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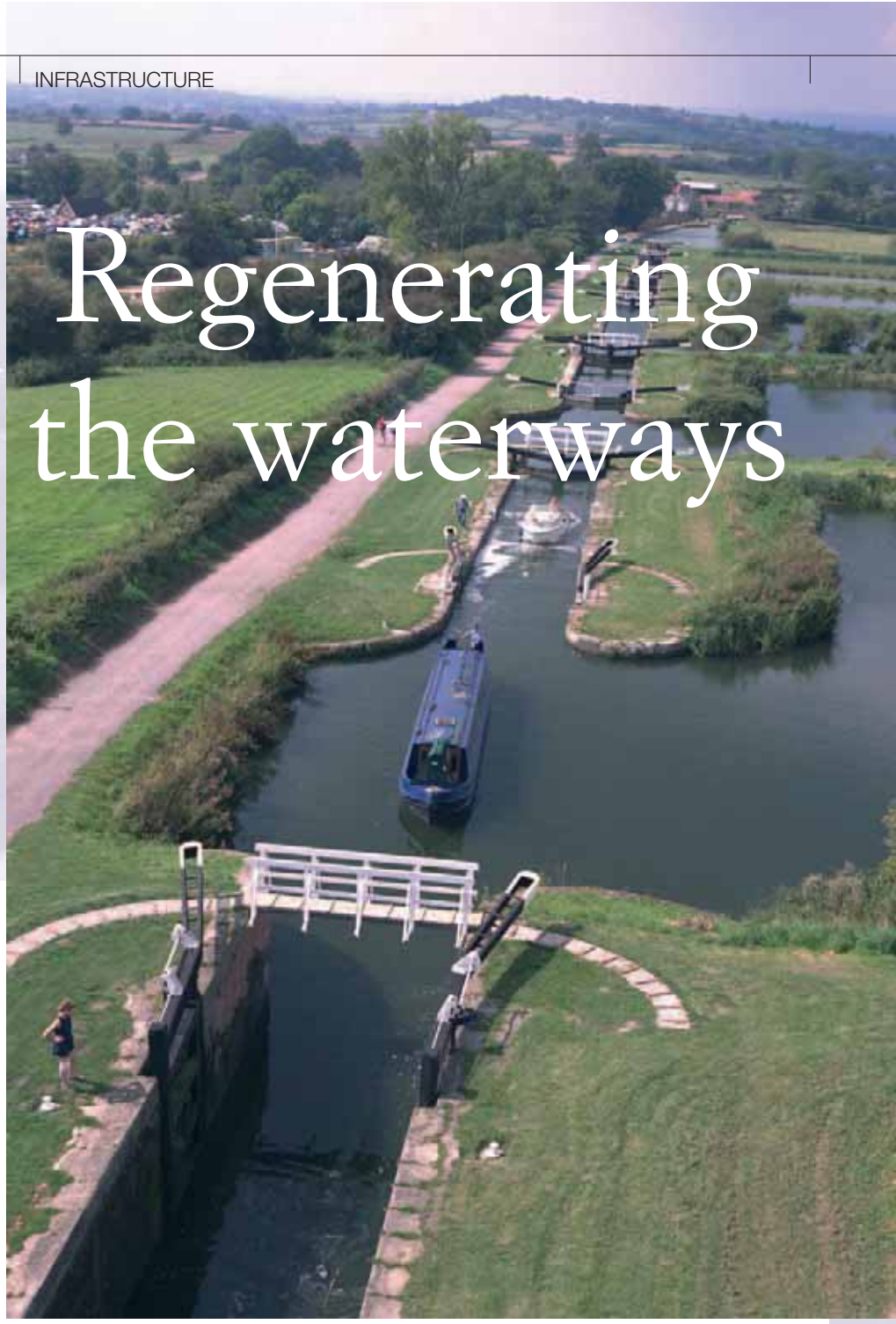
Regenerating the waterways



£2 billion has been spent on regenerating the British Waterways network over the past ten years. From the re-lining of large stretches of canal, to the restoration of the collapsed Standedge Tunnel that was originally deemed impossible, the engineers have been challenged every step of the way. Here, Stewart Sim gives an overview of the various projects that have been undertaken, detailing work on the rejuvenated Anderton Boat Lift and the state-of-the-art Falkirk Wheel

Linking cities, towns and villages, Britain's 200-year old inland waterways were once the primary method of transporting goods and were the catalyst for the world's first industrial revolution. The canals built were cutting-edge engineering solutions of their time, enabling inland waterways to flourish until the emergence of the railways in the 19th century.

Following post-world war decline and disuse, inland waterways are today enjoying a new role in twenty-first-century society. An important part of our heritage, canals and rivers are home to varied wild life habitats and are a leisure resource enjoyed by all.

British Waterways is the public corporation which cares for 2000 miles of canals and rivers across England, Scotland and Wales. Attracting 10 million visitors each year, British Waterways' canals and rivers have become catalysts for both urban and rural regeneration. Their modern-day maintenance and restoration demands engineering solutions that continue to be both innovative and considerate to the wildlife and visitors who enjoy them.

A brief history

Water has been used for transport since primitive times – for carrying goods and ferrying people. At first rivers were used, but rivers can meander and be unpredictable. The Romans created the first man-made British navigations such as the Fossdyke, while the short Exeter Canal was first cut in 1566. However, it wasn't until the late 18th century that Britain acquired the unique network of canals and river navigations that we know today and, by 1793, the country was in the grip of 'Canal Mania'.

Pioneering engineers built structures never attempted before and today's existence of our waterway network is testament to their dedicated work. Waterways climbed slopes by means of flights of locks or around individual planes, were conveyed through hills in tunnels and were carried across valleys on high aqueducts. Many are still as good as new today, like Telford's 300 m Pontcysyllte Aqueduct in Wales or Bingley Five Rise Locks near Leeds.

The arrival of railways brought competition that began the decline of cargo carrying on canals but it was

motorways that effectively killed off widespread waterway freight.

The waterways entered public ownership in 1948 and in 1962 The Transport Act created the British Waterways Board to operate the 2000 mile inland waterway network. Later, the 1968 Transport Act gave first official recognition to the value of the inland waterways for recreation.

By the mid-1990s, after many decades of under-funding for the waterways, British Waterways successfully made the case for increased investment in the network, as pioneering regeneration schemes began to demonstrate the economic, social and environmental potential of revitalised waterways. New funds from the European Union, Regional Development Agencies and the National Lottery – particularly the Millennium Commission and Heritage Lottery Fund – unlocked stalled restoration projects, which dated back decades.

A resource for all

The waterways are a leisure resource for all: half the UK population lives within five miles of a British Waterways canal or river. Well kept canals and rivers improve the environment we live in, ensuring visitors are able to enjoy a broad range of leisure facilities including walking, running, angling, cycling and canoeing or simply visiting a canal-side pub, restaurant or museum.

The boats on canals and rivers remain a common and attractive sight and are central to waterway life. Today's craft are predominantly leisure boats that bring colour and life to waterways, making them fun and vibrant places and attracting people to the canal towpaths and lock sides.

A 200-year history ensures the waterway network is an integral part of the nation's heritage. Visitors enjoy over 2800 listed structures and more than 130 Scheduled Ancient Monuments, over 800 designated conservation sites and 100 Sites of Special Scientific Interest (SSSI). Magnificently engineered structures, landscapes and traditions are becoming increasingly valued.

Whilst leisure and tourism on canals and rivers continue to thrive, some commercial vessels still use the network as an efficient method of transporting appropriate goods. The movement of freight on inland waterways has a small although growing part to play in the government's plans to manage transport more effectively. Total freight carried each year is 3.5 million tonnes and British Waterways has plans to double this figure by 2013.

Regeneration and restoration

The same towns and cities that turned their backs on the waterways in the years of decline and dereliction are now rediscovering historic canals, basins, locks, warehouses and wharves as the focal points of vibrant renaissance. In simple terms, people want to live, work, socialise and relax by water. Today waterways are an acknowledged regenerative catalyst, delivering tangible economic, social and environmental benefits to the lives of millions across the nation.

Over the last decade, British Waterways has been involved in £2 billion worth of regeneration that has bought widespread social and economic benefits to both urban and rural communities, creating thousands of jobs. The recent renovation of the mainly rural Huddersfield Narrow Canal, for example, is helping to create some 3000 jobs and an annual visitor spend of £3.6m.

Figure 1 Refurbishment work on the Manchester Rochdale lock

The decline of canals led to many miles of waterways being abandoned or cut off. After half a century of uncertainty and underfunding, canal restoration has gained momentum with the completion of many key projects. In the last two years alone, 220 miles of waterway have been restored or opened – and even a new navigation constructed – in eight major restoration projects.

In each major restoration British Waterways engineers tackle major obstructions, restore unique historic structures and buildings that require innovative and state-of-the-art engineering solutions. Recent projects include the following:

The Anderton Lift at Northwich in Cheshire is one of the best examples of how to make improvements – in close consultation with conservation bodies like English Heritage – whilst still preserving a unique structure.

The lift was built in 1875 to transport cargo-carrying boats between the River Weaver and the Trent & Mersey Canal 15 m above. It is the world's oldest boat lift and known with some affection

In the last two years alone, 220 miles of waterway have been restored or opened in eight major restoration projects

Figure 2 Relining a stretch of the Kennet & Avon Canal near Bath

as the 'Cathedral of the Canals'. Built using a revolutionary system of hydraulics, Anderton led to a number of similar lifts being built in Europe and North America.

In 1875, the Anderton Boat Lift used two water-filled tanks (caissons) counterbalancing each other and supported on massive hydraulic rams. The lift worked on the deceptively simple principle that drawing a small quantity of water from the ascending tank created a difference in weight. This, with the aid of a small hydraulic accumulator, was all that was needed to cause the heavier tank to descend and the other to rise. The hydraulic rams were operated by a steam engine and pump which was converted to electricity in 1908 when engineering work adapted the lift, counterbalancing each tank separately and operating the whole system mechanically.

The restoration work completed in 2002 reverted back to the 1875 mode of operation. The work included dismantling the structure for repair and took a team of 20 welders and erectors ten weeks to loosen, drill-out or burn-out 3000 bolts. The replacement hydraulic ram shafts replicate the originals and some 1500 m of welding covers more than 1000 repairs to the structure.

Restoration of the Kennet & Avon Canal shows how restoring waterways can benefit the environment. The canal features some of the finest waterway architecture in the country and passes through beautiful, fertile countryside and historic towns and cities including Bath, Bradford-on-Avon and Devizes.

In November 1997 a 'giant bath-plug-pulling' ceremony marked the start of a five-year £29 million restoration project. Extensive relining and conservation work took place along the length of the navigation, including a 10 mile, £11 million stretch between Bath and Bradford-on-Avon which has always leaked, wasting precious water.

The work was both technically innovative and also paid special attention to the protection of the waterway's important wildlife, including water reeds, fish and voles.

Engineers overcame different challenges along the canal, involving piling, dredging, installation of a pipeline, numerous lock repairs, water-saving back pumping and construction of water control weirs.

Hills used to be a canal builder's nightmare – until The Falkirk Wheel opened in July 2002. The wheel is the world's first rotating boat lift and centrepiece of the £84.5 million Millennium Link which has restored and reconnected Scotland's sea-to-sea Lowland canals and also Glasgow to Edinburgh, creating a corridor of environmental, economic and leisure opportunities across central Scotland.

The recipient of many engineering and design awards, the wheel uses twenty-first-century technology to create a twenty-first-century icon for waterways and for Scotland.

Itself costing £17.5 million, The Falkirk Wheel Interchange replaces an original flight of 11 locks that would have used a significant volume of water as boats 'cycled the lock' during their transit through the flight.

The wheel design uses Archimedes' principle to provide very efficient rotation in terms of energy. Up to eight boats enter each gondola and the weight is balanced by the displacement of water in each. In April 2002, a team from BBC *Tomorrow's World* conducted an experiment on site to illustrate the low power levels required to keep The Falkirk Wheel turning. Remarkably, the power required is approximately 18 kW, which *Tomorrow's World* compared to just ten household toasters.

A comprehensive environmental study was carried out prior to work commencing at The Falkirk Wheel. As the wheel was situated on a former open cast mine, ground conditions and contamination issues on the brownfield site had to be examined in detail and solutions identified. Activity included the removal of over 80 000 tonnes of mercury contaminated sediment from the adjoining Union Canal.

The three-mile Standedge Tunnel, on the Huddersfield Narrow Canal, is the UK's longest, highest and deepest. Restoration was thought 'impossible', as the tunnel had collapsed in a number of places with 200 m of Pennine rock bearing down on the 1811 structure.

The Anderton Boat Lift – design of the hydraulic system

The hydraulic rams, and associated drive and control equipment were designed, constructed and installed by Bosch Rexroth in a £1.5 million contract. Each of the two cylinders and plungers consists of a steel tube, with the plungers protected with a special ceramic coating. The overall length of the rams is over 17 m.

The basic performance specification for the system was the ability of the cylinders to work in isolation mode or as a pair in balanced mode and to have a degree of system redundancy. Additional pump sets and control features were added to the basic principle to complete the design.

The original intention of the restoration project was to automate a system based as far as possible on the original, but using mineral oil as the operating fluid for increased life. This system relied on a difference of water levels between the two caissons; 150 mm of water was drained from the lower caisson, making it lighter than the upper caisson. However the size of the cylinder required for mechanical strength and the difference in water level, provided a differential pressure of only 4 bar. This would be insufficient to overcome the friction of the cylinder seals and would not provide good control with a proportional flow control valve.

The alternative design used a 'fully pumped' system, where the oil flow between the two cylinders was boosted through a variable displacement pump. The displacement of the two cylinders is effectively the same, so a closed loop pump was selected and able to accept flow in both directions as the caissons rise and fall.

The hydraulic reservoir, pump sets and main control cabinet were housed in an extension to the existing 19th century brick building below the aqueduct. The mains electrical sub-station, containing two 500 kVA transformers to power the lift as well as rest of the site, was accommodated in the existing building. The building was sympathetically designed to match existing and former buildings on the site.

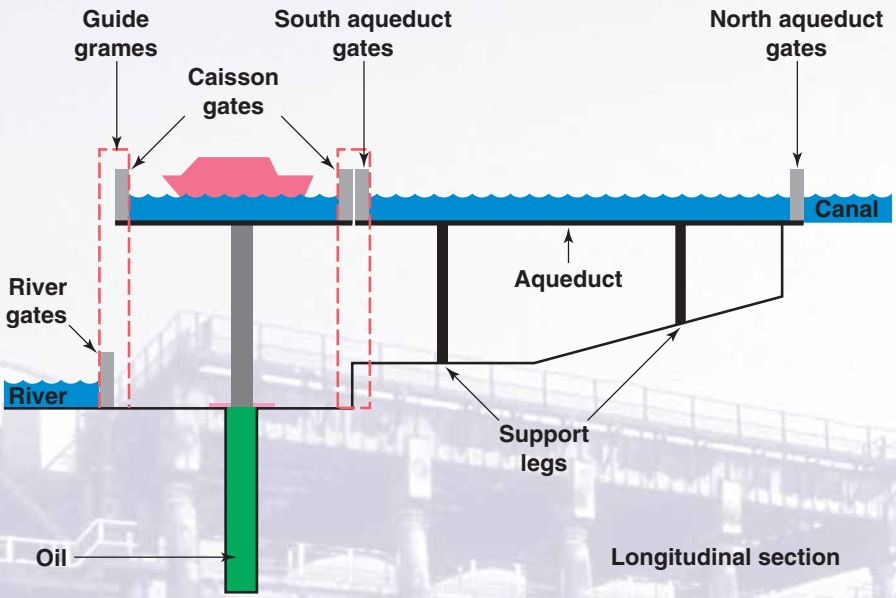


Figure 3 A side profile of the lift in the early 1990s, before restoration work began

Figure 4 Reconstruction of the boat lift, September 2001

Figure 5 Construction work under way

Figure 6 Christmas lights switch-on, December 2002

The Falkirk Wheel – rotating the lift

Throughout the design and construction of The Falkirk Wheel there were many issues and engineering solutions to consider. Challenges were varied and included aesthetical issues such as integrating the design of the aqueduct leading to the wheel into the design of the boat lift, and construction issues such as boring large diameter, 25 m concrete piles down to rock because of an underlying open cast infill.

The wheel itself does not need a rim and turns by ten hydraulic motors acting directly on to a centre axle. The axle sits on bearings at either end, with the outer part of one bearing fixed to the building at the back of the wheel, and the outer part of the other being fixed to the reinforced concrete 'mouse hole' at the north end of the wheel structure. The inner section of the bearing is fixed to the central axle and operates like a slewing ring on a crane, except that it sits vertically, not horizontally. The north end of the axle has no drive and hence the central tube must transmit the driving force via torsion along its full length. Hence the original desire for a glazed central tube was impractical. The power to deliver the hydraulic pressure to the motors is provided by two electric motors which uses about 18 kW when turning the 1800 t structure – 1k W for every 100 t.

The gondolas are supported on two pairs of bogey wheels on each side which run on a rail which is bent to a diameter of about 8 m and fixed to the wheel arms. This means that, as the axle rotates, they run along the rail and stay horizontal. A large cog fixed to each gondola and one to the back of the wheel building, along with the two smaller idler gears fixed to the wheel arms, ensure that the gondolas do not tip as the wheel rotates.

Last year, against all the odds, Standedge Tunnel reopened after a painstaking rebuilding programme. In total, 16 000 tonnes of rock, silt and debris were removed and the tunnel was then secured with over 6000 rock bolts, 6000 m^2 of spray concrete, and new brick linings.

When canals fell into disuse it was common for roads, railways, buildings and even whole town centres to be built across their path, with no thought for future restoration. The Rochdale Canal which opened in March 2003 had 15 miles restored as part of the ambitious project to re-open a 32 mile navigation stretching from Manchester to Sowerby Bridge in Yorkshire. The £25 million restoration included 24 new locks and 12 new road bridges, and the finished waterway is now acting as a catalyst for urban regeneration along its route.

Close to Rochdale town centre, the terminus roundabout of the A627(M) was a major engineering challenge for British Waterways. The bright idea to overcome this significant 250 m blockage involved putting the canal in a tunnel, lifting the junction by up to two metres and converting the roundabout into a sophisticated crossroads and traffic light system which could deal more efficiently with greater volumes of traffic. Similarly, where the M62 motorway had crossed the then derelict canal, engineers had to once again tunnel under the road.

Working in partnership

An extraordinary turnaround in the fortunes of the waterways is largely due to a countrywide collaboration between a broad range of different public, private and voluntary bodies including: local and national government; the lottery; the European Union; canal societies; development agencies; and commercial companies.

British Waterways is also successfully adopting a commercial approach and blending it with public sector values for the benefit of the waterways and the communities who enjoy them. Many commercial partnerships have been generated and, as a not for profit organisation, British Waterways invests income back into waterway improvement projects.

Projects with the private sector include the supply of a range of water and wastewater services and the installation of a 400 mile fibre-optic network under towpaths. In regards to property, a recently formed public private partnership will develop and regenerate numerous canal side locations in run-down inner city areas.

An important part of Britain's heritage, canals and rivers have evolved and now have a valuable role in 21st century society. Maintaining and restoring the canals and historic structures requires both innovative and technical engineering solutions. The investment in new and restored structures is more than justified by the ever increasing numbers of visitors who enjoy the canals and rivers, and the environmental and economic returns that regeneration brings. The message from government is that inland waterways are to be maintained in a sustainable way so that they fulfil their social, economic and environmental potential, and their commitment together with British Waterways' commercial approach is ensuring a resource for all, both today and for future generations. ■

Figure 8 Rock bolting of Standedge tunnel

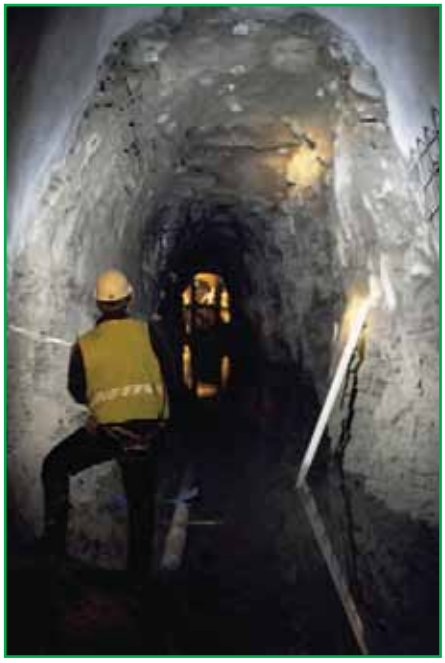


Figure 7 Relining of the Standedge Tunnel

Stewart Sim is a Chartered Engineer, a fellow of the Institute of Civil Engineers and a Member of the Chartered Institute of Environmental Management. He has worked for British Waterways for 29 years and is responsible for the operation, management and maintenance of the 2000 mile network of canals and rivers throughout England, Scotland and Wales.