MANNPOWER
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Survey of hydropower potential within Cheshire West and Chester area

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Introduction

There are a number of sites within the catchment area of Cheshire West and Chester, which have the potential for the generation of hydro-electric power. This study has carried out a brief assessment of each site to provide a full report on the total capacity for hydropower generation within this area. The sites were identified through a combination of site surveys, desktop research and public consultation.

Cheshire West and Chester is a unitary authority area with borough status, in the ceremonial county of Cheshire, North West England. Cheshire West replaced the boroughs of Ellesmere Port, Neston, Vale Royal, Chester District and part of the former Cheshire County Council; this was disaggregated between the two new unitary Authorities of Cheshire East, and Cheshire West and Chester.

Chester is a city in Cheshire, which lies on the River Dee. The River Dee is a 70 miles long and travels through Wales and England and also forms part of the border between the two countries. Other major rivers within the area include the Weaver, Gowy and Dane. The River Weaver is 50 miles long, and is navigable in its lower reaches, running in a curving route anti-clockwise across West Cheshire. The River Gowy rises in Western Cheshire in the hills near Peckforton Castle, very close to the source of the River Weaver. While the Weaver flows south initially, the Gowy flows north for several miles and provides the valley used by the Shropshire Union Canal. It runs just to the East of Chester and passes through the siphon under the Manchester Ship Canal to meet the Mersey near Stanlow. Its total length is around 20 miles. The River Dane flows South West and forms the border between Cheshire and Staffordshire for approximately 10 miles, before flowing West through Congleton and past Holmes Chapel.

Methodology

Energy can be extracted from falling water and harnessed to provide mechanical or electrical power. The theoretical amount of energy available from any given site is directly proportional to two factors: the actual volume of water passing through the site (the flow), and the height through which the water falls at the site (the head). In order to assess the actual hydropower potential of any site it is necessary to have measurements of both the

changing flow and head, over the course of several years. This will determine what can be expected to be the average annual energy capture. Estimates can be also be made on the basis of existing gauged flow data and, where this is not available, a computer analysis of the catchment area feeding the site and local rainfall records.

A desktop identification study of potential sites has been undertaken. The results from this have been tied together with previously identified sites, to produce a digital map showing the extent of sites identified. Please note this map is not exhaustive or conclusive and additional sites may be found and some sites identified may no longer exist, and hence be removed.

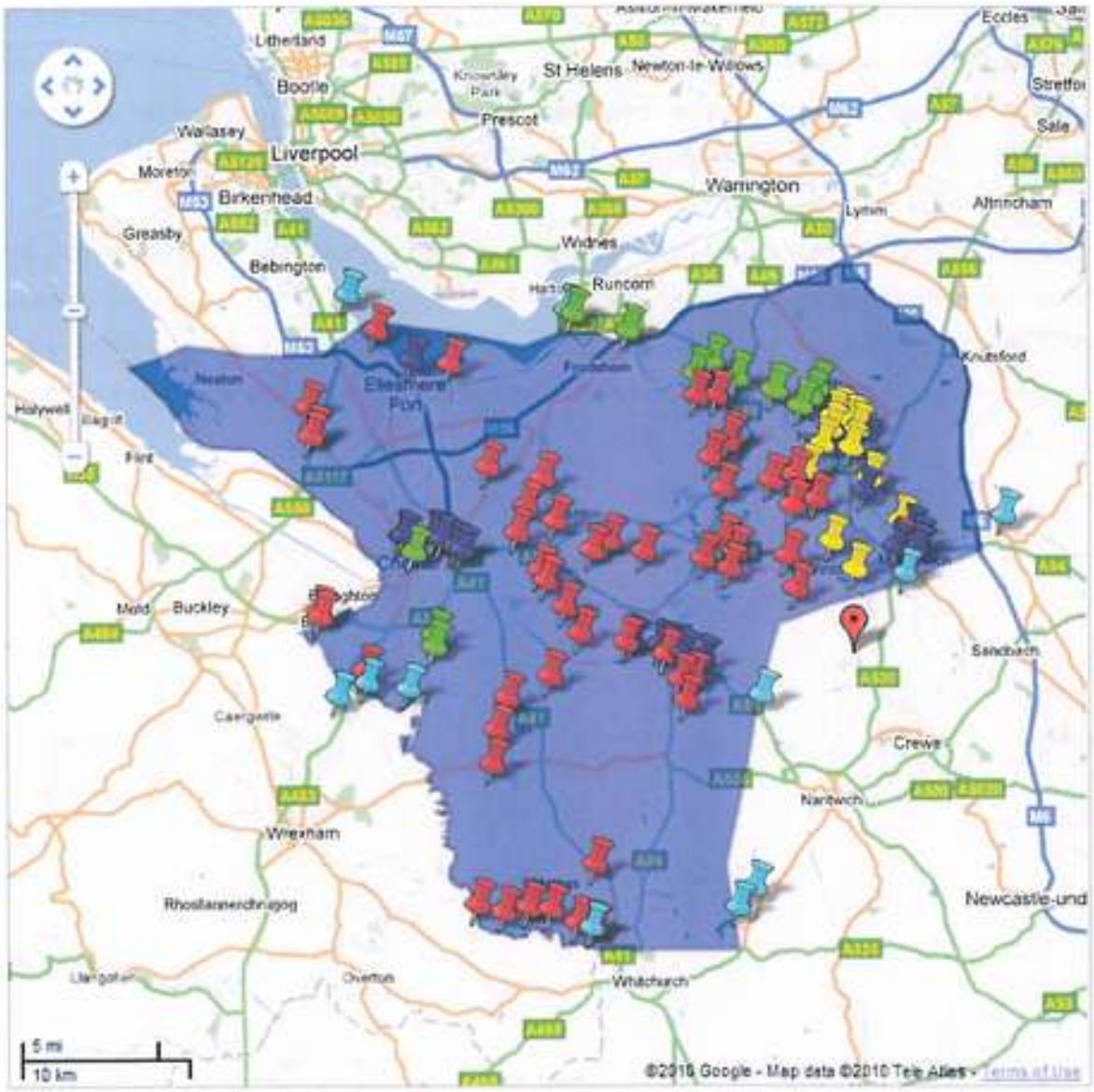


Figure 1: Survey area with sites identified marked with a pin

Map key

The colours denote estimated potential output based on the new Feed-in-Tariff bandings.

Pin colour	Banding
Green	101kW > 2000kW
Yellow	16kW > 100kW
Red	<=15kW
Purple	Navigation Locks
Blue	Possible sites just outside / on the boundary of the survey

Flow estimation

There are several gauging stations across the Cheshire West and Chester area. These have been used to estimate flows available for generation. Several of the rivers have no gauging stations and some sites are a long way up or down stream of a station. In this case the existing station data has been modified in order to provide a suitable estimate for the possible output. Should any scheme be progressed, more accurate data should be sourced. Existing authorised abstractions can also potentially affect the amount of water available for a hydropower scheme. If schemes are developed, information on these abstractions should be requested and included in the assessments. A further restriction to flow may be caused by site specific physical constraints which were assessed on an individual basis.

Head estimation

The head for all those sites visited which were below 10m, were physically measured with laser level equipment. For higher heads and sites which weren't visited, an estimate was made using either cartographic information or evidence based on similar sites.

Efficiency

An overall water to wire efficiency of 65% was used for all schemes, apart from the ten full site reports which got a more detailed analysis. In the separate FS studies there is a more accurate efficiency figure relevant for each site.

Cost estimation

A rough estimate of the likely development cost was made for each of the thirty four schemes indentified, based on current prices for suitable turbines and pipe work, together with an assessment of the civil works required. Further design work and quotations are required to produce more accurate figures.

Revenue estimation

An estimate for likely annual revenue for each site was calculated using today's electricity sales prices, income from the sale of Feed-in-Tariff and the likely capacity factor (how much of the year that the scheme operates).

Hydropower potential

There is potential for a total of over 3.7MW maximum installed capacity within the Cheshire West council area. Some of the schemes would cost a significant amount to develop, and it is often possible to only economically develop a proportion of the maximum capacity. Some of the sites are very small and / or would require a large investment relative to the revenue they could generate (details in the summary table below). Any site considered to be in this category has only been listed in the table and no further information has been included. For each of the top ten sites that appeared to be feasible and/or could provide a catalyst for community involvement, a separate report has been produced. The reports include a breakdown of the detailed measurements and calculations used to populate the table below.

It is, therefore, suggested that the potential for economic development is 3.5MW which is derived from the site data summarised below:-

Name	Location	OS Grid Ref	River	Viable	Gross Head (m)	Net Head (m)	Design Flow (litres per second)	Power (kW)	Outline Cost	Outline Gross Revenue excluding costs	Simple return excluding costs	Simple payback time excluding costs
Chester weir		SJ 405 658	Dee	Yes	2.95	2.75	30000	577.6	£2,900,000	£300,000	11.5%	8.7
Stamford Mill	Stamford Bridge	SJ 468 667	Gowy	Yes	2	1.8	900	12.0	£170,000	£13,000	7.6%	13.1
Walk Mill	Waverton	SJ 483 643	Gowy	Yes	0.647	0.547	500	1.9	£55,000	£2,000	3.6%	27.5
Stanthorne Mill	Middlewich	SJ 654 661	Dane	Yes	3.3	3.2	1200	26.5	£250,000	£22,000	8.8%	11.4
Frodsham Lock	Frodsham	SJ 52685 78743	Weaver	Yes	0.8	0.7	17000	83.3	£3,000,000	£50,000	1.7%	60.0
Dutton Lock	Bartington	SJ 50692 76504	Weaver	Yes	2.4	2.3	17500	261.8	£1,310,000	£185,000	14.1%	7.1
Saltersford Locks	Barnton	SJ 62323 75139	Weaver	Yes	2.3	2.2	17300	266.4	£1,410,000	£200,000	14.2%	7.1
Anderton Boat Lift	Anderton	SJ 64820 76308	Weaver	Yes	15.2	13.68	1000	96.8	£423,966	£89,614	21.1%	4.7
Hunts Lock	Northwich	SJ 65598 72840	Weaver	Yes	3.4	3.3	10000	231.0	£830,000	£152,003	18.3%	5.5
Valeroyal Locks	Northwich	SJ 64078 70349	Weaver	Yes	2.75	2.65	10000	185.5	£840,000	£122,000	14.5%	6.9
Rudheath EA Gauge	Northwich	SJ 66808 71742	Dane	No	2	1.9	4950	65.8	£440,000	£66,000	15.0%	6.7
Croxton Hall	Middlewich	SJ 65646 67336	Dane	Yes	2	1.9	3910	52.0	£413,000	£40,000	9.7%	10.3

Name	Location	OS Grid Ref	River	Viable	Gross Head (m)	Net Head (m)	Design Flow (litres per second)	Power (kW)	Outline Cost	Outline Gross Revenue excluding costs	Simple return excluding costs	Simple payback time excluding costs
Trafford Mill	Mickle Trafford	SJ 45092 70695	Gowy	Yes	2.9	2.8	1180	22.1	£244,000	£17,000	7.0%	14.4
Stapleford Mill weir	Duddon	SJ 48154 54540	Gowy	Yes	2.5	2.4	600	8.4	£150,000	£10,000	6.7%	15.0
Mill Cottage	Hargrave	SJ 49517 62361	Gowy	Yes	2.8	2.7	470	8.5	£160,000	£10,000	6.6%	16.2
Mill Farm 1	Hurley	SJ 50559 60786	Gowy	Yes	2.2	2.1	423	6.2	£160,000	£6,000	4.0%	25.0
Bates Mill	Tarporley	SJ 53241 60211	Gowy	Yes	2.5	2.4	400	6.7	£160,000	£6,000	4.1%	29.0
Tarvin Mill	Tarvin	SJ 49288 67483	Milton Brook	Yes	2.8	2	100	1.4	£80,000	£1,500	1.9%	53.3
Duddon Mill	Duddon	SJ 51310 65749	Milton Brook	Yes	3	2.9	100	2.0	£120,000	£1,500	1.3%	80.0
Bromford Mill	Great Barrow	SJ 48374 70087	Ashton Brook	Yes	1.8	1.7	100	1.2	£120,000	£800	0.7%	150.0
Coddington Mill	Coddington	SJ 45370 55050	Carden Brook	Yes	4.2	4.1	300	8.6	£100,000	£12,000	12.0%	8.3
Acton Mill	Croxton	SJ 55879 74796	Acton Brook	Yes	4	3.1	100	2.7	£70,000	£2,700	3.9%	25.9
Milcot Upper Mill	Coddington	SJ 58015 72077	Coddington Brook	Yes	2.3	2.4	100	1.7	£90,000	£1,000	1.3%	80.0
Milcot Lower Mill	Coddington	SJ 58469 71103	Coddington Brook	Yes	4.8	4.4	100	3.1	£90,000	£2,500	2.0%	36.0
The Old Mill	Moulton	SJ 64678 69940	Pettypool Brook	Yes	3	2.9	100	2.0	£70,000	£1,500	2.6%	26.9
Old Mill/The Wheel House	Little Budworth	SJ 67901 65114	Sandyford Brook	Yes	4	2.1	100	1.5	£70,000	£1,600	2.3%	43.8

Name	Location	OS Grid Ref	River	Viable	Gross Head (m)	Net Head (m)	Design Flow (litres per second)	Power (kW)	Outline Cost	Outline Gross Revenue excluding costs	Simple return excluding costs	Simple payback time excluding costs
The Old Flour Mill	Little Budworth	SJ 59605 65566	Chesterlan e Brook	Yes	4	3.8	100	2.5	£70,000	£1,600	2.3%	43.8
Bunbury Water Mill	Bunbury	SJ 57310 58047	Gowy	Yes	4	3.9	100	2.7	£50,000	£2,700	5.4%	18.5
Oldcastle Mill	Malpas	SJ 46998 44519	Wych Brook	Yes	2.3	2.2	100	1.5	£60,000	£1,600	2.7%	37.5
Dymock's Mill	Oldcastle	SJ 45675 44206	Wych Brook	Yes	2.8	2.7	350	6.6	£130,000	£4,200	3.2%	31.0
Sarm Mill	Malpas	SJ 44113 44715	Wych Brook	Yes	1.8	1.7	360	4.3	£120,000	£5,000	4.6%	21.7
Stretton Water Mill	Stretton	SJ 48107 52693	Carden Brook	Yes	4.5	4.4	100	3.1	£50,000	£2,700	5.4%	18.5
Priestlands Farm	Bunbury	SJ 569 587	Gowy	Yes	1.2	1.1	50	0.4	£60,000	£500	0.8%	120.0
Tilstone Mill	Tilstone Banli	SJ 56752 59362	Gowy	Yes	4.5	4.4	100	3.1	£80,000	£2,700	3.4%	29.6
Willington Mill	Willington	SJ 52294 66274	Milton Brook	No	2	1.9	100	1.3	£80,000	£1,000	1.3%	80.0
Bentley Wood	Utkinton	SJ 54406 65576	Bentley Wood Brook	No	4	3.9	100	2.7	£80,000	£2,700	3.4%	29.6
Eastham Locks	Eastham	SJ 36943 81012	Manchesta r Ship Canal	No	8	7.9	30000	1659.0	£10,000,000	£1,100,000	11.0%	9.1
Shotwick Dale	Shotwick	SJ 34593 72674	Shotwick Brook	No	10	9	100	6.3	£80,000	£6,000	7.5%	13.3
Croxton Wood Hotel	Shotwick	SJ 34444 74356	Shotwick Brook	No	2	1.9	100	1.3	£60,000	£1,000	1.7%	60.0
Croxton Brook Pond	Croxton	SJ 57763 74780	Croxton Brd	No	4	3.9	100	2.7	£80,000	£2,700	3.4%	29.6

Name	Location	OS Grid Ref	River	Visited	Gross Head (m)	Net Head (m)	Design Flow (litres per second)	Power (kW)	Outline Cost	Outline Gross Revenue excluding costs	Simple return excluding costs	Simple payback time excluding costs
Manor Pool	Cuddington	SJ 58469 71103	Cuddington Brook	No	4	3.9	100	2.7	£80,000	£2,700	3.4%	29.6
Rookery Pool	Hartford	SJ 63332 70114	Unknown	No	2	1.9	50	0.7	unviable		-	-
Foxwist Green	Foxwist Green	SJ 63277 68268	Bogart Brook	No	2	1.9	50	0.7	unviable		-	-
Darnhall	Darnhall	SJ 63423 63340	Ashbrook	No	2	1.9	200	2.7	£80,000	£2,700	3.4%	29.6
Oulton Lake	Rushton	SJ 59560 64585	Darley Brook	No	2	1.9	100	1.3	£60,000	£1,000	1.7%	60.0
Old Hydraulic Ram	Stockton	SJ 47262 44511	Wych Brook	No	2	1.9	350	4.7	£70,000	£5,000	7.1%	14.0
Lock 1	Chester	SJ 39987 66662	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 2	Ellesmere Port	SJ 40668 77084	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 3	Chester	SJ 40050 66633	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 4	Chester	SJ 41742 66661	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 5	Chester	SJ 41925 66638	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 6	Great Boughton	SJ 43111 65995	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 7	Christleton	SJ 43525 65779	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 8	Chester	SJ 42284 66436	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 9	Tiverton	SJ 53641 60313	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 10	Tiverton	SJ 56335 59993	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 11	Tiverton	SJ 56651 59738	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 12	Tiverton	SJ 56671 59457	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Bunbury Locks (2)	Bunbury	SJ 57822 59094	Shropshire	No	4	3.9	200	5.5	£100,000	£5,000	5.0%	20.0
Lock 13	Middlewich	SJ 70193 66756	Trent & Mer	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 14	Middlewich	SJ 70647 66120	Trent & Mer	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 15	Middlewich	SJ 70670 65625	Trent & Mer	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Lock 16	Stanthorne	SJ 69412 65755	Shropshire	No	2	1.9	200	2.7	£80,000	£3,000	3.8%	26.7
Milton Farm Mill	Acton Bridge	SJ 595 743	Acton Brook	No	4	3.9	100	2.7	£70,000	£2,700	3.9%	25.9
							Total	3719				

Environmental benefits

If all of these schemes were developed, they could produce as much as 12,000 MWh of electricity per annum, saving approximately 5,160 tonnes of CO^2 from entering the atmosphere every year (Based on 0.43 tonnes per MWh). The average UK household electrical consumption is 3300kWh, so this would provide sufficient electrical power for 3,600 houses.

Feasibility studies

The techniques used in making this assessment and full details of the economic calculations are provided in the individual brief feasibility studies for each site accompanying this report. Studies for the following sites are available:-

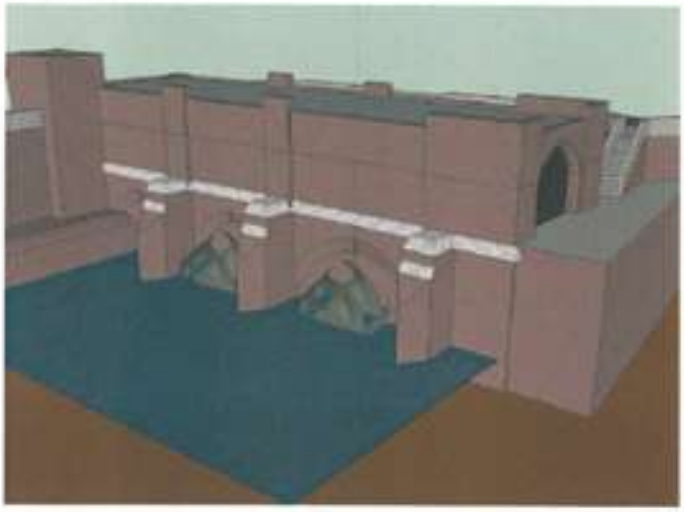
- Chester Weir
- Dutton Lock
- Hunts Lock
- Saltersford Lock
- Rudheath
- Croxton Hall
- Anderton Boat Lift
- Trafford Mill
- Stanthorne Weir
- Vale Royal Locks

Recommendations

There is clearly untapped potential for hydropower schemes within the Cheshire West and Chester area, which could be developed sensitively and without adverse impact on the sites. In particular, there is significant potential on the Weaver Navigation. It could be advantageous to start a Weaver Renewables Group to ensure this valuable resource is harnessed in the most appropriate way. It is suggested that the information gathered in this report is publicised and that the feasibility studies are made available to the owners and / or any interested developers. This should hopefully provide the catalyst needed to begin the detailed feasibility and design work followed by the subsequent development of one or more schemes.

Site reports

1. Chester Weir



Grid reference	SJ 406 658
Ownership	Cheshire West and Chester Council
Power estimation	555 kW
Outline cost	£2,600,000
Outline gross revenue	£300,000
Catchment	1,816.8 km²
Gross head	2.95 m
Mean flow estimation	29,710 l/s
Access / installation issues	Very close to the town centre of Chester. However, access for heavy machinery would be possible to the site. It will probably be necessary to create a temporary hardcore road down to tailrace of the screw for tailrace dredging. Suggested that the screws are delivered in kit form and built on site.
Grid connection	A substation is located inside part of the powerhouse – grid connection should be possible.
Environmental issues	River Dee is designated as a SSSI.
Installation proposal	See example picture above. This station was originally built to be a hydro station. Make use of these existing features and use the three turbine pits, to install 3 Archimedean screws into these spaces. The intake screen bar spacing could be widened to as much as 150mm.

2. Dutton Lock

Grid reference	SJ 58692 76904
Ownership	British Waterways
Power estimation	282 kW
Outline cost	£1,310,000
Outline gross revenue	£185,000
Gross head	2.4 m
Mean flow estimation	17470 l/s
Access / installation issues	There maybe weight limits on some of the access bridges to the island. However, the navigation could be used instead.
Grid connection	Three phase grid connection point exists close by.
Installation proposal	Eight large sluice gates act as a weir and hold the level constant. The sluices allow excess flows to by-pass locks. Two Archimedean screw turbines could be located in front of two sluice gates. A drop-down sluice gate arrangement would allow the sluices to still be used as to relieve high flood flows. At all other times excess flows could be diverted into the turbines.

3. Hunts Lock

Grid reference	SJ 65598 72840
Ownership	British Waterways
Power estimation	231.0 kW
Outline cost	£830,000
Outline gross revenue	£152,000
Gross head	3.4 m
Mean flow estimation	8735 l/s
Access / installation	Access for all heavy machinery and via the navigation canal.
Grid connection	There is a three phase grid connection close by
Installation proposal	Ideal installation site would be in the spare lock. Both Locks here are in better repair, however, due to moderate use of the navigation canal compared to historically, one lock could be sufficient to bear the brunt of the traffic. One Archimedean screw turbine could be installed into the vacant lock chamber, using the gates to help dry out for construction of foundations. Gates could then be retained but closed to place them out of the way for normal screw operation.

4. Saltersford Lock

Grid reference	SJ 62323 75139
Ownership	British Waterways
Power estimation	266.4 kW
Outline cost	£1,410,000
Outline gross revenue	£200,000
Gross head	2.3 m
Mean flow estimation	17295 l/s
Access / installation issues	Access for all heavy machinery and via the navigation.
Grid connection	Unknown
Installation proposal	There are two redundant locks here. An Archimedean screw could be built on-site into the existing lock chamber. The existing doors could be used to help drain out the lock, so foundations can be set, screw put in place. Lock doors can then be closed and put out of the way.

5. Rudheath Environment Agency Gauge

Grid reference	SJ 66808 71742
Ownership	Environment Agency
Power estimation	65.8 kW
Outline cost	£440,000
Outline gross revenue	£66,000
Gross head	2.0 m
Mean flow estimation	4950 l/s
Access / installation issues	Access to the site should be straight forward from the A556.
Grid connection	Unknown
Installation proposal	This particular site is an EA gauging station. The present weir was built for the purpose of measuring flow rates, not for any kind of hydro power application. This means the head is relatively low, measuring just over 1m. Any hydro scheme installed here would not be allowed to compromise the stations current application; hence an appropriate design would need to be fully discussed with the EA from the beginning. It should be possible to mitigate for any impact on the current gauging regime. The ideal installation site would be at either side of the weir. It is likely that for such a low head and high flow, at least two if not more turbines would be required. It maybe possible to connect the output of the system into a nearby school with perhaps the revenue benefitting the said consumer. Two big trenches would need to be dug with concrete foundation works to support the turbines.

6. Croxton Hall

Grid reference	SJ 69646 67336
Ownership	Private
Power estimation	52.0 kW
Outline cost	£413,000
Outline gross revenue	£40,000
Gross head	2.0 m
Mean flow estimation	3910 l/s
Access / installation issues	Access for all machinery is possible.
Grid connection	There is a single phase connection point and a three phase power line close by.
Installation proposal	The original weir has been lowered. A scheme here would involve raising the weir back to its original height. This could be a good candidate for an inflatable weir. Propose to install a screw onto the weir itself. The weir crest could be compensated for by setting the screw forward and creating a small wall to maintain the weir crest length. The screw would be positioned River right. This would be inline with the river flow. Flood flows could be compensated for by lowering the inflatable weir. A flood risk assessment may show that flood is not an issue upstream of this weir.

7. Anderton Boat Lift

Grid reference	SJ 64820 75308
Ownership	British Waterways
Power estimation	96 kW
Outline cost	£420,000
Outline gross revenue	£90,000
Gross head	15.2 m
Mean flow estimation	1,000 l/s
Access / installation issues	Access for all machinery is possible.
Grid connection	There is a three phase power line close by.
Installation proposal	Absorb excess flows from the canal and direct them into a vertical pipe abstracting water from the top of the canal basin and exiting it into the Weaver (an existing spillway does exactly this). Hence the current spillway flows would just be diverted to generate power. The pipe could run from the spillway straight down the hillside to a powerhouse on the banks of the Weaver navigation. It should also be possible to mount it such that it is removable at anytime in the future. A small powerhouse would be required on the banks of the Weaver, but this should be located as close to the bottom of the boat lift as possible. The Anderton Boat lift museum could take power directly from the scheme, with excess feeding into the local supply network. This could add another thread of interest to visitors to the museum and boat traffic alike.

8. Trafford Mill

Grid reference	SJ 45092 70695
Ownership	Private
Power estimation	23.1 kW
Outline cost	£244,000
Outline gross revenue	£17,000
Gross head	2.9 m
Mean flow estimation	1180 l/s
Access / installation issues	Access for all heavy machinery is possible.
Grid connection	A single phase connection point supplies the mill. A three phase supply is approximately 100m away.
Installation proposal	Place an Archimedean screw onto the existing weir (River Left). Set the screw forward and place a sluice gate to act as the new weir. This will raise the upper water level back to what it would have been when the mill was operating. The sluice gate would be automatic and open during to allow high flows past, without obstructing. A flood risk assessment would be required. Increasing the weir height would encourage more water to flow into the old mill pond and would allow the Trafford Mill Trust to fulfil there goal of operating the former mill machinery, which is mostly still in tact and in place.

9. Stanthorne Mill

Grid reference	SJ 694 661
Ownership	Private
Power estimation	26.9 kW
Outline cost	£250,000
Outline gross revenue	£22,000
Gross head	3.3 m
Mean flow estimation	1238 l/s
Access / installation issues	Should be possible for all machinery. However, the bridge will need to be load tested.
Grid connection	Single phase connection point at the mill building approximately 250m away.
Installation proposal	Dredge out the former mill pond behind the weir. Raise the weir height back to former height (add approx 1m). Did out the entrance to the former lade and install and Archimedean screw to put water back in just below the weir.

10. Vale Royal Locks

Grid reference	SJ 64078 70349
Ownership	British Waterways
Power estimation	185.5 kW
Outline cost	£840,000
Outline gross revenue	£122,000
Gross head	2.75 m
Mean flow estimation	8735 l/s
Access / installation issues	Access possible for all heavy machinery. However, the bridge may need to be load tested.
Grid connection	A three phase connection point is near by.
Installation proposal	There are two locks here and a sluice gate. Upstream there is a large stone built structure with two large sluice-gates, acting as a weir and flood relief and level control. A single Archimedean screw turbine could be placed in front of the single sluice gate adjacent to the locks. This location offers excellent access and proximity to export power and for maintenance. There is a long brick built channel in front of the sluice gate, providing an ideal area to drain down. There are stop log slots at either end and the sluice gate could be closed. A system here could even possibly be on floats and lift up and down in the chamber depending on the relative water levels. This would mean it would not impede the flow of water in a flood situation. An alternative would be to use the redundant lock chamber to install a screw in position. The large strong and deep existing structures will make installation relatively cost effective.

11. Stamford Mill

Grid reference	SJ 468 667
Ownership	Private
Power estimation	12.0 kW
Outline cost	£170,000
Outline gross revenue	£13,000
Gross head	2.0 m
Mean flow estimation	944 l/s
Access / installation issues	Access possible for all heavy machinery. However, the bridge may need to be load tested.
Grid connection	A three phase connection to the mill house.
Installation proposal	Install an Archimedean screw turbine into one of the existing sluice gates. The second gate would be automated and opened and closed depending on the flows coming down the river. A spill way would also be created just upstream of the mill, to divert excess flood flows back into what would have been the natural route of the river, before being modified for milling purposes.

12. Walk Mill

Grid reference	SJ 483 643
Ownership	Private
Power estimation	1.9 kW
Outline cost	£55,000
Outline gross revenue	£2,000
Gross head	0.647 m
Mean flow estimation	517 l/s
Access / installation issues	Access possible for all heavy machinery.
Grid connection	A three phase connection to the mill house.
Installation proposal	Either attach a gearbox and generator to the exiting mill wheel shaft, or alternatively, install an Archimedean screw on the opposite river bank. The use of an automatic level sensor would allow the Mill to continue to grind corn as it does today, as the screw would shut down when the wheel was operated.

13. Frodsham Lock

Grid reference	SJ 53685 78743
Ownership	British Waterways
Power estimation	83.3 kW
Outline cost	£3,000,000
Outline gross revenue	£50,000
Gross head	0.8 m
Mean flow estimation	17,470 l/s
Access / installation issues	Access possible for all heavy machinery.
Grid connection	A three phase grid connection exists close by.
Installation proposal	To progress a scheme here the head would need to be raised. Features on the ground suggest that it would be impractical to consider raising the height more than 0.5m. For such a low head and high flow several Archimedean screw turbines would be required, to reach the stated output. This is unlikely to be a viable option, although there is plenty of room in and around the existing structures.

14. Stapleford Mill Weir

Grid reference	SJ 48194 64540
Ownership	Private
Power estimation	8.4 kW
Outline cost	£150,000
Outline gross revenue	£10,000
Gross head	2.5 m
Mean flow estimation	517 l/s
Access / installation issues	Access possible for all heavy machinery.
Grid connection	Single phase connection point approximately 250m.
Installation proposal	Place an Archimedean screw onto the existing weir (River Left). Set the screw forward and place a sluice gate to act as the new weir. This will raise the upper water level back to what it would have been when the mill was operating. The sluice gate would be automatic and open during high flow to allow high flows past, without obstruction. A flood risk assessment would be required.

15. Mill Cottage

Grid reference	SJ 49617 62361
Ownership	Private
Power estimation	8.9 kW
Outline cost	£160,000
Outline gross revenue	£10,500
Gross head	2.8 m
Mean flow estimation	470 l/s
Access / installation issues	Access should be possible for all machinery, though a load test may need to be undertaken on an access bridge over the River.
Grid connection	Single phase to adjacent properties.
Installation proposal	This mill is typical of many of the mills seen on the river Gowy. There would once have been sluice gates to raise the head of water upstream. The wheel and mill machinery have now been removed, and the mill has been renovated as residential accommodation. It would therefore make development more worth while if the head could be raised again. The installation could take place on the opposite river bank to the mill. There is a small area of rough grass adjacent to the weir with ample space for the turbine. This would mean the river was not deprived of any of its flow and only the weir itself would be deprived of any flow. The farming activities use a lot of power and it is thought that most of the power generated could be absorbed back into the buildings on site.

16. Mill farm 1

Grid reference	SJ 50559 60788
Ownership	Private
Power estimation	6.2 kW
Outline cost	£150,000
Outline gross revenue	£60,000
Gross head	2.2 m
Mean flow estimation	423 l/s
Access / installation issues	Access possible for all heavy machinery.
Grid connection	A three phase connection point supplies the farm.
Installation proposal	This mill is typical of many of the mills seen on the river Gowy. There would once have been sluice gates to raise the head of water upstream. The wheel and mill machinery have now been removed, and the mill has been renovated as residential accommodation. It would therefore make development more worth while if the head could be raised again. The installation could take place on the opposite river bank to the mill. There is a small area of rough grass adjacent to the weir with ample space for the turbine. This would mean the river was not deprived of any of its flow and only the weir itself would be deprived of any flow. The power generated could be fed back into the buildings near to the scheme.

17. Bates Mill

Grid reference	SJ 53241 60211
Ownership	Private
Power estimation	6.7 kW
Outline cost	£150,000
Outline gross revenue	£60,000
Gross head	2.5 m
Mean flow estimation	400 l/s
Access / installation issues	Access possible for all heavy machinery. Although in some places the buildings may cause restrictions.
Grid connection	A single supply to the mill.
Installation proposal	The owners have renovated the mill from scratch and have already installed a hydro power scheme. They have had a hydro engineer in for design and installation of the system. The owner uses the mill machinery to drive a generator and produce power off grid, which he uses for his own domestic consumption. In the winter he can generate as much as 3kW and in the summer, between 1 and 2kW. He has also been experimenting with water source heat pumps driven by the head of water. This system may prove more worth while than installing a hydro scheme for some of the smaller sites in this study (further investigation needed).

18. Tarvin Mill

Grid reference	SJ 49098 67489
Ownership	Private
Power estimation	1.4 kW
Outline cost	£80,000
Outline gross revenue	£1,500
Gross head	2.8 m
Design flow estimation	100 l/s
Access / installation issues	Access possible for all heavy machinery.
Grid connection	A three phase connection to the mill.
Installation proposal	Milton Brook has a low flow hence there used to be a very large mill pond which would have stretched back underneath the main road (A54). The mill pond is now heavily silted and the weir itself appears partially lowered. The construction of the A54 by-pass round the village of Tarvin would probably make the re-use of the former mill structures too difficult. However, just downstream of the weir, to the north west, there is a short section where the brook is canalised. This would provide an opportunity to lower an Archimedean Screw along with a sluice gate into this channel section to create in essence, a new weir downstream of the original. However, this would permanently submerse part of the bridge built over the brook, so the highways agency would need consulting before a scheme was progressed. A suitable grid connection point exists at Tarvin Mill itself.

19. Duddon Mill

Grid reference	SJ 51310 65749
Ownership	Private
Power estimation	2.0 kW
Outline cost	£120,000
Outline gross revenue	£1,500
Gross head	3.0 m
Design flow estimation	100 l/s
Access / installation issues	Access possible for all heavy machinery.
Grid connection	A three phase connection point exists close by.
Installation proposal	The original mill has long been demolished and only the wheel pit remains. Like other mills on this brook, a large mill pond and the diversion of other water courses into this pond was necessary for the grinding of corn. Today the mill pond is heavily silted and largely full of willow trees. The main flow appears to either by-pass the mill pond by going over the weir or passes through the mill pond into what would have been the spill way for the mill pond. The former wheel pit offers the best opportunity for a turbine. However, in order to achieve this, the mill pond would need de-silting and the water courses would need to be re-routed back into this pond. The original spill way could be made suitable to take excess flows with an additional spill way upstream of the mill pond. The farm has a suitable grid connection point. There is adequate access via the long drive down to the adjacent farm.

20. Swinford Mill

Grid reference	SJ 48374 70007
Ownership	Private
Power estimation	1.2 kW
Outline cost	£120,000
Outline gross revenue	£800
Gross head	1.8 m
Design flow estimation	100 l/s
Access / installation issues	Possible for all heavy machinery.
Grid connection	A three phase connection to the mill.
Installation proposal	There are the remains of an old water wheel in situ. The main flow passes under a small bridge at this point adjacent to the water wheel. There is a heavily silted mill pond just upstream. There would have been a sluice gate in front of the mill pond to raise the level of water. It would be possible theoretically to reuse the existing wheel, however the full operating head available is much greater than could be encompassed by the wheel. A new sluice would need to be installed and the turbine could be located in a similar position to the existing structure. No other evidence of the mill building appears to exist, so it must have been demolished. A suitable grid connection exists close by.

21. Coddington Mill

Grid reference	SJ 45375 55050
Ownership	Private
Power estimation	8.6 kW
Outline cost	£100,000
Outline gross revenue	£12,000
Gross head	4.2 m
Mean flow estimation	306 l/s
Access / installation issues	Possible for all heavy machinery.
Grid connection	A three phase connection to the mill.
Installation proposal	This mill is built in a very similar style to the mills on the River Gowy, with a large mill pond or Penstock of water controlled by two sluice gates/weirs. The former mill gear still exists although the mill itself has been converted into residential accommodation. Currently, the owners do not run the turbine but this could be serviced and a generator and gear box could be added to the output shaft of the turbine. This means it should be cost effective and easy to get a system up and running here. Currently the main flow passes through the two sluices and the mill pond is heavily silted. The weir up stream would also need some repair as well as some excavation to the tailrace of the turbine. It is anticipated that the majority of power generated could be consumed directly on site.

22. Acton Mill

Grid reference	SJ 58879 74796
Ownership	Private
Power estimation	2.7 kW
Outline cost	£70,000
Outline gross revenue	£2,700
Gross head	4.0 m
Mean flow estimation	100 l/s
Access / installation issues	Possible for all heavy machinery.
Grid connection	Single phase to the Mill
Installation proposal	This mill has a large mill pond and overflow where most of the flow currently passes. There are two manual sluice gates which the owners manually operate to control the mill pond level and flood flows. The mill itself has been converted into residential accommodation. However, both the two former wheel pits still remain untouched. They are however, both sealed. There is an access manhole into one wheel pit via a garage upstairs. A flow of water passes through both wheel pits and into the former tailrace at all times. Due to the space restrictions and high head, any turbine installed will need to be delivered in parts and constructed inside one of the former wheel pits. This may be possible with a cross flow turbine. The tailrace may need to be excavated immediately adjacent to the downstream side of the house, as this has been filled in and throttled down simply to allow an amenity flow through. The manual sluice gates could be automated to control varying flows. The access road should be suitable for heavy machinery. However, it is not envisaged that any significant or disruptive installations would be agreed upon by the owner as this is their family home. The lower floor of the house would provide an excellent area to house the control gear and an access door into the wheel pit could be installed for ease of future maintenance.

23. Milcot Upper Mill

Grid reference	SJ 59515 72077
Ownership	Unknown
Power estimation	1.7 kW
Outline cost	£80,000
Outline gross revenue	£1000
Gross head	2.5 m
Mean flow estimation	100 l/s
Access / installation issues	Access for all heavy machinery is possible, but will need to cross a private garden.
Grid connection	Unknown
Installation proposal	The weir at this site has been breached and water no longer flows into the lade. The weir would need to be repaired and this should be able to be done relatively cheaply. A turbine could be placed adjacent to the weir a short distance into the former lades. The lade would need to be blocked to stop flows trying to run down the lade to the former mill. An earth wall could be created from excess spoil during construction. The nearest grid connection point would be the old mill house which was once part of the mill buildings, approximately 200m away. Access to the site is currently via a public right of way but suitable access could be arranged with the owners of the old mill house, should this be required.

24. Milcot Lower Mill

Grid reference	SJ 59734 72332
Ownership	Private
Power estimation	3.1 kW
Outline cost	£90,000
Outline gross revenue	£2,500
Gross head	4.5 m
Mean flow estimation	100 l/s
Access / installation issues	Possible for all heavy machinery.
Grid connection	Unknown
Installation proposal	The mill has been renovated into residential accommodation with the former wheel pit removed. No evidence exists of this. The overflow for the mill pond has been cultivated by the present owner who has also installed an automated sluice gate to control the mill pond level. The layout of the site would make it difficult for any installation to be simple or low cost. However, it is envisaged that some kind of artesian well system could be used to transfer the head to the tailrace downstream. The tailrace at this point has significant growth of vegetation which could help to disguise a turbine in this location. There is excellent access from the road side and the power should be able to be exported to the former mill.

25. The Old Mill

Grid reference	SJ 64679 68640
Ownership	Private
Power estimation	2 kW
Outline cost	£70,000
Outline gross revenue	£1,800
Gross head	3.0 m
Mean flow estimation	100 l/s
Access / installation issues	Possible for all heavy machinery.
Grid connection	Unknown
Summary	The mill has been renovated into residential accommodation. An ornamental waterwheel has been placed on the side of the mill. The hydraulic features have largely been removed, but a tail race pond still exists. It may be possible to route a hydro scheme in and around the existing buildings. It was not possible to fully survey this area because the owner was not interested. Access would be possible for most machinery depending on type of turbine and location selected. Significant excavation would be required to re-open the former mill channels.

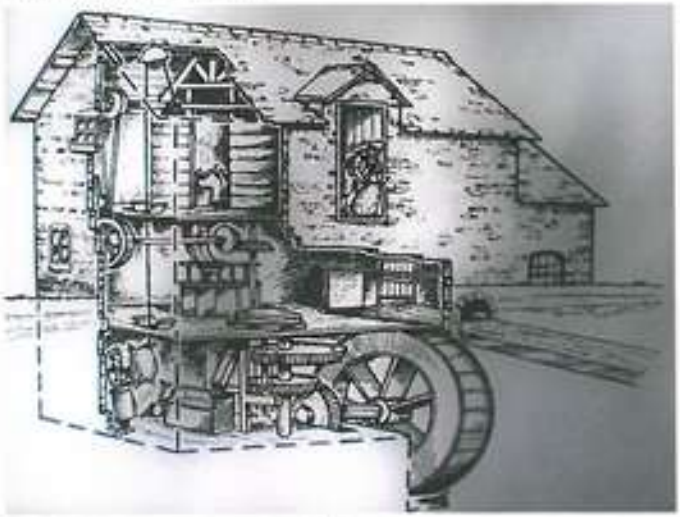
26. Old Mill / The Wheel House

Grid reference	SJ 57981 65114
Ownership	Private
Power estimation	1.5 kW
Outline cost	£70,000
Outline gross revenue	£1,600
Gross head	4.0 m
Mean flow estimation	100 l/s
Access / installation issues	Access to the mill pond and spillway are possible from the road. It may be necessary to arrange access through the garden of one of the residential properties in order to ease access concerns.
Grid connection	Unknown
Summary	The old mill has been renovated into residential accommodation with all the former mill workings stripped out. The intake and tail race have been blocked. Significant residential development has occurred in and around the fields downstream of the mill. A spillway for the mill pond passes under the road before bypassing the housing estate and rejoining the main brook. A turbine could be located onto the spillway itself with the aid of an additional sluice gate to effectively move the weir crest under the road to the downstream side of the mill pond. This would ideally place the system to feed into an adjacent property.

27. The Old Flour Mill

Grid reference	SJ 59958 65566
Ownership	Private
Power estimation	2.5 kW
Outline cost	£70,000
Outline gross revenue	£1,600
Gross head	4.0 m
Mean flow estimation	100 l/s
Access / installation issues	There is good vehicle access from the road to the mill pond and into the garden of the mill.
Grid connection	Single phase to the mill.
Summary	The house has been renovated into residential accommodation. A small country lane now divides the mill pond and the mill. The former intake channel, wheel pit and tailrace have all been blocked. However, the spillway still exists and flows through an ornamental water garden down to the main brook. The spillway passes under the road in a large pipe. It is thought that some kind of coander type intake devise could be located in the end of this pipe to feed a turbine located further down the garden. The coander intake would allow excess and high flows to by-pass the turbine, taking the current route they do today. All the power generated could be fed into the mill. The turbine house and intake pipe should be able to be disguised in and around the ornamental garden.

28. Bunbury Water Mill



Grid reference	SJ 57310 58047
Ownership	Private
Power estimation	2.7 kW
Outline cost	£50,000
Outline gross revenue	£2,700
Gross head	4.0 m
Design flow estimation	100 l/s
Access / installation issues	Possible for all heavy machinery.
Grid connection	A single phase supply to the mill.
Summary	Bunbury Mill is a fine example of an historical watermill. The water wheel and machinery are still maintained. They occasionally grind flour and have in the past opened up to visitors and school groups. There is an educational classroom on site. There are two ways to approach a scheme at this site. Either a gearbox and generator driven directly from the waterwheel shaft or an Archimedean Screw turbine located downstream of the current mill pond spillway. In conjunction with a new sluice gate, there is u-shaped uniform channel which could be suitable to support the upper end of the hydro scheme and bring the head of the mill pond under the road bridge. The power generated could be fed into the existing mill building or alternatively into the nearby by United Utilities processing plant.

39. Oldcastle Mill

Grid reference	SJ 46998 44519
Ownership	Private
Power estimation	1.5 kW
Outline cost	£60,000
Outline gross revenue	£1,600
Gross head	2.3 m
Design flow estimation	100 l/s
Access / installation issues	Access would be more challenging for large vehicles and heavy loads due to the steep gradients of the drive and hair-pin bends.
Grid connection	Unknown
Installation proposal	This mill is currently undergoing some renovation by the current owners. The mill itself is designed to run from a small tributary, which feeds into the Wych Brook. The former mill pond is often allowed to be empty with the flow passing through a spillway into the tailrace via an ornamental garden/fish pond. The ornamental fish ponds would inhibit any hydro scheme and a weir which has been built at the end of the tailrace would need to be removed to allow the wheel to be operable again. Currently the foot of the wheel sits in about a foot of water. A gearbox and generator could be directly coupled to the main shaft of the waterwheel. Two control sluice gates could be located in the mill pond at the entrance to the intake for the wheel. These gates could be used to control the flow of water into the wheel with the spillway sluice gate set at an appropriate level for the operation of the wheel. The power generated could then be fed into the mill building.

30. Dymock's Mill

Grid reference	SJ 45675 44206
Ownership	Private
Power estimation	6.6 kW
Outline cost	£130,000
Outline gross revenue	£4,200
Gross head	2.8 m
Mean flow estimation	357 l/s
Access / installation issues	Access is possible, but may be challenging for some machinery due to the steep gradient.
Grid connection	Unknown
Installation proposal	The mill has been renovated into residential housing. A demonstration waterwheel has been fitted into the wheel pit which appears to be narrower than what would have been originally there. The mill pond is maintained and there is a series of four sluice gates acting as a weir to control the level in the mill pond. A continuous flow passes both through the wheel pit and over/under the four sluice gates. The four sluice gates appear to be maintained in good working order. There is a weir downstream of these four sluice gates, reducing the possible head. This should be removed and an Archimedean Screw turbine could be placed directly in front of one of the four sluice gates. This turbine would have a drop down sluice gate to allow it to be used in a flood event as per today. The drop down sluice gate allows flood flows to pass underneath the turbine. A foundation of a lower end of the turbine would need to be made. The power generated could be fed into the mill house.

31. Sarn Mill

Grid reference	SJ 44113 44719
Ownership	Private
Power estimation	4.3 kW
Outline cost	£130,000
Outline gross revenue	£60,000
Gross head	1.8 m
Mean flow estimation	360 l/s
Access / installation issues	Access on foot only from the mill side. However, heavy machinery maybe able to approach from the opposite side, but this would require cooperation from the land owner.
Grid connection	Unknown
Installation proposal	This mill has been renovated into residential accommodation, with all the mill machinery removed. The undershot waterwheel still exists. There is also a drain down sluice gate on the opposite side of the weir. The weir height would need to be raised to its former height. It may be sensible to consider an inflatable weir crest to ease flooding concerns. The Archimedean Screw turbine should then be located into the former drain down sluice, with a sluice gate behind. The power generated could then be fed either into Sarn Mill or the adjacent industrial properties.

32. Stretton Water Mill

Grid reference	SJ 45107 52993
Ownership	Cheshire Museums Service
Power estimation	3.1 kW
Outline cost	£50,000
Outline gross revenue	£2,700
Gross head	4.5 m
Design flow estimation	100 l/s
Access / installation issues	Access possible for all heavy machinery.
Grid connection	A three phase grid connection is nearby.
Installation proposal	The mill is currently a working museum and two waterwheels have been preserved in excellent condition, along with most of the ancillary components. They plan to drive a small generator from the overshot wheel for the visitors benefit, but this will be off-grid generation only. The other pitch-back wheel has an open space around the non-mill side of the wheel. It is also enclosed within the building. This would lend itself to having a gearbox and generator directly coupled to the shaft. The control gear could be located within the mill building or on a standalone platform. The power could then be exported via the nearby three-phase grid connection.

33. Preistlands Farm

Grid reference	SJ 559 587
Ownership	Private
Power estimation	0.4 kW
Outline cost	£60,000
Outline gross revenue	£500
Gross head	1.2 m
Mean flow estimation	50 l/s
Access / installation issues	There is suitable access for heavy machinery at this site.
Grid connection	Single phase supply to the nearby property. A three phase supply also close by.
Installation proposal	The current sluice gate impounding the water is in a state of disrepair and the level is below the design intended. It would be possible to raise the impoundment to improve the head. An Archimedean Screw turbine could be located at the end of the spillway, which passes under a small access track. A small weir or impoundment would need to be installed alongside the turbine to impound the water and to allow excess flood flows to by-pass the turbine. A small foundation for the upper and lower end of the turbine would need to be created. The power generated could be used to power the farmhouse.

34. Tilstone Mill

Grid reference	SJ 56752 59362
Ownership	Private
Power estimation	3.1 kW
Outline cost	£80,000
Outline gross revenue	£2,700
Gross head	4.5 m
Design flow estimation	100 l/s
Access / installation issues	The installation site is close to a road, therefore suitable for all machinery.
Grid connection	A single phase supply is in the vicinity.
Installation proposal	The mill has been renovated into residential accommodation. The impoundment of sluice gates which would have held the water in the mill pond has been removed. The mill pond is empty and lush with vegetation as a result. The main flow of the river weaves through the mill pond and under a road where the sluice gates would have been around the mill. There is a significant head at the sluice gates therefore an Archimedean Screw turbine in conjunction with a sluice gate could be used to impound water again in the mill pond. A drop down sluice gate would allow flood flows to by-pass the turbine. A suitable grid connection point is close by.

References

Wikipedia. Cheshire West and Chester; the River Dee; the River Weaver; the River Dane; the River Gowy. Route and background information. http://www.en.wikipedia.org [ACCESSED 23-09-10]