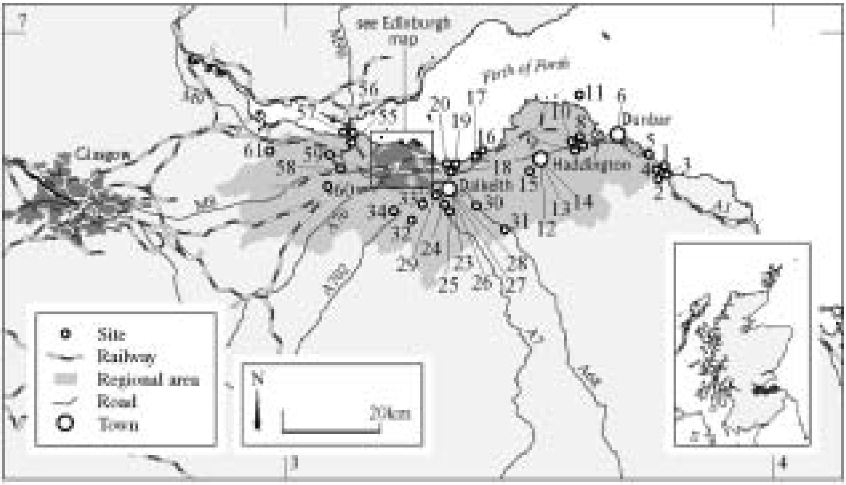

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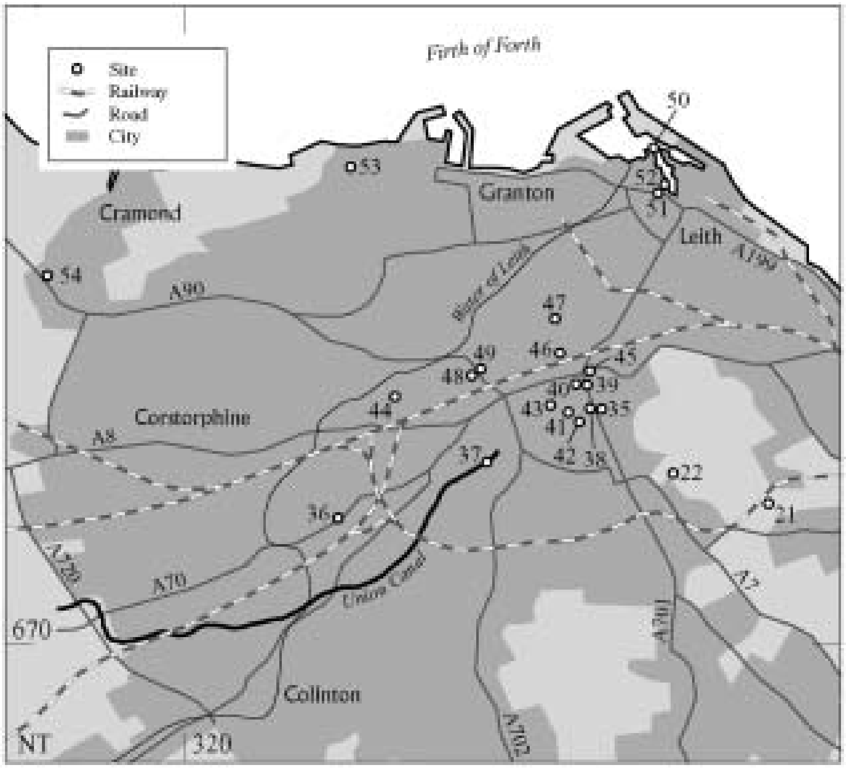

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Lothian and Edinburgh

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3. Lothian and Edinburgh

Introduction

The railways in Lothian developed from the early-19th century. The Edinburgh & Dalkeith became operational in 1831, its surviving works being Braid Burn cast-iron bridge (3-21), St Leonards' tunnel and inclined plane (3-22) and Glenesk Bridge (3-23). This line became part of the North British Railway in 1845 and this company, and to a lesser extent the Caledonian Railway, largely developed the railway network. Their works are represented by the Almond Viaduct and Winchburgh Tunnel (1842, 3-58/59); Dalhousie Viaduct (1846, 3-24); Dunglass Viaduct (1846, 3-3); East Linton Bridge (1846, 3-9); Scotland Street Tunnel (1847, 3-47); Firth Viaduct, Auchendinny (3-32); the Forth Bridge (1890, 3-56); Bilston Glen Viaduct (1892, 3-33); and, in Edinburgh, Waverley Station (ca.1900, 3-40); Leamington canal lift bridge (ca.1906, 3-37); and, on the Caledonian Railway, Murrayfield and Grove Street bridges and Slateford Viaduct, 1848 (3-44).

Water, coal and power provision feature under the historic Castlehill Reservoir and the Grassmarket Well, Edinburgh, (3-43); Glencorse Dam (1824, 3-34), one of the tallest earth dams in Britain when built; Dalkeith Water Tower (1879, 3-28), now a residence; and the extensive Edinburgh Water of Leith sewers of 1864 and 1889 – a fundamental health improvement (3-49); Lady Victoria Colliery (3-25), one of the most complete coal works of its kind in Europe in the late-19th century, now the Scottish Mining Museum; Granton Gas Holder (ca.1903, 3-53); Preston Mill (3-8), representing the once ubiquitous water mill; and Cockenzie coal-fired (1968, 3-17) and Torness nuclear (1979–84, 3-5) power stations. Both were built by Sir Robert McAlpine Ltd who, as a goodwill gesture, relocated the John Rennie Memorial at Phantassie, East Linton, his birthplace (3-7).

Masonry bridges are well represented with 15th and 16th century examples at Cramond, which also had a Rennie bridge nearby (1820–1964, 3-54); Abbey and Nungate Bridges, Haddington (3-12, 3-13); 17th and 18th century bridges at Dunglass (3-1, 3-2); and, over the Esk at Musselburgh, a low-rise Rennie masterpiece of 1808 (3-19). As part of the improvement of turnpike roads in Scotland at the start of the Industrial Revolution from ca.1750, New Mills and Lugton Bridges (3-26, 3-27) were built; and later, on the Edinburgh to Morpeth road improvement, Telford's elegant Pathhead Bridge (1831, 3-30) and culverts at Falla (3-31). In central Edinburgh, the North and South Bridges were building development led projects (3-38, 3-39), as were the Regent Arch (1819, 3-45), Telford's outstanding Dean Bridge (1832, 3-48) and George IV Bridge (1835, 3-41).

Steel bridges are represented by the already mentioned Forth Bridge and Bilston Glen Viaduct; Victoria Bridge, Haddington (1900, 3-14); and the Forth Road Bridge (1964, 3-57). Reinforced concrete bridges include Gorgie (1907, 3-36); Westfield, Haddington (1912, 3-15); and Dunglass Bridge (1932, 3-3) on the then A1 road.

Maritime projects included are Leith Docks, the largest in Lothian, with a plan illustrating their progressive development from 1800, the Rennie Dock Entrance Lock (1806, 3-51), Victoria Swing Bridge (1874, 3-52) and the outer harbour embankment of 1896. Other work includes Fisherrow Harbour (1843, 3-20); Dunbar and North Berwick harbours (3-6); Bass Rock and Barns Ness lighthouses (3-11); Cockenzie Harbour (3-16); and Hawes Pier (3-55).

Unusual works include Edinburgh's colloidal concrete roads (1870–1910, 3-35); the Melville Monument (1821, 3-46), said to have been erected with the balance crane used to build the Bell Rock Lighthouse; and the impressive Edinburgh Museum of Science and Art in Chambers Street with its main hall reminiscent of the Crystal Palace of the Great Exhibition of 1851, but with a timber roof.

North British Railway

HEW 2451

The North British Railway began life in 1846 as a newly-built line 58 miles long between Edinburgh and Berwick-upon-Tweed. It soon absorbed earlier railways such as the Edinburgh & Dalkeith and the Edinburgh & Glasgow, opened to Haymarket, Edinburgh, in 1842 and extended to Central (now Waverley) Station by 1846. The fine original station building at Haymarket and 992 yd tunnel to Princes Street Gardens are still in service. By 1849 the railway included the first leg of the 'Waverley Route' to Hawick which reached Carlisle in 1862. Under the expansionist policy of its forceful chairman Richard Hodgson, the company soon became the largest of its kind in Scotland. Its Fife coal traffic was particularly important. By the turn of the century the firths of Forth and Tay had been bridged and Waverley Station had been created which also served as the company's headquarters.

North British Railway map ca.1900 [unattributed]

The Company's first engineer was John Miller who, up to his retirement in ca.1850, had designed and laid down most of the early main-line railways in Scotland. Later engineers were James Bell and James Bell Jnr. For many years the Company had as its consulting engineer Thomas Bouch, later Sir Thomas, who designed the loading mechanism for the innovative train ferry between Granton and Burntisland.

The North British had the Caledonian Railway as its great rival in Scotland. This rivalry led to the extension of the Waverley route as an alternative line to Carlisle but was never a great success commercially. Another rival venture was the development of the West Highland Railway to serve the fishing port of Mallaig, in competition with Oban, served by a subsidiary of the Caledonian Railway, the Callander and Oban. The Company also competed with the Caledonian Railway for steamer traffic on the Clyde and in the legendary 'race to the north' in 1890. It became part of the London and North Eastern Railway in 1923. [1]

Dunglass Burn Bridges

The development of bridge building over more than three centuries at Dunglass Burn is exhibited at this site.

1. Old Bridge

HEW 2452
NT 7721 7232

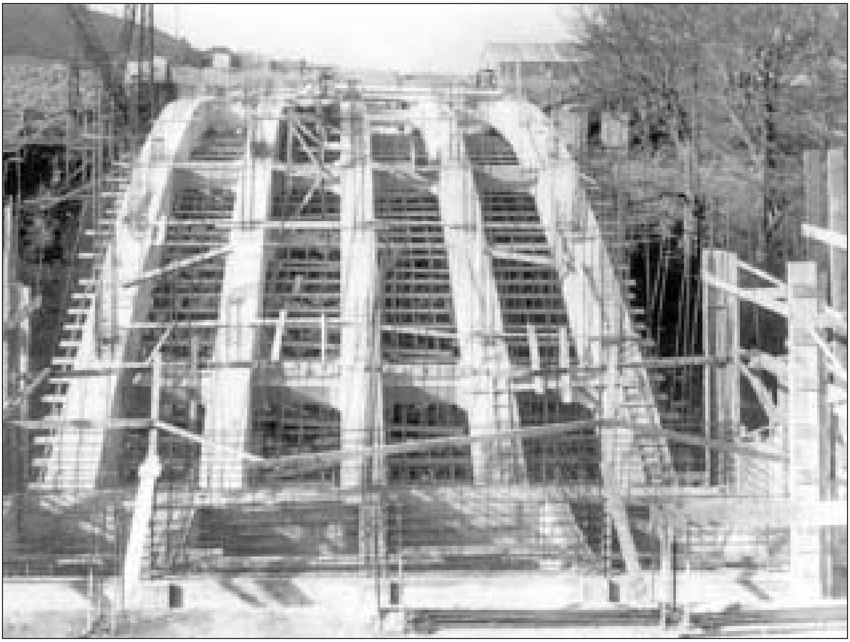
This masonry bridge has the appearance of a wedge of masonry pierced by a single lofty but narrow arch over the burn probably dating from the early-17th century, but with extensive later reconstruction.

It was bypassed by through traffic when the New Bridge was opened in 1798.

2. New Bridge (1798)

NT 7699 7208

A single segmental arch of 83 ft span rising to 77 ft above the bed of the burn. Its masonry is boldly rusticated with castellated parapets, possibly a style chosen to please the local landowner. It was bypassed by through traffic in 1932. Bilsdean Bridge (NT 7630 7250) is in the same style.


Blyth & Blyth

3. Dunglass Bridge (1932)

NT 7710 7219

Top: Dunglass Bridge (1932) under construction

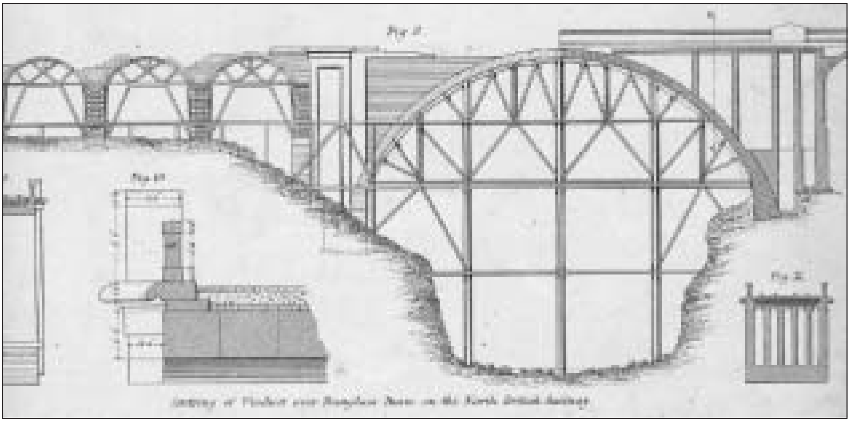
An outstanding example of an early reinforced concrete bridge. Its main arch springs from the rock on each side of the burn with a span of 157 ft and a rise of 38 ft 6 in. The five arch ribs have parabolic soffits, are 3 ft wide and increase in depth uniformly from 4 ft at the crown to 7 ft at the springings. The centring for the arch had a maximum height of 75 ft and required 5000 cu ft of timber. The engineers were Blyth & Blyth and the contractor, Crowley, Russell & Co., Glasgow. [2]

The bridge carried the A1 Trunk Road until recently bypassed by the New Bridge.

4. Dunglass Viaduct (1846)

NT 7706 7214

An impressive segmental masonry arch viaduct designed by and built under the direction of North British Railway Company engineer John Miller on the first railway to cross the Border, now the East Coast Main Line. The bridge has five spans of 30 ft and a main span of 135 ft



Dunglass Viaduct (1846) centring [3]

about 110 ft above the burn, one of the largest masonry arches in Scotland. [3]

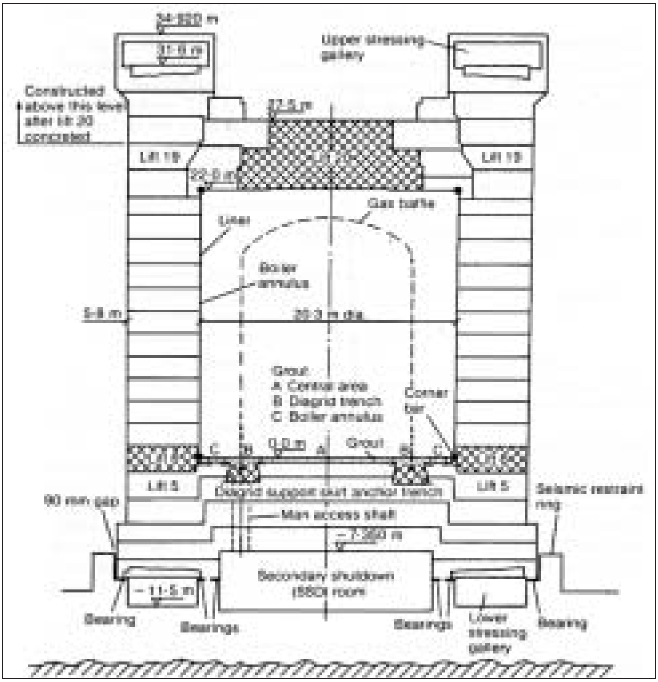
5. Torness Power Station

NT 7453 7514

This power station, which produces up to 1362 MW of electricity from two advanced gas-cooled reactors, was built on a 200 acre site by Sir Robert McAlpine from 1979–84, with the first reactor becoming operational in 1987. McAlpine's had already developed an expertise in this

Torness Power Station [4]

Torness Power Station – section of pressure vessel [5]



field in Scotland having built the power stations at Cockenzie, Longannet, Hunterston 'B' and Inverkip.

The civil engineering work was considerable, involving use of the order of two million tons of materials, a workforce of up to 3000 and a cost of nearly £240 million. There were 340 accidents, none fatal. Site preparation involved the excavation of 3 270 000 cu yards of material and the installation of over $1\frac{1}{4}$ miles of coastal defences with about 500 000 tons of local quarried rock armouring.

More intricate work included the pre-stressed concrete pressure vessels of the reactors. Each was helically pre-stressed by means of about 3000 tons of 0.7 in. compact strand steel wire formed into seven-strand sections. These were incorporated into the 19 ft thick walls and construction was achieved in 20 concrete lifts.

Further information is available at the visitor centre. Torness and Hunterston 'B' nuclear power stations together are said to generate up to 55% of Scotland's electricity.

An unusual use of the facilities occurred in 2005 when a retired supersonic Concorde aircraft, en route for the

Museum of Flight at East Fortune where it is now on display, was unloaded at the jetty. [4, 5]

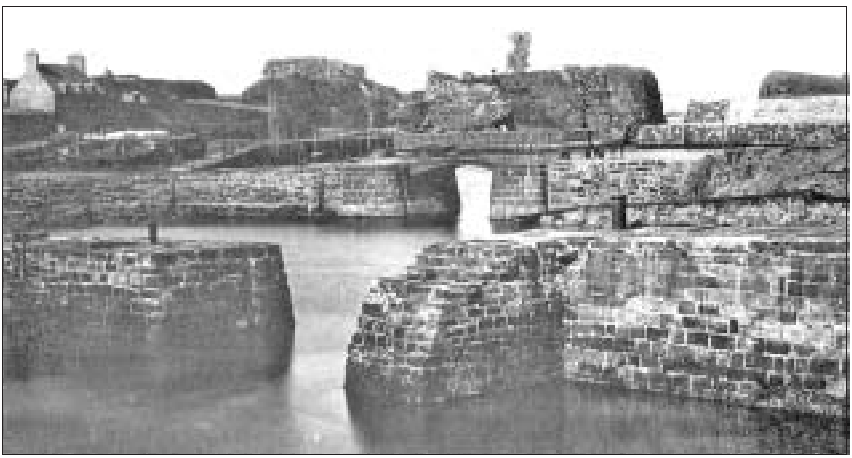
6. Dunbar Harbour

NT 6814 7922

This harbour forms part of a natural tidal anchorage, formerly known as 'Lamerhaven', mentioned in a charter of 1555 some 20 years before the building of the harbour began. To the east of this is the old harbour enclosed by the old main breakwater or East Pier, about 920 ft long, which displays a variety of masonry constructions including beach boulders. Extensive repairs between 1655 and 1906 show further variations in the masonry.

The pier is 16 ft wide at the top with walkways at different levels, perhaps indicating a subsequent heightening on one side. The pier and pier-head to the west of the East Pier is 170 ft long and is of squared, well-coursed blocks and was probably built in 1717. It is shown on Roy's map of Scotland (1747–55) and in the foreground of the view ca.1900. In the background, across and to the west of the haven, the former entrance to which is now closed to the sea, can be seen the 'New' or 'Victoria' Harbour of about five acres extent formed in 1844 at a cost of £15 762 with a grant from the Fishery Board, whose engineer was Joseph Mitchell. Its regular coursed masonry is a good example of best practice in Scottish harbour work at the time.

Dunbar harbour



North Berwick harbour entrance

Lothian Regional Council assumed responsibility for the harbour in 1975, and since then numerous repairs and dredging improvements have been carried out. [6]

Although North Berwick Harbour nearby is of lesser extent it is an excellent example of an historic small tidal harbour which is still well used, particularly for recreation. The end of its breakwater was substantially storm-damaged in 1811, reported on by Robert Stevenson, and rebuilt in its present form. [6]

7. John Rennie Memorial, East Linton

HEW 2456
NT 5960 7715

This memorial consists of a bronze relief of Rennie's head by Alexander Carrick and a plaque that were originally erected in 1936 by local subscription on the south side of the former A1 trunk road bypass of the town. The bronze-work is mounted on the back wall of a curved ornamental masonry pedestrian area which contains a baluster recovered from the demolition of Waterloo Bridge over the Thames engineered by Rennie from 1811–18.

In 1981, by which time traffic had increased greatly on the A1 making access to the memorial difficult, the Scottish Group of PHEW was instrumental with East Lothian Antiquarian Society in arranging with Sir Robert McAlpine Ltd, then building Torness Power Station, for its relocation adjoining the old road in the grounds of Phantassie, the house in which Rennie was born. McAlpine generously relocated the memorial as a goodwill gesture. It was re-dedicated by the Earl of Wemyss on 20 September 1981. [7]

8. Preston Mill, East Linton

NT 5948 7788

The mill is a rectangular masonry building with pantile roof containing millwork driven by an undershot water-wheel. The iron wheel of about 11 ft diameter with wooden paddles can, on request, still operate much of the, probably, early-20th century machinery, including a small Archimedes screw. Adjoining, over a timber bridge, is an early circular masonry, buttressed, drying kiln with conical pantile roof and rotating ventilator and wind vane.

Substantial elements of the buildings, including some timberwork, date from 1660, or earlier, with extensive renovation in ca.1760. The mill ceased to operate commercially in 1950 when it was given to the National Trust for whom Joseph Rank restored the machinery to working order. The mill is now a significant visitor attraction.

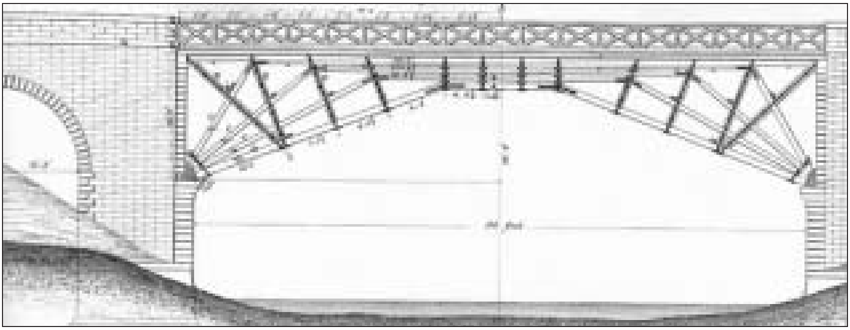
Nearby is Houston Mill where Andrew Meikle, inventor of the corn threshing machine, who probably advised on Preston Mill millwork, was the millwright and with whom the young John Rennie spent an invaluable apprenticeship. In 1772 Meikle invented the ‘spring’ sail for windmills using louvred shutters.

Meikle’s finely executed gravestone of 1811 near the parish church door, not far from George Rennie’s, describes him as a ‘Civil Engineer’. [8]

9. East Linton Bridge (Railway)

NT 5923 7707

This bridge, originally built over the Tyne by the North British Railway under the direction of John Miller, consisted of four freestone masonry arches, of which the central pier and middle two were carried away by a flood in September 1846 soon after construction in which poor workmanship was a factor.



East Linton timber bridge 1846–ca.1870 [9]

Within three months the gap was bridged by a substantial timber structure of 90 ft span to Miller's design which served for several decades until replaced by the present wrought-iron lattice girder span (seen in the view of East Linton Bridge) continuing to serve the East Coast Main Line. Its two original adjoining arches are now used for storage. Both bridges were probably erected under the direction of James Bell. [9]

10. East Linton Bridge

NT 5926 7711

A well-maintained example of a 16th century masonry bridge with buttressed abutments, ribbed arches and pointed cutwater to the pier, dating from ca.1550. An earlier stone bridge was reported to have been razed by the French army in 1549, but a bridge, presumably the present one, existed by 1560.

The bridge, which carried the A1 Edinburgh to Berwick road until bypassed in the late 1920s, has twin arch spans of about 40 ft each, founded on exposed rock in the bed of the Tyne. There are four ribs to each arch, closely spaced, and easily inspected from outcropping rock on the downstream side. The dates 1762 and 1763 on the keystones record when it was widened. The original overall width across the soffit was $10\frac{1}{2}$ ft, increased to nearly 14 ft when it was widened. Other repairs took place in 1884, 1895 and 1934.

In 1927 the bridge was relieved from trunk road traffic by an elegant three-span steel plate-girder bridge of the cantilever and suspended span type with a central opening of 102 ft 8 in. designed and built by Sir William Arrol & Co.

Roland Paxton

East Linton bridges

In the 1990s this was replaced by an embankment and culvert. [10, 11]

11. Bass Rock Lighthouse

NT 6020 8726

In 1897 the Northern Lighthouse Board decided to erect two lighthouses on the Haddingtonshire coast. Barns Ness (NT 7230 7721) with its 121 ft high tower built of stone from Craigree and Barnton quarries, was erected from 1899 to 1901 and Bass Rock from 1900 to 1902.

Bass Rock Lighthouse is said to be located on a former gun platform part way up the rock, a particularly awkward site. Its creation, to quote a later Northern Lighthouse Board engineer J. D. Gardner, required 'the exercise of sound judgment and engineering skill'. The engineer for both lighthouses was David A. Stevenson.

Bass Rock Lighthouse has a circular stone tower 65 ft high and cost about £8000. Its light is about 150 ft above sea level and has a nominal range of 21 miles. It adjoins the site of a former fortress and prison where, between 1672 and 1688, some 40 Covenanter prisoners are said to have perished. Barns Ness was automated in

Roland Paxton

Bass Rock Lighthouse from Northern Lighthouse Board Ship *Pharos* 1986

1986 and is now a minor light with a nominal range of ten miles.

The first lighthouse completed by Stevenson as Engineer to the Board was on nearby Fidra Island in 1885, the station on which, with its Alan Stevenson-type diagonal astragals lantern, can be best seen from the mainland at Yellowcraigs beach, where there is an interpretive board at the car park. [12]

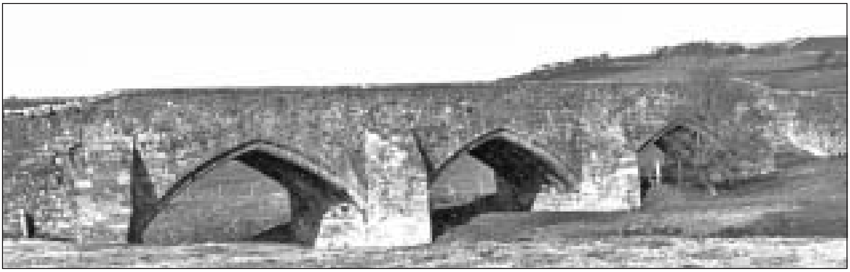
12. Abbey Bridge, Haddington

HEW 1299
NT 5331 7454

A masonry bridge with three pointed arches over the Tyne dated by Inglis to the 1440 to 1540 period, probably early-16th century. Each arch is of about 37 ft span and originally had five masonry ribs 18 in. broad with chamfered edges, some of which have been cut away on each side arch without apparently affecting stability. The ribs were built first, and then slabbed over transversely.

The width is 13½ ft between parapets and 16 ft overall. The west side has been rebuilt in a different style and probably at a later date with slight corbelling and a string course at road level.

An inscription of 1870 on the west coping probably indicates a repair date. The bridge was probably financed



Roland Paxton

Abbey Bridge, Haddington

by pre-reformation churches or abbeys. The bridge is well maintained and in regular use for local access. [13, 14]

13. Nungate Bridge, Haddington

HEW 1260
NT 5192 7379

Another, probably early-16th century at least in parts, sandstone masonry bridge, also over the Tyne, about 210 ft long, and with three low-rise segmental arches of about 44 ft span. Its masonry details are similar in Scotland only to Old Bridge, Musselburgh, for which Inglis poses a date of ca.1530 and that Haddington Bridge is earlier. The width between parapet faces is about $10\frac{1}{2}$ ft and $14\frac{3}{4}$ ft overall.

The bridge shows signs of much alteration and repair and it is difficult to be certain of the dating of its various elements. It was used by vehicular traffic in the last century but is now restricted to pedestrian and cycle use. [14, 15]

14. Victoria Bridge, Haddington

HEW 1493
NT 5180 7396

Building a bridge over the Tyne, just downstream of the narrow Nungate Bridge and upstream of the pre-1856 timber bridge to the corn mill, had been considered by the Town Council from 1849. Various plans and estimates were prepared including, in the 1880s, a scheme to use girders salvaged from the Tay Railway Bridge.

Eventually a design was commissioned from civil engineers Belfrage & Carfrae, Edinburgh, and the present elegant twin steel arch bridge was built from 1898 to 1900. The resident engineer was William Jackson. Its 3 ft deep arched beams with ornamental façades have spans of 60 ft and a rise of only 6 ft. The steelwork and erection contractor was Somervail & Co. of Dalmuir and the bridge cost about

Victoria Bridge, Haddington [photograph 1900]

£9000. It was named after Queen Victoria whose diamond jubilee had taken place in 1897.

The bridge, tastefully refurbished by Lothian Regional Council in 1975 at a cost of about £20 000, is an excellent early example of a provincial steel arch bridge in Scotland, on a smaller scale but more slender than North Bridge, Edinburgh. [16]

15. Westfield Footbridge, Haddington

HEW 1009
NT 5008 7166

One of Scotland's earliest reinforced concrete structures, bearing the date 1912 on its parapet. The bridge, which is owned by East Lothian Council and is still in use, spans the Tyne by means of twin horizontal beams which also form the parapets. These beams are 4 ft deep, $10\frac{1}{2}$ in. wide and 3 ft 3 in. apart and are joined by a slab forming the bridge floor. The underside of the bridge is about 8 ft above normal river-water level. The beams span $52\frac{3}{4}$ ft between concrete abutments and the deck is approached by a flight of concrete steps on each side. Some of the cover has spalled off revealing the reinforcement and the bridge, which is a worthy candidate for preservation, is at present in need of maintenance.

16. Cockenzie Harbour

HEW 1380
NT 3977 7569

This harbour is thought to have been originally begun by the Earl of Winton, probably in 1630, for the export of coal and salt. The Earl of Winton, who supported the Jacobite rebellion in 1715, forfeited his estate which was acquired by the York Buildings Company in 1719. In 1722 the Earl repaired and enlarged the harbour and constructed a wooden wagonway, one of the earliest in Scotland, for the export of coal from coal pits at Tranent some two miles inland to the east side of the harbour. The wagonway featured as a strategic element in the battle of Prestonpans. In 1774 both the harbour and colliery were bought by the Cadell family, co-founders of the epoch-making Carron Ironworks in 1759.

The harbour, of about five acres, was extensively rebuilt in 1833–34 to plans prepared by Robert Stevenson & Sons for the Cadells. It is essentially a tidal pocket of sand and flat rock, flanked and partially protected by ridges of rock. The east ridge carries a main breakwater pier 227 ft long and about 30 ft wide and 30 ft high with a returned head, built of squared red sandstone blocks and, across an entrance (out of sight to the left in the view) of about 90 ft; the west ridge carries a narrower pier of similar construction. The stone used on the works was found in the harbour basin which considerably reduced their cost, which did not much exceed £5000.

The harbour, a good example of a small coal port, was much used for several decades but by the 1880s ships had outgrown the facilities, coal was transported by rail to other ports, and the wagonway was closed after more than 160 years in operation. The piers were extended and refurbished in the 1960s.

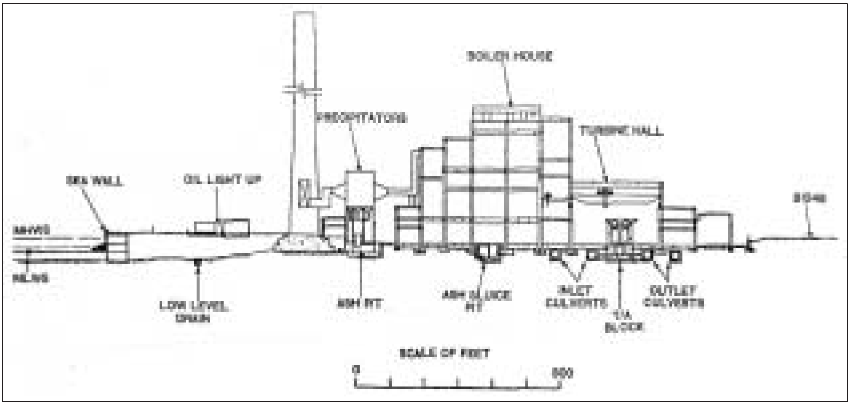
The harbour is still used in a small way but its boat building and slipway use ceased in ca.1995. [17]

17. Cockenzie Power Station

NT 3947 7539

A 1200 MW coal-burning power station adjoining the harbour and Prestonlinks Colliery, formerly one of East Lothian's largest pits, was designed for the South of Scotland Electricity Board by consulting engineers Kennedy & Donkin and Strain & Roberston, and architects Robert Matthew, Johnson-Marshall & Partners.

The contractor, Sir Robert McAlpine Ltd, commenced construction in 1962 and the station was formally opened in May 1968. Coal was supplied by rail from the newly-opened National Coal Board superpits at Bilston Glen



Cockenzie Power Station [18]

and Monktonhall. Its main buildings cover an area of 59.3 acres, half of which was reclaimed from the sea.

The complex is dominated by a large rectangular steel-framed building containing the boilers and superheaters, with an adjoining hall housing the steam pressure turbines. Ash is disposed of in specially-constructed lagoons nearby at Prestonpans and the flue gases are dispersed via two reinforced concrete chimneys nearly 500 ft tall, each lined with heat-resistant brick. [18]

18. Old Bridge, Musselburgh

HEW 1261
NT 3407 7253

This historic, 248 ft long, bridge over the Esk is generally $11\frac{1}{2}$ ft wide between parapets, overall up to 14 ft wide. It has three segmental arches of about 51 ft span and 11 ft rise with hood-moulds and chamfered archstones and is built of large squared-rubble courses. Both piers are protected by large 'whalebacks' of masonry and concrete.

A plausible speculation about the bridge's origin is that an earlier stone bridge, which certainly existed, was damaged or destroyed when the English burned Musselburgh in 1548 and the present bridge was erected in the 1550s at the expense of Jane, Lady Seton. Its similarities with Nungate Bridge, Haddington, have already been noted.

More than 150 years ago the original ramped approaches were replaced by the present steps which restricted the bridge to pedestrian use. [19]

Blyth & Blyth

19. New Bridge, Musselburgh

HEW 1262
NT 3422 7264

This bridge over the Esk has five low-rise (one-tenth span) segmental arches with spans of 37 ft–46 ft and was completed in 1808. It is built of freestone with an original width of 34½ ft before being widened in 1925 on the downstream side to 53 ft, carefully preserving the original façade stone-by-stone as can be seen in the view.

Top: New Bridge, Musselburgh – widening 1925

A metal plaque on the north parapet of the bridge states that it 'was built by John Rennie, Engineer, 1806. Repaired and widened 1924–25. Alexander Mitchell, Provost, Blyth & Blyth, Engineers, John Angus & Sons, Contractors'. The bridge was, and still is, notable for the low almost flat longitudinal profile of the road about 14 ft above the river, of which people exclaimed when they passed over it that they did not realise it was there!

It is a fine example of a Rennie bridge.

20. Fisherrow Harbour, Musselburgh

NT 3343 7303

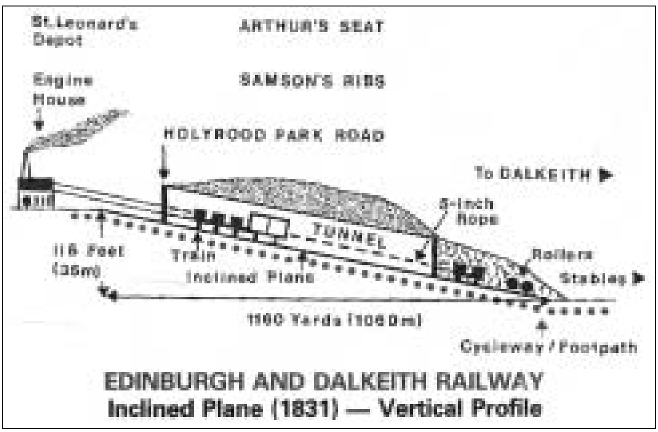
A fishing harbour existed at Fisherrow by 1592. On Adair's map of 1703 the east pier only is marked. The harbour was rebuilt from 1743 and 'lately built' by 1753.

Numerous repairs and alterations took place to 1843, when the west pier was built new on old foundations to a plan by Robert Stevenson & Sons by W. Kinghorn of Leith for £1685. This was about 460 ft long and a round head was added in 1939. An experiment to clear the harbour of silt and sand was tried in 1835 when an arched opening was constructed in the east pier to allow tidal currents to scour the harbour bottom. This was not sufficiently successful and the opening was closed in 1838. The masonry comprises mainly random red sandstone blocks, rather better-dressed on the west pier. [20]

Edinburgh & Dalkeith Railway

The first wagonway from the Lothian coalfields, known as the 'Edmonstone' from pits near Newton to Little France on the Dalkeith Road approach to Edinburgh, was designed in 1818 and superintended by Robert Stevenson for John Wauchope. While useful, a larger-scale facility was needed and the Edinburgh & Dalkeith, one of Scotland's earliest railways, was planned from 1824–26 and constructed from 1827–31. It was planned for use by locomotives or horses, but in the event operated solely by horses, double track, and of 4 ft 6 in. gauge.

The line extended from St Leonards, Edinburgh, for about eight miles to collieries near Dalhousie, with a branch to Fisherrow Harbour. A private extension to the Marquis of Lothian's coal mines in the vicinity of Newtongrange opened in 1832, a branch to Leith in 1835 and



Edinburgh & Dalkeith Railway – inclined plane [Lothian Regional Council leaflet *The Innocent Railway*] another to Dalkeith in 1838 and privately through the town to the Cowden pits by 1841. The company's engineer from 1826 was James Jardine. The manager David Rankine also had an engineering role from the mid-1830s. In 1844 his son W. J. M. Rankine proposed an upgraded line including a tunnel from St Leonards to what is now Waverley Station, but this was not executed.

The principal engineering features of the main line were an inclined plane, partly in tunnel, 1160 yards long with a gradient of 1 in 30. It extended from near the Edinburgh terminus to a stables area about 600 yards beyond the tunnel. The wagons were hauled by horses, but two J. & C. Carmichael 25 hp steam engines were used for haulage up the incline. Near Dalkeith the line crossed Glenesk Viaduct, Scotland's finest pre-Victorian railway bridge and, further south, the multi-span Dalhousie Viaduct. The Dalkeith Branch extension crossed the South Esk on the laminated timber Victoria Bridge with 4×120 ft and 2×110 ft spans designed by John Green (1841).

Unexpectedly, a passenger service begun in June 1832 attracted some 200 000 to 300 000 passengers per year until 1845. Coal traffic amounted to about 300 tons per day. In ca.1837 Dr Robert Chambers dubbed the line 'The Innocent Railway' as a refreshing change from the more familiar 'whizzing, whistling, snorting, puffing and blowing railways', but mistakenly assumed that it 'never breaks bones'. The phrase was derived from a friend of his on account of the railway's 'indestructive character and simplicity of its style of management'. There were no intermediate stations and passengers joined and alighted from the coaches when they wished.

In 1845 the Edinburgh & Dalkeith was bought by the North British for £113 000 and upgraded for locomotive use with a 4 ft $8\frac{1}{2}$ in. gauge under the direction of Miller. The line was reopened in July 1847 and connected to the Central Station at Waverley via Portobello. The line to St Leonards continued in use for coal and goods traffic until 1968. In 1981 Lothian Regional Council conserved the disused line as a cycle path. The depot warehouse at St Leonards dating from the 1830s, with its characteristic columns and beams, has also been conserved. The railway became part of the company's 'Waverley Line' to Carlisle in 1862. [21]

21. Braid Burn Bridge

NT 2861 7208

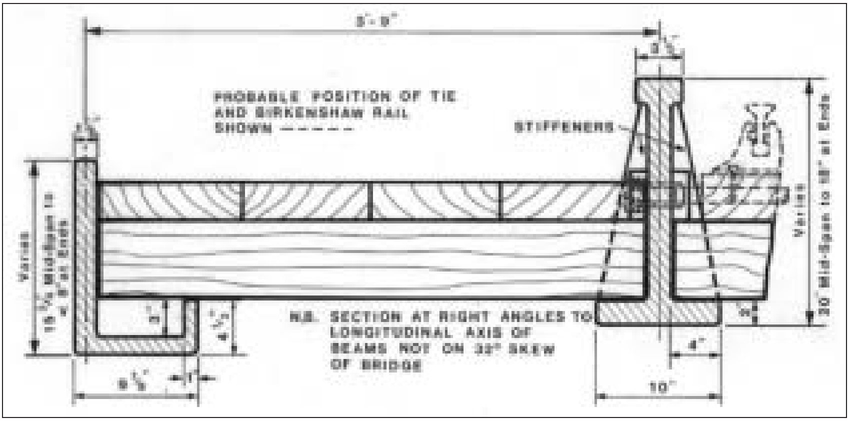
A cast-iron skew bridge which carried the railway over the Braid Burn near Duddingston. It has a span of $17\frac{1}{2}$ ft and was made, erected and painted in March 1831 by the Shotts Iron Company for the sum of £133.50.

The bridge originally extended over the double track width of the railway. The cast-iron beams are in two forms, one L-shaped in cross-section and the others of an inverted T-shape resting on cast-iron, ridged, bank seat plates. These beams are of great interest as they are among the earliest surviving examples of their type and they carried railway goods traffic until 1968 when the line was closed. The bridge is now conserved and interpreted by the City of Edinburgh Council as part of a cycle path.

In August 2001 the beams were raised to accommodate a greater water depth in the burn. The project was awarded a special commendation by the Institution of Civil Engineers Panel for Historical Engineering Works in recognition of the exceptional care taken during the work in preserving 'a prime example of one of the world's earliest surviving cast-iron bridges on a public railway'. [22]

Braid Burn Bridge being lifted 2001

City of Edinburgh Council



22. St Leonards Tunnel

HEW 2462/02
NT 2720 7252

This is believed to be Scotland's earliest tunnel on a public railway. It was excavated in volcanic rock from headings set out by transit instrument from an observatory at the edge of Holyrood Park above the tunnel. It is lined with Craigleith sandstone, with a semicircular cross-sectional top 20 ft wide, 15 ft high at its crown, and 566 yards long, on a 1 in 30 inclined plane. Trains were hauled up the incline, using a 5 in. circumference rope, by stationary steam engine or a combination of the weight of descending wagons and the engine. Construction took place from 1827–30 and cost about £12 000. Jardine was the engineer and the contractor, Adam Begg.

Top: Braid Burn Bridge cross-section [22]

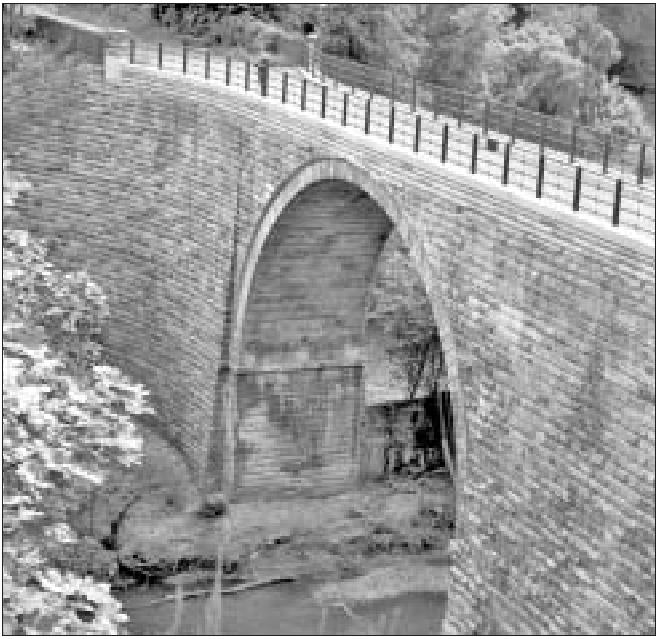
Originally the tunnel was lit by gas and it is now permanently lit by electricity as part of its conservation as a cycle path project planned and executed by Lothian Regional Council in the 1980s and now in constant use. [23]

23. Glenesk Bridge, Dalkeith

HEW 2462/03
NT 3237 6713

This fine bridge consists of a single-span semicircular ashlar masonry arch over the North Esk with a span of 65 ft and an original width of 15 ft between parapets. It was designed by James Jardine and attractively embellished with archivolts, tapering pilasters and extensive curved wing walls with an elevation reminiscent of a superior bridge of the Highland Roads era.

Glenesk Bridge
1829–31



Roland Paxton

The bridge was tastefully conserved in 1993 for pedestrian and cycle use by the Edinburgh Green Belt Trust with a grant from the Railway Heritage Trust. Unsightly steel trussing to protect the arch against the effects of future coal mining was removed together with cantilevered footways probably added by Miller as part of the North British Railway upgrading in 1847. [24]

24. Dalhousie (Newbattle) Viaduct

NT 3269 6484

A 23-span masonry viaduct with brick arch rings on the North British Edinburgh & Hawick Railway, passing about 80 ft above the South Esk and completed in 1847. It has 14 spans of 39 ft, seven of 38 ft, one of 44 ft and one of 43 ft 10 in., the easternmost over the A7 road being a skew arch. The brick arch rings are characteristic of Miller's practice. The line closed in 1972 but plans are now being made to re-open it to Hawick. It replaced a unique 24-span cast-iron pointed arch and timber viaduct designed by John Williamson in 1830 and opened on 21 January 1832. [25]

Dalhousie Viaduct

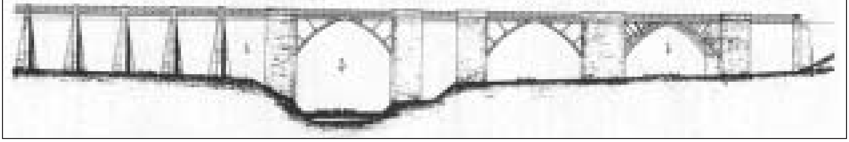
Roland Paxton

25. Lady Victoria Colliery, Newtongrange

NT 3326 6369

This colliery is considered the most complete example of a late-19th century model in Europe. It is the only coherent coal-mining complex to have survived in Scotland following the cessation of deep mining in 2002, and is all the more important because of its situation on the edge of Scotland's finest mining village, Newtongrange. At the time of its sinking by the Lothian Coal Company in the early 1890s, its shaft was thought to be the largest

Dalhousie Viaduct 1831–ca.1846 [25]



diameter and deepest in the country, and was designed to extract 1200 tons of coal per day. This was achieved by a 2400 hp steam winding engine built by Grant Ritchie of Kilmarnock, in combination with a substantial steel headframe constructed by Sir William Arrol & Co. of Glasgow in 1893.

At ground level, the pithead buildings comprise a central block of mostly red-brick arcades through which sidings from the adjacent Waverley line passed, allowing coal to be rapidly dispatched to markets in Edinburgh, and to mill towns in the Borders. The upper levels contain the mine-car circuit, coal-picking tables, and a coal preparation plant. Following the closure of the colliery in 1981 the site was conserved as the Scottish Mining Museum thus retaining its most important elements for posterity and providing a major public visitor attraction.

An unusual surviving 'bridge' element is the reinforced-concrete walkway over the A7 trunk road. This facility connected the pithead with the baths and canteen on the opposite side of the road. It was designed by National Coal Board Scottish Region's Austrian architect, Egon Riss, who was also responsible for designing the new generation of superpits in Scotland (such as Rothes in Fife, Killoch in Ayrshire, and Bilston Glen nearby in Midlothian), as well as the prestigious reconstructions at Kinneil (Bo'ness) and Barony (Auchinleck). [26]

26. Newmills Bridge, Dalkeith

NT 3362 6707

The Dalkeith locality is rich in historic bridge building involving unknown masons and several notable engineers. Newmills Bridge is a masonry arch of 55 ft span, 18 ft wide, built over the South Esk by Thomas Brown in 1754 for the Dalkeith Turnpike Trust (1751–1883) on the main inland route south from Edinburgh at the beginning of the turnpike road era in Scotland. Its retaining walls, which proved to be ill-founded, were replaced in 1770. In 1814, following the collapse of a wall at the east side of the road, engineer Charles Abercrombie was consulted and advised lifting the roadway 6 ft. This work was probably carried out in 1817.

The bridge was widened in 1835–36 under the direction of Jardine who received £150 for his services. Within two years the old part of the bridge gave way and was rebuilt by James Lees in 1838–39 to conform with the new, at a width of 40 ft. The estimated cost was £2360. The bridge is now part of the A68 trunk road.

About 800 yards upstream in a public park, formerly part of the grounds of Newbattle Abbey, is Maiden Bridge, probably dating from the late-15th century. It comprises a single, graceful, segmental arch of 48 ft span supported on three ribs projecting about 15 in. below the soffit. The arch springs from about 8 ft above the water and has a rise to the crown of 23 ft. The roadway is $12\frac{1}{2}$ ft wide between parapets, 15 ft overall. The arch rings have chamfered corners on their lower outer edge above which is a hood mould. The whole of the masonry is much weathered. Another masonry bridge with two pointed arches, possibly of 15th century origin, stands disused beside the B703 near the entrance to Newbattle Abbey. About the same distance downstream of Newmills Bridge is Cow Bridge on the A6094 road, an 1840 replacement bypassing the medieval Cow Bridge said to have been old in 1594 and which still exists. [27, 28]

27. Lugton Bridge, Dalkeith

NT 3295 6757

Another masonry arch of about 50 ft span was built over the North Esk for the Dalkeith Turnpike Trust under a contract made in 1765 with Alexander Stevens. The bridge was widened in 1816–17 under Robert Stevenson's direction and now forms part of the A68 road.

One of the earliest known road-making contracts in Scotland was let for the length of road including the predecessor of this bridge. In August 1751 the Trust accepted an offer to make a road 30 ft wide with an 18 ft wide carriageway, the central 12 ft of which was to consist of an 8 in. thickness of stones not exceeding the size of a man's fist with a top spreading of gravel, all at a cost of £225 per mile.

In widening the bridge, Stevenson paid particular attention to the foundations and specified that if the ground 6 ft below the river bed proved insufficiently firm the bridge was to be founded on 'a platform of beech or elm timber planks 4 in. in thickness and not less than 15 in. in breadth. If the ground should turn out too soft and porous this platform should be supported on piles of the same timber of at least 8 in. in diameter and not less than 6 ft into the ground nor more than 4 ft apart.'

About half a mile upstream, crossing the river on the main approach to Dalkeith House, is the grand Montagu Bridge with a 70 ft semicircular arch span designed by Robert and James Adam and built in ca.1793. [27]

28. Water Tower, Dalkeith

HEW 1499
NT 3274 6699

This tower was built in 1879 by the Town Council as part of an improved water supply to Dalkeith. The engineers for the project, including the tower, were Leslie & Reid, Edinburgh. The 70 ft high tower, built by James Thornburn & Sons, Dalkeith, is constructed of polychrome brickwork with stone facings and is octagonal shape in plan. It is surmounted by a wrought-iron water tank 16 ft diameter and 18 ft deep made by Hanna, Donald and Wilson located within a timber-slatted top storey. In the 1930s the tower became obsolete owing to further improvements in Dalkeith's water supply.

In 1989 the tower was converted to a domestic residence. [29]

Ronald Birse

Water tower at Dalkeith

29. Melville Castle Bridge, Dalkeith

NT 3077 6672

Two early cast-iron bridges spanned the Esk in the grounds of Melville Castle, formerly a country seat of the first Viscount Melville. The castle, now a hotel, was built in 1786.

The larger of the two bridges fronts Esk Cottage and has an arched span of 52 ft 8 in. and a width of 10 ft 8 in. Its construction is of four cast-iron ribs 18 in. deep with narrow flanges, braced at intervals and carrying a timber deck. The plain vertical-member handrails have small ornamental cast-iron urns at mid-span and the abutments. The bridge, which may date from ca.1840, is in good repair and carries light vehicles.

The second bridge, recently removed, was half a mile downstream from the first and of trussed girder construction spanning 54 ft between sandstone masonry abutments. Its width was 6 ft with a timber deck carried on three slightly arched T-section ribs carrying a timber deck. The rib ends were connected by iron tie-rods $1\frac{1}{2}$ in. in diameter with three small strut spacers supporting the T-sections. A curious feature was the sockets for the handrailing cast integral with the T-section beams top flange. This bridge probably resulted from John Neil's estimate to 'furnish and fit up' for £128 including scaffolding. Wm. Paterson offered to do the abutment mason work for £42 6s $6\frac{1}{2}$d. This design, presumably by Robert Stevenson, was a small scale development of his underspanned tension rod suspension bridge proposed for Cramond in 1820. [30]

Melville Castle footbridge

Roland Paxton

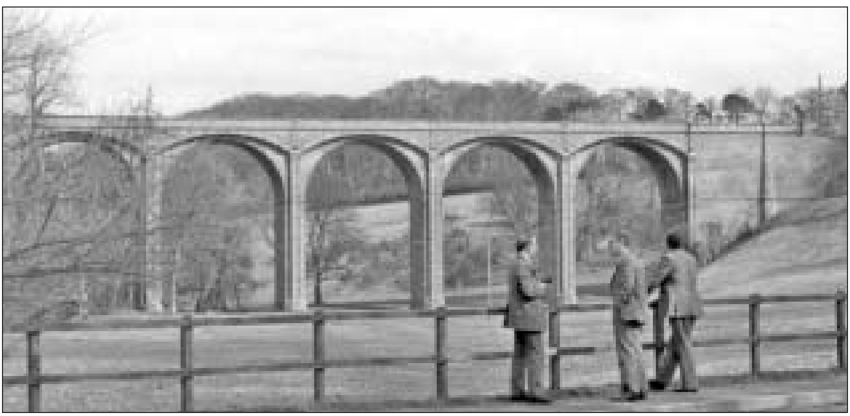
30. Pathhead Bridge

HEW 0892/01
NT 3910 6452

This striking sandstone masonry bridge, crossing about 90 ft above the Tyne Water at the north end of Pathhead, was designed by Telford as part of the Edinburgh to Morpeth road improvement, now the A68. It has five semi-circular masonry arches, each of 50 ft span and was built by James Lees from 1829–31 at a cost of about £8500. The footpaths are partly carried on shallower arches carried 2 ft forward of the main spans but bonded to them. This 'ascititious' or 'external' arch and pier pilaster feature, as Telford called it, was intended to make the bridge look more slender. It is not altogether successful as the eye tends to move restlessly between the two arches affecting the harmony of the elevation. His adoption of this feature at Dean Bridge, Edinburgh, where the external arches extend 5 ft forward of the main spans, is much more effective in producing a slenderness effect.

Problems were encountered in founding the bridge. 'An iron rod was driven 56 ft without impediment so piling became out of the question. Telford, Jardine & other persons of science and skill were consulted and in conformity with their directions, the piers were founded upon platforms composed of double tiers of memel logs and of three tiers of stones from Craigleith quarry. This has occasioned an extra expense of about £2000 and it was unexpected as the ground had been bored', but what was thought to be bedrock 13 ft below the surface turned out to be 'large round stones'. [31]

Pathhead Bridge



Roland Paxton

31. Dean Burn Tunnel, Falla

HEW 0892/02
NT 4496 5971

The Dean Burn passes under the A68 about $1\frac{1}{4}$ miles south-east of Falla, Midlothian, in a tunnel constructed of free-stone masonry, possibly from Craigleith Quarry.

The tunnel was designed by Telford as part of a straightening improvement on the Edinburgh to Morpeth road and built in 1827–29. It is 14 ft high from the invert to the crown of the arch, 20 ft wide and 133 ft long. The arch vousoirs are 2 ft deep. There is also a similar tunnel at Falla. The road improvement was opened on 23 December 1829.

The contractor was Archibald Logan until his firm went into liquidation in December 1828, subsequently Fox & Lowrie. The tunnel was strengthened in the 1950s by a framing of reinforced concrete between the springings of the arched roof. [31]

32. Firth Viaduct, Auchendinny

NT 2582 6161

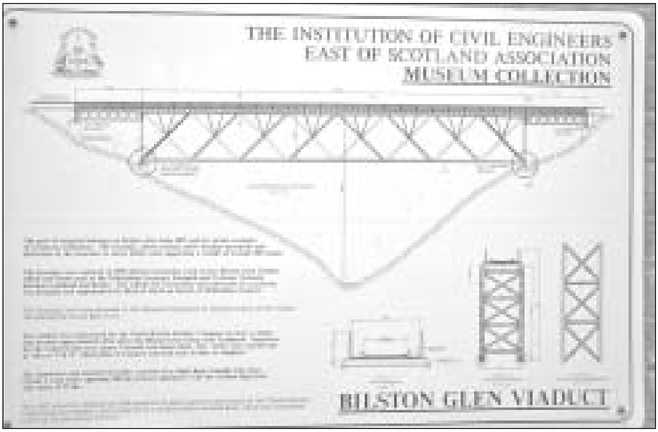
This ten-arch masonry viaduct crossing the Esk on a curve at a height of 66 ft was built in 1872 by the North British Railway on its Penicuik Branch. The arches are all of 35 ft span and semicircular with brick arch-rings similar to those introduced by Miller 25 years earlier.

A curious feature of the viaduct is that the three piers in the river are on the skew, lining in with the direction of flow. This means that there are two skew spans over the river; two hybrid half-skew and half-square spans; and, all others, square spans. The hybrid spans are of unusual arch-ring brick construction in that one elevation of the arch is longer than the corresponding elevation on the other side because of the arch geometry. The viaduct was designed by the company's consulting engineer, Thomas Bouch.

33. Bilston Glen Viaduct, Loanhead

NT 2807 6486

This single track, 15 ft wide viaduct crossing Bilston Burn at a height of 140 ft was erected on the Edinburgh, Loanhead & Roslin branch line worked by the North British Railway. The first viaduct at the site, with six wrought-iron lattice truss spans, was erected in 1872–73 under the direction of



Bilston Glen Viaduct plaque

Roland Paxton

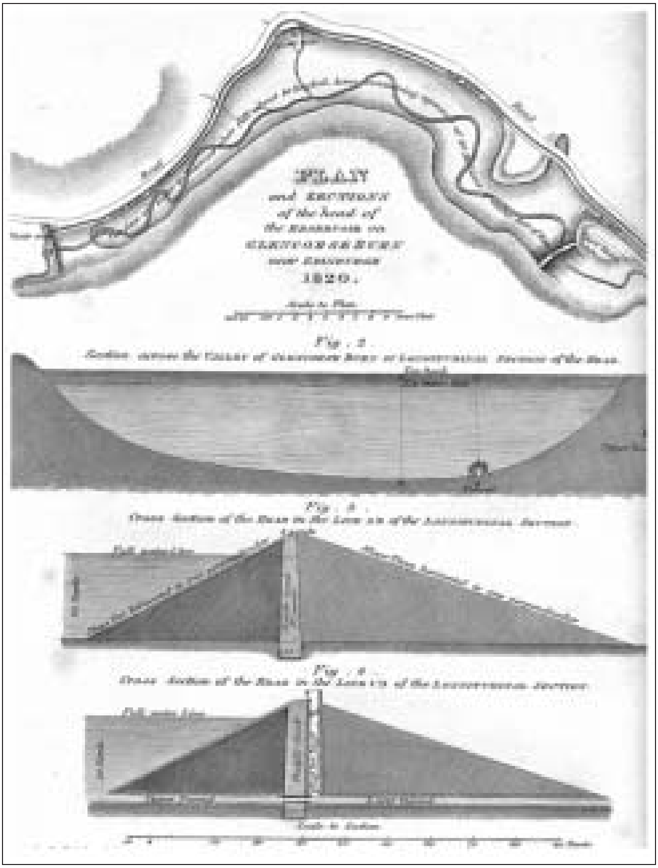
Bouch, its designer. It was decided, perhaps from coal working considerations, to reduce the number of intermediate supports from five to two. This was achieved in 1892 using the old bridge as falsework to erect three girder spans, the centre one of which is a massive 330 ft in length and 42 ft deep, with side spans of 60 ft. Both elevations are shown on the drawing. The Company engineers were James Carswell and James Bell. The bridge was made and erected by P. & W. MacLellan, Glasgow.

The viaduct was tastefully refurbished in 1999 for pedestrian use at a cost of about £1.5M by the Edinburgh Green Belt Trust and a set of its original sliding and rocker bearings, which cost £147 000 to replace, are now interpreted at the bridge, and on Heriot-Watt University campus as part of the ICE Museum. [32]

34. Glencorse Dam

HEW 0133
NT 2215 6353

Glencorse Dam retains the 50-acre Glencorse Reservoir which forms part of the water supply system to Edinburgh. It is located in the Pentland Hills about six miles south-west of the city and was built between 1820–24 to provide compensation water to mill owners for the water taken from Crawley Spring and Glencorse Burn to supply the city. The project was designed by Jardine, the Water Company's engineer, with Telford acting as consulting engineer for the Company's interest and Rennie for the mill owners.



Glencorse Dam – plan and section [33]

The earth dam, when built one of the tallest in Britain, is 330 ft long, 450 ft thick at the base, and about 110 ft high measured from rock level in the bottom of the cut-off trench some 50 ft below the bed of the burn. The illustration is based on Jardine's 1819 specification before work started. There is an oval-section ashlar masonry tunnel carried through the embankment with cast-iron valve-work under a shaft to the top of the dam.

Reaching an impervious bottom for the clay puddle cut-off wall proved a great problem which nearly resulted in abandonment of the dam; 10 000 cu yards of puddle clay being required to effect a seal.

Crawley Cistern, a distinctive masonry building 60 ft long with a stone-slab roof surmounting a semicircular

Glencorse Dam – draw down and scour valves in lower tunnel

Roland Paxton

vault springing from 3 ft above floor level containing the 45 × 15 ft open-topped masonry cistern, was designed by W. H. Playfair under Jardine's direction. The tank is at the head of a nine-mile cast-iron aqueduct, with a maximum diameter of 20 in., passing via Liberton and under Castle Hill to Hanover Street in the New Town on a plinth in a 6 ft × 5 ft wide tunnel.

The pipes were supplied by the Butterley Company and each was proved by subjecting it to a pressure equal to that of a column of water from 300 to 800 ft high. The whole works cost £145 000 and were dubbed by *The Scotsman* in 1825, 'the most extensive, perfect and complete ever executed in modern times'. [33–35]

Edinburgh

35. Early Concrete Road (High School Yards)

HEW 0532
NT 2615 7348

The use of concrete in road construction in Scotland was pioneered by Joseph Mitchell with a section of concrete carriageway on George IV Bridge laid from 1866 to 1870 which proved successful.

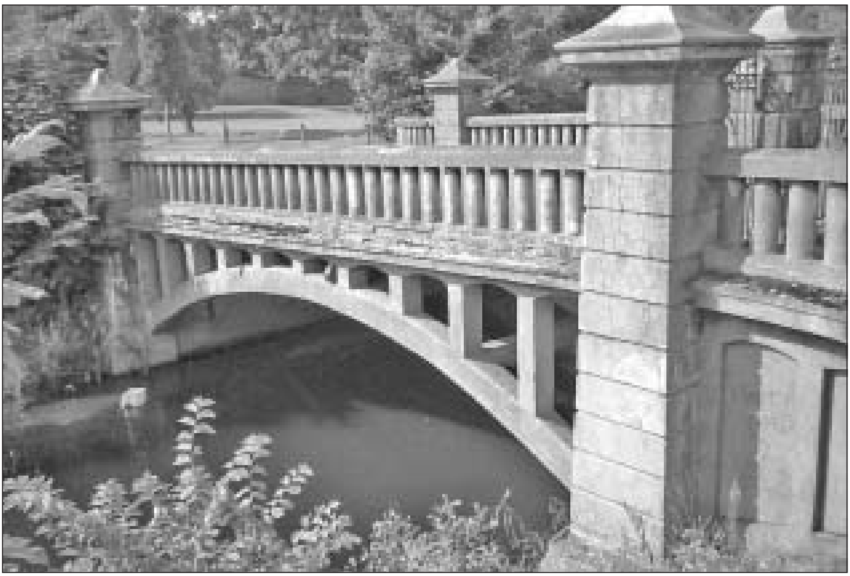
From ca.1873 to 1910 concrete carriageways totalling 5.5 miles were laid in over 100 Edinburgh and Leith streets under the direction of David Proudfoot, City Road Surveyor. Some are still in service but are now covered over. They consisted of a rolled stone bottoming on which a 4½ in. thick layer of 1½ in. whin road metal was uniformly spread and then grouted with a mixture of fine gravel riddled out of Fisher Row gravel and Robin & Co's best Portland Cement. Their cost was about 40% of a road laid with granite setts. Maintenance costs were low, Blackwood Crescent, for example, involved a total expenditure of only £40.00 from 1873 until 1920.

At High School Yards the original concrete surface was still visible until recently. [36]

36. Gorgie Road, Park Access Bridge

NT 2225 7186

This structure is a good example of a Mouchel-Hennebique ferro-concrete bridge and probably the earliest surviving in Scotland. It gives access to Saughton Park site of the exhibition of 1907 for which it was erected. It crosses the Water of Leith from Gorgie Road with a span of 30 ft and was erected in 1907 under the direction of George



Gorgie Road, Park Access Bridge

Roland Paxton

Morham, City Architect. Apart from some spalling of the cover reinforcement the bridge is surviving well.

About a half mile upstream of Saughton was the three-span masonry arch bridge cited by Smiles and Boucher as Rennie's first, built in 1784, but in fact designed by Alexander Stevens in 1783. Rennie, based at East Linton at the time, was probably aware of the project. [37]

37. Leamington Lift Bridge

NT 2445 7269

This is the only surviving example of an electrical lifting bridge on the Union Canal. It was designed by Sir W. G. Armstrong Whitworth of Newcastle for the canal owners, the North British Railway, and installed in ca.1906, not at this site but at Fountainbridge as a replacement for a lift bridge of 1869. This was the next road crossing to the north, just before the terminal basins of Port Hamilton and Port Hopetoun. Because of the decline in canal traffic, these basins were closed and filled in by 1922 and, as the canal then ended south of Fountainbridge, the bridge was dismantled in November 1922 and later re-erected at its present site.

Leamington Lift Bridge

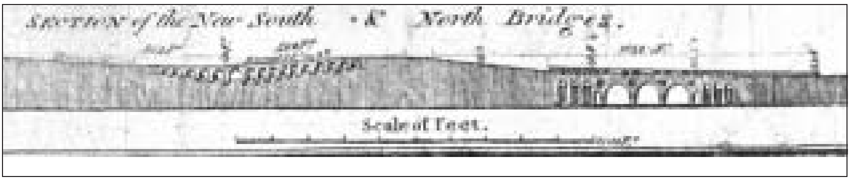
Twin portals of riveted steel box sections support the lifting mechanism and deck during operation, house the motors and keep the deck in position as it is raised and lowered. The navigational headroom is 9 ft.

The bridge, after finally ceasing to operate in the 1960s, was refurbished as part of the Millennium Link Project and has been in regular use since its re-opening on 22 March 2005. It is the first bridge west of the new terminal facility at Lochrin Basin.

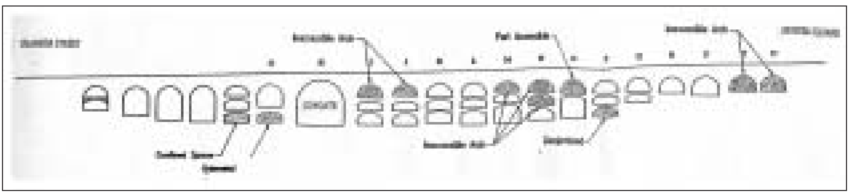
38. South Bridge

HEW 2471
NT 2598 7349

A development-led project designed by Robert Adam for the Town Council in ca.1785, eventually involving 20 arches, with adjoining high-quality buildings structurally independent of the bridge designed and built by Alexander Laing, architect and mason, from 1786–88. The bridge is built of masonry with semicircular arches, and vaults beneath most adjoining each storey, which are hidden except for the tallest crossing the Cowgate at about 31 ft which is also the widest at about 30 ft, most being about 18 ft. A section of 1790 from the *Universal Scots Almanack* and a modern drawing gives an idea of the project and the original North Bridge.



Section along North and South Bridges 1790 — *Universal Scots Almanack Plan* 1790



Section along South Bridge from Chambers Street (left) to Hunter Square 2000

Halcrow Group Ltd

39. North Bridge

NT 2589 7384

This bridge, also originally development-led, linked the Old and New Towns of Edinburgh over the Nor' Loch valley, partially drained by ca.1763, over ground now occupied by Waverley Station.

The foundation stone for the first bridge was laid in October 1763 by Lord Provost George Drummond, but no further work was done until after a design competition in 1765. This was won by David Henderson, but his design was not implemented and the bridge as built was designed by William Mylne. It had three main masonry arch spans of 72 ft about 68 ft high adjoined on each side by a small abutment arch, three tall rubble vaults, and tall abutments reducing in height beyond. The contract was signed in August 1765 for the sum of £10 140.

The bridge was opened to pedestrians in early 1769, but soon after, a vault and side wall at the south side collapsed resulting in five deaths. This seems to have arisen mainly from an error in levels which had led to the vault arches being too low and requiring a great depth of infill to reach road level, the pressure from which caused the collapse. Smeaton was called in to remedy matters and on his advice substantial internal cavitation was incorporated into the superstructure to lighten it. The bridge was eventually completed in 1772 at a cost of about £17 354.

North Bridge and Waverley Station roof

Roland Paxton

From 1894–97 this bridge was replaced by the present 561 ft long, three-span steel segmental arch bridge with 175 ft spans comprising 1935 tons of steel. Each span is supported on six 4 ft deep 'I' section plate girder ribs, with outer façades of cast-iron to a traditional elevation. The width of the bridge is 75 ft, nearly double that of its predecessor. The foundation stone 'containing the usual tokens' was laid on top of the north pier with full Masonic honours on 25 May 1896. The bridge is a fine early example of steel-arch construction in Britain.

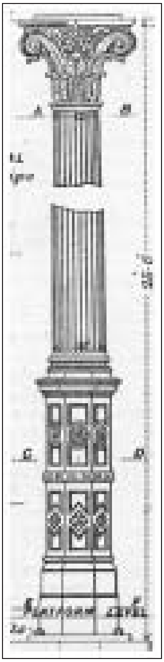
The engineers were Cunningham, Blyth & Westland, Edinburgh, the contractor was Sir William Arrol & Co., and the mason work subcontractors Wm. Beattie & Sons. The contract price was about £90 000. [38–40, 47]

40. Waverley Station

NT 2579 7385

The original station here was planned by Miller and became operational in 1846. It was rationalised to the

Waverley Station booking hall 1900 [41]



design of Charles Jopp by North British Railway engineer James Bell from 1866–74 creating the present basic east–west platforms. In the late 1890s the station underwent major re-design, to basically as now (2006), by Blyth and Westland, engineers.

Notable features include the two-storey central block and booking hall (now demolished), about 225 ft long by 160 ft wide, designed by Raithby, the firm's staff architect, $11\frac{1}{2}$ acres of ridge and valley roof, the entry and exit ramps from Waverley Bridge with their distinctive cast-iron façades, the parcels office, four footbridges, including the one from Market Street to the steps to Princes Street. The roof is carried on steel lattice girders up to 149 ft long, on cast-iron columns, with fluted shafts and highly ornamented capitals and octagonal bases, cast on end by the Widnes Foundry Co.

The walls and booking office block were built by G. & R. Cousin. The steelwork was by Arrol's Bridge & Roof Co. Ltd. The resident engineers were J. T. Harrison (roof) and J. S. Pirie (whole works). [41]

41. George IV Bridge

NT 2566 7343

Above: Waverley Station – cast-iron columns [41]

Another development-led bridge project similar to that already described for South Bridge, also over the Cowgate valley, but stemming from the 1827 Edinburgh Improvement Act. Thomas Hamilton, as architect to the Improvement Commissioners, designed the development to provide a broad picturesque 'Southern Approach' to the Old Town. The foundation stone was laid in August 1827 and the bridge was to take nine years to complete.

The ten spans vary from 29 ft to 34 ft and are constructed of masonry with semicircular arches which are mainly hidden except for those over the Cowgate and Merchant Street.

The Cowgate passes about 50 ft below the roadway of the bridge and its arch is the tallest with about 36 ft headroom. It has three open groined arches supported on octagonal pillars, the timber centring for which was being set up in March 1831. The contractor for the bridge was George Lorimer and the contract sum £17 950. Work was well under way in 1831 and the bridge was passable in 1834 although the alignment from the bridge to High Street had not been settled.

The project encountered financial and management problems which caused delay and difficulties, particularly between Hamilton and Jardine, who investigated the accuracy of Hamilton's statements and estimates for a town committee. Hamilton resigned in 1834. George Smith took over as architect and the bridge was completed on its present line to the High Street opposite The Mound by 1836, with the support of Jardine and Grainger against the opinions of others including William Cubitt who preferred a more westerly line involving demolition of the old Midlothian Council building. The new approach considerably improved the accessibility of the city centre to and from the south. (42)

42. Royal Museum of Scotland, Chambers Street

NT 2582 7329

In 1859–60, as architect of the Science and Art Department of the Government and after having acted as engineer and architect of the South Kensington Museum, Capt. Francis Fowke, RE, designed the new Industrial Museum of Scotland at Chambers Street, the first stone of which was laid by the Prince Consort in October 1861. Its design is reminiscent of the Great Exhibition Building of 1851.

Roland Paxton

Royal Museum of Scotland – main hall

The east wing and the eastern part of the main hall were opened to the public as the Edinburgh Museum of Science and Art by the Duke of Edinburgh in 1866, the remainder not being completed until 1875. A particularly attractive feature is the main hall, about 60 ft high. Its overarching roof is not made of iron as is sometimes thought, but of timber, supported on ornamental cast-iron columns. [43]

43. Castlehill Reservoir

NT 2539 7354

This apparently single-storey ashlar masonry covered reservoir near the head of The Royal Mile was built in 1849–50 for the purpose of storing 1.65 m gallons of water for the supply of the upper end of the Old Town and is not what it seems from its exterior.

Much of the reservoir building is below ground, with retaining walls of ashlar masonry about 10 ft thick at the base tapering to 6 ft at the top founded on rock, creating a reservoir more than 100 ft square and about 25 ft deep. The timber-truss roof is supported on the outer walls and by 24 slender hollow cast-iron columns 9 in. in diameter sited within the reservoir. The building was designed and

T. H. Shepherd drawing, *Modern Athens!* 1829

Grassmarket Well ca.1820

built under the direction of James Leslie, engineer to the Edinburgh Water Company.

In 1991 the reservoir was no longer required and is now tastefully conserved as the Edinburgh Tartan Weaving Shop from a visit to which its original purpose and construction can still be appreciated.

This reservoir replaced a smaller cistern, 43 ft × 28 ft × 6 ft, from one of Scotland's earliest piped water supply schemes by which a supply of 'sweet' water was obtained for the town by means of gravity through a 3 in. diameter cast-lead pipe from Comiston springs at Tod's Well on the Pentland Hills three miles to the south. The elevation of this well is indicated at Castlehill by the cannonball in the wall of Cannonball House.

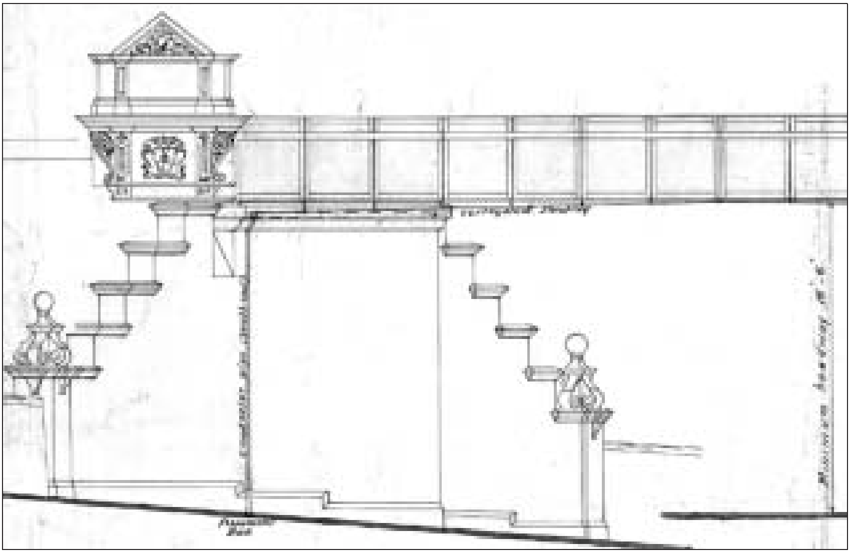
From either this or a smaller Castlehill cistern at the same site, water was introduced by gravity to five stone wells on the High Street in 1681, and later to lower wells, including the one which still exists in the Grassmarket. From these wells women 'caddies' drew the water for households. The engineer for this great public health improvement was George Sinclair, a former professor of philosophy and mathematics at the University of Glasgow. The system was improved later by J. T. Desaguiliers who directed the laying of a $4\frac{1}{2}$ in. diameter lead main from Comiston with 13 air valves and four cleansing cocks in ca.1720. [44, 45]

44. Murrayfield Bridge (Railway)

NT 2315 7318

This single-span structure crossing the A8 road at West Coates is a distinctively decorated iron railway bridge dating from 1861 when the Caledonian Railway opened the branch line from Slateford to West Granton harbour. The span of 61 ft on a slight skew consists of three plate girders of which the centre one is hogbacked. The intricate handrails carry the Caledonian Railway crest in a central panel.

The bridge, which also exhibits ornamental decoration in its abutments, was refurbished in 1991, its ironwork being painted in black, Caledonian Railway blue, green and gold, reminiscent of the bridge practice of a once great company. The line, which was closed in 1962, is now conserved as part of a pedestrian and cycle path.



Murrayfield Bridge (Railway) [old tracing]

The Caledonian Railway's main line into Edinburgh, terminating at the east end of Princes Street in 1848, was closed in the 1960s and redeveloped as the West Approach Road in 1972, which conserved some of the company's other historic retaining walls and bridges, for example, Grove Street plate-girder bridge (NT 2439 7310). The fine viaduct at Slateford (NT 2200 7078) with its 14 masonry arches of 30 ft span designed by Locke & Errington and completed in 1848 is still operational.

45. Regent Arch

NT 2596 7404

Another development-led improvement in the tradition of the North and South Bridges created the picturesque eastern approach to Edinburgh by the Regent Road and Calton Hill, planned by Robert Stevenson and leading architects Playfair, Hamilton and Elliot.

A key element of the Regent Road approach to Princes Street was the Regent Arch, semicircular masonry arch of 50 ft span built from 1815–19 carrying Waterloo Place over Lower Calton Street. It was designed by Stevenson as part of the Waterloo Place building development for which Elliot was the architect.

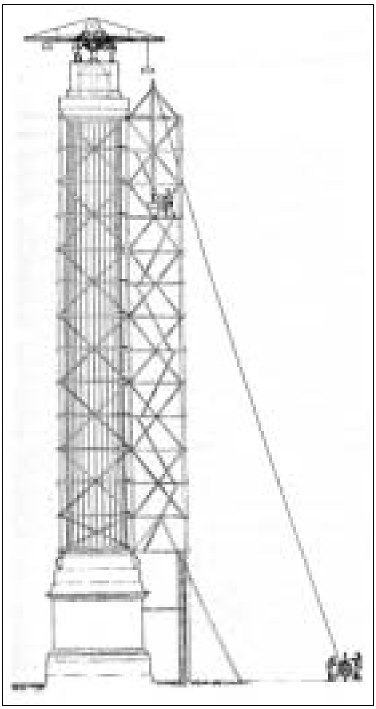
The parapets are ornamented and in the centre are raised to a height of 20 ft above the footway by masonry columns and lintel beams to form a triumphal arch. Stevenson wished to use the term 'Engineer' in the foundation stone inscription but, as an appropriate word could not be found in classical Latin, he had to be satisfied to be styled as 'Architect'.

In front of the Royal High School this road improvement included an immense retaining wall with rustic stonework facing to look like outcropping rock designed and implemented under Stevenson's direction. This can still be seen from the steep footpath leading down to Calton Road. [46, 47]

46. Melville Monument

NT 2559 7410

This fine monument adorning the garden at St Andrew Square, Edinburgh, was erected to the memory of Henry Dundas, Lord Melville (1742–1811), First Lord of the



Melville Monument under erection using balance crane 1821 [48]

Admiralty under Pitt. It was designed by William Burn and modelled on Trajan's Column, Rome. Robert Stevenson, as consulting engineer, finalised the foundations, column dimensions and superintended the erection.

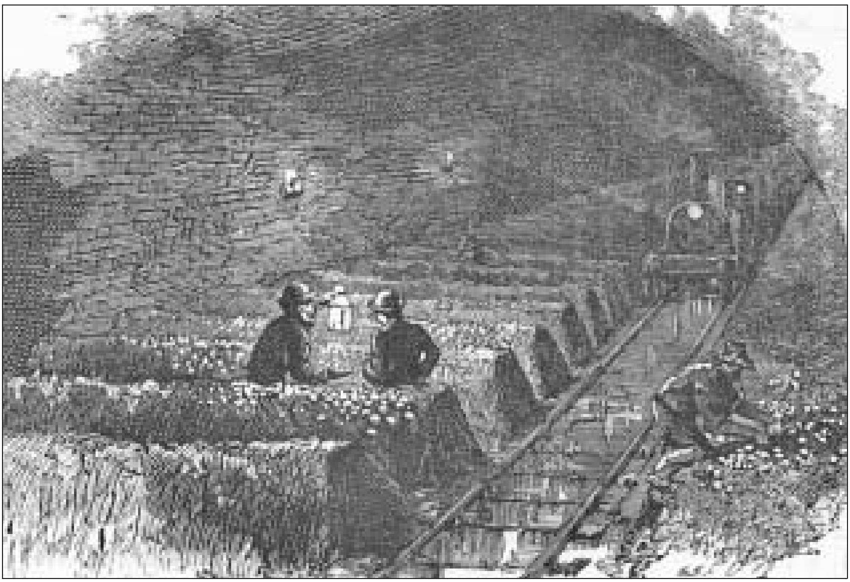
The column, built of Cullalo stone, is 152 ft high and about 1500 tons in weight. It was erected in 1821 using an iron balance crane of the type used by Stevenson at the Bell Rock Lighthouse. The 15 ft high statue of Melville on top by Robert Forrest was added in 1827. It comprises 15 pieces weighing 18 tons riveted together by gunmetal bolts. [48, 49]

47. Scotland Street Tunnel

HEW 1264
NT 2546 7482
(North portal)

This tunnel built from 1844–47 on the main railway north, the Edinburgh, Leith & Granton Railway (from 1847 the Edinburgh, Perth & Dundee), was used for only two decades before being closed on 22 May 1868. It is 3210 ft long on a gradient of 1 in 27, built mainly in brickwork, and is 26 ft wide with an elliptical arched roof 18 ft high in the centre.

In-bound trains were hauled up the incline through the tunnel to the company's Canal Street terminus at Waverley



Scotland Street Tunnel – mushroom cultivation [51]

Bridge Station by means of a stationary steam-operated winding engine – a system that was inconvenient and expensive to operate and was closed down six years after being acquired by the North British Railway.

The tunnel was designed by Grainger, with George Buchanan superintending the works for the City's interest. The resident engineer, who devised ingenious temporary works and prepared a longitudinal section showing the strata, was William Paterson. The contractors were Ross & Mitchell.

For about 20 years after its closure, until the 1920s, the tunnel was used for growing mushrooms on both sides of one line of track on which a North British locomotive operated. Almost the full length of tunnel was used and there were three miles of mushroom beds consisting of 3000 tons of soil and manure. Mushrooms that had been growing in the tunnel three hours earlier were delivered to Glasgow by 10 am daily. [50, 51]

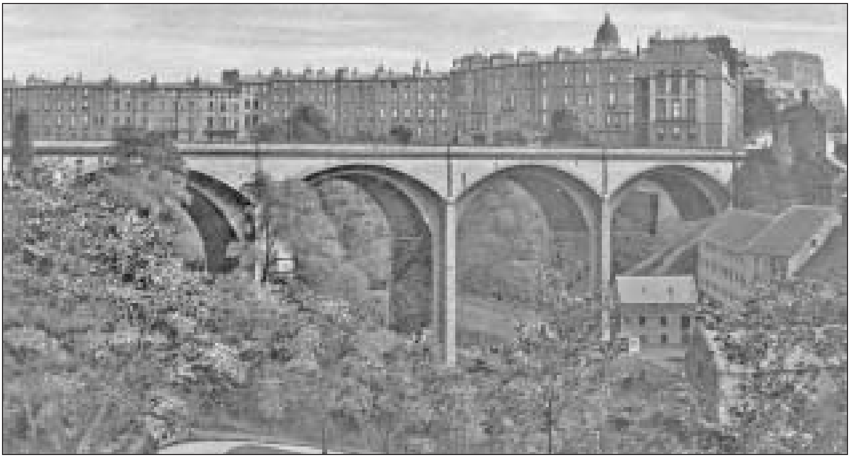
48. Dean Bridge

HEW 0130
NT 2427 7400

This was another building development-led project, in this case to facilitate the extension of the New Town across the Water of Leith. This led to the creation of the last major bridge to be completed by Telford before his death. Constructed from 1829–32, it is perhaps the most majestic of all his masonry bridges, standing 106 ft above the river bed. He originally intended it as a three-span Gothic style design but, perhaps fortunately for modern taste, foundation conditions and financial constraints resulted in the plain lines of the present bridge of four spans.

The bridge is 447 ft long and has four main segmental arches of 90 ft span and 30 ft rise carrying the carriageway. Alongside them, carrying the footpaths, are ascititious or external arches of 96 ft span and 10 ft rise springing from pilasters only 5 ft wide, the formation of which was a particularly delicate and unprecedented operation. As can be seen from the view, this feature gives the elevation an appearance of slenderness which seems almost incredible for a masonry bridge.

The carriageway is 23 ft wide and the footways 8 ft. The bridge is of hollow spandrel construction with tie-stones between the longitudinal walls. In 1972, under the writer's



Dean Bridge [postcard ca.1910]

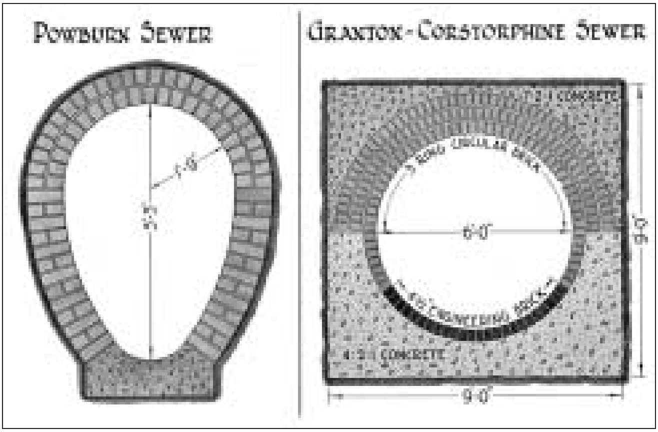
direction, the 5 ft depth of fill above the main arch was investigated and it was found that a layer of broken freestone had been substituted, probably at the outset, for Telford's traditional hand-pitched stone pavement, overlain with a 4 in. clay layer and 6 in. of weak lime concrete to prevent water penetration. Above this was mainly whinstone Macadam.

The contractor was John Gibb of Aberdeen and the cost was £18 556 exclusive of the approach roads. He is reputed to have finished the bridge ahead of time, but declined to hand it over to his building speculator client John Learmonth and the Cramond District Road Trust. Instead he is said to have opened the bridge and charged a toll until the completion date! Since then the bridge has required minimal maintenance and it now carries several million vehicles each year without any weight restriction. [52, 53]

49. Water of Leith Sewers

HEW 2479
NT 2420 7404
(Manhole)

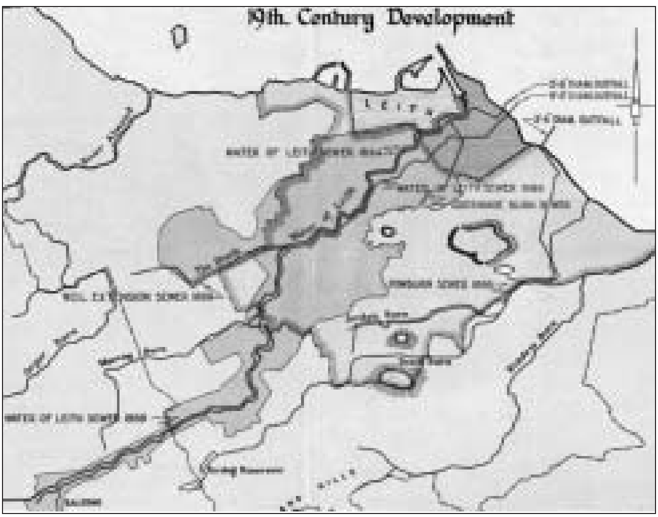
The sanitation of north and west Edinburgh left much to be desired until the Water of Leith Sewers (manholes can be seen in the valley bottom near Dean Bridge) were laid in 1864 and 1889. Their outfalls of 3 ft 6 in. and 5 ft diameter pass the untreated sewage into the Forth. It was not until the mid-1970s that its first major sewage treatment plant at Seafield was completed costing about £20m. It involved the construction of an 11-mile interceptor sewer



Powburn Sewer and Granton–Corstorphine Sewer [54]

up to 10 ft diameter and a $1\frac{3}{4}$ mile 12 ft diameter effluent outfall.

The earliest report was in 1853 but it was not until 1863 that the parliamentary plans for the Edinburgh and Leith Sewerage Act were completed and approved. The 1864 sewer, into which many of the earlier 19th century sewers were connected, while a considerable improvement, extended only as far inland as Roseburn. The engineers were D. & T. Stevenson.



Water of Leith Sewers map [54]

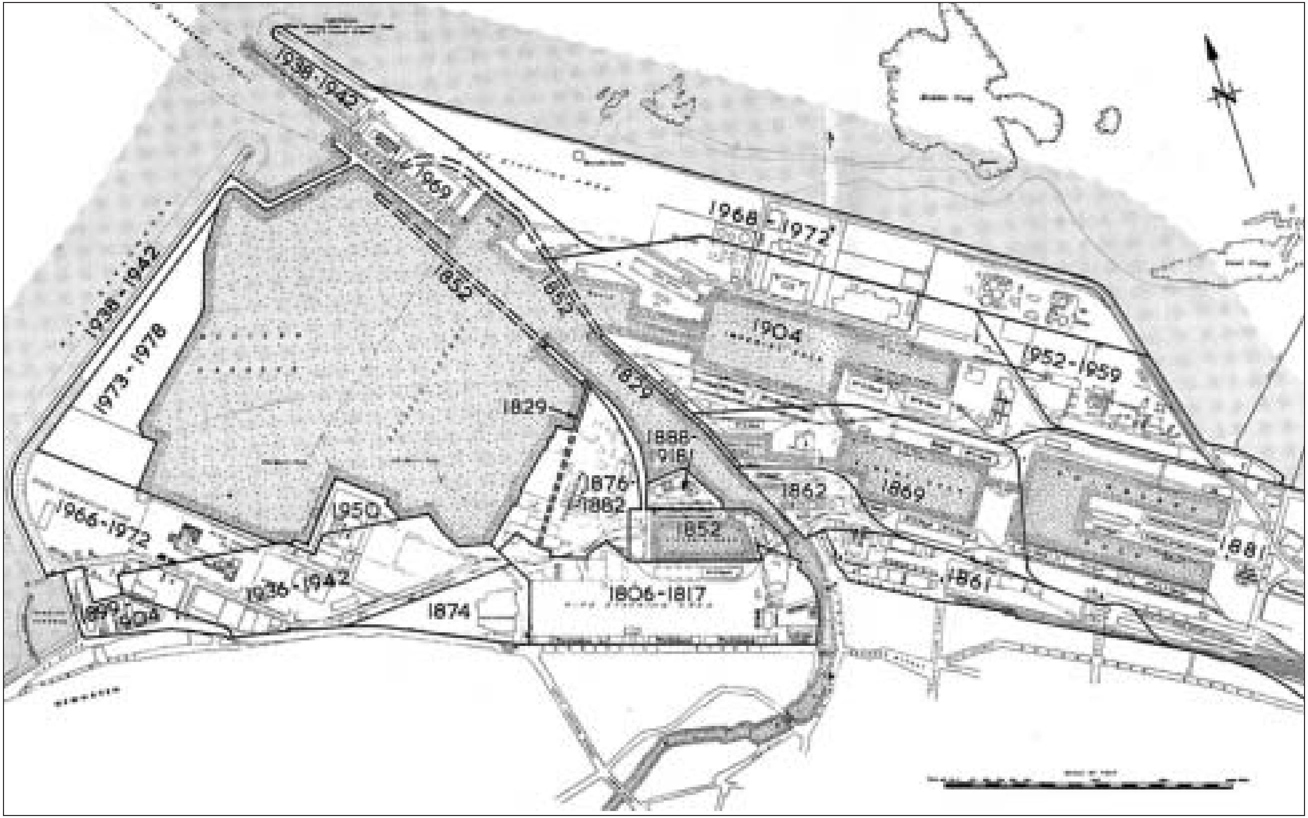
In 1889, in order to make an effective purification scheme for the whole river, the second, deeper sewer was constructed extending inland to Balerno. The local authority engineers were J. Cooper for Edinburgh and W. Beatson, Leith. The consulting engineers were D. & T. Stevenson and Leslie & Reid (in connection with Threipmuir and Harperrig reservoirs). Both sewers, where of 2 ft or more in diameter, were constructed in engineering brick with an extensive use of the egg-shaped, self-cleansing, cross-section. This form of cross-section was still in use in 1929 as can be seen from the illustration of the new Powburn Sewer. A circular section was adopted for the Granton–Corstorphine Sewer of 1929–32. [54]

50. Leith Docks

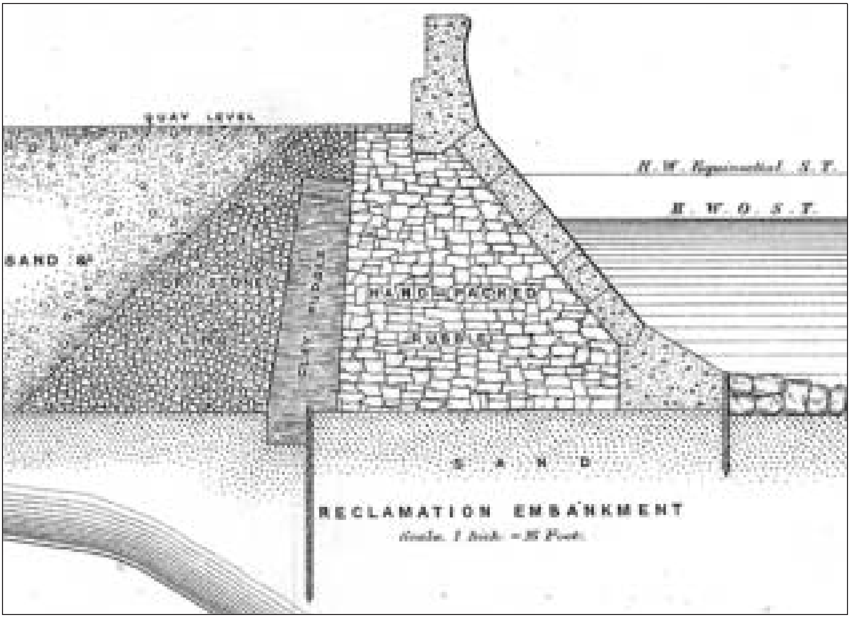
HEW 0080
NT 2691 7736

Leith, the port of Edinburgh, is one of the oldest seaports in the United Kingdom and, from the time of a recorded mention in ca.1329, for nearly 500 years, consisted of quays adjoining the Water of Leith. From the beginning of the 19th century the port developed as a system of enclosed docks, as follows:

Dock name	Date	Length and breadth (ft)	Depth on sill (ft)	Entrance width (ft)	Engineer	Approx. cost (£)
East	1800–06	750 × 300	13 MHWN	36	J. Rennie	300 000
West	1810–17	750 × 300	13 MHWN	36	J. Rennie	
Victoria	1846–52	750 × 300	20	60	J. Rendel	180 000
Prince of Wales (dry)	1859	382 × 70	Disused for many years			60 000
Albert	1862–69	1100 × 450	22	60	J. Rendel & G. Robertson	350 000
Edinburgh	1874–81	1500 × 650	22	60	A. M. Rendel & G. Robertson	500 000
Edinburgh (dry)	1881	300 × 40			A. M. Rendel &	Not known
Alexandra (dry)	1896	335 × 48			G. Robertson	
Imperial	1897–1904	1900 × 550	27	70	P. Whyte Leith Docks	700 000



Leith Docks plan – chronological development 1800–1980 [55]



Leith Docks – reclamation embankment [56]

From 1826–29 the eastern pier followed by the western pier and breakwater were built immediately north of the East and West Docks to the design and under the direction of William Chapman, with a timber deck above a rubble-work for the former (see cross-section 3-51), at a cost of about £240 000. James Leslie acted as clerk of works. Telford was brought in as costs escalated and reported in 1828 that the order of expenditure was not justified by the trade but his advice was ignored. In 1852 these piers were extended as part of the expansion of the port.

By 1896, as a preliminary to building the Imperial Dock, Peter Whyte had designed and directed the provision of a 30 ft high sea wall, 4400 ft long containing almost the whole harbour, of the unusual design illustrated above. Large concrete blocks were used on the sea face, the toe blocks for which are 6 ft × 6 ft × 8 ft long.

From 1936–42 the western harbour was created with the building of the east and west breakwaters and a wider pier entrance.

In 1969, the year after the Forth Ports Authority was established, the port reached its present form with the completion of the state-of-the-art new entrance lock 850 ft

Leith Docks – entrance lock under construction [57]

long and 110 ft wide which transformed the whole harbour into a deepwater port capable of accommodating ships of 35 ft draught at any high tide. The lock was constructed within an immense cofferdam 1700 ft long. A sealing dam about 1000 ft long was constructed to maintain the level of the impounded water within the harbour.

The consulting engineers were Rendel Palmer & Tritton and the main contractor was Edmund Nuttall, Sons & Co. [55–57]

51. Old Dock Entrance Lock and Swing Bridge

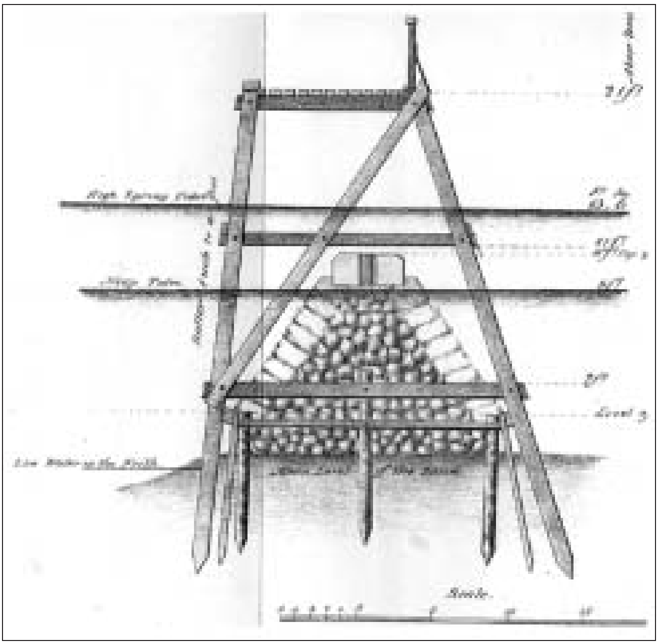
HEW 0080/02
NT 2698 7669

The impressive entrance lock of 1806 to the East and West Docks is 145 ft long by 34 ft wide and 23 ft deep and similar to the entrance from the Thames to London Docks of about the same date, also engineered by Rennie. This fine example of his practice is located at the east end of the no longer existing East Dock, joining to the old inner harbour on the river course. The timber lock gates, slightly curved in plan, and now disused were operated by a chain and winch system. The east gates probably date from an

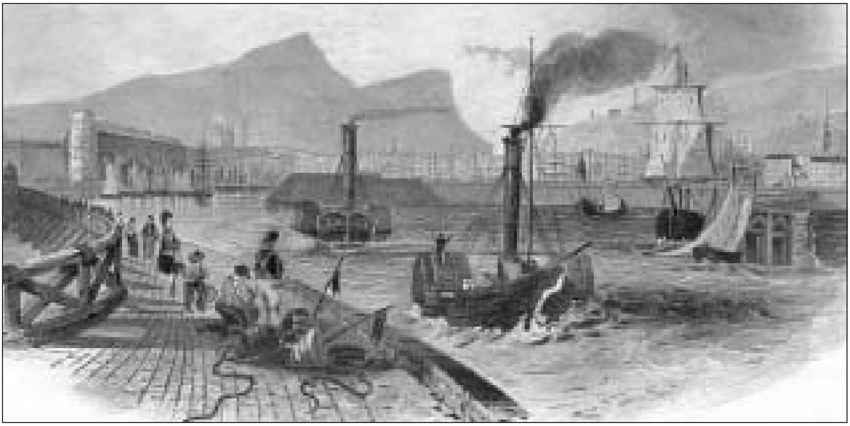
Leith Docks 1838 – entrance lock 1806 on left adjoining slips and dry dock [lithograph 1838]

improvement by James Leslie in ca.1846 and the west gates from 1922.

There have been two turn bridges at this location; the first of timber dating from 1806 and the second, the present iron structure, erected in ca.1850. This bridge is 15 ft wide in two halves giving a clear span of 35 ft 6 in. with a skew of approximately 85°. The distance between the centres of



Pier extension 1826–29 (Chapman) [lithograph ca.1826]



View of port from pier extension ca.1840 [engraving for *Bradshaw's Journal* ca.1840]

rotation is 56 ft and the overall length 87 ft 3 in. The deck is timber with wrought-iron handrails and iron cart-wheel channels.

Structurally the bridge is a three pin arch with six cast-iron ribs. It is opened by raising pivoted sections of the arch members adjacent to the springings by means of winches built into the deck; this frees the two halves of the bridge to rotate in plan. The drive mechanism is operated through capstans turning pinions which engage with racks fixed to the swing sections below road level.

The eastern pier extension of 1826–29 began on the east side of the river opposite and north of the old dock entrance. [55]

52. Victoria Swing Bridge

HEW 0080/02
NT 2708 7681

The construction of the Albert and Edinburgh Docks made it necessary to have an efficient means of communication between the east and west side of the harbour for road and railway use which led to the construction of the Victoria Swing Bridge from 1871 to 1874. Its girders, with an overall length of 212 ft and clear span of 120 ft, are made of wrought-iron and the clear roadway width is 24 ft. The gross weight is 620 tons, including 60 tons of timber and 240 tons of kentledge counterweight which was, but is no longer, lifted and easily turned by means of hydraulic rams. Its clear span is said to have been the largest of any swing bridge in the United Kingdom until the opening of

Roland Paxton

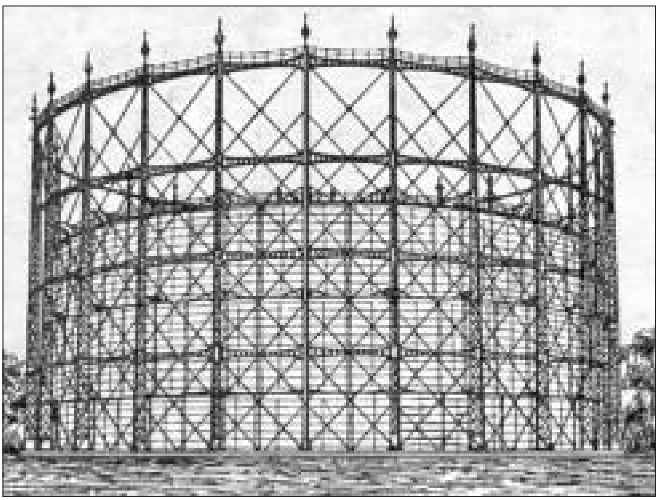
Victoria Swing Bridge

Kincardine Bridge in 1937. The engineers were Rendel and Robertson (resident engineer J. H. Bostock). The contractors for the foundations were McDonald & Grant and, for the bridge, Skerne Iron Works (late Pease, Hutchison & Co., Darlington who made the ironwork). The cost was about £30 000. [55, 58]

53. Granton Gas Holder

NT 2243 7707

This impressive structure, the most elegant gas holder in Scotland in terms of its external framing, was erected as part of a £450 000 state-of-the-art coal gasworks for Edinburgh and Leith Corporations at Granton from 1898



Granton Gas Holder [59]

Granton gasworks retort house 1903 [59]

to 1903 under the direction of their engineer, W. R. Herring. The main contractor was Graham, Morton & Co., Leeds.

The gasholder, now no longer operational, had a maximum capacity of 7 000 000 cu ft and is constructed on the telescopic principle with four lifts. The masonry tank, within which the holder moved up and down, is 252 ft 6 in. diameter by 37 ft deep. It is constructed of brick in cement mortar encased in a puddle bed and was built by Clayton, Sons & Co. Ltd, Leeds.

The associated buildings, including the huge retort house from which the gasholder was fed, have been demolished and the site, which is undergoing redevelopment, includes the new headquarters of Scottish Gas. The possibility of retaining the gas holder within the redevelopment as an outstanding example of Scotland's industrial heritage is under consideration. [59]

54. Cramond Brig

NT 1795 7546

The three-span mediaeval masonry bridge spanning the Almond dates originally from ca.1488. Only the westernmost of its original pointed arches remains, which has four ribs bridged by stone slabs. The roadway width between parapets is 13½ ft. The other two arches, destroyed

Cramond Bridge 1820 under demolition 1963

Cameron Black

by a flood in 1587, were rebuilt in 1619 as vaulted arches, also pointed. The spans are unusual, being 37 ft for the centre span and 40 ft for the two outer spans. The two upstream and the east downstream cutwaters are of one design and probably date from 1619, but the west downstream cutwater looks older and may be original. The inner face of the upstream parapet bears several dates in the 18th and 19th centuries when repairs were carried out. Its outer face bears the date 1619.

Cramond Brig appears to have been the only bridge over the Almond at this location until 1820, when increasing traffic on the Queensferry road required a new bridge. Stevenson proposed an innovative under-spanned wrought-iron suspension bridge, with the superstructure resting on the chains, but this did not find favour with the Road Trustees who in 1820 proceeded with a traditional masonry bridge. It was designed by Rennie just before his death, and had eight 50 ft span semicircular arches with six hollow spandrels.

Rennie's bridge was demolished in 1963 and replaced by the present three-span concrete bridge as an approach road improvement to the Forth Road Bridge, then nearing completion. [60–62]

55. Hawes Pier, South Queensferry

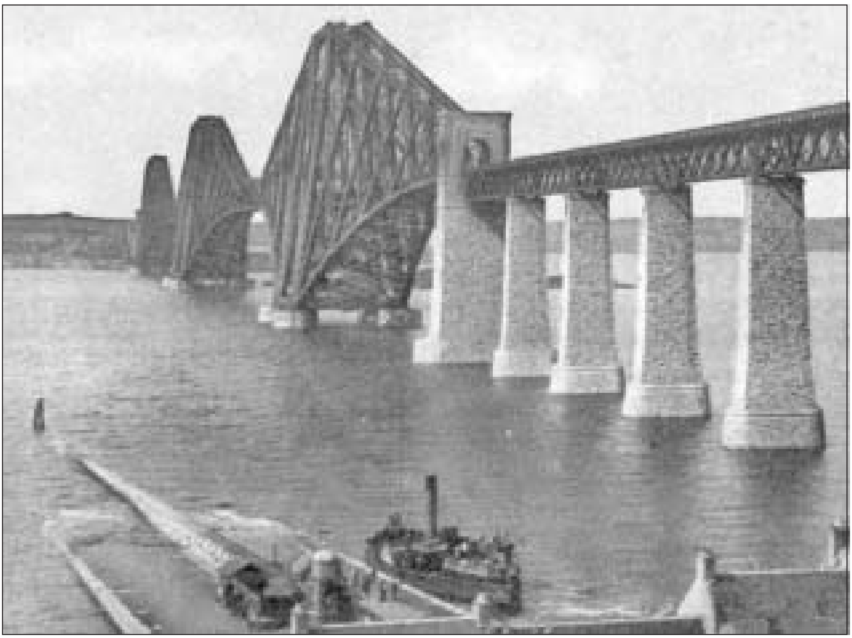
NT 1363 7849

Major improvements took place at the Queensferry landingstages in 1808–17 under Rennie's direction, before the era of steam navigation and when sailings were much at the mercy of wind and sea. These included the ramped pier at Newhalls (Hawes) which by 1812 had been enlarged to about 240 yards in length with a central breakwater flanked by paving at a cost of £8696. Nearby Longcraig Pier (1817) is also a good example of Rennie's pier work.

Robert Stevenson advised on lighting arrangements at the piers. At Hawes Pier, erected ca.1817, he recommended repositioning the signal house reflector at the pier head at 12–15 ft above high water level, presumably the small hexagonal in plan lighthouse seen in the view which still exists. The light source would have been an Argand oil lamp.

The present timber lantern is not original and looks incongruous. This historic light is worthy of restoration to its former glory with a copper lantern. The pier light at North Queenferry has been so restored. [63]

Hawes Pier and light [postcard 1910]



56. The Forth Bridge

HEW 00071
NT 1349 7950

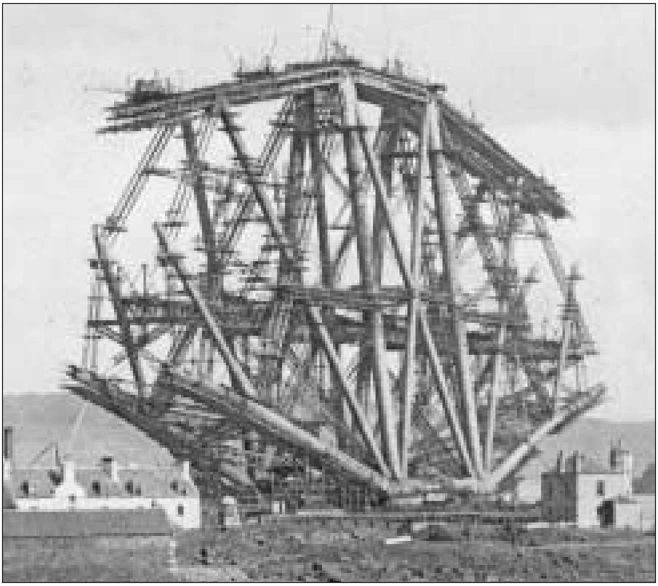
The Forth Bridge, often dubbed 'the eighth wonder of the world', carrying the east coast main line railway across the Forth at Queensferry was designed between 1880–82 in the aftermath of the Tay Bridge disaster. This event engendered a major loss of confidence in Victorian engineering, but resulted in a gigantic leap forward in bridge design and construction with the achievement of the Forth Bridge built from 1883–90.

The bridge was to provide a shorter rail route to the north in place of the time-consuming ferry crossings. In order to cross two deep channels, two main spans of 1710 ft utilising the isle of Inchgarvie were required, a daunting and unprecedented project.

Initially Thomas Bouch proposed a stiffened suspension bridge design with two spans of 1600 ft and construction began in 1878, but, following the fall of the Tay Bridge, confidence in his judgement and design waned, although it had been checked and was being implemented by William Arrol. The base of one of the brick piers of his structure still remains at Inchgarvie, now carrying a beacon.

An innovative design involving the balanced cantilever principle and the use of steel was devised by consulting

Forth Bridge – Queensferry cantilever south-east foundation under construction in 70 ft diameter caisson [photograph July 1885]



Forth Bridge – North Queensferry double cantilever under construction. With the ca.1812 signal house and pier light from the ferry improvements designed by John Rennie [Unattributed photograph July 1888]

engineers Sir John Fowler & Benjamin Baker of Westminster. The Board of Trade laid down the stringent requirement of 56 lb sq ft to be allowed for in the design for wind pressure. Extensive use was made of tubular members in compression, many of unprecedented size. The design was subjected to intense scrutiny as it developed. Wind pressures were recorded and endless tests made on the quality of the steel. Nothing was left to chance.

The contract for constructing the bridge was awarded to Tancred, Arrol & Co. William Arrol took personal charge of the operations, both at his works in Glasgow and on site, Andrew Biggart playing a key role. He showed great ingenuity in the design of plant, including hydraulic riveting machines, cranes and drilling methods, and provided many safety devices for his workers. The carefully devised design enabled the bridge to be constructed with the minimum of temporary works and staging. Much of the labour employed on the bridge was recruited from shipyards of the Clyde and Forth, and steelworkers from Lanarkshire.

The superstructure is basically three towers with cantilever arms on each side. The towers are 330 ft high above the granite pier foundations, and the cantilever arms are each 680 ft long, projecting outwards from the towers.

Sir William McAlpine Bt

Forth Bridge refurbishment – South Queensferry cantilever 2003

The ends of the cantilevers over the river are linked by suspended spans of 350 ft. Other dimensions are:

Main spans	1710 ft
South approach	ten spans of 168 ft
North approach	five spans of 168 ft
Overall length	8296 ft

About 54 160 tons of steel were used in the bridge's construction, secured by 6 500 000 rivets. At the peak of construction 4600 men were employed. For more than a century there were believed to have been 57 fatalities during construction but this number has increased into the 60s following recent research. Electric light was in its infancy, but primitive lighting was employed here for the first time on a major construction site. The final, so called, 'Golden Rivet' was ceremoniously driven by the Prince of Wales at the opening of the bridge on 4 March 1890.

The bridge is now (2007) undergoing a major long-term refurbishment. Its traditional Craig & Rose paint is being replaced by a paint regime developed in the offshore oil industry consisting, after blast cleaning to bare metal, of an application of a zinc based primer (35 microns), a glass flake epoxy paint barrier (400 microns) and a polyurethane gloss top coat (35 microns). [64–66]

57. Forth Road Bridge

HEW 0203
NT 1253 7963

A road bridge at Queensferry was first proposed in the 1920s and in 1926 the Ministry of Transport invited Messrs Mott, Hay & Anderson to prepare a design but no action was taken. In 1934–35 proposals were made for a bridge at different sites, including one half a mile upstream from the railway bridge, at Mackintosh Rock. But the war intervened and it was not until 1947 that the government gave permission for the Forth Bridge Joint Board to obtain proposals and prepare for construction. At this time the estimated cost of the bridge was £6.2 million.

Because of the depth of water at the bridge site at Mackintosh Rock, foundations in mid-channel were impracticable. A navigational headroom of 150 ft was required for access to Rosyth Dockyard. These considerations gave rise to a design for a long-span suspension bridge. The Forth Road Bridge was thus to be the first long-span suspension bridge built in Great Britain in modern times.

The construction of the bridge was to be the first use in Britain of 'cable spinning', by which small-diameter wires are laid side by side in large numbers and then bound together to form a single cable. Much of the technical expertise for this work was derived from USA practice. Wind tunnel tests on a model of the bridge showed that to restrict undesirable oscillations the bridge deck would require longitudinal vents along its full length to assist the dispersal of wind effects.

The construction of the bridge took place from 1959–64 and the bridge was opened on 4 September 1964. It was then the first in the world with a span of over 1 km not designed and built by American engineers, and the longest span bridge in Europe. The consulting engineers were Mott,

Forth Road Bridge from the Forth Bridge

Sir William McAlpine Bt

Hay & Anderson and Freeman, Fox & Partners. The main contractors were John Howard & Co. Ltd for the foundations, and the A. C. D. Bridge Co. for the superstructure. This latter firm was a combination of Sir Wm Arrol & Co. Ltd, Cleveland Bridge Engineering Co., and Dorman Long & Co.

The principal dimensions are:

Main span	3300 ft
Side spans	1340 ft
South approach viaduct	1437 ft
North approach viaduct	842 ft
Total length of bridge between abutments	8259 ft
Height of main towers above mean tide level	512 ft
Diameter of cables	2 ft
No. of wires in each cable	11 618 (dia. 0.196 in.)
Total length of wire in both cables	30 800 miles
Sag/span ratio	1:11
Navigational clearance under main span	150 ft
Carriageway width	24 ft
Cycle track width	9 ft
Footway width	6 ft
Total weight of steel in the bridge	39 000 tons [66–68]

58. Almond Valley Viaduct

HEW 1675/01
NT 1123 7218

This massive railway viaduct is the longest structure on the Edinburgh & Glasgow Railway, designed by Miller as a high-speed trunk line and constructed from 1838–42. The viaduct is in two sections, separated by a high embankment about $\frac{1}{4}$ mile in length, and was founded in September 1839 and completed in the short time of 20 months. The eastern section comprises 36 ashlar-faced masonry arches each of 50 ft span, segmental in shape, and up to 70 ft high. It crosses the Almond Valley in a wide sweeping curve of about $1\frac{1}{2}$ miles radius. Subsequently the arches have been strengthened by unsightly steel spandrel ties to the arch rings.

The western section of the viaduct is of seven arches of which the centre, and largest, bridges the Edinburgh–Bathgate road (A898). This arch is of 66 ft span and has


Crown Copyright: RCAHMS

Almond Valley Viaduct – eastern section

been badly affected by settlement caused by shale-oil workings in the past. It has been strengthened by brick cladding to the existing masonry piers, by the insertion of a steel truss under the arch and by tie-rods through the truss to the arch haunches. Other 50 ft span arches adjacent have been strengthened by brick in-filling to prevent distortion.

Although the strengthenings are unsightly, the viaduct is still serving the inter-city express line after 164 years. The contractor was leading bridge builder John Gibb of Aberdeen who completed his contract, which also included Winchburgh tunnel and cutting, at a loss of £40 000 as his estimate, on which the contract was based, contained a mistake, which, although he had discovered it before tender acceptance, he nevertheless felt bound to honour. [69, 70]

59. Winchburgh Tunnel

HEW 1675/02
NT 0906 7503

This tunnel, also designed by Miller and operational since 1842, is 367 yards long and 20 ft high. It too formed part of Gibb & Son's 9000 yards Edinburgh & Glasgow Railway Almond Valley contract, the first let on the railway in February 1839 in the sum of £147 669, and which included the heaviest work on the line.

The tunnel, which was cut through a ridge of blaes and hard whin rock, took 24 months to complete and was 'lined with brick work formed to the radii of the curves and the lime used of a uniform thickness and as little in quantity as consistent with making solid work. The bricks well burnt and in every respect sound and hard and the lime mortar used properly wrought in a Pug Mill'. Miller set out the line.

In December 1839 fire damp was encountered in cutting the tunnel and a man was severely burned. After Miller had agreed that Gibb & Son would be entitled to additional payment for making a middle shaft and a mine right through the ridge for ventilation, this seems to have been done. In digging the cuttings and tunnel, Gibb & Son removed 200 000 tons of rock more than indicated from the borings and had to work at night at 30–40% above the agreed day-work rates. The whole project proved heavier and more costly than expected and contributed to Gibb's loss.

Great difficulty was experienced in keeping the cutting west of the tunnel dry because, instead of lowering Myers Burn below railway level as provided for in the contract,

Illustrated London News

Winchburgh Cutting after railway accident October 1862 which would have allowed the cutting to drain, Miller insisted in carrying the burn under the railway in a twin 4 ft diameter cast-iron inverted siphon which adjoins the bridge seen in the railway accident view of 1862. This saved the company £3000—£4000 on excavation, but caused Gibb & Son to have steam engines constantly pumping to prevent severe flooding, and led to a substantial claim.

In 1841 Gibb & Son, in order to complete on time, used two locomotives on newly completed track to convey, upwards of a mile, and deposit on the embankments at least 2500 tons of earth and rock every 24 hours. [69–71]

Edinburgh & Glasgow Union Canal

HEW 0325

This canal, the last of importance to be built in Scotland during the canal era, was built mainly to provide a cheap means of transporting coal from the coalfields west of Edinburgh to the city. It was mooted as early as 1792 and from 1797 proposals were made by Rennie, Baird and Stevenson, but conflicting interests of landowners, coal owners and others caused delay. In 1817 Baird was appointed engineer to design and construct the canal from the Forth & Clyde at Lock 16 near Falkirk to Edinburgh. Work began in the following year.

Baird, in consultation with Telford, skilfully engineered the canal almost entirely on one level for operational economy, but at the considerable cost of £461 760. The canal was 40 ft wide at the top, 20 ft at the bottom and 5 ft deep, at 242 ft above sea level, without locks from the top of the 110 ft lift Falkirk flight of 11 locks. The water supply is from Cobbinshaw Reservoir in the Pentland foothills, with feeders from the rivers Almond and Avon. The Almond feeder crosses the river by means of an iron aqueduct of unique construction.

This 'contour' canal was achieved by means of the 696 yard Falkirk Tunnel, 70 bridges, nine road aqueducts and the long Slateford, Almond and Avon river valley aqueducts. The necessity for the costly Falkirk Tunnel, the only canal tunnel in Scotland, arose from the refusal of landowner William Forbes to accept a line which intruded on his view from Callendar House.

The canal was opened in 1822 but experienced financial difficulties from the outset because of its considerable cost and, as railways developed rapidly, the revenues expected to support it did not materialise. Despite a valiant rearguard effort against the railways, with 'Swift' passenger boats carrying nearly 200 000 passengers in 1836 and an inter-city travel time of about seven hours, the canal was unable to compete with train speeds of 30 mph and, in 1849, the canal was taken over by the Edinburgh & Glasgow Railway.

Connection with the Forth & Clyde Canal was severed in ca.1933 with the infilling of the Falkirk locks. Formal closure of the canal eventually took place in 1965. The canal was given a new lease of life with its restoration as part of the Millennium Link project and is now in regular use by pleasure craft to and from the Forth & Clyde Canal. This is made possible by means of the ingenious state-of-the-art Falkirk Wheel boat lift which has become one of Scotland's busiest tourist attraction in its own right (6.38). [72, 73]

Bottom: Almond Feeder Aqueduct

60. Almond Feeder Aqueduct

HEW 0325/01
NT 0864 6852

This aqueduct, erected by May 1822, carries the feeder channel for the Union Canal over the Almond. The trough aqueduct is of cast-iron, 80 ft clear span, 6 ft wide

Roland Paxton

and 11 ft 6 in. high at the centre. The trough is of 0.625 in. thick iron plate with upturned 3 in. flanges across the bottom, and the waterway is 3 ft deep.

The cast-iron trough in addition to acting as a beam is also designed to function as a flat arch and there are radiating 3 in. flange joints on the trough side walls. The lines of the flanges when produced meet at a common point below the river bed at mid-span, the radius of the arch being 80 ft. Bearers span across the top flanges of the trough to form a footway.

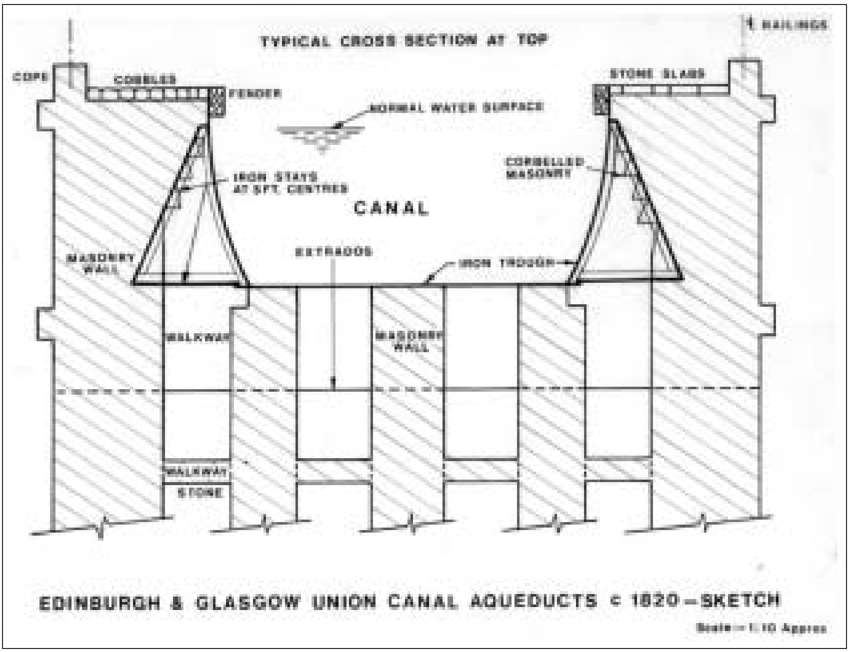
The engineer was Hugh Baird and the ironfounder, Craven, Whitaker & Nowell. [74]

Bottom: Union Canal – typical cross-section of large aqueduct [73]

61. Avon Aqueduct

HEW 0325/02
NS 9672 7581

Avon, Almond and Slateford aqueducts are three magnificent, cast-iron lined structures comprising 12, five, and six similar 50 ft arch spans respectively. Each span was built to a standardised construction with hollow spandrels in the best Telford tradition. Although Telford was not altogether



Avon Aqueduct
1821

British Waterways Scotland

convinced of the need for masonry spans and spandrels in addition to the iron troughs, Baird adopted this practice as the engineer of Avon Aqueduct, is 810 ft long and 85 ft high. All three aqueducts were constructed between 1819–21 by Messrs Craven, Whitaker and Nowell.

The canal is carried along the structure in a cast-iron trough 7 ft deep and 13½ ft wide. The trough is supported on the arches by a series of longitudinal masonry walls, and its sides are backed by the spandrel masonry of the aqueduct (see section). [73, 74]

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