction	6,696	13,392	20,088	26,784	*m^3*
Maximum Daily Abstraction	160,704	321,408	482,112	642,816	*m^3*
Annual Abstraction	24,201,520	90,715,462	121,637,063	146,856,500	*m^3*
Energy Capture					
Annual Energy Capture	96,889	172,727	228,176	269,842	*kWh /year*
CO_{2e} emissions savings	17,622	31,416	41,501	49,079	*kg CO_{2e} /year*
UK homes powered	22	39	52	62	*homes*

Table 8. Archimedes screw modelled system performance summary (existing hydro not operational).

Site Parameters - Fixed					
Mean Flow (Q_{mean})	21.202				*m^3s^{-1}*
Q_{95}/Q_{mean}	0.26				
Gross Head at System Rated Flow	1.106				*m*
Net Head at System Rated Flow	1.051				*m*
System Parameters - Variable					
Turbine Type	Archimedes Screw VSD				
Turbine Rated Flow	1.86	3.72	5.58	7.44	*m^3s^{-1}*
Water to Wire Efficiency	74%	74%	74%	74%	
Rated Electrical Power Output	13.7	27.4	41.1	54.9	*kW*
System Downtime	10	10	10	10	*days*
Maximum Hourly Abstraction	6,696	13,392	20,088	26,784	*m^3*
Maximum Daily Abstraction	160,704	321,408	482,112	642,816	*m^3*
Annual Abstraction	24,201,520	44,892,724	62,921,941	78,861,133	*m^3*
Energy Capture					
Annual Energy Capture	42,496	77,517	106,604	131,092	*kWh /year*
CO_{2e} emissions savings	7,729	14,098	19,389	23,843	*kg CO_{2e} /year*
UK homes powered	10	18	24	30	*homes*

Table 9. Archimedes screw modelled system performance summary (existing hydro operational).

The modelling above is based on long-term flow data, it would be for an 'average flow' year. There can be significant differences between years and wetter and dryer periods, with wetter years generating more energy and dryer years less. For example, with reference to Figure 16 below, 2008 was a wet year and a 3-screw scheme would have generated about 314,000 kWh over the year. 2011 was a dry year and the scheme would have generated about 134,000 kWh over the year. Overall, the values provided above would be reasonable for the long-term average.

There is also seasonal variation, with higher generation occurring over the wetter winter months (see Figure 17).

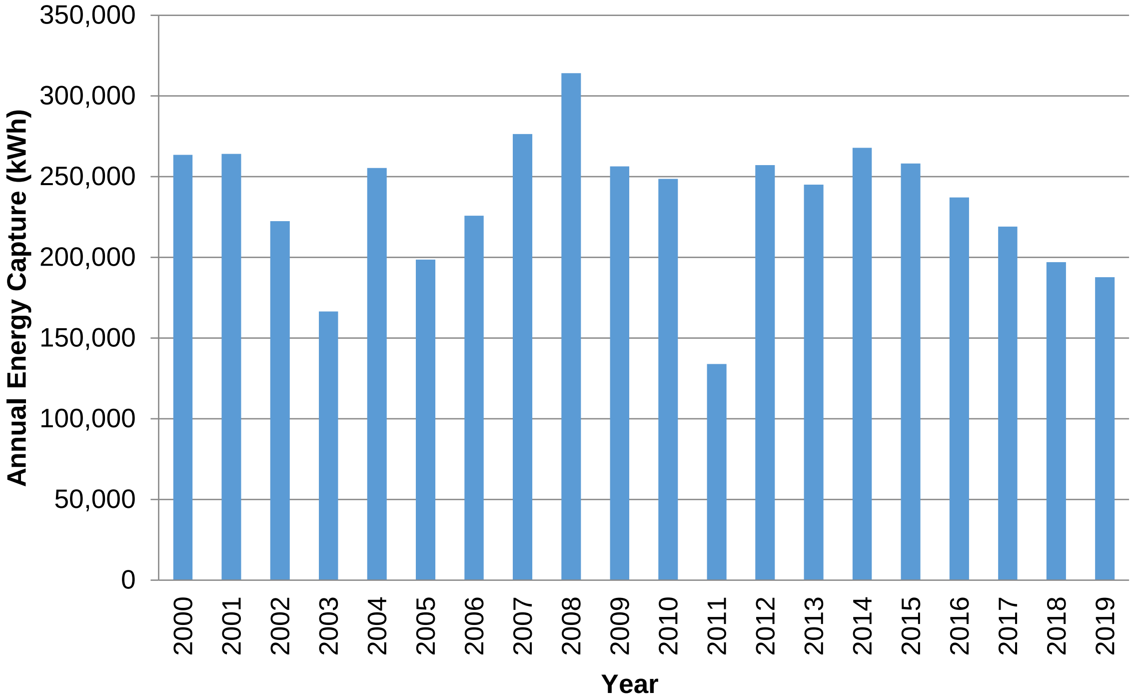


Figure 16. Annual energy capture year-on-year for a 3-screw system without the existing hydro system operating.

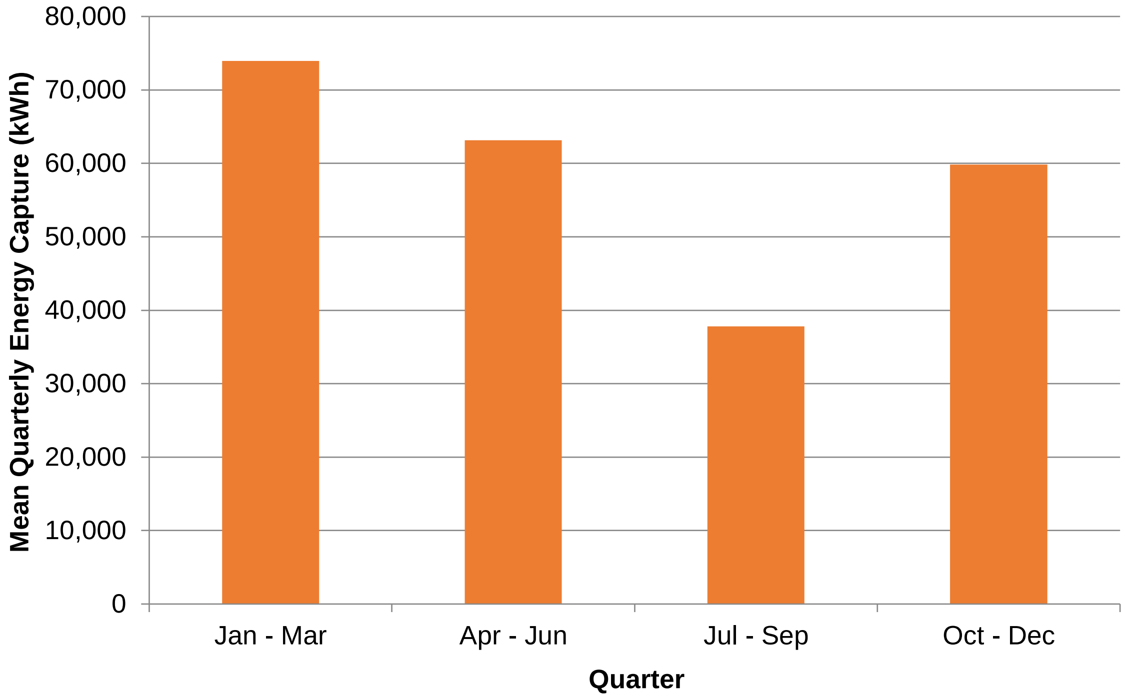


Figure 17. Mean quarterly energy capture for a 3-screw system without the existing hydro system operating.

2.7 Electrics and Grid Connection

2.7.1 Generator

The hydro system is assumed to use an asynchronous (induction) generator, which is basically a standard three-phase motor which is rotated just above synchronous speed (grid frequency 50 Hz) so it generates rather than consumes power.

2.7.2 Control System

The control system manages the turbine and generator so that they operate within the limits specified by the environmental consents and technical design. It also controls the system during start-up and grid-connection. At each site, the system is tailored to maximise energy production whilst maintaining the upstream water level and 'Hands-off-Flow' requirements. The control system also protects mechanical and electrical components from overload.

The control system adjusts the flow rate through the turbine based on the upstream water level. A falling upstream water level will cause the flow through the turbine to be reduced to allow it to recover and vice versa. The level is monitored constantly so that the upstream water level is effectively maintained at a constant level up to the turbine maximum flow rate, at which point the upstream level will increase and the surplus flow will flow over the weir, as it does now. The flow would be controlled by either adjusting the rotation speed of the screw or the sluice gate.

2.7.3 Grid Connection

The output from the generator is metered at the total generation meter, which records everything that is generated. This is then connected into the site distribution board in the same way that a load is connected. The power fed to the distribution board will feed any local loads first and any excess power will be exported to the grid and metered as an export on the import/export meter. If there is insufficient power from the generator to meet local loads, the additional power needed would be imported from the grid and metered as an import on the import/export meter. The diagram below shows a schematic of a typical grid connection arrangement.

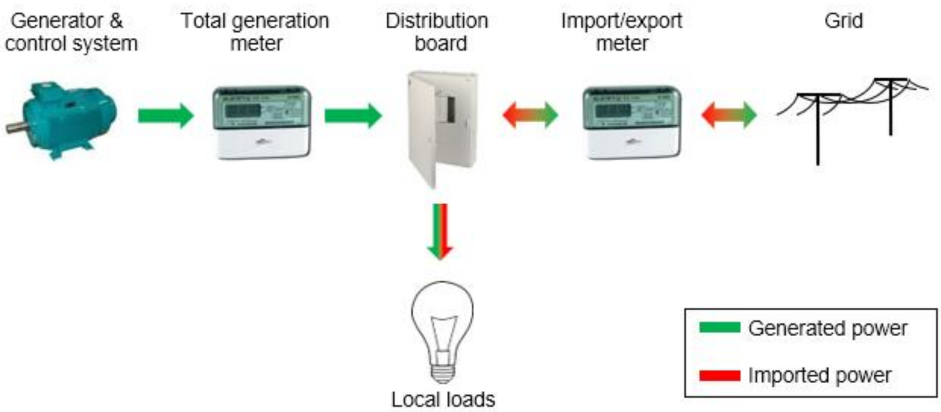


Figure 18. Typical generator grid connection arrangement.

At Eckington there are two possible connection points, both are 11 kV. The first is an overhead cable on the lock island and runs over the river. In order to connect to the proposed hydroelectric scheme location there will need to be a cable running over the lock (taking into account the height of boats) to a pole mounted transformer to 3 phase 400 V AC for the hydro scheme. The alternative is to run the cable through the lock. The second possible connection point is slightly further away (about 360 m East); however, it is on the correct side of the river and could be connected with a long cable running through a trench, and to a transformer. When applying to the DNO, they will assess the available capacity in the grid which may decide the connection point.

Included in the control system is a protection relay designed to meet the grid connection rules. A scheme of this size would fall under the Engineering Recommendation (EREC) G99 grid connection rules, relating to the connection of embedded generators in parallel with public distribution networks.

The site would need permission from the Distribution Network Operator (DNO) to connect the hydro generator.

2.8 Planning, Legal and Environmental Licenses and Permissions

An Abstraction License would be required to pass the water through the turbine. It should be noted that no annual charge is levied by the Environment Agency for water abstracted for hydroelectric schemes of this size.

Any Environment Agency license would almost certainly include a maximum bar-spacing for the intake screen to prevent the ingestion of fish. The Environment Agency recognises an Archimedean screw as fish friendly providing fish bumpers are fitted and would allow 100 mm to 150 mm bar spacing.

A flood risk activity permit (FRAP) may be required from the Environment Agency before construction could commence.

Planning permission is required. Planning permission concerns and requirements are usually based around visual aspects, noise impacts, and the issues already mentioned for abstraction licensing. Hydropower, as a renewable technology, has a very positive place in terms of planning policy, and therefore it is considered that this proposal may be acceptable, provided that disturbance to historic fabric is minimised and where necessary is carried out in a sympathetic way. For this reason, it is suggested that any application at Eckington will be supported.

3 Cost Estimates, Benefits and Returns

3.1 Capital Cost Estimates

The costs below are estimates, based on experience of real installations. They assume the system would operate in parallel with the grid. Firmer costs would be produced during the detailed design stage.

Description	Price (1-screw)	Price (2-screw)	Price (3-screw)	Price (4-screw)
Outline Design	£5,700	£6,300	£7,000	£7,600
Environmental Consents	£16,000	£16,800	£17,600	£19,100
Planning Consents	£3,400	£3,700	£4,100	£4,400
Grid Connection Permission	£600	£700	£800	£900
Construction Design	£17,500	£19,500	£20,500	£22,500
Ground Investigation Works	£11,000	£11,000	£11,000	£11,000
DNO Grid Connection Works	£11,000	£11,000	£13,000	£15,000
Generating Equipment Supply	£109,000	£217,000	£325,000	£433,000
Civils Construction	£250,000	£331,000	£413,000	£494,000
Installation	£25,000	£30,000	£35,000	£40,000
Total	**£449,200**	**£647,000**	**£847,000**	**£1,047,500**

Table 10. Estimated cost for 1, 2, 3 and 4-screw options.

3.2 Annual Operating Costs

The maintenance cost in Table 11 allows for a service visit every year by Renewables First, though this could be by any competent local agricultural mechanic. It also includes day-to-day monitoring by Renewables First. If the client undertook this task themselves, the cost should still be allowed for. The on-site support is for checking and minor works that would be required, and is based on 1 hour per week at £30/hr.

Description	Price (1-screw)	Price (2-screw)	Price (3-screw)	Price (4-screw)
Spare parts	£ 1900	£ 3400	£ 5000	£ 6600
Day-to-day monitoring	£ 2,100	£ 2,100	£ 2,100	£ 2,100
On-site support	£ 1,560	£ 1,560	£ 1,560	£ 1,560
Annual service	£ 600	£ 600	£ 600	£ 600
Total	**£ 6160**	**£ 7660**	**£ 9260**	**£ 10860**

Table 11. Annual operating costs.

3.3 Benefits and Return on Investments

3.3.1 Potential Revenue Streams

Standard export tariffs with energy suppliers (generally under the Smart Export Guarantee) offer a relatively low export rate (7.5p/kWh or less).

Power purchase agreements (PPAs) are one way of obtaining a good export rate. With a PPA, an agreement is made between an electricity generator and an electricity purchaser to purchase all their excess generation for a fixed period. There are various companies that will offer PPAs for small generators and community schemes. Good Energy and Younity are two such companies. A recent offer from Good Energy for a 50kW HEP scheme provided an export rate of 30p/kWh.

A private wire agreement is another option for generating income for a scheme. With private wire, the HEP scheme would be connected directly to a large energy user. The scheme is therefore connected to the national grid via the energy user. As there must be single point of connection to the grid, private wire agreements are generally made with a single large energy user. There is no fixed form for a private wire agreement, but the export rate would generally be set slightly below the import rate that the user is currently paying and would be reviewed annually. Business import rates are currently around 35p/kWh, so a private wire agreement may offer a rate of around 30p/kWh. Strensham Water Treatment Works is the nearest large user at around 0.7km away. This site is likely to be able to make use of any energy generation. However, an agreement with a utility company such is this is unlikely as they will have an existing large energy contract. The cost of the cable installation between the sites may also be prohibitive.

Electric vehicle charging in Eckington village would provide a service to the village as well as a revenue source. The rate charged by commercial rapid charging stations is between 30p/kWh and 70p/kWh. However, the rate charged within the village may need to be on the lower end of this to offer an advantage to residents over charging at home. Any EV charging stations would also be best placed within the village to ensure maximum usage. There would be a significant increase in the capital cost for the scheme to run a cable 0.9 kilometres to the village and to install a commercial charging station. The cost to run the cable and install a single 22 kW charging station would be in the order of £50k. This excludes the cost to compensate the land owners for running the cable across their land and acquiring the land on which to install the charging station. The government grant for EV charging stations currently only offers up to £350 per charger.

In order to ensure the EV charging stations are always available to users, electricity would need to be imported when the HEP system is at low power. Alternatively, battery storage could be installed with the charging station. This would increase the capital cost of the EV charger, but would allow more of the generated electricity to be utilised locally.

3.3.2 *Annual Revenue*

The annual revenue shown in Table 12 is based on obtaining an export rate of £0.30/kWh or £0.20/kWh through a power purchase agreement (PPA).

Export tariffs going forward are uncertain. The rate at £0.20/kWh is shown in Table 12 for reference in case PPA rates available begin to fall.

System configuration	1-screw	2-screw	3-screw	4-screw
Annual revenue with existing hydro not operational and export rate of £0.30/kWh	£29,000	£52,000	£68,000	£81,000
Annual revenue with existing hydro not operational and export rate of £0.20/kWh	£19,000	£35,000	£46,000	£54,000
Annual revenue with existing hydro operational and export rate of £0.30/kWh.	£13,000	£23,000	£32,000	£39,000
Annual revenue with existing hydro operational and export rate of £0.20/kWh.	£8,000	£16,000	£21,000	£26,000

Table 12. Annual revenue.

3.3.3 *Simple Payback, Net Present Value, Return on Investment and Levelised Cost of Energy*

The simple payback, 25-year net present value, 25-year internal rate of return (IRR) and levelised cost of energy are given in Table 13 and Table 14 below. This analysis assumes an export tariff of £0.30/kWh. The discount rate is taken from the UK Government's 'The Green Book' which is the central government guidance on appraisal and evaluation. They describe the long-term discount rate as the social time preference rate set at 3.5% (as per 2020).

Without the existing HEP system operating, the simple payback, IRR, time to reach £0 NPV and levelised cost of energy are all minimised for a 3-screw system.

With the existing HEP system operating, the simple payback and time to reach £0 NPV both exceed 25 years. The IRR is below zero for all scenarios when the existing HEP system is operating. The proposed HEP scheme is therefore unlikely to be financially viable if the existing HEP scheme is operational (if assessed over a 25-year period).

Table 15 provides the results without the existing HEP system operating, but with an export tariff of £0.20/kWh assumed. The 3-screw system remains optimal. However, the simple payback is increased to 23 years and the NPV does not exceed zero until year 30.

	1-screw	2-screw	3-screw	4-screw
Existing Hydro Operating	No	No	No	No
Operating Expense	-£6,160	-£7,660	-£9,260	-£10,860
Capital Expense	-£449,200	-£647,000	-£847,000	-£1,047,500
Annual Revenue	£29,000	£52,000	£68,000	£81,000
Electricity Inflation Rate	2%	2%	2%	2%
OPEX Inflation Rate	2%	2%	2%	2%
Simple Payback (years)	20	15	14	15
IRR (25 year)	3.8%	6.5%	6.7%	6.3%
NPV Discount Rate	3.5%	3.5%	3.5%	3.5%
NPV (25 year)	£18,000	£253,000	£360,000	£381,000
Time for NPV to Reach £0 (years)	24	17	17	18
Levelised Cost of Energy (£/MWh)	£246	£193	£188	£195

Table 13. Financial summary without existing HEP scheme operating and assuming an export tariff of £0.30/kWh.

	1-screw	2-screw	3-screw	4-screw
Existing Hydro Operating	Yes	Yes	Yes	Yes
Operating Expense	-£6,160	-£7,660	-£9,260	-£10,860
Capital Expense	-£449,200	-£647,000	-£847,000	-£1,047,500
Annual Revenue	£13,000	£23,000	£32,000	£39,000
Electricity Inflation Rate	2%	2%	2%	2%
OPEX Inflation Rate	2%	2%	2%	2%
Simple Payback (years)	>50	41	37	37
IRR (25 year)	-4.8%	-1.8%	-1.1%	-1.0%
NPV Discount Rate	3.5%	3.5%	3.5%	3.5%
NPV (25 year)	-£315,000	-£329,000	-£384,000	-£467,000
Time for NPV to Reach £0 (years)	>50	>50	>50	>50
Levelised Cost of Energy (£/MWh)	£561	£430	£403	£401

Table 14. Financial summary with existing HEP scheme operating and assuming an export tariff of £0.30/kWh.

	1-screw	2-screw	3-screw	4-screw
Existing Hydro Operating	No	No	No	No
Operating Expense	-£6,160	-£7,660	-£9,260	-£10,860
Capital Expense	-£449,200	-£647,000	-£847,000	-£1,047,500
Annual Revenue	£29,000	£52,000	£46,000	£81,000
Electricity Inflation Rate	2%	2%	2%	2%
OPEX Inflation Rate	2%	2%	2%	2%
Simple Payback (years)	34	24	23	24
IRR (25 year)	-0.4%	2.1%	2.4%	2.1%
NPV Discount Rate	3.5%	3.5%	3.5%	3.5%
NPV (25 year)	-£180,000	-£99,000	-£105,000	-£169,000
Time for NPV to Reach £0 (years)	49	31	30	32
Levelised Cost of Energy (£/MWh)	£246	£193	£188	£195

Table 15. Financial summary for a 3-screw system and assuming an export tariff of £0.20/kWh.

3.4 Sources of Capital

The intention for this scheme is for it to be community funded. Community funding can take different forms, but generally it is organised by local investors buying shares in the scheme. The community will then receive a return on these shares from the net income from the scheme. More information on community energy funding can be found on the Sharenergy website (https://www.sharenergy.coop/investing/).

The Community Energy England website has further information on the possible legal structures for community energy schemes (https://communityenergyengland.org/how-to-pages/starting-up-a-group-organisation-inc-structure-registration).

There are currently no known grants available for community HEP schemes that would offer significant funding for a scheme such as this.

A bank loan to fund a scheme such as this may be difficult to obtain as the uncertainty over future energy prices means the viability of the scheme is not certain.

4 Conclusion, Recommendations and Next Stages

4.1 Conclusion and Recommendations

In conclusion, a new hydroelectric scheme at Eckington Weir has the potential to achieve a peak power output of 13.7 kW per Archimedean screw. A 3-screw system will generate 228,000 kWh of electricity in an 'average flow' year if the existing HEP scheme is not operational. This equates to a CO_2 emission saving of almost 42 tonnes/year.

An Archimedean screw is the most suitable turbine technology and would be installed around the existing lock. The electrical generation could be exported to the grid and the system would operate in parallel with the grid.

The new HEP scheme would cost in the region of £400k for a single screw system to £1.1m for a 4-screw system. Without the existing HEP system operating, the optimum return on investment is estimated to be for a 3-screw system. The capital cost for this sized system has been estimated to be £847k. Assuming the existing HEP scheme is not operating, the net income for this sized scheme would be around £59k per year (assuming an PPA tariff of £0.30/kWh). Simple payback time is 14 years. The time for the NPV to reach £0 is 17 years, assuming 2% electricity price inflation, 2% operating cost inflation and a 3.5% discount rate. The estimated IRR is 6.7% and the levelised cost of energy is £188/MWh.

It is key for the financial success of the scheme that the existing HEP scheme around the weir is not operational. Further discussion needs to be had regarding whether this scheme is to be made operational again. If it is not an agreement may need to be made to allow its consented abstraction flow to be utilised by the new scheme. If the existing scheme is to be made operational again, the new HEP scheme is unlikely to be financially viable.

4.2 Next Stages

Assuming the issue with the existing HEP scheme can be sorted, the next stage would be to commence the consenting process. The following initial discussions should be had:

1. HEP scheme preapplication submission and initial discussion with the Environment Agency to determine how the abstraction licensing process would work with an existing HEP scheme on the weir. This process would also try and determine if a flood defence consent is required, if there are any environmental constraints and what surveys would be required.
2. Consultation with the distribution network operator (DNO) to discuss a connection agreement, confirm the point of connection and any power export limitations.

Following this, the rest of the outline design and consenting process would be completed, including:

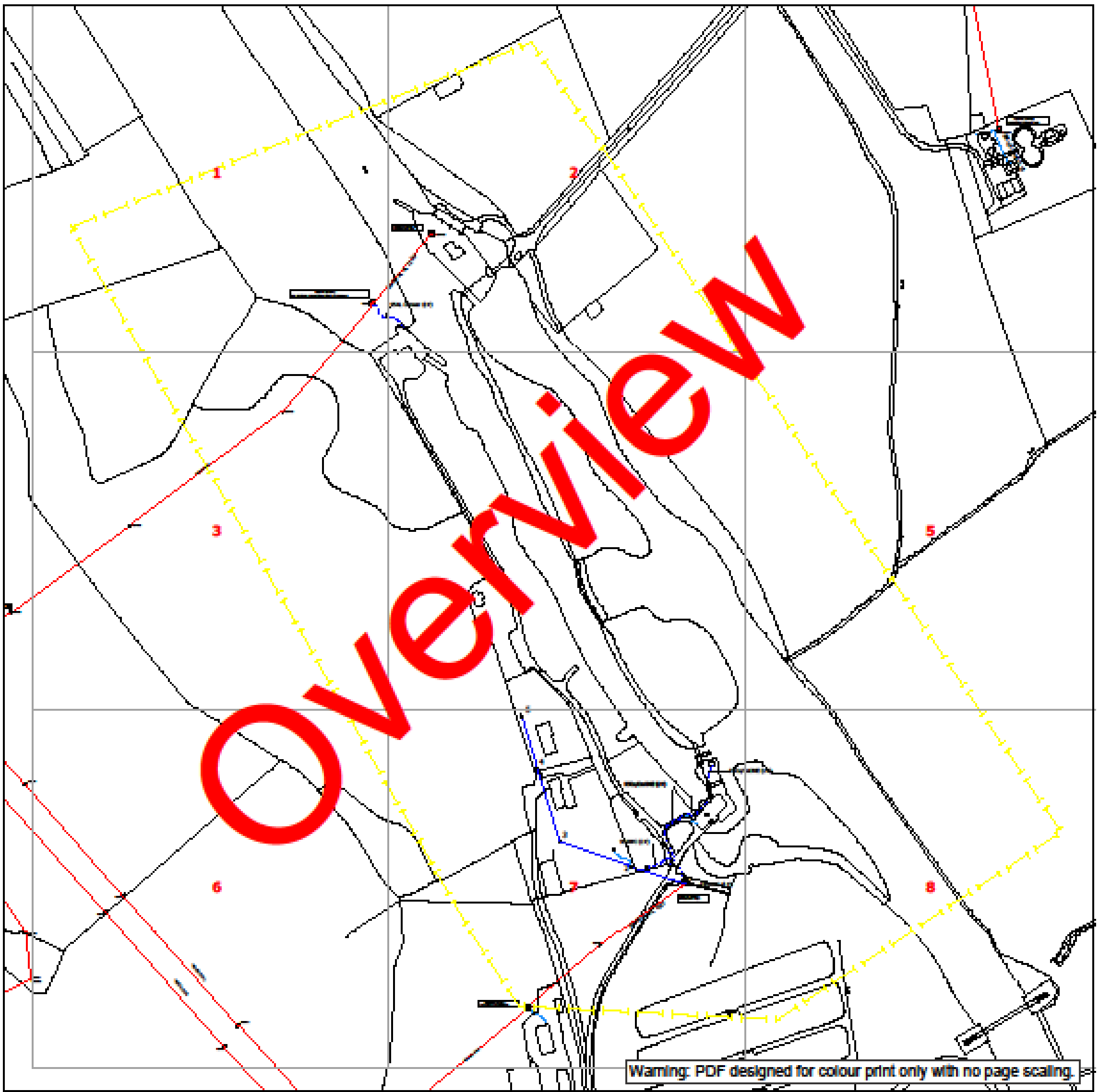
1. Outline HEP system design.
2. HEP scheme full application submission to the Environment Agency.
3. Flood risk activity permit (FRAP) application submission to the Environment Agency.
4. Planning application submission to the local authority.
5. Grid connection application to the DNO.
6. Carry out any surveys required to complete the outline design or to support environmental and planning applications.

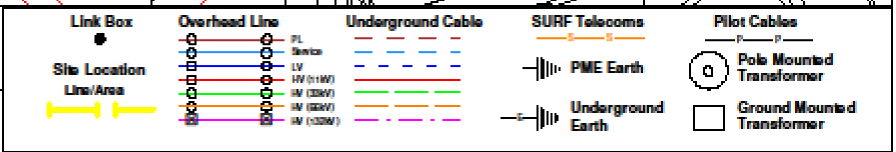
Approximate project timescales are given in Table 16. The project is expected to take just under 2 years from the initial decision to progress through to operation. However, the consenting process in particular can take much longer than quoted, depending on what is required to obtain the consents.

Description	Month
EA preapplication and initial discussions with relevant authorities	0-2
Outline design, environmental consents, planning and grid connection permission	3-7
Ground investigation works and construction design	8-11
Generating equipment supply	12-19
Civils construction	18-20
DNO grid connection works	20
M&E installation	20-21
Commissioning	22
Timescale to completion	**22 months**

Table 16. Project timescales.

Appendix A – Relevant DNO Network Maps





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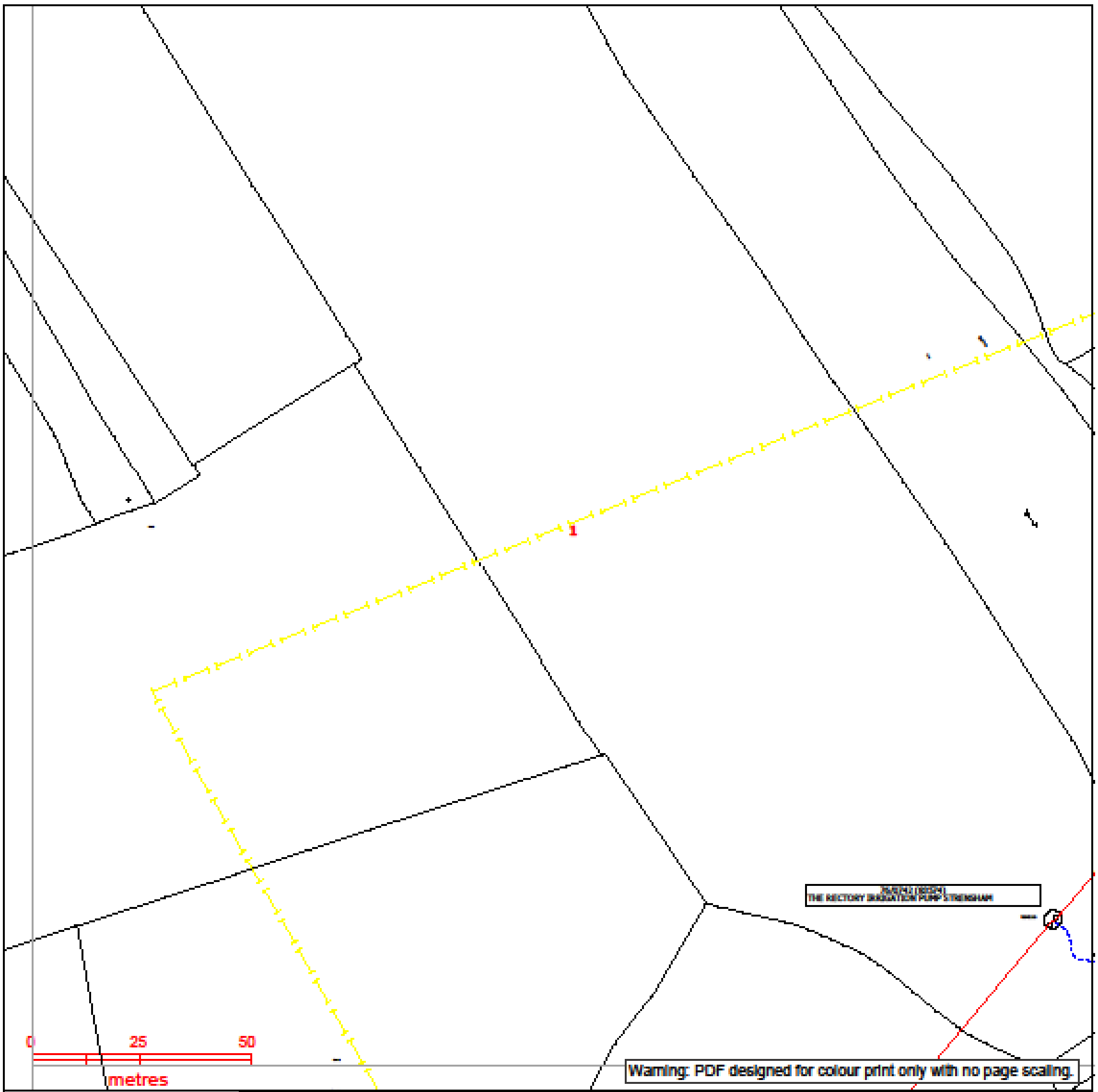

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Link Box	Overhead Line	Underground Cable	SURF Telecoms	Pilot Cables
Site Location Line/Area	PL, Service, LV, HV (11kV), HV (33kV), HV (66kV), HV (132kV)		PME Earth	Pole Mounted Transformer
			Underground Earth	Ground Mounted Transformer

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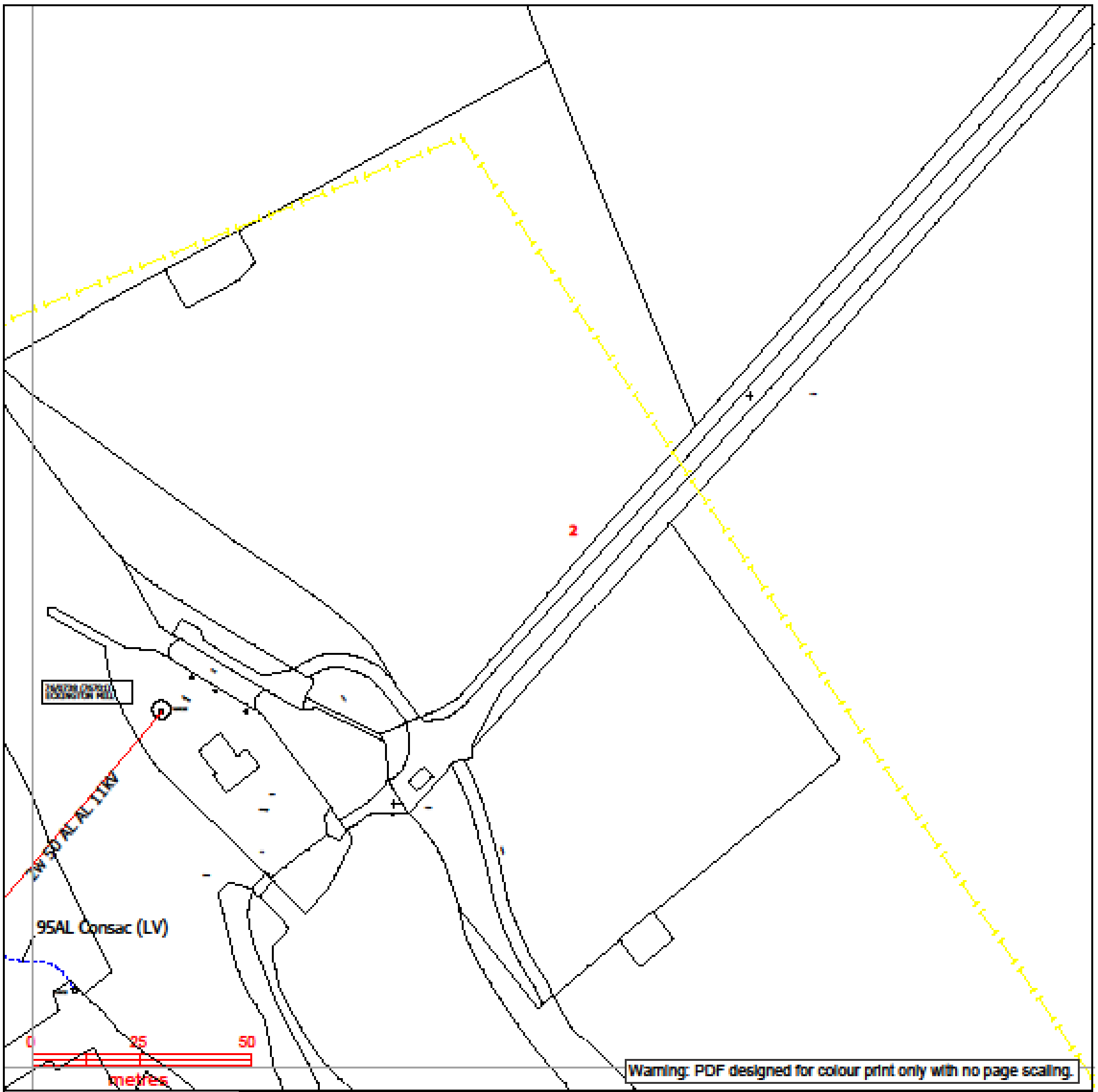

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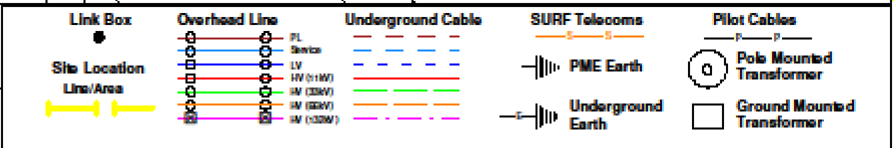

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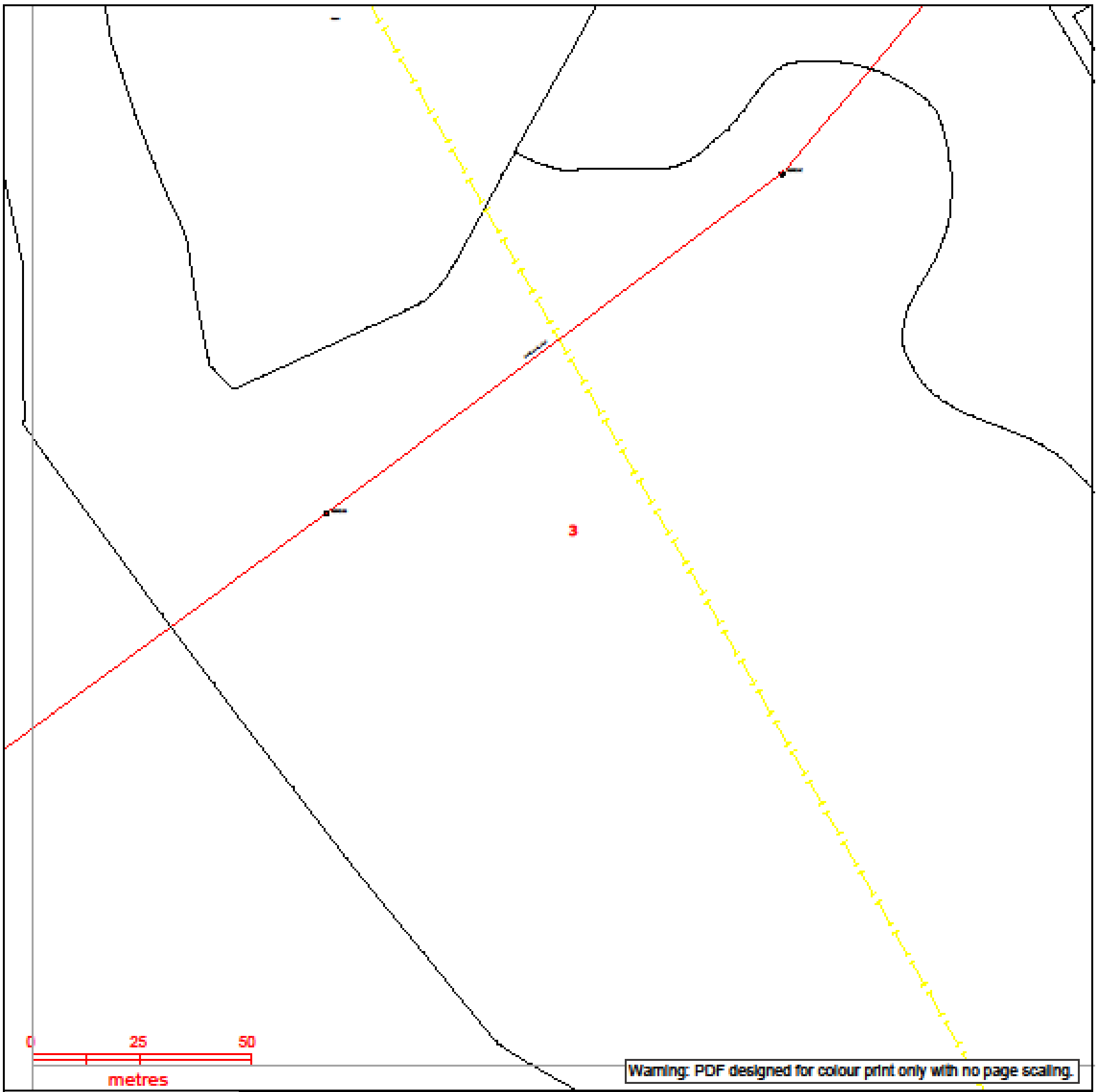

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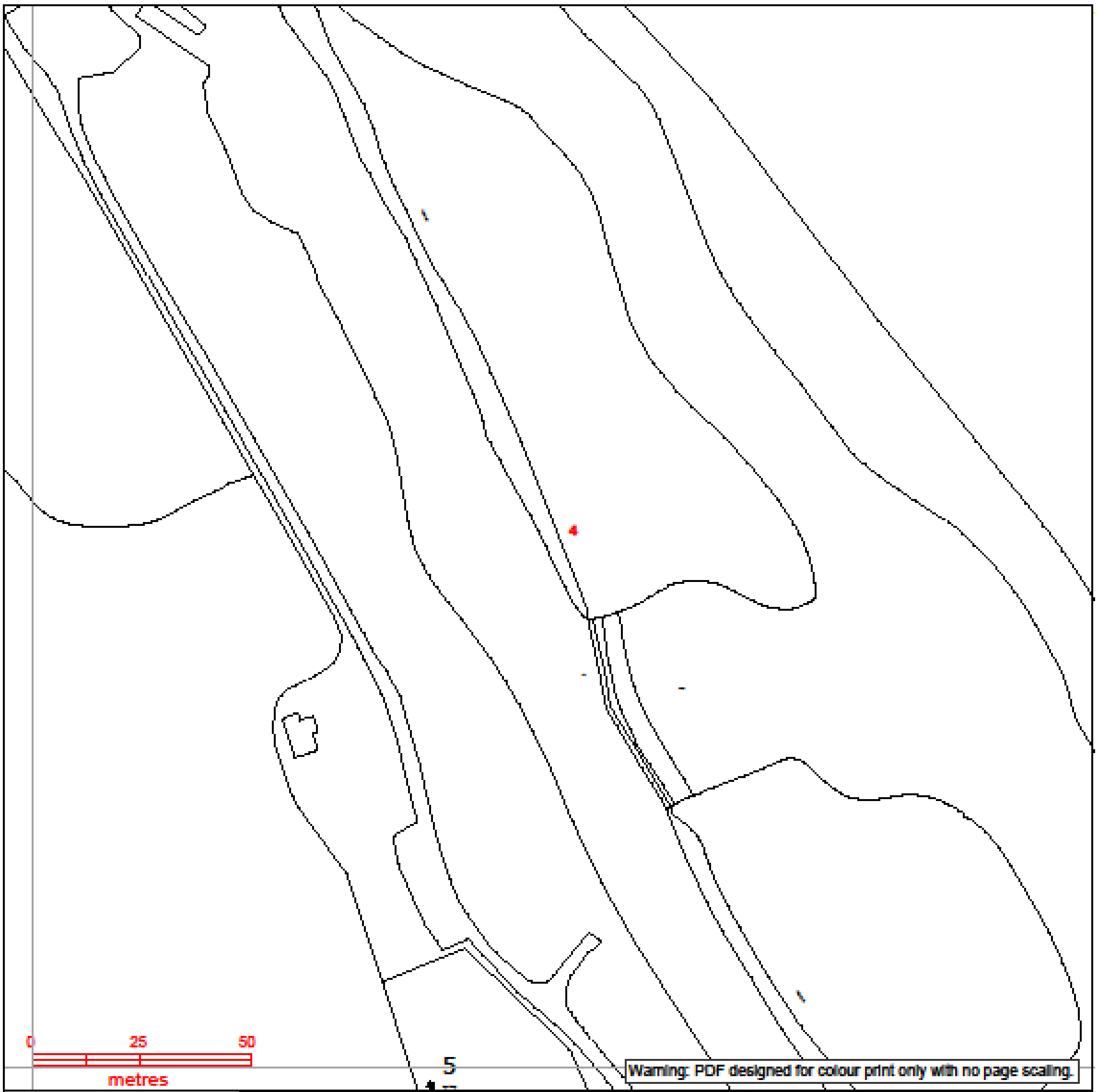

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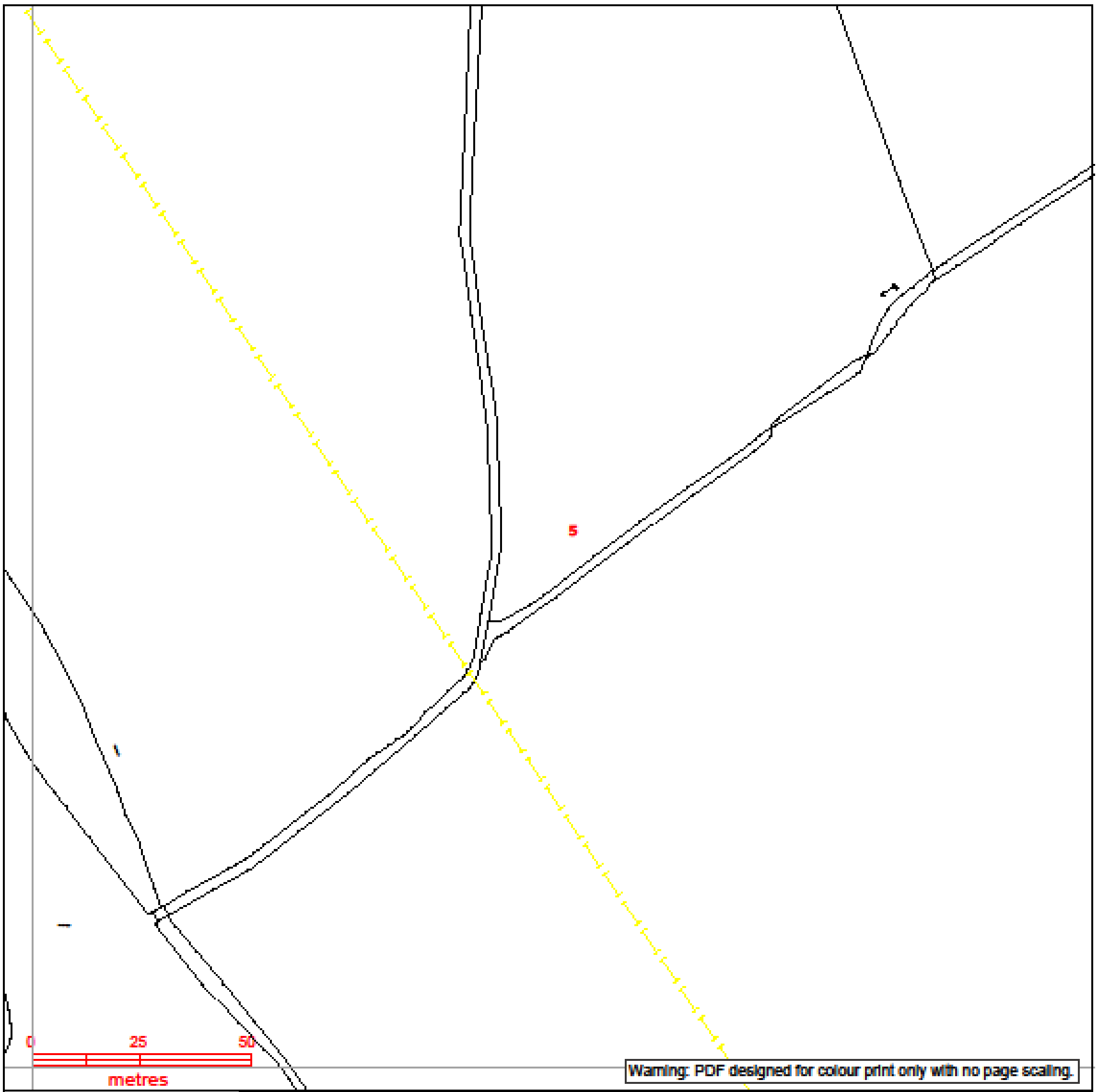

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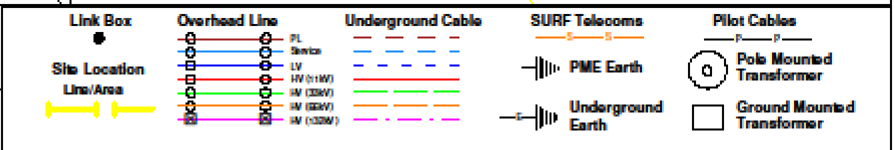

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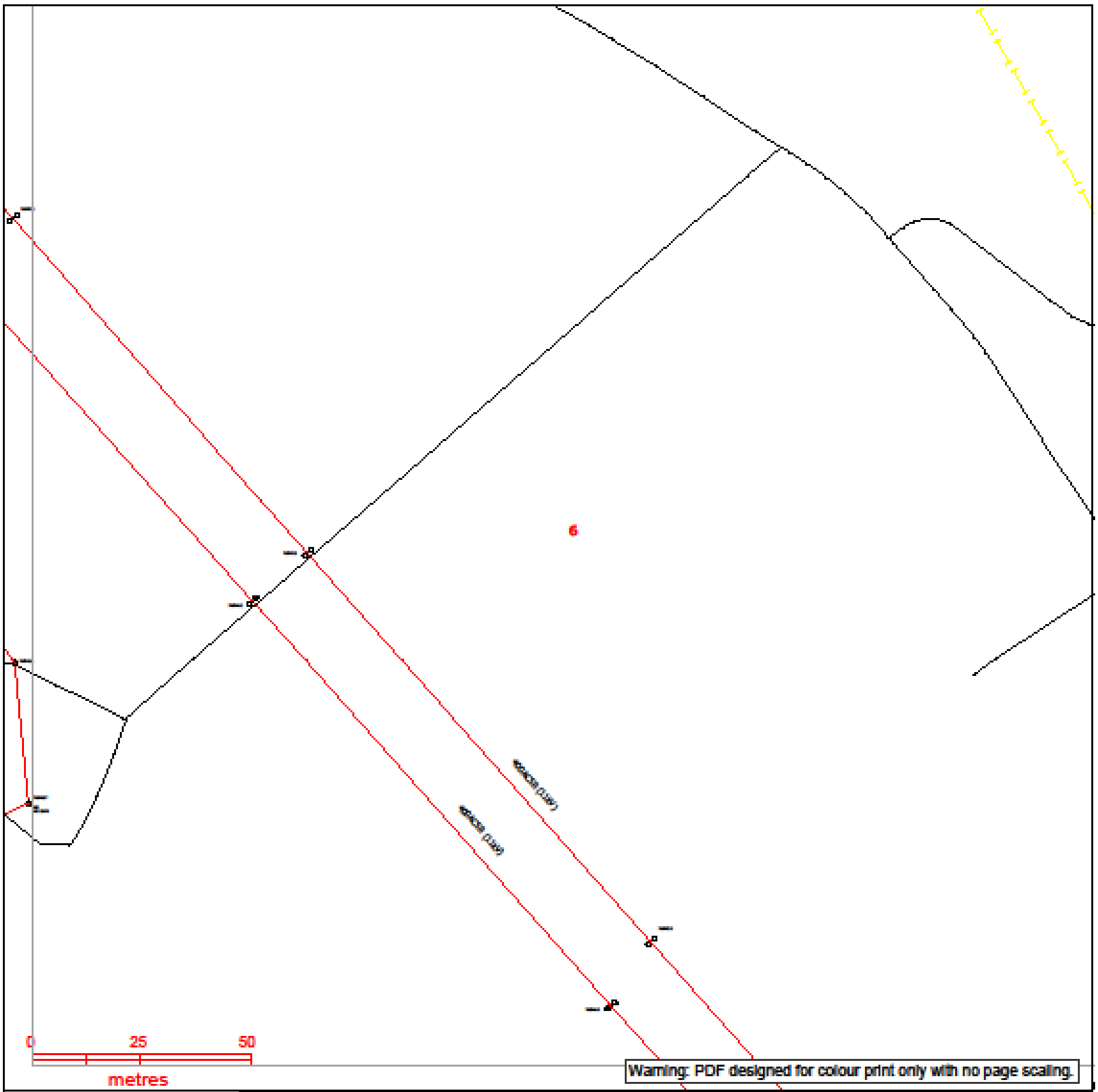

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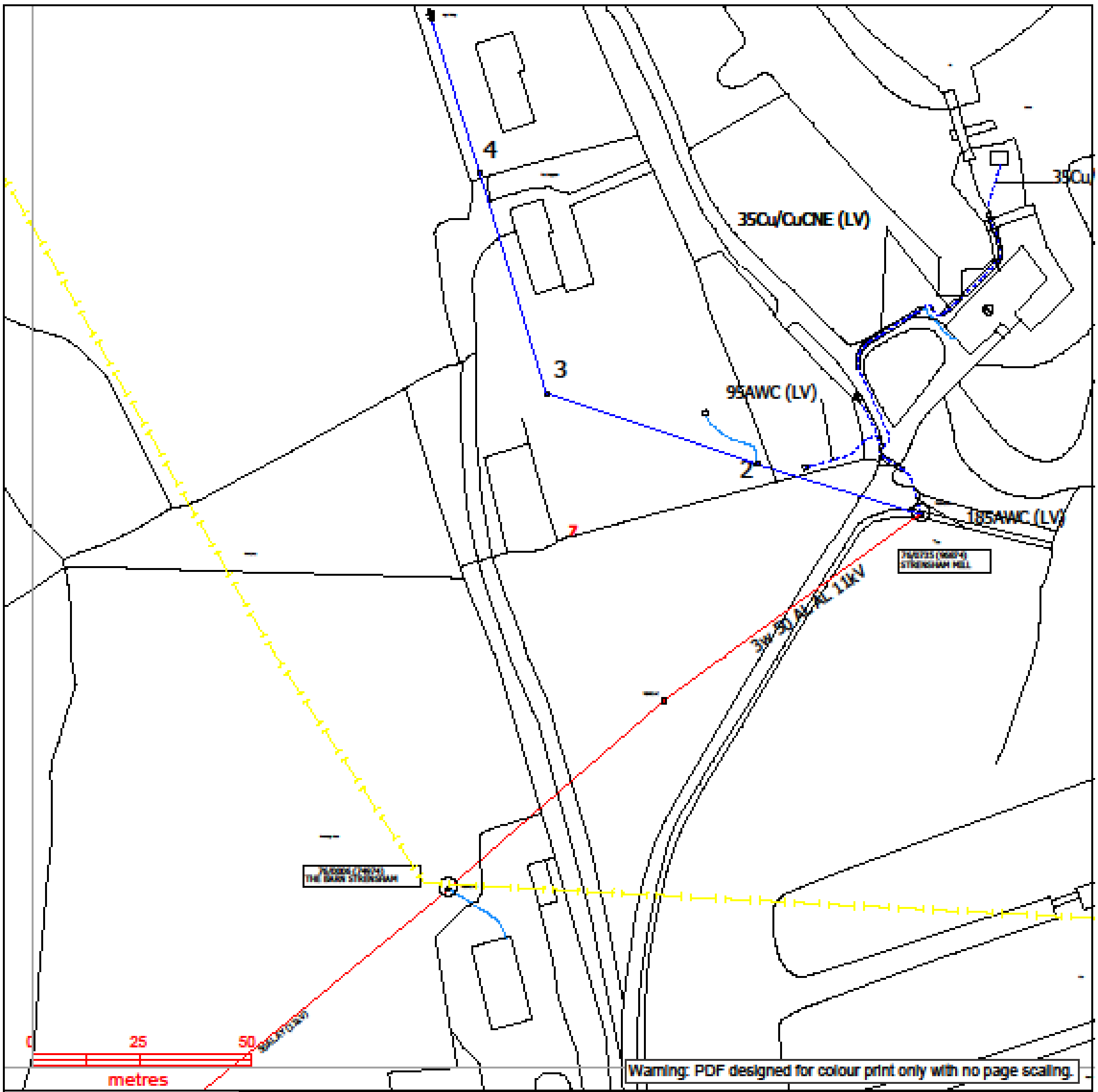

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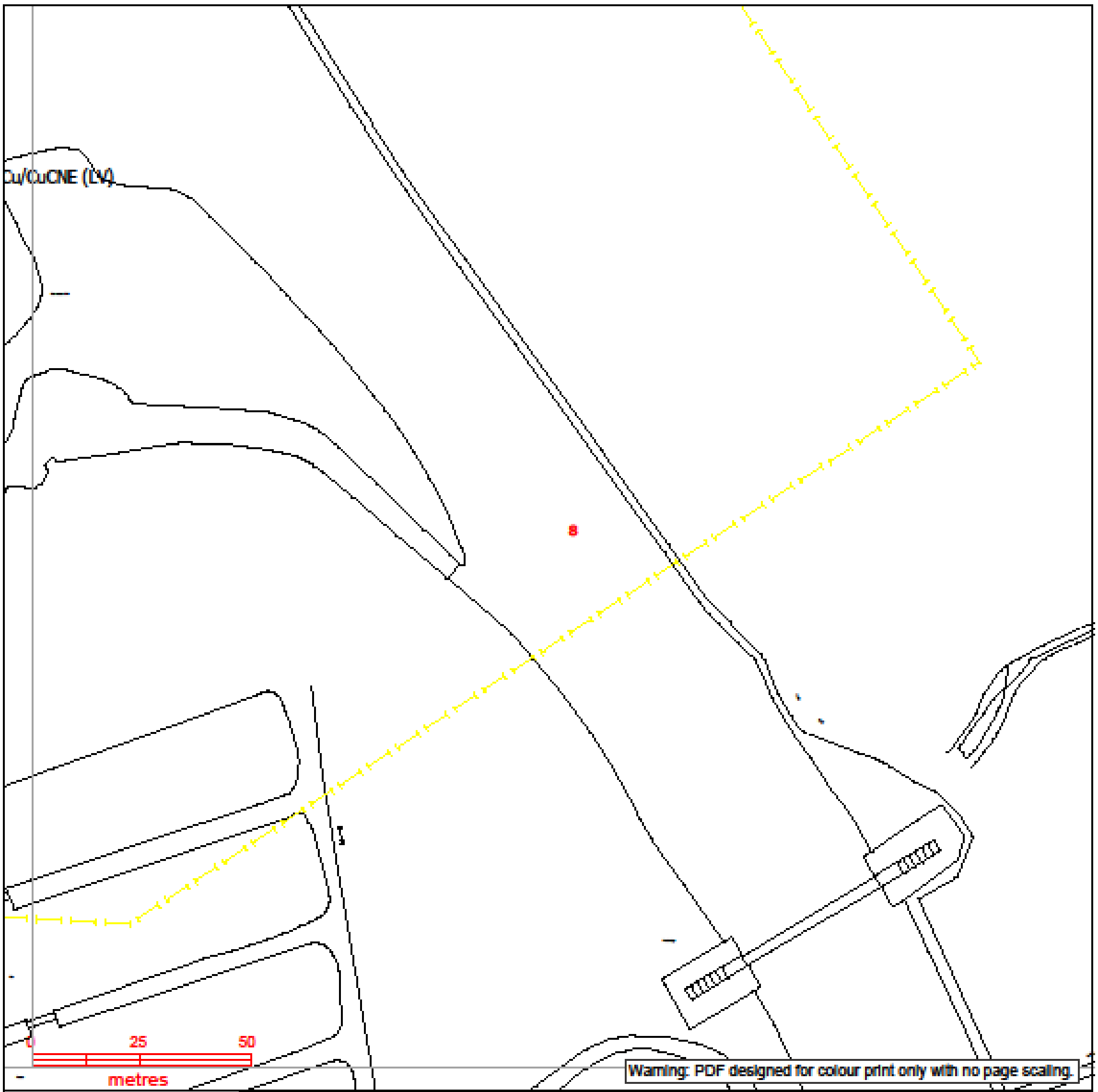

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General Enquiries:
All areas 0800 096 3080

Date Requested: 11/05/2022
Job Reference: 25594803
Site Location: 391603 240266
Requested by:
Mr Alexander Talbot-Rice
Your Scheme/Reference:
ECKTN

Exact Scales:
1:1250 Area or Circle dig site
1:500 Line dig site

Link Box

Site Location
Line/Area

Overhead Line
PL
Service
LV
HV (11kV)
HV (33kV)
HV (66kV)
HV (132kV)

Underground Cable

SURF Telecoms

PME Earth

Underground Earth

Pilot Cables

Pole Mounted Transformer

Ground Mounted Transformer

IMPORTANT NOTICES

- This information is given as a guide only and its accuracy cannot be guaranteed. Services or recent additions to the network may not be shown.
- Cables, overhead lines & substations owned by other electricity network owners or private companies may be present and may not be shown.
- You should always verify exact locations of cables using a cable locator and by careful use of hand tools in accordance with HSE guidance note HSG47.
- When working within 10m of any overhead electric line you should follow the requirements of HSE Guidance Note GS6.
- For further advice on working near our electricity cables or lines, call our General Enquiries number.
- Advice should be sought from the Western Power Distribution General Enquiries team for any work that is to take place in proximity to 132kV underground cables and 132kV overhead lines.

Report damage immediately – KEEP EVERYONE AWAY FROM THE AREA
0800 6783 105

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