ENGINEERS AUSTRALIA
Western Australia Division

NOMINATION OF

STIRLING BRIDGE

FOR AN
ENGINEERING HERITAGE AUSTRALIA HERITAGE RECOGNITION AWARD

Stirling Bridge, 2014

PREPARED BY ENGINEERING HERITAGE WESTERN AUSTRALIA
ENGINEERS AUSTRALIA
WESTERN AUSTRALIA DIVISION
July 2014

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Cover page photo Anthony Riddette

1. INTRODUCTION

A bridge over the Swan River at Fremantle has always been a key focus of interest since the colony was settled in 1829, with the Perth township situated on the northern bank and the port of Fremantle located on the southern. A road crossing of the river upstream of the harbour was the obvious place for a bridge but the fledgling colony did not have the technical and financial resources for some considerable time to accomplish this objective. Eventually two timber bridges were built and one of them is still in use today, having been upgraded several times. The other was demolished in 1947. The Stirling Bridge, located upstream of the existing timber road bridge and steel and concrete railway bridge, was completed in 1974 and is the most recent construction to span these waters.

The bridge forms a link between Stirling Highway and Cockburn Road as part of the bypass of the City of Fremantle. It was designed to meet the traffic requirements generated by the continuing development of heavy industry in the Kwinana area and general urban expansion. The bridge has been planned in two stages. The first, the subject of this nomination, was completed in 1974. The second bridge, to be built when required, will duplicate the existing structure on the upstream side, adding another three lanes, giving a combined width of 35 m.

2. STATEMENT OF SIGNIFICANCE

Several key aspects of the bridge design and construction methods are worthy of note:

- The simplicity of the structural box girder arrangement was achieved due to analytical advances in calculating shear transfer;
- The piled foundations capacities were verified using the first application of the computerised wave equation formula to a major civil engineering project in Australia.
- All 292 superstructure segments were precast offsite using an adjustable steel form to ensure each unique unit was constructed within tight tolerances. Due to intensive planning of the precasting operation, not one unit was rejected.
- The prefabricated steel falsework truss supporting the bridge girders prior to post-tensioning was designed to be reused with each successive span, despite varying span lengths and heights

The bridge was completed three months ahead of schedule and was nominated for the 1974 Construction Achievement Award (Australian Federation of Construction Contractors). It was officially opened by the Premier of Western Australia, Sir Charles Court, OBE, MLA, on 17 May 1974.

The aesthetic design of the bridge was a key factor in receiving an Award of Merit at the 1974 Australian Consulting Engineering Association (ACEA) Excellence Awards. It also received an award for Excellence in Concrete by the Concrete Institute of Australia.

The bridge sits in its environment displaying the elegant lines of its thoughtful design. The reduction in depth of the bridge beams from a maximum of 3.4 metres at the south abutment to a minimum of 1.8 metres at the north abutment complements the reduction in span lengths and soffit clearance from south to north and produces a pleasing appearance, particularly when viewed in elevation. At the time of its construction, the bridge was the longest in Western Australia.

The successful design and construction of the Stirling Bridge was a significant technical achievement, reflecting great credit on the designers, construction contractor and its subcontractors, and their workforces. Its completion greatly improved road access to the City and Port of Fremantle as well as creating a bypass to the expanding industrial area of Kwinana.

3. LOCATION

The locations of Fremantle and the Stirling Bridge are shown on satellite images in Figures 1 and 2 below.

Figure 1. Satellite image of Perth and Fremantle (Courtesy Google Maps)

Figure 2. Satellite image of Fremantle and its harbour (Courtesy Google Maps)

4. HERITAGE RECOGNITION NOMINATION FORM

The Administrator
Engineering Heritage Australia
Engineers Australia
Engineering House
11 National Circuit
BARTON ACT 2600

Name of work : ***STIRLING BRIDGE, FREMANTLE***

The above-mentioned work is nominated to be awarded a

Engineering Heritage Recognition Award

Location, including address and map grid reference:

This nomination refers to the Stirling Bridge located at the Stirling Highway (State Route 5) crossing of the Swan River, between North and East Fremantle, Western Australia. See Figures1-2.

Latitude: 32.039336^{0}S

Longitude: 115.759649^{0}E

Owner (name & address): Main Roads Western Australia, PO Box 6202, East Perth, WA 6892

The owner has been advised of this nomination and a letter of agreement is attached.

Access to site: The bridge is readily accessible by road or foot.

Nominating Body : Engineering Heritage Western Australia, Engineers Australia, Western Australia Division

Mark Bush

Professor Mark Bush, Chair EHWA
Date: 20 July, 2014

5. OWNER'S LETTER OF AGREEMENT

mainroads
WESTERN AUSTRALIA
ABN: 50 860 676 021

Enquiries: Steve Potter on 9323 4242
Our Ref: 05/3806 (D14#154948)
Your Ref:

Professor Mark Bush
Chair, Engineering Heritage Western Australia
Engineers Australia
Western Australian Division
712 Murray Street
WEST PERTH WA 6005

Dear Professor Bush

ENGINEERING HERITAGE RECOGNITION: STIRLING BRIDGE FREMANTLE

Thank you for your letter dated 20 March 2014 about heritage recognition of the Stirling Bridge Fremantle.

I am very supportive of your proposal and, as with the Perth Causeway heritage recognition, believe that a similar process and commemorative ceremony could be undertaken for the Stirling Bridge should its nomination be successful.

I nominate my Manager Executive Services, Mr Steve Potter, to liaise with Mr Don Young on your submission. I understand that Steve and Don had a very good and successful working arrangement with the Perth Causeway submission. Steve may be contacted via telephone at (08) 9323 4242.

Yours sincerely

Stephen Troughton
MANAGING DIRECTOR OF MAIN ROADS

- 4 APR 2014

Don Aitken Centre, Waterloo Crescent, East Perth or PO Box 6202 EAST PERTH Western Australia 6892
Telephone: 138 138 Facsimile: (08) 9323 4430 TTY: (08) 9428 2230
Email: enquiries@mainroads.wa.gov.au Website: www.mainroads.wa.gov.au
14-175750

6. HISTORICAL SUMMARY

The Stirling Bridge is the third major road bridge built over the Swan River after the Second World War. The first bridge, or more correctly, the twin Perth Causeway bridges, were composite steel and reinforced concrete structures linking the east of the city of Perth with the suburb of Victoria Park. They were designed and constructed by Main Roads WA and completed in 1952.

The second bridge, the Perth Narrows Bridge, was designed and supervised by Maunsell, Posford and Pavry of London, with assistance from Architects Sir William Holford and Associates, and prestressing consultant E W Gifford. The Narrows Bridge was the first major post tensioned prestressed concrete bridge built in Western Australia. It consisted of five spans with an overall length of 335 metres. There were eight rows of precast I-beam elements 9'9" (2.97 m) long erected on a falsework of timber trestles supported on timber piles. The construction contractor was a Joint Venture of Christiani & Nielsen A/S of Copenhagen and J O Clough & Son Pty Ltd of Perth and the bridge was completed in 1959.

Subsequent to the completion of the Narrows Bridge, Maunsell established an Australian office and was engaged by Main Roads WA to design and supervise the construction of the Stirling Bridge (Figure 3) in the late 1960s. Maunsell designed a seven span twin post tensioned segmental spine bridge with an overall length of 415 metres, again with precast concrete units 2.97 m long with 75 mm insitu joints. Architectural advice on the design was obtained from Perth based architects, Cameron, Chisholm and Nicol.

Tenders were called in early 1972 and the lowest tender of $2,560,000 was submitted by J.O.Clough & Son Pty Ltd. This was accepted on 12 June 1972, requiring a contract completion by 14 July 1974.

The bridge was completed three months ahead of schedule at a final cost of $2,615,000. At the time of its construction it was the longest bridge in Western Australia.

Figure 3. Aerial view of the Stirling Bridge looking north, on completion (Photo J O Clough & Son)

7. BASIC DATA

Project Name : Stirling Bridge

Owner : Main Roads Western Australia

Location : Stirling Highway (State Route 5) crossing of the Swan River, near East Fremantle, Western Australia, Latitude 32.039336^{0}S, Longitude 115.759649^{0}E

State : Western Australia

Local Government Area : Links City of Fremantle (northern shore) with Town of East Fremantle (southern shore)

Designer : Maunsell and Partners Pty Ltd, Consulting Engineers

Year Commenced: 1972

Year Completed : 1974

Constructor : J.O. Clough & Son Pty Ltd

Physical Description :

The Stirling Bridge is a continuous seven span twin post-tensioned segmental spine concrete bridge, with an overall length of 415 metres. The individual spans are from the south 23.8m, 81.4m, 75.3m, 69.2m, 63.1m, 54.9m, and 47.2m respectively. The southernmost span is contained within the south abutment. The bridge is fixed on the south abutment and the movement taken in finger joints on the north abutment. The superstructure is supported on steel roller bearings. The bridge deck is 16.4m wide comprised of a 14.6 m four lane roadway and a 1.8m wide footpath on the downstream side.

The bridge has a clearance of 9m over the navigation channel and 6m over Riverside Rd at the southern end. The bridge profile rises gradually from the south abutment to a third of the way across then falls gradually to the north abutment. It has a cross fall grade of 1:40.The balustrade and guard rails are galvanized steel coated with high quality paint due to the corrosive environment.

A 450 mm diameter water main was slung under the roadway between the boxes and provision was made for power and communication ducts through the inside of the boxes and under the footpath slab.

Physical Condition :

The structure is in good physical condition.

Heritage Listings : Nil

8. DESCRIPTION OF THE PROJECT

8.1 Aesthetic Design Considerations

The design of the new river crossing was significantly influenced by the historical status of Fremantle and the beauty of the limestone cliffs on the lower reaches of the Swan River. Great importance was placed on preserving the maritime views through the bridge, particularly at water level.

Jim Leslie, a UWA engineering graduate employed by Maunsell and Partners, describes his contribution to the bridge design concept:

> *My role in the design related to the architecture of the bridge within its landscape. This came about by chance. I met Gilbert (Gil) Marsh in the street in Perth one day and he started to talk to about a proposed new bridge across the Swan River at Fremantle. He described the site and asked me if I had any thoughts as to how the project should be tackled. I visited the site and came up with an idea. I sketched this in pencil on an A4 sheet and went back to Gil who liked it. As a result MRD commissioned Maunsell's Melbourne office to do a design study on the basis of my sketch. From then on Geoff Fernie took charge of the design of the project on behalf of Maunsell and subsequently he became Resident Engineer after construction commenced. The design and the built structure were as I had envisaged it in that early pencil sketch, and was unique.*

During the detailed design phase, special consideration was given to the eight-metre level difference between the sandy flats on the northern shore and the limestone cliffs at the southern abutment. This led to the bridge's unique aesthetic form. As the superstructure rises on its route to higher ground across the river, the depth of the deck increases continuously from north to south. As the bridge gains height, each of the six visible spans of the bridge lengthen to maintain the overall aesthetic balance over the 415m long bridge length. These span lengths increase from 47.2m at the northern abutment to 81.4m at the south abutment (Figure 4). The most southerly span is contained within the south abutment.

On the northern shore the approach embankment was set well back from the river edge, increasing the length of the bridge to preserve the open views and impinge as little as possible on the setting.

During the design process architectural advice was sought from Cameron Chisholm and Nicol, in particular the pier column shape. The columns provide a changing sharp contrast of light to shade as the sun moves across the sky. Thorough engineering analysis made possible the omission of diaphragms between the twin single cell concrete deck boxes, preserving the continuity of the bridge line across the river (Figure 5).

The aesthetic design of the bridge was a key factor in receiving an Award of Merit at the 1974 Australian Consulting Engineering Association (ACEA) Excellence Awards. The judges considered that the omission of diaphragms between the beams was a key feature which "produced an aesthetically pleasing bridge within the cost estimate".

Figure 4. View of the Stirling Bridge looking west towards the port of Fremantle (Photo Anthony Riddette)

Figure 5. View of the underside of Stirling Bridge looking north. The view highlights the clean lines of the bridge beams and the architectural profile of the columns (Photo Anthony Riddette)

8.2 Structural Design

Several key aspects of the bridge design and construction methods are worthy of note:

- The simplicity of the structural twin box girder arrangement was achieved due to analytical advances in calculating shear transfer. It was possible to eliminate diaphragm connections between the twin box beams and still achieve a 40% load transfer between loaded and unloaded box beams through an accurate analysis of the shear transfer across the reinforced concrete deck slab spanning between those beams. The design provided for the beams to be continuous for superimposed dead and live loads.
- The deck design allowed for a span-by-span construction sequence with prestressing cables internal to the webs and in the bottom flange.
- The principal foundations comprised 0.73 metre diameter steel shell tubes driven to penetration and set in black sandy clays at depths up to 50 metres. An ultimate resistance of 450 tonnes per pile was acceptable and top driving was permitted. Minimum sets were calculated by the computerised application of the wave equation formular. This was the first general application of this theoretically based approach on a major civil engineering project in Australia. Good correlation was achieved by load testing.

Figures A1 and A2 (Appendix) show the general arrangement drawing and a cross-section of the Stirling Bridge.

8.3 Construction

8.3.1 Falsework design

Influenced by the labour intensive timber pile and trestle falsework method used for the Narrows Bridge construction, Clough decided at the tender stage to use three fabricated steel trusses solely for the falsework for the five northern spans and in part trusses and timber trestles for the two southernmost spans, one of which was within the south abutment and the other over a riverside roadway which had to be kept open to traffic. In addition it was planned that trusses could be winched sideways after a beam stage was completed to allow the companion beam to be constructed. Two trusses were initially 35.5 metres long and the third initially 32.5 metres and they weighed from 72 to 80 tonnes.

Some of the essential points taken into consideration in the falsework design were :

- Successive spans of the bridge in the direction of construction reduced in length. The design of the trusses was arranged so that the appropriate length could be cut off as required as construction proceeded northwards without having to carry out major alterations. The additional end bearings were provided at the appropriate points in the initial fabrication stage.
- In order to reduce bending stresses in the top chords the panel points were arranged so that the supports for the precast units were close to these points. This was possible due to the regular pattern of all units in all of the construction stages except the last one where the reduced loads from the lighter units and shorter span permitted the support of the units away from the panel points.

- The trusses were half span long and supported on the permanent pier pile caps and temporary mid span pier pile caps (which were removed after the completion of the bridge).

8.3.2 Precast Beam Unit Production

Due to the limited area available at the site for the manufacture and storage of the 292 units Clough elected to upgrade its Kewdale precast yard, 24 kms from Fremantle, for the precast beam unit production. A Victorian firm, Concrete Formwork Engineers, designed and fabricated three steel formwork sets. Each consisted of a fixed outer form with a travelling inner form. The soffit form and the travelling inner form were adjustable to accommodate the changes in depth of units from 3.43 m to 1.83 m from south to north (Figure 6). A 55 tonne capacity travelling gantry crane with a 5 tonne auxiliary hoist and a 15.2 m span was used for most lifting requirements.

Figure 6. Precast beam unit travelling steel forms - internal form being released (Photos J O Clough & Son)

Reinforcing steel cages were prefabricated in jigs and lifted into the forms by the gantry which was also used to place 41 MPa premixed concrete delivered to the site by Pioneer Concrete Pty Ltd from its Belmont plant. Overnight steam curing was used to enable a three day casting cycle. Completed precast units were stockpiled in the yard until required at the site.

Due to the intensive planning before casting commenced, excellent workmanship and thorough supervision not one unit was rejected. A total of 4350 cm of concrete was used and quality control of concrete monitored by an onsite testing laboratory.

8.3.3 Substructure

8.3.3.1 Piling

Tubular steel piles 0.73 m diameter x 13 mm wall thickness were specified for the four river piers and one shore pier. The piles were driven closed ended and filled with 32 MPa concrete after drivng. A total of 74 piles were driven, with an average length of 37.2 metres and maximum length of 51 metres. Piles were pitched into guide frames and top driven with Delmag D22 and Kobe 35 diesel hammers. The Wave Equation dynamic pile driving formula (for which Main Roads had developed a computer program) was used to predict ultimate load capacity. A ultimate load capacity of 450 tonnes for a final set of 100 blows/foot (3 mm per blow) using the

Kobe K35 hammer was nominated and good agreement with a pile test loaded to failure was obtained.

8.3.3.2 Pier Pile Caps

The temporary timber piles used to support the pile guide frames were also used to support side forms and a soffit form on which 250 mm of blinding concrete was cast. After de-watering the pile cap soffit load was transferred to four hanger beams spanning between pairs of steel piles and designed to be permanently embedded in the pile cap (Figure 7). Temporary longitudinal beams under the soffit were suspended from the hanger beams with straps composed of mild steel and stainless steel passing through the tremie concrete, the stainless steel section being located at the interface of the tremie and pile cap concrete. Concrete was cast using the crane barge.


Figure 7. Left: Dewatering the pile cap; Right: Placing the hanger beams to transfer pile cap loads to the steel piles (Photos J O Clough & Son)

8.3.3.3 Pier Columns

Each column consisted of eight triangular shaped faces (Figure 8). The plan area at the top of the column was constant but variable at the bottom and because of the varying height of the columns the two prefabricated forms had to be returned to Clough's Kewdale workshop for reshaping after each casting. Concrete was placed to the full height using the crane barge.

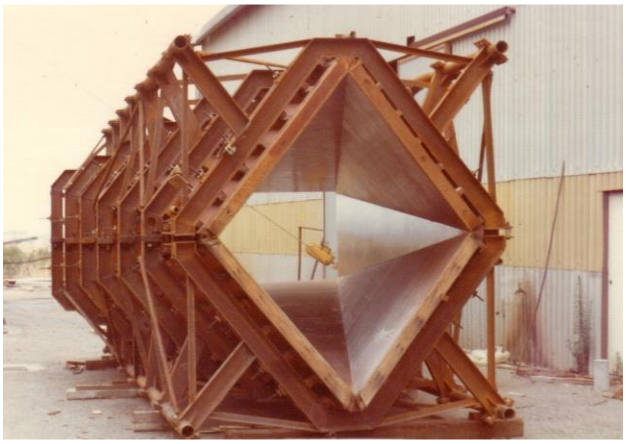



Figure 8. Left: Steel pier column forms; Right: Placing the forms on the pile cap (Photos J O Clough & Son)

8.3.3.4 Superstructure

A five stage construction sequence was specified (Figure A3, Appendix). Stage 1 falsework was made up of timber and steel trestles and fabricated trusses, Stages 2 to 4 inclusive falsework were solely fabricated trusses, and Stage 5 falsework partly fabricated trusses and steel beams. The falsework trusses were supported on sand jacks (and in turn on the permanent and temporary piers) which allowed them to be lowered after each upstream beam was post tensioned and then moved on skates across into position to be accept the precast units for the downstream beam (Figures 9 and 10).

Figure 9. Left: Assembly of falsework trusses on south bank; Right: 200t capacity sand jack (Photos J O Clough & Son)

Figure 10. Left: Truss section being moved into place by crane barge; Right: South shore span falsework with placing gantry in position (Photos J O Clough & Son)

Precast units were transported by lowloader from the Kewdale casting yard and unloaded by a purpose built unloading gantry onto a rail mounted trolley which conveyed the units over previously placed units to be unloaded and placed on the falsework by a placing gantry which was supported on the false work (Figure 11).

Figure 11. Unit transporter connected to placing gantry prior to lifting
(Photo J O Clough & Son)

After units in each stage were aligned prestressing cables were drawn through the ducts with the aid of a winch and draw cable. The 75 mm gap was filled with a specially designed concrete mixed on site and the cables tensioned when the concrete had gained sufficient strength.

The BBR post-tensioning system was used. There were six 81 no. 7 mm wire cables in each web stressed to approximately 400 tonnes and four 56 no. 7 mm wire cables in the bottom flange stressed to 275 tonnes. A total of 285 tonnes of prestressing steel was used on the project. Cable ducts were pressure grouted after stressing (Figures 12 and 13).

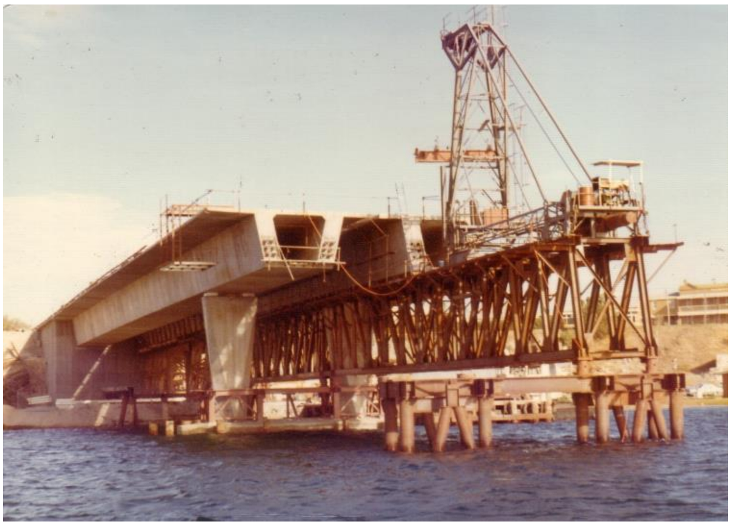


Figure 12. Stage 1 upstream row completed, downstream row placed but not yet stressed. (Photos J O Clough & Son)

Figure 13. Left: Progress near completion of Stage 1, Feb 1973; Right: Progress near completion of Stage 2 (Photos J O Clough & Son)

8.3.3.5 Deck Concrete

An 0.7 m wide gap between the inner cantilevers of both beams was filled with concrete using special precast concrete slabs as permanent formwork.

A cantilever steel form was used to support the casting of insitu concrete for kerbs (and footpath on the downstream beam) to the outer edges of each beam row.

8.4 Bridge opening

The Stirling Bridge was officially opened by the Premier of Western Australia Hon.Sir Charles Court, O.B.E., M.L.A. on 17 May 1974. Other key figures present at the opening included Don Hector Aitken, Commissioner of Main Roads, Western Australia and Ray O'Connor, Minister for Transport and Traffic (Figures A4-A6, Appendix).

Figure 14. Completed bridge, 1974 (Photo courtesy J O Clough & Son)

9. EMINENT PERSONS ASSOCIATED WITH THE PROJECT

John Gilbert (Gil) Marsh **(1925 –)**

Bridge Engineer, Main Roads Dept. of Western Australia (1957-1985).

Graduating from the University of Western Australia in 1946 with a Bachelor of Engineering Gilbert Marsh joined the Main Roads Department WA (MRDWA) as an engineer in the Bridges Branch, working under the direction of the Bridge Engineer, E. W. Godfrey. During this period he gained experience in most aspects of bridge investigation and design, and of bridge construction, using both direct labour and contract workforces. His most significant project was the design and construction of two steel and concrete composite bridges over the Swan River at the eastern approaches to Perth, between 1947 and 1952.

He was promoted to Assistant Bridge Engineer in 1954 and appointed Bridge Engineer in 1957. During the 1960's the Main Roads commenced a programme of road construction, including freeways and arterial roads in the Perth Metropolitan area and the construction of a new National Highway across the northwest Pilbara and Kimberley regions. This involved the construction of many bridges and between 1962 and 1985 Marsh created and supervised a large professional organization which undertook the investigation and design of the majority of the bridges built during this period.

Marsh held the position of Bridge Engineer in Main Roads for 28 years, from 1957 up to his retirement in 1985.During this time Marsh was an active member of the Bridge Committee of the National Association of Australian State Road Authorities [NAASRA, now AUSTROADS].

In recognition of his involvement with NAASRA Marsh was awarded in 1992 the John Shaw award for Meritorious Contribution to Roads by the Australian Road Federation.

Among the many innovations of historical significance introduced during Marsh's tenure as MRD WA Bridge Engineer were:-

- The adoption of partial prestress in bridges, a footbridge over Canning Highway in Perth was the first partially prestressed bridge designed and built in Australia.
- The introduction of incremental launching technique for concrete bridges, the Mandurah Bridge was the first incremental launched bridge designed in Australia.
- The initial development of "Culway", a "Weigh-in-Motion" system for measuring and continuously recording axle loads of heavy vehicles as they pass over a culvert fitted with strain gauges.

In 1999 Gilbert Marsh was awarded the Engineers Australia John Connell Gold Medal. This medal is awarded to a structural engineer, widely recognised as holding eminent standing within the profession, who has made a significant contribution to the standing and prestige of the structural engineering profession.

Geoffrey N Fernie **(1934 –)**

Lead Designer, Maunsell & Partners Pty Ltd

Geoff Fernie graduated in 1956 with a degree in Civil Engineering from the University of Western Australia and was employed by GM&P (Maunsell) as a Junior Engineer on the Perth Narrows Bridge. Between 1957 and 1959 he was part of the Resident Engineers Staff on site under Resident Engineer T G Bingham.

After several years in London, Geoff returned to Australia and was involved in the detailed design of Commonwealth Avenue Bridge (Canberra), various Standard Gauge railway bridges (WA), and the preliminary design of Batman Bridge (Launceston) under the guidance of Partner, Peter Stott. He managed Maunsell's Canberra office during the pre-stressing of Commonwealth Avenue Bridge and associated Parliamentary Triangle works and later transferred to Melbourne to set up Maunsell's Australian Bridge Design team.

Between 1964 and 1971 Geoff was responsible for the design of a wide range of bridges around the country and abroad including the Hume Highway at Bargo, NSW, Victoria Bridge in Adelaide, Tullamarine Airport in Victoria, Gogol River crossing in New Guinea, including the prestressed concrete approach structures and ancillary works for Lower Yarra Crossing, Westgate and Stirling Bridge in Fremantle which received a Merit Award from the Australian Consulting Engineers Association (ACEA).

Geoff became a Partner of the firm in 1969 and in 1970 attended the Victorian Royal Commission into the collapse of the Westgate steel bridge with colleague E M Birkett.

After two years as Resident Engineer during the construction of the Stirling Bridge at Fremantle, Geoff remained in Perth to manage Maunsell's Perth office and develop the bridge design team. During this period he worked on major structures in Australia and Asia including Ap Lei Chau (Hong Kong), Tai Po (Hong Kong) and Redcliffe Bridge over the Swan River (WA) which was awarded an Engineering Excellence Award by the Institution of Engineers, Australia.

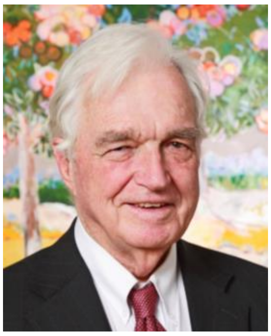
Geoff then went on to develop project environmental impact assessment (EIS) multi-disciplinary teams in Perth employing local and overseas specialists. He managed major EIS preparation for the Yeelirrie Uranium Project (1976), North West Shelf Natural Gas LNG project (1979) and was advisor to Western Mining on the Roxby Downs/Olympic Dam project. Geoff was responsible for the Radiation Safety Assessment section and subsequently participated in the Operation Safety Audit for the project.

Between 1980 and 1984 Geoff was the Environmental Co-ordinator for the 1,100 km Dampier to Bunbury gas pipeline with Fluor/Maunsell Project Managers, and was also Chairman of the ACEA (WA Chapter) for two years during this period.

Following retirement to the town of Walpole in southern WA, Geoff has been involved as Deputy-Chairman of Advisory Committee to CALM on the Management Plan for the 326,000 hectare Walpole Wilderness Area.

William Harold Clough **(1926 –)**

Chairman, J O Clough & Son Pty Ltd



Harold Clough graduated from the University of Western Australia in 1947 with a first class honours degree of Bachelor of Mechanical Engineering. In 1951 he was awarded a United States Fulbright Scholarship and attended the University of California where he gained a Master of Science degree. For the following two years he remained in the United States with Bechtel Corporation before returning to Western Australia to join his father's building construction firm, J O Clough and Son Pty Ltd, which subsequently became the Clough Engineering Group.

In 1957, under his guidance and vision, his company joined with international engineering firm Christiani and Nielsen A/S of Copenhagen, to successful tender for and construct Perth's landmark Narrows Bridge.

Over the next 45 years he guided Clough during its involvement in numerous major construction projects in Australia and overseas before he stepped down as Chairman of Clough Limited, the holding company, in 2002.

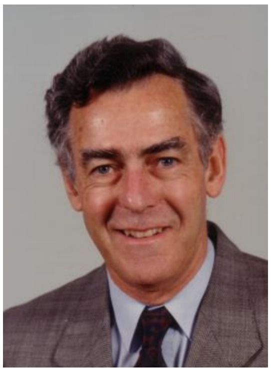
Honours and Awards

Harold Clough was awarded the Queen's Silver Jubilee Medal in 1977, Officer of the Order of the British Empire in 1979, Officer of the Order of Australia and an Honorary Degree of Doctor of Engineering, both in 1980. In 1991 he became an Honorary Fellow of the Institution of Enginers Australia. In 1993 he was awarded the James N Kirby Award by the Australasian Board of the Institution of Electrical Engineers and the Peter Nicol Russell Memorial Medal by the Institution of Engineers Australia. In 1994 he was honoured with the inaugural gold medal for his contribution to engineering, industry and commerce by the WA Division of the Australian Institute of Company Directors. In 1997 he was jointly awarded the International Business Corporation Business Award and also the Australian Constructors Association Award for over 50 Years Service to the Australian construction industry. In 2005 he was awarded the Sir Edward "Weary" Dunlop Medal for long term commitment to enhancing the quality of life in the region and improving Australia-Asia relations.

Harold Clough's enterprise in inviting in 1957 the experienced Danish bridge building company Christiani and Nielsen A/S to Western Australia to construct, in joint venture, Perth's Narrows Bridge has significant historical significance. The bridge was the first major civil engineering public works contract awarded in Western Australia. Subsequently Clough, in its own right, constructed the two other major Perth metropolitan area bridges over the Swan [Stirling Bridge, Fremantle] and Canning [Mt Henry Bridge, Mt Pleasant] rivers.

Donald F Young BE (Hons) FIEAust **(1932 –)**

Project Director, J O Clough & Son Pty Ltd



Don was born in 1932. He won a Commonwealth Scholarship to the University of WA in 1950 and graduated with an honours degree in civil engineering in 1955.

In 1957 he joined J O Clough and Son to work in the Christiani and Nielsen Clough Joint Venture which constructed Perth's original Narrows Bridge. Following a two year period of working in England and Denmark he was involved, with Clough, for the next 32 years, in the construction of many of Western Australia's major resource and infrastructure projects.

When he retired from Clough in 1993 he was Chairman of the Board and Manager WA Operations of the Clough Engineering Group.

In 1993 Don was appointed to the Board of the Water Authority of Western Australia and subsequently to the Water Industry Restructure Implementation Group. When the Water Corporation was established in 1996 he became a foundation non executive director, a position he held for seven years.

He was the inaugural Chair of the Construction Panel of Engineers Australia WA Division in 1992 and held that position until 2001.

During his time with the Water Corporation the Corporation transferred significant engineering heritage elements of the original Goldfields Water Supply Scheme to the National Trust of Australia (Western Australia), for conservation and interpretation. In 2002 the Corporation commissioned Dr Richard Hartley to research and write a history of the Goldfields Water Supply. Don continued to chair the editorial committee after he left the Board and liaised with the National Trust to have the book, River of Steel, published in 2007. Since 2005 he has worked as a volunteer guide at the National Trust's Golden Pipeline Museum at Mundaring Weir.

Don's interest in engineering heritage culminated in his joining the heritage panel of Engineers Australia WA Division (now EHWA) in 2003 and he served as Secretary (2004-2007) and Chairman (2008-2011). During 2008 – 2009 he worked extensively on the successful nomination to have the Goldfields Water Supply given a prestigious International Historic Civil Engineering Landmark award by the American Society of Civil Engineers. In Australian Engineering Weeks 2009 and 2012 he organised and led very successful public bus tours of Perth's major bridges.

As result of his work in identifying and nominating sites for engineering heritage recognition Don was awarded in 2009 an Engineers Australia Medal for meritorious service and in 2012 he was given an Award of Merit by Engineering Heritage Australia in recognition of an outstanding contribution to the conservation of engineering heritage.

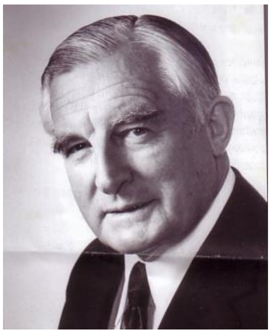
Peter Knight (19xx –)

Site Construction Manager, J O Clough & Son Pty Ltd

[To be updated on Peter’s return from holiday]

Sir Charles Walter Michael Court AK, KCMG, OBE (1911 – 2007)

Premier, Western Australia 1974 - 1982



Charles Court was born in Crawley, Sussex, UK and came to Western Australia as an infant.

He qualified as a chartered accountant in 1933 and became a foundation partner of Hendry, Rae and Court, accountants, in 1938. He served in the Australian Army in World War 2, enlisting as a Private in 1940 and rose to the rank of Lt-Colonel by the end of the war.

He entered the Western Australian State Parliament as Liberal MLA for Nedlands in 1953 and held the seat until he retired in 1982. When the Liberal Government under David Brand was elected in 1959 Charles Court became Minister for the North West and also Minister for Industrial Development. During his tenure he had an important influence on the mineral and energy developments in the North- West and on other rural and mineral developments. He coordinated and was actively involved in the first stages of Ord River irrigated farm development and the establishment of the town of Kununurra, following the signing of the 1959 joint funding agreement between Commonwealth and State Governments to establish an irrigation scheme in the Kimberley region of WA.

He was Minister for Railways from 1959 to 1967 during which time the standard gauge railway was initiated and substantially completed.

During the Tonkin Labour Government (1971-1974) he became Leader of the Opposition and subsequently served as Liberal Premier from 1974-1982. In 1972 he was knighted for his services to state and national development.

Donald Hector (Don) Aitken (1925 – 2010)

Commissioner of Main Roads, Western Australia (1965-1987).

Don Aitken graduated with a Bachelor of Engineering Degree with Honours from the University of Western Australia in 1946. He immediately joined the Main Roads Department of WA as an Assistant Engineer.

After early involvement in materials research and metropolitan and south west construction work he spent twelve months in the United Kingdom gaining wider experience.

In 1953 he commenced a demanding period in charge of various Departmental regional operations throughout Western Australia. In the process he gained a thorough knowledge of the State’s road needs and the road construction techniques required to suit widely different geographical conditions.

When appointed Chief Engineer in 1964 he had served the Department throughout most regions of the State.

His early achievements with the Main Roads Department included the establishment of the Department's first soils laboratory, installing Perth's first set of traffic lights and developing the use of coastal limestone as a road base material.

On April 29, 1965, at the age of 40 years, Don Aitken was appointed Commissioner of Main Roads for Western Australia – the youngest engineer ever appointed to that position. Upon his retirement as Commissioner of Main Roads on 23 October, 1987, he had held the position for more than 22 years, making him the State's longest serving Commissioner of Main Roads.

Don Aitken had a long and distinguished association with the University of Western Australia. Elected to the Senate in 1967, he was a member of the Engineering Advisory Committee of the Faculty of Engineering from 1968 to 1981, Chairman of the Senate Buildings Committee 1972 – 1978, Pro Chancellor 1975 – 1981, Inaugural Chairman, Engineering Graduates Association of UWA 1978, and its patron since 1981, Chairman of the Senate Investments and Endowments Committee from 1979 and Chancellor of the University from 1981 to 1990. He was the first engineer elected to this high office.

Don was awarded Companion of the Imperial Service Order 1977, Queen's Silver Jubilee Medal 1977,Australian Road Federation's John Shaw Award for "meritorious contributions to roads" in 1980, elected a Citizen of the Year in Western Australia in 1982 for the category representing the professions and presented with the Institution of Engineers Peter Nicol Russell Memorial Medal in 1982. Don Aitken was appointed an Officer of the Order of Australia in 1988.

Don Aitken has been a Member and Past Chairman of the National Association of Australian Road Authorities, Director and Past Chairman of the Australian Road Research Board and Member of the Australian Transport Advisory Council Road Group.

The Main Roads Department of Western Australia is responsible for the network of major roads and bridges in Australia's largest state. During his long career as an Assistant Engineer, Chief Engineer and Commissioner Don Aitken gave exceptional service to his State during a period of unprecedented expansion of the metropolitan and country road network. Under his leadership the Main Roads spent more than $2,700 million in maintaining, upgrading and improving Western Australia's public road system, including more than 600 new bridges. This expenditure was vital in facilitating the post war expansion of Western Australia's agricultural and mining industry.

10. HERITAGE ASSESSMENT

Historical Significance

A bridge over the Swan River at Fremantle has always been a key focus of interest since the colony was settled in 1829, with the Perth colony situated on the northern bank and the port of Fremantle located on the southern. The Stirling Bridge, completed in 1974, is the most recent construction to span these waters. Its completion greatly improved road access to the City and Port of Fremantle as well as creating a bypass to the expanding industrial area of Kwinana.

Technical Achievement

Several key aspects of the bridge design and construction methods are worthy of note:

- The simplicity of the structural box girder arrangement was achieved due to analytical advances in calculating shear transfer;
- The piled foundations capacities were verified using the first application of the computerised wave equation formula to a major civil engineering project in Australia.
- All 292 superstructure segments were precast offsite using adjustable steel forms to ensure each unique unit was constructed within tight tolerances. Due to intensive planning and careful workmanship of the precasting operation, not one unit was rejected.
- The prefabricated steel falsework truss supporting the bridge girders prior to post-tensioning was designed to be reused with each successive span, despite varying span lengths and heights

The successful design and construction of the Stirling Bridge was a significant technical achievement, reflecting great credit on the designers, construction contractor and its subcontractors, and their workforces. At the time of its construction, the bridge was the longest in Western Australia.

Social

The bridge sits gracefully in its environment displaying the elegant lines of its thoughtful design. A gradual reduction in depth of the bridge beams complements the reduction in span lengths and soffit clearance from south to north and produces a pleasing appearance, particularly when viewed in elevation. With the abutments set well back from the river edge, the maritime views are preserved.

Rarity

The Stirling Bridge is one of several precast concrete bridge crossings over the Swan River.

Representativeness

The Stirling Bridge is an excellent example of a post-tensioned segmental spine concrete bridge.

Integrity/Intactness

The bridge is intact and still functioning as intended having been designed and constructed forty years ago.

11. INTERPRETATION PLAN AND BUDGET

11.1 40TH Anniversary of Official Opening of Stirling Bridge

The Stirling Bridge was officially opened by the Premier of Western Australia, Sir Charles Court, at a ceremony at the bridge site on 17th May 1974.

If this nomination is successful it is proposed to hold an engineering heritage recognition ceremony for the Stirling Bridge, at a location to be agreed, during 2014, the year of the 40th anniversary of the original opening of the project.

A number of former employees, who were involved in the design or construction of the bridge, either with Main Roads WA, Maunsell & Partners and J O Clough & Son Pty Ltd, have expressed interest in attending the ceremony.

11.2 Probable Themes of the Interpretation Panel

- Site location diagrams
- Photographs of the bridge site before construction
- Progress construction photographs
- Photographs and brief description of roles of eminent persons involved
- Photographs of the near to complete and completed bridge
- Photographs of the official opening ceremony and plaque

11.3 Panel Design

The panel will be similar to the one provided for the Narrows Bridge, ie. with a EHA 300 mm diameter disk mounted on a strut between the legs of the panel.

Ongoing maintenance of the panel will be the responsibility of the owner.

11.4 Budget

The budget for design and production of the interpretation panel has been estimated on the basis of previous works.

ITEM	NOTES	BUDGET
Nomination Production Costs	Photocopy Costs, estimated	$100.00
Panel Design	Estimated cost	$564.00
Panel/Frame Manufacture	Quote received	$2,508.00
Panel Delivery	Estimated	$132.00
Panel Install Costs	To installed by MRWA	unknown
1x PVC Panel	Quote received	$176.00
Ceremony Costs		unknown
	TOTAL COST (known amounts):	**$3480.00**

It is anticipated that Main Roads (owner) will meet the costs of the panel and frame manufacture, and installation and meet the costs and organise a commemoration ceremony. The issue of invitations and registering of RSVPs will be done by the EA WA Office staff.

12. ACKNOWLEDGEMENTS

The authors wish to thank the following for their assistance in preparing this nomination.

Mr Patrick Sands, former Manager Perth Office of Maunsell and Partners

Mr Geoffrey Fernie, Chief Designer of Stirling Bridge and Resident Engineer, Maunsell and Partners.

Mr Jim Leslie, former Senior Engineer, Maunsell and Partners

Mr Peter Knight, Stirling Bridge Site Construction Manager, J O Clough & Son Pty Ltd

Mr Steve Potter, Mr Stephen De Silva and Mr Wayne Giles of Main Roads WA

Mr Jonathon Russell, Consult Australia Sydney

13. REFERENCES

J O Clough & Son Pty Ltd submission for the Australian Federation of Construction Contractors 1974 Construction Achievement Award

Engineers Australia Swan & Canning Rivers Bridges, Australian Engineering Week Tour 2009 and 2012

The Vital Link, A History of Main Roads Western Australia 1926-1996

The Journal of The Australian Consulting Engineer February 1975

Nomination prepared for Engineering Heritage Western Australia by Don Young and Karen Riddette, July 2014.

APPENDIX - ADDITIONAL HISTORICAL PHOTOGRAPHS AND DIAGRAMS

Except where indicated, all photographs and diagrams in this Appendix are by courtesy of J O Clough & Son.

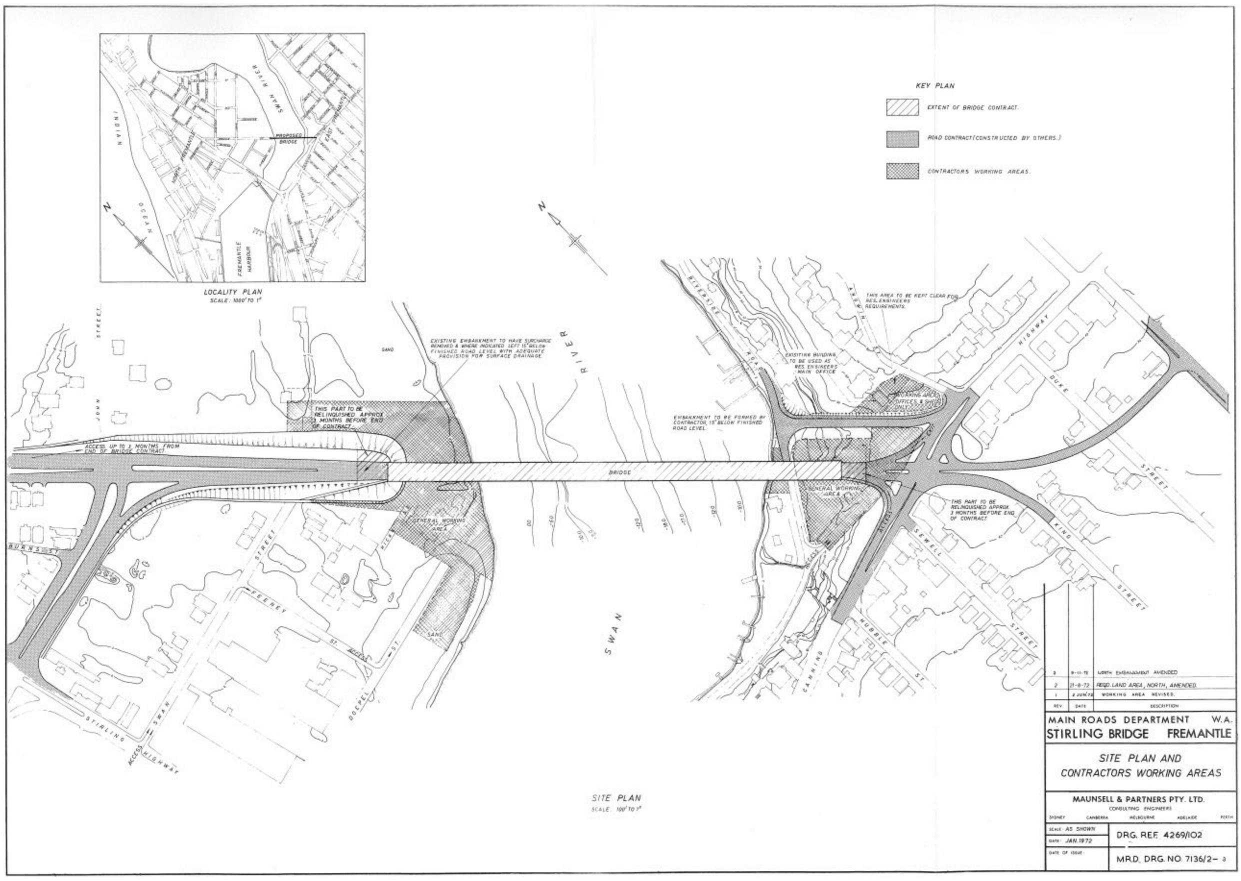


Figure A1. General arrangement drawing of Stirling Bridge

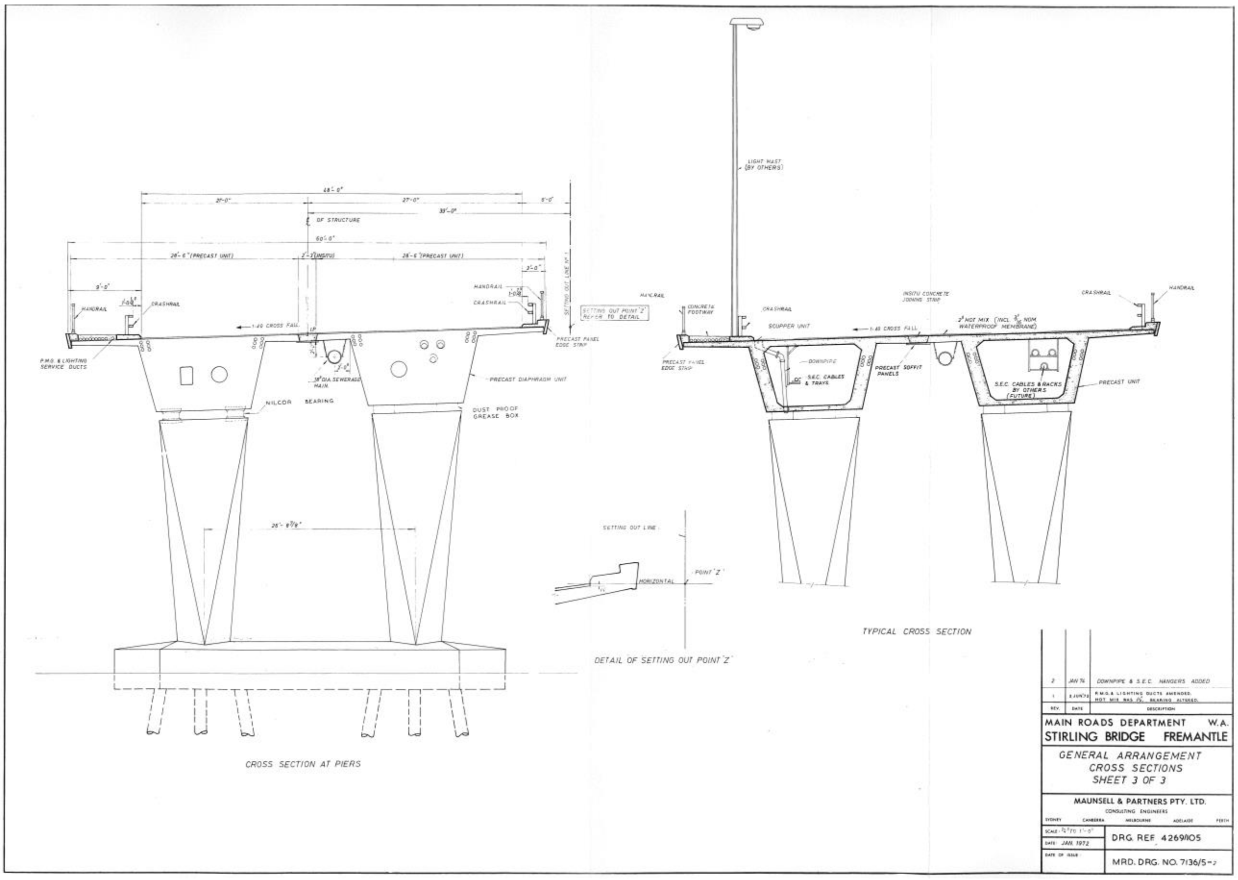


Figure A2. Typical cross-section of Stirling Bridge.

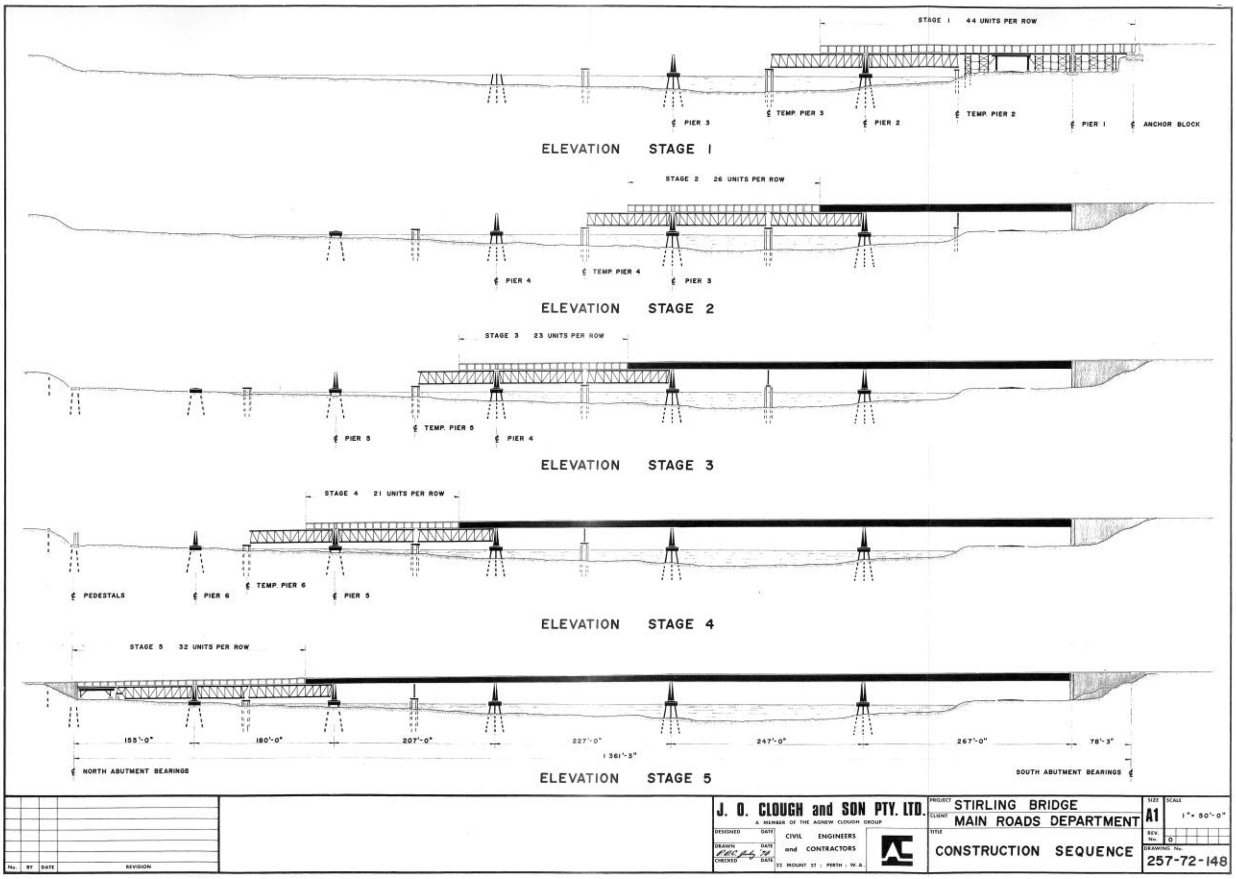


Figure A3. Construction sequence of Stirling Bridge

Figure A4. Guests and dignitaries attending the opening ceremony, 17th May 1974 (Photo courtesy State Library).

Figure A5. Premier Charles Court cutting the ribbon at the opening ceremony, watched by Commissioner Don Aitken, 17th May 1974 (Photo courtesy State Library).

Figure A6. Sir Charles Court with plaque recording the official opening (Photo courtesy State Library).