EHC

NOMINATION OF THE

HAWKESBURY RIVER RAILWAY BRIDGES 1889 - 1946 and 1946

AS A

Centenary of Federation NATIONAL ENGINEERING LANDMARK

1946 bridge, left, still in service, 1889 bridge right, demolished.

Prepared for the
Engineering Heritage Committee
Sydney Division, I E Aust
by
Don Fraser and Ross Best
March 2001

CONTENTS

STATEMENTS OF SIGNIFICANCE

The first Hawkesbury River Railway Bridge, 1889-1946.

1. It was the largest bridge project in colonial Australia and remained so until the completion of the Sydney Harbour Bridge in 1932.

2. The bridge completed the railway link between four mainland colonies, New South Wales and Queensland north of the Hawkesbury River and New South Wales, Victoria and South Australia south of the river.

3. At the opening of the bridge on 1 May 1889, New South Wales Premier, Sir Henry Parkes used the symbolism of the railway union to press for the Federation of all the colonies of Australia.

4. Estimates by John Whitton, Engineer-in-Chief for the New South Government Railways, for a double track railway at the site caused the Colonial Government to take the unusual step of calling for world wide tenders.

5. Much to the chagrin of John Whitton, an American company, The Union Bridge Company, won the contract, a significant event in a British dominated colony.

6. The tender price of £367,000 is equivalent to nearly $50 million in $Y2000.

7. The size of the project received international attention with regular reports in renowned engineering journals.

8. The caissons for the piers were sunk to depths of around 180 feet below water level, the deepest bridge foundations in the world at the time.

9. The superstructure saw the largest application of American style pin-jointed steel trusses in Australia.

10. Sub-contractors were from the USA, England and Scotland with Louis Samuel of Sydney being successful with stone facing of the piers and abutments, the only surviving elements on site.

Unfortunately there were design and construction faults that prevented the bridge from achieving the longevity of service that was anticipated. The superstructure was demolished after completion of the new bridge in 1946. However, there are bridging components still in use at a number of railway locations in New South Wales and structural elements have been salvaged from a steel building at Chullora, now demolished. The original piers and abutments are still prominent on the downstream side of the 1946 bridge.

Collectively, these items evoke memories of one of the most significant engineering works in the history of Australia.

The second Hawkesbury River Railway Bridge, 1946 and still in service.

1. It was one of the largest bridge project in Australia during the 20th century.

2. It was approved and built as an essential wartime (World War II, 1939-1946) project.

3. Its design, fabrication and construction were entirely the work of the engineers, workshop tradesmen and field staff of the Way and Works Branch, New South Wales Government Railways, recognising the faults in the first bridge and using their own and international experiences to build a bridge of strength and durability.

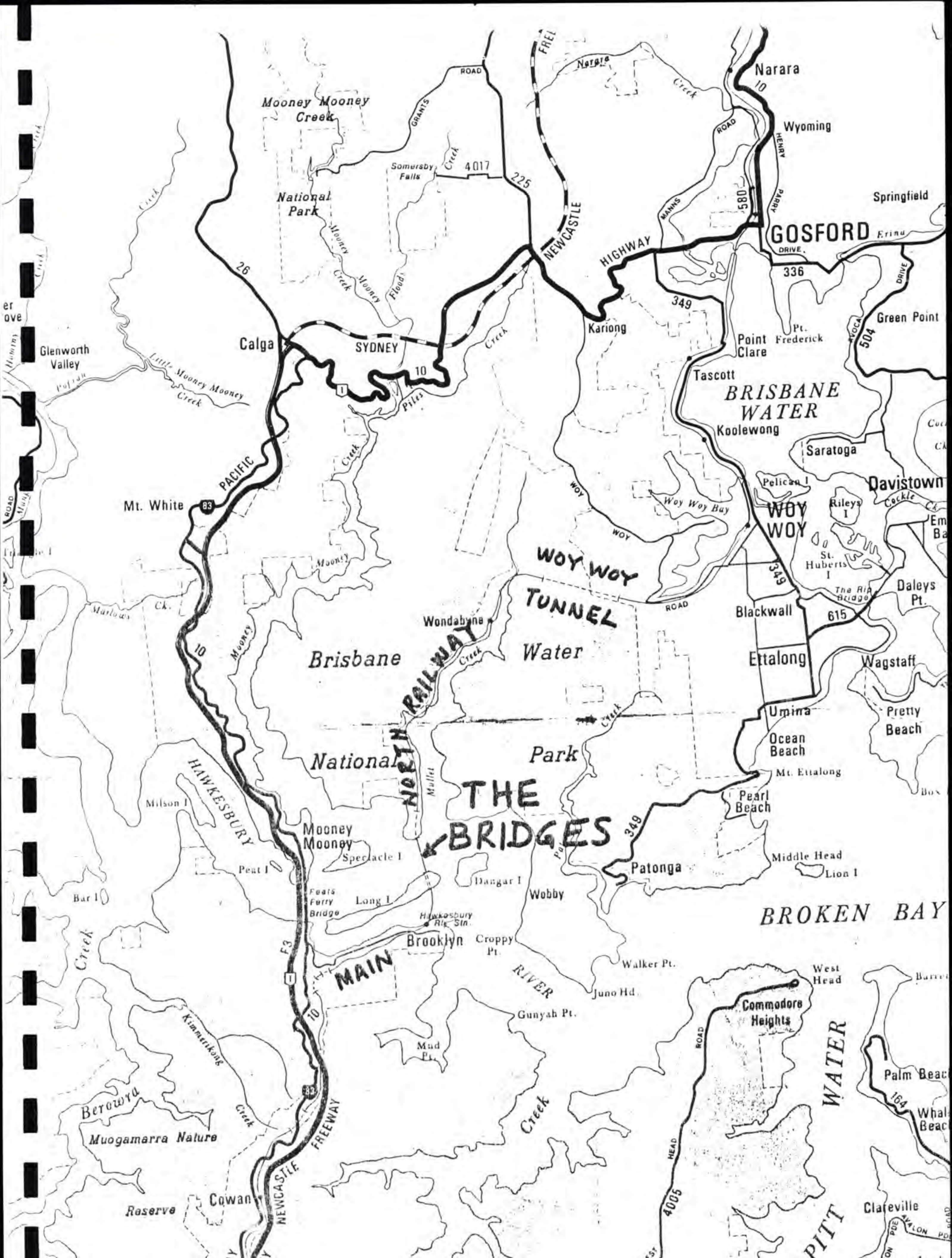
4. It was a significant achievement for the local engineering expertise and was recognised as a bridge of international merit.

5. Even though it cost £1,400,000 (three times the old bridge) it has proved to be a far more cost effective structure, with no threat to its longevity.

6. Built upstream from and parallel to the old bridge, it is founded on the same material and at the same depth, so its piers are also among the deepest bridge foundations in the world.

7. The bridge consolidated the established railway link along the east coast of Australia with enormous social and commercial benefits to the nation.

8. The bridge has been included in the S170 Register of the Rail Infrastructutre Corportion as being of State Significance.



WOY WOY TUNNEL
THE BRIDGES
NORTH RAILWAY
MAIN
Narara
Wyoming
Springfield
GOSFORD
Erina
Green Point
Davistown
Saratoga
Koolewong
Tascott
Point Clare
Pt. Frederick
BRISBANE WATER
Kariong
Calga
SYDNEY
NEWCASTLE
HIGHWAY
PACIFIC
Mooney Mooney Creek
Somersby Falls
National Park
Glenworth Valley
Little Mooney Mooney Creek
Mt. White
Wondabyne
Brisbane Water National Park
Woy Woy Bay
WOY WOY
Pelican I
Rileys I
St. Huberts I
The Rip Bridge
Daleys Pt.
Blackwall
Ettalong
Wagstaff
Umina
Ocean Beach
Pretty Beach
Mt. Ettalong
Pearl Beach
Patonga
Middle Head
Lion I
BROKEN BAY
HAWKESBURY
Milson I
Mooney Mooney
Spectacle I
Peat I
Dangar I
Long I
Peats Ferry Bridge
Hawkesbury Riv. Stn.
Brooklyn
Croppy Pt.
Wobby
Walker Pt.
Juno Hd.
RIVER
Gunyah Pt.
Mud Pt.
West Head
Commodore Heights
Palm Beach
Whale Beach
Clareville
PITT WATER
Berowra
Muogamarra Nature Reserve
Cowan
NEWCASTLE FREEWAY
Kimmerikong Creek
Bar I
F3
GRANTS ROAD
MANNS ROAD
HENRY PARRY DRIVE
WOY WOY ROAD
AVOCA DRIVE
ROAD
HEAD
4005
349
336
504
580
615
225
4017
26
10
83
164

Commemorative Plaque Nomination Form

Date: March 2001

To:
Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
Engineering House
11 National Circuit
BARTON ACT 2600

From:
Engineering Heritage
Committee
Sydney Division

The following work is nominated for a :-

National Engineering Landmark - Centenary of Federation

~~Historic Engineering Marker.~~

Name of work .... The First Hawkesbury River Railway Bridge, memories & relics

Location .... Piers across the river north of Brooklyn and a display at Brooklyn in a new Council-sponsored Federaton Park.

Owner .... State Rail Authority.

Owner's response .... Letter of agreement attached.

Access to site .... Display in new Federation Park, Brooklyn, NSW.
Piers can be seen from (1) a foreshore walk, (2) any water craft or (3) from a train on present bridge.

Future care and maintenance of the work ..... Status of piers monitored regularly by State Rail Authority.

Name of sponsor .... Hornsby Shire Council

....
Chairperson of nominating committee

ADDITIONAL SUPPORTING INFORMATION

Name of work .... First Hawkesbury River Railway Bridge.

Year of construction or manufacture ..... 1889.

Period of operation .... 1889 - 1946.

Physical condition .... Relics in good condition.

Engineering Heritage Significance :

Technical, scientific value .... Largest application of American bridge technology.

Historical value .... Largest colonial bridge project.

Social value .... Important railway link & symbol of Federation.

Landscape or township value ...... Stone piers have visual impact from present bridge.

Rarity .... When in service, greatest use of pin-jointed trusses.

Representativeness .... Not applicable.

Contribution to nation or region ..... See social value.

Contribution to engineering .... Helped establish the change to American bridges.

Persons associated with the work- John Whitton, Henry Deane, Louis Samuel.

Integrity .... Only applicable to the surviving piers.

Authenticity .... Only applicable to the surviving piers and the truss elements in the new Federation Park.

Comparable works (a) in Australia .... Whipple trusses at Nowra, NSW.

(b) overseas ..... Many projects of this type and scale.

Statement of Significance, its location in the documentation .... see Contents

Citation (70 - 80 words) - location in the documentation ..... see Contents

Attachments to submission (if any) ...... Copy of a 1983 (returnable) video of the history and construction of this bridge.

Proposed location of plaque .... On a truss member in Federation Park.

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Engineering House
11 National Circuit
BARTON ACT 2600

From:
Engineering Heritage
Committee
Sydney Division

The following work is nominated for a :-

National Engineering Landmark - Centenary of Federation

~~Historic Engineering Marker.~~

Name of work .... The Second Hawkesbury River Railway Bridge, extant.

Location .... Across the river north of Brooklyn, New South Wales.

Owner .... Rail Infrastructure Corporation.

Owner's response .... Agreement achieved through inclusion of the bridge in the S170 Register of railway underbridges.

Access to site .... Bridge can be seen from the foreshore north of Brooklyn.

Future care and maintenance of the work ..... The bridge is regularly maintained.

Name of sponsor .... Hornsby Shire Council

....
Chairperson of nominating committee

ADDITIONAL SUPPORTING INFORMATION

Name of work	Second Hawkesbury River Railway Bridge.
Year of construction or manufacture	1946.
Period of operation	55 years and still in service.
Physical condition	Good.

Engineering Heritage Significance :

Technical, scientific value	Large group of riveted steel trusses.
Historical value	Replaced the first Hawkesbury River Rly Bridge.
Social value	Consolidated the important colonial railway link.
Landscape or township value	Good view from Kangaroo Point in western sun.
Rarity	A rare combination of truss types and sizes.
Representativeness	An excellent example of heavy duty steel trusses.
Contribution to nation or region	Enormous social and commercial benefits to Nation.
Contribution to engineering	Demonstrated high standards of local engineering.
Persons associated with the work-	Engineers of Way and Works Branch, NSWGR.
Integrity	Retains its original fabric.
Authenticity	The bridge is as originally built.
Comparable works (a) in Australia	Nil, but many equally important rly bridges.
(b) overseas	Many projects of this type and scale.

Statement of Significance, its location in the documentation .... see Contents

Citation (70 - 80 words) - location in the documentation ..... see Contents

Attachments to submission (if any) ...... Nil.

Proposed location of plaque .... On a truss member frm the 1889 bridge in Federation Park, Brooklyn, N S W.

STATE RAIL
Rail Estate Heritage
4th Floor, Transport House
11-31 York Street,
SYDNEY

Tel 9224 3026
Fax 9224 3544

6th November, 2000

TO WHOM IT MAY CONCERN

State Rail supports the initiative by the Institution of Engineers to affix a heritage plaque at the site of the former Hawkesbury River railway bridge, built under the administration of John Whitton.

Stuart Sharp
HERITAGE ADVISER

THE HAWKESBURY RIVER RAILWAY BRIDGES

NATIONAL ENGINEERING LANDMARK for the CENTENARY OF FEDERATION

DRAFT WORDS FOR THE INFORMATION PLAQUE

I E Aust
Logo

HAWKESBURY RIVER RAILWAY BRIDGES

The first railway crossing completed in 1889 by the Union Bridge Co., USA was the largest bridge project in colonial Australia and used American pin-jointed trusses on the deepest piers in the world. It enabled the linking by rail of South Australia, Victoria, New South Wales and Queensland, and was used by Sir Henry Parkes as a symbol in his campaign for federation of the Australian colonies. Deterioration of the piers and load limitations led to its replacement. The new structure completed in 1946, was entirely the work of the Way and Works Branch, New South Wales Government Railways. (100 WORDS)

Dedicated by
The Institution of Engineers, Australia
and Hornsby Shire Council.
2001 - The Centenary of Federation

HISTORICAL DOCUMENTS

Extract from *Sir Henry Parkes' speech* at the opening ceremony for the 1889 bridge

Extract from *Railways and Federation* by Ferry and Pennay

Extract from *Hornsby Advocate*

I E Aust paper *The Hawkesbury River Railway Bridge (1886-1946)* by King and Fraser

I C E paper *The New Hawkesbury River Railway Bridge, New South Wales, Australia* by A C Fewtrell

Extract from *Bridges Down Under* by Don Fraser

felt to be overwhelm- the last of the old taken up. In the Southern was universal south of Ohio, and rs, made preparations for a tives and cars were so con- could be easily effected; and the gauge on 10,000 miles of in. within a week. The re- mileage at the end of 1885 of cent. were of 4ft. 8½in. cent. larger gauges, and ; and the 4ft. 8½in. gauge of the world. and inconvenience, another e considered,—viz., the strategic ry at a moment's notice to men, with guns, ammunition. Under present circumstances unloading places and duplicate this might expose the country nclusion, all I should venture uestion of a uniform gauge though one or more colonies the temporary inconvenience share in the cost. And we ery hour that slips by, every built, increases the difficulties Large things spring from t be that the union of these men desire, may be brought nge of practical politics by the necessity—a uniform railway ustralia. (Cheers.)

proposed the next toast,— He said: My Lord and Gentle- entrusted to me is one which ior to anything that has ever these great colonies. (Cheers.) aggeration of language, assembled rence which has more interest, of the future, than anything place in our history. communication by railway bind the whole population hain. (Hear, hear.) The unrolled may be said to be one of The memories of the past the younger men here on the banks of this nores, a little further up than t Australian settlement took colonisation was confined a few stretches in the county on the shores of these waters ack between the aboriginals place. A little later the hent took place, and then men and women of which, there are few remaining. kesbury settlers were known d manly proportions. They

poem on the greeting of the engines. He made the engine that came from the old States boast of how he had brought the intelligence of Europe and the riches of science and wisdom from the old part of America to the new, but the engine that came from the Pacific shore replied—

> "All the Orient, all Cathay
> Find through me the shortest way,
> And the sun you follow here
> Rises in my hemisphere."

How true it was that, for the first time in the earth's history, the meeting of those engines, after passing the Sierras on the one side, and coming from the old States and prairies on the other, brought together the one kiss of peace, as it were, of the brothers of all the world, and of all old countries and new—(cheers)—all the old histories of the past and new inventions of the present. You will remember that we in New South Wales are the central power in this railway system, and we are to-day, as it were, marrying the north to the south, and the marriage takes place at this board. (Cheers.) We are really a central power, and Bret Harte, speaking of the Central Railway engine, says:—

> Said the Central, "I'm Pacific,
> But, when riled, I'm quite terrific.
> Yet to-day we shall not quarrel,
> Just to show these folks this moral,
> How two Engines—in their vision—
> Once have met without collision."

(Cheers and laughter.) Now, will not this be allowed to remain in the mind of every man here—that we met to celebrate the opening of this great bridge in peace, in friendship, and in friendly pride. We have here a representative of the great Government to our south and of the great Government to our north, and why should not this occasion be an emblem of our future relations? If the engines meet to-day with this special greeting, why should we not shake hands, and be knit together in bonds that cannot be sundered, and forget those things which have created jars that can be easily removed. It is said that the time has arrived for the political federation of these colonies. (Hear, hear, and "No, no.") I am afraid that the federation of great communities like this is not to be brought about by any formal enactment or any formal resolution. I think it must develop by the progress of opinions, and it is in that view that I regard the event which we are met here to celebrate to-day as one of potent influence for the welfare of these colonies. (Hear, hear.) In this great system of material arteries which we complete to-day we see the crimson fluid of kinship pulsing through all the iron veins. In mortal marriages it is said, "Whom God has joined together let no man put asunder." In contemplating the great powers of Australian progress which enterprise, invention, a noble emulation, and nature have here brought together may not the united heart of this great gathering put up the devout prayer that no human force in the long invisible hereafter may be strong enough to rend them asunder. (Loud cheers.) I ask you to drink to the toast of "United Australia."

of Sir Hercules Robinson. A had a federation of the four joining all. He though benefit that in a young tralia the Governments ways, and that at the sa recognise the wisdom of handin of the lines to gentlemen who of political interference. H sympathy and patriotism of way Commissioners support in He believed if the Commission that in a year or two no Minist endeavour to remove them from t While the railway system was not to be worked by a profit, business principles, in trust country and the capital borrowe old country. They should be the railway system, and fai community and they would rea the outlay. He then asked th "Prosperity to the railway Wales." (Cheers.)

Mr. EDDY, the chairman of sioners, rose amidst cheers in cries of "Eddy." He sa Sir Henry Parkes, and have wished that an abler had been called upon to respond toast, because, although I may management of railways, I speaker. (Hear, hear.) Yet, leagues and myself, I thi to be called upon to r a toast and before so im as the present. (Hear, hear.) great confidence the Governmen country have reposed in us in t agement of the great nation railways. That undertaking i we come to think of th country, which is only equal great provincial city and sub half a million of people have miles of railway. (Hear, hear. population of the colony for find that in 1857 it was 305 quent periods the effect of the tion is remarkable, having per cent. in each period. (He in 1857 was only 40, but it gre 204, 598, and 2036 respectively- growth in the mileage the use in greater proportion. in 1857 only numbered to 14,560,000 in 1887. traffic, which in 1857 was only 3,339,000 in 1887, and the rev 13,000 to 2,208,000; and we this year will bring a millions and a-half. (Cheer

THE SYDNEY MORNING HERALD, THURSDAY, MAY 2, 1889.

inconvenience was felt to be overwhelm-, and recently the last of the old ad-gauge rails was taken up. In the Southern tes a gauge of 5ft. was universal south of Ohio, and nagers wisely, for years, made preparations for a ging change. Locomotives and cars were so con-cted that the change could be easily effected; and ally, in May, 1887, the gauge on 10,000 miles of d was altered to 4ft. 8½in. within a week. The re-t is that, in a total mileage at the end of 1885 of ,068 miles, 74 per cent. were of 4ft. 8½in. 4ft. 9in.—12 per cent. larger gauges, and per cent. smaller; and the 4ft. 8½in. y claim to be the gauge of the world. t besides loss, delay, and inconvenience, another nt of view should be considered,—viz., the strategic . It might be necessary at a moment's notice to patch large numbers of men, with guns, ammunition, rage, and horses. Under present circumstances plicate loading and unloading places and duplicate ins would be required: this might expose the country serious danger. In conclusion, all I should venture ay would be that the question of a uniform gauge national one; and though one or more colonies uld have to put up with the temporary inconvenience the change all should share in the cost. And we uld not forget that every hour that slips by, every e of railway that is built, increases the difficulties well as the expense. Large things spring from all ones, and it may yet be that the union of these at colonies, which all men desire, may be brought newhat nearer the range of practical politics by the npletion of an absolute necessity—a uniform railway ige for the whole of Australia. (Cheers.)

Sir Henry Parkes proposed the next toast,—United Australia." He said: My Lord and Gentle-n,—I feel that the toast entrusted to me is one which resents an event superior to anything that has ever urred in the history of these great colonies. (Cheers.) are, without any exaggeration of language, assembled to celebrate an occurrence which has more interest, ecially in anticipation of the future, than anything that has taken place in our history. have formed communication by railway ich may be said to bind the whole population Australia in one chain. (Hear, hear.) The ne where we are assembled may be said to be one of orbing interest. The memories of the past us—and many of the younger men here d to be told—that on the banks of this er, on its fertile shores, a little further up than spot, the first Australian settlement took ce, when Australian colonisation was confined the city of Sydney and a few stretches in the county Cumberland, and that on the shores of these waters most exciting attack between the aboriginals the whites took place. A little later the agricultural settlement took place, and then lowed a race of men and women of which, am sorry to say, there are few remaining. the early days the Hawkesbury settlers were known their athletic height and manly proportions. They re [illegible] hard working, very enterprising, and very d living—(hear, hear)—yes, hard living, for their iple fare was the meal of the maize—that was their ef food. The young women were healthy and strong proportion. We may well regret the inroads which re been made with the result of bringing about a ninutive race. On this beautiful labyrinth of ters many national enjoyments have taken ce, and to-day we meet to celebrate the erection a work which will connect the bulk of the stralian population. It is almost impossible find time to dwell upon what the future may be. at is God's unknown, and the wise amongst cannot measure the future, but we may be ured that a gigantic progress will take place our midst. Invention and Science will e some of their highest achievements here, and hope that Wisdom will show herself a sober and most attractive form. (Cheers.) eems to me a fitting opportunity, if you, gentlemen, l bear with me, to explain what this link in our rail-y system means. (Hear, hear.) It begins with the city of Adelaide with her present population of 115,380 ls, and it ends with the young and bonny city of sbane with a population of 83,500 souls. But in its brace it takes in our august daughter the city of Mel-rne with the enormous population of 437,785 souls. eers.) Then comes the noble mother colony with population of 366,684 souls. (Hear, hear.) This capital, as it has given us a united population of 05,349 human souls—(hear, hear)—a railway sing through cities like Sydney and Melbourne, and poem on the greeting of the engines. He made the engine that came from the old States boast of how he had brought the intelligence of Europe and the riches of science and wisdom from the old part of America to the new, but the engine that came from the Pacific shore replied—

> "All the Orient, all Cathay
> Find through me the shortest way,
> And the sun you follow here
> Rises in my hemisphere."

How true it was that, for the first time in the earth's history, the meeting of those engines, after passing the Sierras on the one side, and coming from the old States and prairies on the other, brought together the one kiss of peace, as it were, of the brothers of all the world, and of all old countries and new—(cheers)—all the old histories of the past and new inventions of the present. You will remember that we in New South Wales are the central power in this railway system, and we are to-day, as it were, marrying the north to the south, and the marriage takes place at this board. (Cheers.) We are really a central power, and Bret Harte, speaking of the Central Railway engine, says:—

> Said the Central, "I'm Pacific,
> But, when riled, I'm quite terrific.
> Yet to-day we shall not quarrel,
> Just to show these folks this moral,
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> Once have met without collision."

(Cheers and laughter.) Now, will not this be allowed to remain in the mind of every man here—that we met to celebrate the opening of this great bridge in peace, in friendship, and in friendly pride. We have here a representative of the great Government to our south and of the great Government to our north, and why should not this occasion be an emblem of our future relations? If the engines meet to-day with this special greeting, why should we not shake hands, and be knit together in bonds that cannot be sundered, and forget those things which have created jars that can be easily removed. It is said that the time has arrived for the political federation of these colonies. (Hear, hear, and "No, no.") I am afraid that the federation of great communities like this is not to be brought about by any formal enactment or any formal resolution. I think it must develop by the progress of opinions, and it is in that view that I regard the event which we are met here to celebrate to-day as one of potent influence for the welfare of these colonies. (Hear, hear.) In this great system of material arteries which we complete to-day we see the crimson fluid of kinship pulsing through all the iron veins. In mortal marriages it is said, "Whom God has joined together let no man put asunder." In contemplating the great powers of Australian progress which enterprise, invention, a noble emulation, and nature have here brought together may not the united heart of this great gathering put up the devout prayer that no human force in the long invisible hereafter may be strong enough to rend them asunder. (Loud cheers.) I ask you to drink to the toast of "United Australia."

The toast was heartily received.

Mr. J. L. Dow, in responding, said the Government of which he was a member had deputed him to come here to-day in the name of the people of Victoria, and in the very best possible spirit, to say that they congratulated them upon having met to celebrate this auspicious event, and to say that they considered it fitting that the parent colony of Australia should, under such auspicious circumstances, complete the greatest engineering work in the Southern hemisphere, which was so significant of the tone and sentiment which had been submitted by his much-respected friend Sir Henry Parkes. He had found that there seemed to be considerable misapprehension amongst the peoples of these colonies with regard to this fact, which seemed always to have struck him as one of the things that they ought to be proudest of. We talked about federation coming and the unity of this great continent, and there was nothing truer than the sentiment submitted by the safe and experienced wisdom of the Premier of the colony, that there were things which could not be forced, and that there were things which did not want forcing at all—something that really existed—something that could not be made to cease to exist—and this spirit of kinship existed not only in the representative of the old British country here in Australia, but also in that other British country where the makers of this bridge had come from—in America, where the narrow prejudices that were most apparent in a small community were removed. He had found the people there [illegible] of Sir Hercules Robinson. At the present time they had a federation of the four colonies by the railways joining all. He thought it was a great benefit that in a young country like Australia the Governments should own the railways, and that at the same time they should recognise the wisdom of handing over the management of the lines to gentlemen who were outside the range of political interference. He would appeal to the sympathy and patriotism of all men to give the Railway Commissioners support in every way they could. He believed if the Commissioners received fair play, that in a year or two no Ministry or Parliament would endeavour to remove them from their positions. (Cheers.) While the railway system was a great national system, not to be worked by a profit, it should be worked on business principles, in trust for the people of the country and the capital borrowed from the people of the old country. They should be true to themselves and the railway system, and fair to every part of the community and they would reap immense benefits from the outlay. He then asked them to drink the toast of "Prosperity to the railway system of New South Wales." (Cheers.)

Mr. Eddy, the chairman of the Railway Commissioners, rose amidst cheers in response to emphatic cries of "Eddy." He said: Your Excellency, Sir Henry Parkes, and gentlemen,—I could have wished that an abler speaker than myself had been called upon to respond to this most important toast, because, although I may be able to deal with the management of railways, I don't profess to be a speaker. (Hear, hear.) Yet, on behalf of my colleagues and myself, I think it a high honour to be called upon to respond to so great a toast and before so important a gathering as the present. (Hear, hear.) We fully recognise the great confidence the Government and the people of the country have reposed in us in the control and the management of the great national undertaking of the railways. That undertaking is a perfect marvel when we come to think of the population of the country, which is only equal to the population of a great provincial city and suburbs at home, and yet half a million of people have created practically 2200 miles of railway. (Hear, hear.) I have looked at the population of the colony for decennial periods and I find that in 1857 it was 305,000. In the four subsequent periods the effect of the growth of the population is remarkable, having increased about 50 per cent. in each period. (Hear, hear.) The mileage in 1867 was only 40, but it grew in these periods to 204, 598, and 2036 respectively—(cheers)—but with the growth in the mileage the use of the lines increased in greater proportion. The passengers, who in 1857 only numbered 329,000, multiplied to 14,500,000 in 1887. (Cheers.) The goods traffic, which in 1857 was only 20,000 tons, increased to 3,339,000 in 1887, and the revenue had grown from 43,000 to 2,208,000; and we confidently expect that this year will bring a revenue of over two millions and a-half. (Cheers.) It has been the intercourse between the colonies, which has been spoken of as creating a bond of union that we will endeavour to facilitate as much as possible by increasing the speed of the trains—(cheers)—and making the carriages more comfortable. (Cheers.) We find that the communication between Victoria and New South Wales was established in June, 1883, and that the growth of traffic between 1884 and last year was 88 per cent. But when we come to look at Brisbane—where we were the other day, and I have had a return prepared showing the traffic by rail between the two great capitals—we find that in the last quarter the traffic was only about 8000 or 9000 passengers, while it was over 9000 by steamer. Having spent two nights and a day in the train, getting there I can well understand how it is that passengers travel by steamer. (Cheers.) If our friends in Queensland will help us in the matter of the gauge, we do hope that before we are many years older we will be able to accomplish the journey in 24, instead of 37 hours, as was the case yesterday, and about 34½ to-day. (Cheers.) In connection with the matte it would be a proud thing for us if we could have a train corresponding to what they boast of in America, the Chicago lightning express, in which passengers could go from Brisbane to Adelaide without getting out for refreshments. (Cheers.) I would like to speak of the mineral resources of the colony, but I do not wish to enter into politics. Still we are concerned in seeing the industrial expansion of the country—(Cheers)—and we think that in our iron and coal we have far greater wealth than in gold and silver

EXTRACT by Stuart Sharp (State Rail Heritage Officer) from a commissioned work ***Railways and Federation*** by historians John Ferry (University of New England) and Bruce Pennay (Charles Sturt University), to be published early in 2001.

THE GREAT NORTHERN LINE

Two significant events occurred in 1889 which brought the Great Northern Railway Line into a continental rail network, and awakened all Australians to the possibility of a federated nation. In May a remarkable bridge across the Hawkesbury River north of Sydney was opened, linking the Great Northern Line to the metropolis and creating a fully integrated New South Wales rail network centred on the city of Sydney. The second event was the famous rail journey in late October by the Premier of New South Wales, Sir Henry Parkes, from Brisbane, where he had held discussion with the Queensland Government on federation, to Sydney via the little border town of Tenterfield which he had once represented in parliament. Both these events tell us a lot about federation.

The Hawkesbury River Bridge was one of those engineering marvels of the Railway Age. It was the largest of its kind in the southern hemisphere, and with regard to its foundations, one of the most remarkable bridges in the world.[1] It was a world-class structure that the local press was happy to compare to the Brooklyn Bridge in New York, the Tay Bridge in Scotland, and the cantilever bridge at Niagara Falls.[2] For such an important bridge, an international competition was called, and, in 1886, the contract had been awarded to the Union Bridge Company of Athens, Pennsylvania for a price of £327,000.[3] That the New South Wales Government Railways had been by-passed for the design of the Hawkesbury River Bridge, together with the fact that the successful construction company was not British but American were both signs of a growing political maturity. There seemed to be a vision that could occasionally look beyond parochial boundaries and imperial loyalties.

As befitted the project, construction was heroic. The Union Bridge Company set up operations on Dangar Island in the Hawkesbury River where the superstructure was erected. Six mighty caissons surmounted by sandstone piers were erected across the river, not far from the island, and when completed the largest of these piers was considerably higher than the tower of the Sydney Town Hall.[4] Seven spans of riveted steel plate, each 415 feet in length, were constructed on Dangar Island, and floated out to the piers on a purpose built pontoon where they were delicately manouvred into position against contrary tides and winds. The last span was set in position on 1 March 1889. The landscapes on either side of the great bridge were obligingly dramatic. The river itself was a drowned valley lapping rugged sandstone gorges covered in thick eucalyptus forests. The line to the Sydney end of the Hawkesbury River Bridge had to descend sharp gradients towards the river, finally entering a tunnel and emerging right on the southern abutment of the bridge. To the north the line left the bridge and entered the famous Woy Woy tunnel, then, and for a long time, the longest tunnel in the southern hemisphere constructed with 10 million bricks, 10 thousand casks of cement and 10 tons of dynamite.[5] The Hawesbury River Bridge was a spectacular golden spike linking a rail network that now united four colonies, notwithstanding break of gauge, and making possible rail travel from Brisbane to Adelaide via Sydney and Melbourne.

With due ceremony the bridge was opened on 1 May 1889. Two special trains left

Sydney for the Hawkesbury carrying the Governor, Lord Carrington, the Premier, Sir Henry Parkes, various ministers of the government, the Chief Commissioner for Railways, Edward Eddy, and Commissioner Charles Oliver. Fittingly there was a representative of the Victorian Government, the Hon. J. L. Dow, and the Hon. John Donaldson represented the Government of Queensland.[6] The trains were crowded with men, and no women took part in this celebration of engineering prowess and mastery.[7] The brief official opening took place on a specially constructed platform on the northern end of the bridge, which was followed by a cruise on the river to inspect the bridge from that vantage.[8] Then 600 guests settled down to an afternoon of speeches and toasts in a large banqueting hall created on board the pontoon which, only weeks before, had ferried the spans of the bridge from Dangar Island.

This was a celebration of the New South Wales Government, but federal imagery and allusions were strong. The guests at the banquet were each presented with a menu the cover of which depicted a classically draped female Australia standing on her own portion of the globe with the British Empire to her left and a sword to her right. Around the borders of the card roses thistles and shamrocks entwined with Australian wildflowers and coiled around cameo views of the capitals of the Australian colonies.[9] It was a distinctly urban view of a federated nation, and the linking of four cities was stressed more than the linking of four colonies. It was also a distinctly imperial view of a new nation within the Empire, as one might expect from a ceremony presided over by Queen Victoria's representative, Lord Carrington. There was no hint of independence or republicanism. A female Australia was benign and dependent, closely and lovingly bound to her Mother England.

The afternoon was given over to hyperbole, but with a new twist. Much of the rhetoric turned on the idea of federation. Lord Carrington raised the topical issue of the day, pointing out that a unified rail network would be the basis of Australian defense allowing rapid movement of troops and supplies if only the break of gauge problem could be fixed.[10] Sir Henry Parkes rose to the occasion with a toast to 'United Australia', claiming that the opening of the bridge was superior to anything that had ever occurred in the history of these great colonies.[11] The bulk of the Australian population was now linked by rail from the 'fair city of Adelaide' with its 115,000 inhabitants to the 'young and bonny city of Brisbane' with 83,500 souls. The link also took in 'our august daughter the city of Melbourne with the enormous population of 437, 785 souls' and then Sydney, the capital of the mother colony, with 366,694 souls.[12] Sir Henry was nothing if not an urban minded politician. He paraded some selected statistics to demonstrate the remarkable features of the Australian railway system when compared to almost anywhere else in the world, then he plumbed the depths of purple prose. 'In this great system of material arteries which we completed today', he said, 'we see the crimson fluid of kinship coursing through all the iron veins'.[13] It was a clear allusion to the famous 'blood and iron' phrase of the German Chancellor Bismarck. That alone marked it as a nation building speech.

The newly appointed Chief Commissioner of Railways, Mr. Eddy gave a more sobering assessment of federation and the railways. He pointed out that the colonies might be linked by rail, but ninety percent of passenger movements between Brisbane and Sydney were by sea. Commissioner Eddy was a newcomer to the colony and he wanted to point out that the railways were a creation of government, whereas coastal shipping was a bastion of private enterprise. He hinted that private enterprise might be more efficient. He was, after all, far more experienced with private companies than with government bureaucracies having spent the previous 22 years working for the London and Northwest Railway Company and then the Caledonian Railway Company in Britain. Upon arrival in Australia only a few months before, he expressed his determination that the railways should pay and should not be a drain on the public purse.[14] To Eddy, when comparing rail and sea, costs and travel time seemed to work against the railways. The break of gauge could become a permanent blight if the colonies did not act immediately and concertedly to create a standard gauge. Ultimately Eddy saw the uniform gauge, not federation, as the most pressing issue of the day.

Mr. Eddy's remarks were followed by those of Sir John Robertson, erstwhile premier of New South Wales and sometime friend of Sir Henry Parkes. Clearly in dyspeptic mood, Sir John fired a shot at the press, then fired another at Commissioner Eddy whom he dismissed as 'a new-fangled, half fledged stranger coming amongst them with [his] new ideas'.[15] He then let fly a broadside against federation claiming that New South Wales was already federated to the British Empire, the greatest federation the world had ever seen, and that was all that was needed. As for the railways, New South Wales had constructed more track than any other people in the world (a dubious claim in a day of dubious statistics), and Mr. Eddy should remember that if he had ever known it. There followed an embarrassed silence and the shuffling of cutlery that gave pause to the federation hyperbole.

The next day all the major newspapers ran with the federal issue. 'United Australia' was the headline of both the Sydney *Daily Telegraph* and the *Newcastle Morning Herald*. The *Sydney Morning Herald* saw the Hawkesbury Bridge as a symbol of 'a more momentous union [of the Australian colonies] in a future not very remote'.[16] The *Evening News* gave a more cautious summary of the prospects for Australian federation., and only the *Echo* gave full coverage to Sir John Robertson's acerbic speech. All in all, the issue of federation got quite a coverage from this railway celebration. However, as the great and the good departed from the Hawkesbury, full of champagne, oysters and sturgeon's roe, older, more parochial issues were reactivated by the new Sydney Newcastle link. Differential freight rates were imposed on the new line to make it more profitable for northern producers to send their goods to Sydney rather than Newcastle.[17] Thus inter-urban rivalry was still at the core of railway politics.

Oddly, the opening of the Hawkesbury Bridge and the rainbow oratory of Sir Henry Parkes did not become the historical icon of the emerging federation movement. Instead, six months later, the spotlight shone on the little town of Tenterfield, the last railway stop in New South Wales before the Queensland border. Here Sir Henry Parkes delivered his famous, but rather pedestrian, Tenterfield Speech on 24 October 1889. Contrary to popular belief, Sir Henry did not choose Tenterfield because of its symbolism as a border town to deliver his call to federate. Rather Tenterfield chose him, as it had chosen him once before, seven years earlier.

Parkes had good reason for his obvious affection for the people of Tenterfield. In 1882, at a low point in his career when he had just been defeated in the general election in the seat of East Sydney, Parkes was offered the seat of Tenterfield unopposed. The initiative had come entirely from Tenterfield and Parkes knew nothing of it until the offer was made. Thus had Tenterfield saved his career, and in February 1883 he visited his electorate for the first time to be entertained at a banquet at the Tenterfield School of Arts.[18]

Now, in October 1889, he was back, no longer as their representative, but as Premier and the Grand Old Man of Australian politics. He was tiring of colonial politics which had occupied all his energies for over thirty years, and was now looking for a more statesmanlike role. He was thinking in terms of 'Australia'. Throughout 1889, from the time of the opening of the Hawkesbury River Bridge, he had offered himself as a leader of a movement to federate the Australian colonies. But Victoria was luke-warm to the idea, not wishing to give the initiative on this great issue to its rival north of the Murray River. So Parkes took himself off to Brisbane to raise the idea there. He travelled from Sydney by sea arriving in Brisbane on 21 October 1889, but refused to tell local reporters what his visit was about. After several days of talks with Queensland cabinet ministers and statesmen on the possibility of calling an inter-colonial conference on the means to achieve federation, he returned to New South Wales by train, crossing the border and arriving at Tenterfield on 24 October.[19]. Already the Mayor of Tenterfield had asked Sir Henry to stop over in the town 'for auld time's sake'. That night in the local School of Arts, he delivered his Tenterfield speech to a gathering of both men and women, which put the issue of Australian federation fully on the political agenda. He then set out, in his special train, on a remarkable journey to Sydney. He stopped in Tamworth to receive speeches of respect and welcome,[20] but pressed on with speed along the Great Northern Line, across the new Hawkesbury River Bridge to make the capital in fourteen hours, a record. Far in his wake was the little town of Tenterfield, its place in Australian history assured.

In terms of oratory the Tenterfield speech was ordinary. The applause from the eighty members of the audience was sparse. The only resemblance of passion was when Parkes advocated a federation without breaking ties with the Mother Country. That drew cheers. But there were no loud cheers, 'hear hears' or shouts of agreement or contradiction as usually accompanied a rousing public speech. Mostly Parkes dealt with the issue of defense and the recent report of the English General J. Bevan Edwards who had recommended a federation of the military forces of the colonies.[21] He raised, too, the problem of the break in railway gauge and the difficulties that caused for troop movements and commerce. These were the two great issues Parkes wanted to lay before the men and women of Tenterfield. If there was any great moment in the Tenterfield speech it was when Parkes revealed his political tactics and provided a way to move forward on federation. Parkes called for a federal convention to devise an Australian constitution, and if the Victorians were reluctant to go along with the idea, he would force their hand by reaching a consensus with Queensland.

This was the importance of the Tenterfield speech, but it was an importance only realised with hindsight. In the days after the delivery of the speech neither the metropolitan nor the country press took to it with any great interest. Only the *Sydney Morning Herald* gave full coverage to the proceedings at Tenterfield,[22] and only the *Freeman's Journal* seemed to attach any great importance to the event.[23] Most of the other papers were discussing federation anyway as a result of Major General Edwards' report on colonial defenses. Then in 1890, Sir Henry Parkes published a book of his important speeches on federation. The book commenced with the Tenterfield speech, and this is what gave the little border town its place in Australian history.

Thus two major events, the opening of the Hawkesbury River Bridge and the Tenterfield speech of Sir Henry Parkes, linked the Great Northern Railway Line to the federation movement in the year 1889. The two events together reveal something of federation as it was conceived in this incipient stage.

In the first place, railways were the technology of the age. Their growth and extension, their ability to link, unite, civilise, and open up the country, provided politicians with an opportunity to talk about visions and futures. It is understandable then that railway occasions like the opening of the Great Southern Line to Albury or the opening of the Hawkesbury River Bridge provided opportunities to talk about federation. Talk became inspiration and inspiration became action. Few other events, apart from organised conventions, provided as good a platform for federation oratory than a major railway project completed.

The railway projects emphasised two important aspects of the Australian colonies. Each colony had its own strong government and those governments were highly centralised. The Australian railways, as impressive as anywhere in the world, were built and operated by colonial government, and the role of government in these colonies had been considerably enhanced by the great railway projects. As well, the railway networks concentrated on the capital cities of the colonies, at least in the cases of New South Wales, Victoria and South Australia. These great railway projects, beginning in the 1850s and reaching a peak of achievement in the 1880s, had reinforced strong central governments in each of the colonies and exacerbated inter city rivalry particularly between Sydney and Melbourne. Any federation had to fit in to that pre-existing template.

As evident at the Hawkesbury Bridge and at Tenterfield, the early federation rhetoric showed clearly that the union of the colonies would be fully and entirely within the greater unity of the British Empire. Leading federationsist were avowed imperialists, or else they sat comfortably at table with the empire loyalists. What is absent from the rhetoric is any sense of growing independence, or of Australian nationalism. That was for the radical press. Most wanted the ties with Britain maintained or even strengthened. Thus a figure like Lord Carrington could always feel at ease as the after dinner speeches and toasts turned to a united Australia. In fact, he could even contribute to the debate and lend his support. Always present, however, were those, like Sir John Robertson, who wanted no federation. They invoked the age-old conservative mantra: If it isn't broken, then don't fix it. If it came to conventions and referenda, as it eventually did, the lovers of things as they are could only be countered by forceful and convincing arguments in favour of change. The federation movement needed issues.

One of those issues dominated the meetings of 1889. The Australian colonies needed to federate for reasons of defense. Lord Carrington raised the issue in his speech at the opening of the Hawkesbury River Bridge, and defense occupied the bulk of Sir Henry Parkes's speech at Tenterfield. It was undoubtedly the issue of the day. In October 1889, Major General Edwards, commander of the British Army in Hong Kong, had delivered his report on the state of the Australian colonies' defenses. He raised the possibility of invasion and the need for the colonies to federate as the only effective means of repelling an invader. The threat of invasion and the thought of fighting for the empire on Australian soil was the stuff of young men's dreams, and the foil for old men's rhetoric. It was a good issue to get the federation ball rolling. Parkes realised this and used defense to good effect initially. However, it did not remain a key issue once serious debate about federation got underway in the late 1890s.[24] But as an issue it would always have appeal to sectors of the voting community which, of course, was exclusively male.

Closely allied to defense were the railways, and more specifically the break of gauge. The Hawkesbury River Bridge opening produced a flurry of statements on the need to address the problem. The expert opinion of Chief Commissioner Eddy. was that a standard gauge of 4 ft 8½in (the New South Wales gauge) be adopted in Victoria, Queensland and South Australia and that the cost of conversion be borne by all four colonies.[25] The in October 1889, Major General Edwards reminded the Australian public that railways were a crucially important factor in war. The break of gauge at the New South Wales borders with Victoria and Queensland would greatly diminish the effectiveness of an Australian army and, concluded Edwards, if full strategic benefits were to be derived from the railways, a uniform gauge must be established.[26] As Sir Henry Parkes pointed out at Tenterfield, a federal government was the best vehicle for achieving a uniform gauge.

A uniform gauge was by no means impossible to achieve. As Chief Commissioner Eddy pointed out, problems with break of gauge had been overcome fairly quickly in Britain, the United States and Canada where private railways, often in competition with each other, predominated. How much easier it should have been for rail systems controlled by governments, in a nation about to be united under a single government. But it was not easy and it was only in the 1960s that any real progress was made on a uniform gauge.[27] On the northern line the issue was not so pressing. Between 1888 and 1930 there was only one point of contact between the Queensland and New South Wales rail systems. Throughout that period, indeed up until the Second World War, shipping remained the overwhelming means of freight transport between the two states.[28] The break of gauge did not hinder trade, but rather ensured that most of it was done by sea. Passenger movements were not nearly so inconvenienced by the break of gauge, and in 1930 a coastal railway line opened between Brisbane and Sydney on a through standard gauge.

But federation was more than just rhetoric and issues, important and necessary as these were in the lead-up to the referenda of the late 1890s. Federation was also about mentalities – the way people thought of their identities and their sense of belonging. Here the railways provided some important indirect contributions to the federation of the nation. The history of the Great Northern Line in New South Wales throws some light on how people's local and regional visions were expanded. As well, the history of this line, especially as it neared the border, shows how New South Wales governments viewed the connection with Queensland.

One of the most interesting facts about the Great Northern Line is that it commenced at Newcastle, not Sydney. By the time Newcastle was being considered as a railway terminus, it was a small port relying on the export of coal, live sheep and some agricultural produce to Sydney. A private railway company was proposed in 1853 to link Newcastle and Mailtand, and so increase the efficiency of delivery of Hunter Valley produce to the Sydney market. By July 1855 the company had passed into public hands. In March 1857 the railway line, now known as the Great Northern, reached Maitland, but a terminus at Maitland did nothing more than deliver coal and passengers to Newcastle. Most produce was still carried by ship from Morpeth, and in order to secure that trade the railway had to press beyond Maitland. And so the Great Northern Railway pushed up the Hunter Valley, reaching Singleton in 1863, Muswellbrook in 1869 and Murrurundi, at the head of the valley, in 1872.[29]

There was no scheme in these years to push the line through to Queensland. In fact for many years the logical terminus was seen as Armidale.[30] Lines like the Great Northern were not built to connect the colonies, to forge a nation as it were. The railway lines in these years were built to open up country, to increase trade and to expand the commercial opportunities of Sydney, the colony's one and only port. Sydney's commercial dominance was paramount and Sydney's commercial interests determined, to a large extent, railway policy. However, one unexpected outcome of the Great Northern Railway was the growth of the port of Newcastle. Coal, the very food of railways, produced a boom in Newcastle, and, as a consequence, its port facilities grew and were connected directly to the Great Northern Line. By the 1880s, Newcastle was able to offer the same overseas freight rates for produce as Sydney,[31] and had become a mercantile rival to the colony's capital and chief port. It was only with the connection of the two cities by rail in 1889 that the exports of northern New South Wales came entirely within the Sydney sphere of influence.

Progress on the Great Northern Line stalled at Murrurundi for much of the 1870s while governments decided how the railways were to proceed. A select committee in 1870 not only questioned the policy of extending standard gauge lines beyond Murrurundi Bathurst and Goulburn, but even raised doubts as to whether the government should use steam power at all to open up the interior. There were many who considered that horse tramways were the solution for the far interior, including New England. The debate was serious and prolonged so it could be said that by 1870 there was no commitment to push standard gauge railway lines to the border of the colony, let alone link with the railways of other colonies to form a continental network.[32] The 1870s was the decade when commitment firmed and the focus was sharpened. The borders of New South Wales came into view.

What became clear in that decade was Sydney's position in relation to the borders of the colony. Much of the Riverina was closer to Melbourne than to Sydney, some of New England was closer to Brisbane, and most of the western Darling River country was closer to Adelaide. One reality was that more New South Wales wool was exported from other colonies than from Sydney.[33] As well, threats of secession or separation in the Riverina had to be taken seriously. It was quieter in the north, but, as early as 1868, there were those who, in their lobbying, were happy to point out that significant New South Wales trade was diverted across the border to Brisbane.[34] The political reality was that Sydney had to look to its remote border lands or risk losing them economically and perhaps even politically.

Equally as important, fiscal and political means became available for Sydney to assert a vigorous expansionist railway policy. The government was realising large amounts of revenue from the sale of Crown Lands to free selectors, and from 1872, Premier Henry Parkes and his successor Sir John Robertson made the most of a booming economy and a healthy treasury.[35] The three trunk lines moved rapidly out from their terminus towns, and across rural New South Wales public expectations of full railway services increased. No one would settle for horse tramways or narrow gauge. Those issues were now dead.

In the north the railway line crossed the Liverpool Range in 1876 and headed off into more open country towards Tamworth. From that time the government was committed to taking the Great Northern Line on towards Queensland. But there was certainly no race for the border. In 1877 the unusual decision was made to build a branch line from the main northern line at Werris Creek west towards Gunnedah. Thus railway resources in the north were split. The north western line to Gunnedah, which would later extend to Narrabri, was a mark of the success of local member T. G. G. Dangar and of railway lobbying in the New South Wales Parliament.[36] From now on branch lines would become political issues and a network grew based upon serving the needs of politically sensitive areas of the colony. There was less coherent planning of railways after 1877.

The Great Northern Railway reached Tamworth in February 1878, but still no firm decision had been made on where it was to go from there. Four weeks later the government decided where the Great Northern Line would meet the Queensland border, but interestingly the initiative had come from Brisbane, not Sydney. The Queensland government had already decided on a line from Stanthorpe to the border eleven kilometres north of the New South Wales town of Tenterfield.[37] It was the Queensland

Chief Engineer who visited Sydney to convince his counterparts to terminate the Great Northern Line at Tenterfield.[38] That much resolved, there followed one of those internecine battles between two New England towns to secure the route north. The Great Northern Line from Tamworth to Tenterfield could go via Armidale or Inverell, and both towns vied for the prize. It was a short but acrimonious contest which Armidale won. It was going to be more than a generation before Inverell got a railway line.

In terms of federation, this brief history of the Great Northern Line shows that the linking of the colonies by rail was not a high priority. There were other more pressing political considerations determining what line went where, and the resulting network reflected decisions by engineers, decisions by politicians, and the successful lobbying of rural electorates. The secondary priority given to the linking of the railways of New South Wales and Queensland is demonstrated by the railway establishment at the border towns of Tenterfield and Wallangarra. The station at Tenterfield was erected in 1886. It was a solid structure, with Gothic influences, but no more imposing than the railway station at Glen Innes, the nearest large town, and on a par with ordinary suburban stations like that at Petersham. It was certainly no counterpart to the grand railway edifice built at Albury.

In 1886 Tenterfield tried to secure the break of gauge which would have increased the importance of the town, but its efforts were unsuccessful. There was a difference of opinion between New South Wales and Queensland on the issue and ultimately it was decided, logically, to make the break at the actual border, on the Queensland side. A railway town, Wallangarra, grew up on the site. Its railway station, too, was nothing spectacular, just a low single storey brick building of no remarkable length. There were no grand architectural gestures being made at the only railway crossing of the Queensland, New South Wales border. As if to emphasise that fact, when the two rail networks joined at Wallangarra in January 1888, there was no opening ceremony, no celebrations, and there was barely a mention in the Sydney newspapers.[39]

This was the only crossing of the border until 1930. But a network of lines in the northwest did develop showing the power of Sydney commercial interests over railway policy. This was nowhere more evident than in the long saga of a railway line to Inverell. After its defeat in 1878, the town pressed frequently for a railway line, but endured enormous frustration. The simplest solution to Inverell's needs was to build a branch from the Great Northern Line, most logically from Glen Innes. But other interests in New England were pressing for an east west line from Glen Innes to the seaport at Grafton. Inverell's cause got caught up with this wider issue, and was defeated with it. The cost of a line to the coast was high given the extraordinarily steep escarpment that had to be negotiated between the tablelands and the coast. As well, a major port in the north would be inimical to Sydney's interests and so all attempts at an east west line failed.

At times in the 1890s, Inverell looked like it would get its branch line from Glen Innes. But then came federation to sour its chances. If the colonies united as looked highly likely after about 1896, border duties would disappear and, and if Inverell were linked to Glen Innes, most of its produce would head to Brisbane rather than Sydney. And so a more circuitous route for Inverell was proposed. An extension of the northwestern line from Narrabri to Moree was already under construction, and a proposal was put for line to extend farther to Inverell. It was an extraordinary solution and produced one of the longest rail journeys on the New South Wales network. But it did secure Inverell produce for the Sydney market, and the people of Inverell were glad for any solution to their transport need. Their long awaited railway line was opened late in 1901.[40] Thus, even on the very eve of federation, Sydney commercial interests still played a major role in railway extensions.

Thus in the decades leading up to federation the railways served the purpose, not so much of uniting the nation-in-waiting but strengthening the sub units, the colonies, both politically and socially. Not only were the colonies strengthened by their great railway projects, their economic and political power was increasingly centred in their capital port cities. Inter colonial rivalry was basically inter city rivalry. The railway networks of New South Wales and Victoria in particular contributed enormously to this process. With so much economic activity centred on single sea ports, much inter-colonial traffic was conducted by coastal shipping, and the railway contribution to breaking down the relative isolation of the colonies was small. A greater contribution came from the negative impact of separate rail systems. Breaks of gauge, border customs, differential freight rates to suit capital city interests, and bizarre railway extensions in border regions were all persistent reminders of the folly of separated, unfederated, squabbling colonies.

Ultimately, Australia became a federation of strong colonies. The federal constitution itself reflected the strengths of the federating parts. Its intent was to create a central government with limited powers and responsibilities. The powers of the central government were, with the exception of defense and foreign policy, concurrent rather than exclusive. Residual powers were left with the federating states, and those states were loath to give any of their powers to the federal government. Railways after 1901 remained a state responsibility. For the first two thirds of the twentieth century they were too big an enterprise, too large a part of the polity, for the states to hand them over to the Commonwealth.

But if the direct contribution of the railways to a united Australia was more along the lines of ensuring a weak federation with strong federating states, the age of steam had a tremendous indirect impact on the country. For a start, the railways revolutionised land transport. Way back in 1877 Thomas G. G. Dangar, that shrewd electorate oriented, 'roads and bridges' politician, made his way from his home in Wee Waa to Sydney. In the course of the trip he had to travel by coach across the Breeza Plain. It was a foul autumn night, raining fiercely, and the road was an interminable bog. The horses knocked up time and again. As the sludged across the open plain the gale increased. Eventually the lead horses lost their footing and fell, breaking the pole and releasing the team from the coach. Armed with coach lamps and tomahawks Mr Dangar and the driver searched through the bush for suitable saplings to repair the broken pole, while other passengers searched in the dark for the missing horses. Hours later than anticipated, cold, wet, bedraggled, and mud-splattered the travellers arrived at the little village of Willow

Tree.[41] Two years later that same trip would be done in less than an hour in the comfort of a train.

The movement of freight was also revolutionised. In the late 1860s, it was not unusual for store goods bound for the tiny town of Uralla near Armidale to be on the road for four months.[42] With the coming of the railway that time would be reduced to a few days in all weathers. In the early 1870s the little town of Tenterfield stood in splendid isolation on the highlands near the Queensland border. Its goods arrived from Sydney by sea to the Clarence River, and from there they were hauled up the steep escarpments of the Great Dividing Range through exceedingly rugged country. The distance overland between Grafton and Tenterfield was only 120 miles but the journey could take weeks in fair weather and months in foul. By 1889, Sir Henry Parkes made the trip from Tenterfield to Sydney in fourteen hours.

The impact of this revolution was profound. Costs for carriage reduced enormously, as did costs for passenger travel, not least because the number of nights spent on the road was greatly reduced. New goods could be transported. Plate glass and galvanised iron, both difficult to transport by drays, changed the appearance of country towns once the railways arrived. Perishables could be transported to the cities without spoiling. Business practices changed. Stores were filled with a greater variety of goods, and there was a more reliable supply. Even as early as 1871 when the Great Northern Line was at Murrurundi, John Moore, Armidale's principal storekeeper, could get Sydney goods to his store within three weeks. Gone were the days when a business could go broke because Sydney creditors demanded full payment before the goods actually arrived at their destination.[43]

Once the railways came, people could travel beyond the bounds of their localities. In 1863 juveniles and youths in Armidale rushed into the streets to gape in amazement at two donkeys passing through the town.[44] Such were the limits of their world that they had never seen such creatures. If children and youths did not travel in the days of long dusty roads, this would suggest that their principal carers, their mothers, did not travel either. Even a reasonably well-to-do woman like Caroline Thomas, wife of the owner of Saumarez Station near Armidale, only travelled from he home on three occasions in the 17 years she lived in the district. The railways altered such restrictions. Speed and safety made it possible for women to travel, even without their husbands or fathers. Every major railway station provided Ladies' Waiting Rooms and Ladies' Toilets, a sure indication that the new technology was being taken up by women.

For all travellers, both short and long trips were possible. Excursion trains opened up the region, and people could visit towns up and down the line on day trips. As well, trips to the city were more possible for those of modest means and more frequent for those of ample. Not only were people travelling more, they were travelling by land. Inter colonial freight might still move largely by sea, but people increasingly moved across land. It was a different view from the railway carriage than from the port hole. People were becoming Australians by engaging with the land. Country people were able to look to the cities, and the cities looked to the bush. From the 1870s there was a city fascination with the bush. Magazines like the *Town and Country Journal*, the *Bulletin* and the *Sydney Mail* capitalised on the linkages, and even the *Illustrated Sydney News* provided its readers with many engravings of rural life. Daily newspapers had far more rural coverage than one would expect today, and poets like Lawson and Patterson made their careers with country poems and short stories for city readers. This was the era of the apotheosis of the bushman, the discovery of national values in rural virtues, and the railways contributed greatly to these developments.

Country towns were in their golden era. With the coming of the railways and increased farming, they grew like they had never grown before or since. In twenty years between 1871 and 1891, Armidale's population trebled to 3,826 people, Tenterfield increased two and a half times in size, and Glen Innes grew by eight times its 1871 population. There was a combination of factors to explain this rapid growth, but each of those towns had been connected to the Great Northern Railway in the mid 1880s, and the significance of the railway cannot be underestimated. These towns were now established and received from government an impressive array of public buildings, court houses, schools, police stations, post offices, and of course, their railway stations. The metropolis impinged upon the distant towns in other ways. The coming of the railway demanded that the towns adjust their clocks to a standard time, invariably the metropolitan time. Railway timetables demanded such standardisation. In 1895, the continent was standardised into the three time zones, eastern, central and western, that we know today.

The railways also changed the economies of the colonies and of the nation in waiting. Changing economies are never based on single factors, but certainly some agricultural industries geared to local and regional markets adapted to colonial, national and ultimately, international markets.[45] The railways played an important part in this process which led to a more integrated, more efficient national economy in the decade before federation and in the decades to follow. In Tenterfield, cattle could now be killed locally and shipped off to Sydney in refrigerated vans.[46] Farmers turned to dairy products, and consignments of eggs chugged off to Sydney. But the process was not without pain. In the farming areas around Armidale a wheat industry had grown up over thirty years based on supplying regional markets in New England and the north west. The coming of the railway was hailed by many as an opportunity for Armidale flour to penetrate the huge city market. However, within ten years of the opening of the railway to Armidale the local wheat industry had collapsed. The regional market had been lost and the local millers could not supply flour even in Armidale at a cheaper rate than imported South Australian flour.[47] Wheat growing in the north of New South Wales was not to take off until the first decade of the twentieth century when prime agricultural land around Tamworth and other places was forced onto the market. By that time the railways were in place and waiting for the advent of a regional industry with an international market.

In the decade leading up to federation a much more integrated national economy was emerging, and people were travelling beyond their localities as never before. The country and the city were less isolated one from the other, and people had a strong sense of colony identity. Many colonists began to see a nation for a continent as a logical and inevitable outcome. When people said 'nation' and meant the continent, it was evidence of a changing mind set, and the railways had helped to create that change.

[1] 'The New Hawkesbury Railway Bridge', *Daily Telegraph,* 2 May 1889, p. 5.
[2] 'The Hawkesbury Bridge – Grand Opening Ceremony', *Newcastle Morning Herald,* 2 May 1889, p. 6.
[3] David Burke, *Making the Railways,* State Rail Authority of New South Wales, Sydney, 1995, p. 96.
[4] Ibid, p. 95.
[5] 'The Woy Woy Tunnel', *Maitland Mercury,* 22 July 1886, p. 2..
[6] 'The Hawkesbury Bridge', *Newcastle Morning Herald,* 2 May 1889, p. 6.
[7] Loc.cit.
[8] 'The New Hawkesbury Railway Bridge', *Daily Telegraph,* 2 May 1889, p. 5.
[9] Loc. cit.
[10] 'The Hawkesbury Bridge', *Newcastle Morning Herald,* 2 May 1889, p. 6.
[11] 'Opening of the Hawkesbury Bridge', *Evening News,* 2 May 1889, p. 3.
[12] 'The Hawkesbury Bridge', *Echo,* 2 May 1889, p. 6.
[13] 'Blood and Iron', *Freeman's Journal,* 4 May 1889, p. 13.
[14] John Gunn, *Along Parallel Lines: A history of the railways of New South Wales,* Melbourne University Press, Melbourne, 1989, pp. 204-205.
[15] 'The Hawkesbury Bridge', *Echo,* 2 May 1889, p. 6.
[16] Editorial, *Sydney Morning Herald,* 2 May 1889, p. 6.
[17] I. M. Laszlo, Railway Policies and Development in Northern New South Wales 1846 to 1889,unpublished M. A. (Hons) thesis, University of New England, 1969, pp. 170-171.
[18] A. W. Martin, *Henry Parkes: A biography,* Melbourne University Press, Carlton, 1980, p. 333.
[19] Ibid., pp. 384-5
[20] 'Sir Henry Parkes in Tamworth', *Tamworth Observer,* 30 October 1889, p. 4
[21] Proposed Organisation of the Military Forces of the Australian Colonies, in Report of Major General Edwards, C.B. on the Military Forces and Defenses of Victoria, *Votes and Proceedings of the Legislative Assembly of Victoria, 1889,* Vol. IV, Government Printer, Melbourne, 1889, p. 973.
[22] 'Sir Henry Parkes at Tenterfield', *Sydney Morning Herald,* 25 October 1889, p. 8.
[23] 'The Premier at Tenterfield', *Freeman's Journal,* 2 November 1889, p. 13.
[24] Jeffrey Grey, *A Military History of Australia,* Cambridge University Press, Cambridge, 1999, p. 50.
[25] Copy of letter dated 18 May 1889 from the Chief Commissioner of Railways to the Honorable the Minister for Railways, Notebook on Uniform Gauge, State Rail Series R93, item 6/44/3/7/5, State Records Authority of New South Wales.
[26] Proposed Organisation of the Military Forces of the Australian Colonies, p. 972.
[27] Garth Stevenson, *Rail Transport and Australian Federalism,* Centre for Research on Federal Financial Relations,Research Monograph No. 48), The Australian National University, Canberra, 1987, pp. 20-21.
[28] Gunn, op. cit., p. 364.
[29] Laszlo, op. cit., pp. 80-88; 94-96.
[30] Editorial, *Armidale Express,* 16 May 1863, p. 2.
[31] Laszlo, op. cit., p. 35.
[32] Gunn, op. cit., pp. 110-120.
[33] Ibid., p. 127.
[34] 'Armidale and New England Railway League, *Armidale Express,* 28 November 1868, p. 2.
[35] Martin, op. cit., pp. 278-279.
[36] John Carr and John Ferry, Werris Creek Railway Station, State rail Heritage Unit, Sydney, 1998, p. 4.
[37] 'Report upon the General Working of the Railway Department during the year ending 31 December 1878, *Votes and Proceedings of the Legislative Assembly of Queensland 1879* (2 Vols), Vol. II, Government Printer, Brisbane, 1879, p. 413.
[38] 'Good News for Tenterfield', *Tenterfield Independent,* 20 March 1878, p. 2.
[39] 'Through Railway Communication with Queensland', *Sydney Mail,* 21 January 1888, p. 155.
[40] Elizabeth Wiedemann, *World of Its Own: Inverell's early years, 1827-1920,* Inverell Shire Council, Inverell, 1981, pp. 160-169.
[41] *Maitland Mercury,* 23 December 1883, quoted in John Ferry, *Walgett before the Motor Car,* Walgett

Shire Council, Walgett, 1978, p. 142.
[42] *Sydney Morning Herald,* 23 August 1870 quoted in Lionel Gilbert, *An Armidale Album, Glimpses of Armidale's history and development in word sketch and photograph,* New England Regional Art Museum, Armidale, 1982, p. 39.
[43] *Armidale Express,* 30 September 1871, p. 2.
[44] *Armidale Express,* 11 April 1863, p. 2.
[45] M. E. Robinson, *The New South Wales Wheat Frontier 1851 to 1911,* Research School of Pacific Studies, Australian National University, Canberra1976, pp. 221-225.
[46] 'Chilled Meat', *Tenterfield Record,* 1 August 1890, p. 2.
[47] John Ferry, *Colonial Armidale,* University of Queensland Press, St Lucia, 1999, p. 60.

HORNSBY AND UPPER NORTH

Advocat

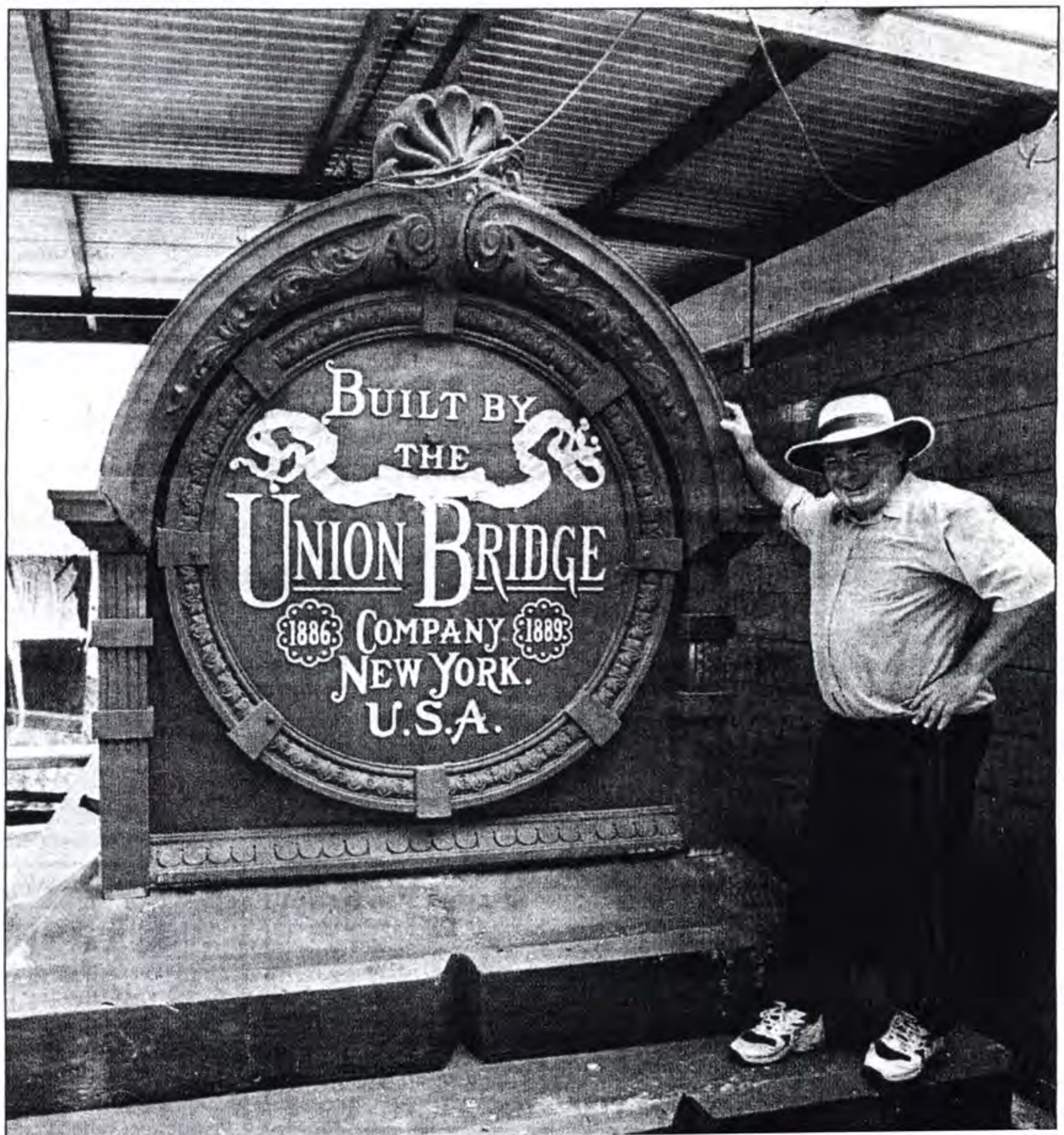
Vol 40, No 3 Thursday, January 21, 1999 Your Local Cumberland Newspaper Phone 94

The Bushland Shire News
LIFTOUT PAGES 33 - 36

WIN A 3-NIGHT CRUISE FOR TWO ABOARD THE P&O Fair Princess
SEE PAGE 32

PATIENTS 'AT

Bridge to the nation's past



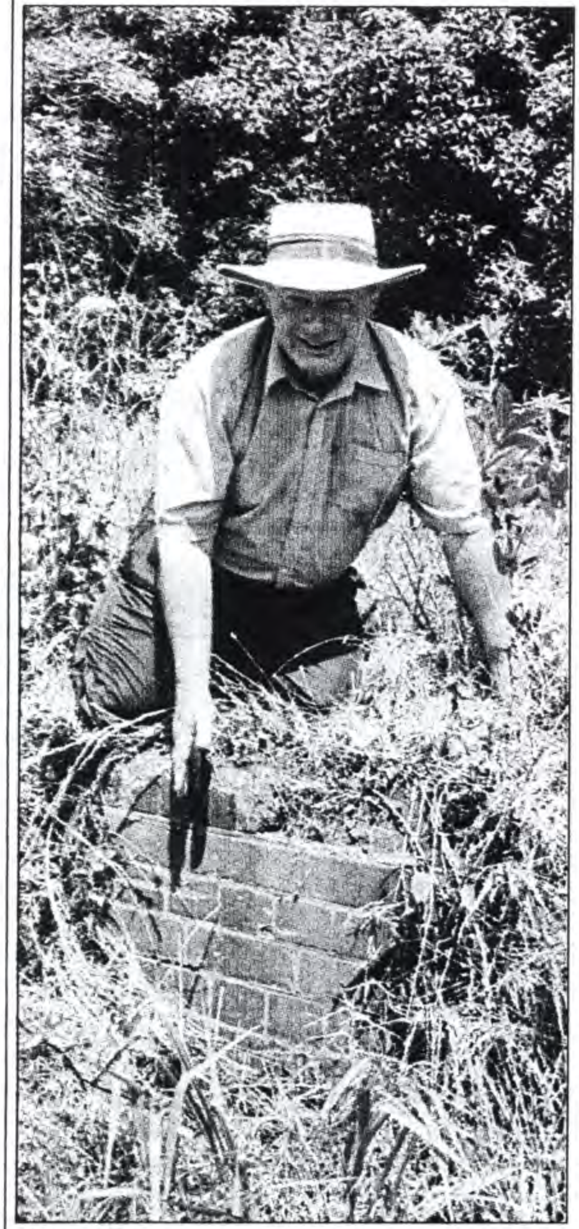
PYLONS reaching skyward from the depths of the Hawkesbury River and a company name plate are all that remain of the original rail bridge traversing the waterway.

But as the centenary of Australia's Federation draws near, the story of the bridge and the river community's role in the nation's coming of age is being retold.

Local historian Tom Richmond describes the official opening of the Hawkesbury River railway bridge on May 1, 1889, as a "definitive moment" in the Federation movement.

In Easter 1891 the area hosted a luxury cruiser with Queensland Premier Sir Samuel Griffith, future Australian Prime Minister Griffith Edmund Barton and

Bridge opening a "definitive



Mr Richmond at the overgrown River Wharf railway station

Engineering feat of unity

The sleepy, picturesque Brooklyn village and its surrounds played a significant role in shaping Australia's Federation movement. With Australia's centenary of Federation just around the corner, Brooklyn historian Tom Richmond took journalist SIMONE RICHARDS and photographer SAMANTHA STUDDERT on a tour of historic landmarks

OPENING of the original railway bridge over the Hawkesbury River at Brooklyn in 1891 was significant.

Historian Tom Richmond explains it was not just because it completed the line through Australia's eastern mainland states — it was also a symbolic link paving the way to unity as a nation.

"Brooklyn was a direct product of the need to provide efficient transport and communication among the Australian colonies," Mr Richmond said.

"The NSW railway line began with two separate systems ... with a missing link between Sydney and Newcastle."

Construction of a railway from Strathfield to Newcastle was approved by NSW Parliament in 1881, passing through Hornsby. From there it would go along the ridge before descending the Cowan bank.

The descent was, in itself, a monumental engineering feat requiring five tunnels, deep cuttings and a massive embankment over Saltpan Creek.

The railway reached Hornsby Junction in 1886, while the Brooklyn section was built between 1883 and 1887.

By 1887, the railway line had reached Brooklyn in the south and Gosford in the north. Travellers took the General Gordon paddle-wheeler vessel from Brooklyn across Broken Bay to Gosford, where they connected with another train.

Once the mammoth Woy Woy tunnel was complete, the General Gordon delivered its passengers along Mullet Creek.

The final obstacle between the two stretches of railway was the Hawkesbury River.

"The bridge was a great colonial achievement and demanded phenomenal engineering skills because of the very deep river bed," Mr Richmond said.

The contract was awarded to the Union Bridge Company of America in 1886 and the company's headquarters was established at Dangar Island in 1887.

The Governor, Lord Carrington, opened the Hawkesbury Bridge on May 1, 1889, referring to it as a significant step toward Federation.

"On top of the bank Lord Harrington flagged the first train away," Mr Richmond said.

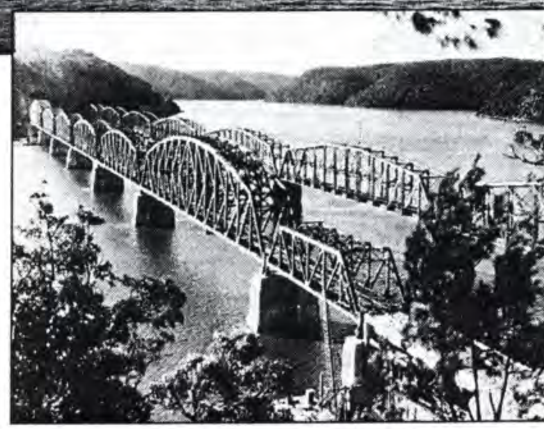
Then guests were taken by the General Gordon to Dangar Island for a banquet.

"Among the toasts offered on this occasion was one to 'united Australia', leaving very little doubt that those present were fully aware of the significance of the event they were attending," Mr Richmond said.

The opening of the Hawkesbury railway bridge was a "definitive moment" in the Federation movement, he said.

"The banquet was held in view of what was a monumental engineering achievement — the largest bridge in the southern hemisphere.

moment" of the nation



Now and then . . . today's rail bridge standing next to all that remains of the original bridge and (right) a photo taken around the time the second rail bridge was opened in 1945

From page 16

it also provided a visible symbol of the future unity of the colonies."

Mr Richmond said the movement toward Federation was a gradual one.

In Easter 1891, a convention aimed at devising a constitution for the new nation was held in Sydney.

Sir Samuel Griffith, who was the Queensland premier, invited a number of guests including future Australian prime minister Griffith Edmund Barton, to join him on the boat Lucinda to work on the constitution during the Easter break. The Lucinda made its way up the coast and cruised various inlets and anchored for the night at Refuge Bay.

"During the day they visited Brooklyn where Sir Henry Wrixon disembarked," Mr Richmond said. "During the cruise they discussed the constitution and made notes about it."

The party also enjoyed a dip under the waterfall at Refuge Bay before travelling to Pittwater and Middle Harbour to complete their work.

Mr Richmond said most of the Australian Constitution was devised during the Easter weekend on the Hawkesbury.

The third significant link between Brooklyn and the Federation movement was in 1901 during the festivities associated with the opening of the first parliament.

The Duke and Duchess of York, who later became King George and Queen Mary, represented King Edward VII for the event.

When they arrived from Queensland, their train was shunted back along the Long Island branch to the wharf where the General Gordon waited. The royal couple were then taken for a trip on the old paddle-wheeler.

"The occasion was a very special memory for Brooklyn residents who crowded the foreshores to catch a glimpse of the Duke and Duchess," Mr Richmond said.

The Advocate thanks BME Boat Hire at Brooklyn for providing the vessel for our sight-seeing tour.

It's time for recognition

THE historic events that shaped Brooklyn have been little remembered or commemorated, much to the dismay of local historians.

Brooklyn resident and historian Tom Richmond said: "No special flags fly and no plaques proclaim the Federation links.

"Areas which felt the presence of Parkes, Reid, Robertson, Barton, Griffith, Kingston, Downer and other founding fathers, remain anonymous to those of the present generation."

The original railway bridge was dismantled after World War II but the builders plaque and the piers remain beside the second railway bridge, built in 1945.

"The old bridge was condemned before World War II but all military traffic during the war travelled across the bridge . . ." he said. "The bridge was in a fact a prime target and was circled in red on a lot of Japanese war maps — bombing the bridge would have destroyed the transport link to the north."

River Wharf rail station is still identifiable at the end of Long Island, but is in an overgrown condition.

"In my humble opinion, the station should be cleared and heritage listed," Mr Richmond said. "There's no indication of it ever being there."

The site of the banquet on the pontoon off Dangar Island is also not commemorated.

"Brooklyn did feature on the first five pound note, but subsequently has had little recognition," Mr Richmond said.

"It has always been on the edge of everything rather than in the centre — we have been neither metropolitan nor country."

Mr Richmond fully supports Hornsby Council's application for a $200,000 Federation Community Projects Program grant to recognise Brooklyn's role in Australia's path to unity.

But he said the proposal to upgrade McKell Park and establish a Federation Foreshore and Lookout was part of a pre-existing plan for the area.

"Few areas of Australia, not even the capital cities, can claim the type of significance in the Federation movement that Brooklyn can," he said. "It would indeed be sad to see this significance unrecognised at the time of the centenary."

Hornsby Council said the grants would be announced in May.

The Engineering Conference,
Newcastle, 18-22 April 1983

The Hawkesbury River Railway Bridge (1886-1946)

W.K. KING
(Retired), Resident Engineer for the Construction of the Present Bridge
and
D.J. FRASER
Senior Lecturer, School of Civil Engineering, The University of New South Wales

SUMMARY The Hawkesbury River Bridge and the Woy Woy Tunnel were the major works on the Sydney to Newcastle railway which itself was of major importance to colonial Australia. With the completion of the bridge in 1889 and the line to Newcastle, the colonies of South Australia, Victoria, New South Wales and Queensland had a continuous rail link. Despite the inconvenience of the breaks in gauge, it was possible to travel by rail from Adelaide to Brisbane, a distance of 2860km, 400km more than London to Istanbul.

The bridge was 883m long and was the largest project of its type in the Southern Hemisphere. It was the subject of world wide tenders, won by an American contractor, and was well reported in the international engineering journals. The foundations proved to be the most difficult phase of the work and were eventually the main reason for replacing the bridge in 1946.

The paper reviews those details that made the original bridge a high point of colonial bridge engineering and now make it worthy of a meritorious place in our engineering heritage, albeit posthumously.

1. INTRODUCTION

The railway system of New South Wales began in 1855 with the 20 km line from Sydney to Granville. Despite some major engineering works such as the famous Zig-Zag near Lithgow, the expansion of the network proceeded at a modest rate, 39km per year, for the next fifteen years. In the 1870's there was a dramatic acceleration (Newcastle Herald 1889) in the rate of construction to 148 km per year. A similar situation was occurring in the adjoining colonies of Victoria, South Australia and Queensland. During the 1880's all thse networks met at their respective borders, Figure 1, and the traveller from Adelaide to Brisbane could expect soon to make a rail journey of 2860km, 400km longer than the journey from London to Constantinople (Istanbul). Indeed, with the extremes of the networks included, a longer journey was in the offering, from Coward Springs in South Australia to Charleville in Queensland; a distance of 4140 km which was 680km further than London to Cairo (Sir Henry Parkes, 1889).

Figure 1. Main line railways of Australia , 1885.

The traveller, however, could not make a continuous rail journey. A change had to be made onto the road or the sea route from Sydney to Newcastle, a legacy of the separate expansions of the Northern and, the Southern and Western rail systems, Figure 1. Successive colonial governments of New South Wales therefore resolved to close the gap and build a railway link between these two principal business centres, including a bridge across the Hawkesbury River. From the outset the Government showed wisdom in authorising "a first-class double line in anticipation of the traffic expected to follow the opening of the through route" (Engineering 1886), and "courage at committing the Colony to such a large project at a high cost, financed by borrowed capital" (Newcastle Herald 1889).

Figure 2. The Sydney-Newcastle railway , 1883-1889.

After the Enabling Bills were passed on November 15, 1881, construction of the railway began at various locations in 1883, but progress was principally in two directions, from Homebush north to Hawkesbury

River, and from Hamilton (near Newcastle) south to the bridge site, Figure 2. The line was opened in sections, Homebush to Hornsby in September 1886, to Hawkesbury River in April 1887, Hamilton to Gosford in August 1887, then to Hawkesbury River in January 1888. When the southern and northern lengths of the railway reached the Hawkesbury River, the Government chartered an American saloon ship "General Gordon", a rear paddle ferry, to transfer passengers across the river, Figure 3. The journey took approximately half an hour. Finally, the river crossing was completed with the opening of the new bridge on May 1, 1889.

2. THE BRIDGE SITE AND ALTERNATE SCHEMES

The site for the railway crossing of the Hawkesbury River is some 60 km north of Sydney, Figure 2, and 20 km from the entrance to Broken Bay, the estuary for the Hawkesbury River. At the bridge site, the river is pratically an arm of the sea with strong tidal currents, around 6 kph, and a range of 2.3m. There is little protection from bad weather and strong winds because the river has long, wide reaches adjacent to the bridge site, Figure 4.

Like Sydney's Port Jackson, the Hawkesbury is a drowned river valley; a deep steeply-sided trough with a considerable depth of sediment ranging from coarse sands on the rock base to silty muds at the river bed, Figure 5. For most of the 880 m crossing the depth to rock is 64m (210 ft) below high water with the sediment depth averaging 45m (150 ft).

The site, therefore, posed difficulties for any scheme to cross the river. One suggestion was to construct a breakwater at Peats Ferry (the road crossing) and incorporate a lock for shipping (Centennial Magazine 1888). This was never taken seriously, but a proposal that was, was to use train ferries such as had been used in various parts of America (N.S.W. Votes and Proceedings 1887).

Of the bridge schemes considered prior to the calling of tenders, only that with a lift span had any merit (ibid) because it did allow for the future use of this deep natural harbour by large ships.

3. CALL FOR TENDERS

A world-wide call for tenders, on a design and construct basis, was made through the Agent-General in London, on December 24 1884. This was an important departure from previous practice, whereby designs were prepared by John Whitton (Engineer-in-Chief)

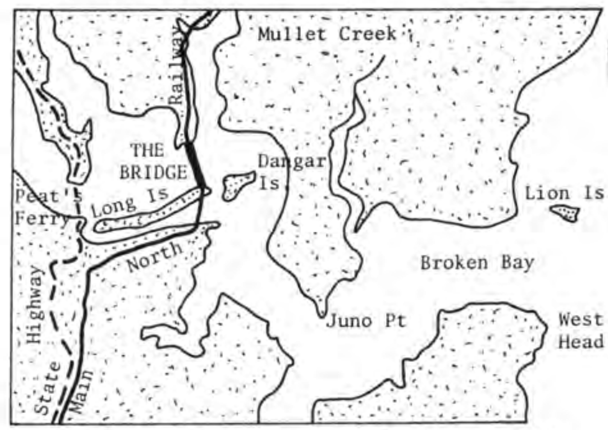


Figure 4. Site of the Hawkesbury River Bridge

and his staff, checked by Sir John Fowler in London, then built (to a large degree) by local contractors. The ironwork was usually manufactured in England. A number of major railway lattice bridge (Best and Fraser 1982) were completed this way between 1871 and 1887, so there was a reasonable body of bridge expertise available locally.

However, the proposed Hawkesbury crossing was a bridge project much larger than any previously attempted and beyond the financial resources of local contractors, so the Government sought to attract a major company from overseas with the requisite experience in bridge works of this scale.

In order to safeguard its own inexperience in such matters, the Governement appointed a Board of Examiners (W.H.Barlow, G.Berkley and Capt. D. Galton) to report on the tendered schemes in London, and then for Sir John Fowler to submit an independent report (N.S.W Votes and Proceedings 1887).

The Specification drew attention to two significant features of the project, (1)the unprecedented depths of the foundations (Iron 1886) and (2) the use of steel for the superstructure. Despite the bore-log information (Burge 1889, The Engineer 1885) the Specification omitted to give a limiting foundation pressure, which led to large differences in tendered foundation costs and which eventually was to prove the basic weakness in the whole design. The requirements for the superstructure, however, were given in minute detail (Engineering 1886).

A total of fifteen firms tendered (8 British, 3

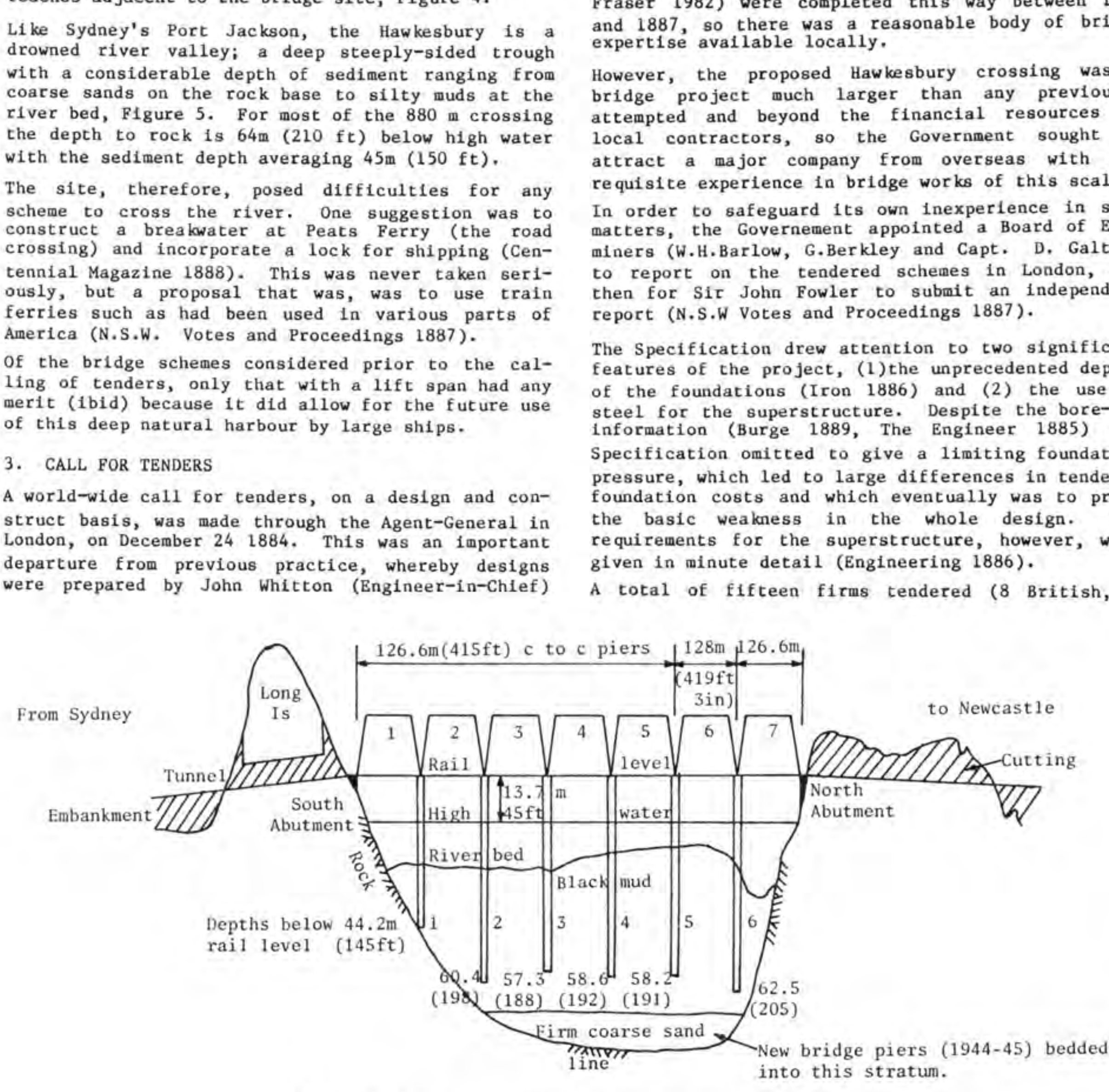


Figure 5. River cross-section and principal details

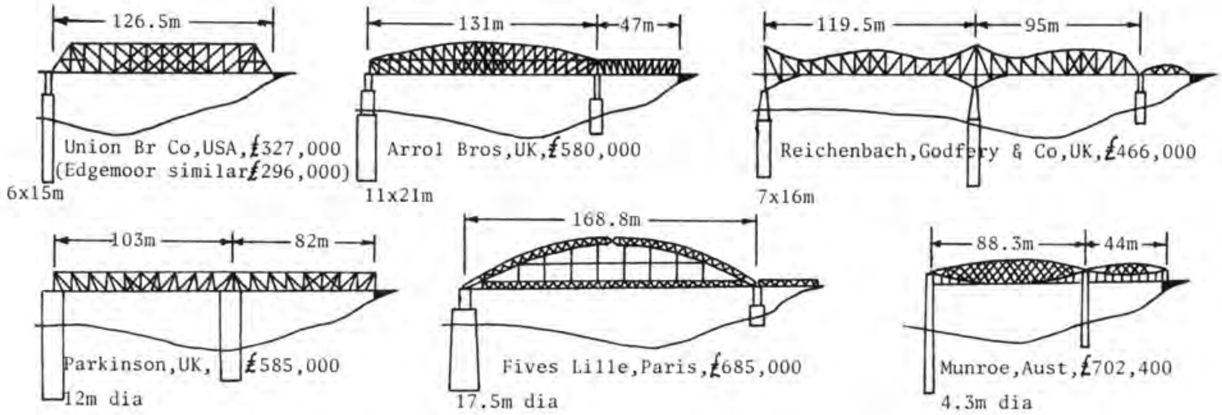


Figure 6. Sample of schemes for the 1889 Hawkesbury River Railway Bridge.

American, 1 French, 1 Canadian and 2 Australian) with some tenders containing more than one scheme. Details of the tenders are summarised in Sir John Fowler's report together with comparative drawings of each complete scheme (N.S.W. Votes and Proceedings 1887), only a sample is shown in Figure 6. Four of the British tenderers had successfully completed bridge works in the Colony as had two American companies, in particular the Edgemoor Iron Co, Delaware, who had supplied the Whipple trusses for the 1879 Shoalhaven River Bridge (Fraser 1981).

4. THE SUCCESSFUL TENDER

The Board of Examiners and Sir John Fowler were unanimous in their recommendation that the tender of the Union Bridge Company, Athens, Pennsylvania, be accepted subject to some minor changes. The Government approved this action on Jan 25 1886 and the Company accepted on Jan 27th at a final tender price of £367 000. The Union Bridge Company then sublet nearly all parts of the project, keeping only to themselves the manufacture of the eye-bars and pins for the pin-jointed trusses. Table I lists the principal subcontractors.

TABLE I
SUBCONTRACTORS - HAWKESBURY RAILWAY BRIDGE

Foundations	Anderson and Barr,New York
Superstructure erection	Ryland and Morse,Chicago
Steel supplier	Colville,Glasgow
Steel for eye-bars	Steel Company of Scotland
Rivetted steel	Arol Brothers,Glasgow
Iron for caissons	Head,Wrightson & Co, Stockton-on-Tees
Cement	Burge and Barrow,Kent
Stonework	Louis Samuel,Sydney

5. BRITAIN v AMERICA

An early reaction to the news of the successful tenderer being American, was one of dismay. The British journal The Engineer (April 9 1886) said "It is to be regretted that this bridge is not to be constructed by English constructors", and then goes on to add a touch of sour-grapes, "but they are better without it if they could not get a fair price in a fair way". The American journal Iron (March 19 1886) was more diplomatic but chortled a little in saying "Of course, the loss of the work to English bridge builders will probably be explained somehow......but we cannot help concurring that it is a great compliment to American engineers that such an important work should be entrusted to them in prefernce to home constructors".

Fortunately, time was to permit a more detatched view because a year later the British journal Engineering (April 22 1887) noted "the concurrence of all these[Barlow, Berkley, Galton, Fowler, Whitton] in favour of the design". This item also noted "that the Union Bridge Company number among its members, names associated with great engineering feats and bridges in America" and concludes that "when the problems of a bridge across the Hawkesbury are considered, the wisdom of the New South Wales Government in obtaining collective experience and advice is apparent".

Not only was trans-Atlantic prestige at stake but so was the merits of two different types of bridge superstructures. On the one hand there was the English "tradition" of rivetted girder type bridges, dominated by the lattice style of construction, relatively shallow and relatively heavy in weight/m^2 of deck and in appearance. By contrast, the Americans had pioneered and developed truss construction to the extent that it could match the strength and stiffness of most British schemes at a lower cost. Features of the many American truss types were (1)the use of pin-jointed construction, single large-diameter pins at the intersections of the members, (2) eye-bars for the tension members and (3) very deep trusses with overhead bracing and end portals that allowed trains to pass through the bridge, like a tunnel. The overall lightweight, spidery appearance was worrisome to the English eye.

6. THE FOUNDATIONS

The foundations of the Hawkesbury Bridge "enjoyed the distinction of being by far the deepest in the world" (The Railroad Gazette 1886). The Scientific America (1888), quoting from the Sydney Mail, sai that the tallest pier was about the height o our[Sydney] post office tower. A similar comparison with Sydney's Town Hall is shown in Figure 7. Anderson and Barr had experience with work of this magnitude on the Atchafalaya Bridge and Poughkeepsie Bridge, both in America, and the Hooghly Bridge in Bengall. Such was the scale of the foundation work that the Railway Resident Engineer said that "what is visible to the spectator is only about half the entire structure, the other half being sunk under water" (Burge 1909); a statement verified in terms of costs by The Railroad Gazette in 1886.

In accordance with their experience and common practice of the day, Anderson and Barr decided to open dredge the caissons although provision was made in the design of the caissons for compressed air working. Details of the wrought iron caissons are shown in Figure 8.

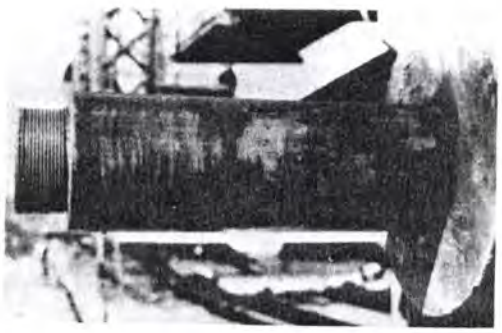
Foundations,piers 1 and 4 complete

Commemorative plaque

Assembling a truss on the pontoon

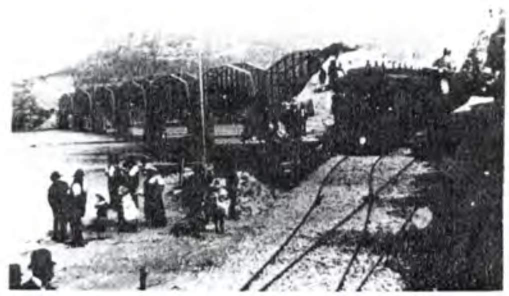
Paddle steam ferry "General Gordon"

Truss floating in mid-stream



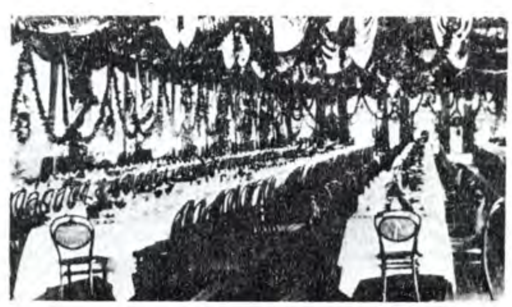
Pin and eye-bar construction

Engineering team at bridge test



Special train for Opening,May 1 1889

The completed bridge



Banquet setting for the Opening Ceremony

Figure 3. Photographs of the Hawkesbury Bridge Project (Railway Archives).

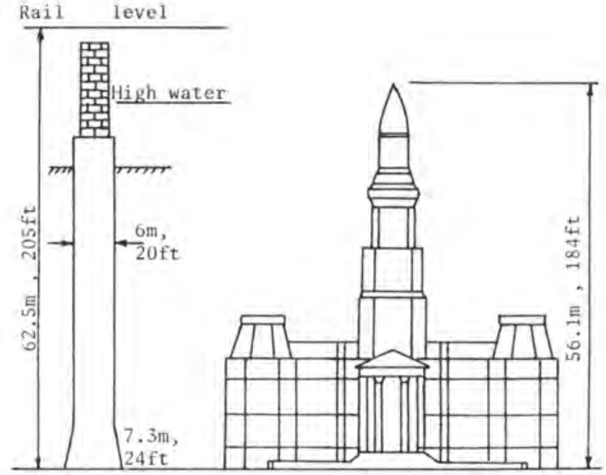


Figure 7. Deepest pier , No6 , compared to the Sydney Town Hall.

The caissons proved adequate structurally, however the form of their construction and method of sinking were generally unsatisfactory, compounding the difficulties of site and depth. Caisson No 5, Figure 5, was the first started on Dec 9 1886 but its pier was the last one completed (Burge 1889). When penetration into the mud was well advanced, this caisson began to move laterally, downstream, across the axis of the bridge. Despite uneven dredging, the caisson continued to drift and as its specified depth was approached, it was off-centre by 5ft at the bottom and 3ft at the top. The Contractor attempted to rectify this situation by constructing a cribwok of piles and rocks against the downstream face to act as a buttress, plus a cluster of piles a short distance upstream with cables secured to the caisson. Dredging in the downstream tube continued some 4.5m (15ft) until the caisson moved to a vertical position, however the buttress and anchoring system simply followed the movement due to the low resistance of the mud to lateral forces.

Caisson No5 was therefore well off centre, so a cresent-shaped caisson was fabricated to fit snuggly against the upstream side of the main caisson. The additional caisson had two dredging tubes with concrete between them to assist the sinking. Success seemed at hand, but then the new caisson collapsed when about 8m from the bottom and so its vertical load capacity had to be ignored. No5 caisson was temporarily abandoned.

The next caisson, No4, was started on March 8 1887 and with little difficulty was bottomed in its correct position three months later. Caisson No6 however developed similar problems to No5, but this time the drift was longitudinally. Nothing the Contractors tried corrected the northerly movement, so when the caisson bottomed, it was vertical and still on line but was over 1m out of position. Fortunately the supply of the trusses was still a year away so consent was obtained to increase span No6 by 1.3m (4ft 3in) and shift the northern abutment by the same amount so that span No7 could be made without change.

At this stage the Contractors modified the bottom splay of the caisson by adding vertical plates with concrete between them and the splay, as shown by the dashed lines in Figure 8. The offset afforded a better breaking of the skin friction and caissons Nos 1, 2 and 3 were founded accurately without difficulty early in 1888, each within four months of starting. Finally, the Contractor returned to caisson No5 and completed the stone pier by corbelling upstream.

In all cases, the caissons were meant to be filled with strong durable concrete so that "it will matter little if after the piers are sunk the iron shells rust away" (The Railroad Gazette 1886). The poor quality concrete actually used and the reliance on rusting shells were two important reasons for replacing the bridge, 1943-1946.

7. THE SUPERSTRUCTURE

Although the seven steel trusses could not claim the same type of world record as the foundations, they did none the less constitute the largest bridge of its kind in the Southern Hemisphere and certainly the largest bridge project in Australia for many years.

When the Union Bridge Company submitted its tender, their engineers proposed to use Whipple trusses, Figure 6, however the Board of Examiners recommended that horizontal stiffeners be added in order to support the tall vertical compression members. Subsequently, the Company changed the design but incorporated the stiffeners, Figure 9. This style of truss based on the successful Petit truss. (Davis 1908) had all the standard features of the American system, particularly the use of eye-bars and large-diameter pins instead of all-rivetted construction. The details are taken from Enginering (1887) and some technical terms are from the contemporary text-book by Johnson et al (1894).

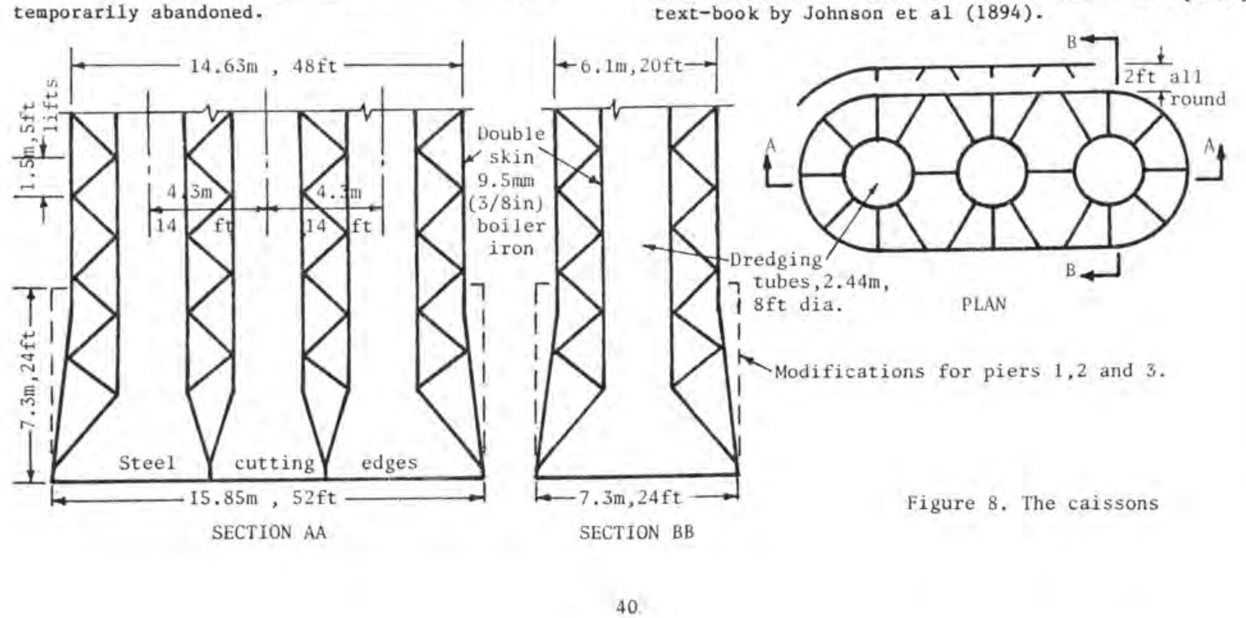


Figure 8. The caissons

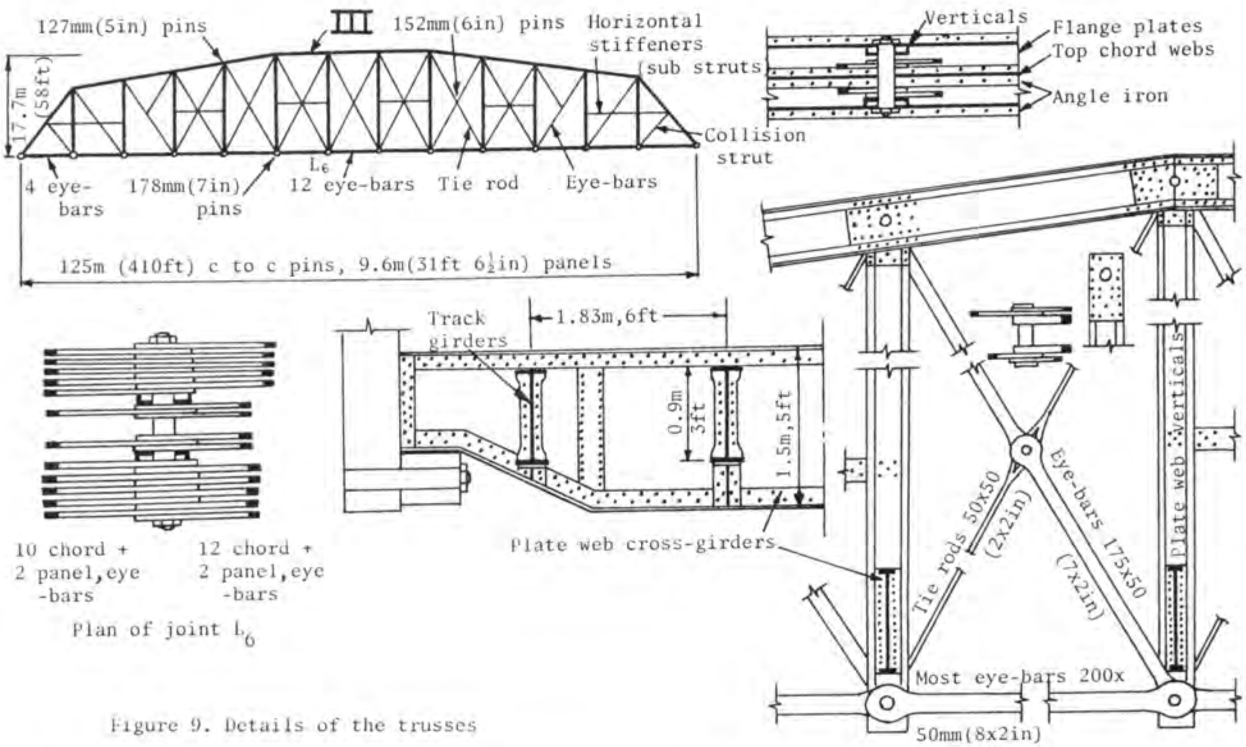


Figure 9. Details of the trusses

The drawings show that American bridges did contain rivetted components. These were the prefabricated shop-rivetted units. It was in order to avoid the defects of field rivetting that pins were adopted for field joints (Morris, N.S.W. Votes and Proceedings 1887). Debate over the advantages and disadvantages of the two methods of construction raged for years without a clear resolution. It was claimed that a pinned bridge could be erected in a quarter of the time required for a rivetted structure. Erection times for the Hawkesbury trusses and the all-rivetted lattice railway bridges confirmed this claim. However, pin-jointed construction had important long-term disadvantages, (1)the pins could not be withdrawn during service for inspection and maintenance because overall structural integrity would be lost, (2)it was very difficult to arrange strengthening of the bridge to carry heavier/faster trains, from Cooper's E25 to E60 loading, and (3)the pins were very difficult to extract during demolition (King.W.K).

A good account of the erection of the trusses is given by Morse (1938) who was a Principal of the erecting company, Table I. The following is a summary. They had planned to drive piles and build timber falsework between the piers and assemble the trusses in their final positions. The nature and depth of the river bed, Figure 5, caused a change of plans. The trusses were assembled away from the bridge site and then floated into position. A huge iron pontoon, 102m long x 18.6m wide x 3m deep, was constructed. It contained 44 water-tight compartments equipped with valves. On top of the pontoon was a 13m high timber trestle upon which the trusses were assembled. This took place in a sheltered site at Dangar Island, Figure 4, 1 km downstream from the bridge. A network of anchor blocks were located in the river bed so that ropes and cables could guide the pontoon and trusses into position.

Overall the scheme was sound and worked well. All seven spans were erected and located in the year ending March 1889, but not without some close calls with disaster. For example, span No1 was blown ashore but survived due to the wind generated "high tide";span No3 was blown off course but the anchor cables held fast and positioning was completed when the weather improved;then the last span No7 crashed into pier No6. Damage was slight and the span was in place an hour later. The river was bridged on March 1 1889.

Prior to the gala opening ceremony on May 1 1889, the bridge was tested on April 24th using three locomotives plus eight trucks loaded with rails, on each track. The detailed report (Deane 1889) shows that the maximum deflection was 55mm (2.2in) or 1/2278 of the span.

8. REASONS FOR REPLACEMENT

Before the bridge was officially accepted by the Government at the end of the contract/maintenance period, an inspection was made in March 1890 of the piers. A cofferdam was used to enable inspections 3m below the start of the stonework, well below water level. The examination revealed poor quality concrete not protected by the iron shell of the caisson. The Union Bridge Company spent nine months replacing the faulty material (King.W.K).

In 1937 a crack formed in pier No4 due to tension developed by the contraction of adjacent spans resting on "frozen" roller bearings. Inspections by divers revealed extensive rusting of the caisson but more importantly, the concrete inside could be easily penetrated by pushing a rod into it. Other piers had similar faults. Diamond drilling indicated a potentially dangerous condition. Line and level of the piers had been regularly measured since 1890 and the results showed that all piers were settling gradually and moving laterally, downstream.

Therefore, after only fifty years of service, this great bridge was marked for replacement. In the meantime temporary repairs were made, a severe speed restriction was imposed and single line working was introduced on the upstream track.

The designers of the new bridge heeded the problems of the site, the difficulties in constructing the first bridge and the construction faults. The new bridge was built on the upstream side of the old bridge by the Railway Department with the co-author as Resident Engineer. A full description was published by the Institution of Civil Engineers (Fewtrell 1949).

9. CONCLUSION

The Hawkesbury Railway Bridge was the last link in the ribbon of iron joining the colonial capitals of South Australia, Victoria, New South Wales and Queensland. Its completion, along with the railway from Sydney to Newcastle, provided a major boost to the commercial development of Newcastle and to the north and north-west of New South Wales.

At the time of its construction, 1886-1889, the bridge was the largest of its kind in the Southern Hemisphere and one of its piers was founded deeper than any other in the world. The calling of tenders on a world-wide basis and the subsequent letting of the contract to an American company, broke the traditional dependence on British technology.

Last to come but unfortunately first to go. The bridge had been a feature of Australia's first centenary. It is a pity it could not have survived to see the second centenary in 1988. However, it played its part in our engineering history and its memory deserves a place in our engineering heritage.

10. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of Railway Archivist, John Forsyth, and the staffs at the Public, Mitchell and Fisher Libraries.

11. REFERENCES

Best, R.E and Fraser, D. (1982). Railway Lattice Girder Bridges in New South Wales. Conference on the Protection of the Engineering Heritage, 1982, Brisbane May 9-12. The Inst of Engrs, Aust, Preprints of papers, pp85-92.

Burge, C.O. (1889-90). The Hawkesbury Bridge, New South Wales. Proc Inst Civ Engr, Vol 101, 1889-90, Part III, pp2-12, Discussion pp38-72. -
(1909) Adventures of a Civil Engineer, Alston Rivers Ltd, London, pp256-270.

Centennial Magazine (1889-90). A Great Railway Bridge. Vol 1, pp253-263, Mitchell Library, Sydney.

Davies, M. (1908). The Theory and Practice of Bridge Construction in Timber, Iron and Steel, McMillan & Co, London, p150.

Deane, H. (1889). Testing the Railway Bridge over the Hawkesbury River. Report to the Engineer-in-Chief, April 27 1889, Railway Archive Office.

Engineer, The - Reports about the Hawkesbury Bridge; Vol 58, Nov 14 1884, p363; Vol 59, Feb 20 1885, p155; Vol 61, April 9 1886, p286; Vol 66, Sept 7 1888, p207; Vol 67, June 14 1889, p500; Vol 68, Sept 13 1889, p223.

Engineering - Reports about the Hawkesbury Bridge; Vol 41, April 16 1886, p367; Vol 43, Feb 25 1887, p190; Vol 43 , March 11 p222, April 8 p318, April 22 p370.

Engineering and Mining Journal (1889). Opening the Hawkesbury Bridge. Vol 47, June 22 1889.

Fewtrell, A.C. (1949). The New Hawkesbury River Bridge, New South Wales. Jnl Inst Civil Engr, Session 1948-49, Paper No5694, pp419-460.

Fraser, D.J. (1981). Two Whipple Trusses in New South Wales - An Engineering Heritage Case Study. Trans.Inst. of Engrs, Australia, Vol CE23, No4, Nov 1981, pp272-283.

Iron (1886) - American Bridges Abroad. Vol 27, March 19 1886, p245.

Johnson, J.B., Bryan, C.W and Turneaure, F.E. (1894). The Theory and Practice of Modern Framed Structures, John Wiley and Sons, New York, pp60-69.

King.W.K. Private papers including notes on the demolition of the original Hawkesbury Bridge trusses, Archives Office, State Rail Authority (NSW).

Morse, E.K. (1938). Erecting the Hawkesbury Bridge, 1887-1889. Civil Engineering, Vol 8, No10, Oct 1938, pp682-685.

Newcastle (Morning) Herald - Reports about the Sydney to Newcastle Railway; Six part series April 2, 6, 9, 12, 13 and 15 1887; Opening Hamilton to Gosford Aug 16 1887. Reports about the Hawkesbury Bridge; Last span in position, March 4 1889; Testing the bridge, April 25 1889; Australia United, May 1 1889; Grand Opening Ceremony, May 2 1889.

New South Wales Parliament (1887). Votes and Proceedings, Legislative Assembly, 1887 (2nd Session), Vol 4, pp699-739.

Parkes, Sir Henry (1889). Speech at the Opening of the Hawkesbury Railway Bridge, May 1 1889, Railway Archive Office.

Railroad Gazette (1886). The Foundations of the Hawkesbury River Bridge. June 18, 1886.

Scientific American (1888). The Hawkesbury Bridge, Australia. Supplement No658, Aug 11 1888, p10504.

State Rail Authority (NSW). Main North Railway, Historical Notes; Photographs of the Hawkesbury Bridge; Woy Woy Tunnel; Plate Web Girder Bridges and Costs. Archives Office.

Sydney Mail (1886). Reports on the Hawkesbury Bridge. Jan 9, Feb 6, July 10 1886.

Sydney Morning Herald. - Reports on the Hawkesbury Bridge.Progress on railway and bridge caissons, Nov 29 1887; Superstructure, June 5 1885, Aug 11 1885, Jan 29 1886, May 1 1889; Visit to the bridge works by the Engineering Society of NSW, Jan 16 1888; Opening Ceremony, May 2 1889 pp8-9.

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Paper No. 5694.

"The New Hawkesbury River Railway Bridge, New South Wales, Australia." †

By Major-General Albert Cecil Fewtrell, C.B., D.S.O., V.D., M.I.C.E., A.M.I.E.Aust.

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† Correspondence on this Paper may be accepted until the 15th August, 1949, and will be published in a Supplement (obtainable on application) to the Institution Journal for October 1949. Contributions should be limited to about 600 words.—Sec. I.C.E.

Introduction.

The opening of the first railway line in New South Wales on 26 September, 1855, between Sydney and Parramatta, initiated a rapid development of the railway system of this State. Its growth expanded outwards from the capital, Sydney, and from Newcastle, 100 miles to the north. From the former, lines were constructed westward to scale the mountain barrier of the Blue mountains by means of the old Zig-Zag, since abandoned, opening up the plains of the west, and in southerly and south-westerly directions to link, in 1883, at Albury, about 400 miles away, with the railway system radiating from Melbourne, Victoria. From Newcastle, the northern portion of the system was pushed steadily forward across the Great Dividing Range, until in 1888 it linked at Wallangarra, on the New South Wales–Queensland Railway, with the line from Brisbane, 232 miles away.

The great natural barrier of the Hawkesbury river between Sydney and Newcastle delayed completion of the rail link between the two cities and it was not until early in 1885 that tenders were called for the construction of a railway bridge across the Hawkesbury river. In that year, the Government of New South Wales invited bridge-building firms throughout the world to submit designs and tenders for the construction of a double-track steel bridge. The design of the foundations and superstructure submitted by the Union Bridge Company of New York, except for minor alterations, was considered the most suitable for the project, and the contract was awarded to that Company in May, 1886.

In 1888 completion of the line from Gosford to Mullet Creek afforded rail communication between Sydney and Newcastle, whilst the ferry steamer "General Gordon" bridged the gap between the northern and southern railheads.

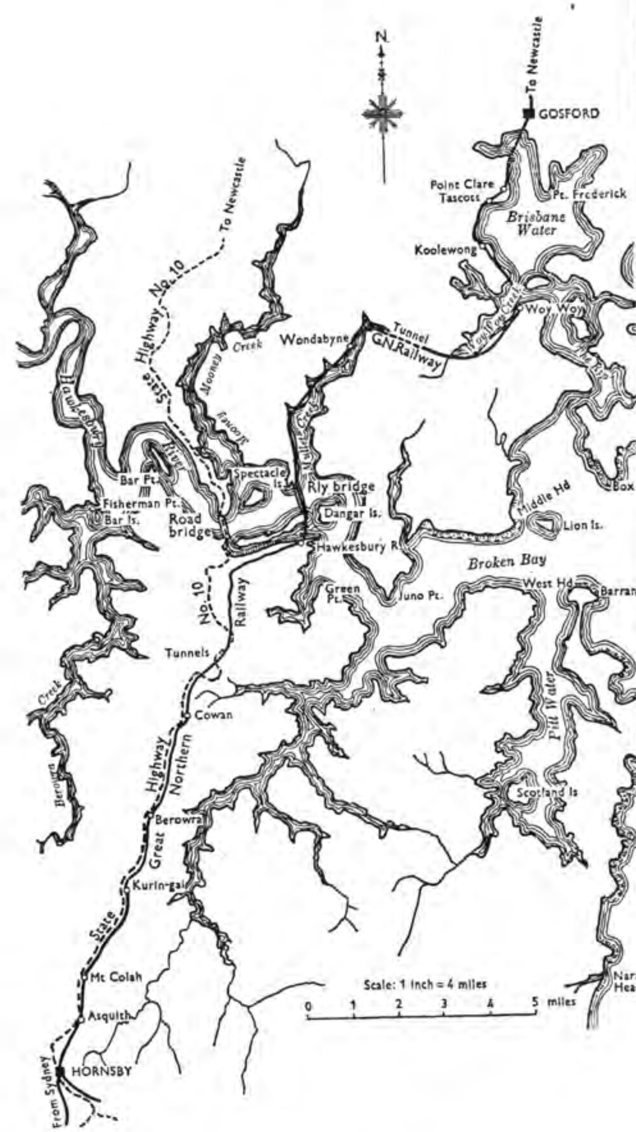
The first Hawkesbury river railway bridge was opened for traffic on 1 May, 1889. Its completion formed the last link in a continuous rail connexion between Australia's principal cities of Adelaide, Melbourne, Sydney, and Brisbane (*Fig. 1*).

Details of Old Bridge.

The first Hawkesbury river railway bridge consisted of seven camelback steel truss spans, each approximately 410 feet in length, of the pin-connected type with a maximum pin-diameter of 7 inches. The trusses had an effective depth at the centre of 58 feet, or a ratio of depth to length of about one-seventh. The main trusses were spaced 28 feet apart and were divided into thirteen panels.

The original design allowed for Cooper's E.25 loading, but in 1928 the floor system was strengthened to take E.40 loading. The main truss members were not strengthened, except for four 5-inch-diameter pins in

Fig. 1.



Location Plan.

the top chord of each truss, where the stress was relieved by the provision of U-bolts supported in heavy cast-steel saddles.

The superstructure was supported on masonry piers, which in turn rested on concrete caissons, the top of the latter being about one foot below low water of ordinary spring tides. The portion of the concrete casing available for inspection, that is, above river-bed level, was of wrought iron. In the lower courses affected by tide, the masonry was of Bowral Trachyte and the upper courses were of Hawkesbury sandstone.

Investigation of Substructure of Old Bridge.

From an early date it became apparent that the bridge would require close watching, and investigations at the time revealed some disquieting conditions. Within twelve months of the opening of the bridge the Contractors were called upon to remove faulty material at the top of the caissons. A cofferdam erected successively at each pier exposed concrete of the poorest quality in each case. At No. 2 pier, for example, 15 cubic yards of what amounted to a mixture of sand, mud, and a little cement had to be removed.

Survey measurements taken between 1890 and 1945 revealed progressive settlement of the piers as well as lateral movement. In May, 1945, the top of No. 6 pier was $5\frac{11}{16}$ inches downstream from its correct position.

Between June, 1937, and August, 1938, cracks appeared in the masonry of No. 4 pier and a scheme was formulated to replace the existing expansion bearings with a more efficient design. While this proposal was being investigated, information came to hand that resulted in a decision to carry out a thorough investigation of the substructure. Speed was reduced to 10 miles per hour and the double track was gauntleted on the down or western side of the structure.

The investigation took the form of a complete examination of all piers below water by a diver; the sinking of a shaft inside a cofferdam at No. 4 pier; and boring a number of test-holes inside the caisson with a diamond drill.

Meanwhile, concurrently with these investigations, recording instruments were used to determine the relative movement between the piers and the spans. The results demonstrated that the piers were being subjected to a push-and-pull action by virtue of the almost inoperative expansion bearings. It was determined subsequently that such movement as was measurable took place when the stresses in the steel built up to the extent that the friction between the top of the rollers and the bearing plate of the expansion shoe was overcome and the action became one of sliding rather than rolling. Each expansion bearing consisted of eleven rollers, 4 inches in diameter.

The implications of the results of the investigations could not be

ignored. The general condition of the bridge, taken in conjunction with the low limit of maximum axle loading which the old structure imposed, rendered the provision of a new bridge imperative.

The decision once made, steps were taken to maintain the old bridge during the period of construction of the new one. In addition to the reduction of speed over the gauntleted tracks, double-headed working was prohibited. The fractured masonry of No. 4 pier was secured by a heavy steel framing. Constant inspection of the substructure and a close watch on the masonry above the water line were put in hand. In connexion with the latter, it is interesting to record that the cracks in No. 1 pier, inactive since 1938, extended rapidly in August, 1945, eleven months before the opening of the new bridge.

Schemes Considered for New Bridge.

Consideration was first given to a proposal to erect a cantilever structure on the eastern or downstream side of the old bridge. In comparison with other schemes prepared, the estimated cost was of such magnitude that it was not adopted. A proposal for ten spans of 360 feet, also on the eastern side of the old bridge, was abandoned because of the number of deep foundations required and the comparatively long approach embankment on the northern bank.

A scheme was then considered for a bridge on the western side of the old one, to consist of eight spans, each 347 feet 6 inches in length, and five of the piers to be founded in a stratum of sand. This scheme entailed the construction of an approach tunnel on each side of the river. Extensive borings were carried out at the site of the principal piers, and it was found that local obstructions were present at No. 7 pier site which would render founding of the caisson rather difficult.

Ultimately, sites were selected for those piers at which dredging could be carried out to found them in the coarse sand. For those piers which were to be founded on rock close inshore by air-lock working, the depths of the foundations were kept to a maximum of 110 feet below H.W.O.S.T. The spans were then arranged as follows from south to north:—two 147-foot spans; one 445-foot 1-inch span; four 347-foot 6-inch spans; one 445-foot 1-inch span; and one 147-foot span. In order to preserve the symmetry of the steel superstructure, two 75-foot reinforced-concrete spans were substituted for one of the 147-foot spans at the southern end.

The general arrangement of the adopted scheme is shown in Figs 2, Plate 1.

Conditions at Site.

Fig. 1 shows the location of the new Hawkesbury river railway bridge. The new and old bridges span the channel of the Hawkesbury river between

Long island and the northern foreshore, and this channel is divided into two by Dangar island, approximately ½ mile downstream from the old bridge.

On both Long island and the northern foreshore the country rises steeply from the water's edge, the Hawkesbury sandstone beds being exposed extensively in each case.

A cross-section of the river-bed along the selected centre-line of the proposed bridge indicated that the sandstone strata extended across the river-bed. At approximately 1,900 feet from the southern abutment the sandstone beds are found at a depth of 285 feet below H.W.O.S.T., and then rise steeply to the northern bank, approximately 800 feet away.

The borings indicated that the river-bed is composed of transported sediments, the result of erosion in the higher reaches of the catchment-area. These sediments overlie the sandstone and consist of beds of black soft mud, black stiff mud, fine muddy sand, clean fine sand, and clean coarse sand. The latter reaches a minimum depth of 165 feet below H.W.O.S.T. and extends to considerably greater depths eventually overlying the sandstone beds. It was ultimately decided to found the piers where practicable in this coarse sand, in view of the great distance to rock.

The borings and soundings revealed that at the site of the proposed bridge the river-bed is in a state of equilibrium and that the possibility of damage by scour to the foundations sunk into the stratum of sand would be very remote.

At the site of the bridge the width of the river at H.W.O.S.T. is 2,690 feet and the depth of the main channel is 45 feet on the centre-line of the bridge. This channel is adjacent to the northern foreshore of Long island, the 75-foot depression near the northern foreshore being only a local one which lenses out about 300 feet eastward of the new bridge site into comparatively shallow water.

The river is tidal, the highest tide recorded being 6 feet 3 inches above the zero of the tide-gauge at the bridge site and the lowest, 1 foot 3 inches below, giving a maximum range of 7 feet 6 inches.

Observations show that at the commencement of the ebb and flood the flow is through the channel between Long and Dangar islands, eventually swinging to the main channel around the northern side of Dangar island. During flood when the streams from the two channels meet, some turbulence takes place along the northern foreshore of Dangar island in the vicinity of the flotation docks.

Main Features of Design.

The bridge is designed to carry two tracks of standard-gauge railway at 12-foot centres. The minimum clear width between the members of the trusses of any span is 28 feet, and the minimum unobstructed height above rail-level is 19 feet 8 inches. For navigation purposes, the clear headway above H.W.O.S.T. is not less than 40 feet.

The total length of the bridge, centre to centre of abutments and inclusive of the southern reinforced-concrete approach spans, is 2,764 feet 3 inches. Whilst the centre-line of the bridge is straight throughout its length, the track centres on the northern half of the northern shore span conform to the transition curve to the 30-chain radius curve through the northern tunnel.

The bridge is designed for Cooper's E.60 loading, with allowances for impact.

Caissons.

Caisson construction was adopted for piers Nos. 3 to 7 inclusive to be founded in the coarse sand and for piers Nos. 2 and 8 to be founded on rock. For piers Nos. 1 and 1A, where the depth to rock and the superimposed load were comparatively small, two cylinders 15 feet in diameter were founded under air pressure.

The caissons were rectangular in shape, being 51 feet by 29 feet, measured at the cutting-edge. At a height of 23 feet 11 inches above the cutting-edge, each caisson was designed to step in 1 foot 6 inches on the sides and 9 inches at each end. The design of the cutting-edges for all caissons is shown in Figs 3, Plate 2. That for the cutting-edges of piers Nos. 2 and 8, founded in rock under air pressure, required modification and a more robust design was adopted.

The mild-steel cutting-edges were welded throughout, such construction resulting in a more economical use of material. The top of the working or dredging chamber was stiffened by framed beams which divided the area into eight sections, each 10 feet square, and an adapter section, developing from a square, connected each of the eight dredging-tubes to the bottom flanges of the beams. To facilitate control of the caissons while sinking, the dredging-tubes were arranged in two rows of four tubes each.

Two sets of nozzles were built into each cutting-edge whereby water- and air-jets could be used if required during sinking operations. The air-jets were located so as to permit a stream of air being forced between the material surrounding the caisson and the caisson wall, to reduce skin friction. The water-jets operated inside the working chamber and were intended to soften and force any stiff material from the walls towards the centre.

The outside walls of the caisson were of reinforced concrete and were designed to withstand a hydrostatic head of 40 feet. For piers Nos. 3 to 7 inclusive, the walls were 12 inches thick to a height of approximately 90 feet above the cutting-edges. Above this height the walls were thickened to 1 foot 6 inches. For pier No. 8 the caisson wall-thickness of 12 inches extended to only 31 feet above the cutting-edge, owing to founding in rock under air pressure at a comparatively shallow depth. The walls were strengthened with vertical reinforced-concrete beams, which in turn were stiffened by steel struts threaded between the tubes.

The eight mild-steel dredging-tubes in each caisson were designed to be 10 feet in diameter up to a height of approximately 90 feet above the cutting-edge. Above this height the diameter was reduced to 9 feet by a special matching section. The tubes were of welded construction, except at the field joints, where 1-inch bolts were used to bolt the sections together. For those caissons to be founded in the sand stratum the tubes were designed to resist a pressure of 25 lb. per square inch. For those to be founded in rock under air pressure, the corresponding pressure was 55 lb. per square inch.

Welded domes in the form of truncated cones were provided for each size of tube, the cover-plate being drilled and tapped to take the necessary valves for air control during sinking. By removing the cover-plate and attaching a matching piece, an air-lock could be brought into use on any of the tubes. The domes were attached to the tops of the tubes and were used to control the stability of the caissons during the floating periods and during the early stages of sinking.

Careful investigations were made of the stability of the caissons during the initial periods of construction, both in the dock and later when anchored at the permanent site, and diagrams for progressive stages were prepared. It was arranged that two tubes could be opened to the atmosphere at any one time during construction prior to the caisson becoming supported by the river-bed, the tubes selected to be diagonally opposite and symmetrical about the short axis of the caisson.

The pressure in the tubes was controlled by an arrangement of pipes and valves which permitted the exhaustion and replenishment of any pair of selected tubes without interference to the pressure in the other six tubes.

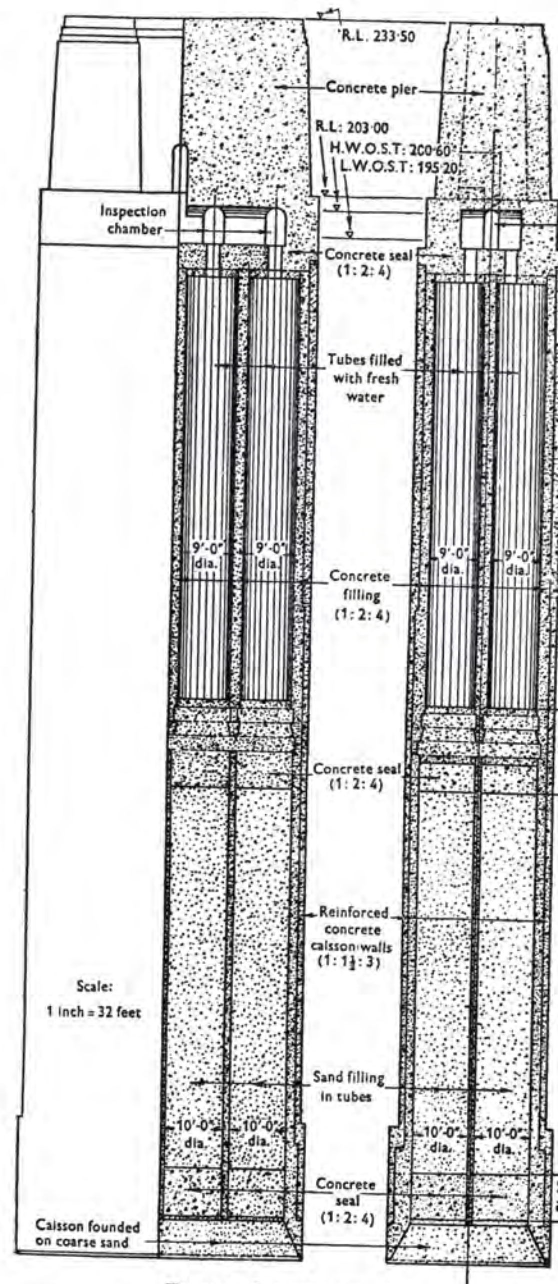
Sealing of the caissons after founding was effected by a bottom plug of concrete, on top of which sand was poured into the tubes to a point just below the reducing section. A final concrete plug, 15 feet thick, was then poured on top of the sand. No sand was used in the caissons of piers Nos. 2 and 8. All tubes were filled with fresh water above the final plug (*Fig. 4*).

The design provided for inspection-chambers to be cast in the top of each caisson. Access to each chamber was made through a doorway on the north side of each pier about 5 feet above H.W.O.S.T.

Piers.

Above low water the piers were carried up in mass concrete in the form of two columns at 30-foot centres, battered 1 in 24, and joined by a tie-wall 12 feet thick. A mat of 1-inch-diameter reinforcement bars was laid 1 foot 9 inches below the top of the pier, and above this was set

Fig. 4.



Typical Caisson and Pier.

a mild-steel grillage of welded construction, with machined plates to support the levelling screws of the bearings.

Loads on Foundations.

Table I shows the calculated loads of the various component parts of piers Nos. 6 and 7, including the superimposed dead and live loads, and the net and gross bearing pressures, after allowance has been made for the estimated skin friction. In this Table, the skin friction has been taken as acting to a height of only 24 feet above the cutting-egdes. As previously mentioned, this is the height at which the walls of the caissons are stepped in.

TABLE I

Item.			Pier 6 : tons.	Pier 7 : tons.
Superstructure			1,140	1,430
Live load E.60 on two tracks			1,920	2,187
Pier (including concrete seals)			11,820	12,100
Sand and water in dredging-tubes			3,456	3,631
Silt above caisson offset			1,046	1,071
Gross total load			19,382	20,419
Less :—	Pier 6 : tons.	Pier 7 : tons.		
Buoyancy	7,528	7,765		
Estimated skin friction	1,028	1,028		
			8,556	8,793
Net total load (estimated)			10,826	11,626
Load per square foot, gross			13·10	13·81
Load per square foot, net			7·32	7·86

Reinforced-Concrete Southern Approach Spans.

The southern approach spans were designed to be continuous over pier No. 1A and consisted of four reinforced-concrete T-beams 7 feet deep by 3 feet 1 inch wide, the slab being 1 foot 9 inches thick.

A total of 825 cubic yards of concrete was placed in the two spans in a continuous pour without construction joints. After curing, the track-slab was covered with a waterproof sheet of asphalt, on top of which was laid a course of brickwork.

Cylinders for Nos. 1 and 1A Piers.

The foundations for Piers Nos. 1 and 1A consist of two reinforced-concrete cylinders, 15 feet in diameter, spaced at 30-foot centres, sunk and keyed into the rock of the river-bed. The cutting-edges of the cylinders were of welded construction and the walls were of reinforced concrete. The bottom concrete seal was placed in the dry and at atmospheric pressure,

and the cylinders were married by a reinforced-concrete beam which acted as a base on which to construct the pier.

Abutments.

Both the northern and southern abutments were designed to be of the mass concrete gravity type with wing walls at right-angles to the faces of the abutments.

Steelwork.

The eight steel spans are divided into three groups. The largest two spans have the K-system of trussing, whilst the intermediate four spans are of the Pratt truss type. Both groups have polygonal top chords. The small span at each end of the bridge is also of the Pratt truss type, but has parallel top and bottom chords.

Table II gives the principal dimensions of the spans and the live loads plus impact used in the design.

TABLE II.

Description.	147-foot span.	347-foot 6-inch span.	445-foot 1-inch span.
Principal Dimensions of Spans.			
Length centre to centre of bearings	147 ft.	347 ft. 6 in.	445 ft. 1 in.
Height of truss at centre from neutral axes of top to bottom chords	30 ft.	60 ft.	75 ft.
Height of truss at end vertical members from neutral axes of top to bottom chords	30 ft.	42 ft.	45 ft.
Distance between cross-girders	24 ft. 6 in.	34 ft. 9 in.	31 ft. 9½ in.
Weight of span (excluding bearings): tons	250	1,030	1,650
Calculated live-load elongation: inches	⅝	1½	1⅞
Erection camber: inches	1¼	3	3½
Live Loads plus Impact.			
Truss	E.68	E.66	E.65
End cross-girder	E.80	E.73	E.73
Inter cross-girder	E.80	E.73	E.73
Stringers	E.93	E.89	E.90

The erection cambers shown were calculated to equal the deflexion caused by the dead load of the span plus a load of 3,000 lb. per foot of each track.

The floor system throughout is of the conventional riveted cross-girder and stringer type, with the exception that in the case of the larger six spans the stringers in alternate panels are seated at one end on special expansion bearings.

All spans were designed for Cooper's E.60 loading, with impact allowance determined by the method laid down in the Report of the British Bridge Stress Committee (1928).[1]

Bearings.

Special attention was given to the question of bearings in view of the failure of those of the old bridge. The inability of the latter to carry the loads afforded an excellent object lesson to be heeded in the design of the new bearings. The general arrangement of the fixed and expansion bearings for the largest span is shown in Figs 5, Plate 2. Similar principles were adopted in the design of the bearings for the intermediate and short spans.

The expansion bearings are of the segmental roller type, the number of rollers in the case of each of the three groups of spans being seven, six, and five respectively. Special provision is made for control of the alignment and angularity of the rollers between saddle and sliding base. Cast steel cover-plates enclose the rollers and attendant gear, and an oil seal prevents the admission of dust, salt spray, etc.

Both expansion and fixed bearings provide for transverse and longitudinal movements of that portion above their fixed bases. With the assistance of two 430-ton jacks the alignment of the span can be corrected in the event of undue settlement of the piers. The effect of direct vertical settlement can be corrected by the use of the jacks only. The expansion bearings of each span are designed for a temperature-variation of from 40° F to 120° F.

To assist in setting up the bearings on the piers, each bearing was supported on levelling screws which were capable of carrying the dead load of the spans and permitted adjustments being made to the bearings before construction of the special concrete pads under the bases.

Survey and Setting Out.

The location of the new bridge was fixed by using as a base the line joining two permanent marks previously established behind the northern and southern abutments respectively, on the centre-line of the old bridge. This distance, as measured by invar band, was 4,616·06 links.

The centre-line of the new bridge was parallel to and 198 feet from that of the old bridge.

The piers and abutments were fixed by intersection of their longitudinal and transverse centre-lines respectively, the latter being established from instrument-stations on the old bridge. These stations had to be re-established frequently because of the movements and racking of the old bridge, and in cases of important checks or final fixing, readings were taken within a few minutes of the re-establishment of the station.

[1] Dept. Sci. Ind. Research. H.M. Stationery Office, London, 1928.

Construction.

Earthwork and Tunnels.

The earthworks for the cuttings and embankments and the driving of the two tunnels were carried out concurrently with the sinking of the caissons for the piers of the bridge. Work commenced on this portion of the project on 18 July, 1939. Double-track tunnels were driven through sandstone interspersed with bands of shale, and were lined with concrete.

Launching of Cutting-edges.

The cutting-edge for each caisson was transported in sections by rail from the workshops at Chullora, near Sydney, the heaviest section being about 7½ tons.

The sections were assembled on a launching cradle for the welding of the field joints, following which the matching sections were welded to the working-chamber roof beam. Each dredging-tube was fitted with a dome with a rubber insertion gasket at the joint.

Figs 6, Plate 2, show the launching arrangements. The launching cradle was a horizontal timber structure, suitably braced, constructed on wheels which travelled on two 3-foot-gauge tracks inclined on a gradient of 1 in 10 into the water and terminating at a depth of approximately 12 feet at mean tide.

The launching of all cutting-edges was commenced at half-flood tide and, when the operations were completed, they were towed to the construction dock. After docking, flexible armoured air-hoses were connected from the tops of the domes to the air-control cabin to implement air-control of the caisson.

Caisson Construction.

A comparatively sheltered site was selected for the construction dock, the use of which reduced to the minimum the construction period at the pier site, where conditions of tide, current, and weather (the pier sites being very exposed) made construction work hazardous, with consequent increased risk of accident and damage to the caissons.

The dock was a pile structure, erected adjacent to and on the upstream side of the southern abutment of the old bridge. Figs 7, Plate 3, show the lay-out and design. It was 54 feet by 31 feet, constructed of braced piles fitted with the necessary timber rubbing-pieces and guides for the caissons, and was connected to the shore by an access footway. A footwalk was also constructed on the three closed sides of the dock to facilitate the placing of reinforcement and concrete, and the control of the caissons. A 5-ton crane was installed for erection purposes, together with a concrete mixing-plant. The depth of water in the dock was 32 feet at L.W.O.S.T.

The first stage of construction in the dock was the placing of concrete between the walls of the cutting-edges. Sliding concrete forms were then attached, and the outside walls of each caisson were built up as shown on the stability diagrams for construction in the dock. Very little departure was made from these diagrams, but occasionally, for greater stability, the steining was poured to a slightly greater height than shown. After this stage was completed, the caissons were towed to their respective sites in the river and moored to prepared anchorages.

Following the mooring of the caissons and the attachment of the air-hoses to the domes, the outside walls were built up and the steining concrete was placed in accordance with the stability diagrams. When sufficient freeboard had been obtained for a particular site, the caisson was gradually lowered into the river-bed by exhausting the air slowly from the eight dredging-tubes. Once the cutting-edge had entered the silt, the pressure in the tubes was regulated to prevent the caisson from lifting during the rise of tide. In the case of pier No. 4, however, exact positioning of the caisson was difficult and it had to be lifted by air a number of times.

The transition from complete buoyancy to full support of the caisson by the mud was effected by the process of dredging from the tubes in selected pairs, pressure being maintained meanwhile in the other six. At the same time, the extension of the outside walls and the addition of the steining concrete was proceeded with as required. Ultimately, on complete support being attained, all eight domes were removed and open dredging was resorted to in the orthodox manner.

When penetrating sand and silt strata, sinking was assisted by further use of air-pressure. Dredging in each well was carried to below the cutting-edge, the domes were replaced, and the pressure in each tube was slowly built up to approximately 25 lb. per square inch.

The water-level in each tube was thus reduced by approximately 57 feet, and the expulsion of this water from under the cutting-edge into the surrounding sand had the effect of "lubricating" the latter and generally disturbing its stability. The air was then suddenly exhausted from each tube by opening simultaneously large valves at the top of each dome, thus causing considerable turbulence in the sand, resulting in further sinking of the caisson. It was noticed that the sand usually rose in each tube to a height approximately equal to twice the run. This method was used in the final positioning of caissons Nos. 3 to 7 inclusive on reaching founding-level in the coarse sand stratum.

The sand in each tube was trimmed to a common level, and a 9-foot plug of concrete was placed under water, using buckets of ½-cubic-yard capacity fitted with butterfly doors. Clean coarse sand was then poured into the tube to an average depth of 85 feet above the cutting-edge. During this operation the water was maintained at mean-tide-level, and on completion of the sand filling the water above the sand was pumped out.

A 5-foot seal of concrete was then placed on top of the sand, care being taken to prevent hydrostatic pressure building up underneath the concrete and thus adversely affecting the seal. Two sections of each tube-lining were then removed, exposing two circumferential chases, 2 feet 6 inches high and 6 inches deep, for which forming had been previously attached to the outside of the tubes prior to the pouring of the steining concrete at that level. The seal was then strengthened by an additional 10-foot plug of concrete which keyed into the chases referred to. Within a timber cofferdam the pier base, including the inspection-chambers and galleries, was constructed to a height of 2 feet 6 inches above H.W.O.S.T. The base was set out accurately within the cofferdam, thus correcting errors of position of the caisson. The variations of the caissons from the true centre-line are shown in *Figs 8* (*a*) and (*b*).

Securing Caissons at Site.

The cutting-edges for caissons Nos. 2 to 8 inclusive were all successfully launched without incident and towed to the construction dock, where the walls were built up and steining concrete was placed to the stage required for floating to the permanent site. In general, the draught of the cutting-edges at launching was 7 feet, with 6½–7 ounces air-pressure in the tubes.

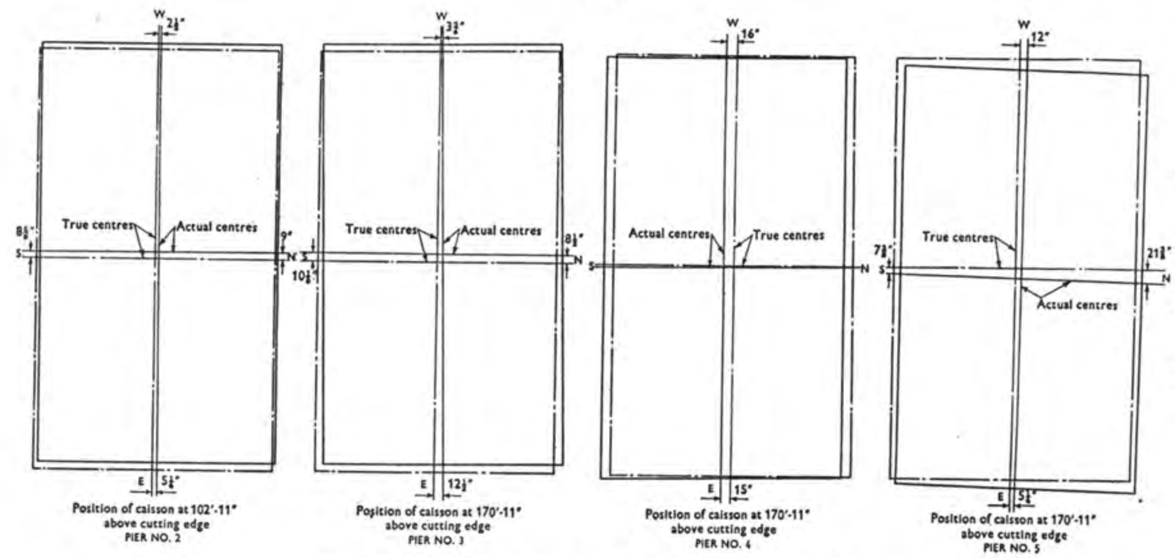
The first cutting-edge (No. 4) was launched in November, 1940. The walls were built to a height of 41 feet 5 inches in the dock, and concrete filling was poured to approximately 17 feet above the cutting-edge. At this stage, the draught was 33 feet 8 inches, with an air-pressure in the tubes of 12 lb. per square inch.

Caissons Nos. 2 and 3 were built in the dock to proportions similar to No. 4 before being towed to site, as the depth of water at each location was fairly uniform. The height of the walls and the weight of the filling of caisson No. 5, however, were made such as to give a draught of 28 feet, in view of the decreasing depth of water. In the cases of caissons Nos. 6 and 7, the walls were constructed in the dock to a height of 27 feet 5 inches, with 11 feet of filling, giving a draught of only 23 feet.

For caisson No. 8, a devious course was plotted from predetermined soundings to avoid the shallow water in the middle of the river. This permitted of as much work as possible being completed in the dock, and consequently correspondingly less work at the final site, where the depth of water was approximately 57 feet. In this instance, the walls were built to a height of 31 feet, which, with 13 feet of concrete filling, gave a draught of 26 feet. During the 60 minutes' passage of the caisson from the dock to its site, the mud of the river-bed was disturbed at one location about 5 chains on the downstream side of the old bridge.

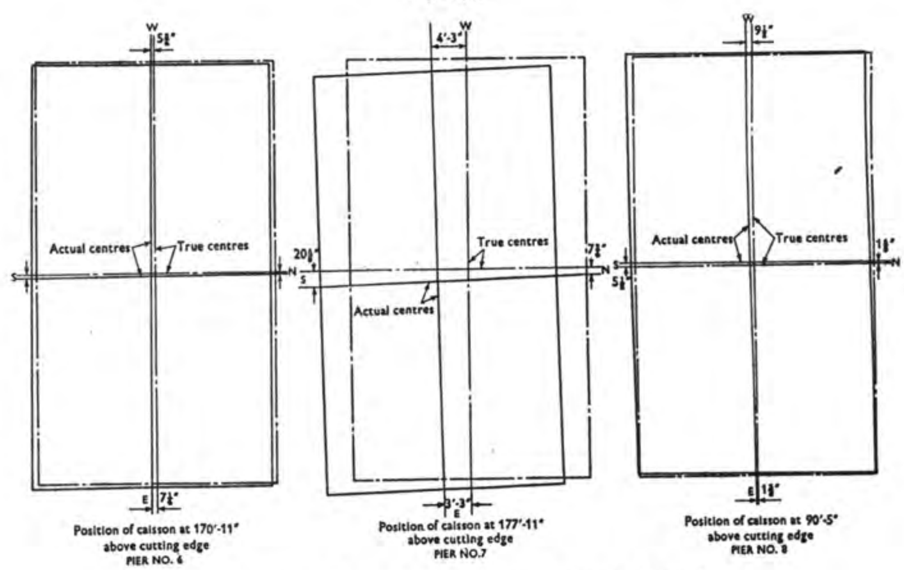
With the exception of caissons Nos. 2 and 5, little difficulty was experienced in mooring and holding them secure. Before caisson No. 2 was completely moored, a strong westerly wind arose, and the upstream moorings parted, allowing the caisson to move downstream towards the old bridge. Temporary moorings were attached to pier No. 1 of the old

Figs 8 (a).



POSITIONS OF TOPS OF CAISSONS FOR PIERS NOS. 2, 3, 4, AND 5.

Figs 8 (b).



POSITIONS OF TOPS OF CAISSONS FOR PIERS NOS. 6, 7, AND 8.

bridge and to the construction dock adjacent, and these moorings held until the wind abated. The caisson was then re-docked until fresh anchors could be jetted down into the river-bed. It was finally towed out and moored on 31 July, 1941.

On Sunday, 31 May, 1942, three weeks after caisson No. 5 had been towed out to its site, the northern anchors dragged during rough weather, allowing the caisson to swing in a southerly direction. As the cutting-edge had penetrated only a few feet into the silt, the caisson drifted on to the mooring punt, damaging the mooring winches, the concrete form-work, and the air-hoses connecting the domes to the control cabin, thus permitting air to escape from the tubes. Before the mishap could be rectified, the caisson had moved in a southerly direction to a position approximately 10 feet off its true transverse centre-line. The maximum air-pressure for stability was then provided in the tubes, but this was insufficient to lift the cutting-edge completely out of the mud. Three-inch-diameter pipes were then jetted down into the mud on the northern side, from where mud was also dredged. Additional moorings were made fast to anchorages in rock on the northern foreshore and a constant pull was maintained. The combined operations were successful, and the caisson was restored to its correct position (*Figs 8 (a)*).

No other untoward incident occurred in the positioning of the caissons, and generally no special preparation was given to the river-bed to receive the cutting-edges, except for caisson No. 8, for which a large quantity of spalls was dumped on to the river-bed to provide a level platform on which to land the cutting-edge.

Control of the caissons by air was found to be very flexible, provided that the cutting-edge had not penetrated too deeply into the mud.

Sinking of Caissons.

Caissons Nos. 3 to 7 inclusive, and Nos. 2 and 8, to the stage where air-lock work was necessary, were put down by the open-well dredging method, using grabs of 32 cubic feet capacity: 5-ton electrically-driven cranes, with 75-foot jibs, were used for operating the grabs and were mounted on 98-foot 6-inch by 40-foot pontoons constructed for this work and later used for the flotation of the spans.

Caisson No. 4 was towed to its site in the river and moored on 2 April, 1941. The main difficulty experienced during the sinking operations was the dredging of the thick black mud, which was not disturbed to any great extent by the water-jets inside the cutting-edge. Teeth were welded on to the bucket of the grab to facilitate dredging, and later 3-inch-diameter pipes were jetted down to a depth of 80 feet below low water at the northern side of the caisson. The tendency was to move southwards, but the out-side jetting proved reasonably successful in correcting the position and, on founding, the caisson was approximately 1 foot 3 inches southwards of the true transverse centre-line (*Figs 8 (a)*). No uncontrolled runs were experienced with this caisson, which was ultimately founded on 1 July, 1942, at R.L. 21·05, the cutting-edge having penetrated 11 feet 4 inches into the coarse sand stratum.

When the cutting-edge of caisson No. 3 was approximately 120 feet below H.W.O.S.T. (R.L. 80·60), considerable difficulty was encountered in grabbing through a layer of thick mud. The water-level inside the dredging-tubes was lowered by 20 feet and the water jets inside the cutting-edge were brought into operation. Having regard to the less stable material underlying the stiff mud, the outside walls were previously built up to what was believed to be a safe height, as it was anticipated that a run of about 10–12 feet would eventuate. The caisson actually sank 18 feet 10 inches, and at the end of the run the freeboard above H.W.O.S.T. was a matter of inches only. Fortunately, the sliding steel forms had been previously fixed for the next 3-foot 6-inch lift of the concrete walls, and the tide was falling. The forms were caulked and the additional lift was quickly poured before the next high tide. Sinking proceeded thereafter at a normal rate, and the caisson was founded at R.L. 22·46 on 2 September, 1942. The run mentioned was the largest recorded in the sinking of all seven caissons. Generally, they were of moderate proportions and were well under control.

Once under way, the sinking of caissons Nos. 5 and 6 proceeded without untoward incident, although the usual difficulties associated with such undertakings were encountered, particularly when penetrating the thick black mud. The consistency of the mud often varied over the area of the caisson, and it was found necessary, in some instances, to back-fill certain wells with sand for some feet above the cutting-edge and to maintain air-pressure therein to act as a brake while open dredging took place in other tubes.

The jets built into the cutting-edges were generally unsuitable for disturbing the mud at the foot of the walls, but those put down as required on the outside proved satisfactory in assisting movements to correct position.

Having regard to the diameter of the wells and to the comparatively small size of grab used, dredging operations were necessarily slow, but the sinking of caisson No. 6 proceeded uniformly throughout 1942. The best rate of sinking was attained during November, 1942, when the caisson was dropped 14 feet in 8 days. It was ultimately founded on 1 January, 1943, at R.L. 22·44, in the stratum of clean coarse sand.

Operations were proceeding concurrently at four major caissons, as well as as at the cylinders for pier No. 1. Limitations of man-power, plant and material due to war-time restrictions imposed a serious strain on available resources, and consequently operations extended over a longer period than would have normally been the case.

Dredging at caisson No. 5 did not commence until 2 months after securing it at the site. Sinking was very slow for the first few months, for the reasons already outlined, and in December, 1942, work was suspended on the caisson for approximately 2 months as a war precaution. On resumption, an accelerated rate of sinking was maintained, owing to additional plant becoming available, and during March, 1942, the caisson was dropped 17 feet in 9 days. In the final drop to founding-level on 1 October, 1943, the sand was forced up to a height of 16–19 feet above the cutting-edge, thus entering the dredging-tubes. This sand was not removed, but was merely trimmed off level before placing the bottom concrete seal. The caisson was founded at R.L. 20·58, having penetrated approximately 20 feet into the coarse sand stratum.

The deepest caisson is No. 7, which was founded at R.L. 17 on 13 April, 1944. The cutting-edge is thus 183 feet 7 inches below H.W.O.S.T. As may be seen from *Figs 8 (b)*, this caisson shows the greatest departure from true centres. When the cutting-edge had penetrated approximately 70 feet below H.W.O.S.T. (that is, 45 feet into the bed of the river) it was found that the caisson, although maintaining a vertical position, tended to move in a southerly direction. Mooring-ropes were made fast to rock anchorages on the northern foreshore, approximately 600 feet distant. In an endeavour to correct the drift, the caisson was bias-dredged from the southern tubes only and the concrete filling was built up on the southern side 20 feet in excess of that on the northern side of the caisson. In addition, jetting-pipes were put down on the northern side to soften the stiff black mud. The object of these measures was to tilt the head of the caisson over towards the south and thus throw the cutting-edge in a northerly direction. However, the caisson still moved slowly in the southerly direction and, when founded, the eastern end was 3 feet 3 inches and the western end 4 feet 3 inches south of the true position. The final drop of this caisson was effected by the method, previously mentioned, for penetrating the sand stratum, and amounted to 7 feet 6 inches.

Dredging operations did not commence at caisson No. 7 until about 5 months after it had been secured at the site, again owing to reasons previously outlined. Work was suspended on the caisson for two periods totalling 3 months, during mid-1943. On the resumption of operations, the rate of sinking was maintained at approximately 10 inches per working day for 2 months, after which penetration into the fine muddy sands retarded the rate somewhat. The greatest run experienced was 5 feet, from R.L. 44·76 to R.L. 39·46, in January, 1944, with the cutting-edge approaching the coarse sands.

Caissons with Air-locks.

The sinking of caissons Nos. 2 and 8 was carried out by open dredging until the stage was reached when dredging became impossible. Air-lock working was then introduced and the caissons were founded in sandstone under air-pressure. In anticipation of the change-over from open dredging to air-lock work, the design of the dredging-tubes was modified in each caisson.

In caisson No. 2, 10-foot-diameter dredging-tubes were used throughout. These were of $\frac{1}{4}$-inch mild-steel plate to a height of 69 feet 6 inches above the cutting-edge, where the thickness was increased to $\frac{1}{2}$ inch.

Prior to the installation of the air-locks, soundings in the wells revealed that, whereas dredging had been carried out to rock in the northern tubes, the bottom under the south-eastern well was very broken and that, contrary to expectations, the cutting-edge would first contact the rock in the north-western corner and not on the southern side. An attempt was made to isolate the mud in the southern portion of the working-chamber by lowering heavy timber shuttering, but this was unsuccessful. Accordingly a combined material and man-lock was placed on the south-eastern dredging-tube, and another on the third northern tube from the eastern end. The former permitted the removal of the timber, previously placed, through an elongated pressure-chamber attached to the material lock.

The two air-locks were retained on the same dredging-tubes until the founding of the caisson. During sinking, the lower portion of an old pile fouled the centre of the southern side of the cutting-edge. The pile had evidently been used during the erection of the old bridge, and considerable difficulty was experienced in removing it.

The caisson was founded in hard sandstone at R.L. 90·08, having penetrated a minimum distance of 8 feet into the rock. Ten-foot test holes were then drilled into the rock to confirm the uniform nature of the underlying strata. The excavation permitted the sandstone to project into the working chamber to R.L. 94·08, a chase 3 feet wide being cut around the cutting-edge to enable it to be founded at R.L. 90·08.

The air-locks were then removed, and it was found that one electrically-driven four-stage centrifugal pump, used intermittently, coped with the water while sealing operations were carried out.

A 12-inch bed of $1\frac{1}{2}$-inch-gauge blue-metal was laid in the chase around the cutting-edge. A 2-inch-diameter pipe, with open tees at 4-foot centres, was laid in this bed, and the two ends led to a sump excavated in the rock dumpling. The cutting-edge was then sealed with $1 : 1\frac{1}{2} : 3$ concrete, 3 feet thick, poured into the chase on top of the metal bed. The main seal of $1 : 2 : 4$ concrete was then poured in seven of the tubes to a height of 16 feet above the cutting-edge. The remaining dredging-tube was filled with water to mean sea-level, and the sump in the rock was sealed off with $1 : 1\frac{1}{2} : 3$ concrete poured under water, thus sealing off the ends of the 2-inch-diameter pipe. This tube was sealed off in the dry, after de-watering, to the same height as the other tubes.

In caisson No. 8, after mooring at the site, the outside walls were increased to a thickness of 18 inches at a height of 31 feet 4 inches above the cutting-edge. The 10-foot-diameter dredging-tubes were reduced to 9 feet diameter at a height of 37 feet above the cutting-edge, and at this height the thickness of the mild-steel plate of the tubes was increased from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch. The walls and tubes were then constructed in accordance with the stability diagrams until sufficient freeboard had been obtained to lower the caisson on to the prepared platform on the river-bed. The caisson was lowered on 11 August, 1943, by exhausting air, the pressure in the dredging-tubes being reduced from $21\frac{3}{4}$ lb. to 17 lb. per square inch.

The dredging was carried out in the following manner. As an additional precaution to prevent the caisson sliding on the inclined rock surface, when the air-pressure was exhausted from the two tubes in which the dredging operations were to be commenced, the air-pressure in the remaining six tubes was increased so as to maintain a total pressure equal to that originally contained in the eight tubes. In this way the required buoyancy for the caisson was preserved. As a further precaution, only one dome was removed at a time from the two tubes. From all tubes spalls and mud were then dredged in rotation to a height of approximately 1 foot above the cutting-edge. On completion of this dredging, the pressure in the remaining six tubes was gradually exhausted and the caisson slowly settled.

Combined material and man-locks were then attached to northern tubes Nos. 1 and 3, and sinking under air-pressure commenced. With the cutting-edge at R.L. 131·00 approximately, 6 feet of spalls were placed in the north-western portion of the working chamber to increase resistance to sinking at that corner. Decomposed sandstone was first contacted at the north-western corner of the caisson on 7 March, 1944, and by 27 September the cutting-edge had penetrated approximately 8 inches in decomposed sandstone in the south-eastern corner and 22 feet 9 inches in hard sandstone at the north-western corner. The caisson was ultimately founded on 17 October, 1944, at R.L. 103·33.

In view of the inferior quality of the sandstone at the south-eastern corner, a 14-foot by 14-foot shaft, 10 feet deep, was sunk in this area below the cutting-edge and, in addition, test-holes were drilled to a depth of 10 feet below each of the remaining tubes and below the bottom of the shaft. The shaft was filled with 1 : 2 : 4 concrete, and a seal of 1 : $1\frac{1}{2}$: 3 concrete was placed around the cutting-edge. Nine-inch brick walls were then built up to the underside of the girders in the roof of the working chamber, thus dividing the latter into eight isolated compartments. The whole of the foregoing work was executed under air-pressure.

The air was then exhausted from the tubes, water was introduced, and a concrete seal, 10 feet thick, was poured in each tube under water. The water was then pumped out, the laitance was removed, and a final seal, 11 feet thick, was poured in the dry. The dredging-tubes were then filled with fresh water as in the case of pier No. 2.

Cylinder Foundations for Piers Nos. 1 and 1A.

The foundations of piers Nos. 1 and 1A consist of two 15-foot-diameter cylinders, placed at 30-foot centres, with reinforced-concrete walls, 2 feet thick. All cylinders were founded in sandstone under air-pressure after dredging operations had taken them down as far as possible.

Comment on Sinking of Caissons and Cylinders.

Having regard to the magnitude of the undertaking, the sinking of the caissons was singularly free from untoward incidents. Progress was at times painfully slow, but it was felt that the caissons were under control at all times. This was due to the method of control by air, which was of value to the founding level and also to the intensive borings taken at each site, during which comparatively undisturbed samples of the various strata, particularly in the muds and silts, were examined and weighed and an assessment was made of their capacity to resist sinking. This was particularly useful in determining such related matters as weight of steining material required, height of walls (that is, freeboard), safe depth of dredging below the cutting-edge, and the lowering of water in the tubes.

It is interesting to note, with regard to the error in the position of caisson No. 7, that the adjacent caisson (No. 5) of the old bridge gave a vast amount of trouble during sinking and was ultimately founded considerably out of position, necessitating the sinking of an auxiliary crescent-shaped caisson at one end. It is not unreasonable to assume that similar conditions obtained at each site, and that the characteristics of the mud and silt, probably related to the time and manner of deposition of the sediments, varied here to a degree not experienced elsewhere.

Exclusive of the cylinders, a total of 884 feet of sinking was carried out below the bed of the river. The interruptions to the work occasioned by shortage of plant and material were unavoidable, and in this connexion it may be mentioned that in 1942, 150 men were transferred, with little warning, to urgent defence works in another part of the State. None of these returned to the bridge prior to its completion. In addition, the bridge employees were used in connexion with the establishment of defence works in and around Broken Bay.

Truss Spans.

The whole of the steelwork for the truss spans was designed in the Way and Works Design Office, Sydney, and fabricated in the Way and Works Structural Workshops of the Department of Railways, New South Wales, at Chullora. All the steel sections were supplied by the Broken Hill Proprietary Company Limited, Newcastle, and Australian Iron and Steel Limited, Port Kembla. All members of each span were sand-blasted, and base-coats of paint were applied prior to the steelwork being despatched from the workshops to the erection site at Hawkesbury river.

Erection site: The foreshores of the Hawkesbury river, in the vicinity of the bridge, are steep with no natural flat areas suitable for a steel erection-site. The site ultimately selected was on the northern foreshore of Long island, immediately westward and on the upstream side of the new bridge.

The steel-erection site consists of an area 53 feet wide excavated from the escarpment of the foreshore with a formation-level 10 feet above H.W.O.S.T. The general arrangement is shown in Figs 9, Plate 3. Three docks to accommodate the flotation pontoon were excavated in rock to 10 feet below H.W.O.S.T. The spacing of the docks was arranged so that both the 347-foot spans and the 445-foot spans could be lifted on two and three pontoons respectively at the relevant points of support.

The actual erection of the steelwork was carried out by an electrically-driven 20-ton jib crane travelling on two running tracks at different levels to suit the configuration of the escarpment. The four intermediate and the two larger spans were erected on this site in that sequence, with the addition that the first small span was erected concurrently with the second largest span.

Erection procedure: The major spans were assembled with the underside of the bottom chords approximately 5 feet above ground-level. They rested on camber blocks of timber crib-work surmounted by steel plates, the camber-block centres being arranged to suit the bottom chord joints. Erection commenced from the western end and followed a simple but effective pattern, care being taken to avoid the erection of too much steel ahead before thoroughly checking each panel for line and level.

No difficulty was experienced in the assembly of any of the spans. This is considered to be due to the care taken in the workshops in the original marking out and drilling and to the control exercised in the field. The ends of the top chord sections were planed and good care was taken in the assembly to ensure perfect fitting at the joints. Each panel was assembled in the workshops in a horizontal position and joined to its neighbour before being sent to the field. This arrangement was fully justified by the ease with which the erection was carried out.

The progress of erection was determined virtually by the speed of riveting and this, in turn, depended upon the man-power available as well as the rate of supply of steel to the field. Work was commenced on the first 347-foot span in January, 1944, and the last span was landed on the piers in May, 1946.

Table III gives details of the erection.

The steelwork for the spans was transported to the erection site from the workshops by rail, a distance of approximately 35 miles. The heavier chord members were unloaded at point A (Figs 9, Plate 3), whilst the lighter members were unloaded at point B. From these locations the 20-ton travelling crane was able to pick up the members.

Lifting-towers: Consideration had been given early to the proposal to float out the spans at low level and to seat them on the piers constructed

TABLE III

Span No.	Length.	Dates erection commenced.	Dates of flotation.	No. of field rivets.	Remarks.
	ft. in.				
4.	347 6	4 Jan. 1944	5 Sept. 1944	48,000	
5.	347 6	18 Sept. 1944	15 Nov. 1944	48,000	
3.	347 6	24 Nov. 1944	27 Feb. 1945	48,000	
6.	347 6	8 Mar. 1945	5 Jun. 1945	48,000	
2.	445 1	20 Aug. 1945	30 Nov. 1945	85,000	
7.	445 1	5 Dec. 1945	5 Apr. 1946	85,000	
1.	147	4 Dec. 1945	30 Jan. 1946	18,000	Erected on trestles over dock No. 2 simultaneously with western end of span No. 7 on construction site.
8.	147	8 Mar. 1946	14 May 1946	18,000	Erected in railway cutting adjacent to abutment on northern foreshore.

to the relevant height. Lifting-towers to be erected on the pier stubs were designed to lift the spans to the required height, after which the piers were to be completed.

The decision to revert to the high-level method of flotation following the return of the Author from active service in December, 1943, necessitated the raising of each span 25 feet above its erection-level. The pair of lifting-towers, completed at the time, were therefore erected at each end of the erection site and each of the six major spans, following its completion, was lifted the necessary height enabling the flotation pontoons to be placed in the docks underneath.

The towers were heavily braced steel structures, each 55 feet high and weighing approximately 235 tons. As the original design called for their erection on the piers, where at certain stages they would be carrying the spans broadside to the full effect of prevailing winds, they were of necessity more robust than would normally be required for use on shore.

The lifting capacity of each tower was 800 tons. The spans were lifted by a series of links attached to lifting-eyes built into the ends of the bottom chords. These links in turn were connected, through a crosshead, to a vertical screw, passing through a screw-nut assembly, with a multiple collar thrust bearing. Two 25-horse-power electric motors provided the power to operate worm wheels to turn the nuts.

Provision was made for hanging the span in cradles while links were changed after each 5-foot lift. On completion of the 25-foot lift, the spans were supported on temporary steel trestles, pending flotation.

Flotation.

All spans, with the exception of the northern shore span, were floated on pontoons from the erection site to their respective piers. Three pontoons were used for each of the two large spans and two for each of the remaining spans.

The pontoons which were constructed on the site were 98 feet 6 inches long by 40 feet wide, measured at deck-level, and each carried a heavy timber trestle superstructure, the top of which was approximately 40 feet above deck-level. Each pontoon carried two cylindrical steel ballast-tanks 9 feet in diameter and 77 feet long, threaded through the trestles. The capacity of each tank was 150 tons of salt water, and by filling and emptying these tanks the freeboard could be varied up to 33 inches.

Flotation of Spans Nos. 2 to 7, Inclusive.

Data concerning the tides were obtained over a long period by means of an automatic tide-gauge installed adjacent to the bridge site. The information thus obtained was correlated with the predicted tides at Fort Denison in Sydney harbour, and a satisfactory degree of accuracy was obtained in forecasting heights and times of tides in the vicinity of the bridge. It was thus possible to prepare a chart for any selected flotation-day, and to indicate thereon all relevant predicted data, including the timing of the various operations.

The floating of the pontoons into the docks provided a nice problem in regulating draught. Each pontoon in flotation trim, that is, with 300 tons of water in the tanks, weighed approximately 600 tons. The distance between the bottom of the dock and the undersides of the bearing-plates attached to the bottom chords of the span exceeded the overall height of the pontoon and trestle by approximately 7 inches. With this margin, the pontoon had to be edged into the narrow dock on a falling tide, being kept buoyant by jettisoning enough water-ballast from the tanks to counter the fall in tide during the operation. With the exception of the first flotation, when the eastern pontoon grounded momentarily, this operation was performed expertly in all cases and rarely exceeded 15 minutes from the initial movement outside the dock to the engagement of the locking-pins.

With the lifting of the span by the rising tide, hand winches were used to haul the loaded pontoons clear of the docks. The greater measure of control afforded by the hand winches was vital in view of the necessity of ensuring that all pontoons emerged at a uniform rate. The restricted clearances between the dock walls and the pontoons rendered the possibility of locking the flotation very real.

On emergence of the span and its pontoons from the docks, auxiliary power pontoons fitted with steam winches, boilers, and hand winches were made fast to the flotation pontoons and the main movement commenced.

The spans were warped across the river to a predetermined turning position by two steel wire cables, suitably anchored and each connected to a steam winch on its respective power pontoon. Movement up and down stream was controlled by wire cables, attachment being made to side winches in these instances. Cables were also connected from stern winches on the power pontoons to holdfasts on the dock site.

The method of controlling the movements of the pontoons for the flotation of span No. 7 is indicated in *Fig. 10*. These diagrams indicate the relative positions of the hauling cables, the power pontoons, and the anchors and the position of the span on its flotation pontoons for each movement during the flotation operation. It will be seen that at all times the flotation pontoons supporting the span were controlled by at least six wire cables.

Additional cables were picked up to turn the spans when opposite their respective piers. Cross tackles from the tops of the piers, made fast to hand winches, on the span ends, enabled the span to be landed with the utmost precision on the bearings with the fall of the tide.

All spans with the exception of No. 4 (the first to be erected and floated out) were successfully landed on their permanent bearings already fixed on the piers. Temporary steel pedestals of a simple design were provided for span No. 4 pending completion of the permanent bearings.

Span No. 1.

The erection of this span at high level centrally over dock No. 2 was commenced concurrently with the erection of the western end of span No. 7 over dock No. 3 and involved novel methods for flotation to its position on the piers. Only one pontoon could be used to bear its weight, but considerations of stability demanded that additional support be given during its passage from the docks to the piers.

The span was eased out of the dock completely water-borne except for a partial bias loading on a stabilizing trestle which travelled on a mono-rail at the eastern end (Figs 11, Plate 3). When the span was clear of the dock the bias loading was transferred to a stabilizing pontoon which enabled the span to be safely floated to its piers.

Reviewing the flotation operations generally, it can be stated at once that, in every case, they proceeded as planned. Every span was lifted, floated out, and landed on the one tide, and the predicted times were closely adhered to. The flotation of span No. 7 (1,650 tons) affords an illustration of what was accomplished. The span became water-borne at 9 a.m. on the morning of 5 April, 1946. The pontoons were eased out of the docks, the power pontoons made fast, and the whole was ready to commence the main movement by 9.20 a.m. At 11 a.m. the span was between the piers with cross tackles secured, after having negotiated a half-mile passage across the stream and executed a right-angle turn,

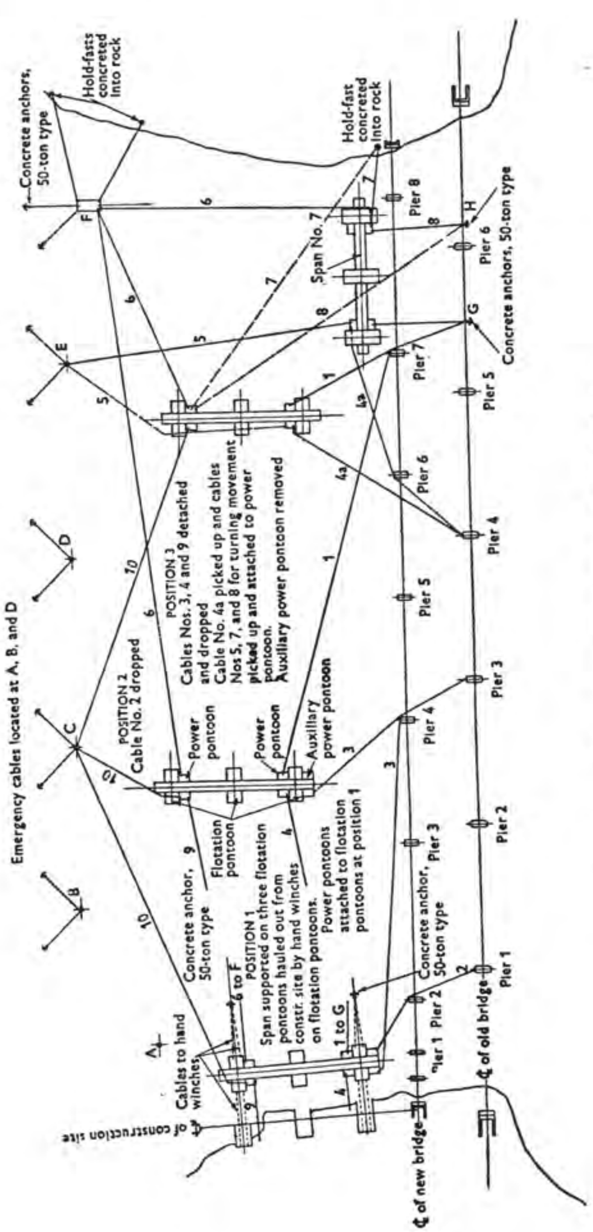


Fig. 10.

DIAGRAM OF CABLES FOR FLOTATION OF No. 7 SPAN.

casting off three and picking up four additional moorings in the movement.

The success of the operations was largely due to the knowledge gained prior to each flotation by rehearsal with a scale-model constructed for the purpose. By the use of this model, (scale $\frac{1}{32}$ inch to 1 foot) the key men engaged on the operation were drilled in the respective tasks that each would have to perform on the pontoons, attendant launches, piers, and docks. The time spent in the study of the tides, cross currents, local eddies, etc., was amply repaid by the positive result of measures taken to avoid untoward movement in the vicinity of the docks and the northern foreshore. The accuracy with which the pontoons and the timber trestles were constructed is reflected in the landing of the spans on their bearings. In the case of span No. 7, 445 feet 1 inch centre to centre of bearings, when the eastern end made contact with the bearings on pier No. 7 the western end was less than $\frac{1}{2}$ inch above its bearings on pier No. 8. This was a general feature for all spans.

The stability of the spans on the pontoons during flotation was a matter of previous investigation. The calculations demonstrated a very stable condition.

Span No. 8.

A number of factors mainly related to the restricted sea-room between pier No. 8 and the adjacent shore influenced the decision to erect span No. 8 on the track formation between the northern abutment and the tunnel portal.

The steel members were brought across the river on pontoons and were handled by two 7-ton electric derricking jib-cranes, one on the west side commanding the pontoon and the other close to the tunnel portal on the eastern side. When assembled, the span overhung the abutment by 30 feet and was supported by a timber trestle.

The span was launched by moving it forward on three-wheeled bogies until its southern bearing-plates could be supported on the extended trestle of the flotation pontoon. A second pontoon was moored immediately eastward of the latter. Jettisoning of the water ballast of pontoon No. 1 enabled the southern end of the span to become water-borne while the northern end was still supported on the bogies. The span was then hauled out until pontoon No. 1 made contact with pier No. 8. Pontoon No. 2 was then eased under the span between pontoon No. 1 and the shore and the load was transferred by releasing the water ballast of the former and by opening the sea-cocks of the latter. This enabled the span to be hauled out until the southern end could be landed on temporary timber cribs on the top of the bearings of pier No. 8. The lowering of the span into position on the bearings (approximately 8 feet) was accomplished in easy stages, using eight 50-ton jacks in the operation.

Figs 12, Plate 4, show the span as erected and Figs 13 and 14, Plate 4, illustrate the various stages of launching.

ACKNOWLEDGEMENTS.

All the work described in the Paper was carried out by the Author's organization, embracing design, workshop fabrication, field assembly, and construction. All officers and workmen associated with the project were drawn from the Department of Railways, New South Wales.

The Author was mobilized on the outbreak of war, but was able to maintain constant liaison with the work during his Army command in New South Wales, the ramifications of which included the Hawkesbury River area.

He desires to express his appreciation of the assistance rendered by Mr. W. R. Beaver, B.E., A.M.I.E. Aust., late Assistant Chief Civil Engineer, who relieved him while he was on military duty; by Lieut-Colonel K. A. Fraser, O.B.E., A.M.I.E. Aust., who was Supervising Engineer and later Assistant Chief Civil Engineer; by Mr. V. W. Mahoney, B.Sc., A.M.I.E. Aust., who relieved Lieut-Colonel Fraser during his absence abroad; by Mr. A. S. Lloyd, B.E., A.M.I.E. Aust., Resident Engineer; by Mr. W. K. King, B.E., A.M.I.E. Aust., who succeeded Mr. Lloyd as Resident Engineer and who, in addition, kindly read through the proofs; and by the Design, Workshops, and Field Staffs, whose efforts were responsible for the successful completion of the work.

The Paper is accompanied by fourteen sheets of drawings, from which the folding Plates and the Figures in the text have been prepared.

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Bridges Down Under

The History of Railway Underbridges
in New South Wales

by Don Fraser

AUSTRALIAN RAILWAY HISTORICAL SOCIETY
New South Wales Division

build two new railways, the controversial Sandy Hollow to Maryvale Line and the suburban Sutherland to Cronulla Line. The former was to have a chequered history and was never completed but 45 years later its eastern half formed the basis of the coal line to Ulan. The Cronulla Line fared better and was opened on 16 December 1939, three months after Australia joined the hostilities of World War II. Seven single-line PWG bridges, six through and one deck, were built, the most significant being the skew girder bridge over the Princes Highway at Sutherland. Skew means crossing the opening at an angle other than square and the effect of a skew crossing is to increase the span, centre to centre of bearings, and the overall length well beyond the values for a square crossing. The large angle of skew at Sutherland required a span of 114 feet and generated an overall length of 132 feet. It was the largest girder bridge in the system for nearly forty years.

As one would expect, the demands of the war effort caused all capital works to be deferred. The railways would have to get by with what they had and cope with huge volumes of wartime traffic as best they could. The vulnerability of shipping to submarine attacks and the severe rationing of petrol for road vehicles caused a massive diversion of goods onto the railways. Without the railway system there would not have been an effective war effort, and the population of reliable bridges played its part. Financially, the NSW railways did well through the war period 1939-45 but could not continue with their planned bridge upgrading programme. Only six new girder bridges were built as a matter of urgency. But there were two major railway projects built during the war, the extension of duplication on the Main South from Cootamundra to Junee and a new Hawkesbury River bridge. Both had been approved by the War Cabinet as being critical to the war effort so were largely paid for from Commonwealth funds. However, projects of their magnitude have long lead times for their design and construction. Consequently neither contributed to the war effort because both were completed in 1946, a year after the war ended. The Captain Cook Graving Dock at Garden Island had a similar distinction but did come into use just before the war ended. On the Cootamundra-Junee duplication, all the bridges were routine plate web girders. The most interesting feature was the Bethungra spiral which eased the gradient for Sydney bound trains. However, for sheer scale of achievement, the new Hawkesbury River railway bridge was comparable with the graving dock.

The New Hawkesbury River Bridge

Despite the strengthening of the deck system of the 1889 trusses of the first Hawkesbury River railway bridge its survival was always in jeopardy due to the poor construction of its piers. The building of the first bridge, its demise and the construction of the new bridge has been well documented,[20,21,22,23] so only a summary follows. The first bridge was opened on 1 May 1889 but within twelve months the contractors were recalled to remove faulty material at the tops of the caissons at the junction with the stone pier above. Generally, a mixture of sand and mud with very little cement was removed and replaced by sound concrete. What was below that junction, below water level and inside the caissons was anybody's guess. It had been known from the sinking of the caissons that No 5 and No 6 were out of position so it was apparent from an early date that the bridge would require close watching. During the next fifty years regular surveys were made which showed a slow settlement of most piers and that No 6 was nearly six inches downstream of its correct position. But this was not a cause for concern.

It was during 1937-38 that large cracks appeared in the masonry of pier No4 and a little later in pier No1. Investigations revealed that the roller bearings had become "frozen" and the expansion and contraction of the steel trusses was progressively pulling the piers apart. Concurrently, divers made an underwater inspection of the caissons and found large areas of the iron caisson tubes had rusted away. That in itself would normally be of no concern because the tubes were only a temporary means of creating a hollow to be filled with concrete. But inside there were huge pockets of no concrete at all or regions of blue gelatinous mass of no structural worth. It seems that during construction, late arrivals of imported cement were delaying concreting of the caissons so the sand and aggregate were placed and a covering of cement added after it arrived. These faults were so extensive that it was impractical to repair even the most accessible regions, and combined with the under strength of the main trusses, which was virtually impossible to improve due to the pin-jointed construction, it was decided to build a new bridge.

20 C. O. Burge 'The Hawkesbury River Bridge, NSW' *Proc. Inst. Civ. Engrs.*, vol .101, Part III, 1889-90, pp. 2-12 and Discussion pp. 38-72.
21 W. K. King and D. J. Fraser 'The Hawkesbury River Railway Bridge (1886-1946)' *Engg. Conf., I E Aust.*, Newcastle, April 1983, pp. 36-42.
22 *The Hawkesbury River Railway Bridge* Video, Audio Visual Unit, University of NSW, 1983.
23 A. C. Fewtrell 'The New Hawkesbury River Bridge, NSW' *Jnl. Inst. Civ. Engrs.*, 1948-49, Paper No 5694, pp. 419-460.

Until that was achieved the old bridge was converted to single-line working using gauntleted track, a speed restriction of 10 miles per hour was imposed (later reduced to 5 miles per hour) and double-headed locomotives were prohibited. Gauntlet track was already in use on the narrow Como bridge. It is an arrangement whereby two separated tracks (two rails each) converge and the inner rails cross each other but do not join the outer rails by a conventional switch, instead they run next to and parallel with the outer rails. Each track continues to use its own two rails such that there are four rails, but trains in each direction use their own pair of rails even though controlled by single-line working. This overlapping arrangement occupies almost the same space as a true single line and avoids the use and maintenance of a set of switches at each end of the gauntleted section of track.

One of the schemes for the new bridge was on a grand scale, being a cantilever bridge in the style of the famous Firth of Forth Bridge near Edinburgh, but the cost was prohibitive. A more realistic plan was to build another series of steel trusses and avoid the errors of the first bridge through sound design and thorough supervision of construction. One scheme placed the new bridge on the downstream or eastern side of the old bridge and consisted of ten 360-foot trusses with approach embankments. But piers costs would have been excessive and the northern embankment would have been on unstable bed material. So, an eight-truss scheme on the western side was investigated involving approach tunnels. Extensive foundation borings were made and the results revealed localised problems that could have led to difficulties in founding the caissons. Consequently, favourable pier sites were selected and the following symmetrical arrangement of trusses was determined: one 147-foot Pratt truss with parallel chords, one 445-foot K-truss with a polygonal or camel-back top chord, then two 347-foot 6-inch polygonal Pratt trusses to the centre, then the reverse to the other shore. With a reinforced concrete frame on the southern shore the total length of the new bridge would be 2,764 feet.

A major problem with sinking the caissons of the first bridge was the use of three dredging tubes in one line which made it difficult to control sinking. Four tubes in a square or diamond pattern would have been better. For the new bridge, eight dredging tubes were built into each caisson, in two rows of four, all able to be sealed and worked under compressed air. Sinking and founding the piers proceeded without incident with Nos 3 to 7 founded in dense coarse sand between 178 and 183 feet below water level, one of the deepest set of piers in the world. In the shallow water nearer the steeply rising banks, the piers were easily founded on rock. Inside each caisson, a thick concrete base plug and interior walls were constructed and then capped by a solid concrete pier. The foundation work started on 18 July 1939 and was completed late 1944. During the war years, the old bridge was protected by submarine nets because after the Japanese submarines were sunk in Sydney Harbour on 31 May 1942, it was found that one of the captains had a map of the Hawkesbury River in his possession. Had the bridge been destroyed there would have been no northern rail link. The alternate route was a 400-mile detour via Lithgow, Dubbo and Werris Creek. This would have seriously interfered with the movement of troops and war supplies.

The trusses for the new bridge were designed in the Way and Works Branch design office and were fabricated at the Structural Workshops, Chullora[152] from steel supplied by BHP, Newcastle and A I & S, Port Kembla. The design load was Cooper's E60, 20% more than the standard E50, but this conservatism combined with sound construction of the whole project has ensured the longevity of the bridge. The bridge is nearly as old as the one it replaced and there is not the slightest evidence of diminished performance. But E60 is the nominal or static load, to this must be added an allowance for impact which varies from low for long-span trusses to high for short-span stringers (see chapter 7). The final load ratings are E66 for the trusses, E73 for the cross-girders and E90 for the stringers, using the British Bridge Stress Committee allowances for impact.

An assembly site for the trusses was prepared on the south shore just upstream of the new bridge alignment. The site consisted of a narrow flat area and three wet docks were cut out of the steeply sloping rocky sides of Long Island. Assembling the trusses began in January 1944 and the last truss was landed on its bearings on 30 January 1946. Each of the six large trusses was assembled on supporting timber and spanned across the open wet docks. When ready to be moved, each was raised by lifting towers to clear the transporting pontoons and their on-board trestles. Three pontoons were used for the K-trusses and two for the Pratt trusses. Each truss was lowered onto its trestles and secured, then, at the appropriate time of the tide the whole unit was floated out of the docks, towed into position between its piers at

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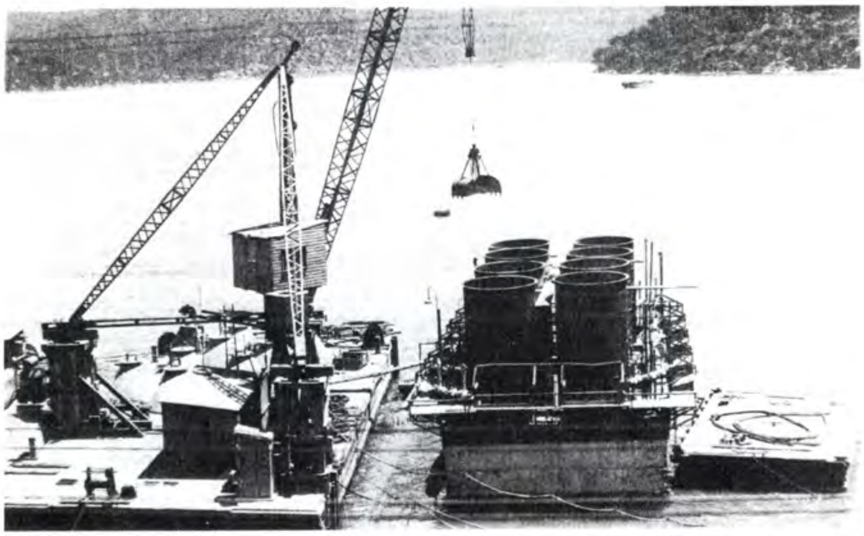
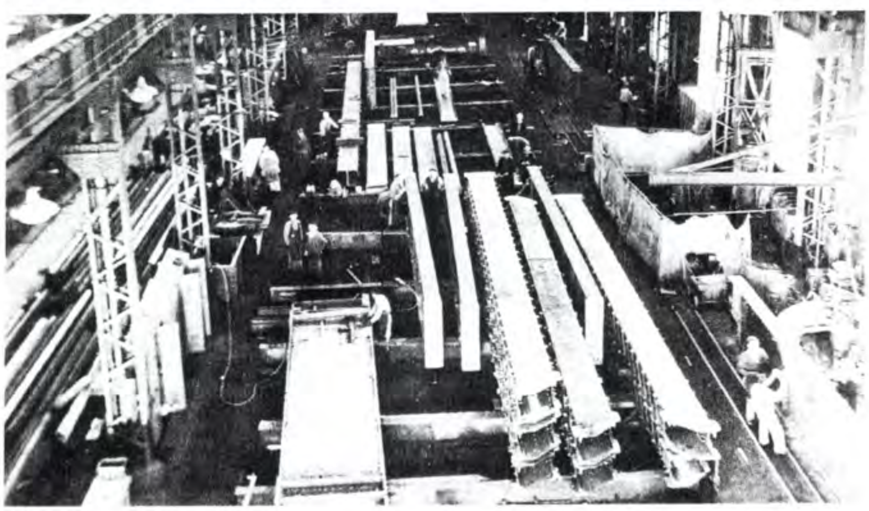
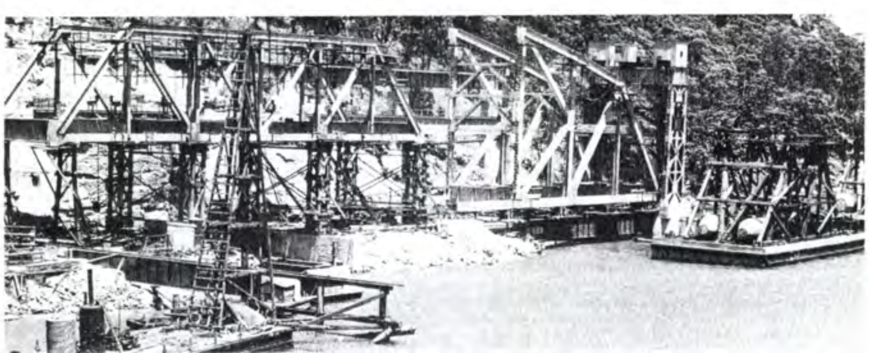
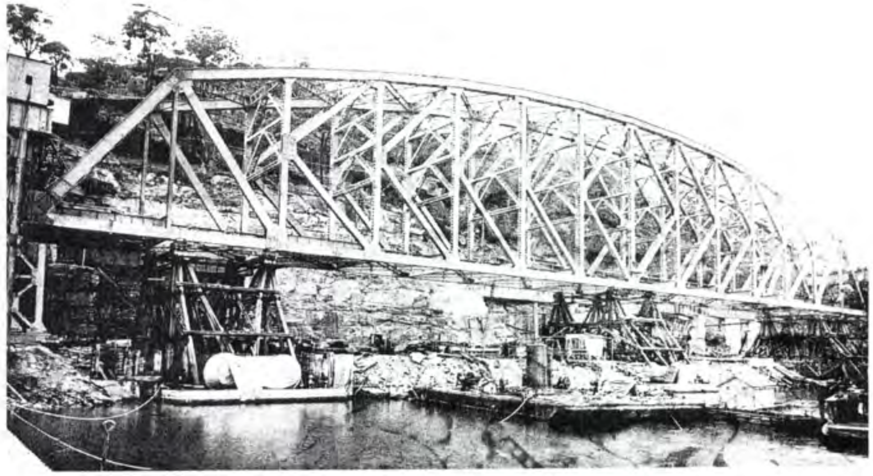
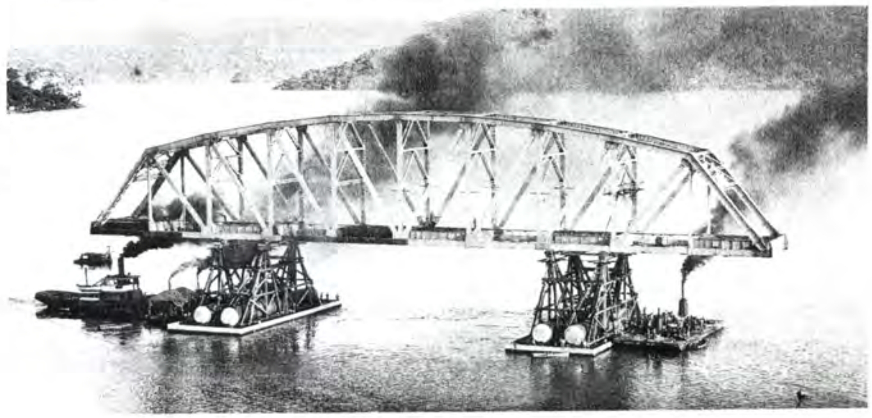




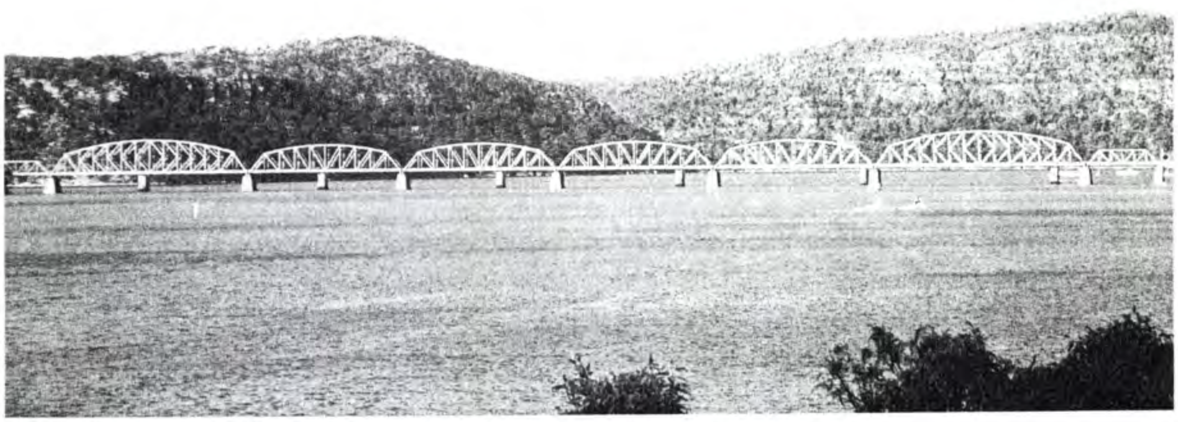


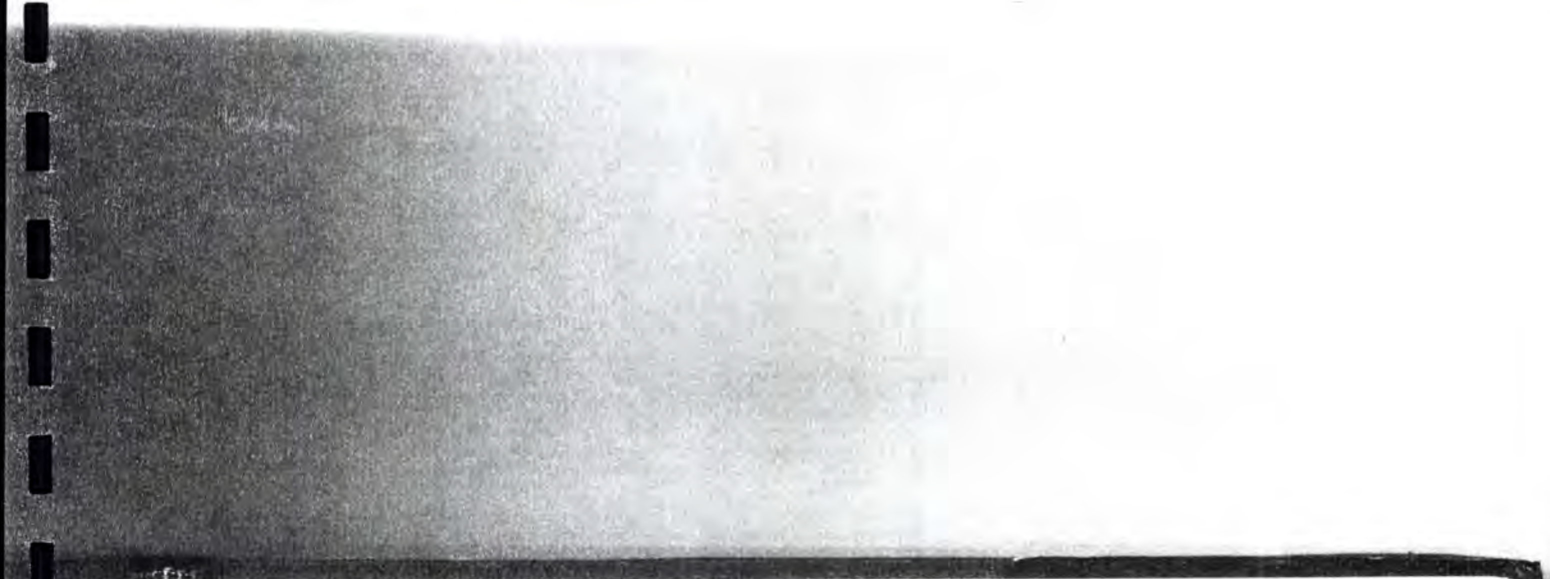
Top *An eight-tube caisson for the 1946 Hawkesbury River railway bridge.*
Centre *Fabrication of the riveted components in the Structural Steel workshop at Chullora.*
Below *Assembly of a large K-truss has begun (right) and that of a short shore span is well advanced.*
(SRA Archives)





Top *A 445-foot K-truss, having been raised, is resting on three pontoons ready to be towed out to its piers (see facing photograph to this chapter).*
Centre *A 347-foot Pratt truss being floated out to its piers.*
(SRA Archives)
Below *Elevation of the symmetrical arrangement of trusses, two short shore spans, two K-trusses and four Pratt trusses.*
(Don Fraser)





high tide and lowered onto its bearings by the falling tide. The success of the operations was greatly assisted by rehearsals using scale-models. In every case the work proceeded as planned, for example, on 5 April 1946 the second K-truss became water-borne in the wet docks at 9am and was in position at 11am ready for the falling tide. The new bridge was officially opened on 1 July 1946 followed by the progressive floating out of the old trusses, dismantling them, sorting out the reusable components and scrapping the rest. The stone-faced abutments and piers are the only reminders on site of the first bridge.

All the work for the new bridge was carried out by staff of the Department of Railways, New South Wales.[23] The Supervising or Resident Engineers included W. R. Beaver, K. A. Fraser, V. W. Mahoney, A. S. Lloyd and W. K. King from the Way and Works Branch under Major-General A. C. Fewtrell, Chief Civil Engineer. Keith King became synonymous with the bridge. Born William Keith King on 28 November 1906 he completed schooling at North Sydney High School[24] and entered the Locomotive Department of the Government Railways on 24 November 1924 as a shop boy on 11 pence per hour. In April 1925 he was awarded an Eddy Memorial Scholarship[25] and was granted four years leave without pay to attend the Engineering School at Sydney University. During Christmas vacations he gained practical experience in Eveleigh Workshops and on the Unanderra-Moss Vale Railway construction. He graduated in March 1929 with Honours in Civil Engineering including the Murray Rainsford Smith prize for Materials and Structures. He resumed railway duties at Head Office as a draughtsman and from 1932 to 1942 he worked on various country projects including a short period on the Hawkesbury River bridge. He returned there in April 1944, became Resident Engineer and supervised completion of the work and disposal of the old bridge. From 1948 to 1950 he was Resident Engineer for the foundation work of a new bridge over the Parramatta River at Meadowbank but the recession closed this and other railway projects such as the Eastern Suburbs Railway. In 1952 he was appointed Technical adviser to the Secretariat where he eventually became an Assistant Secretary for Railways from 1961 until his retirement in 1973 after 49 years of service.

From all the information about both Hawkesbury River railway bridges it is possible to compare them in terms of their cost-effectiveness. In the following table the cost indices were obtained from the Department of Economic History, University of New South Wales, which enabled the cost of each bridge to be converted or indexed as if both bridges were built in 1967 (Item 1). A not unexpected result is that the 1889 bridge was cheaper and lighter than the 1946 bridge given that the design load for the old bridge was equivalent to E25 whereas the new bridge was designed for E60. Therefore, any derived statistic has to include the E-value. Just as the costs have to be indexed to a common reference so also must the load ratings. The bridges were virtually the same length so this does not enter the comparison. Item 2 shows that when load rating is included the 1889 bridge was relatively more expensive than the 1946 bridge by about 20%, which is not particularly significant because seemingly identical bridges can have variations of this order due to natural variations in site conditions. But when the total tonnage is included, Item 3, the difference is quite large, indicating that the old bridge was really very expensive compared to the new bridge. With construction times and methods very similar for both bridges, the most likely cause of the large difference in Item 3 is the high proportion of imported materials, particularly cement and fabricated iron and steel, in the old bridge. As local cement and steels displaced the imported commodities costs decreased between one half and one third which seems to correlate with the change in Item 3 from 1.57 to 0.61.

Another factor influencing the better cost-effectiveness of the new bridge is the use of higher levels of stress in the better quality steel. If the 6,320 tons of steel in the old bridge was increased proportionally with the load rating the new bridge should have used 15,200 tons of steel, but if the stress is 10 tons per square inch rather than 7 tons per square inch then only 10,600 tons should have been used in the new bridge, instead, only 8,120 tons was used. Working the figures in reverse, the old bridge should have used only 4,800 tons of steel whereas 6,320 tons was used. It appears from this that for all its lightness, the old bridge was over designed for its loading. Finally, when both bridges are costed against years of service, item 4, the superiority of the new really comes to the fore. At only 49 years old it already has a performance index better than the 57-year-old old bridge. The longer the new bridge survives, and that seems indefinite at this stage, the lower, hence better, its performance index will become. The 1889 may have been considered a great bridge for its day but the State did not get value for its investment.

24 The Staff, Railway and Tramway Magazine, 21 June 1929, p 355.
25 William Keith King, employment record, State Rail Archives.

Mr. Hawkesbury River Bridge, Keith 'Mick' King, taken in 1957 at the height of his railway career. **(John McDonald, Rector, St Basil's Church of England, Artarmon)**

TABLE 8 – THE HAWKESBURY RIVER RAILWAY BRIDGES
Comparative statistics

ITEM	1889 BRIDGE	1946 BRIDGE
Years to build	4	6
Actual cost (pounds)	367,000	1,400,000
Cost index (1.00 in 1967)	0.146	0.286
Total weight, incl piers (tons)	64,000	134,000
Weight of steel (tons)	6,320	8,120
Load rating (Cooper's E-value)	25	60
Service life (years)	57	49(*)
1 Indexed cost (pounds)	2,514,000	4,895,000
2 Indexed cost / load rating	100,548	81,585
3 Indexed cost / (load rating x total tons)	1.57	0.61
4 Indexed cost / (load rating x service years)	1,764	1,665(*)

* Bridge still in service

After World War II

In 1946 the Railway Department had a new bridge that could carry loads in excess of twice the capacity of the old bridge and at speeds in excess of 60 miles per hour. Not only was this conservatism justified by the strategic importance of the bridge and long standing bridges upgrading policy, dating from Commissioner Eddy's era, but it was timely because in 1943 the new C38 Class Express Passenger steam locomotive came into service. It was specifically designed for the fast interstate and other express trains. The Newcastle Flyer service was the first to be regularly operated by this class of locomotive starting on 24 February 1943.[26] Once the new bridge was opened the trains were able to maintain maximum running speeds across the bridge. The locomotive had a 4-6-2 wheel arrangement with an engine weight of 112 tons which generated an equivalent static load rating of between E41 and E49 depending on the span of the bridge unit.[27] Fortunately, the driving wheels were well balanced such that at maximum speeds, around 70 miles per hour, the impact allowance was only 11% which kept the maximum E-value well below the design load of E60 of the new Hawkesbury River bridge and equal to the E50 limit for the older existing bridges. The new bridge enabled the heavy goods D57 locomotives to work the Main North to Newcastle. But the general population of main line bridges was spared the pounding from heavy fast-moving locomotives for many years because the tracks were too weak to permit high train speeds[28], a condition that persisted for another decade.

26 Alex Grunbach *A Compendium of NSW Locomotives* Sydney: Aust. Rly. Hist.Soc., 1989, pp. 211-217.
27 Drawing SS 403, Plan Room, State Rail Authority.
28 *Sydney Morning Herald*, 25 August 1944.

***A C38-hauled Newcastle Flyer on the New Hawkesbury River bridge.* (SRA Archives)**