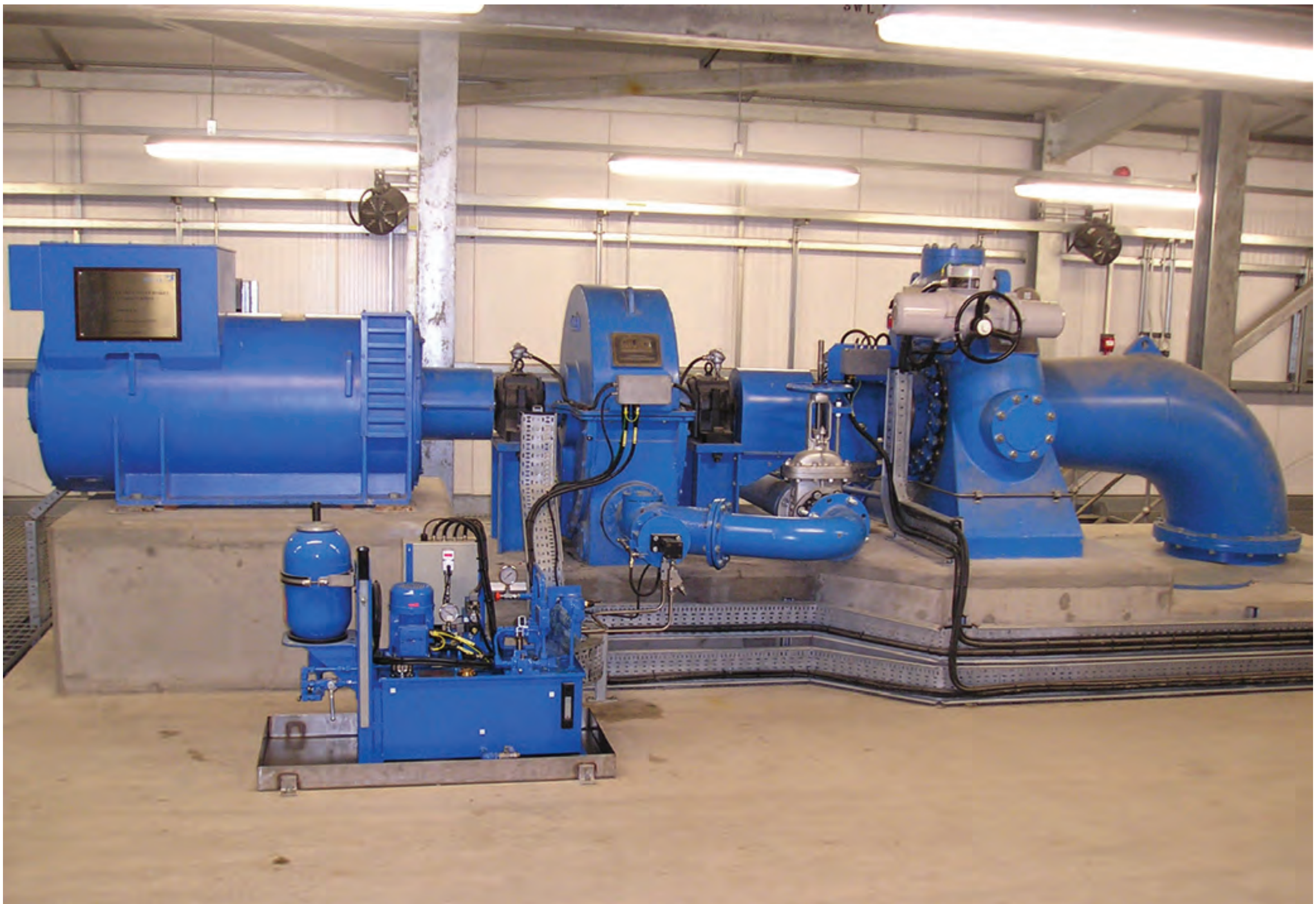
Hydropower Generating Scheme

hydro project will provide Scottish Water with self-generated power for their assets

by William Ancell BA (Hons)

The topography of Scotland means a large amount of Scottish Water's energy use is in pumping water around the country. Additionally, a lot of energy is required to treat water to meet regulatory standards, despite the generally high raw water quality in Scotland. In order to reduce power costs for water supply and treatment by 10%, and in doing so help keep down Scottish Water's operating expenditure, the company is progressing with a £20 million+ hydropower generating scheme that will use the existing water supply pipes to generate electricity for the utility's own assets.



Wide shot of the turbine at Turret WTW in Crieff, Scotland - Courtesy of Scottish Water, Gilkes and Black & Veatch

Project background

The project involves installation of hydro turbines at raw water and treated potable water locations. More than 30 sites have been identified that could, using techniques most commonly seen in hydroelectric schemes, power the water treatment process in areas such as rural Lanarkshire, the Borders, Stirlingshire, Angus and Fife.

The schemes will make good use of existing Scottish Water buildings and also see the construction of some small buildings and electricity infrastructure to transfer the power from the point of generation back to the water treatment works where it is required. Some of the electricity infrastructure will be *'off the grid'*, so any major power loss caused by the power companies would not affect the supply of water to customers. This is a key part of Scottish Water's Climate Change Strategy and will substantially reduce its carbon footprint. The technology offers the dual benefits of improved service and reduced operating costs.

This is nothing new; Scottish Water's asset base is already generating 5% of the company's power requirements across Scotland and this investment will double that output. The project team have identified a number of potential sites and these will be whittled down to the best 20 or so small hydro schemes.

The project team is working closely with the national park authorities, community councils, power companies and planning officials to make sure these small hydro turbines have minimal effect on the landscape. Some of them will be situated in areas that are very remote so constructing them will require very diligent planning work.

Investment

£20m is a large investment, but it will soon pay itself back by allowing Scottish Water to generate its own power. The power derived from the project can be used by Scottish Water to offset required energy at water treatment facilities across Scotland, or to directly feed into the power grid system via a power purchase agreement with NPower; and in some instances, both.

During the project feasibility phase, a number of various scheme types/location have been identified, for example: run of river; dam compensation flows/spills; inlet to water treatment works; and inlet to break pressure tanks and network pipelines.

The turbines

Scottish Water has set up new supplier frameworks for the hydroelectric equipment, and the required turbines will be sourced where possible from Gilkes, Ross-shire Engineering and SSE.

The proposed turbines for installation range from TJ Turgos to Francis and Peltons; however detailed design will clearly identify the "best fit" for each location to match head and available flow.

A Gilkes turbine installed at a WTW by Black & Veatch Courtesy of Scottish Water, Gilkes and Black & Veatch

Civil engineering works

Additional civil structures will be required for the chosen sites/ locations. The main civil work will be undertaken at the run of river locations. These are essentially installed on greenfield sites, so in order to install the hydropower solutions new intakes, penstocks, pipelines, access roads etc will be required.

Civil works will also be required at other locations. However these are within existing Scottish Water operational assets and most have existing pipelines and some structures already in place.

Detail of the external casing of the turbine at Turret WTW Courtesy of Scottish Water, Gilkes and Black & Veatch

Power generation using compensation flows from (raw water) dams/reservoirs

This is the traditional form of power recovery at reservoirs and to some extent at treatment plants, where water requires to be returned to a river/water course to maintain agreed minimum flow regulation.

For these schemes, there is generally a constant flow of water available. Installing a hydro turbine at these locations allows Scottish Water to tap into this existing resource and generate power via installation of a suitable hydro turbine unit. The generated power can be utilised to offset required energy for the water treatment works or be exported to the power grid system via a power purchase agreement, or both.

Inlet to water treatment works

Water entering a plant for treatment will pass through a suitable turbine. This also provides power for use (off-set) on-site or again export to the grid again via a power purchase agreement.

In general a Turgo impulse turbine is used at these locations because it allows inlet flow control to be independent of power generation.

Feasibility studies key to identifying sites

The project team carried out feasibility studies on 48 sites, this was reduced to 34 sites on completion of the feasibility phase. Identified sites range across all of Scotland, from Loch Katrine in the Trossachs, to Glendevon in Fife and to areas in the south, east and west of Scotland.

Under this programme of works, Scottish Water have in the region of 20+ sites that will progress forward to the construction phase. Within these sites the estimated annual energy output ranges between 318MWh-4,632MWh.

Sites being utilised fall into the following categories:

- ***Raw water:*** run of river schemes (greenfield site); dam flows to water treatment works; dam compensation flows & spills to rivers.

- ***Potable water locations:*** Inlet to break pressure tanks, inlet to service reservoirs or by running water through pressure reducing valves (PRVs).

Scottish Water completed the project feasibility phase at the end of August 2011 and has now moved into the development phase with all 34 identified sites.

Regulatory outputs

The regulatory outputs were set by the Water Industry Commission for Scotland (WICS) and are as follows:

1. Increase generation of renewable energy on Scottish Water assets by 25GWh per annum by 31st March 2015.
2. During 2014/15, deliver (net) operational expenditure savings of £2m as a direct result of investment in hydro-renewable energy schemes on Scottish Water assets.

Undertakings

Scottish Water has undertaken a partnering approach with their framework Design and Build contractors. The 34 sites have been split into three groupings then allocated to each of three partners:

- Black & Veatch.
- Amalgamated Construction.
- Ross-shire Engineering.

The development phase is presently programmed for completion across all three groupings by August 2012. The project team are currently liaising with local planning departments, SEPA, National Parks Authority and DNOs (Distribution Network Operators: SSE and Scottish Power).

The design and build partners are developing each of the identified schemes. On completion of the development phase, the project team will identify and take forward 20+ sites into the implementation phase (construction) to allow achievement of regulatory outputs for this programme of works. The identification of the best sites will be based on selection criteria ranging from simple payback to whole life cost analysis.

Progress

Scottish Water procurement has set up new frameworks to cover the requirements of the hydro programme of works:

- Design and Build contractors (now in place).
- Kit suppliers (turbines, now in place).
- Operation and maintenance (presently ongoing).

This work is all part of Scottish Water's wider renewable energy portfolio which also includes wind and biogas production from food waste.

The overall portfolio of green energy projects places Scottish Water at the forefront of innovation in the UK water industry and is in line with the aspirations of the Scottish Government's *'Building a Hydro Nation' Water Bill*, which aims to harness Scotland's renewable energy potential from water and the wider Scottish Water estate and to capitalise on the industry expertise that has been built up over the ten years that Scottish Water has been in existence.

In addition to this project, Scottish Water Horizons, the commercial arm of Scottish Water, has recently installed a micro-turbine at the redundant Touch WTW in Stirling. This is creating power which is then sold back to the current power purchase agreement partner NPower. Horizons is driving forward the green agenda as part of Scottish Water's drive to be a low-carbon business.

The editor & publishers thank William Ancell, Senior Press Officer with Scottish Water, for providing the above article for publication.

Detail of a Gilkes turbine - Courtesy of Scottish Water, Gilkes and Black & Veatch

Turret WTW

£24m upgrade & refurbishment project

by
David Crawford

At 359 metres above sea level, Turret Water Treatment Works (WTW) is the highest in Scotland and sits deep in the picturesque Glen Turret, located approximately 3.5km to the North West of Crieff, a location popular with tourists and hill walkers. Commissioned in 1967, the original WTW serving central Scotland (pe 70,000) comprised of microstrainers and ozone treatment (the first of its kind in Scotland) followed by chlorination. The design included the construction of two hydroelectric generating stations, one at the WTW itself and one further down the valley. With a combined capacity of 1,725 megawatts this was enough to run the entire Plant and allow Scottish Water to sell surplus through the National Grid.

Multiflo Sludge Plant *Courtesy of Scottish Water Solutions & GMJV*

Throughout its life however the Plant was to suffer from periods of very poor raw water quality, primarily due to rain flushes from the peat bogs contained within the catchment. These in turn affected the quality of the final water to supply and, as a result, the Ozonation plant was eventually replaced in 1971 by six Rapid Gravity Filters (RGFs).

In 2005 and after further upgrades including a second clear water tank and sludge handling facilities, it was recognised that the WTW was due for an extensive upgrade in order to comply with future Water Quality Directives.

Scope

The remedial works proposed were designed to deal with various Drivers as laid out by the Water Industry Commission for Scotland and Scottish Parliament. In particular they should allow the Plant to achieve an output of 85MLD during colour/turbidity raw water peaks while continuing to comply with water regulations. The primary

Chlorine Contact Tank *Courtesy of Scottish Water Solutions & GMJV*

elements of the upgrading were: a two stream Actiflo Clarification stage; a new 10 million litre Chlorine Contact Tank & Chlorination system; Chemical building; Sludge Treatment Plant and the refurbishment of the existing six RGFs. In addition, the Turbine Hall at the WTW was replaced with the installation of a new more efficient 550KW turbine & new break pressure tank.

Scottish Water Solutions Project Managed the work, the Design was carried out by Faber Maunsell AECOM and the Construction work was delivered through a partnership of Galliford Try and Morgan EST (GMJV). Work commenced on site in February 2008 and was successfully completed at the end of March 2010.

Design

At the project's inception, it was recognised that successful delivery would be dependent upon effective pre-planning, cooperation and coordination of effort between members of the team and other stakeholders and a prompt start to the physical work in order to meet the tight time schedule. The strategic approach taken was to involve Scottish Water, Stakeholders and the Contractor in all stages of the project to deliver an asset that met the client's requirements in terms of quality; and build a highly effective Project Team that shared experience and expertise in order to achieve the project objectives. Key to the success of the project was the early appointments of a full time dedicated Senior Treatment Operator and Contractor to the Project Team to provide operator input and buildability at the design stage.

Faber Maunsell AECOM developed a two stage design programme that would allow the Scottish Water milestones to be met, whilst also progressing the detailed design to meet construction needs. The main challenge faced was the timescale to meet the legislative deadline for the upgrade work by the end of March 2010. It was therefore essential to start construction on site by early 2008 to achieve the deadline date, so the main elements on the project had to be designed in advance of this to allow the procurement process to progress while the civil work started. At an early stage, packages of work were identified that would need to be developed in advance of the main design deliverables.

The project included the installation of an Actiflo clarification plant, the first major installation of such a plant in Scotland. It was clear that learning about the design, construction and operation of this technology was essential to the team. A series of learning visits to United Utilities existing Actiflo facility in Hodder, Lancashire was therefore arranged so that over the course of several months the designers, contractors and operators were all able to see the plant in operation and learn about the implication for design, building and operation of the facility.

Construction / Delivery Issues

The sole access to the Turret site is via a single 2km track road through the Glenturret estate. The access road was unsuitable for some large vehicles travelling to and from site during construction. After consultation with haulage contractors and Managers of the Estate some sections of road were extended in order to accommodate vehicles with a larger wheel base.

The roads are in constant use by workers on the Estate and members of the public who visit the area for a range of outdoor activities. As a result a detailed traffic management plan was instigated to minimise disturbance and delays. When a major concrete pour was due all the relevant parties were contacted in advance, including the Glenturret Estate and Scottish Water to alert them to increased heavy plant using the access roads. In addition to the public and construction traffic, Scottish Water required regular essential chemical deliveries to the WTW which required additional traffic management measures to limit impact upon any traffic.

To ensure the smooth running of these measures three traffic marshals were employed one on site and two at staging posts on the access roads, the marshals keeping in constant communication to ensure effective management of traffic.

Chemical building *Courtesy of Scottish Water Solutions & GMJV*

Sludge Holding Tanks *Courtesy of Scottish Water Solutions & GMJV*

Adverse weather conditions were identified as a risk factor due to the Turret site's elevation and exposed position. Many precautions were instigated on site including special wet weather gear; thermal gloves and tinted eye protection for operatives; a gritter and a tractor with snow plough to ensure the WTW and site were kept operational. The frequent high winds presented risk when operating the two large crawler cranes on site. Some days temperatures dropped to minus thirteen degrees Celsius on site and some work activities had to be suspended due to the high winds.

Limited space was available for the construction of the chlorine contact tank and 7,000m^3 of rock was removed to create an area for construction of the building. Because of environmental sensitivities it was not possible to remove the rock by blasting. The most effective means of rock removal proved to be the use of a rock planer which broke the rock down into particle sizes. The material was taken out, tested and reused within the project for hard standing with minimal non-conformance winning both cost and environmental benefits.

A number of key pipework tie-ins had to be completed which were considered high risk activities due to the age, unknown condition and restricted time period to complete the installation to maintain the public supply to the mains network. The project team had recognised that the option of an under pressure tie-in would allow the client to continue uninterrupted service with no shut down. It was important to win the confidence of the Scottish Water's operational team, who had not previously experienced a live tie in of this nature, by demonstrating adequate planning had been undertaken and the risks involved in the operation had been identified and managed. The operations were undertaken smoothly and the team were able to achieve the tie-ins in a shorter timescale than the planned conventional method.

Plant Commissioning

The testing, commissioning and handover of the works was an arduous operation and was carried out over a 6 month period, requiring meticulous planning and input from all parties. The main concern was some items of new plant could not be commissioned off line and therefore had potential to put the public water supply at risk. Accordingly, the commissioning plan had to be developed and the risks managed. When the new actiflo plant was brought into service this was completed in phased stages by introducing new elements (e.g. new chemical) and thoroughly testing, monitoring and proving the plant performance before moving on to the next stage of commissioning. To mitigate the risk, facilities were provided to by-pass the actiflo plant and revert back to the original treatment process. Like many complex major process plants, the commissioning of the new plant did have challenges and several design amendments and site modifications were implemented. As such, the new plant successfully completed the process performance testing and was handed over to Scottish Water in time for compliance with the Legislative date of 31st March 2010.

Note: ***The Editor & Publishers thank David Crawford, Project Manager with Scottish Water Solutions, for preparing the above article for publication.*** ■

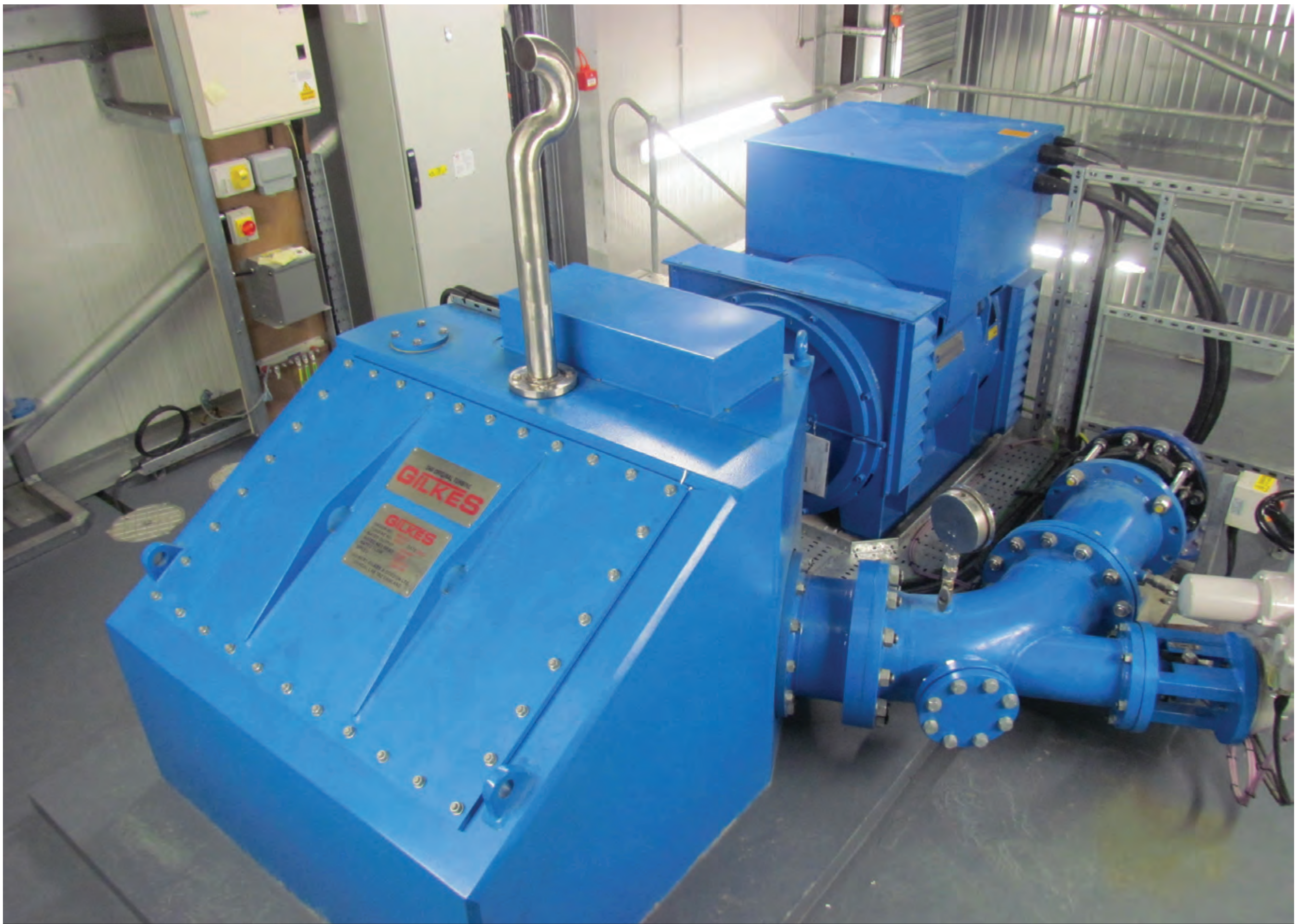
Turbine *Courtesy of Scottish Water Solutions & GMJV*

Sulby WTW Energy Recovery Scheme

hydroelectric scheme generates power from incoming raw water on the Isle of Man

by Tim Woakes MEng CEng MICE

The Isle of Man Water & Sewerage Authority has recognised that due to increasing energy costs and local and global initiatives to reduce carbon emissions they have an obligation to investigate the viability of and pursue sources of green energy. As such they have undertaken an ambitious project to convert the potential energy stored in the Sulby Impounding Reservoir into electricity to power Sulby Water Treatment Works (WTW) by passing the raw water through a turbine prior to the treatment process.



Turbine installation - Courtesy of Auldyn Construction Ltd

Background

The Isle of Man is a self governing Crown dependency which, through its ancient parliament Tynwald, enjoys a high degree of domestic legislative and political autonomy. The Isle of Man Water & Sewerage Authority is a statutory board, charged with ensuring the economic, efficient and effective provision of the services and infrastructure necessary to meet the Island's needs in terms of a wholesome supply of drinking water and the treatment and disposal of sewage.

Sulby WTW, sited on the bank of the Sulby River and completed in September 2005, is one of two modern treatment works on the Isle of Man. Sulby WTW supplies drinking water to approximately 30% of the Island's population mainly in the North and West. The treatment works is fed from Sulby Impounding Reservoir which has a capacity of 4.8 million cubic meters of water when full and a direct catchment area of 16 square kilometres.

The top water level when full is 185m AOD, and the top 4m of water is available for use by the Manx Electricity Authority (MEA) who have a connection to the scour pipe leading to a 1MW hydroelectric power station in Sulby Valley, which discharges directly into the Sulby River. Once the water level is drawn down to 181m AOD the MEA no longer generate electricity, as the storage within the reservoir below this level is solely required for drinking water.

A 300mm ductile iron (DI) pipe connects to three draw offs within the reservoir, the use of which depends on the water level and the seasonal variation of water quality. Approximately 2km down Sulby Valley the main splits into two.

The 300mm DI pipe continues 3km down to the WTW, and is duplicated by a newer 400mm DI pipe. Both mains enter the basement of the works downstream of a swab receiving facility on the opposite side of the Sulby River.

The WTW site is at approximately 35m AOD, with the water level within the inlet blending chamber some 7m above ground level. The excess pressure is destroyed by the flow control valves on the two inlets to the works to prevent over topping of the inlet blending chamber. The works currently processes an average of 10-12MLD, with a capacity of 21MLD for future demand increase.

The Isle of Man Water & Sewerage Authority recognised that due to increasing energy costs, combined with local and global initiatives to reduce carbon emissions that they have an obligation to give due consideration to 'sources' of green energy. Given the consistent flows and a static head of up to 150m at the inlet, Sulby WTW was identified as an ideal location to recover energy using a hydroelectric turbine.

The scheme

The objective of the scheme was to construct a hydroelectric turbine at Sulby WTW to give the shortest payback period with least impact on the existing treatment process. Various studies were undertaken to determine the options available. The conclusions were that the following permutations of the concept should be considered further:

- A machine on top of the WTW inlet blending chamber.
- A machine in its own new turbine house outside, but close to the WTW. This option then required water to be pumped to the WTW's inlet blending chamber.
- A machine in its own new turbine house attached to the WTW building. The turbine would be at a level such that water flowed under gravity into the WTW's inlet blending chamber.

A review of the technical feasibility of each scheme was then undertaken. It was determined that a machine placed on top of the blending chamber would only be feasible if the roof height was increased in its immediate vicinity. Discussions with the Planning Department ascertained that planning permission was unlikely to be granted for this and therefore this option was discounted.

The Planning Department confirmed that the construction of an annex adjacent to the existing WTW would be acceptable on the proviso that it matched the existing works aesthetically and its roof level was not greater than that of the existing WTW.

A whole life costing exercise was undertaken to ascertain which of the two remaining solutions gave the highest return over a 20 year design life. It was determined that a machine at a level such that no interstage pumping was required was the preferred option, to be installed in a new annex immediately adjacent to the existing works.

Investigations were subsequently undertaken into the type of turbine which would be most suitable for this flow/head scenario. This activity resulted in a recommendation that the following types of turbine could be utilised at Sulby WTW:

- Pelton Turbine.
- Turgo Turbine.
- Crossflow turbine.

A design and build team, comprising Isle of Man contractor Auldyn Construction Ltd and Northern Ireland based designer Atkins, was appointed to progress the scheme. The team approached turbine suppliers Gilbert Gilkes & Gordon Ltd of Kendal, Cumbria to assist with the design and ultimately supply the turbine.

A single Turgo Impulse turbine was chosen as the most efficient turbine for this combination of flow and head. The turbine and associated pipework was designed to operate up to 16MLD, flows above which would utilise the second stream into the works.

Annex steel frame - Courtesy of Isle of Man Water & Sewerage Authority

Internal pipework and supports - Courtesy of Auldyn Construction Ltd

Swab launcher at Sulby Dam
Courtesy of Isle of Man Water & Sewerage Authority

Completed annex
Courtesy of Isle of Man Water & Sewerage Authority

The design and build team supported by the Authority's cost consultants EC Harris completed a design, gained planning approval and built up a target cost for the scheme. The target cost was subsequently audited by EC Harris and accepted by the Authority. An NEC3 Option C Contract was awarded for the construction phase of the scheme in February 2012, and work commenced on site that month.

Maximising return

The pipes connecting the water treatment works and the impounding reservoir were known to suffer from high headloss. Pressures exhibited at the works suggested that the pipes had a C value of around 90 to 100 and were in urgent need of cleaning.

The high level of manganese deposition within the first stage filter nozzles suggested that the pipes were likely to be coated with a significant build up of manganese and silts. It was therefore decided that a swabbing exercise should be undertaken prior to the completion of the turbine scheme.

A purpose built swab launcher existed on the newer 400mm pipe but only a removable hatch was present on the older 300mm main. A swab receiver adjacent to the treatment works, but on the opposite side of the river catered for both mains but no realistic environmentally acceptable method of disposing of the dirty water was in place, and hence the mains had not been swabbed effectively for many years.

The first phase of the swabbing exercise was to undertake enabling works. A new swab launcher was installed at the head of the 300mm main at the base of the dam. In order to manage the dirty water which would accompany the swab down the main an old settling tank with a capacity of 300m^3 was connected with 225mm HPPE pipe to the swab receiver, utilising old redundant pipework to cross the river.

These enabling works allowed the swabbing exercise to take place. The dirty water was allowed to settle in the old tank before being decanted into the adjacent river.

Following the swabbing exercise the pressures at the water treatment works increased substantially, with the C values increasing to over 120, corresponding to an increase in 10m head at 10MLD and over 25m head at 16MLD. This has almost doubled the power predicted to be produced by the turbine over the next 20 years.

An additional function to maximise return was included by way of a dump to river facility. This allows flow over and above that to be treated by the works to be passed through the turbine and dumped to the river. This will only be utilised when the impounding reservoir is spilling.

Construction

Construction commenced on the 11 June 2012 with the breaking out of concrete hardstanding in readiness for the piling work which would form the foundation for the steel frame of the annex. A total of 13 (No.) 220mm diameter steel piles were installed and a ground beam constructed above. The steel frame was then installed and the concrete floor of the turbine level cast. This was designed to reduce vibration within the annex.

The annex was subsequently clad with a combination of green oak and Manx stone to match the existing treatment works building and adhere to planning requirements.

The internal ductile iron pipework and galvanised steel supports were installed following the commissioning of the roof level crane. This was also utilised to lift the turbine into place. One of the two inlet pipes was intercepted and diverted out into the turbine annex before re entering the existing building and back into the inlet blending chamber.

Within the existing treatment works building various modifications were undertaken to connect the turbine pipework into the existing. A number of planned works shut downs were utilised to undertake these connections in a safe and controlled manner. ‘Spectacle’ blanking plates were used to keep the existing pipework and the new pipework separate, until the turbine was suitably commissioned utilising the dump to river facility ‘off-line’.

Tycon Automation Ltd and Saftronics Ltd provided significant software support during the scheme. New software was written and installed to seamlessly incorporate the turbine into the control philosophy of the existing works. A vast array of new cabling was installed to connect the new turbine panel in the annex with an existing panel in the main MCC room.

Once all parties were content with the operation of the turbine the spectacle plates were removed and the turbine fully commissioned running water into the treatment works. The turbine began generating electricity on the 1 February 2013.

The turbine currently generates around 90-100kW, approximately 40% of the electricity required to treat water at Sulby WTW. The £950,000 scheme is expected to have a payback period of approximately 9 years.

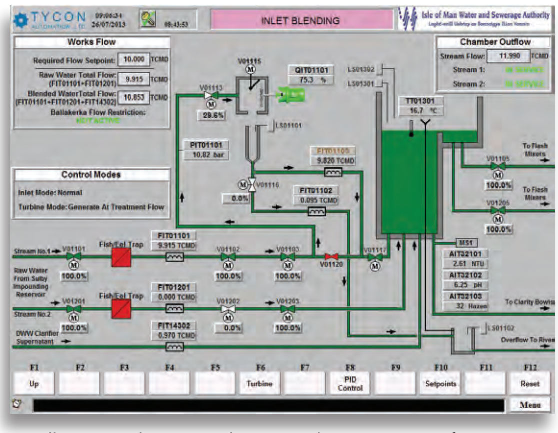
Future schemes

The Authority is now undertaking feasibility studies to ascertain the viability of installing energy recovery turbines at other sites across the Isle of Man.

The Editor & Publishers would like to thank Tim Woakes, Project Delivery Manager with Isle of Man Water and Sewerage Authority, for providing the above article for publication.

New turbine panel within annex - Courtesy of Auldyn Construction Ltd

Connection to existing blending chamber - IOMWASA



Sulby WTW inlet SCADA showing turbine - Courtesy of IOMWASA

Glencorse WTW

Edinburgh's new £130m WTW is a feat of modern construction methods and sustainable engineering

From the sweeping Tweedsmuir Hills in the Scottish Borders, to the rolling Pentlands on the capital's doorstep, gravity carries up to 175Ml/d of clear, fresh drinking water to 450,000 customers in Edinburgh and parts of Midlothian. Glencorse Water Treatment Works (WTW), Scottish Water's £130m flagship investment, is a 21st century replacement for the existing works at Fairmilehead and Alnwickhill (constructed in 1909 and 1885 respectively), which despite serving the city well for over a century, have now reached the end of their operational life. Carried along the Victorian engineered Talla Aqueduct to the new WTW, like Scotland's famous tartans that it is so well known for, the city's water supply blends a mix of ancient and modern.

Glencorse WTW - Courtesy of Scottish Water

Consultation & planning

In April 2006, a decision was taken to replace the ageing facilities at Fairmilehead and Alnwickhill rather than undertake further capital maintenance work and upgrades. Following Scottish Water's largest ever consultation, in collaboration with the latest civil engineering studies, the site at Glencorse was selected as the most suitable and helps meet Scottish Water's drive to deliver renewable energy from its assets. Gravity will carry raw water supplies some 50km into the inlet building, as well as delivering the treated water directly into the capital, reducing the need for energy sapping pumps.

Working closely with Midlothian Council planning department and local residents, in September 2007 the project received planning permission after just 10 weeks, unheard of for a construction project of this size.

Archaeology

Following initial archaeological studies, a Roman Marching Camp was discovered on the proposed site of the treatment building. Neighbouring residents agreed the repositioned works location to protect this important local antiquity. Throughout construction close links have remained between the project team and the community surrounding the new facility. Other finds included Cromwellian military artefacts at the site of an old World War Two army camp situated along the pipeline route.

Raw water supplies

Raw water travels over 50km by gravity through the existing aqueducts and pipes to the new Glencorse WTW, and comes from a variety of sources; primarily the Talla, Fruid and Megget Reservoirs, located in the Scottish Borders. Glencorse Reservoir, located approximately 1km from the works, will also be utilised.

Hydro turbine

The raw water entering the site operates a Gilkes twin-jet Turgo Impulse Hydro Turbine housed within the raw water inlet building. With a designed operating regime of between 30 and 50Ml/d at pressures varying between 53m and 73m of head, the turbine has a nominal rating of 230KW, and will generate roughly one third of the entire energy requirements for the WTW.

Treatment process

Raw water contains impurities which affects the colour, taste and clarity of the water. To ensure that the drinking water meets the Water Supply (Water Quality) (Scotland) Regulations 2001, water treatment processes vary across the country depending on the water supply and the technologies available when each treatment works was built. As Scottish Water's flagship project, Glencorse Water Treatment Works utilises some of the most up-to-date and efficient processes:

- Coagulation: Colloids and other impurities in the raw water need to be removed. Coagulants like alum (aluminium sulphate) will be used to help bind the impurities together to form particles. This solid-liquid separation process requires precise dosing and pH control along with good mixing to be effective.
- Flocculation: The coagulated water is mixed for around 20 minutes to allow the particles to grow in size for effective removal in the next stage. The water passes over and under baffle weir walls forming a 'floc' on the surface. This form of hydraulic flocculation requires no moving machinery, unlike other systems which use mechanical mixers, meaning there is a reduction in power and maintenance costs. In colder temperatures, a chemical polymer can be added to aid the process. The choice of the polymers used may differ, depending on the quality of the raw water.
- CoCoDAFF: Glencorse utilises the innovative CoCoDAFF (counter current dissolved air flotation & filtration) system which combines two forms of impurity removal in one; dissolved air flotation (DAF) and rapid gravity filtration (RGF).

  DAF Process: During the DAF process, impurities are floated to the surface, instead of being allowed to settle at the bottom. A mass of fine bubbles is created by saturating the water with air under high pressure, and mixed with the flocculated raw water to help float the impurities to the surface. This sludge blanket is periodically removed by a flushing of water over a weir into an outlet channel.

  Filtration: After the DAF Process, the water is passed onto the rapid gravity filters in the lower section of the CoCoDAFF cell. Here any remaining impurities too big to pass through the filter are trapped in a media of sand and anthracite. The filter beds are periodically backwashed to remove the build up of impurities. Phosphate is then added to help prevent lead being absorbed from lead pipes at customers' properties.

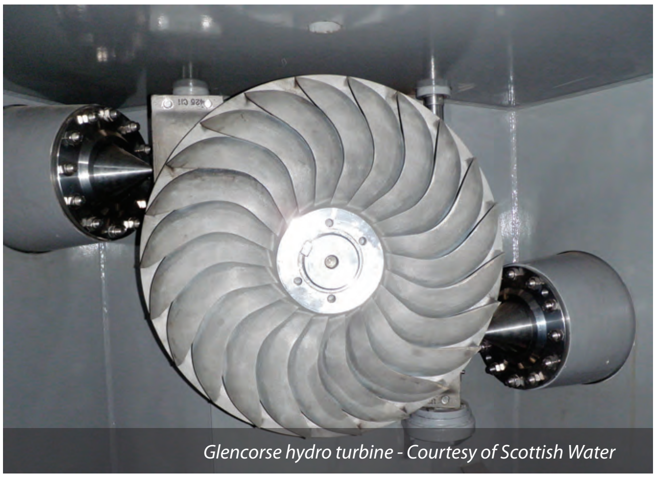
  Footprint: The CoCoDAFF process reduces the size of the overall footprint of the WTW and has significantly helped in achieving the "low impact" building and aids in visual mitigation of the structure(s).
- Disinfection: Disinfection is vital to ensure that water-borne diseases are eliminated, and that the drinking water meets the Water Supply (Water Quality) (Scotland) Regulations 2001. Sodium hypochloride is added as a liquid form and the water passed through a contact tank for around 25 minutes before entering an underground storage tank.
- Sludge: The waste water produced from backwashing the filters and sludge from the DAF process passes through lamella settlement tanks and is recycled back to the head of the of the works. Using this process, approximately 99% of the backwash water can be reused. The remaining waste is a sludge form which is transferred away from Glencorse to be treated at a wastewater treatment works.

The clear water tank

With an impressive 490 internal columns, and 90Ml capacity, the new 208m by 90m clear water tank is one of the largest in Europe, storing the treated water before it commences the journey to Edinburgh. This storage tank is covered with a grass roof, providing hill-walkers with an unspoiled view from the top of the Pentlands.

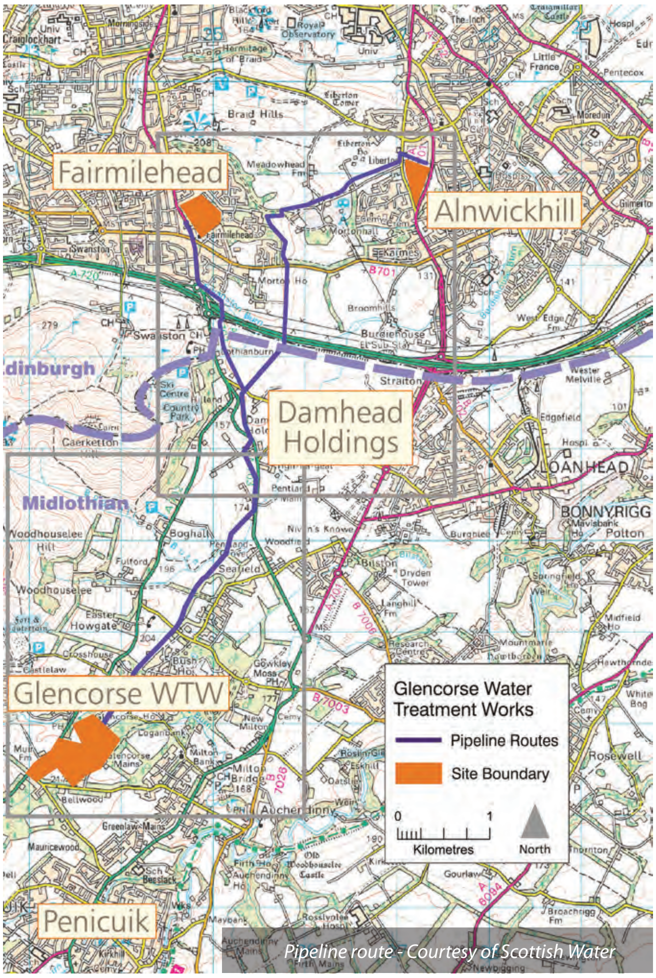
Construction is underway - Courtesy of Scottish Water

Pipe gallery - Courtesy of Scottish Water



Glencorse hydro turbine - Courtesy of Scottish Water

Inside the clear water tank - Courtesy of Scottish Water



Pipeline route - Courtesy of Scottish Water

Mobile pipeline production plant - Courtesy of Scottish Water

Pipelines

Over 7km of twin 1,200mm dia pipes were required to deliver the treated water from the new works into Edinburgh's existing distribution network. The route of these pipelines required careful consideration from engineering, environmental and social perspectives such as:

- Avoiding the need for expensive pumping by choosing a route that allows the water to flow by gravity.
- Minimising disruption to road users and pedestrians by using agricultural land where possible.
- Avoiding sites of archaeological interest.
- Minimise damage to trees and hedgerows in areas that are important for nature conservation by crossing at existing gaps or areas of sparse vegetation where possible.

The twin pipeline runs from Glencorse WTW through agricultural land to Damhead, where it splits. One leg of the pipeline connects into existing pipework and takes water to the Fairmilehead area. The other connects into the network at Alnwickhill. Directional tunnelling under the Edinburgh City Bypass was required to the cross one of Scotland's busiest roads without disrupting the thousands of commuters who use this vital artery every day.

Two smaller pipes were also necessary to connect with the sewerage network and take this minimal amount of sludge away from the Glencorse site for treatment.

Mobile pipeline production plant - *this aspect was featured in detail in UK Water Projects 2009 and on www.WaterProjectsOnline.com*

In a world's first, Scottish water and Black & Veatch 'dropped' a mobile pipeline production plant onto the route of the trunk main connecting the new treatment works with the existing network serving the capital.

Rather than being restricted to using long trailers for the transportation of pipes, it was possible to go beyond the 15m restriction and mould extra long pipes of 22m. This ensured the overall dual trunk main was more robust, requiring fewer welds, and helping to reduce the duration of the pipeline project. Additionally the mobile pipeline project saved around a million lorry miles – enough to reach the moon and back twice.

Minimising the visual impact

The site of the new WTW neighbours the Pentland Hills Regional Park, and so as not to detract from the natural beauty of the area, measures were taken to minimise the visual impact of the project.

Instead of using corrugated metal, a living grass roof covers the treatment building and the clear water storage tank, an area totalling around 43,000m^2, making the works almost invisible from the Pentland Hills, the A702, and surrounding properties.

The wildflower meadow seed mixture provides excellent biodiversity, and the variety of native grasses and flowers fits in well with the surrounding landscape. The grass roof will also harvest rainwater, which will be stored in bio-diverse wetlands, providing rich habitats for a number of insect, animal and plant species. The turf was grown on the banks of Loch Leven near Kinross, at a farm of turf experts Stewartsturf.

To further minimise the visual impact, the treatment building is sunken into the ground and shielded from view by landscaped bunds of earth.

Locally sourced materials

Where possible, the project has used locally sourced materials to ensure a natural fit, reduce the transportation footprint and reduce maintenance. Perimeter walls have been constructed from wire baskets filled with locally quarried stone, which allows


Glencorse WTW - July 2011 - Courtesy of Scottish Water


Directional tunnelling - Courtesy of Scottish Water

the construction spoil to be reused in landscaping the facility. This practice has helped to reduce construction traffic by 75%, significantly improving the projects overall carbon footprint.

Legacy

As well as providing an engineering legacy, the Glencorse project will also provide a living legacy for up to 500 young people who passed through its doors during the 3½ year construction programme, inspiring future generations of young engineers. The project 'adopted' three local primary schools from Year 4, through the evolution of the project, holding classes on an annual basis.

Young people grew up with the project, learning lessons in environmental engineering, health & safety, and civil engineering practice. Lessons were practical, with numerous site visits and tours of the neighbouring Pentlands Park to learn about the plants and animals that call this area home.

Working with the project's education programme 60 oak trees were donated by Green MSP Robin Harper, who also helped the children to plant this living legacy for the young people who took part in this community education programme. The oaks will provide additional landscaping to screen the works from motorists on the A702.

Project delivery team

The delivery team consisted of a partnership of specialists. Scottish Water engaged Black & Veatch (B&V) as Design & Build Contractor for the project, coordinating and managing all phases of delivery. B&V in turn engaged ERM as Environmental Consultants and BDP as Building and Landscape Architects. Scottish Water also engaged EC Harris as Cost Consultants.

The project was delivered on time and under budget. It has won a number of prestigious awards including the CIWEM World of Difference Award; the International Green Apple Environment Award and a trio of Considerate Constructor Gold Awards.

Glencorse is an exemplar project, not only delivering a state-of-the-art water treatment works and providing a 21st century water supply for Scotland's capital, but it is a cutting edge example of how sustainable engineering is possible in a project of such a mammoth scale. Glencorse will now serve Scotland's modern capital for a further century, with additional capacity and room to modernise yet further built into the existing project.

The editor & publishers would like to thank Scottish Water for providing the above article for publication.


First of the pipes being laid - Courtesy of Scottish Water


The green roof - Wildflower grass mix - Courtesy of Scottish Water

Eccup No.1 WTW - Hydroelectric Scheme

hydroelectric installation fully integrated with the previously existing operation to generate up to 700MWh of electricity per annum

by Zoe Kevanhu BEng (Hons)

Eccup No. 1 Water Treatment Works (WTW) is situated within the Eccup Complex approximately 6 miles to the north of Leeds adjacent to Eccup impounding reservoir. The WTW was originally commissioned in 1965 to treat water from the Washburn Valley Reservoirs and provide potable water for many distribution areas within Leeds and Harrogate. The current operating range of the WTW is around 32,000m^3 - 64,000m^3 per day. The inlet works at Eccup No.1 WTW is connected to the lowest of the Washburn Valley Reservoirs, Swinsty Reservoir, some 18.5km to the north west of the WTW, via the Washburn Valley Mains; one 42" and four 30" cast iron mains.

Turbine installation - Courtesy of JN Bentley

Background

Yorkshire Water's vision is *'taking responsibility for the water environment for good'*, with one of their strategic objectives to achieve this vision being the use of sustainable resources - to get the most out of them and reduce emissions and waste in line with their Corporate Challenge.

This was a key driver for the Eccup Hydroelectric scheme, supporting YWS's drive towards ascertaining new and sustainable means of utilising natural resources, with the aim of achieving their target of generating 14% of their own electricity needs through renewable means by 2015.

In 2008 YWS commissioned a feasibility study and a report was produced into the potential commercial viability for renewable energy installations within the YWS clean water network. The report identified the inlet mains at Eccup No.1 WTW as a potentially viable location for a hydroelectric generation facility. At this point energy was being lost as the inlet water stilled within the inlet channel of the works which could be recovered by such an installation.

Reinforced by the introduction of more generous *'Feed-in Tariffs'* for the installation of renewable energy sources by the UK government in 2010, in September 2010 YWS contracted MMB (a joint venture between Mott MacDonald and JN Bentley) to carry out Early Contractor Involvement (ECI) in the form of an Investigation Contract under the AMP5 Framework model for *'Other Installations'*. An ECI report was produced evaluating the commercial viability of a hydroelectric generation installation at Eccup No 1 WTW.

Through interrogation of flow and pressure data from historic records and site trials by MMB, turbine selection with Gilkes & Gordon Limited (Gilkes) and development of a detailed hydraulic model and surge analysis trials with sub-consultants Hydraulic Analysis Limited (HAL), value engineering evaluations were undertaken. Such evaluations facilitated the specification of several key plant items. These included:

- The type and size of hydroturbine to offer the greatest potential for generation over the widest range of works operating flows and mains pressures.

- The type and stroke times of isolation valves to reduce surge effects on operation.
- Inlet water screening requirements with a view to limiting head loss.

Evaluations of all options were developed on the basis of balancing the greatest potential for energy generation while limiting the potential surge effects on the inlet works and upstream system.

The MMB commercial team were able to prepare outline cost estimates based on the specifications developed in the production of the ECI report and conclude that, based on several options presented for further consideration and detailed development, the installation would have an estimated payback period of around 6-8 years. The information contained within the report facilitated the client in securing the required expenditure from within the business for the scheme to proceed to delivery.

MMB were contracted in July 2011 under the AMP5 Framework model for 'Other Installations' for delivery of the hydroelectric generation scheme. Working in partnership with surge analysis experts Hydraulic Analysis Limited, hydropower sub-contractor Gilbert Gilkes & Gordon Limited, control specialist CEMA Limited along with other valued supply chain members, MMB developed, installed and commissioned a horizontally mounted Francis turbine with asynchronous generator in a new hydroturbine building immediately upstream of Eccup No.1 WTW inlet works.

Key design challenges

Dynamics and Surge: A constraint within the contract was to not adversely affect the current operation of the Washburn Mains, as a result of surge pressures from operation of the hydroturbine. Through the development of a detailed hydraulic model and carrying out surge analysis trials, in association with HAL, it was possible to select items of equipment and develop an operating philosophy which minimised the generation and magnitude of any surge.

The dynamic effects of the hydroturbine necessitated the installation being founded on a monolithically cast slab. The shuttering details for such a slab, incorporating several pits and raised plinth areas was challenging, as well as the co-ordination for concrete deliveries to ensure they were on time as waiting between batches would not have been acceptable.

Pipework arrangements: Existing pipework arrangements at the inlet works were such that the installation of our pipework was directly adjacent to the concrete structure of the inlet works. In addition, the bypass main, which was to maintain the flows to the works until the turbine was commissioned, shared a thrust block with the main into which we were connecting. Stitch drilling was undertaken to free the pipe for connection. It was imperative that the works remain operational throughout the construction and as such co-ordination, planning and accuracy were key to ensure the inlet flow was not compromised.

Due to programme constraints to meet the clients key date requirements, coupled with extended lead times on plant items as a result of market conditions at the time, it was necessary to install large diameter pipework prior to the installation of the hydroturbine plant items themselves. As the pipework needed to be cast into thrust blocks at several locations as it was installed, removing any flexibility in the pipework, a bespoke rig was constructed to the dimensions of the final equipment connection points to ensure accuracy.

Through design development with our sub-consultant Gilkes; it was possible to develop a horizontal draft tube section as an alternative to the usual vertical, which would free discharge into a chamber. This enabled us to optimise the pipework arrangement to suit the spatial constraints as described above. The alternative draft tube also removed the need for an additional reinforced concrete structure, providing capital efficiency for the client.

Hydroturbine House: Capital efficiencies were also found in the development of a removable section to the roof of the hydroturbine building. Should the need arise, this will allow removal of the hydroturbine and generator, through the roof as part of a planned removal activity. Due to the relative infrequency of this activity, this option was developed with the client as a suitable and cost efficient alternative to the inclusion of a large permanent lifting arrangement and a larger building to suit this.

The size of the building which houses the installation was a key issue as the Eccup Complex is within the green belt and was subject to planning permission requirements. Close liaison with Leeds City Council Planning Department, including site visit, telephone conversations and responses to requests for additional information resulted in full planning permission being granted for the scheme.

The housing is a brick building with a flat roof. This is fitting with the existing surrounding buildings on the Eccup complex and as a result was satisfactory to the Planning Department. From a cost point of view, MMB carried out a cost comparison of a traditional building versus a secure GRP/steel kiosk type structure which demonstrated that, for the size of structure, a traditional build could be completed for less cost as a result of the utilisation of MMB employed labour, thus providing best value for the client.

Installation of hydrogenation plant items - Courtesy of JN Bentley

Construction of the hydrogenation facility in close proximity to existing structures - Courtesy of JN Bentley

Supply chain interaction

JN Bentley have an extensive skills base within their employed staff and at times the ability to resource tasks at short notice from within this pool, and the flexibility this offers, has proved invaluable to the success of the project in both cost and programme. However, JN Bentley also maintain strong relationships with many sub-contractors offering better value for the client when this is an option. For this project in particular, reinforced concrete sub-contractors, pipework suppliers and roofing detailers and fitters were of particular benefit due to the complexity of some of these items.

Through development of positive working relationships with the sub-consultants involved at the Investigation stage it was possible for MMB to work with these parties during the delivery of the project to develop innovative design details leading to cost efficiencies and programme savings for the client as previously identified.

Programme

The hydroturbine was installed to achieve the client's key date of 31 March 2012. Due to unforeseen restrictions within the Yorkshire Water raw and clean water networks the facility was required to operate on reduced capacity initially. Alterations within the network have subsequently taken place enabling commissioning checks at full capacity to take place during December 2012, allowing the facility to now generate to the design capacity.

Conclusion

Through thorough data gathering, innovative design development and successful planning and co-ordination, it has been possible to deliver a 700MWhpa facility to supply electricity to help power the treatment processes of Eccup No.1 WTW.

By value engineering and searching for the most efficient solutions throughout the scheme we have been able to provide capital efficiencies and best value overall for the client.

MMB have worked collaboratively with all parties involved, client, sub-consultant, sub-contractors and third parties, at all stages of the scheme, and this has been key to achieving the desired outcomes of the scheme successfully.

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Completed hydroturbine building - Courtesy of JN Bentley