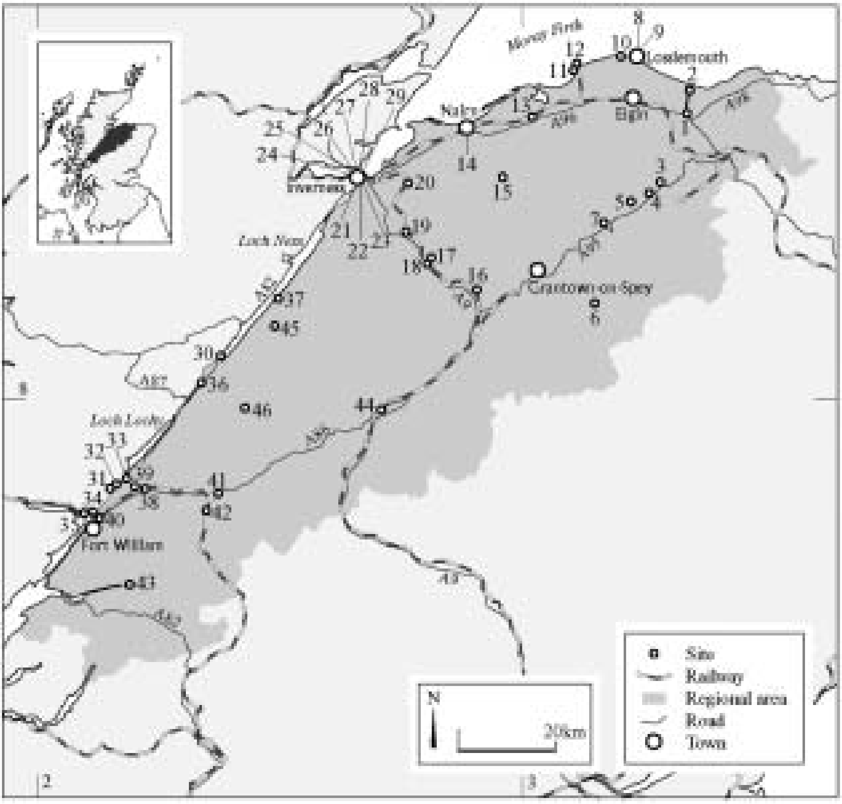


Highlands East and Moray West

1. Old Spey Bridge, Fochabers
2. Garmouth Viaduct (Railway)
3. Craigellachie Bridge
4. Victoria Footbridge, Aberlour (Private)
5. Carron Bridge
6. Bridge of Avon, Tomintoul
7. Ballindalloch Bridge (Railway)
8. Spynie Canal
9. Branderburgh Harbour, Lossiemouth
10. Covesea Skerries Lighthouse
11. Burghead Harbour
12. Torfness House (Private)
13. Findhorn Viaduct, Forres
14. Town Bridge, Nairn
15. Ferness Bridge
16. Carr Bridge
17. Findhorn Bridge, Tomatin
18. Findhorn Viaduct (Railway), Tomatin
19. Allt-na-Slanach Viaduct, Moy
20. Culloden Moor or Clava Viaduct
21. Holm Mills, Inverness
22. General's Well Bridge, Inverness
23. Inverness Harbour
24. Waterloo Bridge, Inverness
25. Greig Street Footbridge and Ness Bridge, Inverness
26. Kessock Bridge
27. Clachnaharry Sea-lock
28. Clachnaharry Swing-bridge
29. Muirtown Locks
30. Fort Augustus Locks
31. Loy and Shangan Aqueducts
32. Moy Turn-bridge
33. Mucomer Cut and Bridge
34. Neptune's Staircase or Banavie Locks
35. Corpach Sea-lock
36. Bridge of Oich or Victoria Bridge, Aberchalder
37. Foyers Power Station
38. Spean Bridge
39. High Bridge, Spean Bridge
40. Lochaber Hydro-Electric Works

41 and 42. Loch Laggan and Loch Treig Dams

43. Kinlochleven Hydro-Electric Works and Blackwater Dam
44. Spey Bridge, Newtonmore
45. White Bridge
46. Dalwhinnie to Fort Augustus

4. Highlands East and Moray West

Introduction

The improvements of the Highland Roads Commission, although less dominant in this area than west of the Great Glen, did include about 100 miles of road, on which two bridges noted as examples on the Laggan Road are, Ferness (1816, 4-15) and Spean (1818, 4-38). Craigellachie Bridge, crossing the often turbulent Spey in a graceful iron arch of 150 ft span, was a particularly fine achievement (1815, 4-3).

Pre-Commission stone bridges are represented by Inverness Old (1689–1854, 4-25); Carr (1717, 4-16); and six military bridges at Bridge of Avon, Grantown and Dulsie (ca.1754, 4-6), White and Inverfarigaig of 1732 (4-45) and High Bridge of 1736 (4-39). Later examples are Spey Bridge, Fochabers (1805, ca.1833, 1853, 4-1), where reinstatement after flood damage resulted in a spectacular timber arch of 186 ft span, later replaced by the present cast-iron arch; Town Bridge, Nairn (1803, 4-14); and the timber Black Bridge, Inverness (1808–96, 4-24), replaced by Waterloo Bridge.

Mid-19th century and later bridges, other than the railway examples mentioned below, includes James Dredge's innovative and economical suspension structures at Bridge of Oich, Aberchalder (4-36); Fort William (4-36); and Ness Islands, Inverness (1854, 4-22), one of which, re-erected in Whin Park, now carries a miniature railway. Also included are the Greig Street and Infirmary suspension bridges of 1881 (4-25) and Kessock Bridge (1982, 4-26), the largest cable-stay bridge in Europe when it was opened. The Findhorn, Tomatin (4-17) and Spey, Newtonmore (4-44) bridges in reinforced concrete formed part of a government job-creation project in 1924–28 on a 78-mile improvement of the A9 road (4-17).

Railways, mainly forming part of the Highland Railway, required numerous large structures because of the difficult terrain. The earliest was an iron plate-girder viaduct over the Findhorn (1858, 4-13); Ballindalloch Viaduct (1863, 4-7); Carron Bridge (1863, 4-5) carrying both a road and railway; Garmouth Viaduct (1886, 4-2) with its 350 ft bow-girder main span; and, on the Inverness direct line from the south, Findhorn Viaduct (1897, 4-18); Allt-na-Slanach timber viaduct (1897, 4-19); and Culloden Moor Viaduct (1898, 4-20).

Maritime engineering is represented by harbours at Burghead (ca.1812, 4-11), Branderburgh (1829, 4-9) and Inverness (4-23), for which an outline of its development from the 17th century is given.

Hydro-electric power projects noted are Kinlochleven with Blackwater Dam, the first major example of its kind in Britain (1909, 4-43); Lochaber (1930, 4-40) with its Laggan and Treig Dams (1934, 4-41, 4-42); and Foyers (1975, 4-37) utilizing the 586 ft difference in head between Loch Mohr and Loch Ness.

Town water supply is not featured except for a mention of the 'Roman' well at Burghead (4-11). A small mass concrete water tower (1898) at Garmouth is unusual in being gravity-fed.

This area includes Britain's largest early ship canal, the Caledonian Canal, connecting the North and Irish Seas across Scotland. Its design and construction was state of the art in its day, and significantly advanced engineering practice and Highland development. Individual elements described are the Clachnaharry Sea Lock (1811, 4-27); Muirtown Locks (1813, 4-29); Fort Augustus Locks (1820, 4-30); Loy and Shangan Aqueducts (ca.1808, 1845, 4-31); Moy iron turn-bridge (1820, 4-32); Mucomer Cut and Bridge (1815, 4-33); 'Neptune's Staircase' of locks at Banavie (1811, 4-34); and Corpach Sea Lock (1812, 4-35).

Perhaps the most unusual work noted is Ben Nevis Observatory (1883, 4-35) planned by Thomas Stevenson.

Highland Roads and Bridges Commission 1804–21

From 1801–03 Telford recommended to Parliament wide ranging improvements in the Highlands which led in 1803 to Acts setting up commissions for making the Caledonian Canal and Highland Roads and Bridges. As engineer to both Telford directed the making of the Caledonian Canal and many roads, ferries and harbours from 1804–21, in particular, opening up Scotland to the north and west of the Great Glen.

East of the Great Glen the road work involved maintaining former military roads, and improvements to the Laggan, Inverfarigaig, Speyside, Argyll, Alford, Findhorn roads and several others under 10 miles long. By the end of 1803, contracts had been let for making the 32-mile Glengarry road from Loch Oich to Loch Hourn and the 38-mile Fort William to Arisaig 'Road to the Isles'.

The procedure for building a road, pier or harbour began with interested landowners presenting a 'memorial' to the Commissioners stating the utility of a project, requesting a survey and estimate, and offering to meet half the cost provided that the government did likewise. If agreed, a survey and estimate was made under Telford's direction and, on deposit of the applicants' share in the Bank of Scotland, details were drawn up and a contract let for the work.

Roads were generally 10–12 ft wide, occasionally more, and typically, although not invariably, consisted of a 6–12 in. layer of random-sized local gravel or stones blinded with fine material. Side drains were provided to keep the road structure dry and minimise flooding. The roads tended to follow the best line available with a minimum of cut and fill. Culverts and bridges conformed to Telford's general specification published in 1804.

In addition to the various dimensions, requirements for foundations, masonry and mortar were specified. Each bridge was to accommodate a roadway 12 ft wide in the narrowest part, built so that the parapets when finished had a curve horizontally of not less than 3 ft in 36 ft in length and a vertical batter of at least 1 in 12. In practice there were variations but the specification was generally followed. Some bridges such as those at Craigellachie,

DIMENSIONS OF BRIDGES.

Span of the Arch.	Rise of Arch from Springing.	Depth of Arch Stones.	Height of Abutments from Bed of the River.	Thickness of Abutments on an average.	Thickness of Spandrels and Wings on an average.	Length of Parapets from Centre of Arch, with Wings under.	Height of Parapets above the Crown of Arch.	Thickness of inverted Arch where necessary.
F. In.	F. In.	F. In.	Ft. In.	F. In.	Ft. In.	F. In.	F. In.	F. In.
4. 0.	1. 6.	1. 0.	2. 6.	1. 6.	1. 6.	9. 0.	1. 2.	0. 9.
6. 0.	2. 0.	1. 0.	2. 6.	2. 0.	1. 6.	10. 0.	2. 2.	1. 0.
8. 0.	3. 0.	1. 2.	2. 6.	2. 0.	2. 0.	12. 0.	3. 0.	1. 0.
10. 0.	3. 6.	1. 3.	3. 0.	2. 6.	2. 0.	12. 0.	3. 2.	1. 0.
12. 0.	4. 0.	1. 4.	3. 0.	3. 0.	2. 0.	14. 0.	3. 2.	1. 0.
18. 0.	6. 0.	1. 6.	3. 0.	3. 6.	2. 6.	18. 0.	3. 2.	1. 4.
24. 0.	8. 0.	1. 6.	4. 0.	4. 0.	2. 6.	24. 0.	4. 2.	1. 4.
36. 0.	12. 0.	1. 9.	4. 0.	5. 0.	2. 9.	30. 0.	4. 2.	1. 4.
50. 0.	15. 0.	2. 6.	6. 0.	6. 6.	3. 6.	36. 0.	4. 8.	——

Dimensions of Highland Bridges up to 50 ft span [1 – 1st Report]

Ferness, Mucomir and Spean Bridge were constructed under separate contracts.

Work was superintended by Telford's inspector, John Mitchell, 'a man of inflexible integrity, a fearless temper and indefatigable frame' whose gruelling workload undoubtedly contributed to his early death in 1824 aged 45. He was succeeded by his son Joseph.

The Commissioners' epoch-making work was wound up in 1821, having achieved 1117 bridges and 1166 miles of road-making (including 283 miles of military roads under maintenance) and 24 piers and harbours at a total cost of more than £600 000. The average price of the roads was under £400 per mile. The Commissioners pointed out with pride that they had found the country 'barren and uncultivated . . . and inhabited by poor and ill-employed peasantry' and left it with 'a profitable agriculture, a thriving population, and an active industry'.

This process of improvement, mainly maintenance, continued under the remit of the Repair Commission until it was wound up in 1863. After 1824, work was carried out under the superintendence of Joseph Mitchell, until the early 1830s under Telford's general direction and afterwards as the engineer. This role included remedying the damage to the Commission's work caused by the Great Moray floods of 1829.

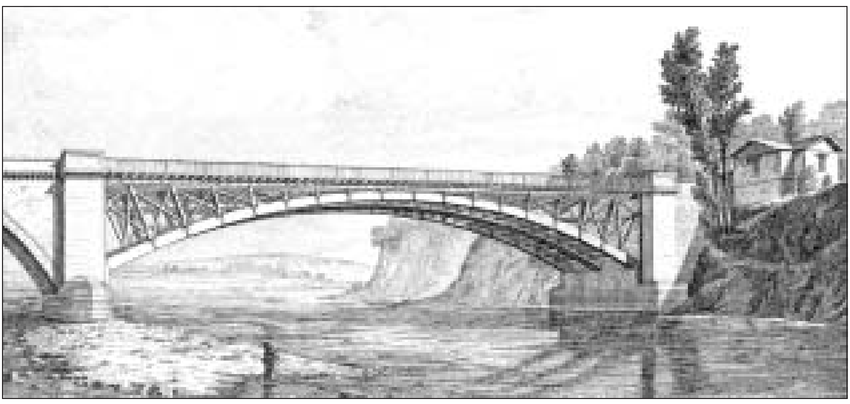
For particular examples see the entries for the Highland Roads Commission (Argyll and Bute in Chapter 1), Dingwall Canal (5-22), Fortrose Harbour (5-23), Wick Harbour (5-37), and the bridges at Dunkeld (6-14 in the *Civil Engineering Heritage Scotland – Lowlands and Borders* book), Potarch (3-14), Craigellachie (4-3), Ferness (4-15), Spean (4-38), Contin (5-18), Sheil (5-5), Conon (tollhouse) (5-20), Lovat (5-21), Alness (5-28), Easter Fearn (5-29), Bonar (5-30), Helmsdale (5-33), Wick (5-36), Greystones and Oldhall (5-40) and Fleet Mound (5-32). [1–4]

1. Old Spey Bridge, Fochabers

HEW 0403/01-04
NJ 3340 5946

The first bridge, spanning the Spey on this site, was built from 1801–05. It was a symmetrical bridge with four spans of 75 ft, 95 ft, 95 ft and 75 ft. At the western end it abutted against a high outcrop of rock and at the east it was approached over an inclined embankment 1043 ft long. The bridge was designed by George Burn and built in partnership with his brother James. Although Telford was critical of the disposition of the piers, the masonry of the bridge, with Burn's architectural detailing, was generally admired.

The great flood of 1829 destroyed the western river pier and the two fallen arches were replaced by a single 186 ft span formed with three timber arch ribs, one of Scotland's most notable timber bridges. The ribs comprised curved



Old Spey Bridge, Fochabers ca.1831–53 [lithograph, S. Leith, Banff ca.1831]

RCAHMS: John Hume

Old Spey Bridge
Fochabers
1853–present

laminated timbers '38 inches in depth at the spring and 34 inches at the crown, composed of three beams in depth, and two in thickness of eight inches each; the whole to be scarfed, overlapped and bolted together . . . with wrought-iron bolts one and three-tenths inches square'. The arch was designed by Archibald Simpson, Aberdeen architect, who dedicated the illustrated view of it to the Duke of Gordon. The contractors were William Minto and William Leslie. A model of this bridge can be seen in the museum at Fochabers.

In 1853 the timber arches were found to be affected by dry rot and were replaced by the present cast-iron arch ribs and posts. The bridge is now bypassed, the A98 road being carried on a modern steel box-girder bridge immediately to the north. [5]

2. Garmouth Viaduct (Railway)

HEW 2524
NJ 3459 6418

This viaduct, built from 1883–86, was constructed to carry the Moray Coast Railway, part of the Great North of Scotland Railway, over the Spey and its floodplain 1 mile south of the coast. The river crossing was initially

Spey Viaduct
1857
[photograph
Whyte 1865]

conceived as three separate bridges spanning the disparate channels, but it was decided to divert the river into a single channel to be crossed on a viaduct with embankment approaches.

The viaduct, 950 ft long, was built to carry a single-track railway. It has an impressive 350 ft long wrought-iron lattice bow girder span over the main channel of the river and three parallel-sided wrought-iron lattice girder approach spans of 100 ft at either end. The lattice members of the main arch, 41 ft deep at mid-span, rise from open box girders at each side of the deck. Cast-iron caissons filled with concrete form the piers of the viaduct. These were sunk to bedrock at depths of 25–35 ft except for the piers at the west end of the central span where it was necessary to sink them to a depth of 75 ft.

The viaduct, erected on a forest of staging, was designed by Blyth and Cunningham and Patrick Barnett, and the contractors for the ironwork of the superstructure were Blaikie Bros., Aberdeen. The contractor for the foundations and masonry was John Fyfe & Co., Kemnay.

At the time of construction, the main channel of the Spey ran to the east of the viaduct, and much of the construction work and work on the concrete spine wall to control the direction of the river was done in the dry. On completion of the bridge the river was diverted beneath the central span.

In 1857 the Inverness & Aberdeen Junction Railway had crossed the Spey about 8 miles upstream on a plate girder viaduct of 230 ft span built by Mitchell & Brand with ironwork made and erected by Wm. Fairbairn & Sons under the direction of Joseph Mitchell (see photograph). It was replaced in the early-20th century by the present steel girder structure. [6, 7]

3. Craigellachie Bridge

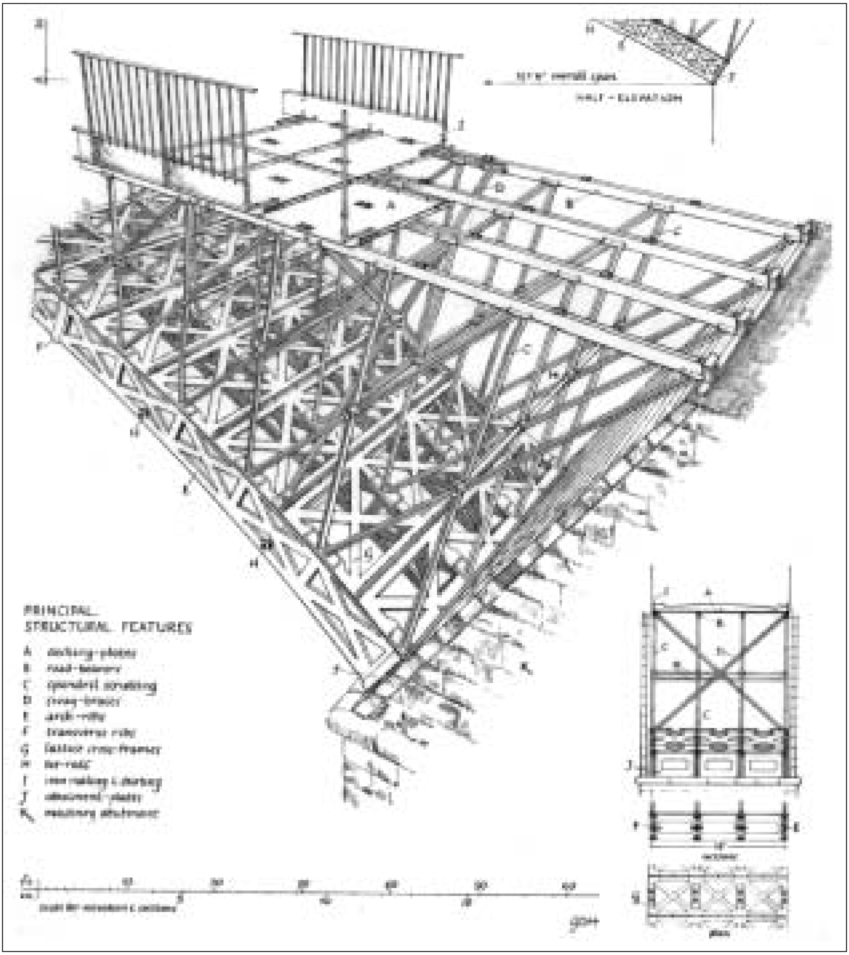
HEW 0024
NJ 2853 4519

This bridge (see front cover), built from 1812–14, incorporates the earliest surviving prefabricated lozenge lattice spandrel cast-iron arch designed by Telford, the first being the main arch of the almost identical Bonar Bridge (1812–92). At least ten arches of this state-of-the-art genre were erected in Britain as far south as Tewkesbury by 1829.

The ironwork was cast at William Hazledine's foundry at Plas Kynaston, Ruabon, Denbighshire, transported by sea to Speymouth and then by wagon to Craigellachie. The contractors were John Simpson and John Cargill. The ironwork was erected on pre-erected centring in August and September 1814 under the direction of William Stuttle, Hazledine's foreman. The bridge was opened two months later.

The bridge spans the Spey with a single arch of 150 ft span and a rise of 20 ft, and three stone arches of 15 ft span on the south-east approach. The iron deck plates of the $13\frac{1}{2}$ ft wide roadway are supported by a series of braced cruciform struts carried on four lattice arch ribs. These ribs are $2\frac{1}{2}$ in. thick and 3 ft deep, cast in seven sections, each about 23 ft long. The cost of the bridge and its approach roads, from the south-east over the floodplain and from the north via a gallery cut into the cliff overhanging the river and right-angle bend, was £8200 of which less than half was for the ironwork.

The bridge, with minor modifications, continued in use until 1963–64 when it was reconstructed above the arch



Craigellachie Bridge drawing

ribs, with significant retention of ironwork and character, by W. W. Lowson, partner of W. A. Fairhurst & Partners, Aberdeen, for Banff, Moray and Nairn Councils. The original cast-iron deck plates were retained. The main items of new, near matching, steelwork, were the side railings and spandrel bracing.

The configuration and lightness of this innovative bridge type to achieve permanent crossings at sites impracticable for founding stone bridges, particularly as here in deep and fast-moving water, demonstrates Telford and Hazledine's mastery of cast-iron in bridge construction.

The bridge was bypassed and closed to vehicles in 1972 when its pre-stressed concrete replacement just downstream, also designed by W. A. Fairhurst, was opened. Craigellachie Bridge is now in the stewardship of Moray Council as an outstanding historical and scenic amenity used by pedestrians and cyclists. [8–11]

Nearby Craigellachie Viaduct, now demolished, carried the Great North of Scotland Railway from Elgin to Dufftown over the Spey. It had four spans, three of 57 ft and one of 200 ft over the main channel, and a clear headroom 20 ft above mean water level which allowed the passage of rafts of logs. The viaduct was of wrought-iron, the shorter spans being plate girders 5 ft deep and the main span lattice girders were 17 ft deep overall.

The engineers were J. Samuel and W. H. Mills, and the contractor for the ironwork was Mackenzie, Clunes and Holland of Worcester. The bridge was completed in 1863 and cost £12 199. The line between Craigellachie and Rothes was closed in 1968. [12]

4. Victoria Footbridge, Aberlour (Private)

HEW 2525
NJ 2622 4291

This structure over the Spey is one of a number of attractive suspension footbridges constructed in ca.1900 by James Abernethy and Co., Aberdeen, and is probably the largest of its genre. It has a span of 287 ft between tower centres, with 2 in. diameter wire-rope cables and $\frac{3}{4}$ in. diameter rod hangers at $5\frac{1}{2}$ ft centres. The bridge has lattice handrailing and lattice pylons, similar to the Polhollick and Cambus o’ May bridges over the Dee.

5. Carron Bridge

HEW 1823
NJ 2245 411

This bridge was built in 1862–63 to carry the single-track Strathspey Railway (Dufftown to Abernethy) and a local road over the Spey. It is one of Scotland’s best surviving large-span cast-iron bridges and was probably the last of its type. It consists of a central segmental arch of 150 ft span with a rise of 20 ft, flanked on each side by a 25 ft span masonry flood-relief arch.

Roland Paxton

Carron Bridge

The main span has three arch ribs, each cast in seven sections and bolted together, with diagonal bracing between the ribs. The deck beams are supported on braced cruciform struts, a feature together with the curvature and span of the main arch are suggestive of a Craigellachie Bridge influence in its design concept.

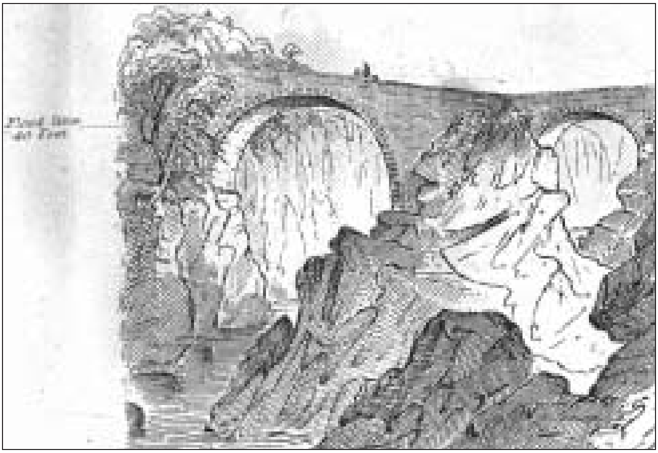
Carron Bridge was designed by Alexander Gibb, engineer to the Great North of Scotland Railway, whose previous experience as a contractor had included numerous major bridges. The ironwork was cast and erected by William McKinnon and Co., Aberdeen.

Although the Strathspey line was closed in 1968 and its deck adjoining the road removed, there were proposals in 1993 for the bridge to be reconstructed in steel. This proposal was opposed by Historic Scotland, PHEW and others at a public enquiry. The bridge with its original ironwork has recently been tastefully refurbished and re-decked by Aberdeenshire Council to carry the present single lane road and footways. [13, 14]

6. Bridge of Avon, Tomintoul

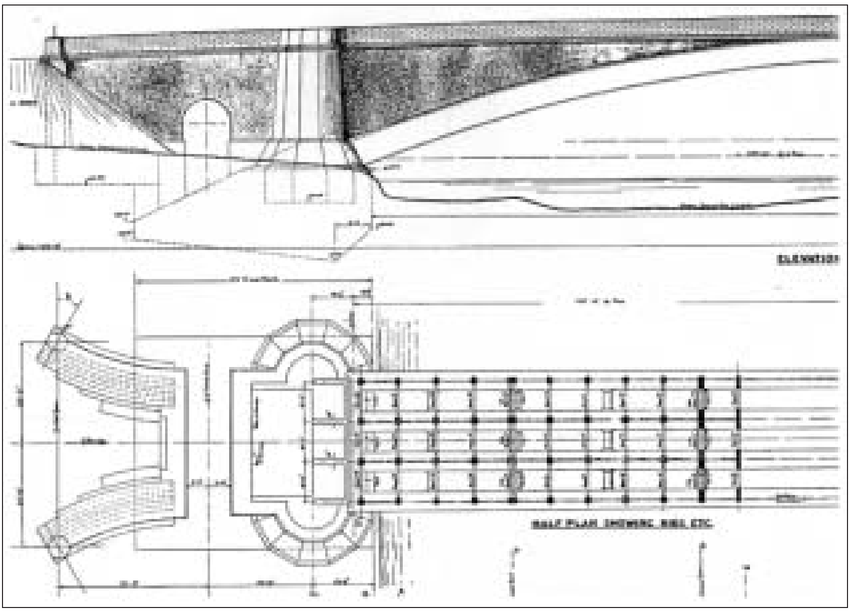
NJ 1496 2014

The Bridge of Avon, over the Avon, together with nearby Grantown (NJ 0395 2630) and Dulsie (NH 9321 4140) (see



Dulsie Bridge [15]

Military Roads map, see pre 4-45) bridges are representative of the genre of Caulfeild military bridges built in ca.1754. They are all asymmetric, of rubble masonry and span dimensions dictated by the need to found abutments on rock outcrops. The Bridge of Avon has spans of 49 ft and 23 ft and is well maintained and easily accessible. It has been bypassed by a modern bridge carrying the A939 road.



Grantown Bridge elevation and half plan [16]

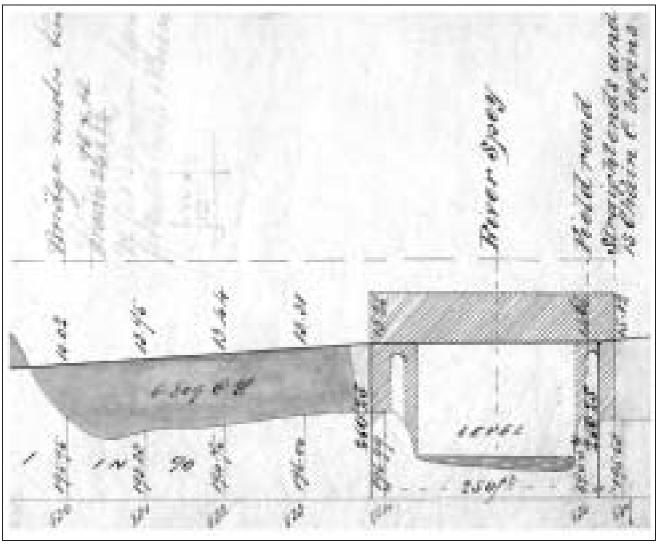
Dulsie Bridge over the Findhorn, one of Scotland's most picturesque bridges, has a main river span of 46 ft and a flood-relief arch at the northern end on a high rock outcrop. In 1829 the river level here rose 40 ft above normal level, causing minor damage to the bridge. Grantown and Dulsie Bridges, which now carry local access roads, have steeply inclined roadways.

The 1930–31 Grantown Bridge [NJ 0335 2680] now carrying the A95 road over the Spey is half a mile northwest of the old military bridge with its three spans of 72 ft, 40 ft, 19 ft and 13 ft wide roadway, which now forms part of the Spey-side Way. The 1931 bridge, shown with its slender 240 ft span reinforced concrete three-pinned arch, then the second largest in the UK, was designed by Blyth & Blyth and built by Melville, Dundas and Whitson at a cost of £32,000. [15, 16]

7. Ballindalloch Bridge (Railway)

HEW 2526
NJ 1687 3679

This triple-span bridge was built in 1863 to carry the single-track Speyside Railway over the Spey. The main elements of the 195 ft long central span are a pair of 17 ft deep overall wrought-iron lattice girders, each constructed of doubled hexagonal plate latticed sections. The top booms of the



Speyside Railway – Ballindalloch Bridge from Gibb's section book girders are tied at intervals, and the short side spans are supported on plate girders. Alexander Gibb was the engineer, from whose line section book the figure is taken, and the contractor for the ironwork was G. McFarlane, Dundee.

The bridge is now conserved as part of the Speyside Way. [7]

8. Spynie Canal

HEW 2527
NJ 2370 7043
(Lossiemouth)

The present canal, about 7 miles long, was built from 1808–12 to a plan prepared by Telford to drain an area of low-lying land known as Loch Spynie between the town of Elgin and the sea. It was an extension of an earlier scheme and had an outfall through sluices into the sea at Lossiemouth. William Hughes was the contractor and the work cost £12 740.

The canal was badly damaged by a flood in 1829. It was 1860 before reconstruction work eventually commenced. The canal, which had silted up, was deepened, and a heavy masonry outfall structure with four self-acting sluices was built at Lossiemouth. The work costing about £8000 was completed in 1863. Peter MacBey, a local surveyor, acted as engineer. [17]

9. Branderburgh Harbour, Lossiemouth

HEW 2528
NJ 2387 7123

This multi-basin harbour, built on a headland at Lossiemouth at a site sheltered from northerly winds, became the port for the town of Elgin after the former port at the mouth of the Lossie had become inoperable due to silting. The new facility, designed and constructed in 1837–39 by James Bremner and superintended by Alexander Gibb, comprised a single basin mainly cut in solid rock protected by state-of-the-art seawalls.

After completing the seawalls it proved impracticable to excavate the rock within the basin by traditional techniques and Bremner, who became a notable wreck-raiser, showed his customary ingenuity. He caulked and shored the inside face of the seawalls, closed the 70 ft or 80 ft wide basin entrance with boom gates and pumped the entire area dry for four months while he excavated the basin floor to 3 ft below low water spring tide.

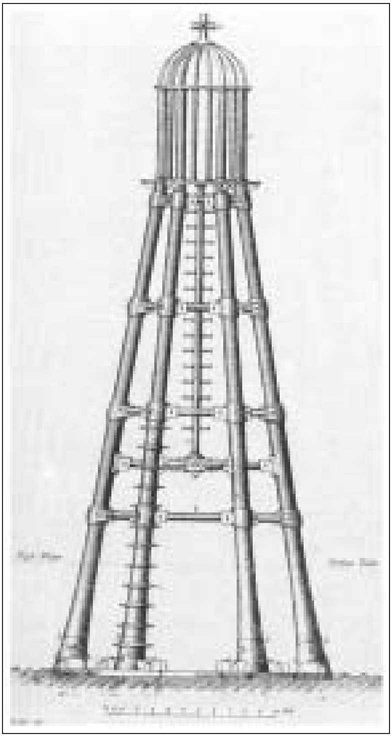
Although large blocks of masonry weighing many tons were used in the seawalls it was breached, requiring substantial repair, but nevertheless the new harbour was successful. At low water the rock, on which the masonry walls are founded, is visible. By 1847 the harbour had been enlarged and had an inner and outer basin with 660 ft of quays, an area of 2 acres and a depth of 12 ft at high water.

The harbour was further enlarged in 1852 with the construction of a south basin and again in 1860 with an extension of the breakwater to the south-west and a new west basin. From 1892–94 the harbour was deepened to allow access for vessels of greater draught. The harbour is now used for leisure activities and fishing.

10. Covesea Skerries Lighthouse

HEW 2529
NJ 2037 7127

Following the loss of 16 vessels during a storm in the Moray Firth in November 1826 applications were made to the



Halliman Skerries beacon [18]

government for lights to be established at Covesea Skerries and Tarbat Ness but it was two decades before Covesea Skerries, one of three lighthouses on the Moray Firth, the others being Cromarty and Chanonry, became operational in 1846. All three were designed by Alan Stevenson and Covesea Skerries was built by James Smith. The stone tower is about 118 ft high with the spiral access stair supported between the external wall and a central hollow shaft for the weights that drove the lamp machinery.

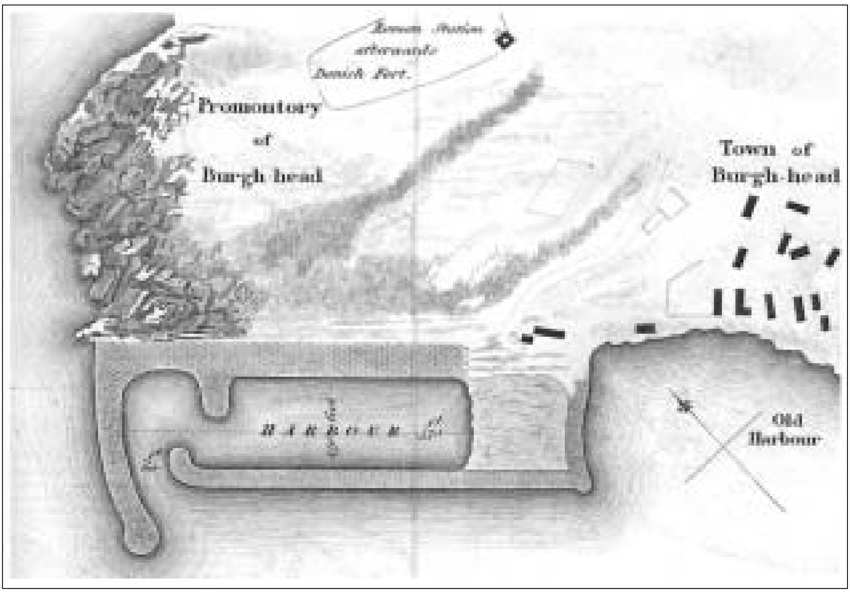
In 1845 a cast-iron beacon, based on the concept of Robert Stevenson's at Carr Beacon in 1821 in *Civil Engineering Heritage Scotland – Lowlands and Borders* (7-12) but about 40 ft tall, was erected offshore to mark Halliman Skerries (see engraving). It is still in service (NJ 2140 7225). [18]

11. Burghead Harbour

HEW 2530
NJ 1082 6902

This small rectangular harbour on the south-west side of the promontory at Burghead was built from 1807–12 by day labour supervised by Andrew Forsythe, mason of Elgin. A short pier at the entrance provided shelter to vessels entering the harbour and by 1835 this had been extended by the construction of a breakwater.

Burghead plan 1821 [1 – 9th Report]



Although a short pier has been constructed within the basin and the external harbour wall has been widened externally to provide more quay space, the harbour retains much of its original character. There is a number of early-19th century warehouses on the quayside.

Telford had an involvement only when it became necessary for the local promoters to apply to the Highland Roads & Bridges Commission for finance to complete the harbour, their plan for which is shown.

The plan of 1821, where marked, 'Roman Station', shows a then newly-discovered open stone water cistern about 11 ft square, in a chamber now roofed over, at the foot of an ancient flight of steps. This 'Roman' or 'Bailey's' well as it is known is not Roman but may date from the Dark Ages. It is a notable early example of its kind which may have had some religious origin.

12. Torfness House (Private)

HEW 2531
NJ 1090 6910

This building, overlooking Burghead Harbour and dating from the early-19th century, was originally a granary warehouse. It has four floors carried on oak beams trussed with wrought-iron spanning 40 ft between walls, a rare survivor of such beams. There are three beams per floor supported on pad stones that cantilever from 3 ft thick masonry walls. Later the building served as a ship chandlery and is now a dwelling house.

13. Findhorn Viaduct, Forres

HEW 0373
NJ 0208 5868

This viaduct of three 150 ft spans over the Findhorn was built for the Inverness and Aberdeen Junction Railway by Thomas Brassey and James Falshaw from 1856–58. The engineer was Joseph Mitchell. It is an early example of an open-top box girder constructed of butt-jointed wrought-iron plates and is an important example of its genre. The ironwork was supplied by Messrs. Fairbairn and Sons, Manchester.

The massive masonry abutments and piers demonstrate Mitchell's architectural and engineering abilities. The river piers are $46\frac{1}{2}$ ft high above the bed of the river and founded on rock 18 ft beneath it, which with good workmanship contributes significantly to the fact that the viaduct is still in service after one and a half centuries. [19]

14. Town Bridge, Nairn

NH 8860 5661

The Town Bridge, an asymmetrical triple-arch structure spanning the Nairn with its middle and western arches, was completed in 1803. It carries a roadway sloping from west to east and its width, since widening in 1936 under the direction of F. A. MacDonald and Partners (Glasgow) Ltd, is 38½ ft between parapets.

The bridge was designed and built by architect-engineer George Burn and exhibits the range of architectural details found on several of his other bridges, recessed arch-rings surmounted by archivolts, blind oculi, denticulated string-courses, ashlar parapets and copings. The bridge was partially destroyed in the great flood of 1829 and rebuilt soon afterwards, and again in 1868.

15. Ferness Bridge

HEW 0320
NH 9596 4623

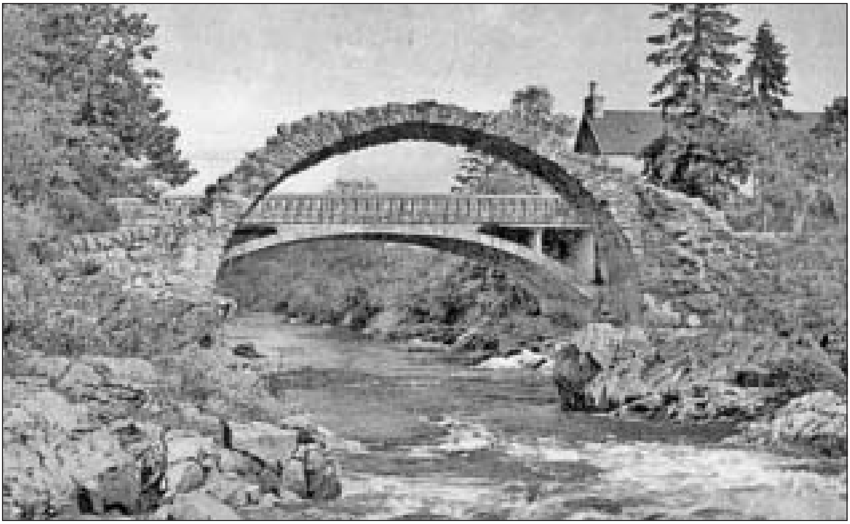
This bridge, built under the direction of the Highland Roads & Bridges Commission and now carrying the A939 road over the Findhorn, was designed by Telford and completed in 1816. The contractor was George Burn. It has three segmental arch granite masonry spans of 36 ft, 55 ft and 36 ft and is similar in construction to its contemporaries at Alford and Potarch in Aberdeenshire.

During the great flood of 1829, when the water level rose 27 ft above normal, the bridge was severely tested. A fine ash tree with a triple stem, the largest being 12½ ft in circumference, was brought down and after rising 40 ft or 50 ft above the water sunk into the vortex at the main arch stem first where 'for three or four minutes it stuck groaning and bellowing as if from torture and then appeared darting below the lower side of the bridge shorn of its mighty honours'. The only damage to the bridge was 'the loss of a part of its southern wing walls and roadway estimated at about £100'. [20, 21]

16. Carr Bridge

HEW 2532
NH 9063 2293

The remains, mainly the arch-ring, of a rubble stone almost semicircular arch bridge over the Dulnain, built in 1717. It had a width between parapets of 7 ft and the steepness of the roadway at each side of the arch indicates that the



Carr Bridges [postcard J. Arthur Dixon 1952]

bridge was intended for pedestrian and horse usage. It is said to have been known as a funeral bridge because it facilitated the carrying of coffins to the burial ground and was reputed to have been built at the expense of the Parish by John Niccelsone, a mason, and cost £100.

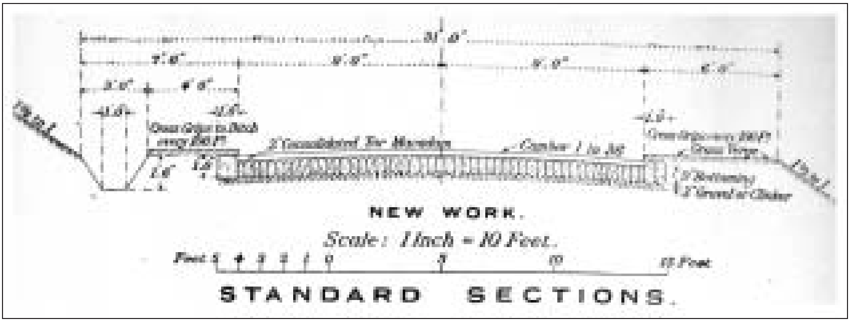
Sir Owen Williams' slender reinforced concrete open-frame arch bridge of the 1930s, shown in the view, was replaced by the present bridge.

17. Findhorn Bridge, Tomatin

HEW 1674
NH 8084 2900

In the 1920s the road from Perth north to Inverness, subsequently the A9, was improved and widened, and a number of substantial bridges were constructed; Spey Bridge, Newtonmore and this bridge over the Findhorn, south of Tomatin (4-44), being the largest. Both were designed by Sir Owen Williams in collaboration with architects Sir J. W. Simpson and Maxwell Ayrton and built from 1924–26 by Sir Robert McAlpine & Sons.

Findhorn Bridge, constructed of reinforced concrete, has twin spans of 98 ft with a roadway 30 ft wide that is carried on the lower booms of 18 ft deep parallel-sided girders somewhat of the Vierendeel type each pierced with semi-hexagonal openings. This unusual design allows maximum waterway clearance below the spans



Great North Road cross-section 1925 [23]

during floods. The top booms of the girders, although appearing continuous, are broken over the central support and at the abutments the girders rest on flexible columns permitting horizontal movement.

The project formed part of a 78-mile improvement of the Great North Road from near Blair Atholl to Inverness from 1925–28; the most extensive since Telford's time. These works, including widening the carriageway from 12 ft to 18 ft using Telford's hand-pitched foundation, and 61 bridges, were conducted under the direction of R. Bruce, chief engineer, cost £654 476. The works, paid for by government, were primarily undertaken to relieve unemployment, and also included a new road via Rannoch Moor and

Great North Road construction in 1926 [photograph 1926]

Glencoe (see 5-39) in *Civil Engineering Heritage Scotland – Lowlands and Borders*. [22, 23]

Highland Railway

HEW 0601

The Highland Railway, based in Inverness, came into being with the amalgamation in 1865 of the Inverness and Aberdeen Junction Railway and the Inverness and Perth Junction Railway. Initially the company operated two principal routes, mainly single-track lines, from Inverness via Forres to Keith where it connected to the Great North of Scotland Railway, as referred to in Chapter 3 (pre 3-18), and from Inverness via Forres to Stanley Junction, north of Perth, where it connected with the Caledonian Railway.

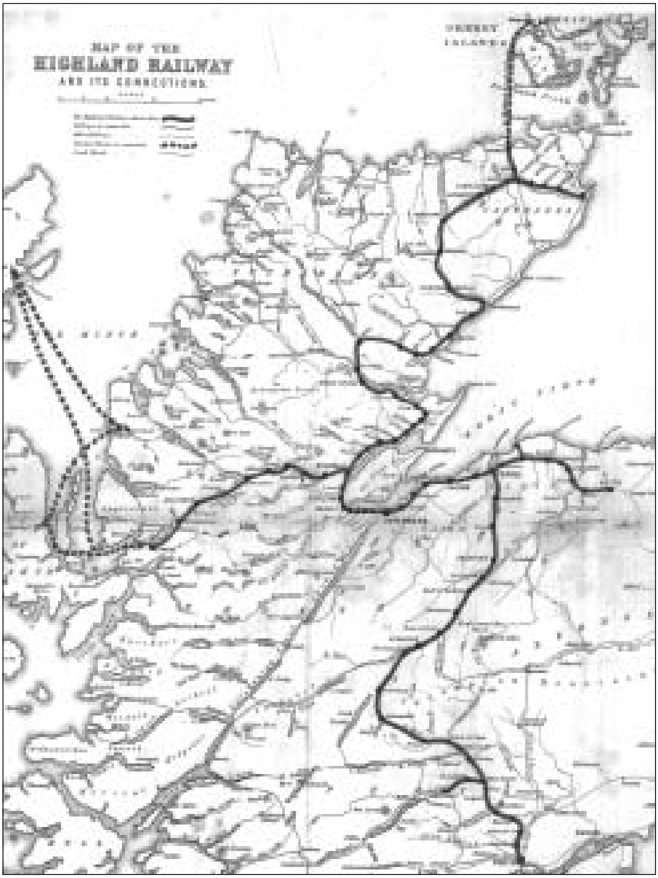
A number of branch lines were constructed from the Inverness–Keith line to ports on the Moray coast, and the company took control of several main routes north of Inverness. In 1898 a shorter, direct route south from Inverness to Aviemore was opened that eliminated the need for through trains to make the detour via Forres. At this time the company had 227 miles of railway in Morayshire and the south Highlands.

Two engineers were largely responsible for the construction of the Highland Railway and its predecessors. Joseph Mitchell was its engineer from 1854 until 1867 when he retired from the firm of Joseph Mitchell and Co., and Murdoch Paterson acted as engineer from 1868 until his death in 1897. Both the lines south to Perth, from Forres and direct from Inverness, were subject to severe gradients with summits of 1052 ft at Dava and 1484 ft at Drumochter, south of Dalwhinnie, and 1315 ft at the Slochd summit.

There were few tunnels on the line and acceptable ruling gradients were obtained by means of heavy earthworks and the construction of viaducts where the lines crossed Highland rivers. Impressive structures on the direct route include Culloden (4-20), Findhorn (4-18), Alltnaslanach timber (4-19), Slochd Mhuic and Dulnain viaducts.

There were two other notable structures, the Findhorn and Spey Viaducts (4-13, 4-2) between Inverness and Keith. The latter was the final link in the line between Inverness and Aberdeen which became operational in 1858. It was replaced in 1906. [19, 24–26]

Highland Railway map ca.1890



G. Waterston Sons & Stewart, Edinburgh

18. Findhorn Viaduct (Railway), Tomatin

HEW 0601/01
NH 8072 2882

This viaduct was built to carry the former Highland Railway across the valley of the Findhorn south of Tomatin. It is a striking and well-proportioned example of Victorian railway engineering. Its construction is unusual for the Highlands as it has slender masonry piers of well-cut stone that carry double-triangulated steel trusses.

The viaduct, built on a curve of about 35 chains, has nine truss spans of 132 ft flanked at either end with abutments pierced by small masonry arches. It reaches a maximum height of 144 ft. The engineer was Murdoch Paterson, and

Roland Paxton

Findhorn Viaduct

Butterley Iron Company was the contractor for the girders. Construction was completed in 1897.

It is said that Sir John Fowler, as consulting engineer, persuaded the directors to adopt a more direct line for the railway over this viaduct saving over a mile in length. The stone used for the viaduct was from the quarries which had supplied granite for the Forth Bridge (Kemnay, Aberdeenshire). [26]

19. Allt-na-Slanach Viaduct, Moy

HEW 0601/02
NH 7601 3494

A timber trestle viaduct erected to carry the single line from Inverness to Perth over the Allt-na-Slanach burn. It was completed in 1897 and provision was made for a double line of track. The designer was Murdoch Paterson and the contractor, John Ross & Son.

Timber was chosen to limit the weight of the structure on the marshy ground. The viaduct has five spans of 23 ft, the centre one spanning the burn. The structural form is simply-supported timber beams supported on four vertical

Roland Paxton

Allt-na-Slanach Viaduct

posts across the width of the bridge. The spans of the beams are reduced to about 11 ft by angled supporting struts to the posts at each end which are themselves braced by similar struts and longitudinal members at a lower level. This arrangement together with transverse raking struts at the sides provides essential stiffness.

In 2001 fungal decay was found in the timber and in the following year a £2.6 million programme of work was undertaken to protect the timber and strengthen the bridge. Specially designed concrete members were introduced to form a new structure on separate foundations such that no railway loading is now carried by the original structure, although it still supports the side gangways.

It is the last timber viaduct existing on a main line Scottish railway, a rare and substantial survivor of a once fairly common bridge type. [26]

20. Culloden Moor or Clava Viaduct

HEW 0601/03
NH 7641 4497

This gracefully curved viaduct with 29 semicircular arches over the valley of the Nairn, east of Culloden battlefield, 1785 ft long and 132 ft high at the river, is constructed of red sandstone and carries a single line of the former Highland Railway. It is asymmetrical with a river arch of 100 ft span,


Roland Paxton

Culloden Moor Viaduct

ten arches of 50 ft span at the north side and a further 18 of 50 ft span at the south side and is sometimes dubbed 'the Forth bridge in stone'.

The piers, apart from at the river span, taper from 5 ft thick at the base to $6\frac{1}{2}$ ft at the spring line of the semicircular arches. Unusually there are no massive intermediate piers to prevent progressive collapse. The viaduct, the longest in Scotland, was completed in 1898 to a design by Murdoch Paterson. The contractors were Charles Brand & Sons, Glasgow. [27]

21. Holm Mills, Inverness

HEW 2533
NH 6551 4313

This building, the former spinning and weaving factory of the Pringle family and now a retail outlet of James Pringle Weavers, is located within a group of buildings between the B862 road and the Ness on the south side of the town. The factory 'was established about 1798 and is the oldest woollen factory in the north of Scotland. It is worked by both water and steam' (Groome, *Ordnance Gazetteer*, 1901).

The building, now a display area, is single storey with five bays of roof trusses about 30 ft span making a width of 150 ft. The roof trusses are timber, some with iron tie-bars, and vary in form from bay to bay. They are supported on timber beams carried on cast-iron columns of $6\frac{1}{2}$–$7\frac{1}{2}$ in.

diameter, probably made in the early-19th century. The 17 columns of the central line are spaced about 6 ft apart making the building about 110 ft long.

As the centres of the trusses and columns do not correspond, the building appears crudely constructed. The ceiling height is $8\frac{1}{4}$ ft and some shafting and mill machinery are still in place on the trusses.

22. General's Well Bridge, Inverness

HEW 0412
NH 6570 4350

This footbridge and its smaller companion, Island Bank Bridge, were built to span the channels of the Ness at the Ness Islands, Inverness. They were of the inclined-stayed economical form of construction, for erection on site with minimal if any scaffolding, developed by James Dredge of Bath, and were constructed under his direction in 1853–54.

General's Well Bridge had a main span of 97 ft and Island Bank Bridge one of 87 ft. They were both 6 ft wide with timber decks suspended from eye-bar rods supported on iron posts with backstays taken down to anchorages. The

General's Well Bridge – Whin Park

Roland Paxton

number of rods in each catenarian chain reduces from six at the supports to only two at mid-span.

In 1990 both bridges were taken down and later the former was re-erected in a modified form in Whin Park, Inverness and now carries a miniature railway over a dry valley.

A larger bridge of this type by Dredge has been conserved in situ by Historic Scotland at Aberchalder. [4–36]

23. Inverness Harbour

HEW 2534
NH 6650 4620

The harbour is located at the sheltered entrance to the Ness chiefly on the east bank of the river. The Old Quay, dating from ca.1675 which accommodated vessels of 70 to 80 tons, was an improvement on earlier arrangements dating back to 1249. The harbour was enlarged from 1725–32 when the 'New' or 'Citadel' Quay was built, following which little seems to have been done to maintain the works although the harbour dues were significant and a factor in the town's prosperity.

In order to accommodate increased trade and traffic during the Industrial Revolution, Thornbush Quay on the west bank was begun in 1813 and completed in 1817. The work was done under Telford's direction by Thomas Hughes using the unusual and economical expedient of building the masonry under water (Weale's *Bridges*, 1839). The bed of the river was deepened, widened and cleansed.

Inverness Harbour 1983

Inverness Harbour Trust

Under an act of 1847, further improvements were carried out under the direction of Joseph Mitchell. The river was deepened, Thornbush Quay was extended and the Upper Quay was improved. Construction of the five-span Ness Viaduct for the Ross-shire Railway in 1862, for which Mitchell was the engineer, cut off the old harbour and resulted in Shore Street Quay being built downstream at the railway company's expense.

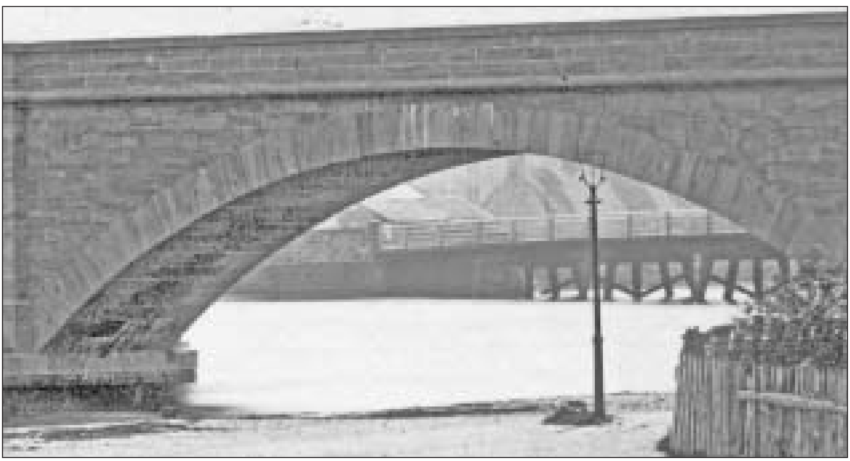
In 1883 a new masonry quay was built at Shore Street in front of the old one. Further improvements were carried out in 1899 and in 1908 a new boat slipway was built at Thornbush Quay. This offered ship repair facilities for drifters and trawlers and encouraged small-scale shipbuilding, services much used during the first and second world wars and still in use.

Further expansion of the harbour took place in 1985 with the construction opposite Thornbush Quay of the 600 ft long Longman Quay, the land reclamation for which can be seen in the foreground of the view. [28, 29]

24. Waterloo Bridge, Inverness

NH 6626 4593

A five equal-span double Warren truss iron road bridge supported on cast-iron columns dating from 1896. It connects Waterloo Place with Grant Street and had replaced a timber bridge with 13 spans of about 30 ft erected in 1807–08 and known as Black Bridge, which is



Below: Black Bridge through arch of Ness Viaduct [photograph Whyte 1865] shown through an arch of Ness Viaduct in the view. The engineer of Waterloo Bridge was John A. Mackenzie, the consulting engineer was Murdoch Paterson and the contractors, Rose Street Foundry, Inverness.

The bridge stood firm in the severe floods of 1989 which reached nearly to deck level and caused the collapse of nearby Ness Viaduct.

25. Greig Street Footbridge and Ness Bridge, Inverness

HEW 2535
NH 6639 4540

This is the larger of the two suspension bridges which cross the Ness on either side of the main bridge at Inverness. Infirmary Bridge to the south is the smaller. Greig Street Bridge was designed by C. R. Manners and erected in

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Greig Street Footbridge

Ness Bridge 1689–1849 [view by Sir John Carr 1809]

1881. It has a centre span of 201 ft, side spans of 67 ft and is of iron construction, with elegant braced towers supporting wire-rope cables from which iron suspenders support the timber deck.

In 1952 the bridge was re-cabled. In 1989 its anchorages were refurbished and access was improved by the addition of concrete ramps. Infirmary Bridge, also erected in 1881, is of similar construction with a main span of 200 ft and side spans of 42 ft. The contractor for both bridges was Rose Street Foundry, Inverness.

Just upstream is the site of the town's historic seven-arch masonry Ness Bridge, built from 1685–89, with a prison vault 12 ft square in the spandrel between the 2nd and 3rd arch at the east end in which a prisoner in 1715 is said to have been eaten by rats. This bridge was swept away in a flood on 25 January 1849, mainly caused by the bursting of the Caledonian Canal bank, and replaced by a 225 ft-span suspension bridge with bar-link chains designed by J. M. Rendel and built from 1852–55, with ironwork supplied and erected by William Armstrong.

In 1939 a contract was let for the building of a masonry faced three-arch reinforced concrete bridge, but work was suspended at the outbreak of war before much progress had been made. It was not until 1959 that Rendel's bridge was replaced by the present elegant pre-stressed concrete bridge with a central span of 120 ft, composed of a 60 ft suspended span between two 30 ft cantilevers. The consulting engineers were Sir M. MacDonald & Partners and the contractors, Duncan Logan (Contractors) Ltd, Muir of Ord.

26. Kessock Bridge

HEW 2536
NH 6651 4761

Kessock Bridge carries the A9 trunk road over the Beauly Firth between Inverness and the Black Isle replacing the former ferry. When built from 1978–82 it was the largest cable-stayed bridge in Europe and the only one of its type in Britain. Its design is said to have been modelled on the Rees Bridge over the Rhine near Dusseldorf.

The navigation span is 787 ft and is supported by groups of eight spiral-strand steel cables up to $39\frac{3}{4}$ in. diameter in a harp arrangement. The steel superstructure is fully continuous over the supports and the open cross-section comprises $11\frac{1}{2}$ ft deep plate girders supporting an orthotropic steel deck. The tender sum was £17.24 million.

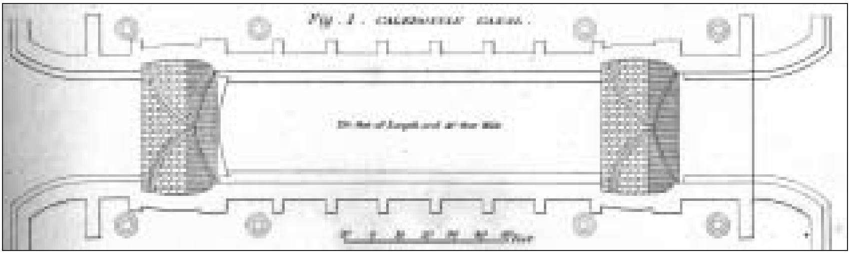
An unusual feature of the design is the need to accommodate possible movement on the Great Glen fault at the north abutment. This is achieved by means of two 394 ton hydraulic buffers.

The bridge was designed for the Scottish Development Dept by Dr Helmut Homberg in association with Cleveland Bridge & Engineering who were also the steel contractors. The consulting engineers were Crouch & Hogg and Ove Arup. The foundations and reinforced concrete work were executed by RDL Contracting Ltd. [30]

Caledonian Canal

HEW 0084

This sea-going canal through the Great Glen links the North Sea and Beauly Firth on the east of Scotland with Lochs Eil and Linnhe and the Irish Sea on the west. In 1773 James Watt prepared a survey for a canal but no action was taken. In 1801 Telford surveyed and reported on the feasibility of a canal which led in 1803 to the creation under an Act of Parliament of the Caledonian Canal Commission for making the canal. Its main purposes were to provide a quicker and safer alternative to the hazardous Pentland Firth for naval and commercial shipping, to



Caledonian Canal lock plan [40]

furnish employment for Highlanders, and to develop the Highlands.

Telford was appointed principal engineer to the Commission with William Jessop acting as consulting engineer. Although the canal was 60 miles long, about 38 miles were through the lochs Dochfour, Ness, Oich and Lochy, leaving about 22 miles to be constructed. This involved 28 locks (later 29), with the summit of the canal 106 ft above sea level, the series of locks then being the world's largest, that is, mainly 180 ft long × 40 ft wide × 20 ft deep (25 ft from invert centre to top of wall coping).

Caledonian Canal – Laggan Cutting and Loch Ness

The canal as designed was 110 ft wide at the surface, 20 ft deep and 50 ft wide at the bottom, but the 20 ft depth was not attained by the opening in 1822 because of difficult ground conditions. Shortly after opening it had a minimum depth throughout of 12 ft, with steam-powered dredging continuing. A 17 ft depth was achieved in 1847 admitting vessels of 16 ft draught.

Construction of this canal at the frontiers of early-19th century technology was an immense and bold undertaking, all the more so for its remoteness, aggressive ground conditions, harsh climate, and largely unskilled itinerant labour. But the project significantly advanced canal engineering practice in design and construction, including the use of horse-traction plateways and special wagons and steam-powered pumping and dredging.

When work began in 1804, Jessop estimated the cost of the canal at £474 000 and the construction time at seven years. It eventually opened in 1822 after an expenditure of £1.2 million. Delays and difficulties were experienced at the sea-lock entrances and Fort Augustus locks. Other problems included raising the level of Loch Lochy by 12 ft, excavating the 40 ft deep 2-mile long Laggan cutting and in diverting the Lochy and using the old river bed.

From 1843–47 the canal was repaired, improved and deepened to 17 ft under the direction of Telford's successors Walker and Burgess. After this the canal attracted some larger vessels engaged in the Baltic trade, but increasing ship size made its use less necessary for safe transit and prevented larger vessels from using it. But the canal continued to make a significant contribution to Highland development through fishing and tourism and was much used in the first world war. For the year ended 30 April 1919 there were 5439 passages.

The lock-gates were mechanised from 1959–68. Repairs and improvements in recent years by British Waterways have brought the canal up to a high standard of maintenance accommodating vessels of up to 13½ ft draught.

Today the canal, essentially as created by Telford and Jessop and authentically conserved, is encouraging increasing leisure use of this great Highlands legacy and facility which has become one of Scotland's most outstanding tourist attractions. [31–34]

27. Clachnaharry Sea-lock

HEW 0084/01
NH 6447 4674

This sea-lock, sited on the mudflats of Beauly Firth, called for outstanding engineering ability in its achievement – a classic case of founding on pre-consolidated fill. It was necessary to build twin artificial embankments, 400 yards long over the mudflats, into a 20 ft depth of water (lock sill level) at ordinary neap tide, to contain the canal, and then to construct the lock, 170 ft long × 40 ft wide, where the mud was 55 ft deep. It was impracticable to use a coffer-dam as the elasticity of the mud would have prevented pile driving.

Based on experience gained in forming the embankments nearby, clay, transported by plateway, was formed into a mound at the site of the lock. This was then surcharged with a kentledge of stones and allowed to consolidate for six months during which it sank 11 ft. The lock chamber pit was then excavated in the consolidated clay and, despite the need to de-water the excavation, at first with a six-horse driven chain pump and, below 15 ft, by means of a 9 hp Boulton & Watt steam-powered pump, the masonry of the inverted arch at the base and the side walls of the lock were successfully completed in August 1812.

Crown Copyright: RCAHMS

Clachnaharry Locks and Railway Swing Bridge

Telford and Jessop were the engineers, Matthew Davidson was the resident engineer, and John Simpson and John Cargill were the contractors. [35–37]

28. Clachnaharry Swing-bridge

HEW 1759
NH 6485 4660

The original bridge was designed by Joseph Mitchell and completed in 1862. It carried a single track of the former Highland Railway over the canal on a skew of 65 degrees. At this point the canal is 120 ft wide and 18 ft deep. The girders and machinery were manufactured by Messrs. Fairbairn & Sons, Manchester (drawing at Inverness City Archives).

The present bridge dates from 1909 when it was rebuilt, essentially to the same design as the original. The main elements of the bridge are two hogbacked wrought-iron plate girders, 126 ft long, pivoting on a platform built out from the eastern bank of the canal to give a span of 78 ft over the canal and a shorter balancing arm 48 ft long. It is painted white to limit temperature effects. [38]

29. Muirtown Locks

HEW 0084/02
NH 6525 4559

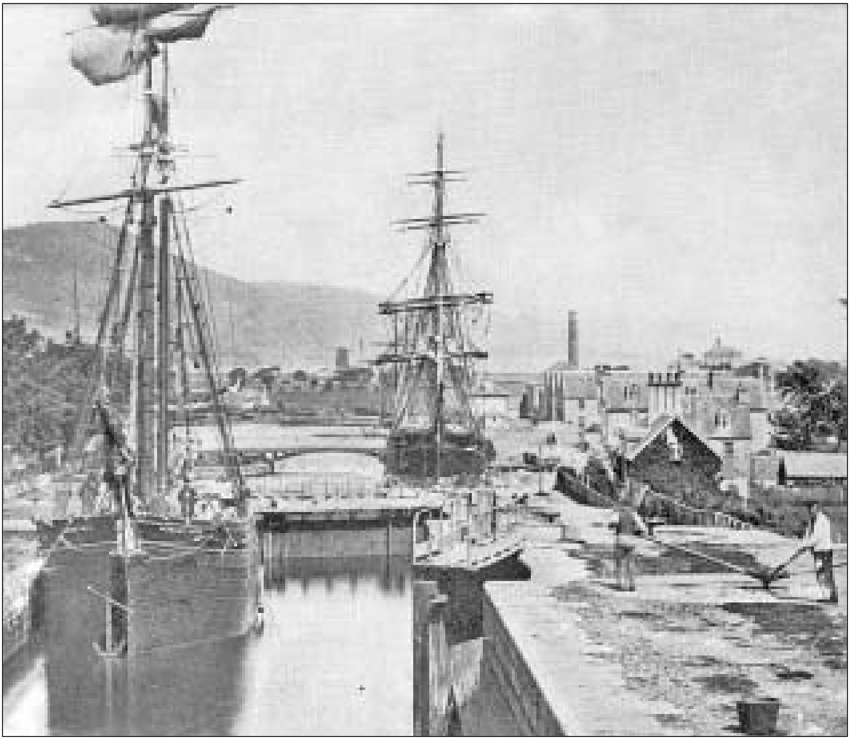
This flight of four locks, each 180 ft long and 40 ft wide about a mile south of Clachnaharry, raises the canal 32 ft from the basin at Muirtown to the Dochfour reach. They were built by Simpson & Cargill from 1808–13.

The present steel-plate girder swing-bridge at the foot of the flight and head of the basin carrying the A862 road was erected by Sir William Arrol & Co. in 1936. The previous crossing was by means of a cast-iron bridge with radial spandrel struts which still existed in 1892 (see view), but whether this was the first one is not now known. It differed from the type surviving at Moy (4-32). [39, 40]

30. Fort Augustus Locks

HEW 0084/03
NH 3777 0918

This flight of five locks, built by Simpson & Cargill from 1816–20, is second only to Neptune's Staircase as being the most impressive piece of masonry work on the Canal. Each lock is 180 ft long and 40 ft wide, and the flight raises vessels 40 ft from Loch Ness to the Kytra reach.

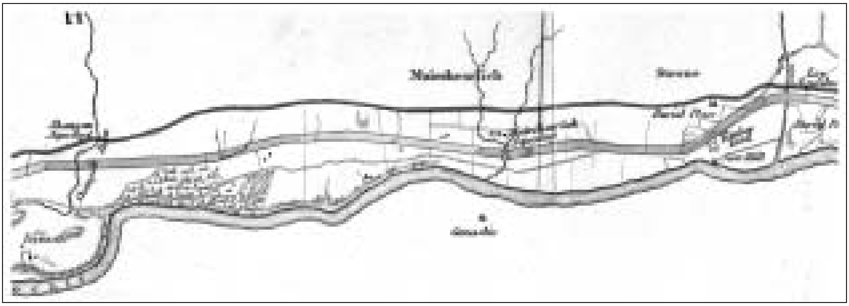


Muirtown Locks and Turn Bridge in ca.1890 [photograph Werner ca.1892]

Severe problems were encountered in 1816 during the excavation for the lock chambers. The base of the masonry for the bottom lock was fixed 24 ft below the water level of Loch Ness in a porous bed of gravel. Three steam-powered portable pumps of 9 hp, 20 hp and 36 hp were needed to keep the lock pit clear of water. The base of rubble-stone masonry was laid on moss to prevent sand being forced upwards through the lock bottom.

The poet Robert Southey visited the locks with Telford in 1819 and wrote in his journal: 'Such an extent of masonry, upon such a scale, I had never before beheld . . . it was a most impressive rememberable scene.'

The flight was completed in 1820. The north-west recess wall of the bottom lock failed in 1857, and in 1882 a steamer rammed one of the lock gates and closed the canal for eight days. Extensive repairs were carried out to the sills in 1984 and further repairs were made to the lock walls and gates in 1995–96. [41, 42]



Above: Caledonian Canal – Shangan to Loy Aqueducts [43 – 6th Report]

31. Loy and Shangan Aqueducts

HEW 0084/04
NN 1492 8177

This stone aqueduct, over the Loy, and an access road, was built from March to October 1806. It was one of five constructed by Simpson & Wilson by 1808 on the 6-mile reach of canal between Banavie Locks and Loch Lochy. Loy Aqueduct had and still has three semicircular masonry spans of 10 ft, 25 ft and 10 ft set in an impressive retaining façade and the tunnels are about 250 ft long. The Shangan Aqueduct of similar construction had and still has three spans of 10 ft. Both were rebuilt as part of the 1843–47 refurbishment. This work was done as a precautionary measure after the Upper Banavie Aqueduct, ½ mile south of Shangan, had collapsed in 1843 emptying this reach of the canal.

There is a water 'let-off' at Strone about 500 yards to the south where the Lochy is close by. It consists of three sluices

Shangan Aqueduct

Willie Johnston

4 ft wide and 3 ft high with sills level with the canal bottom. In Telford's words, 'the water when issuing from the triple sluice falls 9 ft before it strikes the rock over which it tumbles and creates an inundation over the flat land which here intervenes between the line of canal and the River Lockie. No artificial cataract exceeds the fury and foam which this issues from its rocky cavern.' [43, 44]

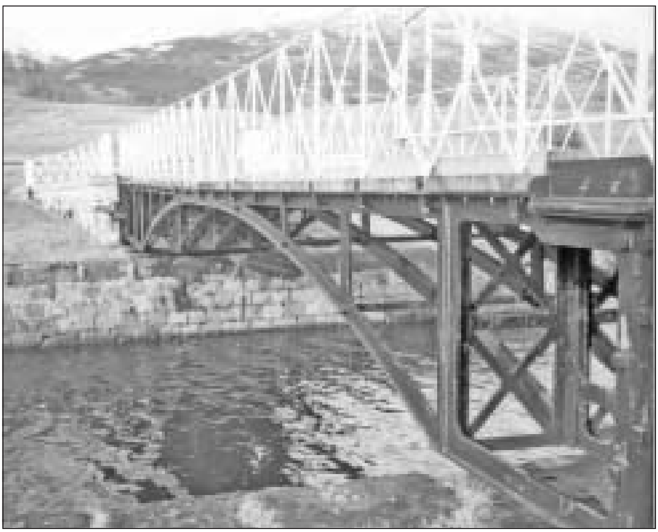
32. Moy Turn-bridge

HEW 0084/05
NN 1624 8263

When planning the canal Telford and Jessop decided to adopt cast-iron turn-bridges, a development of those introduced at the London and West India Docks by 1805. Of several turn-bridges installed over the canal, only that at Moy now remains.

Moy Bridge, erected in 1820, has a span of 40 ft and is 10 ft wide. The ironwork was cast in Wales at the foundry of William Hazledine of Plas Kynaston and the original square-headed nuts and bolts of the period can be inspected. An engraved plan and section exists [40] and a drawing by Thomas Rhodes of a timber version [33], but Telford stated that all the bridges on the canal were cast-iron except the lock-gate footbridges. [41]

The bridge comprises two counter-balanced arms pivoting on horizontal bearings with their ends meeting



Roland Paxton

Moy Turn-bridge

at mid-span to allow road traffic to cross. Until refurbishment in 1995, the counter-balance weights in the back of the frame above the bearings consisted of 3 ft long Jessop plate-rails formerly used for transporting spoil when cutting the canal, one of which is preserved in the ICE Museum at Heriot-Watt University.

The bridge is operated by hand from each side and until recently the bridge keeper had to row across the canal each time the bridge was opened or closed.

33. Mucomer Cut and Bridge

HEW 0084/06
NN 1836 8382
(Bridge)

The half-mile Mucomer Cut, was excavated to allow water to be discharged from Loch Lochy into the Spean and permit the Caledonian Canal to exit from the south-west end of Loch Lochy through a regulating lock at Gairlochy built on the line of the former river bed. As the cut crossed the line of a well-established drove road, and the rocky channel was deep and unfordable, it was necessary to construct a bridge for the passage of beasts.

The bridge, designed by Telford with John Simpson and John Cargill as contractors, was completed in 1813. It had two 52 ft span segmental arches, constructed of coursed sandstone masonry with decorative mock arrow loops at the abutments and piers, to which a third arch of 24 ft span was added later. The roadway of the bridge is 264 ft long with a gradient of 1 in 23.

In the 1960s the channel of the cut was modified when a small electricity generating station was constructed to make use of the water being discharged into the Spean. At this time the bridge was strengthened with mass and reinforced-concrete infill to allow access for construction traffic to the site of the generating station. [45]

34. Neptune's Staircase or Banavie Locks

HEW 0084/07
NN 1134 7695

This flight of eight locks, known as Neptune's Staircase and built by Simpson and Wilson (according to Telford mainly the latter) from 1808–11 with Alexander Easton as resident engineer, was, when built, the longest and most impressive length of masonry on any canal and arguably is still. The

Sir William McAlpine Bt

Neptune's Staircase during renovation 1999

locks, of similar dimensions to those at Fort Augustus, 180 ft long × 40 ft wide, form a stretch of solid masonry 1500 ft long and raise the canal 64 ft from its level at Corpach Moss to the Gairlochy reach.

Telford forecast that construction would take four years and these locks were one of few works on the canal to be completed early. The haste of construction and possible management shortcomings may have been factors in local collapses of the lock walls in 1829 and 1839. In 1844 all the gate recess walls had to be rebuilt.

Passage through the flight of locks is slow, as vessels have to await the completion of the passage of any vessel coming in the opposite direction. In 1845 construction of a passing place midway was considered but was found impractical. Twelve lock keepers were originally required to work the locks, but after mechanisation in the 1960s only two are necessary.

In 1929 a serious accident occurred when a vessel crashed through the gates of the top lock and was swept into the lock below. The locks being suddenly emptied caused the masonry walls to bulge and they had to be rebuilt. This caused the closure of the canal for three months. In 1998–99, during the winter closure of the canal, the lock walls were stabilised and the gates replaced.

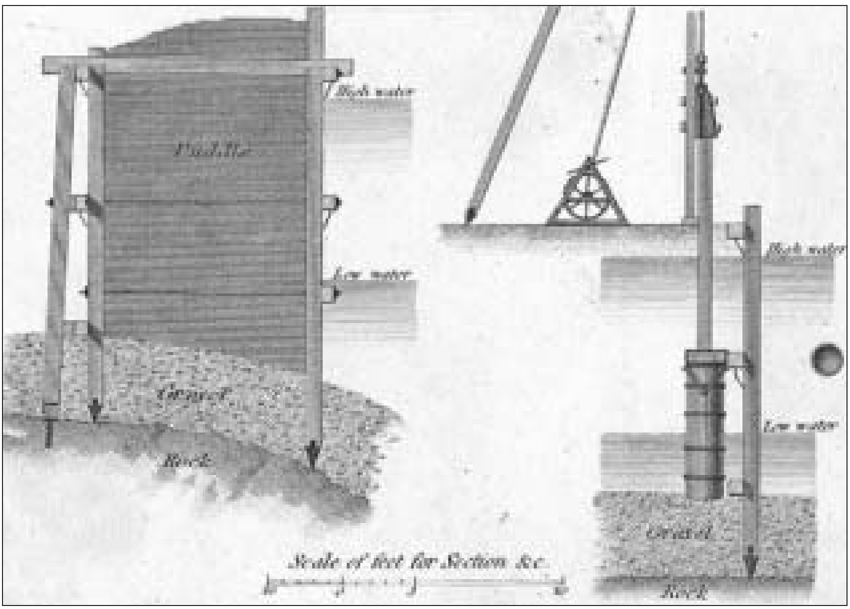
35. Corpach Sea-lock

HEW 0084/08
NN 0956 7663

The construction of this tide lock at Loch Linnhe from 1808–12 called for exceptional engineering skill and provides another classic foundation case study differing from that already described at Clachnaharry. This lock had to be founded on an underwater rock at a point where the lock sill would be covered by 21 ft of water at high water of neap tides. Water-tight mounds faced with rubble-stone were carried from the shore beyond the end of the lock-pit, between which a wooden coffer-dam, with 14 ft thick clay puddle wall, was constructed.

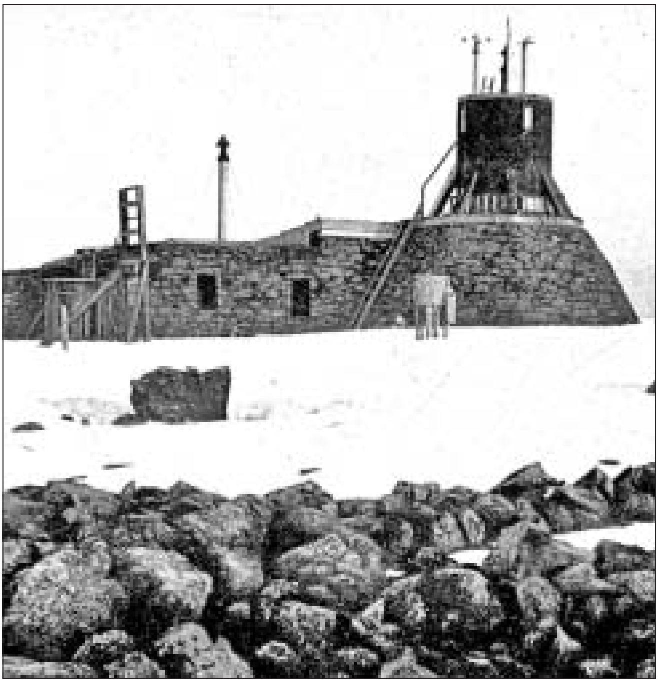
This difficult and unprecedented operation involved dowelling the framing piles into the rock through 8 ft of silt and gravel by means of a hooped cylinder and piling engine with an 1008 lb ram. Steam-powered pumping was used to de-water the excavation, an early instance of such practice on a large scale.

Corpach Sea-lock – construction details [46]



Roland Paxton

Corpach Sea-lock as extended in 1964 and Ben Nevis



Ben Nevis Observatory 1904 with Stevenson thermometer screen [postcard ca.1904]

The contractors were Simpson and Wilson, chiefly the latter. The resident Engineer was John Telford who died in 1807 and was succeeded by Alexander Easton. [46]

From here on a clear day it is possible to see the site of Thomas Stevenson's highest project, the observatory on Ben Nevis which he planned in 1874 as Secretary of the Scottish Meteorological Society. It was completed in 1883, flourished for two decades, and closed for lack of funding in 1904.

36. Bridge of Oich or Victoria Bridge, Aberchalder

HEW 0888
NH 3377 0361

This economical suspension bridge over the Oich was erected by James Dredge of Bath in 1850, and tastefully refurbished by Halcrow-Crouch and Morrison Construction for Historic Scotland in 1997, attracting a conservation award from the Saltire Society in 1998 on the recommendation of the Panel for Historical Engineering Works. The Panel had encouraged Historic Scotland to refurbish the bridge following the sudden demolition of Dredge's Ness Islands bridges in 1990. Victoria Bridge carried main

Bridge of Oich ca.1970 before refurbishment

Roland Paxton

Victoria Bridge, Fort William 1849–1947 [postcard ca.1910]

road traffic until bypassed by the present concrete bridge in 1932, after which it ceased to be adequately maintained and was eventually closed. Its state before refurbishment can be seen in the picture.

The bridge has a span of 155½ ft and two main chains 17 ft apart, comprising a series of rods varying from 6 ft–7½ ft in length and ⅞ in. nominal diameter, which pass over 18 ft high masonry towers to meet at the bridge centre where they are anchored to the deck. At the towers these chains consist of 12 rods in parallel, reducing progressively in number towards mid-span. A similar arrangement exists on the landward side of the towers, with the chains being anchored below ground level. Trussed wrought-iron transoms support the decking transversely.

By reducing the cross-sectional area of the main chains towards mid-span and his suspender arrangement, Dredge produced a light and yet strong bridge, almost certainly erected without scaffolding, in 'barely two months of workable time. The whole of the ironwork about twenty tons was forged and fitted upon the spot, with the exception of a small portion of metal castings, and the Highlanders in the locality of the bridge, with the exception of three smiths and a few Aberdeen masons, did the whole of the work; and the bridge was asphalted, painted, gravelled and completed, at less cost than that of a rude timber bridge.'

Dredge constructed 50 bridges of this type from 1837–54 of which this is now the best surviving example in Scotland. One of his Ness Islands footbridges, Inverness, dismantled in 1988, was re-erected in Whin Park, Inverness, but with its deck propped (4-16).

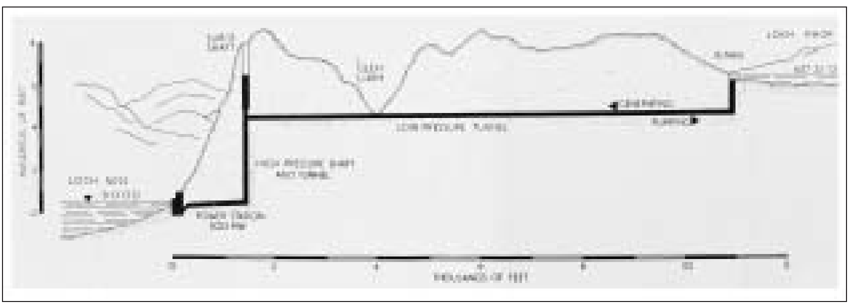
Dredge's largest span Scottish bridges were over the Clyde at Blantyre and Victoria, Lochaber, Fort William, over the Lochy, which was of 250 ft span and 17 ft wide, replacing the ferry. It was erected in 1849 for a cost of less than £2000, compared with £8000 for a stone bridge, and served for 98 years (see view). [47–49]

37. Foyers Power Station

HEW 2537
NH 4970 2105

Foyers is a 300 MW combined conventional and pumped storage project which redeveloped the original catchment of Britain's first sizeable hydro-electric project built on the south-east side of Loch Ness in 1895 by the British Aluminium Company. The company's former power station building still exists.

The new scheme was promoted by the North of Scotland Hydro-Electric Board in 1968 and work began in 1969. The scheme utilises the 586 ft difference in head between Loch Mohr and Loch Ness. When the station is generating, water flows from Loch Mohr through 2 miles of tunnels and shafts to the power station on Loch Ness-side. When pumping, the two 150 MW turbines are driven in reverse to replenish Loch Mohr. This is done using surplus electricity from elsewhere when the load on the system is low. [50]



Foyers Hydro-Electric Project – operational diagram [50]

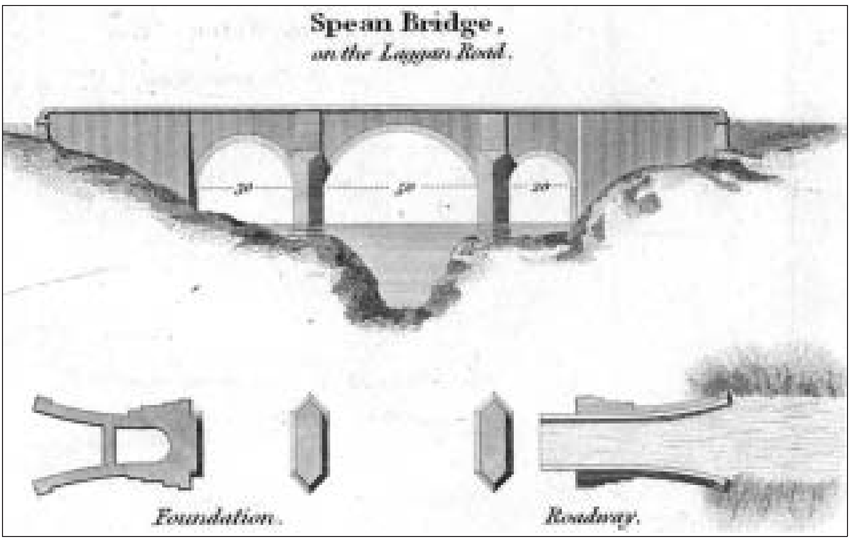
British Aluminium Company's former power station building 1895

38. Spean Bridge

HEW 2538/01
NN 2219 8171

Spean Bridge, with its asymmetrical side arches, an unusual practice for Telford but dictated by ground conditions, was on the longest road built by the Commissioners east of the Great Glen. The 42-mile Laggan Road from the Badenoch Road, now the A9, to Fort William was built from 1810–18 for what the commissioners rewarded as '£23 293; an appalling sum'.

Spean Bridge – elevation and plan [51]



High Bridge [postcard ca.1930]

Incomplete work was swept away twice during construction before the contract for an enlarged bridge was completed by John Wilson in 1815 with spans of 30 ft, 50 ft and 20 ft. It was widened in 1932. [51, 52]

39. High Bridge, Spean Bridge

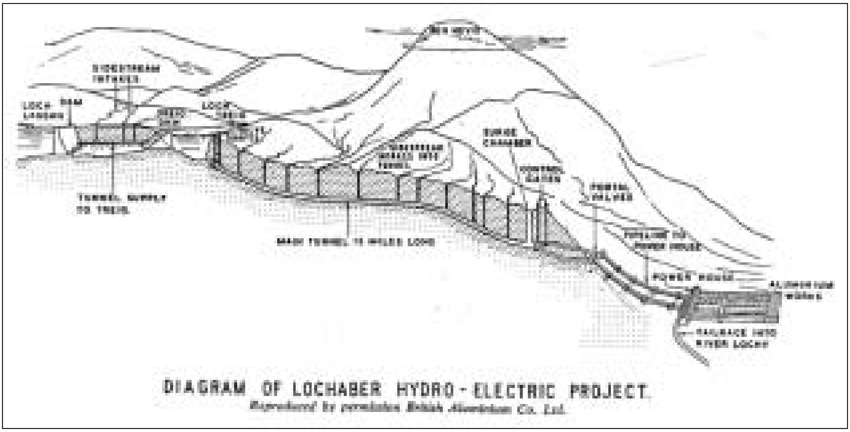
HEW 2539/01
NN 2006 8211

This bridge, now ruinous, carried the military road from Fort William to Fort Augutus and Inverness over the steep sided valley of the Spean. It had three spans of 40 ft, 50 ft and 40 ft, and crossed about 80 ft above river level. The bridge, constructed under General Wade's direction in 1736–37, was one of the most spectacular military bridges. By 1908 it was becoming ruinous and a light iron truss had been placed across the centre span. The masonry arch collapsed in the 1930s but the piers remain and the truss is still in place.

40. Lochaber Hydro-Electric Works

HEW 1434
NN 1277 7510

The Lochaber Power Company was established by Act of Parliament in 1920 to produce aluminium using electric smelters. The company was authorised to develop a catchment area of 303 square miles in the vicinity of Ben Nevis



British Aluminium Co. Ltd

Lochaber Hydro-Electric Project

which had, in places, a rainfall of 160 in. and was admirably suited for the site of a hydro-electric scheme.

The runoff was collected in two reservoirs, Loch Laggan and Loch Treig, connected by a tunnel $2\frac{3}{4}$ miles long and 15 ft diameter. The supply of water was supplemented by the diversion of the upper waters of the Spey into Loch Laggan from a dam 900 ft long and 30 ft high, built 2 miles above Laggan Bridge.

The most remarkable feature of the scheme was the construction of a pressure tunnel 15 miles long beneath Ben Nevis, from Loch Treig to the entry with steel pipes situated 600 ft above the power station at Fort William.

In driving the tunnel, four vertical access shafts were sunk and seven horizontal adits driven to allow 22 separate working faces, all in solid rock. The tunnel has a roughly horseshoe cross-section with an equivalent diameter of 15 ft. Eleven streams on Ben Nevis were dammed and their flows taken into the tunnel through three construction shafts adapted for the purpose.

The tunnel drive began in 1926 and was completed in 1930. The work required the construction of a temporary hydro-station to power construction equipment, an extensive network of 3 ft narrow gauge railway to transport men and materials, and a reinforced-concrete pier 200 ft long on Loch Linnhe which later became permanent. At the height of the work 3000 men were employed. The consulting engineer was William Halcrow and the main contractor, Balfour Beatty & Co. Ltd. [53, 54]

41 and 42. Loch Laggan and Loch Treig Dams

HEW 1433
NN 3725 8075

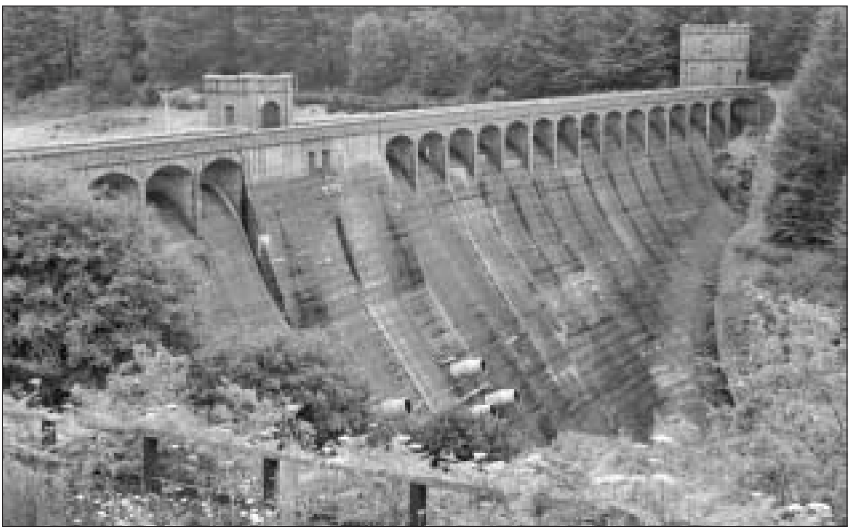
HEW 1435
NN 3479 7718

Work on the second stage of the Lochaber scheme included building dams to increase the water storage capacity of both Loch Treig and Loch Laggan.

The level of Loch Treig was raised 35 ft by the construction of a 400 ft long rock-fill dam built across the river Treig about $\frac{1}{4}$ mile from the north end of the Loch. This was an early example of a rock-fill dam, and it accorded its engineer international attention. The use of such dams is limited in Highland Scotland because the rocks locally available are often unsuitable schists. The dam, in raising the level of Loch Treig, became the principal reservoir of the scheme and necessitated the diversion of the West Highland Railway for a distance of about $1\frac{1}{2}$ miles where it skirted the Loch.

The Laggan Dam is easily seen from the A86 road as it descends to Spean Bridge from Moy Lodge. The dam, a massive concrete gravity structure 700 ft long and 130 ft high, was built across the River Spean $4\frac{1}{2}$ miles below the then outlet to Loch Laggan and increased the length and storage capacity of the loch without raising its water level. This obviated the need to divert roads and to inundate valuable property.

Loch Laggan Dam



Roland Paxton

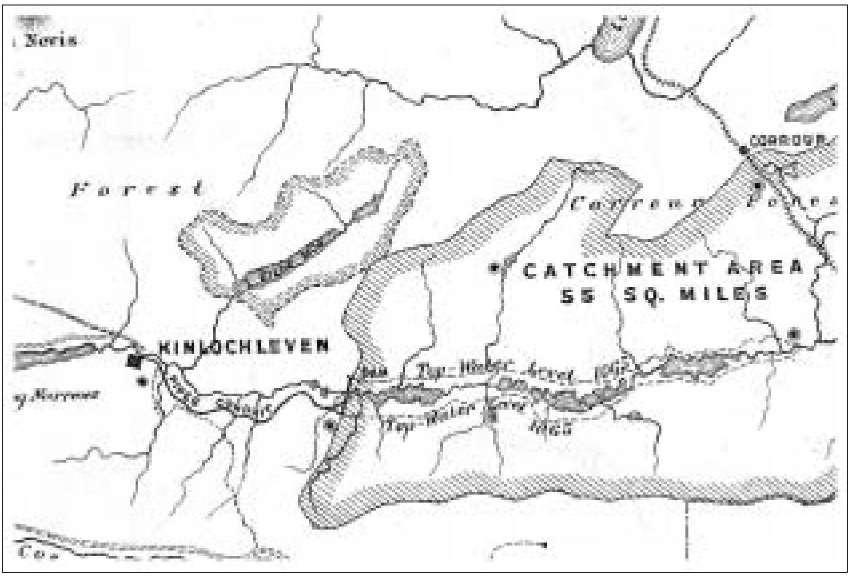
About 1000 men were employed on the construction of the dams. Those working on the Laggan Dam had accommodation at Roughburn camp adjacent to the site whilst those working at Loch Treig were housed at Fersit halfway between the dam sites. Work on both dams was completed in 1934. The consulting engineer was William Halcrow, and the main contractor was Balfour Beatty & Co. Ltd. [55, 56]

43. Kinlochleven Hydro-Electric Works and Blackwater Dam

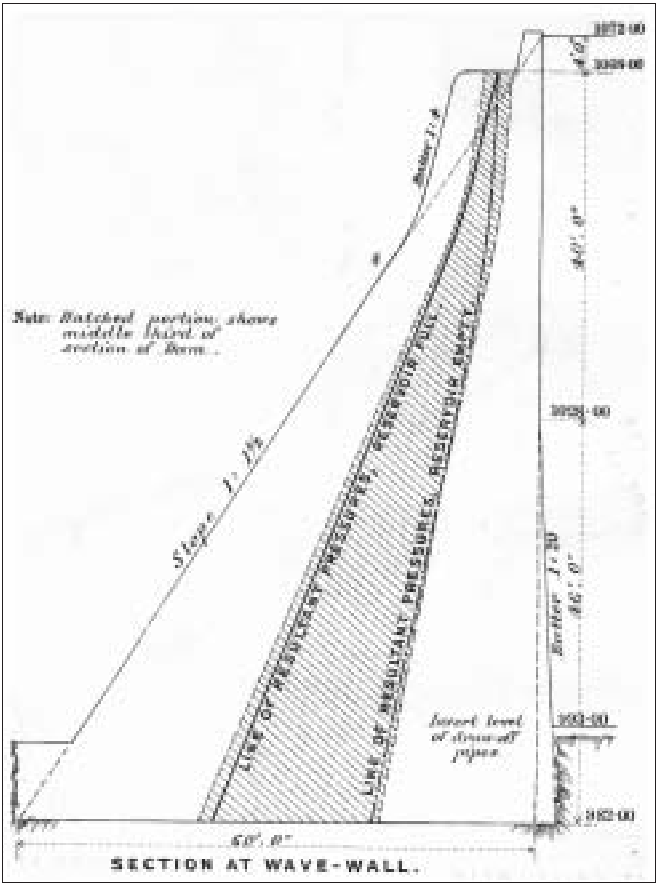
HEW 0611/0611
NN 1895 6184
(Works)

The Loch Leven Water Power Acts of 1901 and 1904 authorised the generation of electricity for the production of aluminium in the West Highlands. Work on what was the first major hydro-electric project in Britain began in 1905 by harnessing the water power available from the western section of the Blackwater chain of lochs stretching from Rannoch Moor to Kinlochleven and was completed in 1909 at a cost of about £600 000.

The Blackwater was dammed to create an 8-mile long reservoir drawing on a catchment area of about 55 square



Kinlochleven Hydro-Electric Works catchment area [58]



Blackwater Dam cross-section [58]

miles. Water from the dam was led to a generating station at the head of Loch Leven which supplied electricity to the aluminium smelters and associated works. The Pelton wheel turbines produced an aggregate power of 30 660 hp with an generator output of 21 088 kW.

The main feature of the hydro scheme was a mass concrete gravity dam 3112 ft long and 86 ft high. It was necessary to amend the cross-section of the dam when it was found that the unit weight of concrete made with locally obtained aggregate was less than that used previously in calculations. The dam profile was amended to give a heavier section with a base 62 ft wide and a factor of safety against overturning of 2.28.

The dam, with a storage capacity for 24 billion gallons, was connected to the 25 MW generating station through a closed concrete conduit $3\frac{1}{2}$ miles long and six steel pipes each 39 in. diameter and 935 ft long.

The transport of materials to site from the wharf at Loch Leven was by means of a cableway $6\frac{1}{2}$ miles long with trestles from 10 ft–130 ft high and spans from 100 ft–1000 ft driven by a 250 hp Pelton wheel. A railway between the same termini followed the general contour of the valley except for two rope inclines of 200 ft and 600 ft rise. This and the derricks at the dam were electrically driven, the power being obtained from a temporary hydro-electric plant provided by the contractor.

The works were designed by Thomas Meik and Sons with Sir A. R. Binnie consulting and the resident engineer A. H. Roberts. The main contractor was Sir John Jackson Ltd, and during construction between two and three thousand navvies laboured in rain-soaked conditions. During one period of 24 hours 5.59 in. of rain fell at Kinlochleven drowning the inner shell dam by 15 ft but it stood perfectly. Robert McAlpine & Sons constructed the jetty and laid the water mains throughout the village. [57, 58]

44. Spey Bridge, Newtonmore

HEW 1765
NN 7088 9802

The roadway across this triple-span bridge falls on a gradient of 1 in 25 from the south and limits the headroom of the arches to create an asymmetrical structure. The bridge, built in 1925–26 on the A9 road improvement (4-17) carried the road over the Spey but it has since been bypassed. It was designed by Sir Owen Williams in conjunction with the architect Maxwell Ayrton, and the contractors were Sir Robert McAlpine and Sons. Other examples of their bridge work exist at Dalnamein, Tomatin (4-17), Crubenmore and Loch Alvie.

It is a traditional arched bridge with hearting constructed of reinforced concrete in lieu of masonry and founded on rock outcrops. The largest span is 107 ft with the adjacent spans reducing to 87 ft and 67 ft respectively. The fill material is retained by spandrel walls, tapering with pronounced vertical curvature from 5 ft thick at their base to 1 ft at the parapet. The vertical expansion joints in the spandrels are strongly expressed as an architectural feature. [59, 60]

Military Roads

HEW 2539

Between the 1715 and 1745 rebellions, more specifically between 1725 and 1740 when General George Wade was commander of the government forces in Scotland, a considerable road-building programme was implemented from north-central Scotland through the Highlands to the forts in the Great Glen. This came about because, after the 1715 rebellion, the army could not penetrate further into the Highlands than Blair Atholl.

The first line of road, built in 1726, connected Fort William and Fort Augustus, and was continued during the following year to Fort George, Inverness and via a variant route in 1732, including White Bridge, on the east

Military roads map [63]

side of Loch Ness. By 1734 roads had been made from Dunkeld over the Drumochter Pass to Dalwhinnie, the barracks at Ruthven and northward over the Slochd Pass to Inverness. Also, a road from Crieff, via Aberfeldy Bridge (*Civil Engineering Heritage Scotland – Lowlands and Borders* 6-3) to join the Dunkeld road at Dalnacardoch, and from Dalwhinnie north via the Corrieyairack Pass at an elevation of about 2500 ft to the military road just south of Fort Augustus. High Bridge erected in 1736–37 was the last large bridge of the Wade era (4-39).

Subsequently two lines of military road were built by Wade's successor, Major William Caulfeild, from Crianlarich via Tyndrum and Kinlochleven to Fort William (1749–50) and from Perth via Braemar, Tomintoul and Grantown (4-6) to Fort George (1752–55). Other roads were made west from Fort Augustus to Bernera and from Dingwall to Poolewe, including Little Garve Bridge (5-19).

The military roads were constructed by officers and often hundreds of soldiers each summer, but were soon destroyed by wear and tear and severe climate effects. The roads were usually constructed of local stone and gravel, 16 ft wide with a 10 ft wide roadway with drainage where practicable.

From a survey by Major Fraser in 1785, when Highland military roads were at about their zenith in development terms, there were 682 miles and 938 bridges with 1031 arches. The annual amount spent on the military road maintenance by government from 1760–79 averaged about £6600, reducing to an average of about £4100 from 1798–1813.

The main lines of military road east of the Great Glen, the basis of much of the modern main road network, came under the Highland Roads and Bridges Commission in 1814 for repair and maintenance under Telford's direction. These roads amounted to 283 miles by 1821, less than half of the network in 1785. [61–63]

45. White Bridge

HEW 2539/02
NH 4891 1537

This bridge, 9 miles north-east of Fort Augustus over the Fechlin and sometimes known as '9-mile bridge', was constructed in 1732 on Wade's later Great Glen road. It carried the road connecting the military garrisons at Inverness and Fort Augustus on a single tall semicircular arch of 40 ft span, founded on rock outcrops.

RCAHMS: J Close-Brooks

White Bridge

Unlike most Highland bridges the arch-ring is of squared masonry with a decorative keystone and a string course projects through the spandrels and follows the line of the roadway. The spandrels are of rubble masonry. Major William Caulfeild, road surveyor under Wade, probably supervised the work of construction.

The bridge has now been bypassed. The nearby Whitebridge Hotel is built on the site of a former King's house used by the officers superintending road-making.

About 6 miles north on the same road is Inverfarigaig Bridge, also built in 1732, which cost £150. It has a span of 37 ft, a width of $11\frac{1}{2}$ ft, with the roadway crossing about 24 ft above the often turbulent river. The bridge is disused and deteriorating since being bypassed by the present concrete bridge in the 1960s.

46. Dalwhinnie to Fort Augustus Road (Corrieyairack)

HEW 2539/03
NN 4280 9842

This 28-mile long road is a branch from the main line of General Wade's military road from Crieff to Inverness and is notable for the engineering work required to take it over the high ground of the Corrieyairack Pass where it rises to an elevation of 2507 ft.

The road commenced at Dalwhinnie in Glen Truim and ran northward, rising to 1250 ft before dropping down into the Spey valley to cross the river at Garva or St George's Bridge, 150 ft long with two 40 ft span arches. It then followed the valley of the Spey, and at Melgarve began to climb more steeply, 1000 ft in $2\frac{1}{2}$ miles, before ascending 500 ft to the summit of the pass by a notable series of traverses 70–80 yards long that were buttressed on the outside by drystone walls 10 ft–15 ft high. Having crossed the summit plateau, the road descended 1500 ft in 5 miles through Glen Tarff before reaching Fort Augustus. It was constructed by six working parties of soldiers, about 500 men, with work being commenced in April 1731 and being completed in October of that year. Up to the year 1732 this road, including five bridges, had cost £3821.

By 1798 the road had fallen into disrepair and was described as 'rough, dangerous and dreadful, even for a horse', but it was still being used by wheeled vehicles. The pass ceased to be used as a drove route when the West Highland Railway reached Fort William in 1894, but it subsequently found a use as an access route when the Hydro Board constructed its transmission line through the pass. The road is now a route for walkers, and with the passage of time the number of traverses has been reduced from 17 to 13 and only traces of the buttresses remain. [61, 64]

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