John Rennie
(1761–1821)
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Welcome

I’m delighted to welcome you to our free exhibition celebrating the 250th anniversary of John Rennie’s birth.

John Rennie was one of the leading civil engineers of the early nineteenth century, following John Smeaton and William Jessop and a contemporary of Thomas Telford. He is not as well known today as he ought to be, and we hope that this exhibition will contribute to a greater awareness of his many achievements.

Our exhibition will take you through the life, works and many accomplishments of this engineering legend. Rennie’s work ranged from mechanical engineering to masonry bridges; land drainage to London Docks and canals to cast iron bridges. You will see examples of his work, original plans, drawings and paintings on display. This guide includes a wealth of further information as well as a detailed guide to what you will see. I hope it will help you explore the exhibition and fully appreciate Rennie’s accomplishments.

If you would like a memento of your visit, commemorative memorabilia is available to purchase from our bookshop at One Great George Street or online at icebookshop.com.

Enjoy the exhibition!

Mike Chrimes
Director Engineering Policy and Innovation
Introduction

John Rennie was a leading civil engineer in Great Britain and Ireland during the first two decades of the 19th century. Originally trained as a millwright, he turned increasingly to civil engineering from 1789 onwards. His earliest involvement was with canals during the canal mania, when William Jessop (1745-1814) took the lion’s share of the projected navigations. As Jessop withdrew gradually from the scene after 1805, Rennie and Robert Mylne (1733-1811) came to dominate the Smeatonian Society of Civil Engineers, the society for the leading civil engineers of the day. After Mylne’s death Rennie was its undisputed head. During these last 10 years of Rennie’s life another engineer came to prominence – Thomas Telford (1757-1834), though Rennie continued to obtain the more important defence projects during the Napoleonic Wars. After Rennie died, Telford, who had been elected the first President of the Institution of Civil Engineers in 1820, was the undoubted leader of the profession until his own death 13 years later.
Several portraits of Rennie are known. The earliest is by George Dance, the Architect and Surveyor to the City of London, whom Rennie would have known professionally. It was done in 1803 (IL1). An undated but apparently early image, which appeared in an obituary in the European Magazine, is by William Behnes (IL2). Behind Rennie’s left shoulder are the outlines of some bound volumes, an allusion to notable library that he built up, including first editions of some of Shakespeare’s plays. The finest painting, in oils, is by (Sir) Henry Raeburn (IL3) and was completed in 1811. It normally hangs in the Brunel room of the Institution of Civil Engineers, but has been brought into the Council room for the exhibition. The last portrait is by Archibald Skirving (IL4) and is probably the best known, as it appeared as the preface to the biography of Rennie in Lives of the Engineers by Samuel Smiles, published in 1862. It was also the basis for the image of Rennie that appeared in a composite portrait Men of Science Living in 1807-08 (IL5) done by Sir John Gilbert and others in 1858-62. The other likeness is a bust by Sir Francis Chantrey made in 1818, which adorns the half-landing of the main stairs in the Institution.

Information about Rennie’s life and works is scattered around many archives in Great Britain and Ireland, but there are three main repositories. The Institution of Civil Engineers has 13 bound volumes of his reports, more or less complete from 1802 on, with a few earlier ones. The National Library of Scotland has an extensive collection of manuscripts, including correspondence to and from Rennie, mostly on engineering matters, as well as many of the pocket notebooks that he carried with him and in which he made memoranda of a wide variety of subjects. The third is the biography in Lives of the Engineers, volume II, based largely on information provided by Rennie’s sons. It is not always entirely accurate, but provides information that is no longer available elsewhere. A portrait of Sir John Rennie (IL6), the second son, hangs in the Council room.
Introduction: display guide

IL1 Portrait of John Rennie, 1803, by George Dance (by courtesy of the National Portrait Gallery).

IL2 Portrait of John Rennie, undated, by William Behnes (European Magazine, 1821, by courtesy of Prof. Roland Paxton).

IL3 Portrait of John Rennie, 1811, by (Sir) Henry Raeburn (Institution of Civil Engineers).
IL4 Portrait of John Rennie engraved by W Holl, after Archibald Skirving (Samuel Smiles, 1862, Lives of the Engineers).

IL5 Men of Science living in 1807-08, a composite picture made by Sir John Gilbert in 1858-62 and engraved by William Walker (Institution of Civil Engineers).

IL6 Portrait of Sir John Rennie, third President of the Institution of Civil Engineers (Institution of Civil Engineers). A portrait of Thomas Telford, the first President, also hangs in the Council room.
Life

John Rennie was one of several Scotsmen who, in the second half of the 18th century, established a national reputation as an engineer. Born into modest farming stock, he enjoyed a successful career as a consulting engineer, practising in almost every aspect of the profession.

John Rennie was born at Phantassie (IL7), East Linton, East Lothian on 7 June 1761, the ninth child of James Rennie, a prosperous tenant farmer. James Rennie died in 1766, leaving his large family in the charge of the eldest son, George, who was then 17 years old. George, who later became a notable agricultural improver, was able to support John’s education at the parish school until he was 12. Rennie then left and went to work for Andrew Meikle, a famous millwright who fortunately was based at Knowes Mill about a mile from Phantassie. After two years at this, Rennie returned to education, this time at Dunbar High School. Having absorbed in two further years all that the school could offer him, and having declined an offer to become a teacher there, he rejoined Meikle. He accumulated sufficient capital and contacts to enable him to set up in business on his own account in September 1779, when his first job was the rebuilding of Andrew Meikle’s own Knowes Mill.

From the profits of his contracts, and by working during the lengthy vacations, Rennie was able to attend Edinburgh University for the three years 1780-83, the first professional engineer to have such an education. Under Professor Robison he studied natural philosophy, a discipline that then embraced what little was known of the subjects most likely to be of use to a civil engineer. On leaving university he returned to millwrighting, but the following year embarked on a tour to Boulton & Watt’s works in Birmingham, taking
in several other manufactories and bridge and canal works en route. Meanwhile James Watt, an old colleague of Robison, had asked the latter whether he knew of a suitable mechanic to assist in the erection of machinery for a large new mill that Boulton & Watt were undertaking in Southwark. Robison recommended Rennie, and after references had been taken up and some misunderstandings about his status had been cleared up, Rennie accepted a seven-year contract to supervise the machinery of the Albion Mills. It was agreed that when his duties there permitted, he could undertake work for other clients on his own account. After a two-month stay with Boulton & Watt, Rennie arrived in London in November 1784.

Rennie had not neglected to come armed with letters of introduction to possible patrons in London. One such letter was from Sir George Buchan Hepburn, a landowner in East Linton, to William Forbes of Callendar (IL8), a fellow Scot who had made a fortune bycornering the market in copper for sheathing warships’ bottoms. He also had an introduction from Edinburgh to John Smeaton, who then stood at the head of the civil engineering profession, which then included mechanical engineering and millwork. He called on Smeaton (IL9) and was immediately invited to join the Society of Engineers (after Smeaton’s death reorganised and called the Smeatonian Society). It was Smeaton who gave Rennie the entrée to civil engineering; by recommending him in 1789 to promoters of canals in the east of England who required a surveyor/engineer to prepare plans for Parliament. Rennie repaid the debt by being a member of the committee that published Smeaton’s Reports (IL10) and editing his Miscellaneous Papers. From 1811 Rennie was Treasurer, in effect the sole officer, of the Smeatonians (IL11).

Rennie regarded himself very much as a professional man, giving his personal attention to the commissions he received. His reports are generally models of clarity, and it is clear that he took considerable pains over them. When setting out the duties of the Superintendent of the Kennet & Avon Canal his draft (IL12) is heavily reworked. The final
version would be copied by a clerk into the bound volume mentioned above. Regrettably, few original drawings by Rennie survive.

The resident engineers and their assistants who supervised the contractors who carried out the works were employed by the project clients, not by Rennie. Nevertheless he insisted on being kept informed of progress and any problems that might have adverse technical or financial results, considering himself ultimately responsible for the successful outcome of each project. Although clients might choose to appoint their own nominees to the supervisory staff, more often than not they asked Rennie for advice. Over the years he built up a corps of competent people on whom he could rely, and with several of whom he was on good social terms. His senior resident engineer in Scotland, John Paterson, sent him frequent letters on local affairs as well as more formal reports.

Rennie also prepared contract documents that set out the duties and rights of the parties involved in a project – the client, the contractor, and Rennie as the chief engineer. As projects became more sophisticated, the contract documents became more detailed and more bulky. (IL13 and 14)

Rennie was responsible for designing and project managing a number of canals, of which the Lancaster, the Crinan and the Kennet & Avon were the most important. He next became involved with road bridges, and was responsible for, amongst others, Kelso Bridge, Waterloo and Southwark Bridges in London. London Bridge was rebuilt to his design by his sons after his death. The most extensive tract of land that he drained was the East, West and Wildmore Fens in Lincolnshire; his far-sighted scheme for the Bedford Level in Cambridgeshire was rejected because of its estimated cost, and it was only in the 1960s that a similar project was carried out. He created or improved several major docks, including London Docks and the first docks at Leith and Grimsby, and the massive rebuilding of Sheerness Dockyard. His harbours included the first breakwater at Holyhead and the extensive basin at Dun Laoghaire. Two of his works that excited the
admiration of his obituarists were the Bell Rock Lighthouse and the Plymouth Breakwater, both of which entailed substantial and innovative erection schemes.

His fees, at seven guineas a day, were the highest of any consulting engineer at the time, and he became quite wealthy, though it was noted that, if he had charged a percentage of the value of the cost of his works, as architects did, he would have been very rich indeed. He died on 4 October 1821, and was buried in the crypt of St Paul’s Cathedral.

The exhibition displays images of many of his works, as well as some of his lesser-known projects and one or two unbuilt schemes, to illustrate the breadth of his expertise and the elegance and solidity of his designs. Each image or artefact has a brief caption and is numbered; the numbers refer to a fuller description in this guide.

‘... the many splendid and useful works by which under his superintending genius England, Scotland and Ireland have been adorned and improved are the true monuments of his public merit ...’

(epitaph on gravestone, composed by Sir John Barrow)
Life: display guide

**IL7** Phantassie, East Linton, East Lothian, the birthplace of John Rennie (Samuel Smiles: Lives of the Engineers, volume 2).

**IL8** Letter from Sir George Buchan Hepburn to William Forbes of Callendar (by courtesy of Falkirk Council Archives).

**IL9** Portrait of John Smeaton engraved by W Holl, after Mather Brown (Samuel Smiles: Lives of the Engineers).

**IL10** Printed report by John Smeaton (ICE Archives).
IL11 Minute book of the Smeatonian Society of Civil Engineers (ICE Archives).

IL12 Draft of a report from John Rennie to the committee of the Kennet & Avon Canal Company (by courtesy of the National Library of Scotland).

IL13 Specification of works, for contract between Southwark Bridge Company and Jolliffe & Banks (by courtesy of London Metropolitan Archives).

IL14 Articles of Agreement between Southwark Bridge Company and Walker’s of Rotherham, iron-founders (by courtesy of London Metropolitan Archives).
Mechanical engineering

Rennie was interested in mechanical engineering from an early age and maintained that interest throughout his career. He made significant improvements in the design of machinery for a wide variety of purposes, and manufactured much of it at the works he established in Southwark.

Although Boulton & Watt had made the initial designs for the machinery of the Albion Mills, Rennie made improvements as the work proceeded and the first engine became operational in February 1786, largely due to Rennie’s skill and perseverance. A second engine was installed, with further improvements in the machinery by Rennie, by 1788 (ME1 and 2). The scale of the Albion Mills was a novelty in London and Rennie was soon showing distinguished visitors around, rather to Watt’s disgust. Rennie’s private business was also prospering to such an extent that he was seeking premises in Southwark in order to establish his own manufacturing works. But he was unhappy with the management of the Mills, believing that the machinery was being overworked without appropriate maintenance. In the event the mills burnt down in 1791, caused by an overheated bearing, though popular rumour was more interested in theories of arson.

At least as early as April 1786 Rennie was seeking collaboration with Boulton & Watt to purchase some vacant premises for a joint venture in manufacturing, rather than relying on subcontractors to do the work. At first his commissions came mainly from flour mills, breweries and distilleries, but later he had a substantial business for sugar mills for the West Indies.
He also provided machinery for several of the construction projects for which he was the engineer. He was the first to use a steam engine for driving piles in cofferdams for the entrances to London Docks and Humber Dock, Hull. He designed cranes for the London Docks (ME3), which he proposed, unsuccessfully, should be driven by a central steam engine. John Smeaton had used a diving bell to inspect the sea bed at Ramsgate harbour, but Rennie improved the design to make it possible to use them for placing stones underwater for piers, or excavating rock from the sea bed which dredgers were unable to remove (ME4). He did this by designing a gantry crane to make them more manoeuvrable. It was first used in the east pier head at Ramsgate, where Rennie had succeeded Smeaton and Samuel Wyatt as engineer, and at Howth in 1813-14. It was further improved for the mahogany shed at West India Docks in London.

For the royal dockyards he was much involved in introducing steam-powered machinery to speed up the repair of ships, and for the construction of Sheerness Dockyard he invented a machine for tonguing and grooving the edges of sheeting piles for cofferdams, by wheels fitted with sharp adzes, which rotated at speed while the piles were moved against them (ME5).

For the Kennet & Avon Canal he designed two different pumping stations. Crofton (ME6), at the east end of the summit level, is steam-powered but Claverton, well down the valley of the River Avon, is driven by a waterwheel powered by the river itself. Although not the first engineer to design steam-powered dredgers, he was involved in their development for river and harbour work, and made one for the Witham Navigation in 1810-11.

He was consulted about the design of Captain Samuel Brown’s Union Bridge, the first suspension bridge in Britain to be built for road traffic, and designed and made for him the proving machine used for testing his patent chain cables.
**Mechanical engineering: display guide**

**ME1** Albion Mills, Southwark: as-built drawing of the second Boulton & Watt engine and some of its associated machinery, July 1787 (by courtesy of the Birmingham Central Library).

**ME2** Albion Mills, Southwark: as-built drawing of the connection from the beam of the second engine, April 1787 (by courtesy of the Birmingham Central Library).

**ME3** Wharf and warehouse cranes for north range, London Docks (by courtesy of the Birmingham Central Library).
**ME4** Mode of working two diving bells with traversing frames (Sir John Rennie: The Construction of British and Foreign Harbours).

**ME5** Rennie’s machine for cutting grooves in timber sheet piles, designed for use on the Sheerness Dockyard project (Sir John Rennie: The Construction of British and Foreign Harbours).

**ME6** Crofton Pumping Station, to pump water up to the summit level of the Kennet & Avon Canal. The Boulton & Watt engine is today the oldest in-situ still doing the work for which it was constructed (by courtesy of the Kennet & Avon Canal Trust).
Canals and waterways

John Rennie’s first involvement with civil engineering was with canals. His status at this early stage of his career is seen in the canal mania of the 1790s, when William Jessop gave parliamentary evidence on 27 canal bills, Rennie on 16, Robert Whitworth on seven and Thomas Telford on one.

Rennie’s colleagues in the Smeatonian Society included the leading civil engineers (in the more restricted, modern definition of the term) of the day. In 1789 Smeaton recommended him to two groups of promoters of canals in East Anglia, one for a north-south route to join London to King’s Lynn, the other for an east-west junction between tributaries of the River Great Ouse and the east coast. Neither was built, though a revised version of the Stort–Great Ouse canal did gain an Act in 1812. He made a survey of the Basingstoke Canal for William Jessop and then for a possible extension to Andover to provide a through route to Southampton. Jessop was generally little involved in the construction of canals for which he had obtained an Act, and when his Ipswich & Stowmarket Navigation ran into trouble in 1792, the promoters turned to Rennie to turn it around. Its successful completion in 1793 led to Rennie’s appointment as Engineer to the Chelmer & Blackwater Navigation from Chelmsford to the sea (CW1). Although completed in 1797, there were problems later with siltation caused by floods in the river, for which Rennie accepted some liability; his alterations to deal with the problem were adopted and the navigation traded successfully thereafter. He was rather less successful with his efforts to obtain Parliamentary approval for the Rochdale Canal. Despite intensive
surveys, assisted by William Crosley senior, to find an adequate water supply while satisfying the needs of the local millowners (CW2), two applications failed and the project was carried through by the older and more experienced Jessop.

At the same time Rennie was Engineer of four other canals – the Lancaster, the Ulverstone, the Kennet & Avon and the Crinan. The Kennet & Avon crossed southern England from east to west to complete a direct navigation between London and Bristol. The going was quite easy at the east end but as the canal approached Bath through the valley of the Avon it was necessary to cross the river twice. Rennie provided designs for these aqueducts that were different from each other and also from any on the Lancaster Canal (CW3). The same was true of the aqueducts over the smaller rivers, illustrated in a beautifully colour-washed series of drawings (CW4) that also recorded some of the lesser structures (CW5). The swing bridges rotated on pivots with large ball bearings, an early use. The flight of locks with their side ponds at Caen Hill near Devizes is one of the more impressive features of the canal system (CW6).

Rennie rather regretted taking on the Crinan Canal, so far from his other projects at the time. Its very remoteness made it difficult to sustain an adequate workforce (CW7). Designed as a ship canal 24 feet wide, in places it was cut through very hard whinstone, up to 60 feet deep, in others it was carried across peaty mosses. When it was first opened in 1801 it had a depth of 8 feet only, compared with the originally intended 12 feet, and repairs and improvements were undertaken for many years. Nevertheless it was a considerable achievement, due in large part to the efforts of the resident engineer, John Paterson.

Another resourceful resident engineer was Thomas Townshend, who worked on the Rochdale Canal and the Royal Canal of Ireland before supervising the improvements to the River Witham in Lincolnshire. Designed by Rennie to improve the navigation, but with due regard to the drainage of the surrounding lands, the works included a substantial new cut to eliminate a loop in the river above Bardney (CW8).
Canals and waterways: display guide

**CW1** Beeleigh Lock on the Chelmer & Blackwater Navigation, constructed in 1793-97 (by courtesy of Peter Cross-Rudkin).

**CW2** Book of correspondence and reports on the surveys of the Rochdale Canal (ICE Archives).

**CW3** Dundas Aqueduct on the Kennet & Avon Canal, constructed in 1795-98 (by courtesy of Peter Cross-Rudkin).

**CW4** Kennet & Avon Canal aqueduct over Semington Brook (ICE Archives).
CW5 Kennet & Avon Canal draw bridge at Little Bedwyn (ICE Archives).

CW6 Caen Hill locks, near Devizes, the final link in the Kennet & Avon Canal, completed in 1810 (by courtesy of Peter Cross-Rudkin).

CW7 A view on the Crinan Canal (by courtesy of David Henthorn Brown).

CW8 Bardney Lock on the Witham Navigation, with the new cut entering from the top left and the old river from the right (by courtesy of Peter Cross-Rudkin).
Canals and waterways: Lune Aqueduct

The aqueduct that carries the Lancaster Canal over the River Lune north-east of Lancaster is the largest all-masonry aqueduct built in Britain. It was also Rennie’s first major structure, and shows his self-assurance even at an early stage in his career.

The Lancaster Canal was promoted to connect the limestone quarries between Lancaster and Kendal with the coalfields around Wigan. Rennie, with assistance from the surveyor William Crosley, managed to find a route entirely on one level from Wigan as far as Tewitfield, about six miles north of Lancaster, but this required two substantial aqueducts, over the Rivers Ribble and Lune. The Ribble aqueduct was never built, but for the Lune Rennie designed the largest all-masonry aqueduct ever constructed in Britain. This was in fact his first major bridge, and he altered the structural design as he came to grips with the problems of such a large structure. His idea about the architectural treatment also changed, at least three times (CW9-12). The foundations were constructed by direct labour under the supervision of the resident engineer, Archibald Millar. The cofferdams were pumped dry by a steam engine on the river bank, under the control of Hugh Baird, a member of a family known to Rennie and later a significant canal engineer in his own right. For the superstructure, Rennie prepared a detailed specification for the quality of work to be produced by the contractor (CW13). The company had difficulty finding people willing to tender, but were fortunate to obtain the services of Alexander Stevens. He died during the construction period, and Rennie wrote a moving tribute to him as a friend.

The construction of the aqueduct was still of sufficient interest in 1837 for S C Brees to include a plate of it in his book Railway Practice (CW14).
There were also several smaller aqueducts over streams, and Rennie provided different designs for each, as well as several alternative treatments for an aqueduct over a turnpike road at Lancaster (CW15).

After the canal mania (c1793-96) was over there was a lull in promotion while those that had obtained their Acts struggled to raise the funds to execute their works. From about 1802 Rennie was employed as engineer to a number of ambitious canal schemes, organising sizeable teams of surveyors working for months to find the best routes to satisfy the promoters and avoid the opposition of local interests. These included the:

- Loch Earn Canal in Scotland
- Central Junction Canal from Abingdon to Stratford upon Avon
- High Peak Canal from Cromford to Chapel en le Frith
- Weald of Kent Canal, crossing that county
- extension of Rennie’s Croydon Canal to Portsmouth (CW16)

The estimated cost of these schemes varied between half and three-quarters of a million pounds and they did not proceed.
Canals and waterways: display guide

**CW9** Lune Aqueduct, Lancaster Canal, design 1792. The spandrel walls have chequered masonry, there is a plain moulded stringcourse and the internal spandrel voids are capped by Gothic arches (by courtesy of Lancashire Record Office).

**CW10** Lune Aqueduct, Lancaster Canal, contract drawing 1794, signed by Alexander Stevens, father and son, the contractors. The spandrel masonry is now banded, there is some ornamental masonry above the archring and a triumphal column on the parapet above the central arch (by courtesy of Lancashire Record Office).

**CW11** Lune Aqueduct, Lancaster Canal, sections 1795. The spandrel voids have been altered, and Rennie has introduced transverse iron bars below the channel to resist the lateral thrust (by courtesy of Lancashire Record Office).

**CW12** Lune Aqueduct, Lancaster Canal as built (by courtesy of Peter Cross-Rudkin).
**CW13** Copy of specification for the Lune Aqueduct, and other structures on the Lancaster Canal (ICE Archives).

**CW14** Lune Aqueduct, Lancaster Canal under construction (S C Brees: Railway Practice).

**CW15** Six designs for an aqueduct over a turnpike road near Lancaster (by courtesy of the National Archives, Kew - see overleaf for full image).

**CW16** A map of a canal proposed to extend the Croydon Canal to Portsmouth, and so provide an inland navigation from London to the south coast. The Wey & Arun Canal and the Portsmouth & Arundel Canal were built instead (ICE Archives).
Image CW15: Six aqueduct designs
Canals and waterways: Image CW15: Six aqueduct designs
Masonry bridges

Rennie’s masonry bridges are noted for combining solidity with elegance. Frequently he provided alternative arrangements of the arches and architectural treatments in order to arrive at the most appropriate solution for a particular site.

Rennie’s first experience in the design of masonry arch bridges came with the commission as Engineer of the Lancaster Canal in 1792. This included the great aqueduct over the River Lune in Lancaster (see ‘Canals’). His first large road bridge was Wolseley Bridge (MB1) over the River Trent between Lichfield and Stafford, built in 1798-1802. Here the longitudinal profile of the road is curved, so the stringcourse has a simple bullnose profile and there are apsidal niches in the pilasters above the piers.

His next major bridge was built over the River Tweed at Kelso in 1800-04 (MB2 and 3). As at Wolseley, it replaced a structure that had been destroyed by flood, but here the river regime was quite complicated and Rennie ordered extensive site investigations before deciding on the site and form of the new bridge.

There is a significant difference in ground levels at the ends of the bridge, but Rennie never designed an asymmetrical bridge, so it was necessary to build a substantial embankment over the low ground on the south side.

The level roadway allowed Rennie to incorporate Doric columns above the piers and a Doric entablature. The five arches each span 72 feet.

A much more ambitious proposal was an alternative to the (cast iron) Southwark Bridge that was actually built (IB4). Rennie produced a design in masonry that would have had
the same spans: the central one of 240 feet would have been easily the longest masonry arch in the world at the time. It is perhaps fortunate that the cast iron was chosen.

The Bridge of Ken at New Galloway in south-west Scotland was another that required careful site investigation. Its predecessor, designed by Thomas Telford, had been swept away when on the point of completion in 1815. After long delays caused by litigation over responsibility for the failure, and discussion of possible alternatives such as a suspension bridge, Rennie spent five days on location in 1819 in order to find the best site for a new bridge. His design allowed 50% more waterway than previously, but the Commissioners had lost heavily over the earlier structure and Rennie’s design was architecturally one of the simplest he made. Built of local granite, it is nevertheless very handsome (MB4). It was completed after Rennie’s death with his son (Sir) John as engineer.

Another of Rennie’s designs that was completed by his son was Bridge of Earn in Perthshire (MB5). Here he mapped out a new line of road in order to cross the river on the square, something on which he invariably insisted. Rennie’s bridge can still be seen beneath a modern widening.
Masonry bridges: display guide

MB1 Wolseley Bridge, Staffordshire, John Rennie’s first major road bridge. Rennie designed a number of other bridges in the county (by courtesy of Peter Cross-Rudkin).

MB2 Kelso Bridge ‘inscribed to John Rennie … by William Daniell’. The bridge is on a bend in the River Tweed, and the River Teviot enters above the second pier from the left (by courtesy of the National Library of Scotland).

MB3 Kelso Bridge today (by courtesy of Peter Cross-Rudkin).
**MB4** Ken Bridge, New Galloway, built to replace a design by Telford that had been swept away in 1815 (by courtesy of Peter Cross-Rudkin).

**MB5** Where an Act was required for new roads, it was necessary to deposit plans with Parliament and the Clerk(s) of the Peace of the county(ies) affected. This is the deposited plan for a bypass of the mediaeval Bridge of Earn in Perthshire (by courtesy of Parliamentary Archives).
Masonry bridges: Waterloo Bridge

Rennie’s Waterloo Bridge over the River Thames was arguably the finest masonry bridge built in this country.

Rennie himself had no doubt of its importance: ‘the bridge being placed in the heart of the Metropolis and where the thoroughfare must of course be immense ought to be executed in the most substantial manner … and likewise to the magnificence suitable to the Metropolis of the British Empire’.

The foundations were built in sheet-piled cofferdams (seen in the left background) (MB6), with steam engines employed to work the pumps that kept them dry. Extensive temporary works were required, including centres designed by Rennie, that were assembled on the river bank and brought whole to the site on barges. The contractors, Jolliffe & Banks, were required to load the tops of the centres with stone as arch construction progressed, in order to prevent them from springing upwards as the arch stones pressed on the haunches (MB6). As the arches grew, it was necessary to bring up the next arch in parallel in order to reduce out-of-balance loads on the piers (MB7). A temporary bridge crosses the river to provide access to the work sites. Three sets of centres only allow access for river traffic (MB8).

Architecturally Waterloo Bridge is quite similar to Kelso Bridge, though it was a much larger structure, with nine arches each of 120 feet. The columns above the piers were not merely ornamental; they were dovetailed into the spandrels to provide some lateral strength to the spandrel walls. All of Rennie’s major bridges had longitudinal voids within the spandrels, so the external walls were quite slender where they abutted the piers. The opening by the Prince Regent on 18 June 1817 was a magnificent affair (MB9). Rennie was offered a knighthood, which he declined.
MB6 Waterloo Bridge under construction, probably in April/May 1813. The centres for supporting the arch stones during construction were designed by Rennie, who used cast iron shoes to make connections between the main members (Smiles: Lives of the Engineers).

MB7 Waterloo Bridge under construction, shortly after the preceding (ICE Archives).

MB8 Waterloo Bridge under construction, probably in late-1814 (ICE Archives).

MB9 The opening of Waterloo Bridge on 18 June 1817 was marked with much pomp, and was witnessed by a multitude of people (by courtesy of the National Library of Scotland).
Cast iron bridges

Rennie’s career coincided with the development of cast iron bridge design. His design for a span of 450 feet over the Menai Straits was not built, but the central arch of his Southwark Bridge was the longest ever built in cast iron, and was the precursor of cast iron bridges for railway traffic.

Rennie made his first design for a cast iron arch bridge in 1791, when the only one in Britain was the original at Coalbrookdale. Based on a concept put forward in France in 1778, it would have had a span of 100 feet, like the Iron Bridge, but it was not built. In 1792-96 Wearmouth Bridge at Sunderland, a similar but larger (236 feet) span was erected by Walker’s of Rotherham, to a design by Rowland Burdon and Thomas Wilson.

Rennie’s next opportunity for a cast iron bridge arose when a bridge over Whiteadder Water in the Scottish Borders was swept away in 1799, and he proposed alternative designs in masonry and cast iron on a new site (IB1), with new roads to improve communications in the area. The scheme was too expensive and a conventional bridge was rebuilt on the existing site.

A proposal by Thomas Telford and James Douglass in 1800 for a single cast iron span of 600 feet to replace the old London Bridge excited considerable interest, and Rennie was one of a number of eminent engineers who were asked by Parliament to give opinions on it. It was not built, but when Rennie was asked the following year to design a bridge across the Menai Straits, he was sufficiently confident to propose a span of 450 feet. It also proved to be too expensive, and Rennie’s first
Cast iron bridge was built at Boston in 1804-07 (IB2). Thomas Wilson had obtained a patent in 1802 for improvements to his Wearmouth design and Rennie collaborated with him in the design here. Although only 86 feet in span its span:rise ratio was a very flat 15½:1.

In 1811, as part of the scheme to drain the East, West and Wildmore Fens in Lincolnshire north of Boston (see LD1-4), Rennie had to provide three footbridges over the improved Maud Foster Drain. These bridges were of a novel design, with Vierendeel frames that narrowed in depth and plan towards the crown of the arch (IB3). With a span:rise ratio of 17:1 they are probably the flattest cast iron arches to have been built. The two remaining bridges are inscribed ‘Cast at Butterley 1811’.

Failures of cast iron bridges at Yarm over the River Tees and Staines over the River Thames, both designed by Thomas Wilson, cast doubts upon the whole concept. Rennie was commissioned to investigate the reasons for the latter, and found, as also happened at Yarm, that insufficiency of the abutments was the cause. Confident in his ability to design adequate abutments, he provided a design in 1812 to cross the River Wye at Chepstow (IB4, see overleaf), in place of a crazy old bridge that was beyond economical repair. Even so, the clients baulked at the cost, and the bridge was not rebuilt until 1816, to a completely different design by John Urpeth Rastrick.

Rennie took great care over the architectural aspects of his work, but the bridge for the Vizier at Lucknow in India was the result of input from several people. Sketches were sent out for approval by the client, who chose one but asked for alterations. Changes to the details of the connections of the arch ribs were also suggested by the contractor, the Butterley Company, and the final ornamentation was designed by William Daniell, an artist who recorded many civil engineering works in Britain at the time.

The central arch of Rennie’s Southwark Bridge had the longest span ever constructed in cast iron (IB5), though at 240 feet it was only four feet more than the arch of
Wearmouth Bridge that had been constructed in 1792-96. The short, open-frame voussoirs of the earlier bridges had been replaced by much longer and deeper, perforated girders in the approved 1811 design and by solid girders in the bridge as built. The spandrel struts were lozenge pattern, a design that Telford also used in his 150-foot cast iron bridges from 1811, though here there was an intermediate longitudinal rib to shorten the effective length of the longer struts. Rennie made calculations for the sizes of the members, and conducted a number of experiments to be certain of the strengths of the materials to be used. He also calculated the effects of temperature changes on the vertical profile of the bridge and was gratified when measurements on the completed structure tallied closely with his calculations. The design was checked by Thomas Young, probably the leading physical scientist of the day, but it was almost certainly unnecessarily heavy. The contractors, again Walker’s of Rotherham, were one of the leading iron-founders in the country, but they had difficulty in producing castings of the size required by Rennie, and the problems associated with the bridge contributed towards their bankruptcy.

Cast iron bridges: display guide

IB1 Three designs for a bridge on a new site near Paxton, Berwickshire in 1800. Rennie rejected the cast iron one (at the bottom of the image) as being more expensive than the stone alternatives, but they too were dearer than the client wanted and the scheme did not proceed. (by courtesy of National Library of Scotland).
IB2 Boston Bridge, 1803-07, was Rennie’s first in cast iron. It was still very much in the tradition of the early iron bridges (Samuel Smiles: Lives of the Engineers).

IB3 Cowbridge Bridge over the Maud Foster Drain near Boston, 1811, probably the shallowest arch ever constructed for a cast iron bridge (by courtesy of Peter Cross-Rudkin).

IB4 Rennie’s signed drawing of his proposed cast iron bridge for Chepstow. The cast iron arch would have spanned 250 feet, and the arch segments are much longer than those at Paxton, but still perforated. The bridge was built four years later to a completely different design by J U Rastrick. (by courtesy of Gwent Record Office).

IB5 Southwark Bridge was a very substantial piece of work. The solid arch ribs and the arrangement of the spandrel bracing foreshadowed railway practice 30 years later. (ICE Archives).
Cast iron bridges Image IB4: Rennie’s proposed bridge for Chepstow
Cast iron bridges Image IB4: Rennie's proposed bridge for Chepstow
Land drainage

Large scale land drainage in Britain has a long history, going back at least to Roman times. Often bedevilled by opposition from landowners and navigation interests, Rennie was fortunate in Lincolnshire to have the powerful backing of Sir Joseph Banks, President of the Royal Society and a personal friend.

As early as 1790 Rennie was consulted by the Clerk of the Sewers for the County of Norfolk about draining Marshland, a low-lying area between Wisbech and King’s Lynn. Nothing came of his report, and little from one which he made with William Jessop and two local engineers in 1800 on Deeping Fen, which was notable for its recommendation to use steam instead of wind power to pump water from the internal main drains. The fens had to wait another 17 years for the first steam engine.

Rennie’s first major scheme of land drainage came at the instigation of Sir Joseph Banks, who was a major landowner in Lincolnshire. The East, West and Wildmore Fens north of Boston comprised altogether a little over 60,000 acres of poor value, being subject regularly to flooding from rainfall on the high ground to the north. Rennie’s solution was to create catchwater drains to take the ‘highland’ water around each fen to a new outfall on the River Witham below Boston; the rainfall on the fens themselves would be taken away by a new system of internal drains to the existing Maud Foster Sluice.

The differences in level of the outfalls were very small (LD1) and the situation was complicated by the crooked course of the Witham below Boston. If the river could be straightened the water level in it...
could be lowered, giving a more certain discharge for water from the fens.

As so often happened in the fens, other schemes were brought forward by local gentlemen in opposition, and the proposal to straighten the Witham outfall was turned down, but Rennie’s scheme gained its Act in 1801 (LD2). The work was carried out over several years, during which time Rennie made significant changes to the lines of the outfalls (LD3), including a siphon to take a catchwater drain over a main internal drain (LD4).

The beneficial effects of straightening a river outfall were seen in 1821 when the Eau Brink Cut was completed. The River Great Ouse took a great sweep to the west as it approached King’s Lynn; in places it was half a mile wide and correspondingly shallow, obstructing the discharge of flood waters from the lands above. Proposals to eliminate the bend had been around for at least a century, and a smaller scheme had proved successful on the River Nene. Nevertheless there was strong opposition from the navigation interests, who feared damage to the port at King’s Lynn, and many eminent engineers were engaged in the arguments for and against. An Act was passed in 1795 but the opposition was so fierce that it was only in 1818-21 that the work was carried out (LD5).

At the time that the Eau Brink Cut was finally undertaken, the commissioners of Swaffham and Bottisham Fens were considering improving their drainage and employed Rennie to report. He in turn employed John Grantham, who had earlier been one of the surveyors of the Croydon–Portsmouth canal (see CW16), who tried to find an outfall by gravity but came to the conclusion that it would be necessary to go below Ely to do so. This was well outside the commissioners’ area and not acceptable, so Rennie, on Grantham’s advice, proposed turning the existing Roman or mediaeval drainage system through 90 degrees (LD6). To lift the water into the river Rennie designed a steam-powered scoop wheel, 20 years after he had proposed one for Deeping Fen.
Land drainage: display guide

**LD1** LiDAR (light detection and ranging) survey of East, West and Wildmore Fens. The River Witham flows from top left to bottom right; Boston is towards bottom centre (by courtesy of Witham Fourth District Internal Drainage Board).

**LD2** ‘A Sketch of Wildmore Fen, West Fen & East Fen with the Marshes and Highlands adjacent, in the County of Lincoln’, engraved for John Rennie’s report of 1800: his first design for catchwater and internal drains (by courtesy of Lincolnshire Archives).

**LD3** ‘Plan of the East, West and Wildmore Fens near Boston with the respective drains which have been executed for the drainage thereof’, by Anthony Bower, Lincoln, 1811. Bower was the Resident Engineer during construction. This shows significant differences from the 1800 scheme (by courtesy of Cambridgeshire Record Office).
LD4 Cowbridge Aqueduct, where the West Fen Drain is carried under the Stonebridge (East and West Fens Catchwater) Drain (by courtesy of Peter Cross-Rudkin).

LD5 Plan of the Eau Brink River and part of the River Ouse with the proposed new bridge, public roads and drains communicating therewith, surveyed by Charles Burcham in 1819 for John Rennie (by courtesy of Cambridgeshire Record Office).

LD6 John Grantham’s preliminary survey of the Swaffham and Bottisham Fens, showing the Roman/mediaeval lodes draining to the River Cam (double lines) and his proposed realignment of the drainage (dotted lines). Rennie’s final scheme took all of the internal water to a steam pump at Upware (lower right) (by courtesy of the National Library of Scotland).
Maritime works formed an increasingly important part of Rennie’s commissions as his career progressed. He was consulted about fishing harbours in the north of Scotland as early as 1792, but when work was undertaken later, Thomas Telford was the engineer. Rennie’s first completed project was a particularly tricky one. The merchants of Grimsby had decided to build a wet dock in order to compete with Hull on the opposite side of the Humber, but having dismissed their original engineer and undertaken the work themselves, they could not prevent the sides of the excavation from caving in. Rennie solved the problem by designing novel cellular walls on inverted arches, which spread the load onto the weak ground much wider than conventional walls would have done. A letter to his resident engineer, James Hollinsworth, outlined his proposals (DH1).

The years from 1800 saw a large investment in new docks and harbours, both for commercial use and to service the Royal Navy in the Napoleonic wars. The wars exposed the inadequate nature of the existing naval dockyards on the River Thames and its estuary. In 1808 Rennie proposed to replace them all by a single new yard at Northfleet, at a cost of just under £9 million. At a time when government’s annual revenue was something over
£50 million, such a sum, even spread over a number of years, was not acceptable and the scheme was stillborn. From 1813 he was involved instead in improvements at Chatham, Woolwich and Deptford, and almost a complete rebuilding at Sheerness. The ground there was very poor, and the sea walls were built on the cellular principle (DH2) that he had earlier employed at Grimsby. Sheerness was also notable for the gates to the dry docks, which were made of cast iron, the first use of that material for that purpose.

The Navy also needed a safe harbour from which to watch over the French fleet in Brest. Plymouth, where there was a naval dockyard, was exposed to winds from the south-west, and in 1806 Rennie and a colleague, Joseph Whidbey produced a report for the Admiralty for a breakwater to protect ships in Plymouth Sound. They expected that it could be completed in six years. Changes of personnel at the Admiralty and the resignation of Earl St Vincent (Rennie’s friend since their meeting on the business of the Chelmer & Blackwater Navigation) as Commander-in-Chief of the Channel Fleet delayed a start until 1812. By 1817 work had progressed sufficiently to afford some protection to ships in the Sound during a gale, and when Rennie died in 1821 the Plymouth Breakwater was one of his works most frequently mentioned in his obituaries. However a more severe gale in 1824 caused substantial damage and the design was reworked to give flatter slopes to the structure (DH3). Further improvements were made subsequently and when the work was officially complete in the 1840s it was 1,700 yards long and had consumed over 3½ million tonnes of rubble stone (DH4).

Another government project was the improvement of communications between Great Britain and Ireland, which had been united politically by an Act of 1800. The Holyhead Road is well known, but it was also necessary to construct new harbours for the packet boats that crossed the Irish Sea. At Holyhead Rennie designed the Admiralty Pier, enclosing what is now the inner harbour. On the Irish side he took over the harbour at Howth, north
of Dublin, in 1809 after a previous scheme had run into trouble. Although the site had been approved by Captain Huddart, an eminent marine surveyor, Rennie was less convinced, and preferred a site at Dun Laoghaire, south of Dublin. Work started there in 1817, just as Howth was coming to completion, and the cores of the twin piers were constructed by tipping loose rock obtained from quarries at Dalkey (DH5). An iron railway, with three inclined planes worked by gravity, transported the rock to the site; parts of the route can still be traced. The quarrymen would have had a fine view of the piers under construction (DH6).
Docks and harbours Image DI4: Plymouth Breakwater

John Rennie 1761–1821
Docks and harbours: display guide

**DH1** A letter from Rennie to his resident engineer at Grimsby, James Hollinsworth, 12 July 1800, giving instructions on how to proceed with rebuilding the dock walls on the poor ground there (by courtesy of the National Library of Scotland).

**DH2** Sheerness Dockyard under construction, showing the cellular sea wall behind a sheet-piled cofferdam. Convicts can be seen at work under armed guard (Sir John Rennie: The Construction of British and Foreign Harbours).

**DH3** A drawing showing the flattened slopes proposed for the Plymouth Breakwater after the storm of 1824 (ICE Archives).
DH4 Plymouth Breakwater today (by courtesy of Peter Cross-Rudkin).

DH5 Dalkey quarries, opened to provide the large amounts of stone required for the piers of Dun Laoghaire Harbour (by courtesy of Peter Cross-Rudkin).

DH6 Dun Laoghaire Harbour today, seen from the quarries at Dalkey (by courtesy of Peter Cross-Rudkin).
In the 1790s the port facilities of London, whose commercial traffic was served only by riverside wharves and a small dock on the Surrey side of the river, were the subject of parliamentary enquiries. Although opposed by the City, who owned much of the existing rights, Acts were passed for the West India Docks, London Docks and the East India Docks. William Jessop was the engineer for the first of these (authorised in 1799), Rennie for the second (1800) and Rennie with Ralph Walker for the third (1803). One of the few original drawings by Rennie still existing shows his plans for the communication lock (DH7); a draughtsman then made copies for use on the site (DH8). George Rennie, John’s elder son, also made drawings of it in his notebook (DH9). It is notable that when the Frenchman Charles Dupin illustrated his book Voyages dans la Grande Bretagne, published in 1824, with examples of modern practice, he chose London Docks (DH10).

The London Docks, although only half the area of the West India, represented an important step forward in the mechanisation of construction. The piles for the cofferdam across the Wapping entrance were driven by a steam engine, the first known example of this use. The dock walls were battered and backward-leaning, with counterforts at intervals, as Jessop had provided at the West India Docks, but at London Docks they had a row of sheet piles at the toe. About 40% of the excavated soil was taken on iron railways, up steam-powered inclined planes to jetties on
the river, where turntables rotated the wagons through 90° to be end-tipped into barges to be taken away; iron railways on the level removed another 20% to open ground to the east. Another innovation was the use of cast iron for the swing bridge over the entrance lock (DH11 and 12); previously swing bridges had been made of timber.
Docks and harbours: display guide

DH7 An unsigned, undated drawing of the communication lock at London Docks that appears to be in Rennie’s own hand (by courtesy of Museum of London Docklands).

DH8 The drawing above would then have been copied by draughtsmen employed by Rennie, for use of the resident engineer and contractors on site (by courtesy of Museum of London Docklands).

DH9 A detail of the communication lock from George Rennie’s sketch book (ICE Archives).
**DH10** This drawing, in Charles Dupin (1824) *Voyages dans la Grande Bretagne*, is thought to be of the Wapping entrance lock, rather than the Hermitage lock as mentioned in Dupin’s text. If correct, it appears that Rennie has added sheet piling under the gates (ICE Archives).

**DH11** ‘London Docks, design for a cast iron swing bridge (by courtesy of the Birmingham Central Library).

**DH12** London Docks, swing bridge after closure of the docks (by courtesy of Malcolm Tucker).
Unbounded originality

As the foremost civil engineer of the day, Rennie was consulted about a whole variety of projects. One of the most challenging was the construction of the Bell Rock Lighthouse, though the site operations were under the control of his assistant engineer, Robert Stevenson.

In 1798 Rennie was asked to suggest means of improving the Clyde navigation up to Glasgow. In 1773 John Golborne had narrowed the river and concentrated its flow by constructing more than 200 jetties of varying lengths. Rennie advised constructing low rubble walls along the river, regularising the outer ends of Golborne's jetties (UO1).

The river's depth was improved and a lot of land reclaimed, though a hundred years later the narrowness of the upper river impeded its development. Rennie made a second report in 1807, advocating dredging to deepen the river further. This was done and proved most satisfactory, but his suggestions for wet docks were not carried out.

In the 1790s the Trent & Mersey Canal needed to increase its water supply and the company's surveyor suggested a site for a reservoir in the Rudyard valley. Rennie was consulted, but found that the ground conditions at the site proposed for the dam were unsuitable.

A better site was located 300 metres upstream and Rennie designed a dam 10.5 metres high (UO2). A notable feature of the scheme was the spillweir (UO3), to allow excess water to flow away without washing over the face of the dam.

As trade increased at the end of the 18th century and shipwrecks became more numerous on the approaches to the Firths of Tay and Forth, Robert Stevenson proposed first a cast iron
beacon and then in 1800 a stone lighthouse on the Bell Rock, off Arbroath.

Robert Southey’s dramatic Ballad of the Inchcape Rock was written in 1802 but a bill to build the lighthouse was rejected by Parliament in 1803. On Stevenson’s advice, Rennie was brought in as Chief Engineer, with Stevenson as assistant engineer. The Act was passed in 1806, based on Rennie’s design, and the difficult task of construction was completed, with Stevenson in charge on site, in 1811 (UO4).

Rennie was engineer for a number of early railways, either to assist in the construction of his projects or for the transport of freight. Of the former, the earliest was probably for the London Docks (see Docks and Harbours), and others were built for the Kennet & Avon Canal and Howth Harbour.

The railway to bring stone from the quarries at Dalkey to the harbour at Dun Laoghaire had three inclined planes, worked by gravity. Its design was based on Rennie’s Caldon Low Railway in Staffordshire, built in 1802-04, which brought limestone down 670 feet from the quarries to a wharf on the Caldon Canal.

His scheme for a Berwick & Kelso Railway (UO5) received its Act in 1811, but was not built; it would have crossed the River Tweed on a suspension bridge, a very early proposal for that type of bridge.

Rennie also prepared reports on alternative canal and railway routes (what would become the Stockton & Darlington Railway), but he was supplanted as engineer by George Overton, a connection of one of the leading shareholders. When the project did go ahead, with George Stephenson as engineer, the Act was based on the earlier one for Berwick & Kelso.

One of Rennie’s least successful consultancies was for the Grand Junction Waterworks in London and the Manchester Waterworks. These were both private companies, promoted by a group of shareholders who were also involved with the Stone Pipe Company in the
Cotswolds. Although the idea of stone pipes for water mains was not Rennie’s, he endorsed it. The pipes proved to be entirely unsuitable and they had to be replaced in cast iron. Some remnants of the stone pipes can still be seen around the quarries (UO6).

Rennie was involved in a number of projects for protecting the sea shore from erosion. The most substantial of these was the repair of the sea defences to Romney Marsh in Kent, where land reclamation had been going on since Roman times.

One of Rennie’s more unusual sea shore projects was to prevent the towers of Reculver church from collapsing into the Thames estuary (UO7). The church itself had been demolished but the twin towers were valuable as a daymark for passing ships. Trinity House did just enough work in 1807 to preserve the towers, though Rennie was still reporting in 1820 on the defences of the adjoining lands.
John Rennie 1761–1821 Unbounded originality Image UO6: A wall in the Cotswolds
Unbounded originality: display guide

UO1 Part of a long plan of the River Clyde from Jamaica Street Bridge to Shielhall, showing the land reclaimed by the jetties that had been constructed John Golborne in 1773, and the new river walls (in red) constructed by Rennie (by courtesy of the National Archives of Scotland).

UO2 Cross-section through Rudyard Dam (G M Binnie: Early Dam Builders in Britain).

UO3 The spillweir at Rudyard Dam (by courtesy of Arthur Silvester).

UO4 Bell Rock Lighthouse.
**UO5** Part of the deposited plan of the Berwick & Kelso Railway, 1811 (by courtesy of Parliamentary Archives).

**UO6** A wall in the Cotswolds, with remnants of pipes made by the Stone Pipe Company (by courtesy of Peter Cross-Rudkin).

**UO7** Reculver Church, a daymark for sailors, for which Rennie provided defences to prevent it being eroded into the sea. The boulders are modern (by courtesy of Peter Cross-Rudkin).
## List of works

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<th>Date</th>
<th>Project Description</th>
<th>Location</th>
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<td>Land drainage and sea defence:</td>
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<tr>
<td>1804-07</td>
<td>Lea Valley inundation works</td>
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<td>1805-06</td>
<td>Dymchurch Sea Wall</td>
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<td>1806-07</td>
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<td>1817-21</td>
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<td>1818</td>
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<td>Bottisham &amp; Swaffham Fen, Cambridgeshire</td>
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<td>Reservoirs and water supply:</td>
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<td>Rudyard Reservoir, near Leek</td>
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<td>1799-1800</td>
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<td>Caledon Low Railway</td>
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<td>1807-11</td>
<td>Bell Rock Lighthouse</td>
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<td>1817-19</td>
<td>Custom House, London, river wall</td>
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Glossary of terms

Abutment: the parts of a bridge (at each end of the arch) that provide resistance to the thrust of the arch.

Adze: a cutting tool with its blade set at right angles to the handle.

Apsidal niche: a niche whose top is a quarter of a sphere.

Breakwater: a structure in the sea to break the impact of waves between the breakwater and the shore.

Catchwater drain: a channel around the base of higher land to intercept rainwater flowing off that land before it can flood the land below.

Cofferdam: a temporary, watertight structure to enable foundations to be built in the dry; usually formed by sheet piling (see below).

Doric: the earliest of the orders of Greek architecture, later modified by the Romans.

Girder: a deep beam.

Pilaster: a rectangular column, partly built into and partly projecting from a wall or the pier of a bridge.

Sheet piling: a series of panels driven into the ground, with continuous interlocking connections to prevent soil or water passing through. In the 18th/19th centuries sheet piles were made of timber with tongue-and-groove connections.

Spandrel: the triangular area between the arch and the deck of an arch bridge.

Span: rise ratio: the ratio of the span of a bridge to the vertical distance between the springing of an arch and its crown. The higher the ratio, the flatter the arch.

Spillweir: a weir built into the side of a reservoir so that any water above the level of the crest of the weir flows away safely and the reservoir does not overtop its dam.

Stringcourse: a projecting course of masonry, often framing the arch or below the parapet of a bridge.

Turnpike road: a toll road; the tolls were paid at gates called turnpikes.

Voussoirs: the individual blocks forming the arch of a bridge.